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# A COMPANION TO THE PHILOSOPHY OF TECHNOLOGY

*Edited by*
JAN KYRRE BERG OLSEN,
STIG ANDUR PEDERSEN, AND
VINCENT F. HENDRICKS

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# A Companion to the Philosophy of Technology

*A Companion to the Philosophy of Technology* Edited by J. K. B. Olsen, S. A. Pedersen and V. F. Hendricks

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*Editorial Offices*
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The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

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# Contents

## Part VI Technology and Ethics 365

# Notes on Contributors

**William Sims Bainbridge.** Co-director of Human-Centered Computing at the National Science Foundation (NSF); part-time Professor of Sociology, George Mason University.

**Ulrich Beck.** Professor of Sociology, University of Munich; *British Journal of Sociology*; Visiting Centennial Professor, London School of Economics and Sciences.

**Wiebe E. Bijker.** Professor of Technology and Society, Maastricht University.

**Mieke Boon.** Associate Professor, Philosophy Department, University of Twente.

**Nick Bostrom.** Director of the Future of Humanity Institute, Oxford University.

**Francesca Bray.** Social Anthropology, University of Edinburgh.

**Philip Brey.** Associate Professor of Philosophy of Technology and chair of the department of philosophy, University of Twente; Director of the Centre for Philosophy of Technology and Engineering Science (CEPTES).

**Louis L. Bucciarelli.** Professor emeritus and former director of MIT's Technology Studies Program.

**Harry Collins.** Distinguished Research Professor, Cardiff University.

**Christelle Didier.** Assistant Professor, Department of Ethics, Catholic University of Lille.

**Jean-Pierre Dupuy.** Professor of Social and Political Philosophy, École Polytechnique, Paris; director of research, CNRS (Philosophy), USA.

**Val Dusek.** Professor of Philosophy, University of New Hampshire.

**Deni Elliott.** Poynter Jamison Chair in Media Ethics and Press Policy, University of South Florida; Professor, Department of Journalism and Media Studies, University of South Florida.

**John R. Fanchi.** Professor, Department of Petroleum Engineering, Colorado School of Mines (now at Fanchi Enterprises, Houston, Texas).

**Andrew Feenberg.** Canada Research Chair in Philosophy of Technology, School of Communication, Simon Fraser University.

**Luciano Floridi.** Professor of Philosophy, University of Hertfordshire, where he holds the Research Chair in Philosophy of Information in the School of Humanities, and Fellow of St Cross College, University of Oxford.

**Warwick A. Fox.** Reader in Ethics, Centre for Professional Ethics, University of Central Lancashire.

**Maarten Franssen.** Associate Professor, Section of Philosophy, Delft University of Technology.

**Jonathan L. Gifford.** Professor of Public Policy, School of Public Policy, George Mason University; director of the Master's in Transportation Policy, Operations and Logistics.

**Thomas F. Glick.** Professor of History and Geography, Boston University.

**Bart Gremmen.** Professor of Ethical and Social Aspects of Genomics, Director of the Centre for Methodical Ethics and Technology Assessment, Wageningen University.

**Bart Hacker.** Curator, Military Technology, Smithsonian's National Museum of American History.

**Kirsten Halsnæs.** Senior Research Specialist, UNEP Risø Centre at Risø/DTU.

**Sven Ove Hansson.** Professor of Philosophy and head of department, Philosophy and the History of Technology, Royal Institute of Technology, Stockholm; editor-in-chief of *Theoria*.

**David M. Hart.** Associate Professor, School of Public Policy, George Mason University.

**Larry Hickman.** Director of the Center for Dewey Studies; Professor of Philosophy, Southern Illinois University Carbondale.

**Søren Holm.** Professorial Fellow in Bioethics, Cardiff Law School, Cardiff University; Professor II, Medical Ethics, Section for Medical Ethics, University of Oslo.

**Nils Holtug.** Associate Professor of Philosophy, Director of the Centre for the Study of Equality and Multiculturalism, University of Copenhagen.

**Sir John Houghton.** President of the John Ray Initiative; Honorary Scientist, Hadley Centre for Climate Prediction and Research.

**Jan Hurlen.** Vice-President, Shecco Technology.

**Don Ihde.** Distinguished Professor of Philosophy, Stony Brook University; Director of the Technoscience Research Group, Philosophy Department, Stony Brook University.

**Christian Illies.** Professor, Technical University, Eindhoven.

**Robert E. Innis.** Professor, Department of Philosophy, University of Massachusetts, Lowell.

**Bruce E. Johansen.** Frederick W. Kayser Professor of Communication and Native American Studies, University of Nebraska at Omaha.

**Erik Jones.** Professor of European Studies, SAIS Bologna Center, Johns Hopkins University.

**David M. Kaplan.** Assistant Professor of Philosophy, University of North Texas.

**Elisabeth K. Kelan.** Research Fellow, Lehman Brothers Centre for Women in Business, London Business School.

**Thomas Kesselring.** Docent in Ethics, Institut Sekundarstufe l, PHBern.

**Jozef Keulartz.** Associate Professor of Applied Philosophy, Wageningen University and Research Centre; Special Chair for Environmental Philosophy, Radboud University, Nijmegen.

**Helge S. Kragh.** Professor of History of Science and Technology, Steno Institute, University of Aarhus.

**Peter Kroes.** Professor in Philosophy of Technology, Department of Technology, Policy and Management, Delft University of Technology.

**Jennifer Kuzma.** Associate Professor, Center for Science, Technology, and Public Policy, Humphrey Institute, University of Minnesota.

**Keekok Lee.** Honorary Research Fellow, School of Social Sciences, University of Manchester.

**Richard Li-Hua.** Director of China Business and Technology Transfer, Newcastle Business School, Northumbria University.

**Noëmi Manders-Huits.** Junior researcher, Department of Philosophy, Faculty of Technology, Policy and Management, Delft University of Technology.

**Anthonie W. M. Meijers.** Professor of Philosophy, Faculty of Technology, Policy and Management, Delft University of Technology.

**Thomas J. Misa.** Director of the University of Minnesota's Charles Babbage Institute; ERA Chair in the History of Technology; faculty member, Department of Electrical and Computer Engineering.

**Carl Mitcham.** Professor of Liberal Arts and International Studies, Colorado School of Mines.

**Keld Nielsen.** Associate professor, head of department, Steno Department for Studies of Science and Science Education, University of Aarhus.

**Alfred Nordmann.** Professor of Philosophy and History of Science, Darmstadt Technical University; president of the Lichtenberg Society.

**William J. Nuttall.** University Senior Lecturer in Technology Policy, Judge Business School and Cambridge University Engineering Department.

**Thomas Søbirk Petersen.** Associate Professor of Practical Philosophy, University of Roskilde.

**Andrew Pickering.** Professor of Sociology, Department of Sociology and Philosophy, University of Exeter.

**Joseph C. Pitt.** Professor of Philosophy, Virginia Tech.

**John R. Porter.** Environment, Resources and Technology Group, Department of Agricultural Sciences, KVL.

**Hans Radder.** Professor of Philosophy of Science and Technology, Faculty of Philosophy, VU University, Amsterdam.

**Jesper Rasmussen.** Environment, Resources and Technology Group, Department of Agricultural Sciences, KVL.

**Jesper Ryberg.** Professor of Practical Philosophy, University of Roskilde.

**Daniel Sarewitz.** Professor of Science and Society, Director of the Consortium for Science, Policy, and Outcomes, Arizona State University.

**Robert C. Scharff.** Philosophy Department, University of New Hampshire.

**Lucien Scubla.** Researcher in anthropology at CREA, Ecole Polytechnique, Paris.

**Evan Selinger.** Assistant Professor, Department of Philosophy, Rochester Institute of Technology.

**Lorenzo Charles Simpson.** Professor of Philosophy, Stony Brook University/State University of New York.

**Andy Stirling.** Science Director, SPRU (science and technology policy research), the University of Sussex; co-director of the joint SPRU/Institute for Development Studies ESRC-funded "STEPS" Centre (on "Social, Technological and Environmental Pathways to Sustainability").

**Richard Susskind.** Honorary Professor and Emeritus Law Professor at Gresham College, London; IT adviser to the Lord Chief Justice of England.

**Iain Thomson.** Associate Professor of Philosophy, University of New Mexico.

**Paul B. Thomson.** Professor, Department of Philosophy, Michigan State University.

**Mary Tiles.** Professor and Chair, Department of Philosophy, University of Hawaii.

**Koos van der Bruggen.** Faculty of Law, Department of International Public Law, Leiden University.

**Jeroen van der Hoven.** Professor of Ethics and Technology, Department of Philosophy, Faculty of Technology, Policy and Management, Delft University of Technology; Professorial Fellow, Centre for Applied Philosophy and Public Ethics, Australian National University; Scientific Director, 3TU Centre for Ethics and Technology.

**Erik van der Vleuten.** Universitair Docent, Department of Innovation Studies, Eindhoven University of Technology.

**Peter-Paul Verbeek.** Associate Professor of Philosophy and Director of the Master Program Philosophy of Science, Technology, and Society, Department of Philosophy, University of Twente.

**Pieter E. Vermaas.** Assistant Professor, Department of Philosophy, Delft University of Technology.

**Marc J. de Vries.** Assistant Professor of Philosophy of Technology, Eindhoven University of Technology; Affiliate Professor of Reformational Philosophy, Delft University of Technology.

**Katinka Waelbers.** Department of Philosophy, University of Twente.

**John Weckert.** Centre for Applied Philosophy and Public Ethics, Charles Sturt University, Australia.

**Langdon Winner.** Thomas Phelan Chair of Humanities and Social Sciences, Rensselaer Polytechnic Institute.

**David Wittner.** Associate Professor of East Asian History, Utica College.

**Edward J. Woodhouse.** Department of Science and Technology Studies, Rensselaer Polytechnic Institute.

# Introduction

## JAN KYRRE BERG OLSEN, STIG ANDUR PEDERSEN AND VINCENT F. HENDRICKS

No major reference work on the philosophy of technology is in existence. The aim of the *Companion to the Philosophy of Technology* is thus to provide an up-to-date review of the philosophy of technology, bringing it into close contact with cutting-edge technology and contemporary technology policy.

The philosophy of technology is highly *interdisciplinary*: it consists of insights from different kinds of technologies, from a variety of epistemological approaches, the humanities, social science, natural science, sociology, psychology, engineering sciences, different philosophical schools of thought, i.e. pragmatism, analytical philosophy, and phenomenology. The philosophy of technology taken as a whole is an understanding of the consequences of technological impacts relating to the environment, the society and human existence. The philosophy of technology is a newcomer in philosophy. As a constituted subject it has existed for about half a century. It is one of the fastest-growing philosophical disciplines. It is also an *intercontinental* philosophical discipline, drawing inspiration and building lasting bridges across the unfortunate divide between Continental and analytic strands of thought in philosophy.

This *Companion* is intended to be the primary navigator for understanding technology and its various roles in the modern complex society. “Technology” refers to many different concepts and phenomena, and it is therefore impossible to give a clear-cut definition of what is to be understood by the term. However, the *Companion* covers the main features of technology, its historical development, its future potentials and risks, etc. With these ambitions in mind, the *Companion* is organized in accordance with the following seven pillars, each covering major areas where technology plays a central role. Each part consists of several short encyclopedia-like case studies, or specialized chapters, describing all issues that add up to actual problems and insights, fleshing out how far technology has come in this particular area or field.

## I History of Technology

This part describes technological development in Western culture as well as in other cultures. It brings into focus Islamic technology, Chinese and other developed

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technological societies. It is of paramount importance to see the extent to which these societies became dependent upon various technologies and what kinds of technologies were preferred. There is an intimate link between our societies today and the choices made in the past.

## II Technology and Science

The focal point of this part is the close connection between technology and science – and their independence. Among other things, the old and still-present issue of technology as applied science will be discussed, the differences between epistemologies and methodologies fleshed out. The connection with the previous part is straightforward; modern science grew out of a society that put more and more emphasis on developing technologies to penetrate the core of nature's secrets.

## III Technology and Philosophy

This part reveals the story from the first attempts to create an engineering philosophy of technology to the more influential humanistic philosophy of technology, towards what today is labeled "philosophy *of* technology."

## IV Technology and Environment

Technology has had a tremendous impact on nature. Technologies have been, in the hands of man, a destructive tool. We are today facing the severest consequences imaginable. As forecasts go, it is only going to get worse. Rescue and damage control also lie in our best technologies at hand. Only by developing intricate instruments can we detect pollution and build complex enough models of the forthcoming developments caused by global warming, global dimming and the greenhouse effects. In this part, management, science and technology are intimately joined.

## V Technology and Politics

Technology is highly political. Governments, the military, all have high hopes and expectations related to technological innovations. However, technology is also taking center stage in order to secure safety and prosperity for society. Therefore the political and economic dimensions of technology are studied in this part within specific contexts – "European Politics, Economy and Technology"; "Asian Politics, Economy and Technology"; "US Politics, Economy and Technology" – where differences in policy-making, in addition to differences in economic and cultural emphasis on technology, stand out with clarity. This is a tangled web that pulls in issues related to all the previous parts of the *Companion* and also extends to the next part.

## VI Technology and Ethics

The development of technology has radicalized classical ethical problems and raised new ones. This part focuses on the responsibilities and values of engineers, scientists, policy-makers and others. Also included are consequences of technologies for the environment. Ethics and technology concern technology in agriculture; within stem cell research; in weapons research, etc.

## VII Technology and the Future

Technologies are undergoing constant changes, and they influence all sides of human life. In order to assess new developments in technology it is necessary to discuss the expectations for the future with respect to human prosperity and possible risks involved therein. This part of the *Companion* discusses the extent to which new technologies contribute to the realization of a desirable future or whether it will be harmful or risky. Some steps have already been taken. The political decision-makers in the EU have drawn up "the Lisbon strategy for economic, social and environmental renewal." Here a colossal emphasis has been put on the development of environmentally friendly technologies – cleaner technologies – that can make use of alternative energy sources like hydrogen. Another important area is nanotechnology, with both military and civilian applications.

Philosophers, and other scholars working with issues related to technology, often define technology differently. We come from different cultures and therefore emphasize certain things differently. All existing definitions of "technology" rest upon specific schools of thought. However, for "technology" there cannot be any simple definition pledging allegiance to one or other school. There are "metaphysical" complications that have to be overcome. The structure of the *Companion* will guarantee this diversity. Definitions are always related to the values of a tradition, of a specific group of thinkers, to a school of thought, and of course to whoever provides the definition. The problem is that "technology" is not one "thing" but a complex of practices, methods, hopes, intentions, goals, needs and desires, besides all the actual technologies in hand. The lack of unity is in turn due to the interdisciplinary nature of technology and technology studies. A single definition simply cannot fathom the complexity of technology in its entirety. In sum, a thorough definition of "technology" needs a "companion" – *A Companion to the Philosophy of Technology*.

Putting this companion together would not have been possible if it was not for all the authors and pillar editors who vividly, eruditely and with great expertise advised and contributed on the way. We should like to extend our gratitude to all our contributors, thank Rasmus Rendsvig for taking care of the logistics in the assembly part of the process, and finally thank Blackwell Publishing and in particular Nick Bellorini and Liz Cremona for taking on this project.

# Part I

# History of Technology

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# 1

# History of Technology

## THOMAS J. MISA

A generation ago, before the much-noted "empirical turn" in philosophy, it was unlikely that an assessment of the philosophy of technology would have prominently featured the history of technology. Put simply, there were relatively few common concerns, since historians of technology rarely engaged in the sort of questions that animated philosophers of technology. Consulting the published volumes of *Research in Philosophy and Technology* and *Technology and Culture* three decades ago suggests two divergent scholarly communities, separated by research methods and background assumptions, and pursuing largely independent investigations. At the time, historians of technology were insisting on technology being an ontologically and epistemologically separate category from science, and vigorously insisting that technology is not merely applied science, while philosophers were ready and more comfortable with sweeping normative assessments about the essential characteristics of technology and its impact on society. In the debates on technological determinism, philosophers of technology and historians of technology were nearly as far apart as possible: while historians of technology adamantly refuted any and all claims of technological determinism, philosophers of technology were as a discipline the most enthusiastic in exploring and embracing the notion that technology determines social and cultural change and that technology develops more or less autonomously of social and cultural influences (Winner 1977; Misa 2004b). In this climate, there was not so very much that the two specialist fields held in common.

In the last ten years or so, however, there has been increasing mutual interest in philosophy and history of technology (Achterhuis 2001; Ihde 2004). It has not been that a hybrid discipline such as the history of philosophy of science has emerged, but rather that some historians and some philosophers have discovered common interests and common concerns. The essays in this volume are testimony to this shared mutual interest, although the individual topics they explore do not really exhaust the range of shared topics and emergent themes (see Misa et al. 2003). The commissioned essays examine the cultural contexts of technology, notably in the specific contexts of Japan, Islam, China and the West, as well as examining the problem areas of defining technology and assessing military technology. These essays develop some of the shared concerns and concepts that are emerging between these two fields. Accordingly, this essay will provide a summary of their main findings but also attempt a wider assessment of

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these shared concerns and emerging problems. I shall do so by accenting three themes: the challenges of defining the term "technology"; the varied concepts and problems in defining "culture" as well as its relations to and interactions with technology; and the issue of technological determinism, a scholarly and practical problem that, for several decades, has merited philosophical reflection and historical analysis.

## Definitions of "Technology"

Historians of technology have for many years pointedly resisted giving a prescriptive definition of the term "technology." This stance, somewhat paradoxically, reflects the disciplinary maturity and confidence of their field. They have frequently observed that no scholarly historian of art today would feel the least temptation to try to define "art," as if that complex expression of human creativity could be pinned down by a few well-chosen words. And similarly, as the noted historian of technology Thomas Hughes has written (2004: 2), "Defining technology in its complexity is as difficult as grasping the essence of politics. Few experienced politicians and political scientists attempt to define politics. Few experienced practitioners, historians, and social scientists try to inclusively define technology." Most historians writing on technology have defined the term mostly by presenting and discussing pertinent examples. Many historians studying the twentieth century have focused on large technological systems, such as electricity, industrial production, and transportation, that emerged in the early decades and became more or less pervasive in the West during the second half of that century.

Other historians even of the twentieth century, however, would strongly prefer to examine technologies from the perspective of "everyday life" or from a user's perspective. Even what might on the surface be considered the same technology can look quite different when viewed "from above" using a manager's or a business executive's perspective or, alternately, "from below" using a worker's or an individual consumer's perspective. Often, the view from above leaves the impression of large systems spreading more or less uniformly across time and space – as, for instance, maps showing the increasing geographical spread of railways and highways or statistical tables showing the increasing pervasiveness of such electrical consumer goods as irons, refrigerators and televisions. Conversely, locally situated studies of individual technologies, sometimes inspired by consumption studies, often find substantial variability in patterns of use and in the meanings these technologies have for subcultures that form around them. As studies inspired by the productive "user heuristic" have shown, there is a great deal of creativity and inventiveness that is uncovered when paying close attention to these local processes (Oudshoorn and Pinch 2003; Hippel 2005). Farmers invented new uses for Henry Ford's classic Model T automobile when adapting it for use on the farm as a source of power. Even the widely popular invention of email was at the start "unplanned, unanticipated, and most unsupported" by the original designers of the Internet (Abbate 1999: 109). Japanese teenagers created new uses for mobile pagers and cell phones, and created a new culture in doing so (Ito et al. 2005). Many times these activities, not originally conceived by the system designers, can be taken up by the producers of these devices and systems and transformed into economically lucrative marketing strategies. This finding of substantial diversity has implications beyond merely complicating any tidy definition of technology; this diversity, especially the agency of users in divining and defining new purposes for a certain technology and new activities around it, also keeps open the question whether technologies can meaningfully be said to have "impact" on society and culture. Normative evaluations of technology, then, cannot assume that the meanings or consequences of technology can be easily comprehended; nor, as was once the case in the early days of the technology-assessment movement, can these characteristics be predicted from the technology's "hardware" characteristics. Indeed, all assessments of technology need to grapple with these epistemological and methodological problems.

Indeed, recent research has productively treated the term "technology" as an emergent and contested entity. Technology is not nearly as old as we commonly think, especially if we have in mind the several technologically marked historical epochs, such as the Bronze Age or the Iron Age. Jacob Bigelow, a medical doctor and Harvard professor, is often credited with coining the term in his book *Elements of Technology* (1829). "The general name of Technology, a word sufficiently expressive . . . is beginning to be revived in the literature of practical men at the present day," he wrote (Bigelow 1829/1831: iv–v). "Under this title it is attempted to include . . . an account . . . of the principles, processes, and nomenclatures of the more conspicuous arts, particularly those which involve applications of science, and which may be considered useful, by promoting the benefit of society, together with the emolument of those who pursue them." Earlier than this, the term "technology" in English, as well as its cognates in the other principal European languages, referred most directly to the treatises and published accounts describing various technical crafts. Bigelow's own coinage did not immediately catch on, however. His speech to the Massachusetts Institute of Technology more than three decades later helped recast the term as an aggregate of individual tools and techniques, an agent of progress, and an active force in history. "Technology," he asserted in 1865, "in the present century and almost under our eyes . . . has advanced with greater strides than any other agent of civilization, and has done more than any science to enlarge the boundaries of profitable knowledge, to extend the dominion of mankind over nature, to economize and utilize both labor and time, and thus to add indefinitely to the effective and available length of human existence" (Segal 1985: quote 81).

Following Bigelow's use, "technology" gained something of its present-day associations in the next several decades. Numerous institutes and colleges of technology in the United States took up the name: not only the flagship of MIT (founded 1861) but also other colleges, schools, or institutes of technology such as Stevens (1870), Georgia (1885), Clarkson (1896), Carnegie (1912), California (1921), Lawrence (1932), Illinois (1940) and Rochester (1944). Polytechnics in Europe, often modeled on the pioneering École Polytechnique (founded much earlier, in 1794) in Paris, provided broadly similar educational opportunities. In 1950, the Indian government founded Kharagpur Institute of Technology, the first in a national network of seven technical universities.

As Ruth Oldenziel (1999) has made clear, in these same decades "technology" took on a distinctly male-oriented slant. Earlier terms such as "the applied arts" or "the industrial arts" could be associated equally with the products of women's work as with men's; but "technology" after 1865 increasingly came to signify male-oriented machines and industrial processes. Oldenziel sees the emergence of technology in the personification of the (male) engineer as an instance of the gender-coding of the modern world. Eric

Schatzberg situates the rise of "technology" as a keyword in the writings of social critic Thorstein Veblen, who drew heavily on the contemporary German discourse around "technik," as well as of the popular historian Charles Beard. "Technology marches in seven-league boots from one ruthless, revolutionary conquest to another, tearing down old factories and industries, flinging up new processes with terrifying rapidity," in Beard's arresting and deterministic image (Schatzberg 2006: 509). Also following Raymond Williams's method of keywords, Ronald Kline (2006) examines origins of "information technology" in the management-science community of the 1960s and its subsequent spread into the wider discourse.

Recently, the term "technoscience" has found favor in the writings of some, if not all, philosophers of technology and historians of technology. Advocates of the term maintain that the practices, objects and theories of science and technology, even if they once were separate professional communities, have blurred to a point at which they share many important features – indeed, to a point at which their similarities outweigh their differences. The term is not merely a recognition that biologists today frequently enough apply for patents and create start-up companies; it also draws attention to hybrid forms of knowledge and practices. (As such, the appeal to hybridity is an important aspect of the anti-essentialism that is characteristic of much recent technology studies.) With a tone of caution, Barry Barnes (2005: 155) writes of "near consensus on the predominance of technoscience as something characteristic particularly of recent times." Philosopher of technology Don Ihde's *Instrumental Realism* (1991) presented an extended analysis of Latour's *Science in Action* (1987), in which "technoscience" was defined and popularized.[1] And, similarly, Ruth Cowan's *Social History of American Technology* (1997) takes up "technoscience" in her final chapter, using the examples of hybrid corn, penicillin and the birth-control pill. Overall, historians conceptualize technology as contingent, constructed and contested.

## Problems of Culture

In making their assessment of the "anthropological variety" of technology (see Li-Hua), the essays of this section attempt to identify and describe the core qualities that can be associated with Islamic, Chinese, Japanese and Western technology. These essays utilize the familiar method of defining by example and discussion, and there is much to be learned from the rich empirical diversity that such an overview provides. It is worth marking at the onset, all the same, that each of these essays takes up a more-or-less bounded and non-problematic analysis of the assigned "culture." This is especially the case, somewhat paradoxically, when the essays examine instances of the transfer of technology between regions or cultures. Even the idea of a technological "dialogue" between different cultures (used to good effect by Arnold Pacey [1990]) can still carry the assumption that there exists a fundamental, identifiable and more-or-less essential core to the culture(s) under examination. Recently, anthropologists and social theorists have preferred to jettison such essentialist conceptions of culture, and to prefer performative ones. Here, there is no stable core to a given culture – i.e. its essential features – that is constant across time and then that might "change" under one set of circumstances or another. A performative view postulates that cultures are continually re-created and performed, so that changes can be small and incremental and/or large and dramatic. Performative conceptions of culture are also helpful in identifying cultural hybridities, where cultural productions take up and incorporate novel elements which may have their origins in "foreign" borrowings but also with "domestic" innovations.

On the surface, Japan might seem a reasonable candidate for an essentialist understanding, owing to its geographic separation and strong cultural identity. What we might today consider to be "quintessentially Japanese" came rather late to Japan. As David Wittner shows, Japan for many centuries received transfers and/or engaged in technological dialogue with China and Korea, the sources of wet-field agriculture, of the basic techniques of working bronze and iron, as well as of weaving, silk, paper and more. Wittner suggests that, beginning in the eighth century, Japanese woodworking, printing, metalworking and other crafts diverged from Chinese practices. The rise of urban centers of innovation in the late Heian period (794–1185) led to distinctive Japanese practices in jointless carpentry, as well as in standardized interior spaces signified by uniform-sized tatami mats. Metal-based military innovations came to the fore during the Warring States period (1467–1568), notably in the fields of sword-making and gun manufacture.

Two prototypically "Western" technologies that were introduced into Japan in the mid-sixteenth century provide an apt way of assessing Japan's remarkable technological sophistication. Gunpowder weapons arrived in Japan in 1543 after a Portuguese ship was wrecked off the coast. It happened that the Portuguese survivors landed on the small island of Tanegashima, that this island was rich in iron ore and consequently also in metalworking skills, and that its local lord commanded one of his artisans to make a copy of a Portuguese gun, achieved in short order, and that this region of Japan was well connected to the mainland through trade and tributary relations (see Lidin 2002). The result was that within three decades Japan was making very large numbers of these muskets, with specially modified firing-lock mechanisms and extra attention to effective waterproofing. Muskets, numbering in the many thousands, played a decisive role in the battle of Nagashino (1875), a turning-point in Japan's political history that led to the consolidation of power by the Tokugawa shogunate (1600–1868). A battle in 1600 is believed to have featured 20,000 muskets.

Western-style mechanical clocks arrived in Japan in 1551, introduced by Jesuit missionaries. In his essay Wittner rightly stresses the unprecedented mechanical complexity of the mechanical clock, and perceptively suggests that its mastery by Japanese artisans forms an important resource for Japan's later industrial prowess with mechanized reeling machines and looms. It also should be emphasized that Japanese artisans invented an entirely distinctive type of clock, which married the mechanical regularity of its interior clockwork mechanism with several ingenious schemes for relating this mechanically uniform time to the seasonally varying hours that typified Japanese concepts of time. There were six equal units of Japanese time between local sunrise and sunset, and also six units between local sunset and sunrise, the length of which then varied by the season. To devise clocks, including automatic bell-striking ones, that would vary the effective length of the hour seems a compelling instance of a thoroughly "hybrid" technology, and certainly not merely an adaptation or transfer of a Western one. Japan persisted with its distinctive, non-Western time-keeping system until 1873, when during the modernization of the Meiji era (1868–1912) the country converted to a Western calendar and Western time practices amid a great number of other Western-inspired institutional changes. Indeed, it may be that the development of "Japanese" identity was a cultural response to the coming of modernity (Caldararo 2003: 465).

The technological and cultural variability one confronts in examining China and Islam is even much greater. As Thomas Glick points out, the "Islamic technology" he surveys is really the technological and scientific knowledge characteristic of the classic Islamic Arab civilization. At its peak in the eighth century, and continuing until 1492, the political and cultural influence of Islamic Arabs extended through North Africa and into present-day Spain. This is why one finds Islamic technology in eastern Spain in the form of so-called Persian-style *qanat* irrigation techniques as well as water-raising *noria*. From the thirteenth century, gunpowder weapons, too, were subject to a wide-ranging geographical transfer process as the Mongols transported this Chinese technology westward with devastating effects. Glick appropriately situates his discussion of Islamic technology in the context of wider continent-scale flows of knowledge and techniques, including the movement westward of the Indian style of agriculture (involving a "distinctive roster" of citrus fruits, rice, sugar cane and cotton) and the diffusion to the Islamic world of Greek astronomy and Indian astronomical tables and instruments. One culturally distinctive set of practices involved the computation of special tables to identify the direction of Mecca as well as accurate timekeeping to mark out the five daily prayer times. Yet, as Glick (1996) and others have recently suggested, "Islamic" technology may also be more of a "hybrid" than a brief overview is able to convey. The specific forms of irrigation in medieval Valencia, for instance, may reflect North African influences and models as much as Arab ones.

Compared with the essays on Japan and Islam, Francesca Bray's essay on Chinese technology is certainly less affected by any sort of essentialist assumptions about the core of China's technology or culture. As an anthropologist herself, Bray offers an essay that at once is close to Chinese assessments of technology and situates itself squarely in the context of historiographic debates on China. She is asking the questions "What do we know about China?," "What do the Chinese know about China?" and "How have the tensions and competitions of the Cold War influenced how we conceptualize China?" One consequence of the political climate of the Cold War, with its long-standing obsession with understanding and conceptualizing the supposedly technology-driven process of industrialization, was the framing and persistence of the "Needham question." Joseph Needham, the eminent British scholar, posed the question why, given China's superior attainments in science and technology – having invented gunpowder, the compass, movable-type printing, all well in advance of the medieval West – did China not also experience a large-scale transformation of its society and economy, which we in the West label as our own scientific revolution or industrial revolution.

Characteristically, however, Bray spends much more time on what Chinese people thought about their own relations to the West, rather than attempting to answer the Needham question. Across most of the entire nineteenth century, China was hard-pressed by the Western powers. Following the experience of "humiliating defeats" in the Opium Wars (1840–2, 1856–60) and the loss of sovereignty attending the forced signing of the "unequal treaties" with the Western powers, the Chinese attempted a home-grown modernization known as "self-strengthening." Despite some successes such as the

Jiangnan Arsenal in Shanghai, the efforts to build up China's economy and technological level as well as achieve a productive accommodation between "Western artifacts and Chinese spirit," the overall results were disappointing. Japan, fresh from its own Western-inspired modernization, invaded China in 1894 and forced additional territorial concessions. Given these setbacks, it was difficult for Chinese people to see and appreciate their own technological heritage; instead they conceptualized "technology" as a foreign, Western construct. Technocratic Chinese advocates of economic development in the 1930s, according to Bray, strove to emulate Western models. For much of the orthodox Maoist period (1949–78), China oscillated between grand attempts at forced-draft industrialization and the upheavals of the Cultural Revolution, with its anti-technocratic slogan "Better Red than Expert." More recently, as Bray notes, scholars of China have entirely shifted away from the comparative Needham questions and instead treated China on its own terms rather than as a reflection of the West.

## Dilemmas of Determinism

Discussion of the common concerns of philosophers of technology and historians of technology must include mention of "technological determinism." As noted above, philosophers and historians have not seen eye to eye when examining the problem of whether, if and how technology brings about social and cultural changes. In their more or less essentialistic framing of the problem a generation ago, philosophers of technology were among the most enthusiastic proponents of the notion of technology as a strong and compelling force for change in history, while historians of technology took great pains to attack any and all forms of technological-determinist arguments (Smith and Marx 1994). Differences in the analytical "scale" at which scholars conduct their studies help account for these explanatory differences (Edwards 2003; Misa 2004b). The cases of military technology and Western technology, which are often cited as leading examples in assessments of the power of technology, offer rich material to explore and assess the dilemmas of determinist accounts of technology.

Bart Hacker frames his essay on "Technology and War" in an interactive framework. "The interplay of military institutions and changing technology has regularly made history," he maintains. His essay presents a richly textured account, over a very long span of human history, of these interactions. His model is that military institutions are both key sites of technical innovation and critical vectors that transport and transform technical innovations. He finds the rise of organized armies in the Near East, in Mesopotamia and in Egypt in the fourth millennium BCE to be a key turning-point that "decisively divided prehistory from civilization." Composite bows and horse-drawn chariots contributed to the effectiveness of the emerging armies, but these complex and expensive technologies required deep pockets; thus the new technologies in this way depended on the state's capability of mobilizing extensive resources. These early states clearly took form through the deployment of military technologies, while these technologies were themselves products of state initiative.

Hacker also provides a detailed account of the rise of feudalism as a social, economic and political form – arising first on the Iranian frontier – and its relation to the (again expensive) technologies of large grain-fed warhorses. Feudalism, with its "centers of local military power that regularly threatened central control," was certainly not the ideal option for a central power wishing to retain control over its lands, but in Hacker's estimation it was a social and economic arrangement necessary to field the war-winning military technology of the time. One classic technological interpretation of feudalism that Hacker does not cite in this essay is that of Lynn White (1962). White famously argued that horse stirrups, heavy plows, and mechanical power were crucial to the rise of feudalism in Europe. Even with many scholarly criticisms over the years, White's overall interpretation retains remarkable persistence among non-specialists (for a recent assessment, see Roland 2003).

A set of "revolutions" related to military technologies rounds out Hacker's treatment. Gunpowder weapons, invented in China in the late thirteenth century, had dramatic consequences for the states that embraced them. Not only were guns useful in claiming territories from lesser-armed foes; the sizable expenses required to field an army with numerous guns (as well as procuring the extremely costly gunpowder) also worked to centralize both political and economic power. These changes – clearly related to technology but certainly not caused by technology – were most evident in the classic early-modern "gunpowder empires" of the Ottomans in the Near East, the Safavids in Iran, and the Moguls in India. Intense competition between rival states in Europe, with none of them able to consolidate power over the continent, led to a period of vigorous institutional and technological innovation. The resulting "military revolution," Hacker writes, "may well have been the key factor that disrupted in the West's favor the rough parity in technology, economy, and polity that prevailed until the 15th century among civilized communities all across the Old World."

By around 1900, in the wake of military, scientific and industrial revolutions, the West's military capabilities would "achieve an almost uncontested hegemony over most of the world." As noted above, the modernizations embodied in China's "self strengthening" as well as in Japan's Meiji restoration were constructed around the adoption of Western weapons and Western models for military institutions. As Hacker concludes, "in the late 19th and 20th centuries, all armies became Western in organization, in equipment, and in spirit."

If "all armies became Western," then might it be the case that Keld Nielsen's essay on Western technology describes the paradigm toward which the world is conforming? Nielsen himself suggests that Western technology has become more or less pervasive, and can be "found on all continents." There are numerous ways in which Western and non-Western technologies share significant characteristics, but it is Nielsen's ambition to identify a number of "unique" characteristics that typify Western technologies. These include, in somewhat compressed form, the ability to extract mechanical energy from fossil fuels; the creation of integrated systems of mass production linking raw materials, production and consumers; the spread of uniform technical standards; the ability to manufacture tools and products to increasing mechanical precision; the mobilization of large capital and financing; the deployment of scientific knowledge; and a commitment to continuous "renewal" through research and development. Nielsen also allows that these immense technological capabilities have made it possible for humans to alter the world's climate or even destroy its population.

As such, Nielsen's list of unique Western characteristics is an admirable one to have identified but a difficult one to defend. One possible defense would be to assert that Western technology is typified by the *package* of these characteristics, taken together, and operating on a large and/or pervasive scale – and not by the characteristics taken individually. Certainly there is a meaningful difference in the technological capacities of, say, Switzerland and of most of the countries in sub-Saharan Africa, as measured in phone lines or Internet connections per capita, access to patents and technology, and agency in dealing with the global economy. Luxembourg has 199 phone lines per 100 inhabitants; Angola has 1.5. Maps of the global Internet, as well as composite photos of the Earth during night-time hours, also indicate that Africa as a continent is in comparative terms literally "off" the electricity and information networks.

The end of the Cold War and the rise of globalization has further blurred lines marking off the "West" and made it more difficult to defend the concept of "Western technology." A Western computer might be designed in Silicon Valley (safely in the West), but software is increasingly written by programmers in India and China, with many components of personal computers manufactured in Taiwan, Hong Kong, China and other formerly "Far Eastern" countries. According to the Basel Action Network, no fewer than 500 large containers (40 feet in length) arrive each month in the port of Lagos, Nigeria, packed with obsolete computers and other electronic equipment. While Lagos has an active market in recycling these components, up to three-quarters of the shipped material is unusable trash, in effect being dumped in Africa owing to cheap global shipping.[2] Apart from the obvious moral issues, there is a puzzle in this example concerning what is "Western" about these computers, and whether they are still fairly considered to be "Western" when manufactured in a Chinese town and then, some months later, disposed of in Africa.

## Notes

1. Latour's definition of technoscience (1987: 174–5) is part of the exposition of his worldview and method, and it is not easy to summarize briefly. The relevant passage reads: "To remind us of this important distinction [the Janus-like quality of science-in-the-making compared with ready-made science], I will use the word **technoscience** from now on, to describe all the elements tied to the scientific contents no matter how dirty, unexpected or foreign they seem, and the expression '**science and technology**,' in quotation marks, to designate *what is kept of technoscience* once all the trials of responsibility have been settled. The more 'science and technology' has an esoteric content the further they extend outside. Thus, 'science and technology' is only a sub-set which seems to take precedence only because of an optical illusion."
2. <www.ban.org/BANreports/10-24-05/index.htm> (21 December 2007).

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# 2

# Definitions of Technology

## RICHARD LI-HUA

Owing to anthropological diversity, the attempt to define technology seems quite challenging. People may have different interpretations as they are positioned differently. This reminds me of the Chinese parable of the blind men and the elephant.

Megantz (2002) further elaborates in the preface to his book *Technology Management: Developing and Implementing Effective Licensing Programs* that technology is a wonderful, amazing, always changing bag of tricks that helps human beings to live healthier, happier (however, these could take place in other way around) and more fulfilling lives. To a scientist, technology is the end product of one's research. To an engineer, technology is a tool or process that can be employed to build better products or solve technical problems. To an attorney, technology is intellectual property to be protected and guarded. To a business executive, technology may be the most important, yet least understood, company asset. Technology is viewed as competitive advantage against rivals.

Technology means state power to both developing and developed countries. Technology is regarded as a strategic instrument in achieving economic targets and in the creation of wealth and prosperity in the developing countries, while technology is taken as an important vehicle to get large profits in the developed countries. The effective use of technology is perhaps the most important issue faced by both developing and developed countries, and will undoubtedly become even more critical in years to come.

The word "technology" usually conjures up many different images and generally refers to what has been described as the "high-tech," or high-technology, industries. It has to be understood that limiting technology to high-tech industries such as computers, superconductivity, chips, genetic engineering, robotics, magnetic railways and so on focuses excessive attention on what the media consider newsworthy (Gaynor 1996). However, limiting technology to science, engineering and mathematics also loses sight of other supporting technologies. Actually, technology includes more than machines, processes and inventions. Traditionally, it might concentrate more on hardware; however, in these days, more on soft side as well. There are many manifestations of technology; some are very simple, while others are very complex.

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## What Is Technology?

But what exactly is meant by the term "technology"? According to Dean and LeMaster (1995, p. 19), technology is defined as "firm-specific information concerning characteristics and performance properties of production processes and product design." While Contractor and Sagafi-Nejad (1981) describe technology simply as "a bundle of information, rights and services," Maskus (2004, p. 9) defines technology as "the information necessary to achieve a certain production outcome from a particular mean of combining or processing selected inputs." However, Maskus (2004) solely distinguishes between embodied and disembodied technology, whereas Kedia and Bhagat (1988) recommend a more detailed classification into process-, product- and person-embodied technology.

Technology represents the combination of human understanding of natural laws and phenomena accumulated since ancient times to make things that fulfill our needs and desires or that perform certain functions (Karatsu 1990). In other words, technology has to create things that benefit human beings. Miles (1995) defines technology as the means by which we apply our understanding of the natural world to the solution of practical problems. It is a combination of "hardware" (buildings, plant and equipment) and "software" (skills, knowledge, experience, together with suitable organizational and institutional arrangement).

The UN Conference on Trade and Development (UNCTAD) has provided the following definition:

> Technology is bought and sold as capital goods including machinery and productive systems, human labour usually skilled manpower, management and specialised scientists. Information of both technical and commercial character, including that which is readily available, and that subject to proprietary rights and restrictions.

However, according to this thesis, technology cannot merely be considered as a production factor, and it is not socially neutral (Mnaas 1990). It seems much easier for understanding "technology" to consider the concept of "technology" as consisting of four closely interlinked elements: namely, technique, knowledge (normally being considered as "technology"), the organization of the production, and the product. However, knowledge does not make sense if the organization of the relevant production goes without producing meaningful product. Therefore, technology must be applied, testified and maintained, which implies a demand for a further input of a suitable range of human resources and skills. However, it should be noticed that it is this latter input that is at the root of the difficulty in transferring technologies between different environments. Nevertheless the modern view emphasizes the coherence of technology and knowledge, and points out that technology transfer is not achievable without knowledge transfer as knowledge is a key to controlling technology as a whole (Li-Hua 2004); some even use "technology" interchangeably with "know-how." Knowledge is closely related to technology since the pure disposal of technology is not sufficient for a successful implementation. In the majority of the cases, especially in complex technology, knowledge, in particular tacit knowledge, is required for a successful international technology transfer.

Technique covers the instruments of labor (machinery and tools), materials and the way they are brought into function by labor in the working process. Both social dynamic (working process) and social contradictions (e.g. between machinery and labor) are inherent in this element of the technology as in each of the subconcepts.

Knowledge consists of three principal categories: applied science, skills and intuition. The weighting between these categories of knowledge is changing historically, but in every case an adequate combination of types of knowledge must be present. *Knowledge is the "key to control" over technology as a whole,* which can be seen both at micro-level (Taylorism) and at higher levels of social aggregation (technological dependency) (Mnaas 1990). However, it is helpful for understanding that knowledge has recently been classified as explicit knowledge and tacit knowledge.

Technique and knowledge must be organized before they can bring about effective results. Organization is therefore an integral part of technology. Organization of a working process of technique and knowledge into a product may have technical causes, but mostly the actual choice of organization will rest widely on social-economic causes and reflect the general social structure of society.

Product. The ultimate purpose of bringing technique, knowledge and organization together is of course to obtain a product. Without including this goal, it is in fact difficult to understand the other three elements properly. It seems natural to include the product in a comprehensive technology concept, not least because in practice the choice of product often precedes the choice of the technique, knowledge and organization by which it is going to be produced.

Rosenberg and Frischtak (1985) pointed out that the specificity of technology has close links with the nature of the inputs to its production and of the resulting outputs. In most advanced countries, at least 60 percent of research and development expenditures are on development, namely expenditure to develop specific products or production processes. It is important to have this dissecting of technology and to have a distinction between technology and knowledge. Knowledge is a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. It consists of truth, beliefs, perspectives, concepts, judgments, expectation, methodologies, know-how; and exists in different forms such as tacit, explicit, symbolic, embodied, en-brained and en-cultured knowledge.

## Explicit Knowledge and Tacit Knowledge

Knowledge is increasingly being recognized as a vital organizational resource that gives market leverage and competitive advantage (Nonaka and Takeuchi 1995; Leonard-Barton 1995). In particular, knowledge has become a substance to be "managed" in its most literal sense. Polanyi (1967) considered human knowledge by starting from the fact that *we know more than we can tell.* In general, knowledge consists of two components, namely explicit and tacit. Technical knowledge consists of these two components, "explicit" and "tacit"; however, the greater the extent to which a technology exists in the form of the softer, less physical resources, the greater the proportion of tacit knowledge it contains. Tacit knowledge, owing to its non-codifiable nature, has to be transferred through

**Table 2.1** Features of tacit knowledge and explicit knowledge (Nonaka and Takeuchi, 1995)

| *Tacit knowledge*<br>*Subjective* | *Explicit knowledge*<br>*Objective* |
|---|---|
| Knowledge of experience (body) | Knowledge of rationality (mind) |
| Simultaneous knowledge (here and now) | Sequential knowledge (there and then) |
| Analogy knowledge (practice) | Digital knowledge (theory) |

"intimate human interactions" (Tsang 1997). In the meantime, it has to be recognized that tacit knowledge is the key to delivering the most competitive advantage, and it is this part that competitors have difficulties in replicating. Tacit knowledge transfer is often intentionally blocked because people understand the significance of tacit knowledge.

Nonaka and Takeuchi (1995) describe some distinctions between tacit and explicit knowledge, which are shown in Table 2.1. Features generally associated with the more tacit aspects of knowledge are shown on the left, while the corresponding qualities related to explicit knowledge are shown on the right. Knowledge of experience tends to be tacit, physical and subjective, while knowledge of rationality tends to be explicit, metaphysical and objective. Tacit knowledge is created "here and now" in a specific, practical context, while explicit knowledge is about past events or objects "there and then." Table 2.1 shows the features of explicit and tacit knowledge.

Having clarified the distinctive features between technology and knowledge, and between explicit knowledge and tacit knowledge, it is now more helpful in this discussion to reflex the current debate on why China's technology strategy of getting technology by giving up its market partly failed. In the last twenty-eight years of economic reform, China has achieved tremendous success and seen the most remarkable period of economic growth in modern times, and will continue to do so. However, the debate is going on that the foreign brands sell well in the Chinese market and foreign companies are strong competitors against local firms, and to some extent China has not really obtained core technology in the car manufacturing industry. It has to be recognized that this thesis is not in a position to provide appropriate answers to these questions. However, bearing in mind that knowledge is a key to controlling technology as a whole, technology transfer does not take place without knowledge transfer. In terms of technology import or technology transfer, what China has obtained in principle is the "hard" ware, such as machinery, equipment, operational manual, specification and drawing, – not the "soft" side, which consists of tacit knowledge, including management expertise and technical know-how and know-why.

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# 3

# Western Technology

## KELD NIELSON

By Western technology is here understood a large set of particular technologies and technological practices which mainly have their roots in inventions and developments in Europe and North America. In particular, since the Second World War, most of these technological practices have spread, so that "Western" technology can now be found on all continents.

Technology has been an integral part of the development of modern Western civilization and the way Western modes of behavior and production have reached all parts of the Earth. Western technologies have been at the heart of the change from a rural-agricultural economy to an urban-industrial one that many countries or regions have undergone during the past 200 years.

It is not possible to distinguish clearly between features of technology and technological practices which are clearly "Western" and those which have been developed in non-Western cultures. Some of the characteristics of Western technology outlined below are common to technologies of many different cultures – including cultures which are now extinct – while some are particular to Western technology and make it stand out as remarkable among the accomplishments of mankind.

In fact, some of the characteristics of technology which are often thought of as unique to Western technology are general features found in the technology of other cultures, too. Examples of such features are: the ability of technology to change the conditions of life by providing better or easier acquisition of food, more safety and better living conditions; the importance of sources of energy, of transport, of storage and of other arrangements of infrastructure, and the close connection between the wealth of a society and its use of suitable technologies; the application of technology by the powerful to maintain their wealth and position including large-scale technological initiatives by rulers or governments; the symbolic use of technology in the demonstration of power and control or of religious authority; the competition and often co-existence of different types or technology; and the use of technology in defense, attack and conquest. Even the close interaction between the technological, the social and the cultural spheres, which is so apparent in modern Western society, appears to be a distinct feature of technology in other cultures and societies, too.

But other characteristics seem to be unique to a recent and "Western" development. Among the most striking features particular to Western technology are: the ability to

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extract mechanical energy from fossil fuel through inventions like the steam engine and the internal combustion engine; mass production through the integration of the extraction of raw materials with transport systems, production facilities and sophisticated systems of distribution of wares to masses of consumers; the widespread use of technological standards and unified measuring systems; a permanent increase in mechanical precision in tool-making and manufacture; an intimate and active relation to capital and investments; the use of scientific knowledge in the development of products and production methods; and the high priority given to renewal through investments in research and development. A specifically "Western" result of the widespread use of technology is also the capacity to disturb Earth's climate and eco-systems on a global scale, and the power to eradicate most – if not all – of mankind through the use of nuclear or biological weapons.

It is an open question at what time in history the development of technology in the West became unique relative to technological scenarios in contemporary cultures. The Middle Ages (sixth to fourteenth centuries) are often identified as the period during which we find the cultural, economic and political origins of what later became modern Western society. But technologically important developments during the Middle Ages like the far-reaching improvement of agricultural techniques brought about by the use of the new heavy plow, an intensified use of water power, or the building of ever larger cathedrals are differences in quantity rather than in essence in comparison with other great technological cultures. Other significant medieval technological innovations like the spinning wheel, paper, Arabic numerals, the compass, guns and gunpowder were imported into medieval Europe from outside. Outstanding local inventions were the horse collar (ninth century), spectacles (thirteenth century) and the weight-driven mechanical clock (thirteenth century). Seen in hindsight, the most important development with regard to the technology of the West was the growth of a large number of autonomous or semi-autonomous cities catering to trade and handicraft production. Here skilled trade developed with novelties like guilds, master craftsmen, journeymen and apprentices. Also, new modes of production involving many steps and division of labor were perfected, for example in the wool and dying industries. Banking systems emerged, making it easier to direct the flow of money toward trade, building and production, and the rising trading companies started to use double-entry bookkeeping.

The Renaissance (roughly fifteenth to seventeenth centuries), however, saw novelties which, also in a global perspective, were remarkable. One was Johannes Gutenberg's development around 1450 of printing with movable type. A somewhat similar technique had much earlier been used in Korea but apparently without the significant impact on cultural and technical development that can be traced in Europe. Highly important for the advance of technology was the subsequent use of printed books to spread technical knowledge. During the sixteenth century a new genre of books appeared that gave detailed information about machines and technological processes, often accompanied by diagrams and other illustrations. This made it possible to accumulate and disseminate knowledge about specific technological details and created a hitherto unknown knowledge base for the work of engineers and other technologists. It also made it possible to collect, preserve and disseminate geographical knowledge and other knowledge about nature in a systematic and cumulative manner, thus paving the way for the boom in knowledge and investigative methods known as the scientific revolution.

Another globally significant occurrence was the European expansion across the oceans, led by Portuguese and Spanish traders and sailors, and soon followed by the Dutch and the English. On the technical side, this was made possible by the development of the full-rigged ship, armed with guns, and the design of new astronomical methods of navigation through the work of Portuguese astronomers. This marks a very early example of the extraordinary ability of Western technology to embody scientific knowledge and to spread across the globe.

Also the granting of privileges to use certain inventions or techniques in manufacture or building, which later grew into the practice of issuing patents to protect the owners of technological novelties, began in the fifteenth century.

During the Renaissance many technological improvements appeared gradually in mining techniques, in the extraction and processing of metals, in the design and use of firearms, in fortification, in the design and use of ships, and in the construction of harbors, canals and bridges. Many developments were tied to the military growth of the ever stronger national states which during the seventeenth century invested in enormous standing armies. Other developments accompanied the rapidly growing international commerce which toward the end of the century found a new hub in the Netherlands. The Dutch Republic became the center of a worldwide trading and processing network based on improvements in shipping and innovations like commodity exchanges and a stock exchange.

During the eighteenth century craftsmen like Thomas Newcomen and James Watt invented and improved the steam engine, which made it possible to convert accumulated solar energy in the form of wood, coal or oil to mechanical motion. A later development led to steam turbines, internal combustion engines and jet engines that have the same function. Before the appearance of such heat-engines, the chief energy source had been the muscle power of men or animals, expensive because they must be fed, putting a strain on food supply. Also the natural energy sources – water or wind – were for all practical purposes limited. Water power was tied to specific locations and could not be geographically distributed in large amounts. Wind power extracted through windmills was uneven in output and highly capital-consuming. With the new engines and plenty of cheap fossil fuel, Western technology broke this otherwise universal constraint on the magnitude of technological activities. During the nineteenth century the heat-engines were at the heart of momentous technological developments. Production in factories or other plants, combined with railway transport and ocean-going steamships, made possible the rise of the US and some European countries as industrialized powers of production on a world scale.

These changes had certain unique Western technological features. Many of the new machines, including the steam engines, were self-acting in the sense that built-in control mechanisms, like James Watt's feedback regulator, managed their operation by turning valves, lifting levers or releasing triggers. During the first half of the nineteenth century a number of machines were developed which, like the mechanical loom, through self-regulation could perform operations previously only mastered by skilled labor. Significantly, the machines could be supervised by unskilled workmen, cheaper to employ and easier to control in the changed production environments.

The manufacture of the new machines was made possible through improvements of "machines for making machines" like drilling machines, lathes, milling machines and more precise measurement instruments. Suggestions of a common standard for screw threads like the one proposed by Joseph Whitworth in 1841 was also part of a move toward more precision and more uniformity. A need for more systematic technological knowledge was met in Europe and the US by the establishment of specific vocational schools and engineering colleges in large numbers.

By the middle of the century a third, but related, strand of development led to a system, first in rifle production, by which one part of a mechanical device could be manufactured with such precision that without individual fitting it could be replaced by a similar part from another similar mechanical device. Before this, every part – even the screws – of mechanical devices were produced and fitted together individually and could not without further filing or grinding fit into another similar device. The new system became known as "the American system of Manufacture." In the 1860s it was introduced in the manufacture of Singer sewing machines and McCormick farming machinery, and high precision and interchangeability are now essential to all modern forms of mass production. A further significant step in the same direction was the introduction of assembly-line production by the Ford automobile works in 1914. A third step was the introduction of robots in production plants from the late 1970s. The Japanese perfection of car production during the 1950s and onwards, now referred to as "lean manufacture," is emblematic of this motion toward rational and systematic optimization. But lean manufacture is also a reminder that the development of "Western" technology is no longer confined to the West.

A recurring theme in the scientific and technological debate of the Enlightenment was the vision of making science useful through the application of scientific results in the development of new technology. During the seventeenth and eighteenth centuries many individual scientists were employed as advisers or troubleshooters in technical projects, but a systematic and effective way of involving science was not found. The nowadays very strong interaction between science and technology found its first efficient working mode in the chemical industry of the nineteenth century. From 1855 onwards, university-trained chemists discovered ways to produce dyes synthetically for textiles – in the beginning accidentally, later systematically. Such dyes had been produced on an organic basis for centuries, but now a growing range of colors could be manufactured in chemical factories at greatly reduced prices. A race among the chemical producers set in, and soon German companies led the way. During the second half of the century they kept their lead by employing university-trained chemists in growing numbers and letting them work in rooms that were fitted out like university laboratories; the industrial research and development laboratory had been invented. A very large part of the technological breakthroughs of the last hundred years have their origin in the now numerous research and development laboratories. Some are funded directly by government agencies, others by the large companies themselves, whether dealing in electronics, drugs, weapons, or any other kind of advanced technology.

Toward the end of the nineteenth century the advent of "modernity" coincided with the appearance of new amazing technologies like the telephone, electrical energy distribution, radio, cars, fast turbine-driven ships, and aeroplanes. At the hospitals, novel science-based medical technologies like X-rays, electrocardiographs and new drugs were introduced, together with new concepts about the bacteriological or viral origin of many diseases. Science, technology and progress seemed to be true companions. But during the First World War advanced technology clearly demonstrated its dark side through the devastating use of poisonous gas, machine guns, improved artillery, submarines, radio telephones, and aeroplanes. During the Second World War all parties used scientists on a massive scale to invent and improve weapons and defensive measures; nuclear bombs, jet fighters, ballistic rockets, radar, sulphur drugs and penicillin being among the most famous. The success of science-like research to develop and perfect new technologies for military purposes set the stage for the massive technological research and development in the US after the Second World War, leading to such – military and civilian – devices as solid state electronics, CNC (computerized numerical control) machines, the digital computer, the Internet and nuclear energy. Technological development projects funded by various American defense budgets have had a tremendous influence on the way Western technology has developed during the past fifty years.

At the beginning of the third millennium, people in close contact with Western technology live their lives surrounded by, and in dependence on, a number of large technological systems. In cities, systems of drinking water, sewage, gas supply, transport, and electricity supply exist side by side with information systems like telephone, radio, television and the Internet. Less conspicuous, but not less important, are other systems that keep track of the weather, monitor pollution, oversee bank transactions and the use of credit cards, convey information about currency and stock exchanges, monitor air traffic and survey the airspace, and so on. The systems interact, mainly because they depend on electricity as their ultimate energy source, and because they depend on connected computers for monitoring and regulation. At the same time, international air traffic spans the globe, cars move people and goods around on enormous road systems, and ships sail the oceans transporting raw materials and finished goods from producer to market in ever increasing amounts.

The most characteristic traits of modern technology seem to be its scale, its pervasiveness, its complexity, and its ability to change constantly. The modern Western style of living, health and welfare would be unthinkable without Western technology. But Western technology also has severe downsides. Previously, its pervasiveness and capability to span the globe created the background for a comprehensive and ruinous slave trade. Later, Western imperialism was much assisted by telegraphs, steam ships, efficient rifles, and railways. It made economic and human exploitation possible and gave rise to a disagreeable feeling of Western cultural supremacy. And, although war is not a recent activity inspired by, or made possible by, Western technology, modern "total" war, in which civilians often suffer more than the combatants, is.

One great challenge created by the now globally distributed Western technology is the enormous economic disparities between the various parts of the globe, most of which now share the same information systems and have access to the same information, but not at all to the same wealth and standards of living. Another daunting challenge is the threatening climatic changes brought about principally by the intensive use of fossil fuels to power transport and production.

# 4

# Chinese Technology

## FRANCESCA BRAY

In this brief essay I address two issues: how concepts of technology in its modern sense have affected the experience of being Chinese and how technological practices and meanings in China might inflect our own ways of thinking about technology.

In the *Novum organum* of 1620, Francis Bacon noted that "Printing, gunpowder and the compass have changed the whole face and state of things throughout the world . . . in so much that no empire, no sect, no star seems to have exerted greater power and influence in human affairs than these mechanical discoveries" (1.129). Karl Marx, in his *Economic Notebooks* of 1861–3, put it slightly differently: they were "the three great inventions which ushered in bourgeois society. Gunpowder blew up the knightly class, the compass discovered the world market and founded the colonies, and the printing press was the instrument of Protestantism and the regeneration of science" (Marx 1861). In his encylopedic research on science and technology in pre-modern China, Joseph Needham documented the Chinese origins of all these technologies but was then faced with the challenge of explaining why they failed to transform Chinese society as they had revolutionized the West. Until recently both Chinese and Western ideas about technology in China were routinely framed in terms of the so-called "Needham question": Given that China surpassed Europe in many technical domains until well into the medieval period, why did imperial Chinese civilization not generate its own scientific or industrial revolution? Why did it achieve so much in early times, then lose its virile drive to innovate and sink into vulnerable stagnation?

Throughout the colonial period and through to the present day, perceptions of technological superiority have played a key role in constructing ideologies of Western dominance, and in shaping national self-images (Adas 1989). The Chinese first had their noses rubbed in the technical ineptitude of their civilization during the first Opium War of 1840–2, when their defenses were pulverized by British warships. This was the first of many humiliating defeats by well-armed Western powers; the Qing government was forced at gunpoint to cede treaty-ports and land, grant access to missionaries, and open its markets to Western industrial commodities. From 1860 the government adopted an innovative but shaky policy of "self-strengthening," hoping to restore Chinese wealth and power through the selective adoption of Western legal and administrative institutions and the development of strategic technologies. Foreign experts were brought in to educate and train Chinese engineers, to construct plant, and to design and manage

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projects for building railways, telegraph lines and, above all, armaments. The Jiangnan Arsenal, founded in Shanghai in 1865 to produce firearms, artillery and warships, was the most famous of these ventures. Despite some signal achievements, by 1894 China was still too poorly armed and organized to withstand a whirlwind invasion by the Japanese (Waley-Cohen 1999). As they signed away Taiwan and the northeastern provinces in the Treaty of Shimonoseki, the Chinese asked themselves why they had failed to modernize when the Japanese, another supposedly inferior Oriental nation, had succeeded so spectacularly. Whereas the self-strengthening movement had proposed an accommodation between "Western artifacts and Chinese spirit," reformers and revolutionaries now felt that Chinese traditions were incompatible with modernity and must be ruthlessly discarded.

Through the last years of empire and the troubled decades of the Republic (1911–49), many Chinese took a technocratic view of the future. Science, technology and technical expertise could – and must – be imported as catalysts for modernization. However, China was believed to lack any indigenous intellectual or material traditions to aid this essential process. Needham's work played a fundamental role in challenging this assumption. Although it is not a tactic that appeals particularly to historians of technology today, Needham's long list of key Chinese technical inventions (e.g. the crossbow trigger and the blast furnace) which predated their appearance in the West effectively challenged the view that China had historically lacked "real" technological skills or understanding.

Needham's findings began to appear in print in the early 1950s. The communist government of the People's Republic of China, established in 1949, warmly welcomed Needham's documentation of what they identified as the skills and ingenuity of the working masses of ancient China (also manifest in the stunning artifacts excavated by archeologists during the 1960s and 1970s). Denied any aid by the anti-communist Western powers, at first the new regime relied upon the Soviet Union to follow a conventional technocratic path of development. But after the Sino-Soviet split of the late 1950s Mao's regime was thrown on to its own resources, consisting principally of an enormous labor pool. The state envisioned a "self-reliant" future built with technology that the Chinese workers and peasants would create for themselves, applying native technical skills (and the indigenous inventive traditions so opportunely demonstrated by Needham) to adapt Western models, thus creating infrastructure and machines suited to Chinese material and political needs and conditions. The destructive excesses of the Great Leap Forward and the Cultural Revolution are undeniable; however, the village and shop-floor technical projects of the period did mobilize popular participation in technical problem-solving, and mass mobilization built basic infrastructure (Sigurdson 1980; Wagner 1997). Such resources underpinned the return to a technocratic model that swiftly followed Mao's death: the Four Modernizations (Agriculture; Industry; Science and Technology; National Defense) and the economic reforms launched in 1978 (Volti 1982; Simon and Goldman 1989).

One slogan of the Cultural Revolution was "Better Red than Expert" – technological knowledge was only considered valuable if it was locally grounded and served the people. Since 1978 official policy has married technocratic and entrepreneurial values, sustaining three decades of steady economic growth and expansion of education and R&D. Technology, some advanced, some less so, has been imported under state auspices, and joint-venture companies – over 216,000 in 1997 (Volti 2002: 11) – have been established to develop expertise. Technology transfer has not always proceeded smoothly, especially where the hand of the state has weighed heavily, but in the last few years greater freedom for joint ventures, more openness to foreign participation, closer links to Hong Kong, Taiwan and diaspora Chinese as effective conduits of expertise and inputs, as well as new approaches to developing internal and international collaborations between state, universities and corporations seem to have paid rich dividends. Although Westerners still prefer to think of the Chinese as copying rather than innovating, China is rapidly emerging as a global leader in several branches of technoscience, including biotechnology and nanotechnology.

In 1930s China, the term "technology" denoted a material manifestation of Western superiority which China needed but could not create for itself. During the self-reliance campaigns of the 1960s, the term carried material, political and ethical connotations that would have been quite alien to most Americans of the period, if perhaps dimly recognizable to Scandinavians. Today basic misunderstandings between a Chinese and an American over what the term "technology" signifies would be unlikely, but there has been one big change: the Chinese post-colonial malaise is cured. Now most young Chinese believe, perhaps even more confidently than Americans, that their nation will play a central role in building the future.

An intriguing parallel to this resurgence of national technological confidence can be observed in the domain of technology studies. Until recently, the Chinese historical experience was usually considered interesting as a case of failure – in the terms of Bertrand Gille, a "blocked system." Marx saw China as a once great civilization which intrinsically lacked historical dynamism. Needham argued that a rich Chinese tradition of scientific and technical dynamism culminated in the Song dynasty (960–1279) but faltered after 1400. He tended to attribute this to the Confucian preference for order and stability typical of late-imperial bureaucrats (Needham 1967). Chinese Marxist historians also blamed imperial institutions and a feudal mode of production for smothering what they called sprouts of capitalism, elements of technical and economic dynamism during the late empire which might otherwise have triggered radical change. Other Western scholars, inspired by Mark Elvin's highly influential concept of involution (Elvin 1973), have sought sociotechnical, demographic or institutional explanations for China's failure to follow the path of Europe. From this perspective, China's history is less valuable in its own terms than as the West's Other. More recently, however, critical historians have turned the tables (Sivin 1982). Instead of trying to explain a supposed failure (to follow the trajectory of the West), they ask what China was at any particular historical moment in its own terms. They then are led to ask in a more anthropological vein which technological domains were of particular significance in that historical context, and what kinds of work, social or symbolic as well as material and economic, they performed. This is proving an exciting and revealing exercise. Examples include: the relation between the design of bells, kingship and cosmology (Falkenhausen 1994); technical changes that supported the emergence of new cultural elites (Kuhn 1987); how technologies were deployed to mark and maintain gender difference in times of social change (Bray 1997); evolving traditions of mass-production – from the ritual bronzes of the ancient Shang to the export-porcelains of the eighteenth century – and their shifting impact upon aesthetics and governance (Ledderose 2000); and philosophies of human material action (Schäfer 2005). Just as the feminist critique has transformed technology studies and undermined its master narratives, so, too, critical studies of technology in non-Western societies, of which China offers a particularly rich span, promise stimulating new perspectives on the nature and meaning of technology.

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# 5

# Islamic Technology

## THOMAS F. GLICK

By the time the Arabs had conquered a great band of territory from Spain to northern India (711–13), they had fallen heir to the scientific and technological lore of ancient China, India, Persia and Rome. A wave of technology emanating from China and India rolled across the Islamic world of the eighth and ninth centuries AD. A package of Chinese manufacturing technologies associated with the vertical, geared watermill equipped with cams arrived toward the end of the eighth-century movement. The package included manufacture of products that required maceration before they could be finished by hand: paper, sugar, and fulling and related industries. The vertical mill could also be used to mill wheat and husk rice. Paper first appeared in the Islamic world in Samarkand around AD 757, its arrival coinciding with the first Indian astronomical tables, the astronomical writings of al-Battani, Indian numerals, and the beginning of the great movement of translation of Greek, Persian and Indian science and philosophy into Arabic. The enormous size of the translation movement was itself an epiphenomenon of paper, without which it could not have attained such vast proportions, while astronomical tables and Indian numerals (for commercial transactions) were also associated with paper. The diffusion of paper presupposed the concomitant diffusion of the chemistry associated with both paper-making and the production of inks that could be used on it.

## "Indian Agriculture"

In the same period, the Indian so-called style of agriculture (*filaha hindiyya*) diffused from India westward. This movement included a distinctive roster of monsoon crops – rice, sugar cane, Old World cotton, watermelon, and citrus of all kinds, to which the artichoke and eggplant were added in Persia – that could only be grown under irrigation in the Mediterranean basin where the growing season was plagued by drought. Therefore, along with the crops came techniques required to irrigate them, most of which were seemingly of Persian origin: the qanat (filtration gallery) and the noria, generically called the Persian Wheel, although it is improbable that it was invented there. Both techniques had begun their diffusion before the Arab conquests: the Romans knew about qanats and built galleries all over North Africa. The Arabs vastly intensified

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the use of the technique: eastern Spain is emblematic by virtue of a profusion of very small qanats, some as short as 3 meters – backyard irrigation systems that any peasant could build.

There are two types of noria (from Arabic *na'ura*, "to groan"). The first is the current wheel that lifts water from rivers or irrigation canals by the force of the water alone. They were large in size and required no gearing. It is the first known self-acting machine. The second is the short-shafted, geared wheel, moved by animal power. In design it is an inverted Vitruvian wheel, which converts the horizontal motion of a wheel rotated by an ox, a camel or a donkey to vertical by engaging the gears on a potgarland wheel on which an endless chain of pots fell and rose, dumping water into a canal or a holding-tank. The device was used in littoral marshlands of the Mediterranean to drain waterlogged land for agriculture; in drier areas it was the basis of small irrigation systems. The noria made it possible for a single household to produce surplus for the market.

The Indian style of agriculture, codified in agronomical treatises such as Ibn al-Wahshiyya's *Kitab al-filaha al-Nabatiyya* (*Nabatean Agriculture*) and the works of the Andalusí agronomical school (Ibn Bassal, Ibn al-'Awwam, Ibn al-Wafid, etc.), was a compilation of peasant lore overlaid with the Greek notion of four counterbalancing qualities (hot, cold, moist, dry). Soils were watered, or dressed with fertilizer or marl, in order to balance the qualities. The result was a finely tuned agricultural system that took advantage of microregional differences in soil and water.

Norms that regulated the distribution of water and the administration of irrigation can also be considered as technologies. In this sense, institutional details such as the specific order of irrigation (from the beginning of a canal to the end, or vice versa) are part of the same technological package as the material elements of an irrigation system: the tapping of water via qanats or diversion dams, as well as the means of transport (canals), storage (tanks and reservoirs) and division (by divisors of given proportions) of water. Not only the norms governing allocation (water rights), but also practical hydraulic know-how (surveying canal routes, leveling canals, and construction of galleries and canals) and horticultural know-how (understanding the water requirements of different crops), are *techniques*, in that they are mechanisms of resource utilization in the same manner as physical structures.

Vertical (Vitruvian) and horizontal watermills – simpler, ungeared structures, where current-driven water-paddles are attached directly to the movable or "runner" millstone above – had appeared virtually simultaneously in the Mediterranean basin, the Middle East and China some time between 100 BC and AD 100. Both were known in the Islamic world, along with a distinctive third type, generically known as *aruba* mills. These are of the horizontal variety, but the water is delivered under pressure from a cylindrical water-tower. This is a way of milling in semi-arid conditions with a scant water supply.

The migration of artisans was the primary conduit for transmission of these ideas: Chinese prisoners were said to have brought paper technology to Bukhara. Persian lusterware potters migrated to Málaga in the later thirteenth century, fleeing the Mongols. Lusterware required updraft kilns, which were introduced concomitantly. The Persian loom, with enough heddles to reproduce the complex patterns characteristic of Persian textiles, likewise arrived in al-Andalus with Persian migrants. Migrants are typically risk-takers and thus less wedded to the traditional practices of the different crafts.

## Practical Astronomy, Surveying and Time-keeping

Medieval Muslims developed an approach to astronomy that was based on Greek astronomical theory (especially Ptolemy's *Almagest*), Indian astronomical tables, and the astrolabe, an observational tool that performed a variety of tasks including finding the time of the day or year or of a celestial event, or determining latitude. Finding the *qibla* (the direction of Mecca) astronomically gave rise to a specific body of tables. An astrolabe, or a simplified version of one, could be used in navigation to determine the altitudes of the sun, the moon, the pole star or other celestial bodies. Arab ship captains, however, preferred a simpler instrument, a wooden block and knotted string called the *kamal*, which was used to take celestial altitudes.

In the medieval Islamic world there was a well-defined science of astronomical time-keeping called *'ilm al-miqat*. It was used, first, to determine the five daily canonical hours of prayer. A muezzin could do this with an astrolabe, or a professional astronomer called a *muwaqqit* could be hired. At the popular level, the hours of night could be determined by anybody who knew some astrology by looking at the lunar mansions; in daytime, by measuring the length of one's own shadow – and there were twenty or more methods of how to do this. At the learned level, scholars like al-Khwarizmi wrote prayer-tables for each latitude. Muezzins were enjoined to use astronomical tables for determining prayer times and the astrolabe for finding the *qibla* (the direction of Mecca).

The rules of surveying area fell under the broad science of measurement called *'ilm al-misaha*, and that of leveling fields and irrigation canals part of *'ilm al-mizan* ("the science of the balance"). In order to ascertain the gradient of the route of an irrigation canal, various kinds of level were used. These were described in treatises devoted to *'ilm al-mizan* ("the science of the balance"). On large-scale, government-directed canal projects, as in the Tigris and Euphrates basin, labor costs were figured by calculating the volume of the canal algebraically.

Leveling instruments ranged from the very simple, like a plate or pipe filled with water or a large A-level with plumb bob, to sophisticated instruments like the astrolabe and the quadrant, and geometry. Builders measured the perpendicular with similarly simple or difficult methods, ranging from a plumb bob, a plumb bob and quadrant, or a gnomon.

## Gunpowder and Firearms

Gunpowder was a serendipitous invention of Chinese alchemists while experimenting with mixtures of sulfur and saltpeter in an attempt to make gold. The oldest surviving recipe dates from AD 800, and by the thirteenth century they had developed fragmentation bombs and kinds of explosive projectiles. The Mongols transmitted the technology westward, and gunpowder recipes appear in Hasan al-Rammah's *Kitab al furusiya wa'l-munasb* *al-harbiya* (*Treatise on Horsemanship and Stratagems of War*), written in 1280. Muslims introduced artillery into Nasrid Granada, where "iron pellets that were shot with fire" were used in an attack on Elche. In the seventeenth century, Muslim exiles from Spain (then called Moriscos) introduced advanced weapons technology into Ottoman North Africa, where Ibrahim ibn Ahmad ibn Ghanim al-Andalusi wrote an influential artillery manual based broadly on Luis Collado's *Plática Manual de artillería* (1592): *Kitab al-izz wa'l-manafi lil-mujahidin fi sabil illa b'il-madafi* (*The book in which one seeks triumph and advantage when fighting against the infidel with military stores*). It was a precept of Ottoman jurisprudence that infidels must be opposed with their own weapons. Such an ideology makes intelligible the demand for foreign military technology.

## Philosophy of Technology

There is a debate among historians of Islamic technology over the meaning of the mechanical arts (*hiyal*), particularly with respect to the building of elaborate models of clever machinery (mechanical clocks and the like) as in al-Jazari's thirteenth-century *Compendium of Theory and Useful Practice in the Mechanical Arts* (*al-Jami' bayn al-'ilm wa'l-'amal fi sina'at al-hiyal*), where *hiyal* (singular *hila*) means "artifices" or "devices." Jazari's definition of technology is a man-made device that performs actions contrary to the natural forces of nature, his example being the lever. His patron had praised him for making models and bringing them forth from potentiality (theoretical principles) into actuality (practical applications). Each *hila* gives palpable form to a specific concept of physics, according to al-Farabi and other medieval Muslim philosophers, following Aristotle's *Mechanical Problems*.

Ibn Khaldun, the great fourteenth-century polymath, expounded a philosophy of the craft trades in some detail, mixing Aristotelian explanation with his theory of the rise and fall of dynasties. In the *Muqaddimah,* he states that, first, crafts – which are concerned with both action and thought – have to be learned. That is, there is a mental component of technology (*'ilm*) that informs the mastering of a specific craft practice (*'amal*). Once mastered, such skills become rutinary and are performed by habit: "A habit is a firmly rooted quality acquired by doing a certain action and repeating it time after time, until the form of [that action] is firmly fixed." Crafts are mainly learned by observation, and the skills an apprentice acquires are owing not only to the quality of teaching but also to the "habit" of the teacher. It is in the mind that craft skills are transformed from potentiality into actuality (alluding to this well-known Aristotelian notion).

He then unites Aristotle's construction of technology with his own views on the environmental input. The skill level in crafts is also a function of the locus of demand: sedentary, urban civilization pushes the transformation of those skills from potentiality to reality. That is why the quality of urban craftsmanship is better than that of rural craftsmen because in the countryside the primary concern is survival. A small Bedouin settlement requires only the simplest of crafts: there, you will find a carpenter, a blacksmith, a tailor, a butcher, or a weaver. But their performance is imperfect and underdeveloped with respect to the same crafts in an urban setting.

Then he works in his dynastic cycle hypothesis: crafts are so rooted in cities that, even when those cities lose their wealth with dynastic decline, the craft skills learned and transmitted there are still substantially higher than those found in cities of new foundation. The example is al-Andalus, which, even though reduced to the kingdom of Granada, retained craft skills unequaled in any other Muslim Mediterranean polity. When a city is nearing senility, craft skills finally diminish.

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# 6

# Japanese Technology

## DAVID WITTNER

Much of Japan's technological history can be described as a dialogue. From the earliest times this dialogue took place between Japan and its East Asian neighbors, in particular China and Korea. Later it was an exchange between Japan and Western visitors. In the mid-nineteenth century and beyond, the government and the private sector fostered increased translation of foreign technical knowledge into Japan. Regardless of the era, there was also an internal discourse in which absorbed and indigenous technologies were transformed to suit local resources, needs and sensibilities.

There is clear evidence of technological interaction with China and Korea since at least the Jōmon period (c. 10,000 BCE–300 BCE) with the introduction of wet field agriculture in the fourth century BCE. Japan first received iron and then bronze implements – primarily weapons, agricultural implements and ceremonial objects – from Korea and China throughout the Yayoi period (c. 300 BCE–300 CE). Distinctively Japanese weaponry found at archeological sites indicates that the Japanese began working with iron and bronze based on continental interaction. A variety of ceremonial objects including bronze mirrors and glass beads were also imported and later manufactured in late Yayoi Japan. Perhaps an unfair characterization, much of Japan's history of technology until the seventh or eighth century reads more like a list of received innovations from the continent including irrigation techniques, plows, weaving, brewing, sericulture and paper-making.

Beginning with the Nara period (710–94), however, we can see greater indigenous development of technologies. Divergence from the Chinese model is especially notable in woodworking, textiles, ceramics, printing, paper-making, agriculture and metalworking. Much of what we know of technology from this era comes either from the artifacts, such as temple roof tiles or actual eighth-century buildings, or from a tenth-century text, *Engi shiki*, which provides information on workshops in the capital that specialized in crafts such as paper-making, silk weaving, metal working, woodworking, and sake-brewing.

Beyond the *Engi shiki* and a variety of illustrated scrolls depicting craftsmen at work known as *shokunin zushiki-e*, our knowledge of technological developments during the late Heian (794–1185), Kamakura (1185–1333) and Muromachi (1338–1573) eras is mixed. During the Heian era there was a gradual breakdown of the traditional political system which, over the course of several centuries, led to the country being divided

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into semi-autonomous holdings known as *shōen*. Crafts production, too, became compartmentalized as *shōen* evolved into private estates. Craft traditions were transmitted orally, because most craftsmen were illiterate, and through a protective apprenticeship system that was largely hereditary. As in earlier eras, beyond illustrated scrolls and a few written records, much of our knowledge of technological change and development from this time comes from the artifacts themselves.

Accompanying the growth of private centers of political power in medieval Japan, came an increase in the number of urban centers whose inhabitants were primarily warriors, artisans and merchants. While there were some technological improvements in the countryside related to agriculture, the greatest area of change was in the cities where demands for luxury items, consumer goods, and weapons drove innovation.

Many artifacts and techniques that are now considered quintessentially Japanese were developed at this time. In woodworking, Japanese carpenters developed complex systems of joinery that required no mechanical fasteners. There was also some standardization of interior space with the increased use of tatami mats of uniform size. These innovations can be seen through religious and secular architecture. There were also developments in ceramics and textiles. Potters, silk-reelers, cotton-spinners and weavers moved their crafts, originally based on Chinese techniques, in directions that increasingly diverged from continental methods. During the latter half of the Muromachi era, know as the Sengoku or Warring States era (1467–1568), there was significant innovation in metalworking, especially as related to the military. Swordsmiths refined techniques for forging blades that exhibited the best qualities of hard and soft steel. Craftsmen working in bronze and fine metals refined the techniques for producing sword and weapon appurtenances such as *tsuba* (sword guards) and *menuki* (decorative pieces on a sword's grip). Many of these techniques were quickly translated into more mundane fields of daily ironworking or into the decorative arts.

Beginning in the mid-sixteenth century, Japan entered a period of heightened technological activity. Stimulated by increased trade with China and the arrival of the Portuguese, a series of new technologies were internalized by Japanese craftsmen. Aided by imported technical manuals, Japanese craftsmen made significant improvements to indigenous practices in paper-making – which further drove the production of indigenous manuals – metalworking, weaving, shipbuilding and navigation. Europeans also brought knowledge of optics, new techniques for glass-making, and improved techniques for amalgamation and mining. Having perhaps a greater impact on Japan's future technological development were two imported artifacts: firearms and the mechanical clock.

European firearms first arrived on Japan's shores in 1543 with the Portuguese. Quickly, Japanese metalworkers reverse-engineered these early matchlocks. In the course of several decades, firearms and light artillery played an important role in Japan's political unification. Japanese firearms development is a good example of technological dialogue. Craftsmen learned directly from Western sources, either the artifacts or the foreigners themselves. They modified the absorbed technologies, for example reversing the lock mechanism and protecting the powder tray from moisture. And, although firearms technologies were eventually monopolized by the *bakufu*, craftsmen also produced manuals with which to disseminate the technology.

Despite the decisive role played by firearms in Japan's political history, mechanical clocks, introduced in 1551, are in many ways more significant for the history of

Japanese technology. In order to reproduce a mechanical clock, Japanese craftsmen were required to work with a greater degree of precision and at previously unknown levels of complexity. Precision gear manufacture, springs, bearings and axles/shafts fostered the refinement of metalworking and casting techniques that would have application beyond clock-making and craft industries. Over the course of the next century, many of the techniques developed by clock-makers found their way into a variety of applications. Automata, mechanical dolls, were the Tokugawa era (1603–1868) heir to the clock-maker's art. Gears, bearings and shafts (driven and driving) were also reproduced on a larger scale and in wood for a variety of agricultural applications such as pumps, water wheels and rolling mills. The *zaguri*, a gear- or belt-driven silk-reeling machine, was also a beneficiary of this technological dialogue. Eventually, these developments were to form part of the knowledge base that would help drive Japan's nineteenth-century program of industrialization.

In 1639 the era of expanded contact with the West came to a close. With the exception of a Dutch trade factory on Deshima Island in Nagasaki harbor, and information obtained from China via Korea, the Tokugawa *bakufu* was largely successful in regulating contact with the West until the mid-nineteenth century. None the less, Japan continued to receive and absorb a variety of things from the Chinese mainland including books on agriculture, technology, medicine and mathematics. The most celebrated was a Ming dynasty text, *Tian Gong Kai Wu*, rendered in Japanese as *Tenkō kaibutsu* (*Development of the Works of Nature*), which contained information on agriculture and a variety of craft, mining and manufacturing techniques. The significance of this and other manuals was that they extended the technological dialogue. Techniques described for one field were often adapted to others. For example, early bell-casting techniques became the basis for Tokugawa-era cannon foundries, in much the same way that gears moved from clock-making to agricultural and textile machinery.

The nature of the Tokugawa political system had profound effects on the continued development of Japanese technology. The country was divided into a series of semi-autonomous domains that responded to the authority of the Tokugawa shogun but vied with each other economically. At most levels, this created a barrier to the dissemination of technological information, yet it also nurtured a high degree of craft specialization as artisans within the various domains sought to create new regional products for a growing market. Through systematic experimentation, Tokugawa craftsmen cultivated a tradition that recognized the value of incremental innovation. Always looking for additional sources of income, domain lords (*daimyō*) supported the growth of local industry. As a result, craft technologies spread throughout the country on a relatively even basis. Craft distinction was seen through technique and attention to certain types of detail.

Despite the proliferation of craft technologies throughout the country and well beyond the confines of cities, many Tokugawa technologies were guarded within a system of hereditary apprenticeship. Families maintained control of the technologies and techniques by which they created unique and specialized goods. Their methods were labor-intensive, and technical innovations within most craft industries tended to be labor-intensive as well. Because Japan had a stable population throughout the Tokugawa era, and little in the way of an export market, there was no incentive to increase levels of production. Similarities can be seen in agricultural technologies where an ample supply of labor inhibited the development of labor-saving devices. There was also a system of rural craft by-employment, driven by the sporadically labor intensive nature of Japanese farming. Farm families supplemented their income through cottage industries such as sericulture and silk-reeling. Sericulture is always labor intensive, but even more so in the Japanese case. Entire families would dedicate countless hours toward ensuring the health and well-being of silkworms. Absolute dedication to the most minute detail prevented Japan from experiencing the silkworm *pebríne* virus that devastated Europe's silkworm crop in the mid-nineteenth century. An ample supply of labor and possible concerns over product quality also prevented the rapid dissemination of the more efficient *zaguri* silk-reeling machine into many areas of the country. Although known, water-powered reeling machines were even less popular.

Yet Tokugawa technology was far from stagnant. Economic growth and the development of a market economy drove merchants and craftsmen, at the behest of *daimyō*, to bring a greater variety of products to market. This in turn gave rise to incremental innovations, new machines, techniques and tools. Simultaneously, the rise of commercial agriculture at the beginning of the eighteenth century led to the proliferation of agricultural manuals which, through illustrations and simplified text, discussed new techniques, tools, and methods by which to process agricultural products. Improvements in printing also helped spread technical craft manuals throughout Japan.

Technical knowledge of the time was not limited to crafts and agriculture. *Rangaku*, or "Dutch-learning," gained in popularity throughout the era with the educated classes. Alternately suppressed or finding favor with the *bakufu*, *Rangaku* scholars provided Japan with a basic knowledge of European science, medicine and technology in no particular order. For about a century following 1720, Western knowledge flowed into Japan. Scholars actively translated and published books on anatomy, physics, chemistry and electricity, to name just a few areas. As with other technical dialogue, Western knowledge found new applications once absorbed into Japan. Physician Hanaoka Seishō, for example, combined Western and Chinese medicine to perform probably the world's first surgery using general anesthesia.

As the tenor of Western visitors to Japanese waters rose in the mid-nineteenth century, so, too, did the importance of *Rangaku*. Caught in the debate of whether to open Japan to foreign intercourse or remain closed, *Rangaku* scholars were marshaled to the defense of the state. Early initiatives were taken by *daimyō* from domains that were traditionally hostile to Tokugawa authority. Regardless, their actions pushed Japan toward industrial modernization along Western lines. Based on the translation of an 1826 Dutch book on cannon-casting, samurai-scholars built and operated reverberatory and, later, blast furnaces with the ultimate goal of producing modern, Western-style artillery. Soon, iron and coal mines, shipyards and textile mills followed in the wake of *Rangaku* knowledge. The opening of Japan in 1854 signaled the end of *Rangaku*, although the school of learning provided an essential ingredient for Japan's rapid industrial modernization in the decades to follow.

The final years of the Tokugawa *bakufu* ushered in significant changes for Japanese technology. At first, attempts to modernize Japanese industry and defenses were made by the combined efforts of traditional craftsmen, who lacked Western scientific and technical knowledge, and samurai-scholars, who lacked technical ability. Following 1854, however, foreign engineers, mechanics and adventurers made their way to Japan, first in the employ of the Tokugawa government or various domains, and later of the Meiji government. During the Meiji era (1868–1912), Japan underwent industrial modernization along Western lines. The first two decades can be considered a period of technological and scientific tutelage in which Japanese technologists, entrepreneurs and engineers experimented their way through the early stages of modernization. The period following 1886 is often considered Japan's industrial revolution, in which techniques – technologies and organization – internalized during the first decades of the Meiji era came to fruition.

The Meiji era perhaps best exemplifies Japan's technological dialogue. The government simultaneously imported technologies, either in the form of foreign artifacts or engineers; created institutions of higher and technical education; and indigenized foreign knowledge by hybridizing technologies in some instances and by the direct licensing of Western technologies in others. By casting its net widely, Japan was able to attain industrial modernization and a high degree of technological independence in a relatively short period of time.

In an era of high imperialism, Japan was spurred by slogans such as "Rich Nation, Strong Army," This translated into the development of export industries, such as silk-reeling, and heavy industries, such as shipbuilding and eventually an ironworks, for national defense and nation-building. Japan's victories over China in the Sino-Japanese War (1894–5) and Russia in the Russo-Japanese War (1904–5) further stimulated the technological dialogue. The First World War provided both an economic boom and a stimulus for industrial development. As a result of the war, and being cut off from German science and technology, the government and private industry created the Institute for Physical and Chemical Research, known by its abbreviated name Riken, in 1917. Based in part on the success of Riken and cooperation between the government and the private sector, heavy industry – most notably chemicals, shipbuilding, optics and aviation – grew substantially throughout the 1920s and 1930s. The success of Japan's program of industrial modernization carried it into and through the Second World War.

In the postwar era Japan continued to follow the pattern of technological development that has sustained it since the earliest times. With the support of government agencies such as the Ministry of International Trade and Industry (MITI, established 1949) and the Science and Technology Agency (established 1956), Japan followed a coordinated policy of technological absorption and industrial development. Amongst other things, these agencies facilitated the licensing and dissemination of foreign technologies in Japan. As in earlier eras, Japanese industries modified foreign technologies. Often through a series of incremental innovations, such as miniaturization or artifact recombination, Japanese engineers created and patented indigenous variants of formerly foreign technologies.

Throughout the modern era, Japanese corporations, engineers and entrepreneurs have a consistent record of innovation that complements foreign achievement. Some Japanese innovations were based on foreign knowledge, others were more thoroughly indigenous developments. Examples include the first fully automatic power loom invented by Toyoda Sakichi in 1903, KS Magnetic Steel in 1917 by Honda Kōtarō, Yagi

Hidetsugu's television antenna in 1926, Sony's introduction of the first video tape recorders for the home market in 1963, and the Sony Walkman in 1978. More recently, Sony has been responsible for much of the pioneering work in High Definition television; Japanese automotive engineers led the way in onboard navigation systems.

Because of the close ties between major Japanese corporations and small and medium-size enterprises (SMEs) that serve as subcontractors, technologies originally introduced at the highest levels of Japanese industry are rapidly disseminated throughout the country. Japanese corporations also tend to invest a significant portion of their profits in research and development (R&D). Specifically they look to find innovative new applications for existing foreign and indigenous technologies. Although the trend has changed somewhat in the last decade, much R&D investment has been in applied technology rather than in basic research.

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# 7

# Technology and War

## BART HACKER

The interplay of military institutions and changing technology has regularly made history. Military institutions, like other social institutions, organize major areas of values, attitudes and interests in the service of critical social needs. Unlike most social institutions, however, military institutions appear only in state or near-state societies. Armies were closely linked with the origin of civilization, may in fact have been a necessary, if not sufficient, cause for the transition to state organization and civilized life. Cause or not, military institutions remain very close to the core of complex societies. Throughout history, military technological innovation has led through military reorganization to significant societal change. By the same token, social change has regularly reshaped technology. Fundamental shifts in military technology and institutions may well serve as useful benchmarks for organizing a study of general history that addresses deeper structures of stability and change in addition to more superficial patterns of event and personality.

Through most of the Neolithic era, archeology provides few hints of armed forces or organized warfare anywhere in Eurasia. Neolithic sites rarely show signs of fortification, although walls became the hallmark of the cities that define civilization. Specialized weapons likewise seem to have been unknown. The first distinct weapon technology emerged with metallurgy in the transit to civilization. Other than ornaments, the earliest bronze artifacts are clearly weapons, not merely hunting tools that might double as man-killers. Walls and weapons were the physical manifestations of a social invention, the army. The Near Eastern invention of armies during the fourth millennium BCE marked the first and greatest military revolution. It provided rulers with the means to organize coercive force, to control and direct the efforts of disparate individuals toward collective goals, to promote the disciplined order necessary to civilized life. When warfare became a corporate activity of hierarchically organized state-sponsored armed forces, warriors gave way to soldiers, who marched on foot and fought in formation armed with mace, ax, sword, spear and shield. Cooperation and discipline mattered at least as much as individual prowess or courage. Armies became the bedrock upon which arose chiefdoms, states, kingdoms and empires. Developing armies and rising states went hand in hand. Military force, however modest, was the indispensable prelude to building states; growing states, in turn, yielded resources for enlarged armies. Armies decisively divided prehistory from civilization.

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Mesopotamian city-states appear first to have crossed the military divide, followed closely by the kingdom of Egypt and soon by many others. A new weapon, the composite bow, joined the armory in the mid-third millennium BCE. This mechanical innovation converted archery from an annoyance on the battlefield to a potentially decisive arm of great range and power. Composite bows demanded much time and skill to manufacture, making them very costly, but their revolutionary implications appear obvious, as the first great empires in the Near East coincided with their spread. When civilized military techniques spread to the hinterlands, a new dynamic evolved as the union of horse-drawn chariot and composite bow in the mid-second millennium BCE fostered another military transformation. Armies built around relatively small numbers of chariot-borne bowmen swept all before them; on suitable terrain they appeared all but invincible. Chariot armies attacked civilized centers everywhere in Eurasia. Relatively fragile states in the eastern Mediterranean and south Asia collapsed under the assault, Mycenaean Greece and Vedic India rising on the ruins. Further east, Bronze Age charioteers may also have founded the first Chinese state, long identified with the Shang dynasty. Chariots themselves became potent symbols of power, widely adopted even in lands where they served little practical purpose.

By the late second millennium BCE, elements of still other radical changes in military technology and organization began to coalesce. Cheap iron displaced costly bronze as the preferred metal for weapons and armor. Lower equipment costs swelled the potential numbers of men-at-arms, dulling the once-decisive edge enjoyed by aristocratic charioteers. When iron became common, infantry reasserted itself on the battlefield and remained the core of state armies for the next thousand years and more. The spread of iron technology coincided with another wave of internal upheavals and barbarian invasions, exemplified in the Greek dark ages. The demise of chariotry only temporarily interrupted the horse's military career. By the ninth century BCE, after Eurasian steppe dwellers had learned how to draw the bow from horseback, mounted archers became the arbiters of battle. Equestrian techniques spread most widely on the fringes of civilized society. The lifelong association of steppe pastoralists with horses gave them an inherent and often decisive tactical advantage over sedentary farmers for the next two millennia. With this cavalry revolution began the long era when animal-herding nomads regularly threatened, and periodically conquered, their civilized neighbors.

Civilized societies could normally offset the tactical advantages of steppe horsemen or other invaders with larger populations and greater resources. By the first millennium BCE, growing economies could support standing armies. Pioneered by the neo-Assyrian empire early in the millennium, then improved by the Persians, standing armies of even a few thousand men greatly reinforced central power and became the basis for even greater empires. Standing armies also helped shield civilized societies from outside attack, although raiders constantly probed the borders and their numbers might quickly swell into full-scale assault at signs of weakness or disorganization. For centuries, heavy cavalry armed with composite bows proved a most effective counter to nomad raiding. Essential to this success were the large, grain-fed horses first bred along the Iranian steppe frontier late in the first millennium BCE. Bigger and stronger than grass-eating steppe ponies, they could carry riders armored against nomad weapons, yet move quickly enough to block most incursions. The result tended toward standoff because the great horses lacked the stamina for long pursuit and could not flourish on the steppe's meager forage. Heavy cavalry was also expensive. Civilized societies could not match the integral place of horse and horsemanship in pastoral economy and society that made cavalry a straightforward expression of steppe culture. Creating, training and maintaining special-purpose cavalry absorbed substantial resources; how to meet the costs of such forces became a problem for every state that adopted them, and the costs might be more than economic. Feudalism, the answer pioneered on the Iranian frontier, created centers of local military power that regularly threatened central authority. Despite such problems, heavy cavalry provided an effective defense in depth against steppe raiding. Byzantium and China adopted their own versions without the feudal trappings; they maintained a centralized, tax-supported force to deal only with serious incursions.

As the second millennium CE began, the logistic demands of a million-man army helped prod Sung China toward an incipient industrial revolution. Military technological innovation also flourished under official auspices. Gunpowder made its first appearance in the historical record at the beginning of the eleventh century, the first true firearms toward the end of the thirteenth. Both spread rapidly from China throughout the civilized world. Gunpowder weapons rendered much existing fortification obsolescent. Everywhere in Eurasia during the mid-second millennium CE, great guns seemed to inspire military imaginations to a far greater degree than did small arms. Artillery improved rapidly, though every increase in power meant heavier, clumsier and costlier guns. In the attack and defense of fixed positions, such shortcomings mattered less than the enormous weight big guns could throw, and their great expense meant that central governments ordinarily enjoyed near-monopolies on their use. Throughout most of Eurasia, guns weakened all forms of resistance to central authority. Gunpowder empires – Ottoman in the Near East, Safavid in Iran, Mogul in India, and, in part, Ming in China – consolidated power across the ancient band of Asian civilization, while lesser empires spread on the periphery, in southeast Asia, in Japan and in Russia.

Only in the western reaches of Eurasia did the imperial impulse fail, though just barely. Economically innovative and intensely competitive European states had the resources to maintain strong armed forces and the motivation to keep them well practiced. That no individual state matched the power of the Habsburg Empire and its allies mattered little. Because the empire rarely enjoyed freedom to concentrate on a single opponent, smaller states could deploy forces well able to resist imperial aggrandizement. The pattern of interstate military competition that created the standoff persisted and intensified, with far-reaching consequences, not least among them the modern nation-state. European armed forces steadily expanded, weapons and tactics improved, and organization and coordination grew more sophisticated, in contrast to the relative stagnation that overtook military institutions in lands where empire had become firmly established. These early modern European innovations that Michael Roberts termed "the military revolution" may well have been the key factor that disrupted in the West's favor the rough parity in technology, economy and polity that prevailed until the fifteenth century among civilized communities all across the Old World.

Initially, the West enjoyed only a modest advantage, limited largely to the heavy guns of ocean-going sailing ships, a combination that far outclassed anything then afloat. Western enclaves flourished under shipborne guns along the coasts of Africa and Asia, and even expanded sporadically in India, but elsewhere Western forces could make little headway against either the vigorous new gunpowder empires in civilization's classic centers or the relatively weaker states of Africa and Southeast Asia. Before the nineteenth century, only Petrine Russia systematically sought to emulate Western arms and military organization. Europe felt the limits of power even in the less-developed world. Foes equipped with neolithic weapons doubtless facilitated the mid-second-millennium European conquests in Mexico and Peru, as it did the later conquest of warlike chiefdoms in the Pacific, though such victories may have owed as much to Eurasian diseases as to European arms. Despite terrible losses, Native Americans survived the initial onslaught and learned how to fight back. Their success in keeping European colonization largely confined to the continental fringes for centuries owed much to skillful adaptations of firearms and equally skillful manipulation of rival Europeans to maintain sources of supply. Western firearms proved no less attractive in sub-Saharan Africa, where they became major factors in eighteenth- and nineteenth-century state-building. They exerted a degree of fascination even in the old centers of civilization, though other aspects of Western culture seldom held much appeal.

But not until well into the nineteenth century, after military, scientific and industrial revolutions had worked their transformations, did Western arms achieve an almost uncontested hegemony over most of the world. Only then did Western military institutions become the model for all others. By the early twentieth century, the last of the old empires had passed away or transformed themselves – a process that began invariably with the adoption of Western weapons and the Westernization of their military institutions. Ottoman reform, Manchu self-strengthening and Meiji restoration are only the best-known instances. In the late nineteenth and twentieth centuries, all armies became Western in organization, in equipment and in spirit. The most recent revolution in military affairs, as such transformations have lately come to be called, has taken the form of information control, based on the extraordinary development of electronics during the last half of the twentieth century, led by radio communication, electronic computing, and orbital satellites.

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# Part II

# Technology and Science

*A Companion to the Philosophy of Technology* Edited by J. K. B. Olsen, S. A. Pedersen and V. F. Hendricks

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## 8

# Technology and Science

## DON IHDE

The term *technoscience* has come into vogue in the last two decades. It suggests a sort of hybrid combining of technology and science, and has been used by many of the best-known Science and Technology Studies writers ranging from Bruno Latour to Donna Haraway and others. Such a hybridization stands in contrast to an older usage which suggested not only distinct differences between science and technology, but also a clear relation of dependence of technology upon science, as in the once popular usage of "applied science" referring to most engineering in its modern sense. This usage prevailed well into the twentieth century and still exists as a title for some programs, but has increasingly been called into question.

Are we undergoing a major shift in the terms of the once *master narrative* which both characterized and distinguished technology and science? Paul Forman, intellectual historian and curator of Medicine and Science at the Smithsonian Institution, thinks so. In a recent special issue of *History and Technology* (vol. 23, 2007), he argued that intellectually there was a "primacy of science in modernity" and that this shifted to a primacy of "technology in postmodernity," but that this shift was not recognized until recently by historians owing to their own ideology. Part of Forman's thesis is that the watershed for the shift was roughly 1980, and with a historian's scrupulous footnoting – 424 of them! – he shows how, in modernity, it was presumed that science was the primary source of ideas, theories and practices which both defined it as "prior" to technology and also distinct from it.

The shift, of course, began to be glimpsed well before 1980; and Forman recognizes, for example, the prescient role played by Martin Heidegger in the mid-twentieth century. Heidegger's famous "The Question Concerning Technology" (1954) raises the question about the *ontological priority of technology over science.* In his convoluted way, Heidegger claimed:

> Chronologically speaking, modern physical science begins in the seventeenth century. In contrast, machine-power technology develops only in the second half of the eighteenth century. But modern technology, which for chronological reckoning is the later, is, from the point of view of the essence holding sway within it, the historically earlier.
>
> (1977: 23)

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And Heidegger early on also points out that science itself uses and is dependent upon technologies:

> It is said that modern technology is something incomparably different from all early technologies because it is based on modern physics as an exact science. Meanwhile, we have come to see that the reverse holds true as well: Modern physics, as experimental, is dependent upon technical apparatus and upon the progress in building technological apparatus.
>
> (1977: 14)

While in some sense Heidegger is prescient concerning technoscience, in another – in his view that there is a sharp disjunction between modern and pre-modern technologies – he remains under the perspective of the primacy of science in modernity.

Clearly, in anthropological–historical terms, technologies as used by humans *predate modern humans (Homo sapiens)* since even our premodern ancestors used technologies for more than a million years prior to our own evolutionary emergence. But what of science? If the modernist master narrative is to be believed, this would make science much "later" than technology in a different sense. The modernist narrative places science, as with Heidegger, in the seventeenth century and, additionally, originating largely in a Western or European context in the Eurocentric narrative. But a Eurocentric interpretation of science is equally an invention of modernity and, as with the primacy of science over technology, is today under severe criticism. Its Eurocentrism, however, was not always taken for granted even in our own history. As early as the beginning of the seventeenth century, Francis Bacon claimed that the inventions which most benefited progress, and thus modernity, were paper-making, gunpowder, the magnetic compass and the movable-type printing press. But he also recognized that the inventors were the *Chinese*, who "completely changed the world's appearance . . . and displayed [the biggest] influence upon human progress" (1623). Thus, at the beginning of early modernity, what later became thought to be dominantly a Western and European science was not. Joseph Needham, much later, continued to chronicle Chinese technology, but he also claimed that this inventiveness died out and did not develop into the Western, theoretical science which became the ideal of late modernity.

If Forman is right, then the inversion of primacy – science with modernity and technology with postmodernity – poses a set of questions which arise with respect to technology and science and which begin to take different shapes contemporarily. One set of agreements would now seem to hold: the sciences are *instrumentally embodied.* But they are so embodied in different ways in the different sciences. While the positivist program earlier in the twentieth century included a hope for a unified science, ultimately related back to physics as foundational, it is clear in a postmodern era that such a program no longer is possible. Different sciences exhibit different science cultures and practices. For example, in astronomy, observation – until what is today called the *new astronomy* – had always been limited to what could be seen within the limits of optical light. Indeed, until early modernity the limits to optical light were also limits of what humans could themselves see within their limited and relative perceptual spectrum of human vision. With early modernity and the invention of lensed optical instruments – telescopes – astronomers could begin to observe phenomena never seen before.

Magnification and resolution began to allow what was previously imperceptible to be perceived – but within the familiar limits of optical vision. Galileo, having learned of the Dutch invention of a telescope by Hans Lippershey, went on to build some hundred of his own, improving from the Dutch 3x to nearly 30x telescopes – which turn out to be the limit of magnificational power without chromatic distortion. And it was with his own telescopes that he made the observations launching early modern astronomy (phases of Venus, satellites of Jupiter, etc.). Isaac Newton's later improvement with reflecting telescopes expanded upon the magnificational-resolution capacity of optical observation; and, from Newton to the twentieth century, improvement continued on to the later very large array of light telescopes today – following the usual technological trajectory of "more-is-better" but still remaining within the limits of the light spectrum. Today's astronomy has now had the benefit of some four centuries of optical telescopy. The "new astronomy," however, opens the full known electromagnetic spectrum to observation, beginning with the accidental discovery of radio astronomy early in the twentieth century, and leading today to the diverse variety of EMS telescopes which can explore the range from gamma to radio waves. Thus, astronomy, now outfitted with new instruments, "smart" adaptive optics, very large arrays, etc., illustrates one style of instrumentally embodied science – a technoscience. Of course astronomy, with the very recent exceptions of probes to solar system bodies (Moon, Mars, Venus, asteroids), remains largely a "receptive" science, dependent upon instrumentation which can detect and receive emissions.

Contemporary biology displays a quite different instrument array and, according to Evelyn Fox-Keller, also a different scientific culture. She cites her own experience, coming from mathematical physics into microbiology, and takes account of the distinctive instrumental culture in her *Making Sense of Life* (2002). Here, particularly with the development of biotechnology, instrumentation is far more *interventional* than in the astronomy case. Microscopic instrumentation can be and often is interventional in style: "gene-splicing" and other techniques of biotechnology, while still in their infancy, are clearly part of the interventional trajectory of biological instrumentation. Yet, in both disciplines, the sciences involved are today highly instrumentalized and could not progress successfully without constant improvements upon the respective instrumental trajectories. So, minimalistically, one may conclude that the sciences are *technologically, instrumentally embodied.* But the styles of embodiment differ, and perhaps the last of the scientific disciplines to move into such technical embodiment is mathematics, which only contemporarily has come to rely more and more upon the computational machinery now in common use. Isabel Stengers has seen, perhaps more clearly than many, the imaginative possibilities of such an instrumentally embodied mathematics, hinted at in her *The Invention of Modern Science* (2000). She glimpses the new styles of analysis which become possible through computer simulation, modeling and tomographical processes which are only now coming into preliminary maturity.

In a broad sense, of course, historians, anthropologists and archeologists have always known that technologies are "older" than science *if science is conceived of as it was by the modernist notion of science propagated by modern philosophy of science.* The Stone Age tool kit goes all the way back to *Homo erectus* and beyond. But other soft technologies, such as nets, fiber, bamboo and wood, also must go back into the prehistoric–premodern human. Wooden spear-shafts dated 400,000 BP have occasionally been discovered, but such discoveries are rare compared to Acheulean hand axes of 1,000,000+ BP. The historical commonplace, "Science owes more to the steam engine than the steam engine to science," which points to the historical fact that the questions which led to the discovery of the laws of thermodynamics came from questions of energy loss in early steam engines, not from observations of nature, is part of this pre-Forman shift to post-modernity's primacy of technology over science.

So how and why did modernity hold so tenaciously to the primacy of science? Part of the answer relates to the question: Who *interprets* science? And with respect to the twentieth century it is arguably the case that *philosophers of science* tended to prevail. Here several generalizations do seem to hold up: first, the paradigm or dominant science forefronted by philosophers of science in the twentieth century was *physics* – particularly mathematical physics – and its nearest relations. Earlier, one could argue that astronomy and cosmology occupied much of early modernity's interpretation, but even here the caveat is that the central interest of philosophers of science remained the laws of motion and their generalization into universality, thus, physics. The giants of early-twentieth-century philosophy of science were Pierre Duhem, Jules Henri Poincaré and Ernst Mach, all themselves mathematician-philosophers and all decreeing the mathematical "essence" of physics. Thus, the image of science which emerged from this set of interpreters was a science which was *ahistorical, acultural, "mathematical" or theoretical* and *context-free.* By the time of positivism and logical empiricism, most of that image of science was retained as was the centrality of theory-bias, although one could add a weighting to logical and propositional focii to the earlier mathematization emphasis, along with concerns with observation for verification purposes. Programs such as the unification of science and the proliferation of positivist philosophy of science in the universities are well-recognized parts of this part of the history of the philosophy of science to the mid-twentieth century. Rudolph Carnap, Hans Reichenbach, Herbert Feigl, Carl Hempel, Moritz Schlick et al. were some of these familiar names.

By mid-century, objections began to counter the positivist programs, and what today is usually called the "positivist-anti-positivist wars" began. Karl Popper, Imre Lakotos, Paul Feyerabend and pre-eminently Thomas Kuhn were the anti-positivist critics. And, although concrete *histories*, *instruments* and, to some degree, *experiments* begin to play a role in science interpretation, it was not until later in the twentieth century that a shift to a *praxis*, *laboratory* and new *experimental* focus began to overwhelm the earlier trajectory of theory-centered interpretation. Before leaving philosophers of science as key interpreters of science, the appearance in the 1980s, precisely after Forman's watershed year, of experiment- and instrument-oriented philosophy of science began to make inroads. Ian Hacking's *Representing and Intervening* (1983), with its marked shift to intervention and manipulation via experiment and instruments, was one landmark. Robert Ackermann followed with *Data, Instruments and Theory* (1985), and Peter Galison with *How Experiments End* (1987).

To this point, interpreters of science from the philosophy of science have been noted; but, even before the new experiment- and instrument-sensitive philosophy of science gained momentum, new challengers for interpretations of science which were *practice-oriented* and focused upon experiments, instruments and laboratories were under way. This was especially marked by the new and largely "post-Mertonian" sociologies of science from both the United Kingdom and Europe. "Social Constructionism," "The Strong Programme" and "Actor Network Theory" by the mid-1980s were in strong contention with interpretations of science which looked at the social and sometimes material cultures of science. Here the names of Trevor Pinch, Harry Collins, Steve Woolgar, Michel Callon, Bruno Latour, Karin Knorr-Cetina began to appear. Philosophers of science had new interpretive competition, and the "wars" which occurred were an indirect recognition of the contention.

What of the philosophy of *technology*? For the most part, one can say that the philosophy of technology is primarily a twentieth-century development. While, at the end of the nineteenth century, the two neo-Hegelians, Ernst Kapp and Karl Marx, both turned "idealism" upside down and began to look at technologies and productive processes as leading to, or even determining, societal outputs, it was only after the strongest effects of the Industrial Revolution and the emergence of militarized technologies from the two world wars that major philosophers looked deeply and seriously into technology. With the exception of John Dewey on the American scene, most early philosophy of technology was European, and mostly deriving from what could be called the more *praxis*-oriented traditions such as Marxian, phenomenological, and including American pragmatism. Looking back over the last century, there is now close to a consensus regarding the beginnings of the philosophy of technology. Publications range from Carl Mitcham's well-recognized history of the philosophy of technology, *Thinking through Technology: The Path between Engineering and Philosophy* (1994), to the work of the Twente group of philosophers of technology under the leadership of Hans Achterhuis with *De Maat van de techniek* (1992) and *Van Stoommachine tot Cyborg: denken over techniek in de nieuwe wereld* (1997), later translated with updates into *American Philosophy of Technology: The Empirical Turn* (2001). Following Achterhuis, one could characterize early-twentieth-century philosophy of technology as concerned with technology-in-general at a "transcendental" level; as often dystopian in tone; and as portending an end to the modern era. Friedrich Dessauer, a neo-Kantian, and Martin Heidegger both addressed technological themes as early as 1927; but Ortega y Gasset, Karl Jaspers, many of the principals of the Frankfurt School, including Adorno, Herbert Marcuse and Jürgen Habermas, also began to write about technological themes. In contrast to these early-to-mid-twentieth-century thinkers, in the later twentieth century a second generation of philosophers of technology were seen as taking an "empirical turn" to the closer-up examination of a plurality of particular technologies, as more pragmatic in outlook; and as democratic in aim. Achterhuis's *American Philosophy of Technology* includes introductions to Albert Borgmann, Hubert Dreyfus, Andrew Feenberg, Donna Haraway, Don Ihde and Langdon Winner as those who are located under the new descriptions. With respect to technologies and science, I will mention my *Instrumental Realism: The Interface between Philosophy of Science and Philosophy of Technology* (1991), which addresses a wide spectrum of both philosophers of science and philosophers of technology with emphasis upon science's technologies. And my earlier *Technics and Praxis: A Philosophy of Technology* (1979) had already argued that science has all along been technologically embodied.

Thus, from an enlarging field of differently based interpreters, the roles of technology vis-à-vis science have become more visible from the late twentieth century into the twenty-first. In this section of the *Companion to the Philosophy of Technology*, the contributors to the themes of technology and science again also actually display a variety of opinions, clearly calling into question any "standard view" of the primacy of science over technology, but not often going so far as to invert the relationship to a "Heideggerian" one of the primacy of technology over science, nor to the hybridization of technology and science into a technoscience.

Three of the contributing philosophers – incidentally all from the Netherlands – all recognize the contemporary shift which has occurred in philosophies of science. Hans Radder notes that, from the earlier, one could say more elitist perspectives of "scientism" and "technocracy," current shifts towards "methological naturalism" and "critical normativity" are also more concrete and, one could say, empirical, with respect to the earlier and more ideological tones of the last century. Bart Gremmen claims that the science–technology relationship to the seventies was dominated, again, by the theory concerns of philosophy of science, thus confirming the modernist frame suggested by Forman as well. Gremmen, however, sees something like an interaction schema replacing the modernist one, in which there remains a certain distinction between technology and science and the interrelation of the cognate philosophies thereof. And Mieke Boon, quite aware of the emergence of the notion of technoscience, sees the shift centering on emphases on a "new experimentalism" related both to philosophy of science and philosophy of technology, but also relates this to a movement toward recognizing a unique style of *technological knowledge*. In all three cases, the older traditions of a strong distinction between *episteme* and *techne* are called into question.

Indeed, the largest group of contributors to this section could be characterized as interested precisely in forms of "technological knowledge." Anthonie Meijers and Marc de Vries make technological knowledge their primary theme, arguing against now dated notions of "applied science" and for a distinct and recognizable *technological* knowledge. Peter Kroes argues, in a parallel vein, that, in so far as engineering and design must take into account human needs, actions and values there can be something like a history of intentionality which plays into the human–technical juncture. Somewhat more extreme, Wiebe Bijker, one of the principals in the social construction of technology movement, shows a wide spectrum of social–cultural aspects which permeate technologies, drawing from some of his past work on specific technological developments. Louis Bucciarelli, while allowing as a background phenomenon the older notions of science, forefronts the notion of an *engineering science,* again having its own validity as a type of knowledge. Along with Kroes and Meijers and de Vries, function plays a strong role. Keekok Lee plays a similar role in the critique of the ancient *episteme*/*techne* distinction when dealing with technology and biology. The very notion of a biotechnology and its manipulations and constructions of new biological entities belies such ancient distinctions. Finally, in some respects coming the closest to an inversion of the modernist primacy-of-science notion, are the essays of Helge Kragh, W. J. Nuttall and Andrew Pickering. All hold, in different contexts and for different sciences, variants upon how new technologies or discoveries in technologies not only impact upon science, but also effectively invent to stimulate new sciences. Kragh does this historically with respect to chemistry: the discoveries of phosphorus, soda and sulfuric acid were all made either accidentally or serendipitously and led to one of the first "Big Sciences" in chemistry, without benefit of theoretical science which only later could deal with the atomic and molecular theory needed to have such a chemical science. Nuttall, by tracing aspects of nuclear science and the development of nuclear weaponry, shows how, once again, a set of technologies carries enormous implications for the practices, politics and formation of science – in this case Cold War physics and engineering. Pickering, again drawing from developments in the same era, takes cybernetics as yet another "technological" development which leads to a new type of science, one still under development in a number of science disciplines. These entries, not unlike that of the steam-engine-to-thermodynamics maxim cited above, come the closest to the primacy of technology over science in a postmodern sense. And in all cases it is clear that a modernist consensus regarding the sheer primacy of science over technology no longer holds for most contemporary thinkers. And it should equally be clear that the "thin" and theory-biased image of science, often narrowly concerned with physics, has equally been called into question. A more complicated image of science, in some ways actually looking more like a technologically practiced science, has emerged. Such a science is, or has, cultural, historical, contextual, social–political features – and is, as Larry Laudan proclaims for all contemporary philosophy of science – fallibilistic.

If the ground has shifted, particularly with respect to modernism, and, if the criticisms of modernism need to take into account cultures, histories, technologies, what would a *technoscience interpretation* of the relations between technology and science look like? Here, rather than take the direction taken by Forman concerning the "primacy of technology," this reframing will examine a more symbiotic technology/science direction, one suggested by the term "technoscience." This, too, would be a reframing of the question, but one which reflects some aspects of a more *pragmatist* interpretation. Such a reframing would hold that (*a*) the style of robust, repeatable and dependable knowledge which we identify with science *has always been a process which entails technologies*; (*b*) since it is a human activity which responds to needs for knowledge in a variety of contexts, it should be identifiable wherever and whenever it has occurred; and (*c*) it can also be variously contexted, relative to the needs and shapes of the societies into which such practices fit. This reframing, as will be shown, ends up being multicultural, occurring in many different places and times, and is developmental, particularly with respect to the refinement and progression of the technologies used in producing the knowledge entailed.

Once again, this reframing narrative begins with the very ancient science – astronomy. Even our prehistoric ancestors observed the celestial motions of the night-time skies and very early on began to develop *calendars*, which are one form of "writing" technology which can make repeatable patterns available, including passing on a record for later generations to recognize. Moon phases have been found marked on reindeer antlers, counting-sticks and the like, going back at least as far as the Ice Age images of 30,000+ BP. The full lunar and solar calendars, some more accurate than those of the European Middle Ages, can be found in a number of ancient civilizations stretching from the Middle East to Meso-America. And the writing technology of the calendar-artifact is, as contemporary archeoastronomy has now shown, not the only technology relevant to the ancients. *Observational instruments* also played an apparent role. It has long been surmised that Stonehenge (4500 BP) was used as an observational instrument; and, as Anthony Aveni and Dick Teresi have pointed out, similar stone rings, sighting tunnels and the like have been found aligned with ancient observations in many areas of the globe. In fact, some are so ancient that only by taking into account the shift in precession changes in celestial alignment can dating of prime usage time be established (Amerindian rings have been dated for such usage at least 3000 BP). The point here is simple: observations of this sort have been made in many cultures, in great antiquity, and were both recorded on various forms of writing technologies and observed by means of simple instruments. Is this, then, ancient technoscience? If so, it has plural origins, but can also accommodate our own standard history, which also includes significant discoveries. Robert Crease's *The Prism and the Pendulum* (2006) is a monograph responding to a physics educators' poll concerning the ten most beautiful experiments in science history. The most cited example was from Hellenic Greek times, that of Eratosthenes' measurement of the circumference of the earth. By using a gnomon, a stick sundial which at the summer solstice cast no shadow, combined with relatively simple geometry with a known distance between two cities – one the observation site, the second where the angle of shadow could be measured – through simple triangulation he was able to produce a respectable measurement of the earth's circumference. This, too, is an instrumental-styled, mathematically interpreted technoscience, this time within our standard master narrative theme.

The reframing being suggested here takes account of both multicultural instances of science, better technoscience, and of its embeddedness in both a material culture and material instrumentalization. And, while few recent authors have ventured into the multicultural aspect of this territory, some have made significant gestures in this direction, including: Sandra Harding with *Is Science Multicultural?* (1998); Dick Teresi, *Lost Discoveries: Ancient Roots of Modern Science* (2002)*;* Helaine Selin's massive *Encyclopedia of the History of Science, Technology and Medicine in Non-Western Cultures* (1997). Such studies only now begin to expand and supplement the older traditions – such as those of Bacon to Needham mentioned above – which recognize only limited non-Western technoscience origins such as China. What emerges is a different, more scattered, but also more understandable profile of scientific and technological inventions and discoveries. For example, and again only due to contemporary dating techniques, it is beginning to be understood that grain domestication occurred in many different places of the earth roughly between 8000 and – 10,000 BP, in the Middle East, in Asia, and even in Meso-America – and with different grain combinations, usually a dominant grain or a few dominant grains, with most grains not undergoing selection for hypertrophism. Thus, wheat, rice and corn respectively fit into the samples above; but other examples, too, have begun to be recognized (figs, squash and beans, and the like). Granted, there is a kind of irony with both why and how such a reframing can take place in postmodernity. The irony is that only contemporarily do we have the instrumentation to determine with accuracy the dating, the identification of the materials involved and thus the recognition of past, often previously lost practices. This same inventiveness, the multiculturalists have begun to recognize, can also occur in much more abstract activities. Teresi points out, along with others such as Robert and Elaine Kaplan, that "zero" has been invented a number of times in a number of ancient cultures. The Babylonians may have been first with zero as a place-holder 3800 BP, but later with a genuine zero, 3100 BP; but Hindu culture also invented zero, and, from these sources in Asia and the Middle East, Arabic culture borrowed and then conveyed the notion of zero into a reluctant and late European culture which, only on accepting Arabic number concepts, incorporated zero into its own system. And, although very separate from the Old World cultures mentioned, the Mayans also independently invented zero. Thus, once again, one must call into question the monodimensionality of the older master narrative so much taken for granted in Eurocentric histories. The antiquity of writing is another multi-origin example: cuneiform writing continues to hold its place from at least 6000 BP in the Old World history, but twentieth-century finds of tortoise-shell writing from China now also equal a 6000 BP dated origin. Here, then, a pragmatist human-inventivity model for the production of tools again allows for the recognition of such a pluralistic set of histories.

Admittedly, much of the ancient knowledge now re-emerging had disappeared. There does not seem to be anything like a single continuous history of sciences any more than there is a continuous history of "civilization" as such. But, within these plural histories, there are also telling examples of how technologically progressive trajectories lead both to refinements of knowledge and to breakthroughs. As noted, astronomy underwent a many-millennia period limited to human visual observation in relation to simple, fixed observational instruments. Lenses qualitatively changed the range and type of observation possible and allowed for the four-century history familiar to the Eurocentric account. Interestingly, sunspots and their periodicity was first noted by Galileo in the early seventeenth century with the aid of a telescope of his own design, and which included a helioscope to cast sunspot images on a screen. In China, however, sunspot activity had been noted and charted since 2500 BP by Gan De, Shi Shen and others. Without telescopes, how could these phenomena be observed? While the answer is not definitive, one can note that very early lens development in China included the use of dark quartz, which could have been used for precisely such sightings. Yet, in spite of the earlier charting of sunspot activity in China and the later charting in early modernity, the discovery of the eleven-year sunspot cycle and its relation to auroral activity had to await later modernity in spite of the fact that the charts from antiquity evidence this pattern. The point being made is that technologies, instrumentation, mediate and make possible different and refined observations. And, in one sense, this becomes even more pronounced in late modernity, as Peter Galison has pointed out in *Einstein's Clocks, Poincaré's Maps: Empires of Time* (2003). The history and discovery of special relativity and its relationship to time relates to the more accurate time-keeping which became possible only in the twentieth century. Until clocks were both accurate enough to measure microseconds, and put into synchonized systems – such as the various proposals for a universal time to govern railway traffic which patents Albert Einstein dealt with in his 1905 career – could the clearer implications of relativistic time be more deeply probed. Galison shows how this technological lifeworld is the concrete context within which relativity is conceived.

Thus, the framing being suggested here, in both its pragmatist sense which emphasizes human inventiveness in its material dimension including technologies, and in a phenomenological sense in which human perception and embodiment plays a role, can more fully accommodate a technoscience, or hybridized technologies and sciences in what can be understood as both symbiotic in relationship and multicultural in origin and pluralistic in both temporal and geographic localities can here come into view.

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# 9

# Science and Technology: Positivism and Critique

## HANS RADDER

The notion of positivism, which is primarily used in relation to science, is notoriously ambiguous. Karl Popper, for one, strongly argued against positivist philosophy of science *and* was sharply criticized for being a positivist philosopher of science himself. In epistemology, positivism is often seen as equivalent to empiricism; in philosophy of science, it usually means "anti-realism"; in methodological discourse, it frequently refers to a unity-of-science approach according to which the social sciences should follow the methodology of the natural sciences; in social science, it commonly stands for a preference of quantitative over qualitative methods; and in ontological debates it may denote reductionist or materialist positions.

Clearly, some limitation and clarification is in order, the more so since not all of these senses of positivism will be equally relevant to both science and technology. For the purpose of this essay, I start with the influential views of (the early) Jürgen Habermas, who conceived of science and technology as being intrinsically related. Habermas proposes a very broad characterization of positivism as the view that, because of their obvious successes, there is no need for a critical reflection on science and technology "as such." The latter qualification is important, since positivism acknowledges, and even explicitly aims to criticize, the occurrence of particular deviations from scientific or technological rationality.

In addition to this, positivism often includes a stronger normative view, saying that a scientific or a technological approach is the best, or even the only legitimate, approach to tackle any economic, socio-cultural or personal problem. Put differently, positivism equates knowledge with science and accordingly claims that only science and science-based technology can bring us material and social progress. In the case of science, this approach is called scientism; in the case of technology, one speaks of technocracy. Such views are still quite current (though not unchallenged) among scientists, technologists, policy-makers, politicians and the general public. For instance, a scientistic approach to human intelligence holds that intelligence is what IQ tests measure, and a technocratic policy proceeds by replacing culturally specific actors' notions of intelligence with scientific practices, such as testing children at school and adults during application procedures. Or, in the face of the threatening exhaustion of fossil fuels, technocracy advocates a technological fix through a strong expansion of nuclear power (despite its many unsolved problems), while legitimate concerns are being silenced through

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the scientistic strategy of distinguishing between the objective risk revealed by the scientific experts and the merely perceived (and hence subjective and unreal) risk of the lay critics.

In his *Knowledge and Human Interests*, Habermas (1978) criticizes Auguste Comte's and Ernst Mach's positivist views of science for being unreflexive. They focus on methodological and epistemological issues, such as the function of scientific experience and the nature of scientific theories. In doing so, they forgo the reflexive Kantian question of the general conditions of the possibility of scientific knowledge. As already mentioned, Habermas sees this "disavowal of reflection" as the core problem of positivism. Positivism unjustly takes the factual successes of the scientific approach to be enough epistemic justification and social legitimation. Against this, Habermas first points to the significance of human, instrumental or experimental action as the condition of the possibility of scientific knowledge; second, he claims that critical reflection on science should take full account of communicative action, which is the condition of the possibility of the interpretive humanities and, more generally, of mutual understanding in our life-world. That is to say, the sphere of communicative action constitutes a more basic outside "position" from which the development of science may be critically questioned. Thus, Habermas' critique of positivism in science results in assigning science its proper place, relative to the interpretive disciplines and to our life-world. Science is a legitimate human endeavor, but it is also one-sided, and hence its unconstrained expansion should be counteracted from the sphere of communicative action.

Something similar applies to technology since, according to Habermas, science is intrinsically related to technology, with experimentation being the crucial link. Both science and technology aim at prediction and control of the events studied theoretically and realized experimentally or technologically. Technology has its proper place as an instrumental means for supporting the survival of individual human beings and of human kind more generally. All too often, however, technology intrudes on, and intends to replace, communicative discourse and action concerning societal goals (see Habermas 1971). Positivism provides an ideological underpinning of this improper "colonization of the life-world," since it claims that the actual practices of science and technology need not, and should not, be normatively constrained from an independent domain of communicative action.

It is along these lines that Habermas analyzes and criticizes the scientistic and technocratic doctrines of positivism. Yet one may argue that Habermas' approach still includes a positivist residue: because of his claim that the validity of scientific facts and the effectiveness of technological artifacts are independent of *particular* societal interests and *specific* norms and values, his account of the conditions of the possibility of science and technology is inadequate. Science and technology are seen as yielding universally valid knowledge and objectively working tools that are normatively neutral and acquire value only when applied for specific social purposes. Thus, laser science and technology as such provide neutral knowledge and effective tools, which only become value- and interest-laden when used, for instance for healing or for killing people.

More recent studies of scientific practice, however, have claimed that scientific knowledge is never neutral and universally valid, but socially constructed on the basis of particular social goals and interests or as a result of specific processes of social negotiation (see Barnes, Bloor and Henry 1996). Thus, the new experimental procedures advocated by Robert Boyle and the dispute about those procedures between Boyle and Thomas Hobbes are claimed to depend crucially on a local aspect of the seventeenth-century English social order. In technology, the "validity" – that is, the objectivity and effectiveness – of technological artifacts and systems has similarly been claimed to be socially constructed through negotiation among involved actors or through powerful individual and institutional system-builders (Bijker, Hughes and Pinch 1987). Illustrations are the development of the bicycle in the last decades of the nineteenth century and the evolution of the system of electric light and power in Western societies between 1870 and 1940. At present, such detailed studies of scientific and technological practice abound. They have been framed into a comprehensive (social) constructivist research tradition. This tradition may be characterized as broadly naturalistic: it focuses on accurate empirical description and explanation of actual scientific or technological practices with the help of (social) scientific methods.

Thus, from a (social) constructivist perspective, Habermas himself is still a captive of positivism in that he endorses its untenable doctrines of the universality and neutrality of science and technology. One reason for holding these mistaken views is the abstract nature of Habermas' theorizing, which does not include any illustrations from science or technology, let alone extensive studies of actual scientific or technological practices. But how does (social) constructivism itself relate to positivism? In terms of Habermas' characterization, constructivist reflection has explored in great detail not only the general but especially the particular conditions of the possibility of science and technology. More specifically, constructivism has emphasized the methodological and epistemological disunity and the ontological multiplicity of the sciences (see Mol 2002). Furthermore, in their explicit declarations, constructivists do not endorse the strongly normative claims of scientism and technocracy. For these reasons, the constructivist tradition might be classified as anti-positivist.

Yet one important element of Habermas' anti-positivism is missing from this tradition. Habermas advocated not mere reflection on the conditions of possibility of science and technology, but *critical* reflection in the sense of including a normative critique of the roles of science and technology in our present society. In contrast, many naturalistic studies of science and technology claim to provide no more than an impartial description or explanation of scientific and technological practices, and quite a few argue strongly against taking a normative stance on the scientific and technological issues they study.[1] Put differently, while constructivists have rightly questioned the rigid contrast between science and society, made by both the positivists and Habermas, they have wrongly concluded that this also entails the dissolution of the notion and possibility of critical normativity. The latter, however, is a non sequitur (see Winner 1993; Radder 1996, chs 5 and 8).

Consider, for instance, Habermas' emphasis on the importance of the notions of technological prediction and control. These notions may be reinterpreted as being *theoretically* necessary for successfully realizing a stable and reproducible technology (see Radder 1996, chs 6 and 7). Of course, it remains a matter of empirical study to see whether or not this success has materialized in actual practice. None the less, the *attempt* at realizing stable and reproducible technologies may be critically assessed for two reasons. A first question is whether the required material and social control needed for successfully realizing a stable and reproducible technology can be reasonably expected to be feasible. If not, we should refrain from realizing this specific technology. But, second, even if this material and social control can be successfully realized, the normative question should be asked whether living in such a controlled world is seen as desirable. If not, we have another reason for not realizing this specific technology. The two points can be illustrated with the example of nuclear energy. In this case, there are good reasons for questioning the feasibility of keeping the system of nuclear power production stable and reproducible (and hence safe) during a period of decades, centuries, and longer. Moreover, even if this control were feasible, there is the question of the desirability of the strict control and discipline needed to keep this technology stable and reproducible.

Andrew Feenberg's critical theory of technology constitutes another approach that combines theoretical, empirical and normative insights. Feenberg (1999) identifies two different "aspects" or "levels" of technology: the *functional constitution* of technical objects and subjects, called primary instrumentalization, and the actual *realization* of the constituted objects and subjects, called secondary instrumentalization. Thus, technology instrumentalizes humans and nature in two distinct ways. The distinction is analytic, meaning that in any actual technological artifact or system both aspects always go together. Feenberg develops this theory of technology by adding further characteristics of the two notions of instrumentalization. He specifies four "reifying" moments of primary instrumentalization (decontextualization, reductionism, autonomization and positioning) as well as four "integrating" moments of secondary instrumentalization (systematization, mediation, vocation and initiative). Primary instrumentalization is claimed to entail universal characteristics of technologies. Secondary instrumentalization creates further characteristics that might vary in principle but are in fact fixed by the dominant values and interests of a particular social group or society. The aim of Feenberg's critical approach, then, is to expose these underlying values and interests, and to argue for alternative – that is to say less oppressive and more democratic – secondary instrumentalizations of the technologies in question. An example of such a "democratic rationalization" is the bottom-up hacking of the French Minitel system in the early 1980s.

The aim of this essay has been to point to some of the central issues in past and present debates about positivism and anti-positivism in science and technology. While the older disputes focused on the doctrines and practices of scientism and technocracy, more recent approaches discuss the pros and cons of methodological naturalism and critical normativity.

## Note

1. For reasons of space, the present discussion is restricted to constructivist studies of science and technology. Of course, "naturalism" is a much broader category, including for instance the influential evolutionary approaches to the study of science and technology (see, e.g., Lelas 2000).

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# 10

# Engineering Science

## LOUIS L. BUCCIARELLI

"Engineering science" refers to either a body of knowledge or the activity which generates that body of knowledge. Engineering science *as knowledge* is codified in the textbooks used in undergraduate courses in engineering – courses in thermodynamics, solid mechanics, fluid mechanics, aerodynamics, mechanical vibrations, electronics, wave propagation, materials science, control system theory and now biomechanics, computer science and nano-whatever. These domains – and there are others – constitute the "engineering sciences." Engineering science *as an activity* is the research engaged by faculty allied with departments of mechanical, electrical, chemical, civil engineering – many of which teach the undergraduate engineering science courses. Industry, too, has its research laboratories where engineers do engineering science. And there is something of a history of the engineering sciences, but we will not say much about that. (See B. Seely, "Research, Engineering, and Science in American Engineering Colleges: 1900–1960," *Technology and Culture*, 34 [April 1993]: 344–86.)

The question arises: How is engineering science, as a body of knowledge and/or research activity, distinguished from ordinary science? One claim made is that scientists seek truth, to reveal nature's secrets, knowledge for knowledge's sake, etc. Engineers seek to make things work in accord with their designs. They care less about truth. They aim for a robust and reliable design, increased efficiency, or higher productivity and profit. The purpose of their work is perhaps the most important and oft-stated factor distinguishing the work of engineers from the work of scientists. But does this distinction apply when we focus on those engineers with advanced degrees who spend their time in a laboratory doing research?

Another useful way to attempt to distinguish science from engineering science is to consider the kinds of phenomena studied by scientists and by engineers active in research. Here we seem to be on firmer ground. In line with the pragmatic orientation of the engineer, the engineer as researcher studies the behavior of a product of human agency – an artifact – or a phenomenon intimately associated with that behavior. The scientist studies natural phenomena – events and processes of widely varying scale in space and time.

We can take this a bit further: Because the object of research of the engineer is an artifact, its "nature" is malleable. Engineers doing research in materials science is perhaps the best example of this. Moved to make it stronger, lighter, less susceptible to

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corrosion, more easily mass-produced, etc., the engineer as researcher will analyze, reconstitute, run the test again, seeking the desired outcome. (This is not the case for the physicist, the chemist or the biologist – at least according to the traditional picture of what the natural scientist does in a laboratory. We leave aside what a constructivist might claim. Alternatively, one might claim that, if the natural scientist does have the ability to shape the object of research, and does so, then he or she is doing engineering.). In such a context, what does objectivity mean?

This ability to alter, not just the assumptions in an analysis or the conditions of an experiment, but the actual object under study itself, may be why engineers seem less dogmatic in their assertions about the ontological status of the objects and entities that enter into the phenomena they study. Whereas the natural scientist, according to the traditional picture, posits the existence of entities as fact, the conjectures of an engineer are fully acceptable if stated in the form "If $x$ is modeled as a $z$, then $y$," knowing full well that $x$ is not really a $z$; i.e. "If we assume the beam behaves as an elastic, perfectly plastic material, then collapse of the beam will occur when the weight at the end exceeds 1,000 pounds." The "truth" of the assertions rests on the usefulness of the results of the research, i.e. "*that which is true is what is useful.* This thought . . . is in sharp contrast to the 'dogmatic' conception of truth as a fixed, static transcription of an impersonal reality external to man, a reality in which man is shorn of any active role" (E. A. Tiryakina, *Sociologism and Existentialism: Two Perspectives on the Individual and Society* [Englewood Cliffs, N.J.: Prentice-Hall, 1962], p. 158).

There is another way by which this interplay of subject and object can influence, if not define, the product of engineering research. If we take a historical perspective, we see that developments in engineering science proceed as the artifacts, the technology to which the science applies, proceed to improve and become more sophisticated. The manufactured world ever presents a new reality to the engineer. As technological developments accumulate, new concepts and principles as well as methods become thinkable. For example, the principle of continuity of displacement, in the development of the engineering science which applies to the behavior of structures, had to await the availability of materials uniform in their nature, of consistent and reliable ways of fabricating and of assembling structural elements into a whole. Before the last half of the nineteenth century, the principles of force and moment equilibrium were the lone pillars of, confessing the anachronism, the engineering science of structures. Only "statically determinate" structures could be analyzed. Would it be correct, then, to say that the engineering science of structures was incomplete or – stronger still – in error, not true, before then? If we take utility as a criterion of truth, we respond negatively.

Some claim that, because their motivation (and rewards) and subject matter differ, engineers think in ways different from those of scientists. Walter Vincenti presents a compelling argument for such a difference in his history of the development of a particular perspective and method used so effectively in the analysis of problems in thermodynamics and in fluid flow, namely "Control-Volume Analysis." The use of a control volume enables the engineer to ignore the details of what goes on within the control surface yet still obtain useful results:

> engineers frequently must deal with flow problems so complex that the underlying physics is not completely understood. . . . In such situations control-volume analysis, by

> working with information only on boundaries and ignoring the interior physics, can often supply limited but highly useful results of an overall nature.
>
> (W. G. Vincenti, "Control-Volume Analysis: A Difference in Thinking between Engineering and Physics," *Technology and Culture*, 23, 2 [1982], p. 150)

But note that here, too, the usefulness of the method depends upon the ability of the engineer to arrange and manipulate the object in the study of the phenomenon – whether the drag on an airfoil, or the efficiency of a triple-expansion reciprocating steam engine – such that certain conditions are met – e.g. steady flow, no separation, the internal machinery behaves in accord with its design – or at least approximately satisfied.

We see there are significant differences in the interests, the ways and objects of thought, and the methods of engineers as researchers and those of scientists. But from another, social/political perspective they look very much the same. Like scientists, engineers apply to the National Science Foundation, or another government agency, for grants to support their research. They employ graduate students as assistants who, upon completion of their research, are awarded an advanced degree. The result of their research is published in scholarly journals and available to the world. They work unfettered, for the most part, by the immediate needs of industry – though this is changing as government support of research in some domains of engineering science dwindles and industrial support increases. And younger faculty in engineering seeking tenure recognize that the most important factor weighed in the tenure-granting and promotion process is the number and significance of their research publications – just as it is for their peers in the science departments at the university.

Finally we note that, like the scientist, the engineer engaged in research will make heavy use of mathematics in the representation of phenomena and in the processing of experimental data. A good bit of research in engineering science is directed at the development of mathematical methods albeit for the solution of practical problems: e.g. finite element methods in continuum mechanics. There is a strong tie between engineering science and applied mathematics, a tie reflected in the existence of university departments labeled as such.

The similarities suggest that another comparison might illuminate the engineering sciences. Normally – and it has been the case here – the comparison is made with science. What if we turn the tables and explore how engineering science differs from, or is like, engineering? (By that I mean engineering practice.)

The first thing to note is the different degree requirements for doing engineering science and entering engineering practice. The latter requires but a bachelor's degree (or a three-year, two-year, bachelor's, then master's, degree in accord with the Bologna recommendations). To do engineering science requires a PhD – as in science.

A second thing to note is the context of use of the results of their respective efforts. Engineers working, usually in a team, on a product for the mass market, a facility for the general public, or a system for managing the flow of information over a network, etc., face significant uncertainties about how the object of their design will be handled, used or misused. The engineering scientist, on the other hand, like the scientist can control the context of use, out on the road as well as in the lab.

Another significant difference is that the engineer designing generally works as a member of a team whose other members have different interests, competencies and responsibilities. Designing is a polyvalent process or multi-paradigmatic process. Research in engineering science may also be done in teams; but ordinarily, and like research in science, participants in the project work within a single paradigm. The engineer as scientist need only be concerned with one knowledge domain.

We might conclude that engineering science is more like science than it is like engineering! Indeed, there are those who claim that the emphasis on engineering science as knowledge within the undergraduate curriculum is excessive. While all will agree that learning the "fundamentals" of (some) engineering science is essential and necessary to qualify as a professional engineer, that form of learning is never sufficient.

# 11

# Technological Knowledge

ANTHONIE W. M. MEIJERS AND MARC J. DE VRIES

## 1. Types of Knowledge in Technology

In this article we shall take technological knowledge to be the knowledge that is involved in the designing, making and using of technical artifacts and systems. Both engineers and users of technology can have such knowledge. For instance, engineers know about theories in natural sciences; they know how to solve design problems; they are acquainted with technical norms and standards; they know about economics and about legal matters; and they know how to translate clients' desires into technical specifications. Users know what technical devices, machines and systems are for; they know which actions need to be executed in order to make an artifact work; and they sometimes know how to maintain or repair the artifact. This quick survey already shows that the types of knowledge involved in the design and use of technical artifacts are varied. The challenge to philosophy (of technology) is to identify the characteristics of these types of knowledge and to investigate whether they can be accounted for by existing theories of knowledge. At face value, technological knowledge appears to have a distinct nature in that it involves descriptive *and* normative elements. Knowledge of the behavior of artifacts as described by the natural sciences is of a descriptive nature, while the knowledge that "screwdrivers of this brand are always good" is of a normative nature. The latter example indicates that some types within the domain of technological knowledge are probably different from knowledge in natural science (a scientist will never claim to "know that electrons produced by linear accelerators are good").

## 2. A Neglected Topic

Reflections on the nature of technological knowledge are fairly recent in the philosophy of technology. In more general epistemological debates, technological knowledge hardly ever features as an object of serious considerations. Laudan (1984) presented possible reasons for this. The first is the popularity in philosophy of the view that technology is primarily a form of applied natural science. This idea was advocated in a "classic" article by Bunge (1966). It has also been the dominant view in science and

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technology policy in the decades following the Second World War. The idea of technology as just the application of natural science implicitly suggests that technology is not a separate field of knowledge. Maybe knowledge in technology differs somewhat from scientific knowledge in that it contains empirical elements that complement the idealized concepts and theories taken from science, but that can hardly be a justification for regarding technological knowledge as a separate kind (Layton 1974). According to Laudan, a second possible explanation for the lack of interest is that part of technological knowledge has a tacit character. The lack of an in-depth analysis of technological knowledge may also be explained by the fact that the engineering sciences themselves have not been the object of study in philosophy of science, which is traditionally biased toward physics, and more recently also toward biology.

If technological knowledge has been studied at all, it was in the context of the relation between science and technology. These studies mainly focused on the role of technology in the acquisition of new knowledge in science, by providing artifacts for scientific experiments (instruments for observation and measurement). Vice versa, some studies investigated how science contributed to technology by providing concepts and theories. Owing to their focus, and therefore understandably, these studies hardly gave evidence that technological knowledge is different from other types of knowledge (Skolimowski 1966).

## 3. Empirical Studies

First initiatives to study the nature of technological knowledge were not taken by philosophers, not even in the philosophy of technology, but by historians of technology. A harvest of historical studies up to 1980 was made by Staudenmaier. Based on a survey of articles in the journal *Technology and Culture*, he claimed that technological knowledge does indeed comprise concepts that have been derived from science, but also that it contains a lot more. This includes empirical data specific for technology (data which are not just instrumental for the development of scientific theories), technological theories and technological know-how (or skills). So one of the first things these historians derived from their historical accounts is that technology cannot be accounted for adequately by the "applied science" hypothesis. One of the first philosophers to recognize the distinct nature of technological knowledge was Alexandre Koyré. He called technology not just a set of techniques, but a "system of thought, based on common sense", which does not depend on science but is influenced by it indirectly. He also emphasized that, in order to be useful for engineers, scientific knowledge needs to go through a certain transformation. He was quoted in an article by Layton (1974), who identified *design* as a "common denominator" for technological knowledge.

Later historical studies into the nature of technological nature have followed that vein, and as a result insights were gained primarily by studying processes of invention and design, rather than production. Vincenti (1990) conducted a series of case studies in the field of aeronautical engineering. He identified six types of knowledge that engineers had used. These types are: fundamental design concepts (e.g. knowing the basic components of a car), design criteria and specifications (e.g. knowing that interfaces need to be understandable for users), theoretical tools (e.g. calculation methods for forces in a construction), quantitative data (e.g. the strength of a material), practical considerations (e.g. knowing how to strike a balance between costs and safety) and design instrumentalities (e.g. knowing how to trace the cause of a failure in an efficient way). He also listed six types of knowledge-generating activities in engineering: transfer from science, invention, theoretical and experimental engineering research, design practice, production and direct trial. Faulkner (1994) extended the analysis and developed a typology of technological knowledge by studying industrial innovations. She came up with the following types: knowledge related to the natural world, to design practice, to experimental R&D, related to final products, and related to finding new knowledge. Altogether it can be concluded that not much substantial has been written since Vincenti's study in 1990.

## 4. Philosophical Explorations

The historical studies mentioned above made sense to philosophers (see, e.g., Ropohl 1997 and Pitt 2001 for a response to Vincenti's taxonomy), but the way they were derived from case studies was seen as fairly ad hoc. It was acknowledged that a more systematic approach is needed and that these reflections have to be integrated in philosophical debates. One such debate is about the question whether or not technology can indeed be described as only "applied natural science." Two characteristics of technology challenge this idea: collectivity and context-dependentness.

### *(a) Collectivity*

Technical norms and standards are part and parcel of technological knowledge. They differ from natural phenomena in that they require a community of professionals for their existence; obviously, these norms and standards are often the result of collective decision-making, they are social constructs. This is reflected in the epistemic standards that apply to them. In contrast to natural science knowledge, justification criteria are purely social, because in the latter case it is entirely up to the group members to decide about the truth (or effectiveness) of the beliefs; in principle there is no need to check against the external (natural) world. It can even be the case that certain members of the group are authorized to make decisions about what beliefs to accept.

### *(b) Context-dependentness*

In the natural sciences one aims for rigorous theories that can be applied to any context; in the engineering sciences one looks for knowledge that can be relevant for solving problems for specific (types of) contexts. The "technology as applied science" thesis can account for this context-dependency. When natural science knowledge is applied, knowledge for a specific domain emerges. However, in technology this is only part of the story. Technological knowledge also emerges from other sources bottom up, so to speak; for instance, in the design, production and operation of artifacts. In engineering sciences, that knowledge is generalized so that it can be applied to contexts (e.g. design problems) other than the ones in which this knowledge originally was developed. These generalizations, though, never move too far from these specific contexts in order to remain practically relevant.

Another philosophical debate is the one about the "justified true belief" account of knowledge. This has been challenged by Edmund Gettier's well-known counter-examples. Two other characteristics of technological knowledge suggest additional problems: normativity and non-propositionality.

### *(c) Normativity*

In epistemology, normativity usually features only in the epistemic norms *for* knowledge. In the case of technological knowledge there is also normativity in the *content* of certain types of knowledge. We have already mentioned technical norms and standards. But an engineer saying "I know that this is a *good* hammer" also displays knowledge with a normative component. Perhaps less obvious, but yet still normative, is the expression "I know that this is a hammer," because it is more or less equivalent to the expression "I know that this is a device that *ought to* enable me to insert a nail into a piece of wood." This latter example is what can be called "knowledge of functions." Houkes (2006) has argued that this is a type of knowledge of particular epistemological interest, because it is related to practical reasoning (in particular means–ends reasoning) through a "use plan" for the artifact. A consequence of this type of normativity is that truth is not the only criterion for knowledge, but prudence or efficiency can also serve as such, thus challenging the "justified true belief" account.

### *(d) Non-propositionality*

Technological knowledge is partly expressed in non-propositional ways. There are several reasons for this. First, an important part of technological knowledge is of the "knowing-how" type. Ryle in his book *The Concept of Mind* (1949) introduced this term to indicate skill-like knowledge that cannot fully be expressed in propositions (e.g. knowing how to hammer a nail into a piece of wood). Often that sort of knowledge remains tacit (Polanyi 1967). It is embodied in persons and difficult to transfer to other persons. Second, as Ferguson (1992) argued, technical drawings and diagrams contain knowledge that is almost impossible to express in propositional terms. There is probably an irreducible visual aspect to technological knowledge. Third, artifacts themselves may embody knowledge. Baird (2004) has developed a material epistemology, in which the focus is not theories but things. He claimed that technological artifacts such as scientific instruments not only generate but also *express* technological knowledge. It can be "read" from them what insights the engineer must have had in order to design the artifact (he uses the term "thing knowledge" for this). This insight is built into the device and is subsequently separated from human agency and thus from human beliefs. The type of knowledge involved is thus thing-based, not belief-based.

This short exploration suggests that there are good reasons to believe that technological knowledge may be hard to account for within traditional approaches in epistemology. Obviously, an in-depth analysis is needed, which has only recently started in the literature.

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# 12

# The Interplay between Science and Technology

## BART GREMMEN

Until the 1970s the debate on the science–technology relationship was dominated by theoretical issues from the philosophy of science. The history of technology had limited theoretical import, and sociology of technology was almost nonexistent. The development of both of these disciplines led to criticism of the subsumption schema (the domination of science over technology), and to the rise of the so-called interaction schema as an alternative schema. Although the interplay model belongs to the interaction schema, the interaction between scientific and technical practices is considered to be more than just a simple exchange of results between practices. Both kinds of practices are changed in some manner, yet each also maintains its uniqueness and integrity.

In 1965, Derek de Solla Price formulated one of the first versions of the interaction schema: science and technology as relatively independent but closely interacting activities. This interactive schema of the science–technology relationship must be seen, according to Barnes, as a major reorientation in our thinking about the science–technology relationship. We have to recognize science and technology to be on a par with each other. The interaction model is a model that captures much of current thinking; and, following Barnes, we can identify two necessary developments for the emergence of the interactive model. First, the recognition of science and technology as being forms of culture: new science developing from old science and new technology from old technology. Second, the acceptation that knowledge does not have inherent implications: it is not possible to trace a technological innovation backwards and to make it out as a logical consequence of the newest scientific theory or discovery encountered in the line of its development. In the interaction schema the interpenetration between science and technology has become an important aspect of their interaction.

Science and technology are enmeshed in a symbiotic relationship – a weak, mutually beneficial interaction. Science as one context of inventive activity (an activity which by its nature demands evaluation in relation to human objectives) may readily become conditioned by criteria from the technology, the other context, and vice versa. Different models are developed to provide a more detailed description of the nature of this interaction process. Rip developed one such model, using the metaphor of dancing partners to describe the science and technology relationship. He looks at science and technology as ongoing processes with interactions that cluster in various ways and are

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labelled "science" and "technology," also in a variety of ways. In this respect he wants to add, in a threefold way, to the analysis of de Solla Price, who tended to look at science and technology as separate, unified wholes. In the first place Rip argues that there is a certain mutual adaptation and division of labor between science and technology, created in particular historical circumstances and made possible by particular "cognitive infrastructures." In the second place economic and strategic considerations come in after science and technology have not only produced their products but are part and parcel of the production process. Third, it must be possible to trace changes in the relations between science and technology, transformations even, in the past and in the present. Rip argues that a new kind of intertwining of science and technology is occurring, as part of a conscious, strategic mobilization of cognitive-technical potential.

Productive interplay between technical and scientific practices requires in any case the creation by one or more of the involved practices of an "interface." An interface is the means by which interplay (i.e. ongoing interaction) is effected at the place where multiple intersections of different practices occur. A "broker practice" is a main interface between scientific and technical practices. As a practice in its own right it mediates between technical and scientific practices. In order to "get off the ground," there must be mobilization of interest and resources. Thus, a broker practice resembles a situation in which large numbers of people, laboratories and organizations rapidly commit their resources to one approach to a problem (what Fujimura calls a "bandwagon"). For example: combinations of problem and data representations, methods, and theory. In the case of bandwagons, the emphasis may be on its temporary character, a passing fad even.

A more permanent "broker" practice is a practical science. The practical sciences are a group of academic disciplines that provide the engineer with the knowledge necessary for the production and use of certain material objects. Practical scientists work on the following problems: prognosis of the behavior of a projected functional object, prognosis of the results of a projected procedure, determination of the structure and composition of a functional object necessary for a certain intended behavior, and determination of the procedures one should follow in order to achieve an intended effect. The solution to the question of how to manufacture something is not identical to the act of manufacturing. The development of new procedures and functional objects has become a specialized systematic activity. The point of practical research is, however, the bringing about of events and processes. Practical science relates to the activities of designers, engineers, technicians and production workers, and also concerns the users and consumers of whatever is produced.

In the debates on the science–technology relationship the interplay model is a kind of interaction model. We can summarize the philosophical basis of the interplay model in three points:

1. External influences on a practice are results of the interaction between practices. This interaction is seldom a one-way influence; the practices involved are changed in the interaction.
2. There are no hierarchically dominant practices in a strict sense.
3. Innovation in practices does not derive from scientific discovery, as it were in a linear sequence.

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# 13

# Instruments in Science and Technology

MIEKE BOON

## 1. Science and Technology

At present, many accept that modern science and technology are interwoven into a complex that is sometimes called "technoscience": the progress of science is dependent on the sophistication of instrumentation, whereas the progress of "high-tech" instruments and apparatus is dependent on scientific research (see Galison 1987, 1997; Baird and Faust 1990; Radder 1996, 2003). From this perspective, an understanding of *how* scientific research interacts with technology, in particular in the development of instruments and apparatus, is a topic for both philosophy of technology and philosophy of science. The focus taken here is *how* scientific research *contributes* to the development of instruments and apparatus for technological use.

In philosophy of technology, recent interest has been in the nature of *technological knowledge* (e.g. Vincenti 1990; Kroes 1995; Pitt 2000), rather than in *how* scientific research contributes to technological development. In that literature, science is valued for its heuristic role, whereas scientific approaches to the development of technology are nonexistent. Conceptual and historical reasons may explain this focus. Traditionally, science and technology were distinct domains. The classical dichotomy between scientific knowledge (*episteme*) and technological knowledge (*techne*) was grounded in the ontological distinction between their objects: scientific knowledge is about "things" that exist of necessity, things that are universal, eternal, ungenerated and imperishable; technological knowledge is about things that have their origin in their maker, "things" that are variable, generated and perishable. This dichotomy has caused conceptual confusion when trying to understand the relation between science and technology in modern scientific practices. Mario Bunge (1966) put forward the thesis that "technology is applied science." What he meant to say is that in technology the method and the theories of science are applied to solving practical problems. An outcome of this scientific approach is technological knowledge, which is made up of theories, grounded rules, and data. This thesis – and its implicit implication, which is that technology *results* from science – has been much debated in philosophy of technology of the 1970s and 1980s. It was rejected on the basis of conceptual analyses of scientific and technological knowledge (e.g. Skolimowski 1966). But also historical studies showed that the factual contribution of science to new technologies in the past

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was less significant than many seemed to believe. Most technological devices were developed by craftsmen, independent of science. Engineers did not need a scientific understanding of the phenomena they utilized and of the technological devices they invented. For development and design they used phenomenological laws and "rules of thumb" (see Layton 1974).

## 2. Instruments in Science

Philosophy of science, on the other hand, has long ignored the role of instruments and laboratory experiments in science. In a traditional philosophical view, the aim of science is the production of reliable, adequate or true knowledge about the world. The role of experiments is testing hypotheses in controlled laboratory settings. But experimentation was seen as a mere data-provider for the evaluation of theories, and the production of empirical knowledge by instruments is not a topic of philosophical concern. We observe nature through technological spectacles, which do not influence the resulting picture of nature, and instruments are *instrumental* to the articulation and justification of scientific knowledge of the world.

Some of the philosophical problems in traditional philosophy of science seem to result from this neglect of the role of instruments and experiments. One such problem for the positivistic idea of testing theories is the Duhem–Quine problem of underdetermination of theories by empirical evidence. If an experiment or observation is persistently inconsistent with theory, one could either revise the theory or revise the auxiliary hypotheses – for instance those which are about the proper functioning of the instruments. Another severe problem to the positivistic image of science came from Popper (1959), who claimed that all observation is theory-laden. To him, observations, and observation-statements that represent experimental results, are always *interpretations in the light of theories*. Kuhn's (1970) notion of paradigms was conceived in a similar vein: rather than observation, the paradigm is basic to our knowledge of the world, and observations only exist in so far as they emerge within the paradigm.

The view that non-empirical factors, such as ontology and theoretical background knowledge, are prior to observation and experiments has been a severe threat to the traditional view that scientific theories are tested by means of an empirical and logical methodology, as it was conceived by logical positivism and logical empiricism, and opened the road to extreme skeptical appraisals of science. Social constructivists, for instance, have raised objections to the view that experimental results are accepted on the basis of epistemological or methodological arguments, and argue that social factors play an ineliminable role (e.g. Bruno Latour, Harry Collins and Andrew Pickering).

## 3. New Experimentalism

New Experimentalists share the view that a number of problems, such as the underdetermination of theory by empirical knowledge, the theory-ladenness of observation, and extreme skeptical positions – such as social constructivist – that result from it, stem from the theory-dominated perspective on science of positivistic philosophers of science.

They defend that focusing on aspects of experiments and instruments in scientific practice holds the key to avoiding these problems. Some of the key figures of this movement in the 1980s and early 1990s are Ian Hacking, Nancy Cartwright, Allan Franklin, Peter Galison, Ronald Giere, Robert Ackermann, and more recently Deborah Mayo. These authors do not accept the restriction to the logic of science that positivistic philosophers had set for themselves. Traditional philosophical accounts of how observation provides an objective basis for evaluation of theories – by the use of confirmation theory or inductive logic – should be replaced by accounts of science that reflect how experimental knowledge is actually arrived at and how this knowledge functions. The traditional distinction between the "context of discovery" and the "context of justification," which motivated why philosophers should restrict their task to the logic of justification of scientific theories, is abandoned. New Experimentalists, instead, aim at an account of the rationality of scientists in scientific practices that includes how scientists reason about experiments, instruments, data and theoretical knowledge.

This new philosophical tradition heavily relies on historical case studies of science, which focus on aspects of experiments and instruments. These historically informed approaches in philosophy of science strengthened the tradition that may have been ushered in by Thomas Kuhn, and which is now called the "history and philosophy of science." The focus is on epistemological aspects of experiments, instruments, data and the processing of data, and different layers of theorizing. Thus, although New Experimentalists admit that non-rational, sociological and contingent factors may determine the course of science, they deny that sociological factors are determining methodological and epistemological criteria internal to scientific practices. The examples below aim to illustrate how the focus of New Experimentalists on the role of instruments provides new perspectives on scientific research.

## 4. Instruments in Scientific Practice

Several authors have defended that the theory-ladenness problem of instruments can be excluded in some cases. A favored example is observations by means of microscopes and other instruments with which objects can be made visible (e.g. Hacking 1983; Zik 2001; Chalmers 2003). This also holds for *data*. Data given by instruments – such as data produced by a conductivity meter – may be given independent of a theory. Instruments create an invariant relationship between their operations and the world. After a change in theory, it will continue to show the same reading. However, the *meanings of data* – such as superconductivity – are not given by the data, since the data are interpreted as a *phenomenon* by theories. Thus, although data have an internal stability, which results from being reproducible by instruments, their meaning is neither manifest nor stable (e.g. Ackermann 1985; Gooding 1990). In particular in exploratory experiments it requires the formation of *new basic concepts*, such as the notion of a current circuit in the case of Ampère, before the data produced by the instrument can be interpreted as a phenomenon (e.g. Harré 1998; Steinle 2002; Heidelberger 2003).

Nevertheless, the view that data produced by instruments are independent of theory has also been challenged. Even the most basic "data-generating" instruments, such as thermometers, have gone through a long, intellectually and experimentally challenging route to knowing that these instruments tell us the temperature correctly. Finding empirical knowledge of temperature involved theoretical assumptions about the properties of matter. Therefore, a basic problem for a philosophical account of empirical science, which demands that theories should be justified by observations, is that observations involve theories, for instance about how things work (e.g. Chang 2004).

This latter finding also holds for other instruments and apparatus that inhabit our laboratories. According to Nancy Cartwright, such instruments are to be understood as *nomological machines*. A nomological machine is a fixed arrangement of components, or factors, with stable capacities that in the right sort of stable environment will give rise to regular behavior. Laws represent this regular behavior of nomological machines, which implies that those laws hold as a consequence of the repeated, successful operation of nomological machines. Therefore, laws – understood as a necessary regular association between properties – do not necessarily hold for the world beyond the nomological machine (Cartwright 1983, 1989, 1999, and also Harré 2003; additionally, important articles on the role of instruments in scientific practice are in Radder 2003; see also Boon 2004).

What these examples illustrate is that, in scientific practice, theories and instruments are developed in a mutual relationship. Rather than being spectacles on the world, instruments take part in our theoretical knowledge. This has been well expressed by Hacking (1992), who claims that our preserved theories and the world fit together, less because we have found out how the world is than because we have tailored each to the other. As a laboratory-science matures, it develops a body of types of theories and types of instruments and types of analysis of data that are mutually adjusted to each other. Any test of theory is related to instruments that have evolved in conjunction with it – and in conjunction with modes of data analysis. Conversely, the criteria for the working of the instruments and for the correctness of analyses are precisely the fit with theory. Thus, contrary to the Duhem–Quine thesis that theory is underdetermined by data, Hacking argues that the constraints by these interrelated elements narrow the degrees of freedom for finding adequate theories.

## 5. The Interwovenness of Science and Technology

The picture that emerges is that instruments are not passive technological spectacles through which we perceive the object of science, i.e. “things” that are *universal, eternal, ungenerated* and *imperishable*. The ontological distinction between the objects of *episteme* and *techne* becomes blurred once instruments are used in scientific investigations. Much of our empirical knowledge results not from passive observation by means of instruments but from *interventions* with instruments and technological devices. Observation as a source of empirical knowledge is extended by *doing*, by *interacting* and *intervening* with the world through our instruments. This claim of Hacking (1983) pulls down the traditional distinction between science and technology. The spectacle metaphor of instruments is replaced by a metaphor in which instruments and technological devices provide a material playground where we learn a lot – not about the traditional object of science, but about "things" that are *local*, *generated*, *variable* and *perishable*, i.e. about the traditional object of *techne*. But, in their interventions and interactions with "things," scientists concurrently search for a solid ground, i.e. for those "things" that do not change or that work in a reproducible way, which is the traditional object of *episteme*.

Thus, New Experimentalists' focus on scientific practice gives a new perspective on the role of instruments, technological devices, and experiments in modern scientific practice, which also explains the interwovenness of science and technology. For instruments have an important role in *producing* reproducible *phenomena*, and these phenomena may have technological applications. For instance, the important contribution of the discovery of superconductivity was not that it confirmed a theory about the world; the important contribution was the simultaneous discovery of that phenomenon and how that phenomenon can be technologically produced. The urge for theoretical understanding of the phenomenon, and of materials and physical conditions that produce it, is not for the sake of theories about the world, but for the sake of understanding this phenomenon and how it is technologically produced. In many cases theoretical understanding of a phenomenon is in the context of technological applications. This insight also involves a new perspective on the aim of science. The traditional view assumes that science aims at the production and justification of theories. The picture that has emerged from New Experimentalists' study of scientific practice is that scientific research also aims at creating phenomena by means of instruments and technological devices, as well as at a theoretical understanding of phenomena and of the instruments that create them. This pictures a practice in which science and technology, i.e. scientific research and development of technological devices, are interwoven.

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# 14

# Social Construction of Science

## HARRY COLLINS

The study of the "social construction of science" refers to the analysis of social influences on the content of scientific knowledge. That there are social influences on what we count as knowledge is an old idea, most closely associated with Karl Mannheim whose writings gave rise to the subject "sociology of knowledge." Quite simply, what people in different societies count as truth varies from society to society. What you believe depends on where you were born and how you were brought up. For example, it is impossible for an inhabitant of an Amazonian tribe to count it as true that market economies are better than command economies just as it is impossible for a Western economist to count certain complex claims about witches and spirits (I do not know how to say what they are) to be true. If you have not encountered the "knowledge," then it cannot be part of your universe.

So far, so incontestable, but things get a bit more tricky as we come closer to home. If I am brought up in a Catholic community of Northern Ireland, I am likely to become a Catholic and believe that the wine turns to blood during the mass. If I am brought up in a Protestant community in the same country, I am likely to believe that the idea of the "change" is symbolic rather than real. Here two groups know about each other's beliefs, and so it is less obvious that they must be bound by upbringing. And, indeed, some people change their beliefs. Still, most people do not change their fundamental religious and political beliefs, and the sociology of knowledge is well supported by such statistics – what people believe is strongly associated with their upbringing.

Talking about that impressive statistic can cause trouble. Though the believers are sure they believe what they believe because it is true, the statistics tend to suggest that for most people it is more a matter of accident of birth. Nevertheless, for the true believer, the statistic presents no deep problem – it is just that some were "chosen" or fortunate enough to be born in the right circumstances and some in the wrong circumstances. You think you are among the lucky ones; that the other group thinks it is they who are lucky and you who are unlucky is their problem. Furthermore, any doubts can be resolved by experience – the experience of revelation that accompanies true faith. On the other hand, sociologists and the like, who are sufficiently impressed by the statistics to believe that faith is causally linked to location in society, and who find it indicative that personal revelation can confirm even the details of historically situated collective

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practices and institutions, are likely to attract the wrath of all because they appear to be casting doubt on all faiths.

When we come still closer to home the danger becomes manifest. Consider those who believe in the truths of science. They are well aware that others do not believe in those truths, but just like the faithful they consider these others to be simply less fortunate than themselves. Again, doubts can be dispelled by reflecting on experience, this time, not of revelation, but of repeated experiment and the force of theoretical deduction. Those who believe in science have a systematic method for arriving at the truth which is said to be independent of accidents of birth. But actually it is the religiously faithful who have the advantage here because anyone can open their soul to revelation. To test the truth of a scientific claim is almost impossible for all but a very small elite. It is one of the strangest facts about science that the belief that anyone can test a scientific claim remains robust in the face of the fact that hardly anyone can or has. For example, who has ever tried one of the tests of relativity or confirmed the observation of the W-Boson? In fact, different beliefs about the nature of the physical world persist even among different groups of scientists for decade after decade. It becomes clear that, first, there is ample logical space for a sociology of scientific knowledge and, second, that those who practice it are likely to be thought to be questioning the truths of science and find themselves the subject of attacks such as are more typically directed at religious heretics than at scholars. There was even a period, in the 1990s, which became known as the "science wars" because of the tenor of the attacks on sociologists of scientific knowledge by certain natural scientists.

When we turn to those who actually engage in the sociology of scientific knowledge we find a wide spectrum of positions, many of which are not at all critical of science even though they involve a reassessment of the way science works which sometimes departs from models dear to scientists. Admittedly, there are those who claim that because Western science is just one belief among many it follows that, for example, Western-style medicine should not be brought to societies with radically different beliefs. There are also those who stress the "interest-based" component of the social influence on knowledge and take it to justify a generalized anti-Western-science stance, or an opposition to white-male-dominated science. There are others who use the ideas of the sociology of scientific knowledge to found a distrust of a science-based capitalism as a whole and/or the effect of industrialization on the environment. In general, these critics are not found among the small group who study science closely. Most of the members of the latter group claim that the social analysis of scientific knowledge does not imply a questioning of that knowledge. For example, the group based in Edinburgh and associated with what is known as "the strong programme" insist that their concern is the way social forces contribute to the content of all scientific knowledge claims. They insist that these can be found at work in all such claims, both those which we treat as true as well as those which we treat as false, so that being affected by social forces is not to be equated with doubts about validity. It has to be said, however – and this is merely a statement of the fact – that more than thirty years on from the initial statement of the strong programme position there are still critics who are failing to make complete sense of this claim.

One way to go forward is to look at examples of practice. We can all agree that scientific knowledge is affected by social forces to at least some extent even if only in the short term. If we want to study those social forces, it is sensible to concentrate on them alone. The duty of the sociologist is clear: one should concentrate on the social causes of belief in "p" and cease to argue or worry about whether belief in "p" has anything to do with the truth of "p." Thus, suppose I want to study the social forces that helped or hindered the acceptance of the theory of relativity. To do it well, I should assume that the truth or otherwise of the theory of relativity had no effect on its acceptance. To take the truth of the theory as a causal contributor to its acceptance can only divert attention from the social processes I am trying to understand; to press the social analysis to its limits, it is vital not to cut it off prematurely by saying that things just "had to come out this way because the theory is true." Whether or not the theory is true, the crucial point is to look at the social forces involved in bringing people to believe it was true; the analysis should be no different in the case of relativity than in the case of, say, astrology. No philosophical commitment to the truth or otherwise of science is required to adopt this methodological stance – it is known as methodological relativism. This approach is not dissimilar to agnosticism as a prescription for doing science itself. If, as a scientist, one wants to understand, say, what caused the fundamental constants to have the particular values that enabled life to exist, one must ignore claims or arguments along the lines "God made it thus," and get on with looking for physical causes.

The actual analysis of how facts and theories come to be believed can be conducted at a variety of levels. Thomas Kuhn's influential book *The Structure of Scientific Revolutions* pointed out the way that whole communities of science would sometimes become caught up in shifting-fashion-like switches of view – analogous with "gestalt switches" in psychology. After a gestalt switch, the same data from the same experiment or observation can be seen as pointing to quite different conclusions. A "paradigm revolution," as Kuhn called such changes, is a social phenomenon. It ought to be mentioned that many of Kuhn's ideas about how the same facts and observations can be consistent with different theories were worked out much earlier by the medical researcher Ludwik Fleck, reflecting on his own practice in the study of syphilis. The later ideas of the philosopher Ludwig Wittgenstein can also be taken to give a more detailed underpinning to the notion that what we take to be the logical compulsion of rules of action and analysis are really matters of social convention within a "form-of-life" – a matter of certain "ways of going on" being "taken for granted."

An example of a much more detailed analysis that follows through the implication of such philosophical ideas is the examination of the actual process of checking of scientific results by replication of experiments. "Believers" in scientific method often cite replication as one of the crucial differences between science and other kinds of belief – anyone, from anywhere, who checks the results of a scientific experiment will get the same result, so experimentally determined facts stand outside society. It has already been mentioned that experiments are expensive to carry out, so the "anyone" in "anyone can check" is often a very small number of people. For most of us, including scientists, belief that the checks have been carried out and have confirmed the initial claims depends on assessing the credibility of the small number of replicators and the reliability of the media through which the results are conveyed to a wider audience. Obviously, these assessments depend upon wider assumptions about how society works – most of us would make different assumptions if the claims concerned witchcraft, magic, or even experimental results concerning, say, paranormal phenomena.

That is what happens "at best." Often, however, even the members of the elite group who have the means to test an experimental claim find themselves in dispute. Under these circumstances the social components intrinsic to the very process of replication become clear. Thus, it is not enough to have the logistic resources required to repeat an experiment; one must also have the necessary skills to do it. To some extent, skills turn on "tacit knowledge" that cannot be expressed. Therefore, if someone fails to confirm an experimental result, it may not be that the result was wrong – they may not have possessed the necessary skills. The only clear way to find out if the necessary skills are in play is to see if the experiment "works," but what it is to "work" is usually the subject of the dispute – e.g. should a working gravitational wave detector of a certain sensitivity see gravitational waves or should it not see them? The experimenters find themselves caught in the "experimenter's regress": to know if an experiment has been soundly performed, one has to show it has the right outcome, but to know what the right outcome should be one must first conduct a series of sound experiments. Disputes of this kind are settled by agreements to agree on what count as the sound experiments; and this, again, turns on judgments of credibility and so forth – these are sociologically analysable processes.

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## 15

# Social Construction of Technology

## WIEBE E. BIJKER

The social construction of technology is one approach among several constructivist ways of studying science and technology that emerged in the 1980s. Here, "constructivist" means that the truth of scientific facts and the working of technical artifacts are studied as accomplishments – as being constructed rather than as intrinsic properties of those facts and machines. The term "social construction of technology" can be used to denote two different things. First, it is a research approach to study technical change in society, both in historical and in contemporaneous studies. And, second, it is a theory about the development of technology and its relation to society.

## Constructivist Studies of Science and Technology

The phrase "social construction" was first used by Berger and Luckmann (1966) in their "treatise in the sociology of knowledge." Building on the phenomenological tradition, and particularly on the work of Alfred Schutz, they argue that reality is socially constructed and that these processes of social construction should be the object of the sociology of knowledge. Berger and Luckmann focus on the social construction of ordinary knowledge of the sort that we use to make our way about society. Other scholarship developed around such themes as the social construction of mental illness, deviance, gender, law and class. Similarly, in the 1970s the social construction of scientific facts developed, followed in the 1980s by the social construction of artifacts.

Constructivist studies of science and technology come in a wide variety of mild and radical (Sismondo 1993). The mild versions merely stress the importance of including the social *context* when describing the development of science and technology. The radical versions argue that the *content* of science and technology is socially constructed. In other words, the truth of scientific statements and the technical working of machines cannot be explained as being derived from nature but as constituted in social processes. Radical constructivist studies of science and technology share the same background, have similar aims, and are even being carried out by partly the same researchers. The remainder of this article will focus on technology studies and more precisely on the radical versions of the social construction of technology.

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## The Origin and Development of the Social Construction of Technology

The social construction of technology (SCOT) grew out of the combination of three distinct bodies of work: the science–technology–society (STS) movement, the sociology of scientific knowledge and the history of technology. The first started in the 1970s, mainly in the Netherlands, Scandinavia, the United Kingdom and the United States. Its goal was to enrich the curricula of both universities and secondary schools by studying issues such as scientists' social responsibilities, the risks of nuclear energy, the proliferation of nuclear arms, and environmental pollution. The movement was quite successful, especially in science and engineering faculties, and some of the STS courses became part of the degree requirements. The sociology of scientific knowledge (SSK) emerged in the late 1970s in the United Kingdom on the basis of work in the sociology of knowledge, the philosophy of science and the sociology of science. The central methodological tenets of the strong programme (especially its symmetry principle) seemed equally applicable to technology. In the history of technology, especially in the US, an increasing number of scholars began to raise more theoretical and sociologically inspired questions (influential were Constant [1980], Hughes [1983] and Cowan [1983]). Path-breaking advocacy for this body of work in the history of technology provided the reader edited by MacKenzie and Wajcman (1985). Researchers from these three traditions convened in an international workshop in 1984 in the Netherlands. The subsequent volume from that workshop, edited by an STS-er, a historian of technology and a sociologist of scientific knowledge (Bijker et al. 1987), has been heralded as the starting-point of the social construction of technology.

Additionally, it is important to recognize that the social construction of technology developed like any normal scientific program: its agenda, central concepts, and even unit of analysis shifted in response to research findings and discussions among scholars. In that sense, one can distinguish early and late (or recent) versions of the social construction of technology.

An important starting-point for the social construction of technology was to criticize technological determinism. Technological determinism was taken to comprise two elements: (1) technology develops autonomously, and (2) technology determines to an important degree societal development. This view was seen as intellectually poor and politically debilitating. Technological determinism implies a poor research strategy, it was argued, because it entails a teleological, linear and one-dimensional view of technological development. And it was considered politically debilitating because technological determinism suggests that social and political interventions in the course of technology are impossible, thus making politicization (see below) of technology a futile endeavor. To bolster this critique on technological determinism, it was necessary to show that the working of technology was socially constructed – with the emphasis on *social*. Key concepts in this program, as will be discussed in the next section, were "relevant social group," "interpretive flexibility," and "closure" and "stabilization." The unit of analysis was the single artifact. The choice for the artifact as unit of analysis was a choice for the "hardest possible case." To show that even the working of a bicycle or a lamp was socially constructed seemed a harder task, and thus

– when successful – more convincing, than to argue that technology at a higher level of aggregation was socially shaped.

The agenda of demonstrating the social construction of artifacts by an analysis on a micro level resulted in a wealth of case studies. A few years later, the program was broadened in two ways (Bijker and Law 1992). First, questions were raised at a meso and macro level of aggregation as well – for example about the political construction of radioactive waste, clinical budgeting in the British National Health Service, or technically mediated social order. Second, the agenda was broadened to include again the issue of technology's impact on society, which had been bracketed for the sake of fighting technological determinism. Concepts developed for this agenda were "technological frame," and various conceptualizations of the obduracy of technology (Hommels 2005). The unit of analysis was broadened from the singular technical artifact to the more comprehensive and heterogeneous sociotechnical ensemble. The emphasis now was on *construction* rather than on *social.*

Present research in the social construction of technology combines ongoing empirical case studies with more general questions about modernization of society, politicization of technological culture, and management of innovation. It now becomes increasingly difficult (and unfruitful) to observe the boundaries between the various approaches within the broader social construction of technology: research collaboration and conceptual combinations emerge between, for example, the actor-network approach, the social construction of technology (in the narrow sense), and gender and technology studies.

## The Social Construction of Technology as a Heuristics for Research

As a heuristics for studying technology in society, the social construction of technology can be laid out in three consecutive research steps (Bijker 1995).

Key concepts in the first step are "relevant social group" and "interpretive flexibility." An artifact is described through the eyes of relevant social groups. Social groups are relevant for describing an artifact when they explicitly attribute a meaning to that artifact. Thus, relevant social groups can be identified by looking for actors who mention the artifact in the same way. For describing the high-wheeled Ordinary bicycle in the 1870s, such groups were, for example, bicycle producers, young athletic Ordinary users, women cyclists, and anti-cyclists. Because the description of an artifact through the eyes of different relevant social groups produces different descriptions – and thus different artifacts – this results in the researcher's demonstrating the "interpretive flexibility" of the artifact. There is not one artifact; there are many. In the case of the Ordinary bicycle: there was the Unsafe machine (through the eyes of women) and there was the Macho machine (through the eyes of the young male Ordinary users). For women, the bicycle was a machine in which your skirt got entangled and from which you frequently made a steep fall; for the "young men of means and nerve" riding it, the bicycle was a machine with which to impress a lady.

In the second step, the researcher follows how the interpretive flexibility diminishes, because some artifacts gain dominance over the others and meanings converge – and, in the end, one artifact results from this process of social construction. Here, key concepts are "closure" and "stabilization." Both concepts are meant to describe the result of the process of social construction. "Stabilization" stresses the process character: a process of social construction can take several years in which the degree of stabilization slowly increases up to the moment of closure. "Closure," stemming from SSK, highlights the irreversible end point of a discordant process in which several artifacts existed next to each other.

In the third step, the processes of stabilization that have been described in the second step are analyzed and explained by interpreting them in a broader theoretical framework: why does a social construction process follow this way, rather than that? The central concept here is "technological frame." A technological frame structures the interactions among the members of a relevant social group, and shapes their thinking and acting. It is similar to Kuhn's concept "paradigm" with one important difference: "technological frame" is a concept to be applied to all kinds of relevant social groups, while "paradigm" was exclusively intended for scientific communities.

This three-step research process thus amounts to: (1) sociological deconstruction of an artifact to demonstrate its interpretive flexibility; (2) description of the artifact's social construction; and (3) explanation of this construction process in terms of the technological frames of relevant social groups.

## Some Philosophical Questions

The social construction of technology also provides a theory of technology development and of technology's relation to society. Here some of the implications for a philosophy of technology will be discussed by briefly reviewing the questions that Mitcham (1994) identified. I shall follow the agenda in his chapter "The Philosophical Questioning of Technology."

## Technology and Ideas

Extending its research heuristics, SCOT also implies "ideas about technology": the recognition that "technologies could have been otherwise" by denying a determining internal logic in technology development, the socially constructed nature of even technology's obduracy, the key role that technological frames (and thus the cultural values and social rules that are embedded therein) play. Such ideas, then, generate questions that constitute core issues in the philosophy of technology, even if they will not be spelled out here.

## Conceptual Issues

The relation between science and technology is approached by SCOT as an empirical rather than a theoretical question. Rather than trying to characterize the transistor as a technological (patents!) or as a scientific (Nobel Prize!) accomplishment, Pinch and Bijker (1984) suggested that it would be more fruitful to investigate empirically how actors in practice define a problem as technical or scientific. The same applies empirically tracing the negotiations about the boundaries between, for example, economic and technical, or technical and social, or political and technical (Callon 1987).

## Logic and Epistemological Issues

Technological frames comprise also criteria to identify primary and secondary problems and problem-solving strategies. That is, thus, the conceptual *locus* for identifying and studying different styles of technological thinking in SCOT. These styles show a clear correspondence to pragmatist philosophy, though this has been argued only for the political dimensions (Bijker 2006).

## Ethical Issues

SCOT offers a variety of entry points for ethical analysis of technology, especially because of the core idea that "things could have been otherwise." However, the one thing that SCOT does *not* provide is a conceptual framework to characterize ethical technologies in any context-independent and intrinsic way – that import technological determinism through the back door (philosophers who criticized constructivist studies of science and technology for this are Radder [1992] and Winner [1993]). A pragmatist approach seems most fruitful (Keulartz et al. 2004).

## Issues of Political Philosophy

We live in a technological culture: our modern, highly developed society cannot be fully understood without taking into account the role of science and technology. SCOT offers a conceptual framework for politicizing this technological culture. "Politicizing" here means: showing hidden political dimensions, putting issues on the political agenda, opening issues up for political debate. The social construction of technology approach not only gives an affirmative answer to Winner's (1980) question "Do artifacts have politics?" but also offers a handle to analyze these politics. Technology is socially (and politically) constructed; society (including politics) is technically built; technological culture consists of sociotechnical ensembles. The issue of political decision-making about technological projects acquires a special guise under the light of the social construction of technology. If it is accepted that a variety of relevant social groups are involved in the social construction of technologies and that the construction processes continue through all phases of an artifact's life cycle, it makes sense to extend the set of groups involved in political deliberation about technological choices. Thus, several countries experiment with consensus conferences, public debates and citizens' juries. One of the key issues here is the role of expertise in public debates. The social construction of technology approach suggests that all relevant social groups have some form of expertise, but that not one form – for example the scientists' or engineers' – has a special and *a priori* superiority over the others (Bijker 2004).

## Religious Issues

Once a social constructivist perspective has been adopted, religious values also come into play as part of the technological frames of relevant social groups. The concept of interpretive flexibility can help to distinguish different – religious and otherwise – identities of artifacts and thus open up new research entries to understand relations between technology and religion.

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# 16

# Theory Change and Instrumentation

## JOSEPH C. PITT

Philosophical theories of scientific change have tended to ignore the role of instruments and the impact of innovation in instrumentation on theory change. What are often referred to as the "standard" theories, those of Thomas Kuhn, Imre Lakatos and Larry Laudan, with their focus on theory, concentrate primarily on abstract considerations. These include such factors as anomalies (Kuhn), degenerating research programs (Lakatos) and problem-solving ability (Laudan). However, in none of these cases is attention paid to the mechanics behind change. Thus, we are informed that over time paradigms accumulate anomalies, but how these occur is not explained. Research programs degenerate, but what are the specific causes of degeneration? And what exactly contributes to the problem-solving ability of theories? One clear answer is "instruments."

Instruments contribute to theory change in different ways. Thus, it would be incorrect to propose a single theory regarding how instruments are involved in theory change. Part of the issue here is that theories change in a variety of ways and under multiple circumstances. Thus, one would expect that instruments would also be involved in those changes is a myriad of ways. But there is one constant: if science is what scientists do, then instruments change the way scientists work. So the focus here is on how instruments change science, rather than on theory change *per se.*

Consider just a few of the ways that instruments are involved in scientific change. New instruments can make possible new observations that place the status of a current theory in doubt. New instruments can stimulate the development of new sciences. Instruments developed in the context of one science can be imported into a science providing the impetus for a variety of changes. And, finally, devices developed for use outside the sciences can be incorporated into scientific work in ways that amount to a massive shift in how science is done or, rather, in what scientists do.

An episode in the history of science that vividly illustrates one role instruments play in theory change concerns Galileo's telescope. Galileo did not invent the telescope, but he was the first to put it to scientific use. In 1609 he published *Siderius nuntius.* It contained the results of his telescopic observations of the Moon. According to the then current theory of the structure and nature of the universe, the Moon, as a celestial body, was perfect – it was smooth and without blemish, as were all the bodies of the heavens. Claims such as these were part of the geocentric theory elaborated by Aristotle that

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proposed that, while the earth was a body that experienced constant change, the heavens did not. Galileo's reported observations showed that, contrary to what Aristotle proposed, the Moon was not a perfect sphere – it contained mountains and craters. Other observations included the revelation that Jupiter had moons. This dealt a heavy blow to the Aristotelian claim that there was one center to the universe, Earth, and that all other celestial bodies revolved around it. It now seems that there were many "centers" if Jupiter had moons. In short, the geocentric theory was in serious trouble. It is not too much to claim that Galileo's telescopic observations were highly instrumental in the final rejection of Aristotelian theory and its eventual replacement by Newton's account.

In the standard accounts of theory change we shall find acknowledgment of the observations, but not of the key role of the instrument, the telescope, that made those observations possible. And, more to the point, there is no understanding, in the standard accounts, of the role instruments play in changing not just the science but also our understanding of the world of experience. That is, of the kind of experiences we can have. Kuhn alludes to the world changing when paradigms change, but does little to elaborate. But it is clear that, following Galileo's discoveries regarding the Moon and Jupiter, the potential for human experience changed. That is, there is a very real sense in which the very meaning of "observation" changed, because the instrument made it possible to see things that hitherto it had not been possible to see.

Another instrument that influenced not only the development of science, in this case biology, was the microscope. But the role it played in theory change was different from that of the telescope. Rather than playing a key role in replacing a major entrenched theory, it was, to put it strongly, responsible for the creation of not just a new theory, cell theory, but a whole new science. The microscope emerged in the early decades of the seventeenth century. Galileo made one, Leeuwenhoek reported numerous microscopic observations, as did Robert Hooke, whose *Micrographia* was the first textbook of microscopy. Like the telescope, the microscope made it possible to see what we could not have seen before. In the early years, however, it was not clear what was being observed. New vocabularies were invented to try to give some structure to this new microscopic world that was being opened up. For example, Leeuwenhoek spoke of "animalculus," and Hooke invented the term "cell." But what actually was going on in the arena of the very small was unclear because there was no theory of the very small. What were these things, and why did they do what they did?

It took another two centuries before a systematic response to these questions was formulated in cell theory. In the intervening years improvements to the instrument had been made, and many speculated on what was going on at the microscopic level. The main impetus for the development of cell theory came from efforts to understand the causes of human disease. Attempts to use the microscope to understand the makeup of human organs proved unfruitful because no one was clear about what they were seeing. In some respects these problems echoed Hooke's complaints. The common thread running through them could only be answered by the development of staining techniques, which in turn could only follow from a theory of the cell finally articulated by Theodor Schwann and Mithias Jacob Schleiden around 1839. So in this case we have the development of an instrument that stimulates the search for theory to explain what the instrument reveals. And, like the telescope, the more useful the microscope became in revealing the world of the very small, so, too, did there occur changes in what we understood to count as an observation.

There are numerous cases where devices developed outside the contexts of science are imported into a science with astonishing results. The photograph is one such example. Today, in astronomy, the photograph has become an essential component in the doing of science. Using a telescope is in itself a complicated business. To begin with, since the Earth moves at a different rate from that of the heavens, keeping a telescope aligned with the object of study is a major problem. When Galileo was making a record of what he saw on the surface of the Moon he would have to stop his observing and turn to the parchment on which he was sketching his observations, then turn back, only to find that the Moon was no longer in the same place. He would then have to resight his telescope and make sure he had properly sketched the surface and then turn back and realign the telescope again. Today it is possible to attach a camera to a home telescope that has a built-in tracking device that keeps it aligned with the object of study and to take pictures of it, preserving the moment for later study. The Hubble Space Telescope has entertained the world with the pictures it has taken of deep-space phenomena in addition to providing the astronomical community with detailed images the analysis of which is changing our understanding of the expanding universe. In short, in astronomy, the camera (in some form or other) has become an instrument of science.

Finally we turn to a device that has transformed the face of many sciences, but in particular of space science: the computer. The computer plays increasingly important roles in nuclear physics, mathematics, statistics, sociology, astronomy, space science – and the list goes on. Interestingly, it plays different roles, and they have to be carefully delineated. Here we shall concentrate on nuclear physics and space science.

From the beginning of the hydrogen bomb project in the United States, the computer has been an integral part of the development of nuclear physics. At first it was used to assist in making calculations to predict reaction times. It was not essential to that job, since the Soviet Union used batteries of mainly women with hand calculators to achieve the same result. But it is increasingly essential today. For those countries that are signatories to and abide by the conventions of the anti-nuclear proliferation treaty, the computer has become the means by which to continue development of our knowledge in this area through the use of simulations. Simulations are important not only for the purpose of designing newer generations of nuclear weapons, but also for the development of new nuclear energy plants and for tracking the deterioration of existing nuclear warheads.

However crucial computers are to nuclear developments, it is safe to say that space science would not exist without them. Space science involves more than astronomy and cosmology. It involves chemistry and geology and biology, and it increasingly relies on information-gathering by mechanical probes sent off to various planetary and celestial locations. And the computer is involved in virtually all stages. Consider the following scenario. NASA sent a probe, appropriately named Galileo, to Jupiter and put it into orbit around the planet. To accomplish that simple act, scientists and engineers on Earth had to communicate with the probe, telling it when to do the appropriate maneuvers needed to achieve orbit. Essentially, they were communicating with a computer program. When the Galileo probe's "cameras" took pictures of the surface of Jupiter's moon Io, it was essentially storing digital data governed by computers. When it sent that data back to Earth, the computers on board aligned the antenna with earth and then sent the data, to be recovered and transformed into "pictures" by computer programs. Likewise for the pictures we now have of the surface of Mars. From the construction of the probe, to its launch, to its arrival at its destination, to the acquisition of data and their return to Earth and reconstitution, computers are integral.

In a similar fashion, computers are an essential feature of nano-science. This is a science that relies heavily on an array of electron microscopes all governed by computer programs. And, similar to the pictures we get from the Hubble, the pictures we obtain of the atomic level from a scanning tunneling electron microscope are "computer enhanced." The enhancement consists of, among other things, providing the vivid coloring so characteristic of nano-scale pictures. The crucial thing here is that we would see nothing without the computer enhancements since there is no color at the atomic level. The computer makes it possible for us to gain knowledge of the structures of the atomic level, knowledge that would otherwise be impossible.

If instruments are essential components of the development of science, attending to their roles and their own development is equally essential to our understanding of the developing sciences. As was merely suggested above, there are complicated relationships between the construction and use of an instrument and its impact on a science. But, likewise, the instruments themselves are impacted by the demands of the various sciences. New theories allow for novel predictions the testing of which requires new instruments or enhanced versions of old instruments, and the symbiotic interplay proceeds. Attending to the transformation of science and its instruments also means attending to the environments in which the science is being conducted – if you will, the social. In so doing, science itself becomes a much more vibrant and exciting world than sterile theories of scientific change would have us believe.

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# 17

# Biology and Technology

KEEKOK LEE

## Introduction

Biology may briefly be defined as the science which studies living organisms, at all levels of their organization; technology (for the purpose of this essay) as techniques for transforming the natural world/environment to meet specific human goals, interests or needs. Biology and technology appear to have nothing to do with each other, as they occupy very different ontological domains – the former is about autopoietic living matter, the latter about artifacts. However, one is not justified to conclude from this that human ingenuity cannot make artifacts out of living organisms. This essay explores and explains precisely such a transformation.[1] But, before doing so, one needs first to give a short history of technology.

## History of Technology

Technology has existed as long as *Homo sapiens*. It is not possible to do justice to all the historical forms of technology here, but it suffices to distinguish between that type which existed since the first adze made by our Stone Age ancestors and the modern varieties rooted in modern science. However, it would be a mistake to think that the latter began with the beginning of modern science itself, usually dated to the seventeenth century in Western Europe; instead, modern technology lagged behind modern science for a good two centuries and did not take off till about the 1840s. Up to then, humans relied on what may be called craft-based technology rather than science-induced/applied technology. The first industrial revolution was based on the former (the water–wind–wood complex); so was the second (the steam–coal–iron complex), as it relied on the steam engine.[2] However, the third industrial revolution occurred under very different circumstances, as it was induced by the theoretical discoveries of physics (such as electro-magnetism on the part of Faraday, and then others including Volta, Galvani, Oersted, Ohm, Ampère and Henry, leading to inventions like the electric cell, the storage cell, the dynamo, the motor, the electric lamp, not to mention the electric power station, the telephone, the radio telegraph) and of chemistry (such as Faraday's isolation of benzene which made the industrial use of rubber possible, while advances in organic

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chemistry permitted the industrial utilization of coal beyond its use as a direct source of energy). Till then, the inventor led and the scientist followed; from the 1840s, science has led and radical inventions followed – the paths of pure (theoretical) science and technology no longer diverged, but began to be harnessed to work as joint forces. However, given the complexities in the history of technology, it would be arbitrary to withdraw the term "technology" from that long phase of several millennia and confine it only to what has happened in the last 150 years.

## Technology and Artifacts

Technology is normally associated with the production of abiotic/exbiotic artifacts, such as houses, machines. Aristotle, in his analysis in terms of the four causes – material, efficient, formal and final – used a statue as prototype of an artifact. This might have, subconsciously, over the centuries, influenced our understanding of the concept of artifact, making it difficult for some to grasp that artifacts could be either abiotic or biotic. This means that a living organism could be transformed by human technology to become an artifact;[3] this is to say that the ontological status of a living organism as a naturally occurring being could, in principle, be transformed to become that of an artifactual one.

Artifacts are, therefore, the ontological foil of naturally occurring beings. The latter may be defined as that which have come into existence, continue to exist, and go out of existence, in principle, independently of human existence or manipulation; the former, in contrast, may be defined as the material embodiment of human intentionality, as they would not have come into existence, continue/cease to exist without the explicit intention and intervention of *Homo faber*. The ontological difference between the two domains may be further explained in terms of the following three theses of teleology:

1. External – this may be said to embody a strident anthropocentrism as it holds that Earth has come into existence for the very specific purpose of serving humans, a view which is not uniformly sanctioned and championed by contemporary theological thought, nor is it compatible with scientific thought since Darwin, whose theory of natural selection precisely dispenses with such a thesis: natural evolution, in accordance with natural selection, does not require the intervention of extraneous ends or designs, whether supernatural or human. Instead, the mechanism of natural selection is consonant with and requires the second thesis of teleology.
2. Intrinsic/immanent – each organism is simply concerned with maintaining its own functioning integrity in order to survive and to reproduce itself; in other words, it exists "by itself" (as it has come into existence independently of humans) and "for itself" (as it breathes, ingests nutrients, excretes waste, reproduces independently of humans) as an autopoietic being. Those individuals which happen to have certain traits (in their genetic make-up) which are favorable to survival and reproduction in a certain environment are able to leave behind offspring (or more offspring); those which do not, either die before they reach maturity to reproduce, simply fail to reproduce, or their offspring themselves die as soon as they are born or fail to

thrive and to survive to sexual maturity. In other words, the theory of natural selection in natural evolution, while denying external teleology, presupposes intrinsic/immanent teleology if it is to be intelligible. However, Aristotle may be said to hold both; but it would be a travesty of this thought to ignore his implication that intrinsic/immanent teleology is prior to external teleology. As a result, his anthropocentrism is more nuanced than certain modern versions, which simply uphold external teleology, while rejecting intrinsic/immanent teleology.

3. Extrinsic/imposed – *Homo faber* in making an artifact expresses its own will and intention; the *telos* (formal and final causes) of the artifact is designed into it, while the *telos* of a naturally occurring being has nothing to do with human design and manipulation. Should, one day in the future, the human species with its peculiar kind of consciousness go out of existence, the concept of artifacts would die with it – there would be no more motor cars, no more Chartres cathedral, only piles of matter such as metal, stone, wood, etc. In contrast, the oak or the bee, as autopoietic beings, would continue on their own respective trajectories, living out their own respective *tele,* which unfold altogether independently of human existence, intention, sustenance or intervention.

## Biology, Technology and Biotic artifacts

Craft-based technology was used in transforming living organisms to become biotic artifacts when the first plants or animals were domesticated about ten thousand years ago. The process of domestication was based on trial and error, although it has led to spectacular results indeed. It remains the method in many parts of the world even today, but in the developed world it has been, by and large, superseded by double hybridization (1930s), a technology induced by the fundamental discoveries of the first revolution in genetics, namely Mendelian genetics, and since the 1970s it is supplemented (rather than totally superseded) by biotechnology, induced by the fundamental discoveries of the second revolution in genetics of the twentieth century, namely DNA genetics (1957) and molecular biology.

What these three types of technology have in common, in spite of the great differences between them, is their common goal of transforming naturally occurring organisms to become biotic artifacts – humankind through them selects a particular characteristic(s) possessed by a plant/animal deemed to be desirable (high yield, drought-resistance) or a specific characteristic deemed to be undesirable (prone to pest-infestation, too short/too tall) to be bred in or out of the organism.

In other words, at each of these three levels of technological development, the concept of the biotic artifact correspondingly evolved. Under craft-based technology of artificial selection and breeding, the procedure for achieving the breeder's goal usually took a very long time, sometimes even hundreds of years, as it depended by and large on trial and error. The length of time is also dependent on generational duration, on how long it takes for the organism to become sexually mature and reproduce; the fruit fly (*Drosophila melanogaster*) has a life cycle of only two weeks, whereas an elephant of even over seventy years. Such a technology implicitly recognizes (in sexually reproducing organisms) that males and females transmit their characteristics to their offspring. This common-sense or proto-scientific knowledge served humankind well until the arrival of the (classical) science of genetics with the rediscovery of Mendel's laws of inheritance in 1901, followed by the discovery of the chromosome (Thomas Hunt Morgan), when it was established that genetic material is carried by genes on chromosomes – this made clear why the earlier craft-based technology had worked as well as it did. As a result, artificial selection and breeding became a scientific, more precise and controlled undertaking; its procedures also shorten the length of time required to achieve the desired outcomes, even though, like the more primitive technology it has superseded, Mendelian technology also rests (in the case of sexual reproduction) on the exchange of genetic material (contained in the whole sperm and egg) in the act of reproducing the zygote (embryo) irrespective of whether reproduction takes place *in vivo* or *in vitro*. However, this limitation is finally overcome with the arrival of biotechnology slightly more than half a century since the first appearance of Mendelian hybridization. Biotechnology, as we all know, enables humankind to bypass the traditional route of genetic transmission, as it is based not so much on the whole sperm or egg, but only on specific DNA sequences containing characteristics deemed desirable or undesirable which can be inserted or removed at will.

The above confirms that the greater and the deeper our understanding and knowledge of how living organisms function and reproduce, the greater, the more precise is our ability to control and manipulate living organisms, in our attempts ontologically to transform them from being naturally occurring entities to become biotic artifacts. As artifacts, they differ from abiotic/exbiotic ones in that, while the latter are inert, they are alive. However, the fact that they are alive, that they breathe, eat, excrete, grow, develop and reproduce, does not necessarily undermine the claim that they are artifacts, as those autopoietic biological mechanisms have been captured and diverted by *Homo faber* to serve, no longer their own *tele*, but the goals and intentions of humankind – true, the transgenic cow still produces milk, but the milk she produces contains a human protein which is alien to the cow genome, and which has deliberately been inserted into it in order to advance a specific human (pharmaceutical) end.

The deeper the science, the deeper becomes the level of manipulation through its corresponding technology, and therefore also the deeper the level of artifacticity embodied by its products. Domesticates produced by the craft-based technology of artificial selection/breeding by trial and error are, therefore, at the lowest level of artifacticity. The next level is brought about by Mendelian hybridization technology, operating still through the whole organism in reproduction, but, nevertheless, at the same time, focusing on the gene-chromosome (cellular level) as the unit of genetic transmission. Finally, with the arrival of DNA genetics and biology at an even deeper level of understanding, the technology it engenders operates at a correspondingly far deeper level, namely the molecular level, thereby generating an even greater level of artifacticity in its end products. Biotechnology no longer relies on breeding in the traditional sense which underpins both craft-based and Mendelian technologies, but bypasses it; this enables biotechnology to be a much more radical technology than that based on the gene-chromosome theory, as it can cross not only species but also kingdom barriers. Not only can the transgenic cow be made to express a human protein in her otherwise normal cow milk; the transgenic tomato can be made frost-resistant by having inserted into its genome a DNA sequence belonging to the flounder fish. *Ex hypothesi*, in terms of natural evolution, the cow and the human could not mate; neither could the tomato plant with the flounder fish. This testifies to the radical nature of biotechnology, the deep level at which it manipulates genetic material, and hence the depth of artifacticity in its transgenic products.

## Conclusion

There is a close link throughout human history – since humankind became sedentary and practiced agriculture and husbandry – between biology and technology. On the one hand, the (modern) science of biology may study, in the main, naturally occurring plants and animals (in their natural habitats); on the other, especially since the turn of the twentieth century, genetics (as a biological science) has consistently lent its theoretical understanding of organisms to the technological domain, and hence, crucially, brings about not only the technological but also the ontological transformation of naturally occurring beings to become biotic artifacts.

## Notes

1. For details, see Keekok Lee, *Philosophy and Revolutions in Genetics* (London: Palgrave Macmillan, 2005).
2. Ironically, the attempt to raise its efficiency led Sadi Carnot to discover the fundamental science of thermodynamics.
3. Some animals also have technologies – the beaver and its dam, the chimpanzee and its termite twig.

# 18

# Nuclear Technologies

WILLIAM J. NUTTALL

## 1. Introduction

Nuclear technologies lie close to the heart of the post-Second World War *Zeitgeist.* They give us the Bomb and nuclear power, which shaped, and were shaped by, socio-political change, including mass protest. The power of the atom challenges technocratic notions of: utilitarianism, several domains of ethics, political philosophy, and the impact of technology on society. Nuclear science has made numerous contributions to medicine for diagnosis and therapy. However, here we shall restrict discussion to the domains most closely connected to the core of nuclear science – fission.

## 2. The Physicists and the Bomb

Key to the provenance of nuclear technologies is physics. Physics was transformed by the Second World War. Physics had given the Allies radar and the atom bomb.[1] Before the Second World War physics had not been appreciated:

> . . . industries had been peculiarly obtuse in not seeing any conceivable use for physicists. Young men in the 1930s, with doctorates and good research to their credit, considered themselves lucky to get decent jobs in schools.
>
> (Snow [1981], p. 42)

In the 1920s and 1930s the first murmurings of the nuclear age came from solitary figures working in small academic groups on the European continent.[2] The only industrialization of nuclear properties concerned the use of radium in largely unscientific medical therapies and for luminous dials for clocks and aircraft instrumentation. Radium, a highly radioactive element, occurs naturally as the result of the radioactive decay of isotopes of thorium and uranium.[3] One of these isotopes, uranium-235, is fissionable, i.e. can be split when hit by a neutron releasing large amounts of nuclear energy. "Collect enough uranium-235, and there was the chance of an immense explosion. There the pure science finished" (Snow [1981], p. 100). Uranium-235 fission also made possible the first self-sustaining nuclear reactor. Enrico Fermi's 1942

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Chicago Pile-1 also demonstrated production of the man-made, but stable, fissile isotope: plutonium-239.

The use of fission in the Second World War Manhattan Project, and the resulting atomic bomb, transformed physics. For the history of the development of the fission weapon in the UK and the US, see Ronald Clark's *The Birth of the Bomb* and Richard Rhodes's *The Making of the Atomic Bomb.*

Even before the detonation of the first nuclear weapon at the Trinity Test in New Mexico on 16 July 1945, the first signs of dissent had emerged within the scientific team. Joseph Rotblat (Nobel Peace Prize 1995) was the first scientist to resign from nuclear weapons work on the grounds of conscience. Rotblat believed that scientists should be concerned with the ethical consequences of their work and he would go on to be the youngest signatory of the pacifist Russell–Einstein memorandum of 1955.[4] Klaus Fuchs was another Eastern European physicist who passed through the UK on his way to the Manhattan Project. Fuchs's response to his, and his family's, experiences under the Nazis was to betray the Allies' nuclear secrets to the Soviet Union. The Second World War and the Cold War led the physicists to confront realities for which they had not been trained. Their world had changed. "To the chagrin of most physicists, and the apprehension of some, the Cold War not only produced an escalation of the arms race; it also put barbed wire and guarded gates around the Radiation Laboratory at Berkeley" (Kevles [1971], p. 378).

Despite the individual misgivings, the physicists found themselves the winners in a competition for defense research funding. This has been described as a "victory for elitism" (Kevles [1971], ch. 22). The power of nuclear physics was tangible, rational, secretive, and the underpinning knowledge obscure. Nuclear technologies emerging from the hyper-rationalist world of physics and the largely unquestioning hierarchism of military control became arguably the most positivist and technocratic of postwar technological developments. Although Rotblat and others hoped to undermine this paradigm from within, they and their concerns were soon forced out *beyond the wire* both literally and metaphorically.

## 3. Thermonuclear Weapons and the Cold War

The building of the vast nuclear military industrial complexes (to use President Eisenhower's cautionary phrase[5]) occurred during the Cold War. The dominant project was not the atom bomb but the thousand-times-more-powerful thermonuclear fusion weapon – the H-bomb. The Soviet Union and the United States raced to produce a deliverable fusion weapon. The first deliverable weapon test with a fusion element to the blast actually occurred in the Soviet Union with the adoption of Andrei Sakharov and Vitali Ginzburg's Layer Cake single-stage design in which Lithium Deuteride (for fusion) was layered in with the elements of a fission weapon boosting its yield (Rhodes, 1995). The concept was successfully tested to a 400 kilotonne yield in the "Joe-4" test of 12 August 1953. This, however, was not a two-stage *hydrogen bomb* with the possibility of a megatonne yield. That required an elegant breakthrough insight from Stanislaw Ulam and Edward Teller in the United States. The resulting megatonne test of the enormous Mike device predated the Joe-4 test, occurring on 1 November 1952.

The first deliverable hydrogen bomb, Castle Bravo, was tested by the US on 1 March 1954. The Ulam–Teller insight is (probably) still not in the public domain today. That, however, has not stopped the publication of the secret of the H-bomb from having a place in the history of the US Constitution. The US Federal Government, for only the second time in its history (the first being the Pentagon Papers), briefly sought a prior-restraint injunction barring a magazine, *The Progressive*, from publishing on the grounds of national security, although later publication occurred legally.[6] Nuclear technologies were affecting notions of the freedom of the press.

In addition, the threat of nuclear war was altering notions of fear. Nuclear technologies have several special places in the history of fear: the blast, the fallout, and post-apocalyptic Hobbesian societies (Bourke 2005). Spencer R. Weart has splendidly argued that nuclear technologies were frightening before nuclear fission had even been discovered. The attributes of nuclear fear – that, for instance, radiation is imposed, invisible and mutating – have always existed in the human mind (Weart 1988). The realities of nuclear fear shape the policy landscape not just for nuclear weapons, but also for nuclear power generation; and it is arguable that nuclear energy, if it is to progress, must establish a new social contract with lower levels of technocracy, secrecy and fear (Nuttall 2006). This raises notions of risk and trust in our changing societies, and these matters have been ably explored by Ragnar E. Löfstedt (2005).

The notions that nuclear technologies are fearful products of insufficiently accountable technocratic elites lead one to two vital questions. The first is essentially anthropological. Why would decent people work on such technologies? Hugh Gusterson has shown that decent, often liberal progressive people work for the US Sandia National Laboratory on nuclear weapons systems and given a range of insights as to why (Gusterson 1998). The second question concerns the substance of the moral issues inherent in nuclear weapons. For these aspects the work of Douglas P. Lackey is particularly insightful, albeit stoical, separating, as he attempts to do, nuclear weapons from nuclear war (Lackey 1984). He considers nuclear weapons through the lenses of human welfare, rights and justice. He makes clear that nuclear weapons relate to notions of a *Just War*,[7] force a stronger separation of the tactical from the strategic and drive consideration of détente and risk.

## 4. Atoms for Peace

Nuclear technologies are, of course, far more than those of weapons. The development of civil nuclear power in the USA, the Soviet Union, Britain and France followed shortly behind the weapons programs. The world's earliest nuclear reactor for electrical power was at Obninsk, Soviet Union (1954), followed by the first commercial-scale plant at Calder Hall, UK (1956). The first US power reactor was developed at Shippingport, Pennsylvania, in 1957. These civil initiatives followed a major US push to internationalize the benefits of nuclear power via the "Atoms for Peace" process launched by President Eisenhower at the United Nations on 8 December 1953. The process yielded a series of celebrated exhibitions in far-flung places, some with dubious nuclear futures, such as Tehran, Iran, and Karachi, Pakistan (Weart [1988], p. 163).

Arguably the world's most successful innovation in civil nuclear power has been the development of light water reactors (LWRs). These technologies use ordinary water as both a reactor coolant and a neutron moderator.[8] Two main types exist – the Pressurized Water Reactor, developed as an offshoot of US naval propulsion research, and a later innovation, the Boiling Water Reactor. While early European reactors which used graphite as a moderator (e.g. the Magnox series) bear similarities to technologies previously developed for weapons plutonium production, the US LWRs had little or no connection with nuclear weapons. Interestingly, the LWRs had naval military origins not dissimilar to the military aviation origins of the gas turbines now widely used to generate electricity. It is also important to note the existence of the Canadian Deuterium Uranium Reactor series known as 'CANDU'. This civil power plant technology has completely civilian origins, but sadly its benign credentials became badly tarnished when, in 1974, India used materials obtained from its CANDU program to conduct its so-called "Peaceful Nuclear Explosion" (PNE) (Nuttall [2005], §II.5.2). While India's interest in the peaceful possibilities of nuclear explosions appears to have been less than sincere, it is interesting to note that both the US (with its Plowshare program) and the Soviet Union ("Industrial Explosions") had previously considered the possibilities of PNEs.

In my book *Nuclear Renaissance* I consider the prospects for the future of civil nuclear power via three policy lenses – economics, the environment and the security of energy supplies. The book comments on proliferation and security in an afterword and notes that a nuclear renaissance does not require the production of either highly enriched uranium or separated plutonium (the key ingredients of nuclear weapons). The North Koreans seemingly joined the nuclear weapons club in October 2006,[9] and now the relationship between, to quote the title of a recent book, *Nuclear Power and the Spread of Nuclear Weapons* has become ever more pressing (Leventhal, Tanzer and Dolley 2005). Jacques Hymans argues in his book *The Psychology of Nuclear Proliferation* that the psychology of individual leaders has always mattered greatly in regard to whether a country develops nuclear weapons. Kim-Jong Il and Kim Il Sung would appear to be no exceptions.

## 5. Deterrence, Détente, 9/11 and Dirty Bombs

Nuclear technologies have passed through several phases: the initial moves to fission and fusion nuclear weapons, deterrence, the development of civil nuclear electricity systems, the emergence of détente and the SALT treaties in the face of possible mutually assured destruction, the threat of nuclear weapons proliferation, and perhaps most recently a diverse range of threats from well-resourced, technically able and suicidal terrorists. Each phase has raised its own set of issues for the social sciences.

The risk of subnational organizations possessing nuclear weapons, perhaps as a result of a nuclear weapon state becoming a failed state, is a current concern. Our security resides in the difficulty in obtaining both fissile materials, including the cannibalization of diverted nuclear weapons to improvise a new weapon,[10] and prerequisite nuclear know-how. While important pieces of know-how appear to remain undisclosed, Allinson warns that talented undergraduates, such as John Aristotle

Philips at Princeton University in 1977, can apparently design a workable nuclear weapon from purely public-domain information (Allinson [2004], pp. 87–9).

Fears of nuclear proliferation have led the United States, via the Bush Doctrine following 11 September 2001, to reassess its notions of a just war, in contexts of weapons of mass destruction proliferation, to permit pre-emptive strikes. In a world of proliferation fears, it is important to remember that for the first five nuclear weapons states the delay from fission weapon test to workable thermonuclear weapon was, on average, only seventy-one months (Norris and Kristensen 2003). A world with loose thermonuclear weapons would surely be different from today with, at the very least, strongly authoritarian security countermeasures. Those who advocate the possession of nuclear weapons for utilitarian reasons[11] must acknowledge not only the risk of a nuclear war but also the separate risks of a plutonium society.

Nuclear terrorism goes beyond notions that terrorists might acquire or develop a nuclear weapon to include the concept of the "dirty bomb" in which they seek to disperse highly radioactive material using conventional explosives. Such a device would probably not cause an enormous number of casualties, and hence is not a weapon of mass destruction, but it has been characterized as a weapon of mass disruption (Allinson [2004], p. 8).

## 6. Nuclear Waste

Civil nuclear power has an important place in the history of energy as the first technology to internalize fully and to manage its wastes. In the early days, wastes were discarded using methods which included sea dumping, but these days the level of harm associated with civil nuclear power emissions is remarkably low when compared to issues such as greenhouse gas emissions, acid rain or particulates in urban air.

At the back end of the civil nuclear fuel cycle is a key choice: one possibility is the direct disposal of spent fuel, with the majority of its embedded energy untapped, and recycling, known as reprocessing, with its greater number of technical challenges and, conventionally, the separation of plutonium.

Nuclear waste is frequently described as the Achilles heel of commercial nuclear power. In 1976 in the UK the Royal Commission for Environmental Pollution, chaired by Lord Flowers, recommended in its sixth report that a resolution of the waste question should be found before the UK could embark on a renewed program of nuclear build. Although the recommendation had limited direct impact – Sizewell B PWR was constructed in the 1990s – it put in place the idea that nuclear renaissance requires a resolution of the waste question.

Britain's approach to nuclear waste in the 1970s to 1990s has been characterized as one of Decide, Announce, Defend (Grimston and Beck 2002). This approach derailed in 1997 with the blocking of plans for an underground laboratory in Cumbria, England (Nuttall [2005], §I.4.2). In recent years, initially in Scandinavia, a new way forward has been found based upon far greater levels of public engagement in the process (Nuttall 2006). In the UK recent moves toward nuclear new build have been accompanied by a fresh approach to the waste question led by the Committee on

Radioactive Waste Management (CORWM). Nuclear waste policy is increasingly the domain of the polity rather than of *Atomic Priesthoods*.[12]

## 7. Climate Crisis

Key to the position of commercial nuclear energy in the twenty-first century will be the issue of global climate change. James Lovelock warns the world that attempts at sustainability are insufficient and that the world must mobilize all its technological and intellectual resources to combat the threat (Lovelock 2006). Society must balance its nuclear fears against the prospect of devastation from global warming. Nuclear energy has the potential not only to contribute to the decarbonization of our electricity system, but also, perhaps via a move to a *hydrogen economy*, to help tackle the more difficult challenge – how to decarbonize our transport system.

## 8. Conclusion

Nuclear technologies have raised, and will continue to raise, a host of philosophical and political issues. Perhaps at the heart of nuclear science and technology in the twentieth century has been the notion that science, and especially nuclear science, is on a deterministic, almost preordained, path, and that the most we can hope to do is to slow its progress in undesirable directions. As such, it is arguable that many, perhaps most, decision-makers felt that such inevitabilities rendered irrelevant all issues of morality. The issues became more matters of management than of leadership.[13] Thus far, the twenty-first century is giving us hope, from developments in commercial nuclear power in particular, that the old technocratic paradigms are breaking down. However, simultaneously there is growing apprehension as nuclear proliferation seems to be quickening pace.

## Acknowledgments

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## Notes

1. Nazi Germany's engineers had produced ballistic missiles and British mathematicians had broken secure German ciphers, but in the years immediately after the Second World War these were either still too foreign or still too secret to represent celebrated genius.
2. See: http://www.accessexcellence.org/AE/AEC/CC/radioactivity.html (accessed October 2006).

3. See: http://www.ead.anl.gov/pub/doc/natural-decay-series.pdf#search=%22radium%20decay%20thorium%20uranium%22 (accessed October 2006).
4. See: http://www.pugwash.org/about/manifesto.htm (accessed October 2006).
5. See: http://www.eisenhower.archives.gov/farewell.htm (accessed October 2006).
6. Howard Morland provides personal insight into the *Progressive* legal case in his paper (Morland 2003) available from the Federation of American Scientists. http://www.fas.org/sgp/eprint/mhttp://www.fas.org/sgp/eprint/morland.htmlorland.html (accessed October 2006).
7. The concept of a Just War has been debated for centuries. Prominent thinkers include St. Augustine (354–430 CE), author of *The City of God*, and St. Thomas Aquinas (1225–74 CE), author of *Summa theologica*.
8. Nearly all commercial nuclear power plants employ neutrons that have been slowed from their initial fast speeds, when emitted by the fission process, to levels natural for the temperature of the reactor core. The process of slowing down is known as "moderation" (Nuttall 2005, §I.3.1).
9. North Korea claims to have tested a nuclear weapon on 9 October 2006. Seismic data indicate that some form of event occurred. See: http://www.iaea.org/NewsCenter/Focus/IaeaDprk/ (accessed October 2006).
10. Such cannibalization might arise from a need to get around the diverted weapon's in-built protections such as "permissive action links" (Leventhal and Alexander 1987, p. 15, and Allinson 2004, pp. 89–92).
11. i.e. policies consistent with an expectation of the greatest happiness for the greatest number.
12. – to use the evocative phrase introduced in another context by linguist Thomas A. Sebeok as part of the 1981 work of Bechtel Group's Human Interference Task Force.
13. With thanks to Dr. Simon Smith, York University, for helpful discussions.

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# 19

# Engineering Design

PETER KROES

## General Characterization

One of the core activities of engineering that distinguishes it from science is designing. Engineering design, as defined by the Accreditation Board for Engineering and Technology (ABET):

> is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic science and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective.[1]

The stated objective is laid down in what is usually called a list of specifications. This list is derived from the function that the thing to be designed (system, component or process) is required to perform; and that function, in turn, is related to certain human ends (needs). If the designed artifact meets all the specifications, it is deemed able to realize the desired function. Whether that is indeed the case depends on whether the list of specifications adequately captured the function. If the reasoning from end to function has been performed adequately, the designed artifact can be used as a reliable means to realize the specified end.

Engineers design a great variety of things ranging from mass-produced computers to unique oil platforms, from telephones to high-rise buildings, from components to complex systems, from micro-organism to software, etc. Correspondingly there is also much variety in engineering design practices. In some practices, the design phase includes the actual making and testing of prototypes of the designed object; in others, the actual making of the designed object falls outside the design phase. In some, aesthetic criteria are of paramount importance; in others, not. Some design projects may be performed by a single designer; others require a large, multidisciplinary team of design engineers. There is also a great deal of variety in the types of design problems to be solved. Vincenti (1990) distinguishes between normal and radical design, and between design tasks that are high or low in the design hierarchy.

With so much variety, the question arises whether it is possible to define domain-independent general principles and procedures for engineering design. Simon (1996 [1969]) maintains that such a general science of design is possible. Moreover, with the

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growing complexity of the objects of design, the need for a systematic approach to engineering design has become more urgent. In recent decades, new fields such as system design and design methodology have emerged that study the principles and procedures of engineering design with the aim of rationalizing and improving design practice (Sage 1992; Pahl and Beitz 1996). Within these fields, analyses of and proposals for engineering design methods are often domain-independent.

## A Design

The outcome of an engineering design process involves typically a material object or its description. These objects are technical artifacts and are different from natural objects in that they are based on (human) designs. Exactly what a design in this sense is, is not so easy to spell out. On the one hand, a design may be taken to be a blueprint for production: a description of all the physical (chemical) properties of a technical artifact that are relevant for actually making a token of the artifact type defined by the design. In this sense, a design is a complete description of all the parts and their relations. But this does not capture the full notion of design. Somebody with the appropriate skills and equipment would be able to produce such a technical artifact without having any idea what it is for. The notion of design has strong teleological connotations in that a designed object has a specific property of "*for*-ness" as it has been made to do something: to be *for* something (see analysis of teleology in relation to technical artifacts in McLaughlin 2001). A design may therefore, on the other hand, also include a description of the function of the technical artifact, and furthermore (usually implicitly) an explanation of how the physical structure realizes that function (Kroes 1998). In this "thick" sense, a design becomes a description of a "teleological arrangement" of physical parts that together realize a function.

A closer look at the outcome of a design process shows that it is not just a (description of a) technical artifact, but that it also comprises the manual, that is, the description of how to use the technical artifact correctly. The outcome may, therefore, be characterized as a "*use*-plan," that is, as a considered series of actions to achieve a certain end, with (a description of ) the technical means necessary for executing the "*use*-plan" (for more details, see Houkes, Vermaas et al. 2002).

The growing complexity of modern technical artifacts and the use of computers in supporting the solution of engineering design problems have increased the need for more formal, unambiguous representations of designs. Such representations are important in developing engineering data management systems for computer-aided design (CAD). Especially the formal representation of a function has proved problematic (Dym 1994). Much work is being done in developing taxonomies of functional primitives (a field sometimes referred to as "functional modeling"), functional representation and functional reasoning in AI quarters with the aim of supporting engineers in solving design problems and accurately representing design solutions.

## The Design Process

According to the ABET description, engineering design is a decision-making process. Designing involves decision-making on different levels, at different stages and about different kinds of issues. Simon (1996 [1969]) considers this decision-making process to be all about the problem of making rational choices between available alternatives. Bucciarelli (1996) characterizes it more as a social process in which negotiations between different stakeholders also play a role, thus stressing that more is involved in engineering design than mere instrumental rationality.

From the point of view of the object to be designed, the engineering design process can be described as a process through which a functional description of the object is "translated" into a structural description. A purely functional description of an object "black-boxes" its internal structure; it is oriented toward the environment of the object and describes it in terms of desired input–output relations. Three different kinds of input–output relations are often distinguished, which correspond to the conversion of matter, energy and information. A structural description specifies all the physical/chemical properties of the technical artifact (as in the blueprint for production) and how it will behave under various input conditions. The structural description, however, does not specify which one of all possible input–output relations is the one that corresponds to the desired function: in this sense, the structural description black-boxes, so to speak, the environment. To what extent the content of the black box is, in practice, already fixed at the beginning of the design process depends strongly on the nature (radical or normal) of the design task.

What kind of reasoning and knowledge is involved in translating a function into a structure? From a logical point of view, it is not possible to deduce structure from function (form does not follow function in a logical sense), nor the other way around. In solving this translation problem, "means–ends" reasoning seems to be of paramount importance. Means–ends reasoning is based on causal relationships (Von Wright 1963). If we know that A causes B, then we can realize B by bringing about A (if this is technologically possible). So A can be considered as the *means* in relation to B, the *end*. In spite of its importance in engineering practice (and daily life), the formal (logical) analysis of means–end reasoning has received relatively little attention up till now. The intimate relation between means–ends reasoning and causal relations explains why scientific knowledge plays such a dominant role in modern design practice. However, it would be misleading to interpret engineering design as simply the application of scientific knowledge (or knowledge produced by the engineering sciences). According to Vincenti (1990, ch. 7), the anatomy of engineering design knowledge includes at least six different categories of knowledge, some of which do not derive from scientific knowledge at all (such as the "know how" acquired on the shop-floor). All these various kinds of knowledge are important for turning a functional description of the object to be designed into a structural one.

The overall design process may be divided into various phases or steps that correspond to distinguishable aspects of solving a design problem. Within design methodology the triad "analysis–synthesis–evaluation" is often taken as a starting-point for modeling the design process. As long as designing is an activity performed by a single individual, these phases are relevant mainly from a conceptual point of view. But as soon as designing becomes a matter of teamwork, which is by and large the situation in modern industry dealing with complex and large systems, the phasing of the design process becomes an important institutional tool for organizing, controlling and steering the process of product development. The well-known VDI phase diagram for the design process contains seven steps (with iterations between these steps). These steps are: clarify and define the task; determine functions and their structure; search for solution principles and their combinations; divide into realizable modules; develop layout of key modules; complete overall layout; prepare production and operating instructions (VDI 1987).

A problem that hampers discussions about the usefulness of implementing such phase diagrams in engineering practice is deciding which criteria can measure the success of the outcome of an engineering design process. From a strictly engineering point of view, the simplest success criterion is simply meeting the list of specifications. But this assumes that the list of specifications is fixed immutably at the beginning of the design process, which is often not the case. Because of problems encountered on the way, they may have to be adjusted during the design process. Furthermore, decisions about what performance criteria to use and the development of methods for measuring these performance criteria are often an integral part of the design process. Moreover, various participants may evaluate the outcome in different ways. In spite of these difficulties, design methodologists claim that implementation of systematic approaches to design improves the design process (see, for instance, Pahl and Beitz 1996, pp. 499–501).

## Rationality and Creativity in Engineering Design

The lack of clear criteria for evaluating the outcome of design processes also affects discussions about the role of rationality in engineering design. The ABET definition suggests that the decision-making in engineering design is strongly governed by instrumental rationality, that is, choosing the right means for realizing a given end. The objective is set from outside, and the design process is about finding the optimal means to realize this objective. The fundamental norms or values on which instrumental rationality is based are efficacy and efficiency; these would constitute the main criteria for evaluating the outcome of the design process. This view on the role of rationality in engineering design is problematic. As already remarked, the objective itself may have to be adjusted. Decisions on how to redefine the objective, however, fall outside the scope of pure instrumental rationality. Furthermore, engineering design is not just about rationally choosing the best alternative from a given set of options (even, that is, from the point of view of rational choice theory not always a straightforward matter; problems arise in case various options have to be evaluated against multiple criteria [Franssen 2005]). Engineering design is also, and often primarily, about generating the various options (means) from which a choice can be made. Here, decisions have to be made about how many options to generate, about which options to drop because they are too problematic, about which options to develop further because they are promising (and all this under constraints of time and resources, which themselves may become the object of decisions or negotiations). It seems highly unlikely that such decisions can be justified on the basis of instrumental reasoning. This is not to say that engineering design is irrational but that the notion of instrumental rationality is too narrow a concept adequately to analyse the issue of rationality in engineering design.

Engineering design, therefore, is essentially a creative activity since it is all about creating new technical artifacts and processes. It is often thought that the use of rational problem-solving methods stifles creativity, especially within those engineering disciplines in which aesthetic criteria are more important. There is, however, no reason to assume that creativity and rationality do not both make a valuable contribution to engineering design. On the one hand, design involves the generation of new ideas for solving design problems, while on the other hand these ideas have to be evaluated against available resources, customer requirements, in-house state-of-the-art technology, production facilities and so on. Coming up with proposals may require creative thinking; but, once the proposals are on the table, choices have to be made and then the rational appraisal of the various options comes into play. Creativity and rationality are complementary elements that are both necessary for effective engineering design.

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## Note

1. http://www.me.unlv.edu/Undergraduate/coursenotes/meg497/ABETdefinition.htm (accessed 28 September 2006).

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# 20

# Cybernetics

## ANDREW PICKERING

The canonical history of cybernetics is US- and Wiener-centric. It begins with Norbert Wiener's work at MIT during the Second World War that sought (unsuccessfully) to build an anti-aircraft predictor – a machine which could extrapolate a plane's trajectory into the future and hence improve the chances of shooting it down (Galison 1994; Mindell 2002). Philosophically, the key feature of this device was that it could be thought of as both a purposeful machine in itself and as a model for understanding purposeful behavior in living creatures, thus eliding the distinction between machines, animals and humans – an idea set out in a classic essay by Rosenblueth, Wiener and Bigelow (1943) and developed at greater length in the 1948 book that first gained the field worldwide attention, Wiener's *Cybernetics; or, Control and Communication in the Animal and the Machine*. Alongside Wiener himself, historical attention has focused on a series of conferences supported by the Macy Foundation between 1946 and 1953 as the principal locus for the elaboration of cybernetic ideas in the US (Pias 2003, 2004). Both Heims (1991) and Dupuy (2000) have written book-length studies based on the Macy *Proceedings*, the former focusing on cybernetics as social science, the latter as cognitive science. The chairman of the Macy meetings was neuropsychiatrist and philosopher Warren McCulloch, the most important figure in the immediate postwar history of US cybernetics (Kay 2001); the secretary for the later meetings and editor of the *Proceedings* was the Austrian émigré physicist Heinz von Foerster. Institutional centers of cybernetics were the Research Laboratory of Electronics at MIT, where McCulloch's group was based, and the Biological Computer Laboratory at the University of Illinois established by Foerster (1958–75: Müller and Müller, forthcoming). Beyond the canonical history, cybernetics had a rich and varied life outside the US. It flourished in France and Germany, and became almost the official science of the Soviet Union (Gerovitch 2002). In Britain, the publication of *Cybernetics* catalysed the formation of the Ratio Club, an informal dining club of proto-cyberneticians that met between 1949 and 1958 (Pickering forthcoming).

The substance of cybernetics can be defined in many ways. Wiener's book ran together several concerns and new developments of the wartime era, including notions of feedback control, neural networks (Anderson and Rosenfeld 1998), information theory and the new electronic digital computers, and all of these have their own history. It is perhaps better to define early cybernetics in terms of its primary referent: the brain.

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Though this has been obscured by Wiener's background in mathematics, cybernetics began as a science of the brain, and its distinctive character derived from its conception of the brain as an organ of performance rather than of cognition – the brain as a key organ in our bodily functioning and, especially, in our adaptation to situations we have never encountered before. And, materially, one hallmark of early cybernetics was the construction of electromechanical models that could illuminate "the go" of the performative and adaptive brain (Cordeschi 2002). Wiener's predictor was such a model, exemplifying a functional system that might underlie goal-oriented behavior more generally. In 1948 two of the British cyberneticians, Grey Walter and Ross Ashby, built further important models (Asaro 2006). Walter's "tortoises" were mobile robots that searched for and homed in on lights; Ashby's "homeostat" randomly reconfigured itself to come into dynamic equilibrium with differing environments. These machines could be understood as models of the pathological as well as the normal brain, and thus offered a novel scientific basis for psychiatry (to which McCulloch, Ashby and Walter all had professional affiliations). On the other side of the Atlantic, in the 1950s, Gregory Bateson, one of the founders of the Macy conference series, developed a very different but also cybernetic approach to psychiatry, which was put into practice in the 1960s by R. D. Laing and others at Kingsley Hall in London. In its early years, then, cybernetics constituted a singular conflation of novel forms of adaptive engineering and robotics, brain science and psychiatry, and this protean quality continued to mark the subsequent development of the field as it was extended beyond the brain into many areas, including biological computing (Asaro forthcoming), social theory and practice, politics, spirituality, education, music, the arts, theater and architecture. And, although the word "cybernetics" has gone out of fashion, much current work in all sorts of fields – including management, complexity theory, robotics and the arts – continues to elaborate distinctly cybernetic approaches.

There is presently a growing resurgence of interest in cybernetics across the humanities and social sciences, with Donna Haraway's "Manifesto for Cyborgs" (1985) and N. Katherine Hayles's *How We Became Posthuman* (1999) amongst the key works – an interest that reflects the conviction that cybernetics is a "new kind of science" (Wolfram 2002) importantly different from more familiar sciences such as physics or mainstream sociology. One way to get at that difference is ontologically (Pickering 2002; forthcoming). As the subtitle of Wiener's founding book suggests, cybernetics decenters the human and effaces the usual dualisms of modernity, putting humans, animals, machines and nature on the same plane and emphasizing both parallels and constitutive inter-relations between them. More generally, another cybernetician, Stafford Beer (1959), argued that modern sciences like physics are sciences of knowable systems, and defined cybernetics, in contrast, as the science of "exceedingly complex systems" – systems that we can engage with but which we can never fully understand. The central problematic of cybernetics on this definition is a concern with how such systems (including ourselves) can get along and come to terms with one another (and hence the centrality to cybernetics of the adaptive rather than the cognitive brain).

The tortoise and the homeostat were early materializations of this ontology, each adapting in its own way to its environment, performatively rather than cognitively, and many of the strangest and the most imaginative cybernetic projects subsequently staged some version of the same ontological stance. Around 1960, Beer and another cybernetician, Gordon Pask, developed a distinctive approach to "biological computing," which sought to entrain some naturally occurring, exceedingly complex system – a pond ecosystem, for example – as a controller for another such system, a factory. In the early 1950s, Pask built a machine called Musicolour which translated musical sounds into a light show. The key feature of the machine was that its internal parameters changed in time as a function of the performance itself, so that the performer was never in full command but had instead to adapt to the emergent properties of the machine (themselves adapting to the performance). Musicolour, in turn, was a model for Pask's later work on adaptive architecture – both on reconfigurable buildings that could respond to emergent patterns of use and invite new ones, and on design systems that, as exceedingly complex systems, could genuinely collaborate with architects (Mathews 2003; Sadler 2005).

A sort of politics, or subpolitics, goes with the cybernetic ontology. The modern sciences and philosophy often portray the world asymmetrically in a way that is centered on human knowledge and agency: we know the world and can thus bend it to our will. From a cybernetic perspective, this is nonsense. Implicit in the cybernetic decentering is a notion of respect for the other (human or non-human): if we cannot dominate exceedingly complex systems, we should be interested in their performances and alert to unexpected possibilities as well as dangers. One thinks here of Heidegger's (1976) contrast between "enframing" and "revealing". Enframing characterizes late modernity, with its grim obsession with dictating to people and things how they should behave, and with disaster as its frequent corollary (think of New Orleans and Hurricane Katrina, or the US invasion of Iraq); revealing is open to what the world has to offer us. In general, cybernetic projects and products look very different from their more familiar modern counterparts. Politically, we could see them as a set of sketches of another future, another way to be in the world. This, no doubt, is another source of the renewed interest in the field.

Other outgrowths of cybernetics have taken ontological decentering further. If modernity is characterized by a whole constellation of dualisms and dichotomies that circle around specific definitions of mind, brain, body, self, spirit and matter, then cybernetics is a non-modern science focused on continuities and inter-relations between all these terms. This has translated, for example, into an interest in strange performances and altered states. Grey Walter's *The Living Brain* (1953) discusses the ability of Eastern yogis to suspend normal bodily functions (breathing, the heartbeat) as well as the achievement of nirvana. These altered states can in turn be associated with material "technologies of the self" (Foucault 1988), with the self now understood as itself decentered and non-modern. Walter was very interested in flicker – the effects brought on by stroboscopic light – including epilepsy (brain science again) but also visions – of moving geometrical patterns and scenes that are not there. (Huxley 1956 is a long catalogue of technologies of the non-modern self, including flicker and psychedelic drugs.)

Eastern philosophy crops up repeatedly in the history of cybernetics, and we can understand this along similar lines. From one angle, meditation is a technology of the non-modern self. From another, Bateson and Laing appealed to Buddhist philosophy to grasp the altered states that characterize schizophrenia and to reconceptualize psychiatric therapy. Stafford Beer taught tantric yoga and integrated his tantric experiences and beliefs into his cybernetic approach to management and organization. Coming from the direction of matter rather than of self, cybernetics has often been associated with a certain hylozoism – a vision of matter itself as lively and infused both with mind and spirit – and with a distinctly non-modern stance on design. Modern design imagines an artful rearrangement of matter to bring it into conformity with our purposes; hylozoism, in contrast, suggests an exploratory engagement with the agency of things. Think of biological computing juxtaposed to the industrial manufacture of digital computers. Much cybernetic art has a hylozoist quality, thematizing the agency of nature: a tortoise-like robot, for instance, controlled by a cockroach instead of electrical circuitry (Hertz 2006).

Finally, as a non-modern science, cybernetics has resonated with wider nonmodern cultural formations. The heyday of cybernetics was the 1960s when it crossed over into the counterculture and its "explorations of consciousness." William Burroughs and the Beat writers and artists were, like Aldous Huxley, intensely interested in flicker, for example. Kingsley Hall was a key site for both a radical cybernetic psychiatry and the London "underground" scene. Gordon Pask's *Colloquy of Mobiles* – an assembly of robots designated male and female that engaged in uncertain matings via sounds and lights – was exhibited at the *Cybernetic Serendipity* exhibition at the Institute for Contemporary Arts in London in 1968. Since then modernity has regained and intensified its grip on the popular imagination, but echoes of cybernetics can still be found in all sorts of cultural formations running from "cyberculture" (Turner 2006) to New Age philosophy and spirituality.

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# 21

# Chemistry and Technology

## HELGE S. KRAGH

From a historical perspective, chemistry is the quintessential "mixed" science, as much concerned with making and developing useful materials as with generating scientific knowledge. Practical or technological chemistry was well known in ancient Egypt and continued to be developed in Europe, China and the Islamic world, independently of scientific or philosophical ideas of matter and its transformations. Until the seventeenth century, chemistry (or alchemy) was basically a craft rooted in empirical traditions, yet the absence of guidance from chemical theory did not prevent practical chemists from manufacturing many chemicals and developing new instruments and techniques. During the scientific revolution, the new corpuscular theories of matter, as developed by Pierre Gassendi, Robert Boyle and others, were inspired by practically working chemists and alchemists, but they did not result in new technological applications. Briefly, while scientific chemistry was to some extent technology-driven, progress in practical chemistry was by no means science-driven. To mention but one example, the discovery in 1669 of phosphorus – the first chemical element isolated since antiquity – was made by a Hamburg merchant and alchemist with no knowledge of scientific chemistry. Thirty years later, the discovery had been transformed into a commercial manufacture of phosphorus, a process in which science played no role.

It is, though, problematical to speak of the relationship between scientific and practical chemistry prior to the second half of the seventeenth century, as it was only then that chemistry began to take shape as a branch of science independent of production and medicine. By the start of the eighteenth century, chemistry had become a branch of natural philosophy, hence "scientific" in a sense recognizable today. The phlogiston theory was successful in so far as it provided, for the first time, a common framework for interpreting a wide range of chemical phenomena, but from a technological point of view it had little to offer.

Although the emergence of inorganic chemical industry in the second half of the eighteenth century coincided with the so-called chemical revolution of Antoine-Laurent Lavoisier and his allies, the actual impact of the new chemistry on industry was practically nil. Within a century, soda and sulfuric acid became the backbones of a heavy chemical industry of enormous economic significance, yet science played but a limited role in this success story. The popular view of early chemical industry as the fruit of new advances in scientific chemistry is not supported by historical research. Thus, the

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celebrated Nicolas Leblanc, who in 1789 developed the method of soda production named after him, was an ordinary chemical worker whose success did not depend on use of new scientific principles. By and large, until the mid-nineteenth century, chemical industry and technology was more important to scientific chemistry than the other way around. Several elements have been discovered, more or less accidentally, in connection with chemical manufactures (e.g. iodine in 1812 and selenium in 1817).

Nevertheless, it is with some justification that chemical industry is said to be the first industry that profited significantly from advances in pure science. There is even some truth in the claim that important parts of chemical industry around 1900 were science-based, in the sense that these industries would probably not have emerged and flourished had it not been that they utilized fairly new insights based in contemporary scientific research. A technology does not merit the epithet "science-based" merely because it happens to make use of knowledge or apparatus that have their origin in some scientific context; the science in question has to be *essential* to the technology.

The prime early example of a chemical industry rooted in science is the huge complex of organic–synthetic industry that emerged in Germany after 1870 and in which scientifically trained chemists played a crucial role. There is no simple road from August Kekulé's discovery of the hexagonal structure of benzene to the mass-production of organic dyes, but it is beyond doubt that pure science played an important role in the complex process. Whereas William Perkin's synthesis of mauvein in 1856 was serendipitous, later advances in industrial organic synthesis relied crucially on scientific insight in the structure of organic compounds and the corresponding reaction mechanisms. In the 1890s the German chemical company BASF succeeded in transforming laboratory-based knowledge into a full-scale industrial manufacture of indigo, a dyestuff of great economic importance. The entire process was based on scientific advances in organic synthesis and other branches of chemistry, but of course this is only half the story: although scientific advances were necessary conditions, they were not sufficient conditions.

Much the same story can be told about other breakthroughs in chemical industry in the first decades of the twentieth century, such as the Haber–Bosch process for synthetic production of ammonia fertilizers and the invention of nylon. The first case illustrates the maxim "Necessity is the mother of invention," whereas the second goes better with the inverted maxim "Invention is the mother of necessity." In the early years of the new century there was a marked shortage of nitrogen-rich fertilizers for European agriculture, which was the direct background for the high priority given to experiments with "fixating nitrogen," that is, to convert some of the atmosphere's molecular nitrogen to solid or liquid fertilizers. It did not require an expert chemist to make nitrogen react with hydrogen, but the problem was to maximize the yield under circumstances that were economically feasible. This turned out to be a formidable problem that involved scientific problems in chemical thermodynamics, equilibrium theory, high-pressure reactions and the mechanism of catalysis. It is an indication of the scientific basis of the Haber–Bosch process that its two main architects, the theoretical chemist Fritz Haber and his industrial colleague Carl Bosch, were both awarded the Nobel Prize in chemistry; also two other Nobel laureates, Walther Nernst and Wilhelm Ostwald, had significantly contributed to the scientific knowledge that made the first industrial plant a reality in 1913. It is to be noted that the technology on which the ammonia manufacture rested did not flow from scientific results obtained independently in the laboratory; rather, these results were direct responses to technological needs.

The history of the synthetic ammonia process exemplifies a class of technologically oriented research that takes on the character of fundamental scientific research, except that "techno-scientific" research programs are much more closely tied to socio-economic goals than academic-scientific research. Another noteworthy example from the pre-Second World War period is the American physical chemist Irving Langmuir, who worked for General Electric and whose experimental program (aimed at improving the efficiency of filament lamps) included surface chemistry, for which he was awarded the 1932 Nobel Prize. To generalize, chemical technology is not to be thought of as an independent variable, drawing its ideas parasitically from science; rather it is an equal partner contributing as much to the common stock as it draws out.

The Haber–Bosch process was obviously driven by economic, political and military needs. In the 1930s, when the Du Pont corporation succeeded in manufacturing nylon, the consumers felt no need at all to get dressed in clothes made by synthetic fibers. Du Pont had to create a need, which they and other companies eventually did. The polymeric nature of macromolecules was a novel and somewhat controversial scientific insight of the 1920s, when the field was pioneered by the German organic chemist Hermann Staudinger in particular. To turn the insight into profit made a strong research base imperative, and it was with this purpose that Du Pont hired the university-trained chemist Wallace Carothers in 1928. Carothers's research program was "oriented basic research," meaning that it was fundamental research in macromolecules guided by the wish to manufacture commercially useful synthetic fibers. His research resulted in the development of a new polyamide fiber which Du Pont marketed as "nylon" in 1938 and which marked the beginning of the "synthetic revolution."

One should not believe, though, that all advances in the new synthetic industry were based in a planned scientific approach. It is significant that another major success of the early industry, the discovery of polyethylene in the laboratories of ICI in England, was a result of a research program investigating the effects of high pressure on organic materials. The involved chemists were not aiming at finding a new plastic material but happened to do so serendipitously. Although science did not show the way, their approach was thoroughly scientific.

The examples mentioned illustrate certain general features of chemical industry and its relation to scientific chemistry. Whatever the kind of manufactured product, in a commercial chemical-technological process it is of decisive importance that it can be governed and controlled. The aim is not merely to manufacture a certain product, but to gain complete control over the process. Therefore, the factors that govern the reactivity and output of the process must be known, and methods to control and analyze the product must be developed. Technology is about purposeful manipulation of materials. Successful manipulation of tiny units such as atoms and molecules requires scientific knowledge of the nature of matter and the processes of transformation. Contrary to, say, mechanical articles, the chemical units are invisible. For this reason, knowledge of their behavior and means of influencing them is best-obtained through scientific theory and systematic experiments. This does not mean that technical chemistry must necessarily rely on scientific knowledge. The alchemists and technical chemists of the Renaissance were happily unaware of molecules, thermodynamics and reaction rates, and yet they manufactured many useful substances. But it does mean that the scientific approach has enormous advantages, and that a highly developed and efficient chemical industry cannot be based on empirical rules only. It is not too much to say that modern chemical industry is crucially based on science, although in most cases not the most recent science.

Post-Second World War chemistry has relied heavily on high-technological instrumentation, and in several cases the instruments used in the laboratories had their origin and were shaped by experiences in the industrial sector. For example, infrared spectroscopy – which provides a "fingerprint" of molecules based on their vibrational states – was applied and developed by the petroleum industry in the 1930s and only widely adopted by organic chemists after the war, soon to become indispensable for their scientific research. The instrumentation revolution promoted an idea of "instrumental objectivity" which emphasized cost efficiency and the reduction in the role of human judgment. Starting in analytical chemistry, this kind of objectivity ideal soon spread to a wide range of measurements, from food labels to pollution monitors.

To speak of chemical industry purely in terms of "science" and "technology" is a considerable oversimplification that tends to ignore much of what is specific to chemical engineering. Although manipulation of chemical compounds and reactions is at the heart of most chemical industries, they also deal significantly with physical processes (such as heat exchange and crystallization) and apparatus associated with them. Chemical engineering is not science-based in the traditional sense but better-understood as an independent class of applied science oriented toward industrial processes in general.

Modern chemical industry is characterized not primarily by its products but rather by its processes, that is, the succession of actions – whether physical or chemical – that transform raw materials into a new chemical product. Processes and their conceptualization in terms of "unit operations" are at the heart of chemical engineering. According to the American Arthur D. Little, who introduced the concept in 1915, any chemical manufacturing process can be broken down into a series of discrete physical processes known as unit operations. The number and order of these operations will vary from chemical to chemical, but the variety of manufacturing processes can nevertheless be understood in terms of the same set of building blocks.

Chemical engineering based on the intellectual innovation of unit operations came to dominate the chemical industry after the Second World War and made possible a much more efficient, coordinated and scaled-up production of chemicals. In modern chemical industry, advances in "chemical process software" have been no less important than advances in "chemical material hardware." This also means that scientific competences entering chemical industry have carved out their own niche. They are neither wholly scientific nor wholly technological but a hybrid form of knowledge in which the computer is of greater importance than the glasswares and instruments of the classical laboratory.

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# Part III

# Technology and Philosophy

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## 22

# Introduction: Philosophy and Technology

VAL DUSEK

The field of philosophy of technology as a branch of professional philosophy is relatively recent. It is only some three decades old as a flourishing specialty. Traditional branches of philosophy, such as metaphysics and ethics, are almost two and a half millennia old. Philosophy of science as a specialized brand of technical philosophy, by contrast, stems from the second and third decades of the twentieth century. During the nineteenth century a number of scientists, primarily physicists, wrote works specifically dedicated to the philosophy of science. Despite the importance of technology to human life and society throughout human history (and, indeed, prehistory), there has not been a continuous tradition of the philosophy of technology. There have been sporadic major contributions to the field among the classical philosophers. Socrates, Plato and Aristotle discussed the crafts, expertise and *techne*.

Socrates and Plato contrasted the concrete and effective knowledge possessed by craftspeople with the spurious claims to knowledge of ethical and political matters on the part of politicians of the day. On the other hand, Socrates and Plato contrast the narrow, concrete and specialized craft knowledge with the comprehensive wisdom pursued by genuine philosophy. Socrates and Plato considered ethical and political knowledge, when achieved, as genuine theoretical knowledge. Aristotle also contrasted theoretical with practical and productive knowledge. For Aristotle, however, practical wisdom is not itself a kind of theoretical knowledge as Socrates and Plato had claimed. It does not admit the precision of mathematical or scientific knowledge. While Plato held training in mathematics to be an ideal prerequisite for the study of ethics and politics, and in his later "unwritten doctrine" conflated philosophical knowledge with a higher form of knowledge of numbers, Aristotle strongly contrasted practical knowledge, gained from mentors and learned by example, depending on intuitive judgment calls based on life experience, with precise and explicit mathematical knowledge.

Almost two thousand years later Francis Bacon emphasized the role of technology in experimental knowledge and in contributing to the prosperity and welfare of society. Bacon took seriously the importance of craft knowledge in gaining theoretical knowledge of and mastery over nature. In this Bacon differed greatly from the "British empiricists" (Locke, Berkeley, Hume and Mill), who are generally considered his philosophical progeny during the next three centuries, in that the latter concentrated on

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the association of ideas based on perceptual knowledge and not on knowledge as based on practical, manipulative activity.

In the nineteenth century Henri de Saint-Simon and August Comte in France, as well as Karl Marx in Germany, devoted attention to the role of technology in the development of society. Comte and Saint-Simon did not focus on the details of particular technologies (though Comte had a fairly detailed knowledge of mathematical physics) but both did make the concept of "industrial society" central to their conceptions of the culmination of historical development and the social structure of contemporary society (Comte being the father of sociology). Marx, who characterized the essence of contemporary society as capitalism rather than as industrialism in general, did, in his later economic works, do analyses of particular technologies with respect to their effects on workers and their contribution to productivity.

Nevertheless, scores of major philosophers in the eighteenth, nineteenth and early twentieth centuries had very little or nothing to say about technology. Even with the growth of early modern science and technology followed by the industrial revolution, the Continental European rationalists and British empiricists of the seventeenth and eighteenth centuries (with the exception of Bacon), despite two centuries of intense concern with theory of knowledge and the nature of knowledge in pure science, had surprisingly little to say specifically about technology. Why was this?

One suggestion is that in the modern era technology has been seen purely and simply as applied science. If one could understand the nature of scientific knowledge, then the problems of philosophy of technology were essentially solved. The direct application of science to technology was seen as largely unproblematic. Furthermore, the main streams of rationalist, empiricist and Enlightenment philosophers right up through the works of the logical positivists saw technology as an almost unalloyed benefit to society. Technology would, following Bacon, contribute to the national health, wealth and welfare. There were no major ethical problems in technology. (Granted, Leonardo da Vinci and Francis Bacon did raise some concerns, but most of the major early modern philosophers did not.) The theory of scientific knowledge and political theory offered issues and problems, but once these were solved there were no problems left solely involving technology.

It is true that from the end of the eighteenth and beginning of the nineteenth century the Romantic tradition included questioning and criticism of technology and emphasis on the harms of technology, but even here the major writers concerned with the harmfulness of technology were Romantic poets, novelists and literary essayists, not the Romantic philosophers such as Fichte and Schelling. Similarly, the actual Luddite movement was a practical, political one of industrial sabotage, not a primarily theoretical movement. Those nineteenth-century writers who have sometimes been called honorary "Luddites" for their negative assessment of the industrial revolution were for the most part poets, art critics and essayists who sometimes presented philosophical ideas, but who are not included in the canonical history of philosophy.

In Germany, defeat in the First World War led to a popular wave of disillusionment with technology and a neo-Romantic interest in "return to nature" in the German Youth Movement. However, in the rest of Western Europe, Britain and the United States, it would seem that only after the Second World War, especially because of nuclear bombs and the nuclear arms race, were large numbers of people willing to entertain the idea that technology might be at least as harmful as helpful to humanity. Similarly, although there had been criticisms of the harmful effects of technology on the environment, particularly among the Romantics, mass popular concern about negative impacts of technology on the environment did not surface until the 1960s and 1970s. Thus nuclear weapons and widely reported ecological side-effects of technology made reflection on the ethical balance of the benefits and risks of technology a widespread phenomenon. With development of biotechnology, particularly the possibility of genetic modification of humans, and concomitant speculation about engineering human nature itself, intensified concern about this seemingly more intimate and "essential" intrusion of technology into humanity grew.

There was a further barrier to the widespread and intense development of philosophy of technology within philosophy for the first two-thirds of the twentieth century and beyond. Philosophy of technology is a field of philosophy that involves a wide variety of branches of philosophy. Philosophy of technology involves philosophy of science, theory of knowledge, philosophy of action, ethics, political philosophy, and may involve aesthetics, metaphysics and philosophy of religion as well. Within analytical philosophy, focus on philosophy of science and focus on ethics have involved disjoint classes of specialists. At least into the 1980s, most ethicists often appealed to a somewhat dated philosophy of science, if they appealed to it at all. Philosophers of science, with a few exceptions, have not worked on problems of ethics. The interactions between political philosophy and philosophy of science have not been quite so exclusive, but have generally been by no means intimate for most practitioners.

Another feature of philosophy of technology may have impeded its earlier development. Not only does the field demand simultaneous engagement in a diversity of branches of philosophy, but also contributors to philosophy of technology have come from a number of schools of philosophy. These diverse schools for most of the twentieth century did not communicate with one another. Often they did not respect or take seriously one another's style and product. The split between analytic and Continental philosophy began around the turn of the twentieth century. After the early exchanges between the phenomenologist Edmund Husserl and the grandfather of much logical analytical philosophy, Gottlob Frege, for instance, or the early mutual and co-respective awareness of Martin Heidegger and Rudolf Carnap, despite the harsh criticisms of the former by the latter, analytic and Continental philosophy remained mutually incommunicado for at least three-quarters of the century. There were some exceptions to this, as in the reviews of Husserl by the leader of the Vienna Circle logical positivists, Moritz Schlick, and reviews of the works of the Vienna Circle by the early Frankfurt School critical theorists such as Max Horkheimer and Herbert Marcuse (although these cross-school reviews were uniformly negative). Anglo-American analytical and linguistic philosophers tended to dismiss much of German and French philosophy as obscurantist, pretentious and meaningless, while professionals in the mainstream of Continental philosophy often dismissed analytical philosophy as narrow, trivial and irrelevant to the great issues of the age.

Only in the last few decades of the twentieth century had there begun to be analytic commentaries on major twentieth-century Continental philosophers such as Heidegger and Husserl, while a number of Continental philosophers, such as Jürgen Habermas, Karl-Otto Apel and Ernst Tugendhat, took seriously and grappled with Anglo-American linguistic philosophy. Scandinavian and Dutch philosophers, dominated by neither German nor British traditions, were able to make fruitful use of both traditions earlier than their German and British counterparts. In recent decades in the United States there have been a number of philosophers occupied with various projects of "bridge-building" between analytical and Continental approaches.

There are contributions to philosophy of technology not only in the analytical and linguistic vein, as well as from the phenomenological, existential and hermeneutic traditions; there have also been further contributions from British social constructionists, French postmodernists and American pragmatists. During the last decade there has been a surprising renewal of interest in the work of the early-twentieth-century Anglo-American process philosopher Alfred North Whitehead among social constructionists and French actor-network theorists such as Donna Haraway, Bruno Latour, Andrew Pickering and Paul Virilio.

The twenty-first century shows strong evidence of the overcoming of these disciplinary and scholastic barriers, as exemplified by the works in following sections of this *Companion*. The old disjunction of philosophy of science and moral philosophy, as well as the older divisions of the various schools of twentieth-century philosophy, is in the course of being transcended in much of the best contemporary work.

By forcing the integration of ethics and political philosophy with epistemology and philosophy of science, as well as inviting the mutual employment and combination of the methods of logical and linguistic analysis with phenomenology, hermeneutics, social constructionism and process philosophy, philosophy of technology will move from being a marginal and neophyte specialty to playing a central role in the cross-pollination of both subject fields and methods of contemporary philosophy leading to a reunited world philosophy community.

## Philosophy of Science and Philosophy of Technology

Both analytic and Continental philosophy of science are integrated into contemporary philosophy of technology. Within Anglo-American philosophy of science, the post-positivist currents associated with Thomas Kuhn and several others opened various avenues to the analysis and evaluation of technologies that had not been open to approaches beholden to the logical positivist account of science. Just as the mathematical logic-based early work of Ludwig Wittgenstein, partially misinterpreted, was appealed to by the original Vienna Circle logical positivists, the later, ordinary-language-based work of Wittgenstein influenced the work of Thomas Kuhn, Norwood Hanson, Stephen Toulmin and a number of other post-positivist philosophers of science. Although these writers of the late 1950s and early 1960s did not originally emphasize the extra-logical social and cultural influences on science, the more contextual and non-formalistic approach of the post-positivists allowed the consideration of non-scientific political, gender and other influences on scientific theories. Although Thomas Kuhn did not develop the occasional brief references to social influences on science in his work, the British social constructivist sociologists of scientific knowledge did so during the next decade.

A weakness of much of the immediate reaction against logical positivism of the followers of the later Wittgenstein mentioned above was over-emphasis on theory, even though the conception of theory allowed the broadening of "theory" to include ideological and cultural influences. What Don Ihde and Davis Baird independently called "instrumental realism" shifts the focus from purely intellectual theory to the instrumentation and practical means of experimental investigation. Ian Hacking, Peter Galison and others have helped reorient philosophy of science toward the production of instrumental "effects" and imaging. Don Ihde has further integrated this work with a hermeneutics within science. (See discussion of hermeneutics below as well as Ihde's entries on hermeneutics and imaging technology in this section.)

## Phenomenology and Technology

Phenomenology is the description of experience. Franz Brentano contributed the notion of intentionality of acts of consciousness, always directed toward an object, but Edmund Husserl was the major influence on twentieth-century phenomenology. Although most of those who appealed to Husserl as philosophical mentor focused on issues in description of everyday life, ethics and religion, Husserl himself began from training in mathematics and psychology, and returned in his later work to reflection on physical science. Husserl did a dissertation on the calculus of variations under the leading nineteenth-century mathematical analyst Karl Weierstrass and continued with studies in psychology under Carl Stumpf.

Husserl's description of experience contrasted with the atomistic analysis of the British empiricists and many of the logical positivists. Rather than portraying experience as consisting of atomic sense data or sensations, Husserl described the field of consciousness as containing organizing wholes and containing horizons, both outer (which give a sense of the extension of the field beyond what is immediately in consciousness) and inner (potentially yielding detail beyond that initially evident). Husserl introduced the phenomenological *epoche* or bracketing in which one suspends judgment concerning the existence or nonexistence of the objects of experience and the notion of eidetic intuition of essences in experience.

Husserl later turned to the analysis of Galileo's "idealization" of ordinary lived experience (lifeworld) and the subsequent mistaken identification of reality with our idealized abstractions rather than with our lived experience. This later work of Husserl opened many paths in the phenomenology of science. With respect to its usefulness for philosophy of technology, this later work of Husserl shares a deficiency with the original post-positivistic philosophy of science in its overemphasis on theory and insufficient attention to instrumentation. Don Ihde has called Husserl's Galileo a Galileo without the telescope.

Maurice Merleau-Ponty, who, along with his fellow Frenchman Jean-Paul Sartre, is sometimes called by American followers an "existential phenomenologist," developed the conceptions of the later Husserl. Merleau-Ponty's elaboration on the conception of the "lived body," a body neither the purely mechanistic body of external, physical analysis, nor the subjective conscious mind of introspection, but the body as experienced has much potentiality for the account of technological activity and relationships between humans and their machines. Hubert Dreyfus has made fruitful use of this concept as well as of Husserl's account of the field of consciousness in his critique of artificial intelligence.

Martin Heidegger, student of Husserl, and one of the most influential philosophers of the twentieth century, transformed the rather Platonic conceptions of essential intuition in Husserl's phenomenology into a more concrete, existential account of human existence. Heidegger also gave equal emphasis to the account of objects as pragmatic means through which we act and work, along with the more traditional account of objects present to hand as detachedly observed and independent of us. Heidegger also enriched phenomenology not only with concrete existential themes but also with the centrality of the interpretation of meaning.

In the later works of Heidegger, in contrast to those of Husserl, technology itself becomes a central theme. According to Heidegger, technology characterizes the nature of modern society in the way that nature did the world of the Greeks or religion was central to the Middle Ages. Technology structures modern humans' entire comportment to the world, turning all objects into resources, and the centrality of modern technology makes all our thinking oriented to instrumentality and control of nature even at the most rarified levels of philosophical reflection. Experiences of the world in a non-technological manner become much more rare and fragile than in previous epochs. Albert Borgmann has emphasized how we may treasure and maintain the "focal" and communal experiences that free us from the technological enframing of the rest of life.

## Hermeneutics

Yet another philosophical methodology that holds an important place within the philosophy of technology is hermeneutics. Hermeneutics began as the specialty of biblical interpretation. At the beginning of the nineteenth century, its sense was broadened by Friedrich Schleiermacher to include the interpretation of all sorts of written texts. At the end of the nineteenth century it was further expanded by Wilhelm Dilthey to include the interpretation of culture in general. In the late twentieth century the scope of hermeneutics as a branch of the humanities and literary interpretation was even further extended to include science. At first the hermeneutics of science encompassed only the interpretation of science as a part of culture. However, in recent decades Don Ihde has further expanded hermeneutics to "hermeneutics *in* science," that is an account of the role of hermeneutic interpretation as part of scientific procedure. The "texts" interpreted by hermeneutics in science include prominently the deliverances of scientific instruments.

## Marxism, Critical Theory and Technology

Marxism and neo-Marxism are another major component of contemporary philosophy of technology, both as a source of ideas and as an object of criticism. Marx's later economic writings contain detailed discussion of the effect of factory *machinery* on workers. Ironically, "orthodox" Marxists of the half century after Marx did not greatly elaborate on these specifically technological inquiries of Marx, though they emphasized the technologically deterministic aspects of Marx's account of history. Much of the neo-Hegelian rediscovery of the dialectical and social constructivist aspects of Marxism in the first half of the twentieth century, so-called "Western Marxism," concentrated on aesthetics and literary criticism rather than on the economy and technology. Critical Theory was an exception to this de-emphasis on technology within neo-Marxism. However, the critical theorists tended to treat technology and technological reason as a monolithic unity. (This was true of other mid-twentieth-century writers such as Jacques Ellul as well.) Andrew Feenberg corrects this tendency of critical theory to treat technology as an undifferentiated repressive phenomenon, examining particular technologies with regard to emancipatory as well as repressive potentials.

## Social Constructivism

Another trend in the philosophy of technology is that influenced by the social construction of technology (SCOT). The social construction approach originated in the social construction of scientific knowledge. The constructionist tradition in philosophy goes back to Thomas Hobbes and Giambattista Vico. Both of these early modern philosophers claimed that we know best that which we ourselves make. Vico emphasized mathematics and history as human products while Hobbes emphasized the role of social contract in the constitution of society and of science and definitional convention in the constitution of scientific knowledge. The next major contributor to constructivism was Immanuel Kant in the late eighteenth century. Kant claimed that we constitute our knowledge through the application of categories of the mind applied to the manifold of sense experience. Johann Gottlieb Fichte radicalized Kant's constructivism by claiming that the mind does not simply organize and systematize the inputs of sense experience but posits or creates the objects of knowledge. In 1923, György Lukács combined the constructive trend of German idealism with Marxism. Rather than the forms of mind or reason as such, it is the forms of economic production that structure knowledge and worldviews. In the 1960s the social constitution of knowledge was revived in a number of forms. In the 1970s this approach was applied to the sociology of scientific knowledge by the British social constructivists of science.

Social construction of technology is in some ways less controversial than the social construction of scientific knowledge. There are three aspects or levels of constructivism. One is the construction of the physical instruments of science and technology. A second is the construction of knowledge. The third is the construction of natural objects and facts. The notion that hypotheses and theories are constructed by knowers is not in itself controversial, especially since the general rejection of the earlier British empiricist claim that theories emerge automatically from inductive observations. The addition of the term "social" to constructivism emphasizes the widely accepted view that science is a social enterprise, a product of the scientific community. The most controversial thesis of the social construction of science is that the natural objects and/or facts of science are socially constructed. If by "fact" one means what is accepted as a fact by the scientific community, this thesis is not controversial. It is only when there is a slippage between fact in this sense and fact as an independently existing state of affairs that the thesis of the social construction of facts becomes controversial. Instrumental realists such as Ian Hacking point out that in experimental physics "effects" are produced by instrumentation. The artifacts of technology are, literally, physically constructed.

What may be more controversial in SCOT would be the claim that what counts as "efficient" in technology is itself socially constructive and is not simply a matter of inputs and outputs of physical energy.

## Pragmatism and Technology

Pragmatism has been the distinctive American contribution to philosophy. In contrast to previous philosophies that evaluated claims in terms of principles or axioms that logically justify them or in terms of perceptual data on which they are based, pragmatism evaluates claims in terms of consequences for action. Charles S. Peirce initially presented pragmatism as a principle for the evaluation of meaning and had a different characterization of truth. When William James used the pragmatic principle as a definition of truth, and understood truth as results in the broadest possible sense, Peirce dissociated himself from James's account by calling his own approach "pragmaticism." John Dewey developed an account of evaluation of claims in some ways closer to Peirce's but did use the pragmatic maxim as a means of evaluating truth as well as meaning. Dewey at one point suggested that, since the term "truth" is so closely associated with the classical notion of correspondence with pre-existing, independent facts, one should give up the term "truth" for "warranted assertability."

During the middle third of the twentieth century in the USA the émigré Central European logical empiricists became allied with the pragmatists on many issues. Pragmatist criticisms of logical empiricism, such as those of W. V. O. Quine and Wilfrid Sellars borrowed theses from pragmatism to criticize the logical positivist criterion of meaning in terms of verification by sense observations, but were in philosophical style and interests far closer to analytical philosophy than to the classical pragmatists. They lacked the broad concerns with social problems of industrial society and democracy expressed in the writings of Dewey. Richard Rorty expressed sympathy with Dewey but turned in the direction of what many see as relativism and Continental literary postmodernism.

Among the classical pragmatists it is John Dewey whose writings deal most with themes of interest to the philosopher of technology. Peirce focused on the physical science and philosophy of mathematics, and had little to say about social problems and issues. James concerned himself with psychology in his early work and religious belief and commitment as well as general epistemology in his later work. In contrast, issues related to or applicable to technology pervade Dewey's writings. Larry Hickman has been a contemporary philosopher concerned with reviving interest in Dewey on technology and emphasizing the value of Dewey's views for the reform of technology.

The very term "instrumentalism" that Dewey used to characterize his approach shows his affinity to the philosophy of technology. For Dewey, not just physical tools, but concepts and methods are instruments. Dewey's conception of technology as the evaluation of tools and techniques (which include ideas and concepts, habits and institutions) is extremely broad. For Dewey there is no contrast between technology and the rest of culture.

Dewey wishes to treat all the traditional philosophical dichotomies, fact and value, mind and body, thought and action, as poles in continua, or phases of activities, not as absolute distinctions of kind. This aspect of Dewey fits well with the philosophy of technology's need to deal with ethics as well as science, concepts as well as theory of action.

Dewey has been criticized by European critical theorists and by hermeneutic phenomenologists for excessive optimism concerning the future of technological and industrial society. However, Dewey's optimism is not uncritical, and his emphasis on revision and reform as part of the very nature of technology is a useful corrective to the portrayal of technology as all-encompassing, uncontrollable, dominating and oppressive that is found in much twentieth-century German writing about technology.

## Toward an Integrated Philosophy of Technology

Philosophy of technology has been approached through a variety of philosophical perspectives and "schools." These include post-positivist philosophy of science, phenomenology, hermeneutics, social constructivism, critical theory and pragmatism discussed above.

One of the impacts of the philosophy of technology is to encourage and, in the context of problem-solving, in some cases to force the integration of various philosophical approaches. In jointly deploying the methods of these various approaches to deal with philosophy of technology, the shared features of many of these schools of philosophy become more evident.

One feature of the various schools of recent philosophy applied to the philosophy of technology is their sensitivity to the issue of context. Ordinary language philosophy, in contrast to earlier logical positivism and formal-logic-oriented analytical philosophy, emphasizes the context of utterances. Deweyan pragmatism likewise is a thoroughgoing contextualism.

Another feature of the philosophies deployed in the philosophy of technology is the emphasis on the role of language and meaning as structuring perceptual experience. Ordinary language philosophy of the later Wittgenstein stands to the earlier logical positivism and empiricism as hermeneutics and the hermeneutic phenomenology of the later Heidegger stand to earlier phenomenology, in that both emphasize the inextricable relatedness of linguistic meaning to the description of experience.

The emphasis on action rather than passive apprehension in knowledge has been central to both Marxism and pragmatism. Furthermore the understanding of meaning in pragmatism and in ordinary language philosophy is one that emphasizes use in practice rather than correspondence to abstract entities. One asks in pragmatism not what abstract terms are but what they do. Similarly the slogan "meaning as use" has been central to ordinary language philosophy.

A variety of other approaches, such as conceptual role semantics, are more precise variations on this approach to meaning in use.

Similarly an emphasis on the role of embodiment in human life and knowledge distinguishes a number of the mid-to-late-twentieth-century approaches to philosophy from earlier approaches emphasizing the dualism of mind and body. The lived body of Merleau-Ponty and Dewey's emphasis on technologies as extensions of embodiment are just two of these emphases on embodiment. Michel Foucault's focus on the power of and control over bodies and feminist philosophy's critique of the neglect of embodiment in classical early modern philosophy are other developments of this theme.

Another turn in the treatment of knowledge and action shared by a number of the philosophies made use of in discussing technology is the social nature of knowledge. Marxism, critical theory and social constructivism are among those approaches that most obviously emphasize the social dimensions of knowledge. Ordinary language philosophy emphasizes the social nature of language, and pragmatism incorporates the social nature of knowledge. Emphasis on the role of the scientific community in post-Kuhnian philosophy of science is another example of the inclusion of the social dimension of knowledge. There is now widespread awareness of, although disagreement about, the role of gender and culture in the formulation of theories and norms of action.

The importance of construction of social arrangements and of knowledge is another theme shared by several of the philosophies we have examined. It is most evident in the very name of social constructionism, but pragmatism in its Deweyan form is also a constructionism. This construction was previously presented as a purely mental construction as in Kant, but the philosophy of technology has brought to the fore the role of literal physical construction.

Another area of integration of approaches is the way that the philosophy of technology forces use of both descriptive and normative or evaluative considerations to give adequate accounts of technological artifacts and projects. Developments in post-positivist philosophy of science and social constructionist accounts of science have foregrounded the role of norms of science in knowledge, both with respect to the norms of knowledge and the ethics of scientific practice. Since technological systems incorporate both physical apparatus, rules, and human organization and skills, accounts of technology must characterize the cultural, political and moral norms involved in technological developments and the controversies concerning them.

The shared features of the various approaches to philosophy utilized in the philosophy of technology may partially answer the question of why the field of philosophy of technology is so recent, developing centuries after the scientific and industrial revolutions. Early modern philosophy, such as that of the rationalists and empiricists, sharply separated the dualities of mind and body, theory and action, individual and social, descriptive and normative, that needed to be integrated or overcome for an adequate philosophy of technology. It is only in the last two-thirds of the twentieth century that philosophies such as ordinary language philosophy, hermeneutic phenomenology, and social constructionism developed. These philosophies initially did not show much interest in technology as such, and it took further decades for their application to technology as subject matter.

## 23

# Semiotics of Technology

## ROBERT E. INNIS

The fundamental premise of a semiotic approach to technology is that technology can be analyzed with the conceptual tools of semiotics, the general theory of signs. Semiotics has as its goal to explore the "logic" of signs and the "factors" of semiosis, the production and interpretations of signs. Signs are the carriers or supports of semiosis, which is itself a complex phenomenon. Signs, in the most general sense, are meaning-carriers, while semiosis, which relies upon signs, is meaning-making, on both the productive and receptive side. Signs are produced, intentionally or unintentionally, and they are interpreted, both operatively and thematically. The possibility of a semiotics of technology is dependent upon the successful application of the semiotically informed category of *meaning* to technology as such on both the structural and the process sides. A primary concern is whether semiotics is being used to model and hence to interpret technology or whether technology is itself an intrinsically semiotic phenomenon. This is a kind of ambivalence that, rather than being theoretically debilitating, can be extremely enlightening when we try to grasp technology in its root structures.

Both semiosis and "technics" are dependent upon a fundamental materiality. They are through and through material processes. While signs are embodiments of meaning, tools, in the broadest sense of that term, are embodiments of technico-practical intentions and goals. Although the ability to embody meanings and the effective conditions of human practical actions in various material arrays – that is, signs, tools and models – supplies essential *enabling* conditions for the circuit of human activity, widening, expanding and transforming it, on both the level of semiosis and the level of technics, material conditions also *constrain* the range and types of activities. Language, the species-specific mark of humans, is not an immaterial phenomenon, any more than the derivative activities such as art and music are. Whether it is puffs of air, complex gestural and finger movements, or marks on some sort of semi-permanent surface, language and other human symbol systems have to appear in some material form. Likewise, a hammer or a knife, certainly paradigmatic tools, or the great auxiliary apparatuses of technology such as containers and machines, cannot be constructed out of papier-mâché nor can we create an outdoor statue out of gelatin. Semiosis and technics, in all their forms, must be *supported* in some stable and semi-permanent way, subject clearly to the conditions of entropy.

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Semiotics has for the most part developed along a number of predominantly parallel and only occasionally intersecting paths, and has used quite different conceptual frameworks. Jakob von Uexküll developed within the context of a biologically based theory of meaning a schema of the functional circle of human activity. Charles S. Peirce, the American polymath, developed a largely philosophical framework for semiotics with his differentiation of signs into the three great classes of icons, indexes and symbols, based on just how our signs are related to the objects they make known. Ferdinand de Saussure, in his *Course in General Linguistics*, developed a fundamentally linguistic model, with the presupposition that its analytical apparatus, focused on language as a dynamic system of differences, would apply to other semiotic – or, in his terms, "semiological" – phenomena. Ernst Cassirer, whose *Philosophy of Symbolic Forms* is one of the central texts of the tradition of philosophical semiotics, developed a model based on his triadic schematization of the forms of sense into three levels: the expressive, the representational, and the pure signifying, all the while, in his later work, also seeing the relevance of Uexküll's work.

These different frameworks bear upon the problem of a semiotics of technology in rather different ways. They lay quite different grids over technology as a total phenomenon and highlight quite different features of technological structures and processes. But each framework has its own advantages for the semiotic analysis of technology.

Uexküll's functional circle displays the "circuit of meaning" of any organism *qua tale*. It is extremely important, as heuristic schema, for the proper understanding of the possibility of a semiotics of technology. The organism, on Uexküll's account, is defined by a deep receptivity to perceptual stimuli and by varying degrees and types of reactions that change the originating stimuli in a constant dynamic spiral. The path from the meaning-bearing object to the organism Uexküll calls the "receptor arc." The path from the organism to the meaning-bearing and meaning-receiving object Uexküll calls the "effector arc." Generalizing from this schema, we can distinguish between "perceptual technologies" and "effector technologies" all the while acknowledging the intimate relations between the two. In fact, the "perceptual" and the "effector" are rather "dimensions" than separate spheres, since the organism is never merely passive or purely active, never merely interpreting or materially constructing. Uexküll's revolutionary insight is that we should think of these arcs in semiotic terms, that is, in terms of meaning and of differential cue-carriers. The receptor arc is marked by the grasp of "differences" in the perceptual field. While other organisms are for the most part confined to predetermined fields of cues, humans are open to a vast array of "articulate" cues, having not an *Umwelt* but a *Welt*, that is, not an "environment" but a "world." This human world is an "open world," permeated by articulate, exosomatic systems that inform and embody perception, in the broad sense of that term. This world is constituted by the material and semiotic *results* of human constructive action, which introduce vast systems of differences into the natural and the social world. These "effected differences" are themselves perceived by the organism in a continuous and ever-expanding spiral.

A semiotic analysis of technology is hence faced with understanding, in semiotic terms, what types of cue-carriers are circulating and are produced in this semio-technical spiral and what their relations to one another are. Peirce, Saussure and Cassirer offer three differently configured sets of analytical tools for developing a fine-grained semiotic analysis of technology.

Peirce distinguished three different ways anything functioning as a sign could make an object known to an interpreter or sign-user. The sign–object relation can be based on resemblances, the resulting sign type being an *icon*. If the relation is based on some sort of physical or existential connection, including a part–whole relation, the resulting sign-type is an *index*. The *symbol*, the third type of sign, exemplified paradigmatically by human language, is based on purely conventional relation between sign and object. Peirce's triadic schema allows us to distinguish iconic, indexical and symbolic dimensions of technology. The paradoxical upshot of such a distinction is that, in effect, semiosis is assimilated to technology, to productive activity rather than technology being assimilated, as such, to semiosis.

*Iconic* technologies, on the Peircean interpretation, are all those systems that rely upon resemblances, including, but not restricted to, all technologies of the image. Images are not just interpreted; they are also produced. The semiotics of technology must, therefore, concern itself with both the creative techniques for the production of images and the contents or forms of presentation of these systems. Images convey messages and have a distinctive rhetoric. *Indexical* technologies rely upon interventions, upon systems of action and reaction. We not only read the signs of nature and try to transform them into systems of effective action; these systems also make a material difference in the world. Science is distinguished from technology here by its essentially representational interest, which is not, however, absolutely separate from intervening. But, while the point of science is cognitive, the point of technology is effective control and exploitation. *Symbolic* technologies are exemplified first and foremost by language and mathematical systems, which, in fact, make the other two systems distinctively human and intentional. Languages and all notational systems, including algebraic and other mathematical forms, have to be developed just like tools, machines and other apparatuses have to be developed.

The pivotal point, however, is that on Peirce's account each type of sign gives rise in the interpreter to a distinct type of "interpretant," which he calls the "proper significate effect of a sign." No technology, in its entrance into the functional circle of human action, leaves the interpreter or agent untouched. The aim of iconic technologies is to establish deep affective bonds in, to "qualify" the affective field of, interpretive agents, to establish "shared qualities" of feeling by inducing and shaping distinct forms of participatory presencing and attunement. Indexical technologies aim at establishing systems of action and reaction, of reciprocal relations, between humans and nature, which Peirce calls "energetic interpretants," since they exploit human and non-human energies for an effective action and end. The proper significate effect of symbolic technologies is the establishing of a concept, thought or idea. Furthermore, if we follow the semiotic line drawn by Peirce, we can clearly see that technology has a *syntactic* dimension, which involves the relations of tools, instruments and processes to one another, a *semantic* dimension, which traces their different ways of relating us to the world, and a *rhetorical* dimension, which defines their relationship to us, the practitioners of technics as materially embodied semiosis.

Saussure's linguistic model also has a clear and powerful bearing on the semiotics of technology. For Saussure, language was first and foremost a system, a structure, defined by internal relations of its units. Each unit in the system had a "place" defined not by its material structure but by its relations to all the other units. These units, like pieces on a board, allowed only certain "moves" to be made – certain types of game-actions, so to speak. This "language-game" analogy is a powerful model for the analysis of technology. But even more powerful is the doctrine of the two axes of language: the axis of selection and the axis of combination, or, with different emphases, the paradigmatic and the syntagmatic. Technological systems have selected and combined elements from the natural and humanly constructed worlds. As to selection, at each point in time there are only a limited set of possible units that can be chosen and used to play the game of technology, to make a move on the great board of nature. Their combination, as a state of affairs, gives us the technological system. But the dynamic nature of technological inventions constantly gives us new units to combine, and the rules of combination are constantly changing, as is the system itself. Technology is a kind of game we play with nature in which not only the pieces but also the rules themselves are in perpetual transformation. But, on the Saussurean position, technological systems are *meaningful*. Killing instruments, for example, are multiple. A bow and arrow can be substituted for by a crossbow, which itself can be substituted for by a pistol or a rifle, which can be substituted for by a cannon or a machine gun, and these by a dynamite-powered bomb, itself then being substituted for by a nuclear or biological device. Each addition of a unit to select from changes the relation of all the other pieces in the system. Technology is a dynamic relational system, self-mediating internally and mediating us to and with the world. We are to see technology as a system of possible substitutions and combinations – as a continuous stream of technological "utterances," so to speak. The system makes possible the stream of technological "events" that make up the history of technology. Saussure offers us a "structuralist" model of technology. We can only understand any technological phenomenon by seeing it in the system(s) to which it belongs and its differences from other phenomena.

However, while Saussure thinks of language as a system without positive terms – that is, language is a purely formal system – it is clear that technology is not purely formal. The phonetics/phonology distinction, which underlies much of the modern model of language, could, however, be used to mitigate such an objection to some degree. Technology selects from out of all the possible transformations of matter only those which are significant for accomplishing a specific end. It looks for relevant differences in the material world. More generally, in our attempts to understand technology from the point of view of semiotics, we should ask not only about the actual nature and transformations of materials, but what is significant or formally defining in any new technological invention. New technological units or placeholders in the system are not to be defined only materially but in terms of a new "logic." Radio and television are not just variations of information technologies at a distance, as Marshall McLuhan showed. They are logically different units. Television changed the system in semiotically novel ways, just as the technology of writing (and of the book) has been differentially changed by the invention of printing and the invention of the computer (and with it the arrival of "the electronic word").

Cassirer insightfully applied his semiotic schematization of the "form worlds" of meaning, which he undertook in his *Philosophy of Symbolic Forms*, to the phenomenon of "technics." The expressive, mythical level of consciousness is paralleled in the domain of technics by a mimetic, participatory phase, rooted in mythic consciousness's subjection of itself to a fundamental wish-world of magic and ritualistic acts. One is, in this phase, "in thrall" to one's tools. The representational level of consciousness is paralleled by an analogical, extending phase wherein every tool is to be seen as an externalization of the hand or other bodily organ and processes. What is known as "organ-projection" becomes the key both to the development and the interpretation of technics. The logic of the body, on this level, defines the concrete logic of technics. The pure signifying level of consciousness for Cassirer involves a fundamental "transparency" of signs. It is paralleled in technics by the rise and functioning of a purely abstract or "symbolic" phase that transcends or supersedes, either in scale, speed or inner form, the organic limits of human being-in-the-world. The progressive "dematerialization" of the sign charted in Cassirer's semiotic phenomenology, its abandonment of intuitive supports, is matched by a progressive dematerialization of the body and its extensions in technics. The hinge of Cassirer's position is the thesis that the conceptual–linguistic–semiotic "grasping" of the world is paralleled by an isomorphic material grasping through the medium of effective action. Form-giving runs on these two parallel and at times intertwining paths, and occurs on an arc running from the utterly concrete to the utterly abstract.

A semiotic approach to technology, consequently, supplies powerful analytical tools and offers fresh insights into technology as a distinctively human phenomenon. It does not merely offer sets of formal models, but asks us to explore how our embodiment in technology involves not just a semiotic biasing of perception on the "modal" or "access structure" level but also the mediation of novel contents, which have been made possible by the new media, in every sense of that term. Hence, the semiotics of technology can take its place alongside the historical, the ethical, the political, and other frameworks of analysis and valuation.

## References and Further Reading

Classic texts of semiotics and a discussion of their bearing on the semiotics of technology are found in the following two books, with copious references to collateral materials.

Innis, R. (1985). *Semiotics: An Introductory Anthology* (Bloomington, Ind.: Indiana University Press).

Innis, R. (2002). *Pragmatism and the Forms of Sense: Language, Perception, Technics* (University Park, Pa.: Penn State University Press).

# 24

# Critical Theory of Technology

## ANDREW FEENBERG

The concept of critical theory of technology was introduced in my book of the same name in 1991. I attempted to achieve two somewhat different goals with this concept. On the one hand, it signified a general type of philosophy of technology that had not yet been clearly distinguished from the dominant views in the field. These views are commonly understood to be instrumentalism, the notion that technology is the neutral servant of our desires, and substantivism, the opposed notion that technology is autonomous and inherently biased toward domination. On the other hand, "critical theory of technology" indicated the connection between my own version of this type of philosophy and the heritage of the Frankfurt School. Perhaps it would have been better if I had distinguished these two usages by employing the plural "critical theories of technology" in the first case, and reserving the singular for my own approach.

## Critical Theories of Technology

Critical theories of technology argue that technologies are not separate from society but are adapted to specific social and political systems. Technologies are thus not neutral tools, because they are implicated in the socio-political order they serve and contribute to shaping, nor can they be characterized by a singular "essence of technology" because they evolve historically along with other aspects of society. Just as institutions, laws and customs can be changed by human action, so can technological systems. The substantivist idea of the "autonomy" of technology describes at most certain large-scale technical systems. These systems possess what Thomas Hughes calls "momentum." However, autonomy in this sense is a contingent feature of technology, not the essential property it appears to be in the theories of Jacques Ellul and Martin Heidegger.

Critical theories of technology are not new. Marx and Dewey each offer representative versions. Nevertheless, some form of instrumentalism continues to prevail in common sense. Hence the scandal provoked in 1964 by Marcuse's claim that "Technological rationality has become political rationality." By 1980, when Langdon Winner published his classic article asserting that "artifacts have politics," the critical view was still controversial but it had gained wider currency. Today it seems self-evident to most students of technology in the humanities and social sciences. The reason to formulate a general

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Table 24.1

| *Technology is* | *Autonomous* | *Humanly controlled* |
|---|---|---|
| Neutral (complete separation of means and ends) | Determinism (e.g. modernization theory) | Instrumentalism (liberal faith in progress) |
| Value-laden (means form a way of life that includes ends) | Substantivism (means and ends linked in systems) | Critical Theory (choice of alternative means-ends systems) |

concept of critical theory of technology is thus primarily to enable students of technology to identify their commonalities in opposition to the prevailing popular view and, hopefully, to contribute to altering that view.

Making the unity of approach of these various theories explicit has a political context and implication. From the late 1960s on, controversy and reform projects gradually undermined the technocratic faith in expertise that characterized attitudes in the postwar period. With the rise of the environmental movement, the struggle of AIDS patients for access to experimental drugs, and the re-invention of the Internet by its users as a communication medium, the political dimensions of technology became clear. In this context the notion of a critical approach to technology began to make headway.

In Table 24.1, I have represented the relation between critical theories of technology and the alternatives in a chart with two axes – a vertical axis corresponding to the relation of technology to values, and a horizontal axis corresponding to the relation of technology to human action.

My own critical theory of technology is a particular application of this general perspective. It derives from Marcuse's version of Frankfurt School Critical Theory. Marcuse argued that the existing modern technology forms a quasi-dystopian system that might be changed through political action. Marcuse's writings are very abstract, but I have concretized his position through a constructivist approach to the analysis of specific technologies, such as computer-mediated communication and experimentation on human subjects. Critical theory of technology thus represents a unique synthesis of ideas drawn from the Frankfurt School and contemporary science and technology studies.

## Technology and Democracy

Critical theory of technology is a political theory of modernity with a normative dimension. It belongs to a tradition extending from Marx to Foucault and Habermas according to which advances in the formal claims of human rights take center stage while in the background centralization of ever more powerful public institutions and private organizations imposes an authoritarian social order.

Marx attributed this trajectory to the capitalist rationalization of production. Today it marks many institutions besides the factory and every modern political system, including so-called socialist systems. This trajectory arose from the problems of command over a disempowered and deskilled labor force; but everywhere masses are organized – whether it be Foucault's prisons or Habermas's public sphere – the same pattern prevails. Technological design and development is shaped by this pattern as the material base of a distinctive social order. Marcuse would later point to a "project" as the basis of what he called rather confusingly "technological rationality." Releasing technology from this project is a democratic political task.

In accordance with this general line of thought, critical theory of technology regards technologies as an environment rather than as a collection of tools. We live today with and even within technologies that determine our way of life. Along with the constant pressures to build centers of power, many other social values and meanings are inscribed in technological design. A hermeneutics of technology must make explicit the meanings implicit in the devices we use and the rituals they script. Social histories of technologies such as the bicycle, artificial lighting or firearms have made important contributions to this type of analysis. Critical theory of technology attempts to build a methodological approach on the lessons of these histories.

As an environment, technologies shape their inhabitants. In this respect, they are comparable to laws and customs. Each of these institutions can be said to represent those who live under their sway through privileging certain dimensions of their human nature. Laws of property represent the interest in ownership and control. Customs such as parental authority represent the interest of childhood in safety and growth. Similarly, the automobile represents its users in so far as they are interested in mobility. Interests such as these constitute the version of human nature sanctioned by society.

This notion of representation does not imply an eternal human nature. The concept of nature as non-identity in the Frankfurt School suggests an alternative. On these terms, nature is what lies at the limit of history, at the point at which society loses the capacity to imprint its meanings on things and control them effectively. The reference here is, of course, not to the nature of natural science, but to the lived nature in which we find ourselves and which we are. This nature reveals itself as that which cannot be totally encompassed by the machinery of society. For the Frankfurt School, human nature, in all its transcending force, emerges out of a historical context as that context is limned in illicit joys, struggles and pathologies. We can perhaps admit a less romantic and more Hegelian conception in which those dimensions of human nature recognized by society are also granted theoretical legitimacy. This view converges with the emphasis on the development of human capacities in the work of Amartya Sen.

Technological representation becomes salient when individuals find that important aspects of their humanity are not well served by the technological environment. Then controversies and protests arise, as in the case of laws or customs considered unjust or outmoded by those they govern. Controversies aim to alter technical designs to ensure better representation of more aspects of the humanity of users and in some cases victims of technology. Struggles over technology thus resemble political struggles in important respects. And in fact, in the contemporary world, struggles over technology are often the most important political struggles.

Yet, because the foundations of our political philosophies and arrangements were elaborated in the seventeenth and eighteenth centuries, there is still a tendency to distinguish sharply between politics and technology, the one supposedly based on rights and values, the other on scientific knowledge. In reality, the political consensus is largely shaped by the available technological form of life rather than rational argumentation, and all the scientific knowledge in the world will not get an engineer from the general idea of a function to a concrete device. The many technically underdetermined aspects of design must be decided by reference to social principles and demands. This situation must be more widely understood to bring technology into the public sphere where it increasingly belongs.

The blindness of political theory to technology blunts its critical force. Modern societies offer ever more technical powers to those with money and governmental authority. As a consequence, democracy is reduced to a reflection of the media and political manipulation. All too often this situation is regarded as an inevitable consequence of modernity. But, for Critical Theory, the truth of the present can only be understood from the standpoint of its potentialities, the alternative it both makes possible and suppresses. From that standpoint, it is clear that modern societies will only be able to realize their democratic values when public control of technology becomes routine. As with all earlier democratic movements, democracy engenders democracy: technical publics, like every earlier disempowered group, can learn from the exercise of power how to understand their interests and constrain public institutions to serve them. This requires adapting the technological environment itself to the requirements of freedom.

Critical theory of technology thus projects a future in which the politics of technology is recognized as a normal aspect of public life. The means the public can employ to express its will are already foreshadowed in many current practices such as citizen juries, technical controversies, protests, boycotts and legal challenges, hacking and other creative appropriations of technologies, and of course such familiar methods as elections and government regulation.

In such a technical democracy, technical work would take on a different character. Design would be consciously oriented toward politically legitimated human values rather than subject to the whims of profit-making organizations and military bureaucracies. These values would be installed in the technical disciplines themselves, much as the value of healing presides over the medical synthesis of biological knowledge of the human body.

Technological rationality would no longer be defined as purely instrumental but would become conscious of its value-laden character and as such open a space within its compass for moral and political rationality. This would be the recovery of what Max Horkheimer called "objective reason," a reason that combines means and ends, in contrast with the "subjective reason" of modern times that has no intrinsic goals.

## *Instrumentalization theory*

This perspective on a possible future distinguishes critical theory of technology from much contemporary philosophy and sociology of technology. While many philosophers continue to make grand normative claims based on classic texts such as Heidegger's famous "Question Concerning Technology," sociologists have the opposite vice and can frequently be found stirring the empirical fragments with no overall conception of modernity and its problems. Critical theory of technology has attempted to bridge this gap by integrating insights and methods from both traditions in what I call "instrumentalization theory."

The anti-essentialist assumptions of contemporary empirical technology studies contrast with the abstract essentialism of traditional philosophy of technology. However, technology is obviously distinguishable from other types of objects, and technical action has an undeniable specificity that determines its appropriate range of application. This dilemma is resolved by a socio-historic notion of the essence of technology, enabling the researcher to do empirical work in the light of larger normative issues and vice versa. The instrumentalization theory accordingly distinguishes the cognitive and imaginative conditions of technical activity, on one side, and the social mediations that intervene in the design of devices and systems, on the other.

Every concrete technical achievement presupposes the ability to perceive the world in terms of functions and affordances. That perception constitutes what I refer to as a "primary instrumentalization." Objects of technical activity are defined and isolated from their natural context through the primary instrumentalization which decontextualizes them and reduces them to their usable aspects. We describe this as the faculty of "cleverness," which humans share with a few other animal species. When a child piles boxes on top of each other to create a tower, she is already learning to engage with the world technically, isolating the boxes from their normal place for a usage which ignores their many aspects for a single one, their capacity to stack. This relation to reality, which Heidegger called "readiness-to-hand," is a generic feature of human being, corporeally present in the opposable thumb.

Objects introduced into technical networks are more or less transformed. They generally bear the mark of the primary instrumentalization to which they have been submitted. It is this which constitutes the intrinsic limit of the technical as a form of thought and action. Hence we reject the idea that there are appropriate techniques for everything, from forming friendships to enjoying Thanksgiving dinner. Clearly, the decontextualizations and reductions characteristic of the primary instrumentalization have at most a subordinate place in the background of close human relations and festive occasions.

Technical objects can only achieve realization in a device or system by taking on more and more social determinants at each stage in the production process, from the working up of raw materials to the final output of finished products. The technically underdetermined aspects of the objects are decided along the way so as to adapt them to a given social world. This process of social determination is called the "secondary instrumentalization."

The social appears in the technical domain in two principal forms I call "systematizations" and "mediations." Systematizations are the causal interconnections between the various parts of a device and between the device and its technical, human and natural environments. Since there is no unique causal logic determining the optimum functioning and relationships of technologies, empirical study finds society even in this apparently pure technical aspect. Mediations operate at the level of meaning and govern aspects of technologies that fall under ethical and aesthetic criteria. These aspects are not limited to prohibitions and external appearances but penetrate to the technical heart of the object.

Automobiles exemplify both aspects; they are designed systematically to work with specific types of roads and fuels, and stylistically to appeal to various aesthetic tastes, these latter influencing in turn technical features such as dimensions and engine position. The interaction of these two dimensions is an iterative process in which the meaning technologies take on in the lifeworld feeds back into their design from one stage in their development to the next.

The primary instrumentalization has been studied primarily by philosophers in the existentialist tradition. Their reflections on what Peter-Paul Verbeek has called the "transcendental" preconditions of technology form the basis of a critique of modernity. This excessively negative approach overlooks the way in which the secondary instrumentalization adapts and complements the initial decontextualization and reduction to which objects are submitted as they enter the technical field. The secondary instrumentalization is studied by social scientists and historians, who focus precisely on what philosophers overlook: the concrete social forces and meanings at work in the design process. But, without a theory of the intrinsic structure of the technical, they lack a normative perspective on the consequences and limits of technology. Critical theory of technology attempts to combine insights from both sides of this deadlocked argument.

## Code and Bias

Each type of technology is characterized by a particular configuration of primary and secondary instrumentalizations. These configurations often prevail for a very long time. I call social principles that are successfully and durably inscribed in technological designs "technical codes." This terminology does not suggest, as might Marcuse's notion of "technological rationality," that reason in itself is the object of critique. Technical codes operate at several levels of generality. The most general codes lay down such principles as the secular tendency to deskill labor through technical advance. Specific codes determine the meaning of particular devices.

In every case, a technical code describes the congruence of a social demand and a technical specification. A process of translation links the two in the course of the evolution of technical objects. To continue with the automotive example, a demand for greater attention to safety is translated into seatbelts and airbags; operationally speaking, this is what safety *means*. Thus technology and values are not alien realms, as are facts to values in the treatises of philosophers. Rather, they communicate constantly through the realization of values in design and the impact of design on values. This fluidity of the technical, highlighted in Bruno Latour's concept of delegation, explains why the vaunted trade-off of efficiency and ideology, dear to conservative economists, is largely mythical.

The two instrumentalizations characterize technical production in all societies but are only clearly distinguishable in modern times. This has led to the illusion that they are entirely separate entities enjoying external relations. In fact the distinction is primarily analytic even today, although large organizations often separate certain primarily social functions, such as packaging, from engineering operations. The existence of technical disciplines appears to confirm the common-sense notion that technology and society are separate entities, but these disciplines are actually full of traces of social choices that have been crystallized in standards and materials imposed originally by social actors in the past. A technological unconscious masks this history.

Nevertheless, radical versions of constructivism are wrong to insist that there is literally no distinction between the social and the technical. If that were true, technical disciplines would not exist, and the makers and users of products would not have to communicate through translations. It would be more accurate to say that modern technology is a particular expression of the social in artifacts and systems, functionalized by rigorous decontextualization, reduction and systematization. Ordinary social belief and behavior is quite different, mixing the technical and non-technical promiscuously. Meanings guide improvisational action in everyday life, forming patterns that intersect with difficulty with engineered products, as Lucy Suchman argues persuasively.

Technical codes are always biased to some extent by the values imposed by the dominant actors. The critical theory of technology aims to uncover these biases. Technical bias is, however, difficult to identify since the unjust social consequences of technical decisions appear to be mere side-effects of "progress." Critical theory of technology rejects the alternative – technical rationality or social bias – and argues that the latter shows up in the former through the social content of technical choices.

This point turns out to be central to the ability of technology studies to contribute to public debate over technical issues. The focus on technology makes it possible to contest the hegemony of neo-liberal economics in the public sphere. The notion that political and property rights create a neutral system in which everyone can pursue their private conception of the good is difficult to criticize effectively. To show that such a system is inherently biased requires an unfamiliar type of argument that has been most often deployed by technology critics. Examples of such arguments are Marcuse's notion that the neutrality of technology places it in the service of the dominant powers, and Albert Borgmann's critique of the mutual implication of liberalism and the "device paradigm" in a bias toward private consumption as a way of life. Critical theory of technology generalizes such arguments through a distinction between "substantive" and "formal" bias.

The usual common-sense notion of bias attributes unjust discrimination to prejudice and emotion. This "substantive bias" is based on factually questionable beliefs which have no place in the technological realm. The intrusion of prejudice and emotion where cool rationality ought to prevail leads to avoidable inefficiencies and breakdowns. But, even where bias in this ordinary sense is avoided, efficient operations are often unfair. Thus critical theory of technology introduces the concept of "formal bias" to understand how a rationally coherent and well-designed and -operated technical device or system can nevertheless discriminate in a given social context. This concept of formal bias parallels notions such as institutional racism and serves much the same purpose, namely to enable a critique of rationalized activities that appear fair when abstracted from their context but have unjust consequences in that context. Identifying and changing formally biased technical codes is essential to democratic advance in modern societies.

## Modernity, Premodernity, Alternative Modernity

According to prestigious academics, we are supposed to be postmodern or amodern. Critical theory of technology argues instead that we must choose between alternative forms of modernity. The concept of modernity retains its validity in this context and cannot be reduced to the various straw men so energetically refuted by the critics. There is a good reason not to dismiss this concept. It enables us to distinguish between societies based on modern technology and all others. Of course, where that distinction is overdrawn in self-congratulatory terms it deserves critique. But the distinction is inevitable in some form nevertheless.

Premodern and modern societies attach different relative weights to systematization and mediation. In premodern societies, technical networks are relatively short and their nodes loosely coupled. However, very elaborate mediations control every aspect of technical life; here technique merges with what we moderns identify as art and religion. Thus tribal weapons and huts may share a common symbolism, but they are not systematically related by technical specifications of great precision as are modern technologies. As a result, premodern societies have a limited spatial reach but they conquer time in the sense that they can be reproduced successfully over thousands of years.

Modern societies, on the contrary, emphasize systematization and build long networks through tightly coupling links between very different types of things and people over huge distances. This can only be accomplished by stripping technical objects as much as possible of ethical and aesthetic mediations. The resulting overemphasis on the primary instrumentalization and systematization makes possible both large-scale hierarchical organization and technical disciplines. But, despite the power over human beings and nature they achieve, modern societies have so little control of time it is uncertain if the form of life they have invented will even survive through the new century.

An alternative modernity worthy of the name would recover the mediating power of ethics and aesthetics at the level of technical disciplines and design. It would devolve power to the members of technical networks rather than concentrating it at the top of administrative hierarchies. These formal changes would result in new technical designs and new ways of achieving the efficiencies that characterize modern technological activity generally. Whether such a society would be competitive on neo-liberal terms is not the issue. Its members will value it for offering a better quality of life, a more democratic political order and a sustainable civilization.

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# 25

# Cyborgs

## EVAN SELINGER

Cyborg discourse is inter-disciplinary. As the opening to *The Cyborg Handbook* quite appropriately notes:

> Cyborgology has become a central concept for academics, not only people in science and technology studies, but also political theorists, military historians, literary critics, human factors engineers, computer scientists, medical sociologists, psychologists, and cultural observers of all types.

To this list we can add literature and film; in these contexts cyborg imagery cuts across "high" and "low" cultural presentations.

Many of the current discussions touch upon themes that can be traced back to ideas that were germinating over half a century ago. In particular, conversations attributable to Norbert Wiener, Manfred Clynes and Nathan Kline feature prominently. During the 1940s and 1950s, Wiener founded the discipline of *cybernetics* – a term which can be traced back to the Greek *kybernetes* (*Κυβερνήτης*), which means steersman. The central cybernetic theme is that human, animal and machine behavior can be explained by the *same principles* of communication, control, learning and feedback. As Peter Galison notes, Wiener's Second World War work on the AA Predictor – an airplane designed according to cybernetic principles that was supposed to anticipate an enemy pilot's movement in order to shoot him down – proved decisive for Wiener's attempt to create a "new symbol for man" that would replace the outdated mechanical figures made by eighteenth-century clockmakers, and the revered icon of nineteenth-century engineers, the steam engine. In the 1960s, Clynes and Kline used the term "cyborg" to discuss the possibility of astronauts enduring long periods of space travel. In light of the special physical conditions that would prevail, they considered what kind of enhanced human–machine hybrid would be appropriate for the task.

Contemporary cyborg discussions tend to be polarized between advocates and critics. In order to be effective, both positions have had to take into account – even if only implicitly – Donna Haraway's pioneering work that began in *Socialist Review* with "Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s." Although situated as an ironic political intervention that had significant implications for feminism and military history, Haraway makes three startling observations about

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"transgressed boundaries" and "potent fusions" that theorists of all stripes are still reckoning with. First, the boundary between humanity and animality has been "breached." Countless examples from evolutionary biology and its related fields reveal that creative, intelligent, tool-using and social behaviors that were once thought to be found only in human practices can be found through the animal kingdom. Second, the boundary between humans and machines has become "leaky." Countless examples ranging from the use of prosthetics to advances in artificial intelligence and artificial life attest that it is becoming increasingly difficult to demarcate human possibilities, desires and identities from technological dependencies and machine-generated outputs. Third, the boundary between the physical and the non-physical has been rendered "imprecise." Many of the very images of traditional divinity, such as omnipresence and light, have become apt descriptions of portable and miniaturized microelectronic devices.

On the advocacy side, some scientists and engineers have emerged as spokespeople for a *posthuman* future in which the boundary-transgressions associated with cyborgs become the norm. They insist that, while romantic and nostalgic sentiment might deify our current form of humanity, such a future – one made possible largely by advances in biotechnology and nanotechnology – will free us from the current limitations of embodiment and labor, therein opening up new horizons of scarcely imaginable creativity, collaboration and invigorating challenge. According to Ian Pearson, futurologist at British Telecom, the following scenario is not science fiction but, rather, a plausible historical outcome:

> "Homo Cyberneticus" will emerge with a "full duplex link between man and machine." This creature will in turn merge with "Homo Optimus," the genetically engineered "elite race of people who are smart, agile, and disease resistant." Together they will form "Homo Hybridus," which will have no trouble displacing "Homo Ludditus."

For many advocates, the displacement of "Homo Ludditus" should be viewed as a positive evolutionary moment – a cause for celebration in which disgust, not longing, is the appropriate sentiment to have when considering previous incarnations of humanity.

Within the diverse constituency of advocates, the philosopher Andy Clark has emerged as a rather unique voice. His *Natural Born Cyborgs* is a "naturalist" account of humans as "cognitive opportunists" whose "cognitive fossil trail" demonstrates that they deserve to be understood as cyborgs precisely because their special neural plasticity has, at least since the invention of writing, allowed them to facilitate exploitative "symbiotic mergers" that traverse organic and non-organic domains and allow agency to be distributed amongst a "shifting coalition of tools." From this perspective, most concerns about a posthuman future are misguided. Whereas the typical worries center on upcoming technologically induced threats to a stable human identity, it is more scientific, Clark contends, to recognize that a proper understanding of our evolutionary past demonstrates that such a conception of identity was the result of misguided theorizing. Thus Clark insists that, in order to bring about the best of all possible futures, it is incumbent upon people in the present to understand better what it means to be human so that a future can be created that best capitalizes upon the drive of "human nature" to "annex, exploit, and incorporate nonbiological stuff deep into our mental profiles."

On the critical side, theorists such as Francis Fukuyama, Leon Kass and Bill McKibben have featured prominently. One of McKibben's most interesting arguments against a posthuman future stems from his sense of how human identity and self-understanding relate to certain forms of embodied action. In contrast to the intellectualist tradition of associating the acquisition of self-understanding with conversation and textual engagement, McKibben notes that basic bodily practices, such as Albert Borgmann's paradigm case of running as a "focal practice," provide unique experiential windows into our finitude. For example, running: (1) can bring about a state of utter presence; (2) can induce a *Gestalt* switch by magnifying the felt qualities of experience; (3) can bring one towards a "core" that psychological defenses typically protect us from; (4) can create a sense of meaning that is inseparable from context; (5) can facilitate a sense of personal meaning that may not be accessible from a third-person perspective; (6) can facilitate united forms of communal participation in which shared embodied experience does not compromise the individual's singularity; (7) can create a link with evolutionary past and cross-cultural present; and (8) can create a sense of meaning that is irreducible to mere sensory experience. While some of these features may remain in a posthuman future, McKibben contends that it is hard to envision others as persisting. After all, much of the meaning involved from practices such as running stem from the notion of "authentic choice" – from the fact that an individual freely designated a particular practice to have personal significance and to be worthy of committed effort, when others could have been selected just as easily. The prospect of designer babies and the use of pharmacology for the purpose of performance "enhancement," however, is said to pose a serious challenge to this sense of authentic engagement. Similarly, the communal connections that practices like running can engender are also said to be threatened. Posthuman runners would lose the primal bond with past generations of human runners. They would also lose that connection with all the present and future beings who, for moral or financial reasons, did not "upgrade" themselves accordingly.

# 26

# Simulation

## EVAN SELINGER

According to Sherry Turkle, "In the culture of simulation the notion of authenticity is for us what sex was to the Victorians – 'threat and obsession, taboo and fascination'." This observation invites an explanation that can clarify why such strong and mixed sentiments concerning simulation abound.

To the delight of some and the chagrin of others, many of the current debates about simulation can be traced back to Jean Baudrillard's *œuvre*. According to Baudrillard, the history of imaging contains four distinct interpretations of what "images" are and symbolize. Initially, Baudrillard contends, images were understood as representations. A proper image, therefore, reflected "basic reality." In this context, the simple properties of basic images were said to correspond directly to real phenomena: primitive cave paintings referred to real events, like hunting animals, and religious artifacts reflected the basic reality of God's existence. But, as time progressed, visual culture changed. Baudrillard contends that the *mimetic* sensibility became eclipsed by three transformative stages that culminated in the present, in an age of simulation. Today, images proliferate that do not contain indexical traces of an original referent. Today, ubiquitous images exist that fail to symbolize the melancholic *memento mori*. To clarify these points, the remaining three stages require elaboration.

In the second stage, the image becomes synonymous with the process of concealing and "perverting" a basic reality. Perhaps what Baudrillard has in mind in this context is landscape painting from the eighteenth and nineteenth centuries. This art form restored a beatific significance to nature, even though that significance had already been lost as a result of the emergence of early industrial culture. While nature had come to be viewed as an instrumental resource to be appropriated for commodity and capital, landscape paintings represented nature in a completely different light. There, nature was portrayed as a divine gift to be cherished for its own intrinsic value. Indeed, during this time period, the institutions of the gallery and the museum were invented as cultural forms. Painterly images of an extinct nature thus became absorbed by the insufficiently critical gaze of middle-class culture.

In the subsequent stage, the image came to be defined as that which masks the "absence" of a basic reality. The context that Baudrillard is referring to is likely the period of mass production in which machines dominate. During this period, essentially indistinguishable copies of a single prototype become prevalent (e.g. mass-produced books,

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automobiles, clothes, photographs, etc.). These copies were not counterfeits. Instead, they were viewed as items to be judged as having just as much reality and significance as their guiding model. As a consequence of this shift in sensibility, the concept of the "original" began to lose what Walter Benjamin calls "aura." (Note: Since it is still possible to distinguish between the prototype and its copies during this phase, Baudrillard might have been clearer had he characterized the period as one in which the value of a basic reality is no longer privileged.)

In the fourth and most contemporary stage, Baudrillard insists that the image "bears no relation to any reality whatever: it is its own pure simulacrum." The basic mode of production in this context is not the machine but, rather, information technology. In the present "information age," we are surrounded by simulations that are not designed as copies of original prototypes. Virtual reality, computer models, genetic engineering, status-symbol commodities and media fabrications are paradigm cases of this phenomenon. Since Baudrillard has written extensively on the latter, a few remarks on the topic are in order.

The shift in American opinion about the Vietnam War in the 1960s was largely due to the televised coverage of "real" battlefield and civilian casualties. But recent works such as Baudrillard's provocatively titled *The Gulf War Did Not Take Place* and Paul Virilio's *Strategy of Deception* suggest that a significant shift in visual culture has occurred since then. For example, during the first Gulf War the media presented relentless images of "smart bombs" destroying only deliberately chosen and carefully delimited targets. This, in turn, created misleading impressions about the frequency of indiscriminate bombing and the amount of civilian causalities. A more recent argument, presented by Michael Moore in his Oscar-winning documentary *Bowling for Columbine* is that the media distortion of topics such as urban violence has produced a "culture of fear" in which American citizens routinely become hysterical over sensationalized reporting that masquerades as unbiased presentation.

In addition to media issues, new questions concerning the nature and scope of identity are arising as people continue to explore (and sometimes become psychologically dependent upon) virtual relationships that are cultivated through digital avatars and online personae. These activities are not limited to replacing or enhancing traditional face-to-face encounters. Rather, their very allure lies in their transformative potential: new forms of solitary and inter-subjective experience are arising. For example, the Internet has made it easy to invent alternate life experiences and to explore previously inhibited or underemphasized desires. Indeed, interacting through different and even inconsistent personalities has become so commonplace that it no longer appears conspicuous. The popular Second Life (http://secondlife.com/), an interactive three-dimensional virtual world that is built and owned by its residents, exemplifies this point well.

In this context of controversy concerning the quality of simulation-based relationships, worries about the impact of videogames are frequently articulated. In addition to articulating sobering thoughts about obesity, anti-social behavior, depression and de-sensitized judgment, concern has also been expressed over the adverse cognitive and emotional effects that may be arising as a consequence of the military stylizing its recruitment campaigns in a videogame format. As is widely noted, such a distinctive use of visual culture is not innocent.

The appeal to videogames and videogame imagery is being staged during a time in which fighter pilots routinely train with simulators and electronic wargames are "realistically" modeled upon recent combat scenarios. Because skepticism already exists concerning the objectivity of embedded wartime reporting, additional complications can be expected to arise as a result of videogame designers including Associated Press news reports as graphics while urging potential gamers to second-guess whether the US really needed to kill Saddam Hussein's sons. Indeed, collective memory may be weakened as new forms of historical revisionism (and, perhaps, propaganda) threaten to engender dire political consequences.

Moreover, as Catherine Wilson emphasizes, it is important to recognize the fundamental difference that distinguishes videogame violence from cinematic and televised violence. In the latter cases, the audience remains passive. They are merely spectators of violent acts that have been choreographed by others in advance of the viewer witnessing their cinematic and televised unfolding. By contrast, in the case of the former, videogame players assume the role of active agents. The choices they make are responsible for setting causal sequences of violence and predation in motion.

Finally, it should be noted that use of simulation is leading researchers to make innovative and potentially radical proclamations about human behavior. For example, under the auspices of Patrick Grim, the Group for Logic and Formal Semantics has been using game-theoretic models to provide a new understanding of why contact – at least in some instances – can reduce prejudice. Owing to ethical and practical constraints, empirical psychologists cannot conduct the ideal controlled experiment. Such an experiment would require an extreme scenario; "outgroups" would have to be relocated to live with the very "ingroups" who view them prejudicially. The use of simulated agents, however, frees researchers from the limitations that circumscribe how human experimentation should be conducted. While such work may be cutting-edge, it is not unique. Comparable analyses into ethnocentrism, genocide, cultural extinction and other socially relevant topics have also been conducted.

# 27

# Technology as "Applied Science"

ROBERT C. SCHARFF

According to Descartes' famous metaphor, the tree of philosophy has three main parts. Metaphysics tends the roots; scientific knowledge of nature ["physics"] constitutes the trunk; and medicine, morals and mechanics form its three main branches. Descartes' interpretations of metaphysics, physics and their requisite epistemology were all contested from the start; but there has always been less criticism of his ultimately practical conclusion, namely that the principal benefit of philosophy comes from gathering the fruit of its three branches (Descartes 1985: 186). Here, Descartes may be seen as giving a full and systematic elaboration of Bacon's slogan, knowledge is power (Schouls 1989: 173); and the obvious moral of this story is that "What is knowledge?" and "What do we use it for?" are the key philosophical questions. *Technology*, on the other hand, is just the totality of means for *applying science* to do/produce whatever we choose.

Of course, many would be uncomfortable actually stating this conclusion in all of the circumstances in which they nevertheless understand it to be true. Who, for example, is eager to characterize prestigious activities like medical care as merely applied science, so that surgery is no different in principle from plumbing? Yet it would be difficult to exaggerate how deeply the technology-as-applied-science model has affected modern Western thought. Even the good life itself tends to be conceived as a kind of technological product, a planned outcome of the right theory. All we need do, it seems, is find the appropriate social scientific, economic, political or even (by analogy, for those still hostile to science) religious knowledge and put it into practice.

In twenty-first-century retrospect, this model of knowledge, practice and their relation no longer seems quite so innocent or commonsensical, and philosophers of technology now object to it in various ways. But why have their objections come so late? Undoubtedly the success of modern science in both acquiring knowledge and altering our circumstances is part of the answer. Yet, even after these successes began to seem a mixed blessing, the very definition of a civilized mentality seemed, above all, a matter of cultivating the scientific tree and harvesting its fruits. The key is to notice that, in this model, technology-as-mere-means typically functions as silent assumption, not as explicit concept. Hence, even after objections to rosy progressivist claims about a scientific culture became plentiful, this assumption could remain unchallenged. To meet the objections, it seemed sufficient to redouble efforts to defend science, analyze

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its epistemic structures, and exercise greater care in deciding how to use it. Here lay philosophy's central topics and civilization's greatest hope (Sorell 1991). One sees all of this played out as the main strands of modern thought develop after Descartes (Mitcham 1990).

In the Anglo-American empiricist, French/German Enlightenment, and European positivist traditions, technology typically continues to be conceived in straightforwardly Cartesian fashion. Science tells us what there is; technology simply employs this knowledge in whatever way we decide. "From science comes foresight, from foresight, action," declared the father of positivism (Comte 1988: 38). The primary philosophical issues therefore lie either before or after technology. Before we can receive the benefits, we must have reliable knowledge – hence the need for an epistemology of science. Once we have it, we must decide among the technologically possible goals that science empowers us to achieve – hence the need for an ethics (in the broad sense, including socio-political inquiry). With philosophy focused on how we can know and what we may do, technology falls uninterestingly between them.

In the modern romantic-expressivist and post-Hegelian Continental traditions, technology tends to be just as philosophically uninteresting, but for different reasons. At first glance, this might seem surprising, since these traditions are notoriously less likely to define knowledge on the model of science, or to regard the use of science as mostly a force for good. Suspicious of the reductive scientism and false historical optimism that seem to lurk in Enlightenment philosophy, these traditions tend to think of science as expressive only of our theoretical/cognitive and instrumental interests. To ensure a place for other values associated with other interests (e.g. beauty and artistic creativity, the reflective "understanding" of self and others, socio-political liberation, a spiritual life), they tend to give critically restrictive or even dystopian accounts of both scientific rationality itself and its applications to the natural and social world. Yet, precisely in thus curbing the scope and function of science, romantic and post-Hegelian thinkers implicitly reaffirm the status of technology as philosophically inessential. For if the main task is to avoid overrating science and to defend other, non-instrumental purposes, then technology – albeit reconceived as potentially serving several masters – remains in the position of simply being the means for enacting chosen purposes.

By the 1970s, however, this pinched conception of technology was under attack from several directions (Dusek 2006). One line of criticism accompanied growing dissatisfaction with the dominant positivistic tendency to define science in terms of a narrowly formalist, ahistorical model of theory confirmation. As philosophical models of scientific reasoning became more contextualized and pluralized (Kuhn 1996, Longino 2002) and integrated into a new perspective that tended to view science as a human practice instead of just a kind of reasoning (Fuller 2002, Stengers 2000, Rouse 1996), the old idea of technology as merely making use of science also became untenable. Philosophers began to acknowledge what historians and sociologists of technology had always known, namely that modern science and technology are mutually interdependent (Latour and Woolgar 1986). Even early modern science relied upon the prior existence of technical devices (e.g. telescopes, microscopes, measuring instruments) invented by persons who had no recognizably "scientific" concerns (White 1962). Indeed, technology has always mattered in ways only remotely connected with the urge to obtain natural knowledge – ways driven directly by a desire for useful tools and efficiently "mechanized" practices, or even by a sheer inventiveness and love of gadgetry (Nye 2006).

Philosophical interest in technology, then, began in opposition to the objectivism of traditional philosophy of science. It was no longer possible to ignore the fact that philosophical, sociological and engineering issues concerning technology and science are all in fact intertwined (Knorr-Cetina 1999, Mitcham 1994). At first, these issues were considered primarily at a global level. Debates over concrete ethical, social and political issues only seemed to perpetuate old, deeply held but now obviously problematic general assumptions about science, its appropriations, and the proper role of science and technology in human affairs.

Most famously, Heidegger (1993) suggested that the instrumental definition of modern technology as applied science is "correct," but if we ask what makes it correct we find it is really premodern technology, not modern science, that we must ultimately reconsider. For 2000 years, Western humanity has been elaborating the ancient Greek notion of *techne* as a kind of making that is akin to the productiveness disclosed to us by the cosmos. As a result, we have now come to fashion a world in which, for the most part, our activities, the things we deal with, and even we ourselves all seem to happen together in a world where everything is "enframed" – that is, disclosed and understood as part of a "stockpile" of materials and personnel available for technological purposes. The implication of this argument for our idea of technology is not hard to see. When modern philosophy privileges science and ethics, and largely ignores technology, it gets things backwards. For it is in the "techniques" of both premodern and modern activities that our basic understanding of what there is and what to do with it already resides. If we now find this sense of things constricting or even dangerous, the solution can only be, in Heidegger's phrase, to work out a "free relation" with today's technology.

Heidegger's work is certainly not the only source for these themes, but much recent thinking about technology can be seen as reacting to the general outlook expressed there. One strain explores, more or less specifically in light of Heidegger's own position, what "being freely with" technology might mean (Spinosa et al. 1999, Borgmann 1985). Other strains begin by objecting to views like Heidegger's for their pessimism and for exaggerating negative experiences with technology, and then move on to offer either more phenomenological accounts of contemporary technoscientific life (Ihde 1990) or political and social programs that promise to overcome the restrictive and dehumanizing aspects of today's technoscientific practices (Feenberg 2005a, 2005b; Llewelyn 2004, Haraway 1997).

Some applaud these critical reactions toward Heidegger and others of his generation (e.g. Mumford, Ellul, Ortega y Gasset) as marking an "empirical turn" in recent philosophy of technology (Verbeek 2005, Achterhuis 2001). Some suggest it also signals a welcome revival of elements of the pragmatist tradition (Hickman 2001). Still others praise the long-overdue recognition of the "materiality" of (as opposed to the thinking in) technoscientific practices (Ihde and Selinger 2003). What is noticeable in all the recent trends, however, is their steady enrichment of topics assumed to be included in any philosophically adequate inquiry into today's "technoscientific" life (Ihde 2004). The provocative implication, of course, is that the analysis and critique of technoscientific practice might provide a better entrée to all the major philosophical issues in contemporary human affairs than ethics or the epistemology of science.

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## 28

# Technological Artifacts

PETER-PAUL VERBEEK AND PIETER E. VERMAAS

## 1. Introduction

Technological artifacts are clear-cut manifestations of technology. Our world is full of material objects made by engineers for practical uses, and through these objects technology affects society and our daily lives. The philosophical characterization of technological artifacts is less clear-cut. Carl Mitcham (1994) singles out technological objects as a separate field of philosophical analysis, beside manifestations of technology as activity, as knowledge and as volition. Yet analyzing technological artifacts will immediately invoke Mitcham's other fields, since artifacts are made and used, which are activities, and since the demarcation of technological artifacts from artisan products and works of art is related to the types of knowledge and the aims involved in these activities. Moreover, the everyday intuition that technological artifacts are objects made by human agents is in philosophy often loosened to definitions of technological artifacts as objects that are intentionally or less intentionally selected to be used, raising issues about their demarcation from natural objects. We start by discussing those definitions and then broaden our scope to further philosophical analyses of technological artifacts and their social and cultural roles.

## 2. Definitions of Technological Artifacts

Technological artifacts are in general characterized narrowly as material objects made by (human) agents as means to achieve practical ends. Moreover, following Aristotle, technological artifacts are as kinds not seen as natural objects: artifacts do not exist by nature but are the products of art. This general characterization is incorporated in Risto Hilpinen's acceptance condition: "[a]n object is an artifact made by an author only if the author accepts it as satisfying some sortal description included in his productive intention" (2004: sect. 3). This condition applies also to events and works of art; it can be restricted to technological artifacts by limiting the sortal descriptions to technological ones such as "material means to achieve practical end *x*."

Unintended by-products of making (e.g. sawdust) or of experiments (e.g. false positives in medical diagnostic tests) are not artifacts for Hilpinen. Objects that result

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from actions of collectives of agents but do not satisfy sortal descriptions in one of the agent's productive intentions (e.g. some paths and villages) are merely artifices. Objects made by agents but not accepted to satisfy the intended sortal descriptions are "scrap."

Hilpinen specifies making as a physical modification of an existing object or as the assembling of existing/modified objects, such that "[t]he existence and some of the properties of an artifact depend [counterfactually] on an author's intention to make an object of certain kind" (2004: sect. 1). Technological artifacts as made objects are different from natural objects in two ways: they can have physical properties that natural objects do not, and they are considered as means to ends. Hilpinen considers the borderline case in which making becomes only selecting (for including "found art" [1993: sect. VI]). If this case holds for technology, a technological artifact becomes more widely a material object accepted by its author as satisfying some technological sortal description. The difference from natural objects is then only that technological artifacts are objects considered by agents to be *usable* as means to practical ends.

Randall Dipert (1993: ch. 2) characterizes technological artifacts also primarily as objects made by agents but broadens his analysis to usable objects by taking artifacts as special cases of tools, which in turn are special cases of instruments. An *instrument* is "an object one of whose properties has been thought by someone to be a means to an end and that has been intentionally employed in this capacity." A *tool* is an object that "has been physically modified, intentionally, to serve as a more effective means to an end" (tools are roughly Hilpinen's artifacts). An artifact is, for Dipert, "an intentionally modified tool whose properties were intended by the agent to be recognized by an agent at a later time as having been intentionally altered for that, or some other, use." This definition also applies to events and art; technological artifacts are artifacts that serve practical purposes (1993: 17).

The characterization as usable objects is more explicit in the "Dual [structural-intentional] Nature" analysis by which technological artifacts are "(i) designed physical structures, which realize (ii) functions, which refer to human intentionality" (Kroes and Meijers 2006). Designing is analyzed as the development of use plans for objects – series of actions that include manipulations of objects – by which agents can achieve ends, and as the description of the physical structure of those objects (Vermaas and Houkes 2006). Designing, in this broad sense, turns the described objects into means (Dipert's instruments) but does not require that the objects be modified: if existing objects – technological artifacts or natural objects – meet these descriptions, modification is unnecessary.

These three analyses relate technological artifacts to intentions of individual authors, selecting agents, or designers. A fourth approach takes distance from single agents and describes technological artifacts by societal mechanisms. Basalla (1988), for instance, has given an evolutionary account of technological artifacts in which their creation and use are determined primarily by (longer-term) cultural reproduction and selection. Artifacts are still typically made, but the ends for which they are made are related to (successful) uses over time, and typically not by the intentions of individual (creating) agents.

Characterizing technological artifacts as made objects agrees with the Aristotelian contrast between technological artifacts and natural objects but may be too strict: pieces of flint that were selected by our predecessors seem equally technological artifacts as the ones that were carefully cut. Yet characterizing technological artifacts as usable objects may be too permissive and lead to including natural objects: the sun is often used for orientation, but it seems odd to take it as a technological artifact.

## 3. Technological Artifacts in Philosophy

### *3.1 Technological artifacts and categorization: function theories*

Technological artifacts are often taken as objects with functions, as (made) means to ends (this approach has been criticized, as we discuss below). The philosophical tradition of function theory analyzes this concept of function, in part to distinguish types of technological artifacts. Functions are not the only features by which technological artifacts are categorized (see Mitcham 1994: ch. 7) but they are of particular interest because of the relation they establish between technological artifacts and human intentionality, and as part of an ongoing discussion in metaphysics about taking functions as nominal or real essences of technological artifacts (e.g. Baker 2004, Elder 2004, Thomasson 2003, Wiggins 2001: ch. 3). The analysis of functions originated to a large extent in philosophy of biology, in which analyses of biological functions were generalized to include also artifact functions. One can distinguish three approaches. In the first, fitting analyses of technological artifacts in terms of intentions of individual agents, functions are the capacities or purposes for which agents make or select artifacts (e.g. Neander 1991). In the second approach, fitting the evolutionary account of technological artifacts, functions are those capacities for which artifacts are reproduced over time (e.g. Millikan 1984, 1993). And finally Robert Cummins's (1975) approach, compatible with both the intentional and the evolutionary accounts, in which functions are causal roles of technological artifacts that contribute to their (successful) uses. In recent analyses of functions in technology these three approaches are criticized and combined to theories that take more notice of the particulars of technological functional descriptions. Beth Preston (1998) has argued for a pluralist theory in which functions of technological artifacts are described as reproduced capacities and/or as causal roles. Vermaas and Houkes (2006) have argued for a (monist) function theory that integrates elements of the three approaches.

### *3.2 Technological artifacts and society: Science and Technology Studies*

In Science and Technology Studies, two distinct types of analysis of technological artifacts have developed. The "social construction of technology" (SCOT) approach analyzes technological artifacts as the outcomes of processes of social interaction between designers and relevant social groups (Bijker 1995). Actor-network theory (ANT), however, proposes a symmetrical approach, in which both humans and artifacts play constructing roles (Latour 1993), and in which technological artifacts are *constructed* and *constructing* at the same time. Understanding artifacts as constructions, rather than as *social* constructions, requires taking into account the constructing role of both humans and a variety of "non-humans," like the material environment in which the artifact will function and the characteristics of the materials out of which it is made. The constructing role of technological artifacts in society is often indicated with the concept of "script" (Akrich 1992), making visible that technological artifacts, similar to the script of a theater play or a movie, can prescribe specific actions to their users, like speed bumps that help to determine human driving behavior. Latour has even analyzed such forms of agency of technological artifacts in terms of morality (Latour 1992, 2002). On a more political level, Langdon Winner has analyzed the social role of technological artifacts in terms of "politics," with the help of his well-known example of the bridges on Long Island in New York over the road to Jones Beach, deliberately built very low by architect Robert Moses to prevent buses passing through, thus blocking access for poor and black people who normally use public transit (Winner 1986).

### *3.3 Human–artifacts relations: philosophical anthropology*

In philosophical anthropology, several approaches to technological artifacts have been developed, with different analyses of the nature of the relations between humans and artifacts. The first approaches were mainly *instrumentalist*. Ernst Kapp (1877) approached technological artifacts as projections of human bodily organs. Related to this, Arnold Gehlen (1988) argued that human beings should be seen as "*Mangelwesen*," deficient beings needing technological artifacts to compensate for their poor abilities to survive in an environment to which they are not equipped by nature. Both approaches give technological artifacts the instrumental role of replacing specific human possibilities, enhancing human capacities, or relieving humans from burdensome tasks.

A second approach focuses on the *alienation* supposedly brought about by technological artifacts. Existential philosophers like Karl Jaspers (1951) held that society has become an apparatus of machines, bureaucracy and laborers, creating mass rule rather than authentic existence. Operating machines in a factory reduces human beings to mere appendices of the machinery, producing mass products which do not allow attachment to or engagement with them. Rather than being merely functional extensions of the human, technological artifacts are seen here as a threat to it. Their perfection could even lead to a sense of humbleness, indicated by Günther Anders (1987) as "Promethean shame" – as opposed to Prometheus' pride at having stolen fire from the Gods.

A third approach to the relations between humans and technological artifacts focuses on their interwoven character. Don Ihde (1990) developed an analysis of human–technology relations, arguing that technological artifacts do not alienate us from the lifeworld but, rather, mediate our relations to it and help to shape a technological culture. Donna Haraway (1991) and Bruno Latour (1993) even go one step further by arguing that it becomes ever more difficult actually to make a distinction between human beings and technological artifacts. With their notions of "cyborgs" (Haraway) and "hybrids" (Latour), they aim to make visible that both are interwoven to such an extent that one cannot exist without the other, since the "human" and the "technological" help to shape each other. A biological, and radical, variant of this position is transhumanism, which is defended by authors like Hans Moravec (1988) and Nick Bostrom (2005a, 2005b), who announce the end of *Homo sapiens* and the advent of a transhuman life form which will be a blend of organic and technological elements.

### *3.4 Technological artifacts and the lifeworld: phenomenology*

In close connection to anthropological approaches, phenomenological approaches to technological artifacts were developed, initially by Martin Heidegger, and later by Don Ihde and Albert Borgmann (cf. Verbeek 2005). In his early work *Sein und Zeit*, Heidegger analyzed the role of "tools" or "equipment" (*Zeug*) in the relations between human beings and their world (Heidegger 1966). In order to understand equipment, Heidegger stated, one should try to describe not its properties but how it is present to human beings when they use it. Artifacts in use typically withdraw from human attention; they submerge in human involvements with reality, which take place "through" the tool. Tools in use are "ready to hand"; they remain unnoticed, as centers of a complex structure of references and relations. Only from a distanced and observing standpoint – for instance when they break down – tools are "present at hand" objects.

In his later work, Heidegger developed a radically different approach (1977), stating that technology should not be understood in terms of artifacts, but as a way of "revealing reality" – a fundamental understanding of reality which lets us interpret it in terms of raw material, available for human manipulation. Technological artifacts do not help to shape human relations with the world any more now, but function as expressions of a specific way of taking up with reality (for an analysis of the development of Heidegger's thinking about technological artifacts, see Verbeek 2005). Albert Borgmann (1984) has brought this analysis in closer relation to actual technological artifacts. He makes a distinction between "things" that require engaged interaction with themselves in order to be used and "devices" that impede engagement because they typically make commodities available which can be consumed without engagement with the machinery producing them. The boiler, thermostat, pipes and radiators of a central heating system deliver "warmth" as a commodity that can be consumed without active engagement, whereas a fireplace requires engaging practices like gathering wood, chopping it, and filling, poking and cleaning the hearth.

Don Ihde (1979, 1983, 1990) uses Heidegger's tool-analysis as a starting-point for analyzing what he calls "human–technology relations." Ihde distinguishes four such relations between human beings and technological artifacts: the *embodiment* relation, which resembles Heidegger's "readiness-to-hand," and in which humans perceive the world through the artifact, as when looking through a microscope; the *hermeneutic* relation, in which the artifact gives a representation of the world which requires interpretation, like reading off a thermometer; the *alterity* relation, in which humans experience the artifact itself, much like Heidegger's "presence-at-hand"; and the *background* relation, in which technological artifacts shape a background for our experiences, like the switching on and off of the fridge. Ihde elaborated how technological artifacts, from all these human–technology relations, mediate how human beings experience and interpret the world. These mediations are not essential properties of technological artifacts, though, as Ihde indicates with the concept of multistability; human beings can appropriate them in different frameworks of interpretation and use practices, which can result in various mediating roles.

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# 29

# Technical Practice

## BART GREMMEN

In traditional actor-theory, an actor is separated from the means used in action and from the objects of action in reality. From the perspective of technical practice, however, practitioners, the means and the objects are integrated in the socio-natural world. The concept of a practitioner is an alternative to the concept of an individual actor in standard theories of social science. Practitioners take part in societal activities and cannot practice on their own, and what they are and what they do cannot be isolated from the practice in which they participate. It is their competent performance in the practice which makes them into practitioners, which defines them as such. When they lack the competence (or are labeled as lacking it), they will be redefined as not belonging: "He is not a real engineer" is the phrase then.

Because practitioners behave according to standards, their performance can be understood from a socio-logical perspective. In articulating the normative structure of technical practice, the difference between individual behavior and competent performance is important. In their competent performance, practitioners can be said to make normative claims about the quality of their performance. These claims are made to, or refer to, other practitioners. In their evaluation, criticism and other reactions, the quality of the performance is established. It is an achievement of all practitioners together. Thus competent performance is the unity of the technical practice.

Competent performance as the normative structure of a technical practice consists of four aspects. One way to examine these aspects is by looking at the way practitioners discuss failures in competent performance. The unity of the practice then appears in the possibility to shift from one aspect to another without creating a break (or a category mistake).

The *first aspect* is labeled "positioning." In their positioning, practitioners assume their role as practitioners, and take up the responsibilities of their practitionership. Good working relations, loyalty, discipline and circumspection are examples. The communicative relationship between those who participate in a technical practice is at stake. In a technical practice, practitioners in interaction constitute a public for one another. What people are doing is rarely properly described as *just* eating, or *just* working, but has stylistic features which have certain conventional meanings associated with recognized types of personae.

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The *second aspect* is the ways and means practitioners use to position themselves as practitioners: it is labeled "representation." They steer the interaction between practitioners by regulating mutual access to their interpretations of being a practitioner. This does not imply expressive behavior, but stylizing the expression of one's own experiences as a practitioner to other practitioners. This aspect is evaluated by looking at the use practitioners make of media and instruments.

The *third aspect* is the strategic "judgmental," the laying down of relevant directions of the performance, or the question of what has to be done when. In this process, aims and means are combined by strategies, and in a complex technical practice many different means may be used for the same aim. A good practitioner is able to choose between alternative strategies and to avoid bad judgment. Judgment is essential, and practitioners, when articulating the third aspect, often talk in terms of judgment.

The *fourth aspect* is the "execution" of the strategic planning of a performance. In a technical practice, certain processes in the socio-natural world are controlled by operations which manipulate the appropriate socio-natural processes. In controlling these situations, the social processes are not "secondary." This in fact is one of the most important accomplishments of a new practice. The ongoing competent performance involves reconstruction of both the natural *and* the social world. Often this is a result of a performance's own operating requirements: it simply will not work unless human behavior changes to suit its form and process.

A difficulty in this analysis of a technical practice is that only a practitioner is defined in terms of competent performance, but a practice also has participants. The latter concept includes both the practitioners and the clients or patients of the practitioner. In engineering practice an engineer and his clients both participate, but only the engineer is a practitioner. Even so, clients also have to perform well in order to make the practice an ongoing concern. The distinction between practitioner and client/patient is the result of professionalization strategies, and can be contested.

The dynamics of a technical practice is the development of a technical practice over time. Since a technical practice is an ongoing process of competent performances, it is difficult to demarcate the beginning of such a practice. On a closer look, the birth of a technical practice dissolves into contingent processes. What one *can* identify is the emergence of a repertoire and, especially, key experiences that serve as an example, or exemplar, in the evolving repertoire of the emerging practice. An exemplar, an opportunity for doing-as, indicates that the basic structure of competent performance is in place, and as soon as action is seen as action by practitioners the mutual evaluability of performance, i.e. the social side of a practice, can function. Then, a technical practice has emerged, and the repertoire will evolve continuously. Reflection-in-action is the way in which technical practices evolve: it is indigenous rationalization. According to Schön, when someone reflects-in-action, he or she becomes a researcher in the practice context. There is a difference with the norms of controlled experiment. Science is often, and mistakenly, seen as the ideal way of advancing knowledge, while in fact its progress is predicated on the practical possibility to create closed systems. Practitioners are advancing knowledge while working with open systems. So there are good reasons to consider practitioners' research as a limiting case. Then, the dynamics of technical practices should relate primarily to such indigenous practitioners' research rather than to an influx of so-called scientific knowledge.

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## 30

# Technological Pragmatism

## LARRY HICKMAN

From its inception, the philosophical movement now known as classical American pragmatism was strongly committed to the methods of the sciences. Charles S. Peirce (1839–1914) was employed by the US Coast and Geodetic Survey. William James (1842–1910), who was trained as a physician, taught physiology before turning to psychology and philosophy. John Dewey (1859–1952) and his team at the University of Chicago performed experiments related to perception and attention.

The close relationship between pragmatism and experimentalism is evident in Peirce's 1878 maxim: "Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object" (Peirce 1986). William James extended the application of this proposition by asserting that, for the pragmatist, "theories become instruments, not answers to enigmas, in which we can rest" (James 1975). Dewey pushed it still further by treating logical objects, numbers, hypotheses and other abstract entities as tools that are designed, developed and utilized in much the same ways as material tools, that is, for the sake of achieving some desired end.

Building on his insights into the relations between tool use and inquiry, Dewey had by the 1890s already begun to develop a comprehensive project that would ultimately relate technology to the history of science, education, social and political philosophy, the arts and even religion. His application of philosophical tools to a critique of technological culture thus preceded the efforts of most other twentieth-century philosophers of technology by several decades. Unlike most of his philosophical contemporaries, however, he also thought that an improved understanding of technological culture could effect a reform of the tools and techniques of philosophy. The fact that Dewey's contributions to the philosophy of technology were not generally acknowledged until the 1990s (Hickman 1990) may be due in part to his failure to devote any single work to the subject. His philosophy of technology instead leavens his extensive published work.

In his 1896 "The Reflex Arc Concept in Psychology" (Dewey 1972), published three decades before the publication of Martin Heidegger's *Being and Time*, Dewey distinguished between two modes of experience that Heidegger would later term "readiness-to-hand" and "present-to-hand." He developed this material further in 1916 in *Democracy and Education* (Dewey 1980a) and in 1925 in *Experience and Nature* (Dewey 1981). Given

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the relative paucity of discussions of educational issues by other philosophers of technology, it is noteworthy that Dewey employed this distinction in the curriculum of his experimental elementary school during the 1890s (Dewey 1979, 1980a).

Like the Heidegger of *Being and Time*, Dewey rejected the ancient Greek view of technology that demeaned the work of the craftsman by subordinating the practical and the productive to the theoretical. Unlike the later (post-Second World War) Heidegger, however, who some critics view as having turned to a nostalgic and romanticized view of technology that tended to overshadow or even negate his earlier phenomenological commitments, Dewey consistently linked the accomplishments of the technosciences since the seventeenth century to their ability to treat theoretical and practical activities as equal partners in inquiry, negotiating the business of producing new tools and new outcomes.

Dewey's position stands in stark contrast to that of Jacques Ellul (Ellul 1964), whose work was highly influential during the classic period of the philosophy of technology. For Ellul, technology was essentially an autonomous system that leaves virtually no room for human freedom. For Dewey, however, "technology" does not name a thing, system or force that could be autonomous. It names instead a particular type of human activity that thrives on freedom of thought and prudent innovation. As the *logos* of *techne*, technology is for Dewey inquiry into tools and techniques in the same sense in which biology is inquiry into forms of life.

Technological success or failure is in Dewey's view the responsibility of human actors as they engage social networks as well as networks of non-human objects and events. Although past successes may provide platforms from which future technology can be mounted, there is no general recipe for technological success. Technology requires sensitivity to context. One consequence of this view is that "appropriate" technology does not necessarily require small projects: projects of any size may be appropriate, depending on the types of problems to be solved. It also follows from this view that technology, as inquiry into tools and techniques, cannot be exported. This thesis has important social and political consequences.

Dewey's position also differs sharply from that of "first generation" critical theorists Max Horkheimer and Theodor Adorno (Horkheimer and Adorno 1987), who linked technology to ideology and alienation. Dewey did not think that there was anything essentially ideological or alienating about technology. He was well aware of the excesses of *laissez-faire* capitalism; he worked throughout his long career to address racial and economic injustice; but he did not think such problems the fault of technology. In 1930, during the Great Depression, for example, Dewey wrote that "'Technology' signifies all the intelligent techniques by which the energies of nature and man are directed and used in satisfaction of human needs; it cannot be limited to a few outer and comparatively mechanical forms. In the face of its possibilities, the traditional conception of experience is obsolete" (Dewey 1984b).

Dewey's response to the "ideology" and "alienation" arguments advanced by first-generation critical theorists was to naturalize technology by locating inquiry into tools and techniques within an evolutionary account of human development. It was in this connection that he refused to draw a sharp ontological distinction between tools that are concrete or tangible and those that are abstract or intangible. He regarded both a hammer and the number 2, for example, as tools that have been refined from the raw materials of human experience in order to serve evolving ends. The primary distinction between the two types of tools is functional: "intellectual tools," he wrote, "are indefinitely more flexible in their range of adaptation than other mechanical tools" (Dewey 1980b). Dewey also recognized the ceremonial objects and ideas of art and religions as tools, although he argued that progress in refining the tools of the latter had tended to lag behind other areas of human development.

Dewey's naturalistic thesis has important consequences for environmental philosophy. Rejecting transcendentalist arguments, Dewey's pragmatic technology utilizes one part of nature to transform or reconstruct another part of nature. Some situations call for what is relatively external to the organism to be altered or adapted to the needs of the organism. Other situations require the organism to accommodate itself to what are relatively external conditions. In most cases, however, what is required is what Dewey terms "adjustment" – a judicious balance between adaptation and accommodation. Dewey's pragmatic technology is thus neither essentialist nor reductionist.

The phrase "relatively external to the organism" carries special freight in this connection. Dewey refused to identify the mind with the brain, or even with the brain plus the peripheral nervous system. He instead treated mind as functional, as intentional, and as verbal: mind*ing* involves brain and nervous system as well as tools and other artifacts, both tangible and intangible. In this matter Dewey anticipated Marshall McLuhan's treatment of media as the extensions of human organisms (McLuhan 1962) and, more recently, the dynamic systems theory of W. Teed Rockwell and others (Rockwell 2005).

Early on, Dewey identified his philosophical position as "instrumentalism." This designation has been the source of difficulty among some of Dewey's European readers, who have misunderstood his project as a version of "instrumental rationality," or the view that efficiency of means trumps evaluation of goals or ends. By using the term "instrumentalism," however, Dewey signaled his "praise of tools, instrumentalities, [and] means, putting them on a level equal in value to ends and consequences, since without them the latter are merely accidental, sporadic and unstable" (Dewey 1984a). Dewey thus rejected "instrumental rationality" at the same time that he provided a basis for evaluating tools and techniques, including the cognitive tools utilized by the main strands of Western philosophy. In this latter role, instrumentalism "involves the doctrine that the origin, structure, and purpose of knowing are such as to render nugatory any wholesale inquiries into the nature of Being" (Dewey 1978).

Dewey's critique of technology also differs in important ways from that of "second generation" critical theorist Jürgen Habermas. Dewey would have certainly rejected Habermas's claim that the human sciences proceed in a manner that is totally different from the technosciences because the former are primarily concerned with meaning and value whereas the latter are primarily concerned with data-gathering. His pragmatic technology provides the basis for relating and integrating within a general theory of inquiry the several interests – the empirical sciences, the historical hermeneutical sciences, and the critical sciences – that Habermas tends to maintain as distinct (Habermas 1971).

Since the 1990s some philosophers of technology have begun to reassess the claims of the classical period of their discipline along lines that are quite familiar to Dewey's readers. Rejecting the approach of what he regarded as Heidegger's overly romanticized position, for example, Don Ihde (1991) developed an "instrumental realism" that treated instruments as the interface between the philosophy of science and the philosophy of technology. Andrew Feenberg (1999) distanced himself from his roots in critical theory by moving to replace an essentialist understanding of technology with one that is functional, rejecting the idea of technology as ideology, and recharacterizing technology in ways that involve greater appreciation of social networks. Peter-Paul Verbeek (2005) argued that Heidegger and other classic philosophers of technology had been looking in the wrong direction: instead of attempting to understand the conditions for the possibility of technology, they should have been developing an account of tools and artifacts as they take their place in life's activities. Each of these positions was both anticipated and developed in detail as a part of John Dewey's pragmatic technology.

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# 31

# Hermeneutics and Technologies

DON IHDE

At first glance, it might appear that hermeneutics as a theory of interpretation, and technologies as the array of artifacts used by humans, might not be easily related. However, in so far as all technologies as used by humans are ascribed with ranges of often complex meanings, so also are texts, so that at a deeper level hermeneutics and technologies potentially exhibit considerable interrelations a few of which will be explored here.

Hermeneutics is also usually thought of as pertaining to linguistic phenomena, and most primarily to written or *textual* interpretation. Clearly, in the pre-modern European traditions, hermeneutics was most focally practiced with respect to sacred texts, particularly biblical ones. However, with the spread of modernist thought and with beginnings largely in the eighteenth century and the subsequent rise of "biblical criticism," or the question of interpretation which questioned the historical origins and formations of biblical texts, the notions of a *critical intepretation* began to expand into a broader critical theory. By the nineteenth century the main currents of scholarly thinking began to differentiate disciplines into more distinct practices with the methods and aims of the natural sciences – previously "natural philosophy" – and the human sciences into two distinguishable styles of thinking. The most famous and longest-lasting set of distinctions remains associated with Wilhelm Dilthey and his *Naturwissenschaften* interpreted by an "explanation theory," in contrast to the *Geisteswissenschaften* interpreted by a "theory of understanding." In the Diltheyan context, it would be clear that hermeneutics would be one form of understanding or *Verstehen* and be associated with the humanities. But Dilthey was not alone with this yet more widely expanded notion of hermeneutics since the theologian Friedrich Schleiermacher also quite explicitly elevated hermeneutics as effectively *the* method of the humanities and of a universal interpretation of humanity.[1] Capping off this expansion of hermeneutics as an ever expanding theory of interpretation, in the twentieth century Martin Heidegger explicitly called for ontology itself to be *hermeneutic* in his landmark publication *Being and Time* (1927). As such, hermeneutics becomes an even broader theory of interpretation, encompassing being-in-the-world.

Where, then, in this expansion of a hermeneutic theory of meaning, from sacred texts to ontology, do technologies fit? In this context within the philosophy of technology, two interesting suggestions will be posed: First, beginning quite specifically with the

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older and narrower sense of hermeneutics as focusing upon *texts*, while it should be immediately apparent that any theory of meaning or significance relating to texts must recognize that *texts are technologically produced*! Written language – resulting in texts – is a process of some kind of writing production entailing artifacts. In the still widely accepted master narrative concerning written language, it is usually held that cuneiform was probably the earliest datable form of writing, going back to 6000 BP. However, tortoise-shell writing from China also seems to date back to 6000 BP, suggesting multiple origins for this process.[2] Here the technological system is one which includes a tablet of wet clay, a stylus, probably most commonly a sharpened stick; and engaging a set of skills applied by a human scribe. The scribe *inscribes* a set of marks upon the clay tablet, which after baking or other hardening processes can be be *read* – visually interpreted – by a skilled reader. Antiquity produced a considerable range of such textual-technological processes: cuneiform, as just mentioned, but also papyrus reed "paper" inscribed with a brush plus ink and again entailing a skilled scribe and skilled reader to complete the system; Asian rice paper with brush and ink and a different writing system; and of course the later, major invention of the alphabet in its many variations, first amongst Semitic peoples, then refined by the Greeks. Here, quite literally, *hermeneutics meets technologies* in the invention, history and development of written language. Put more strongly, the technologies of textual production make hermeneutics as a theory of interpretation necessary and possible.

The materially productive connection between the development of text producing technologies of writing has, in postmodernity, been revisited by the variations upon several "linguistic turns" in the humanistic disciplines. First, amongst analytic philosophers, the task became one of language (and logical) analysis, soon followed by a similar but more textually based turn by hermeneutic philosophers.[3] But, in both cases, there can be noted very little sensitivity to, or interest in, the technologies which produce such writing or its end product, texts. Only the echo of such a process appears, for example, in Jacques Derrida's notion of *inscription* and the *trace* which he does acknowledge are the marks produced by material using activities. Similarly, Bruno Latour's later claim that all laboratory equipment produces *inscriptions*, or *visible displays*, also echoes, at best, the underlying technologies of production.[4]

A second perspective upon a technology–hermeneutics relationship emerges by reversing the order which views the materially productive bases of writing technologies to texts, to a view which begins with the array of technologies and the meaning-contexts into which technologies fit. Technological artifacts, although they can be simply any material object including non-designed and non-manufactured ones, typically are artifacts which have been shaped and "designed." Indeed, the dominant common notions of designing and shaping often entail a belief that "designer intent" is or should affect both the meaning and use of the technologies involved. Yet such constraints are at best partial and in terms of actual histories may actually often fall away or take very different trajectories. Edward Tenner catalogues a history of unintended side-effects which accompany many, if not most, technologies.[5] An older example, frequently recounted, relates to Alfred Nobel's invention of dynamite, an explosive technology "designed" to make the mining process easier and more effective, which, tragically, also made wartime explosives more effective. Tenner's examples include the notion that electronic communications would produce the "paperless society," but which today uses more paper than ever before, and the list goes on indefinitely. This, however, can be taken as a *hermeneutic problem.* That is, technologies, precisely because they can be taken and used in a multiplicity of contexts, uses and trajectories, *display a range of indeterminancy of meaning* which is precisely the phenomenon which any hermeneutic theory of meaning must engage.

Here, one can begin by approximating some of the classical textual and literary problems in hermeneutics to analog problems with technologies, and show the beginnings of creative interaction between hermeneutics and technologies. In literary and textual contexts, one question relates to origins, such as the question of "author's intent," but also to the historical-cultural-social context of the origin of the text. The same kind of question with respect to technologies can be raised concerning "designer intent," and the historical-cultural-social context of the origin of the technology. Technologies, like texts, are embedded in social meanings. In their classic examination of the development of the bicycle, in *The Social Construction of Technology,* Trevor Pinch and Wiebe Bijker show how social meanings – not only technical capacities – relate to development. The association of the high wheel Penny Farthing bicycle with bold young masculine males, and the Safety Bicycle (with brakes and accommodation to skirts) with women, clearly played a role in this technical evolution. Technologies are open, they argue, to interpretive flexibility.[6] In the history of literary critical hermeneutics, for example, the notion of author's intent as the meaning of a text has become criticized as the "intentional fallacy," since in many cases intent cannot be discovered and in others meanings other than intended often come to dominate. Similarly, in the history of technology, "designer intent" is often radically modified as technologies come into use and/or are modified over time. Historically the prosthetic design intent of both the telephone and the typewriter lost out to other communication and commercial uses and meanings.[7]

Drawing from the traditions of the interpretation of sacred texts, the role of *commentary traditions* are also of importance. Commentary traditions deflect interpretive trajectories and change their directions by showing new possibilities. Imagine a simple example: the Fall of Adam and Eve in the Garden. The biblical story has three characters – Adam, Eve and the Serpent. Taking of the forbidden fruit of the knowledge of good and evil constitutes the "fall" from innocence. But which character is to be assigned the blame? The text is not transparent, thus commentary, itself situated in some cultural-historical-social context, will provide possible perspectives. Adam, if viewed hierarchically and patriarchally, will be most responsible; or Eve, if viewed in the context of some sexually loaded context, or the Serpent, if viewed in a pre-existent flaw of Nature are all possibilities. Similarly, the choice today to replace lightbulbs with incandescent, in a strictly short-term economic context, halogen or fluorescent if in a longer-term, energy-saving context, are choices of which dominates parallel to the commentary example. The hermeneutics–technologies relationship is, at depth, one of texts and technologies both being humanly produced but in ways in which meanings accrue and from which trajectories can be taken. Critical interpretation is called for with both texts and technologies.

There is finally yet another step possible. What could be called a *material hermeneutics* is yet another expansion from pre-modern hermeneutics. Here the focus is upon meanings inherent in, or expressible from, technologies, particularly those which are instrumental in the production of knowledge. Metaphorically this would be a hermeneutics which helps *things* or materiality "speak." Physical anthropology and archeology are two disciplines which entail prior developments of such a material hermeneutics. In both, significant physiological shaping – tooth enamel and shape and size in physical anthropology can help determine function and species – and cultural stylistics – typical style of pottery and other use-objects – can help determine which culture and period is being examined. But, beyond these traditional means, contemporary means which utilize carbon 14 dating, thermo-luminescence, mass spectroscopy, penetrate and yield interpretations which far exceed those of traditional observations. This, too, can be recognized as a hermeneutic, a materially hermeneutic process.

## Notes

1. An extensive history and comparison of hermeneutics may be found in P. Riceour, *The Conflict of Interpretations* (Evanston, Ill.: Northwestern University Press, 1974). Also see D. Ihde, *Expanding Hermeneutics: Visualism in Science* (Evanston, Ill.: Northwestern University Press, 1998).
2. See S. R. Fischer, *A History of Writing* (London: Reaktion Books, 2005).
3. R. Rorty (ed.), *The Linguistic Turn: Essays in Philosophical Methodology* (Chicago, Ill.: University of Chicago Press, 1967). Unnoticed by most analytic philosophers, however, was the similar turn by J. Derrida, *De la Grammatology* (1974), later *Of Grammatology*, trans. G. C. Spivak (Baltimore, Md.: Johns Hopkins University Press, 1976).
4. Derrida's notion of the *trace* and the *inscription* takes shape in *Of Grammatology* and is also similarly noted with respect to laboratory experiments interpreted as *inscriptions* or *visualizations* by B. Latour, *Science in Action* (Cambridge, Mass.: Harvard University Press, 1987). Also see Don Ihde's use of *hermeneutic relations* in a similar instrumental context in *Technology and the Lifeworld* (Bloomington, Ind.: Indiana University Press, 1990).
5. E. Tenner, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* (New York: Alfred A. Knopf, 1996).
6. W. Bijker, *Of Bicycles, Bakelites and Bulbs* (Cambridge, Mass.: MIT Press, 1995).
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# 32

# Analytic Philosophy of Technology

## MAARTEN FRANSSEN

The first thing that should be noted about analytic philosophy of technology is that there is not a more or less unified subfield of that name within philosophy with a consensus on a list of central problems and a canon of key writings, as is the case for (analytic) philosophy of science. It is only during the last four decades that analytic philosophers have turned to technology. Analytic philosophy of technology is, therefore, at best an emerging discipline, and it is still too early to be convinced that it will grow into a mature field comparable in extent to the philosophy of science. The contingencies of historical development play a large role in such matters.

Analytic philosophy is primarily a way of doing philosophy, or a view on what meaningful philosophy is about: what sorts of questions are worth asking and what sorts of answers to these questions are acceptable. Accordingly, it is defined by method, not by subject. Nevertheless, some subjects in philosophy are closer to the heart of analytic philosophy than others. What characterizes analytic philosophy is an abhorrence of system-building and speculation, a preference for a detailed treatment of clearly delineated problems, an emphasis on clear definitions of the concepts used to put a problem and to answer it, an emphasis on language, conceptualization and formalization, a general acknowledgment of the relevance of empirical facts, and a great respect for the findings of science – to such an extent, even, that science and philosophy are considered to merge into each other or to form in some sense a continuum. Given this general outlook, questions concerning knowledge and theories have traditionally been at the centre of analytic philosophy, and for an analytic philosopher the philosophy of science is a respectable field of inquiry *par excellence*, though fields like metaphysics and ethics, which were regarded with extreme suspicion by the earliest analytic philosophers, have since been taken up to be studied from the analytic perspective. The following overview of some core issues in analytic philosophy of technology – the character of technological knowledge, the study of design and action, and the status of technical artifacts – will show that they are close to the heart of analytic philosophy.

The neglect that the philosophy of technology for a long time had in analytic philosophy may be attributed in part to a lack of reflection on the relation between science and technology – an attitude that is often presented, perhaps somewhat dramatized, in the form of a claim that technology is "merely" applied science. Indeed, a questioning of this relation was the central issue in the earliest discussions among analytic

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philosophers of technology. In 1966, in a special issue of the journal *Technology and Culture*, Henryk Skolimowski pointed out that technology is something quite different from science. Science concerns itself with what *is*, whereas technology concerns itself with what *is to be*. A few years later, in his well-known book *The Sciences of the Artificial*, Herbert Simon emphasized this important distinction in almost the same words, stating that the scientist is concerned with how things *are* but the engineer with how things *ought* to be. Although it is difficult to imagine that earlier analytic philosophers, in particular the logical empiricists, were blind to this difference in orientation, their inclination to view knowledge primarily as a system of statements may have led to a conviction that in technology no knowledge claims play a role that cannot also be found in science, and that therefore the study of technology poses no new challenges and holds no surprises regarding the interests of analytic philosophy. Additionally it must be noted that a close relationship between scientists and philosophers had grown around several foundational issues – the reality of atoms, the status of causality and probability, questions of space and time, the nature of the quantum world – that were so lively discussed during the end of the nineteenth and the beginning of the twentieth century. No such intimacy existed between those same philosophers and technicians; their worlds barely touched. And as the saying goes: unknown, unloved.

In the same issue of *Technology and Culture*, Mario Bunge defended the view that technology is applied science, but in a subtle way that does justice to the differences between science and technology. Bunge acknowledges that technology is about action, but an action heavily underpinned by theory – that is what distinguishes technology from the arts and crafts and puts it on a par with science. According to Bunge, theories in technology come in two types: substantive theories, which provide knowledge about the object of action, and operative theories, which are concerned with action itself. The substantive theories of technology are indeed largely applications of scientific theories. The operative theories, in contrast, are not preceded by scientific theories but are born in applied research itself. Still, as Bunge claims, operative theories show a dependency on science in that in such theories the *method* of science is employed. This includes such features as modeling and idealization, the use of theoretical concepts and abstractions, and the modification of theories by the absorption of empirical data through predictions and retrodictions.

In his comment on Skolimowski's paper in *Technology and Culture*, Ian Jarvie proposed as important questions for an analytic philosophy of technology, what the epistemological status of technological statements is and how technological statements are to be demarcated from scientific statements. This suggests a thorough investigation of the various forms of knowledge occurring in either practice. A distinction between "knowing that" – traditional propositional knowledge – and "knowing how" – non-articulated and even impossible-to-articulate knowledge – had earlier been introduced by Gilbert Ryle, one of the most important British analytic philosophers of the mid-twentieth century, but this distinction was not used to investigate the epistemological status of technological claims. Whether it would have been fruitful in this respect is still an open question. Not much progress seems to have been made in philosophy in this respect. These early analytic philosophers of technology still shared the philosophy of science as point of departure. As a result, they tended to miss an important, if not the most important, activity that sets technology apart from science, that of design. To understand this part of technology properly, a thorough acquaintance with engineering practice is required.

In his 1990 book *What Engineers Know and How They Know It*, the aeronautical engineer Walter Vincenti gave a sixfold categorization of engineering design knowledge (leaving aside production and operation as the other two basic constituents of engineering practice). Vincenti distinguishes (1) fundamental design concepts, including primarily the operational principle and the normal configuration of a particular device; (2) criteria and specifications; (3) theoretical tools; (4) quantitative data; (5) practical considerations; and (6) design instrumentalities. The third and fourth category can be assumed to include Bunge's substantive technological theories. Of the remaining four categories, Vincenti claims that they represent prescriptive forms of knowledge rather than descriptive ones. Here, the activity of design introduces an element of normativity, which fails in scientific knowledge. Take such a basic notion as "operational principle," by which is meant the way in which the function of a device is realized – how it works, in short. This is still a purely descriptive notion. Subsequently, however, it plays a role in arguments that seek to prescribe a course of action to someone who has a goal that could be realized by the operation of such a device. At this stage, the issue changes from a descriptive to a prescriptive or normative one. In analytic philosophy, such arguments are studied under the headings of practical inference, instrumental rationality and means–ends reasoning. A lot of work still has to be done on the precise ways technological action, as included in the activity of designing, is linked to the study that these fields present of action in general.

This task requires a clear view on the extent and scope of technology. If we follow Joseph Pitt in his 1999 book *Thinking about Technology* and define technology broadly as "humanity at work," then to distinguish between technological action and action in general becomes difficult, and the study of technological action must absorb all descriptive and normative theories of action, including the theory of practical rationality, and much of theoretical economics in its wake. There have indeed been attempts within analytic philosophy at such an encompassing account of human action, for example Tadeusz Kotarbiñski's *Praxiology* (1955), but a perspective of such generality makes it difficult to arrive at results of sufficient depth. It is a challenge for analytic philosophy in general to specify the differences among action forms and the reasoning grounding them in, to single out three prominent practices, technology, organization and management, and economics.

Another issue of central concern to analytic philosophers of technology is the status of artifacts. Philosophy of science has emphasized that the concept of natural kind, such as exemplified by "water" or "atom," lies at the basis of science. In technology, artifacts are similarly represented as forming kinds, but such kinds – in particular functional kinds like "knife" or "aeroplane" – lack the property that makes them so important in science, that of supporting natural laws. There are no regularities that all knives or all aeroplanes answer to. In fact the character itself of a functional kind is unclear: is a knife everything that can be used to cut, or everything that was made with the intention that it be used for cutting? The former would classify splinters of glass and sharp rocks as knives; the latter would have us include in the class of knives all failed attempts at designing a knife and all remnants of knives worn beyond recognition. Neither alternative is attractive. This broad concept of functional kind is, however, not the only relevant notion of a kind in technology, nor the most important one. It can be argued that engineering design is aimed at creating a *kind* or *type* rather than one or several individual artifacts. Since these kinds are specified in terms of physical and geometrical parameters, they are much closer to the natural kinds of science, in that they support law-like regularities.

The contrast between these two sorts of kinds reflects the more general problem of the relation between structure and function in technical artifacts. Structure and function mutually constrain each other, but the constraining is only partial, and it is therefore unclear whether a general account of this relation is possible. In relation to this it is equally problematic whether a unified account of the notion of function as such is possible. This notion is of paramount importance for an understanding of artifacts. An artifact's function is, roughly, what it is for, where it is open whether this for-ness is based ultimately on what the artifact is designed for or being used for. Several researchers have emphasized that an adequate description of artifacts must refer both to their status as tangible physical objects and to the intentions of their users and designers. Peter Kroes and Anthonie Meijers (2006) have dubbed this view "the dual nature of technical artifacts." They suggest that the two aspects are "tied up," so to speak, in the notion of artifact function. Function, however, is also a key concept in biology, where no intentionality plays a role. Up till now there is no accepted general account of function under which both the intentionality-oriented notion of artifact function and the non-intentional notion of biological function – not to speak of other areas where the concept plays a role, such as the social sciences – can be subsumed. The collection of essays edited by Ariew, Cummins and Perlman (2002) presents a recent introduction to this topic.

This presentation of some of the core issues addressed by analytic philosophers of technology might suggest that they are not interested in ethical and social problems in connection with technology, just as the ethical and social dimensions of science are almost completely ignored in analytic philosophy of science. This is not so, however, but their interest is triggered more by the engagement of analytic philosophers of technology in engineering practice than by the interests of philosophical ethics. Analytic ethics is primarily a form of meta-ethics, that is, it discusses the character of ethical judgments and ethical statements and the way these are related, through rules of inference, for instance, with other types of statements. It is not apparent that technology presents special challenges to meta-ethics – none, at least, that do not already occur within the philosophy of action and the theory of rationality. Rather, analytic philosophers of technology share in a broadly felt conviction that any form of philosophical reflection on technology must address the ethical and societal problems raised by technology. The way they address these problems reflects the general orientation of analytic philosophy. In line with the central place they give to conceptual analysis, analytical philosophers stress the importance of clarifying key notions like responsibility. And, in line with their urge to take the empirical facts into account, they argue that a thorough acquaintance with the way engineering design is organized and the way technical artifacts are implemented and used is crucial to an understanding of the way in which ethical problems related to technology emerge, an understanding that must precede any sensible proposal to deal with such problems. Similarly, with regard to the sweeping claims concerning the meaning of technology in human culture and the good or bad ways in which it shapes human life that can so readily be found in traditional philosophy of technology, analytic philosophers of technology point to the need to analyze and make more precise concepts like man, mankind, culture, thought, freedom, and the like, before such statements can be meaningfully proposed and discussed.

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# 33

# Technological Rationality

## LORENZO C. SIMPSON

Technology and technological systems are embedded in a variety of social, political and economic contexts – contexts that ultimately shape the concrete form that material technologies and technological processes will assume.[1] Despite such contextual differentials, an underlying rationality can be discerned. This can be captured by the idea of technological rationality.

Implied by the idea of technological rationality is the existence of a core set of characteristics that runs through a variety of types of action. The meaningful use of the expression "technological rationality" would demand that its criteria of application serve to exclude some rationales for action while including others and serve to delimit features of the phenomenon that allow for its identification and reidentification. So, presupposed by the idea is our ability analytically to isolate such a core or at least indicate intelligible connections among families of such characteristics.

Though its origin can be traced to the Aristotelian notion of *techne*, or making, the conceptual genealogy of technological rationality stems perhaps most directly from Max Weber's analysis of action types in modern societies. Weber put forward a threefold distinction: what he called purposive-rational action was opposed to so-called value-rational action, and both were opposed to tradition-based action. Purposive rationality (*Zweckrationalität*) refers to the idea of assessing action from the point of view of its adequacy as a means to the realization of an agent's ends or goals. Value rationality (*Wertrationalität*) refers to the idea of assessing action from the point of view of its coherence with a value or norm held to be of intrinsic significance, regardless of the action's prospects for success in the attainment of a projected end or goal. The end-oriented nature of technological or purposive rationality is then contrasted with a rationality that is oriented by a concern with the way in which an action is done or with the values embodied in it or by the norms governing it. Tradition-based action is determined by ingrained habituation and is typically not mediated by rational assessment. According to Weber, modernity is characterized by the increased scope given to instrumental or purposive rationality.

The idea of instrumental or purposive rationality and its social ramifications in late capitalism and in modern, post-industrial society became a central concern of the first generation of the German social theorists known as the Frankfurt School (Max Horkheimer, Theodor Adorno, Herbert Marcuse and others). They saw technological

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rationality as essentially embodied in the purposeful organization and combination of productive techniques – directed either by public or private agents – that are aimed ultimately at more and more effective and efficient social control.[2] To this instrumental rationality they opposed what they referred to as critical rationality, but without elaborating a rigorously systematic and coherent account of the latter. Jürgen Habermas – the most prominent member of the second generation of Frankfurt School social theorists – elaborated upon Weber's distinction, maintained that instrumental rationality does not exhaust modernity's rational potential, and opposed to this mode of rationality a systematic account of what he calls communicative rationality.

Habermas's conception of communicative rationality provides a backdrop for further delimiting the contours of technological rationality. Communicatively rational action is linguistically or symbolically mediated, is governed by norms that are shared by at least two agents, each of whom acknowledges the other's recognition of the norms, and is oriented towards seeking mutual understanding and agreement.[3] This rationality that underlies reaching agreement with others in language is sharply distinguished from the rationality that underwrites successful intervention in the objective world based on knowledge of the causal determinants of processes in that world.

Other significant aspects of technological rationality come to the fore when we understand technology itself to be a response to our finitude, to the realization that we are vulnerable and mortal and that our time is limited. And technology has been a response to our finitude from the beginning. The earliest instances of tool-using in foraging societies were to "increase the reliability and productivity of . . . subsistence strateg[ies] by using time-saving devices."[4] This suggests that time-saving is an important aim of technological rationalization.[5] Indeed, it can be argued that the rationality that informs technological practice, by placing a premium on efficiency and control, encourages what can be called a domestication of time, a reduction of time to manipulable, interchangeable and dispensable units geared toward future goals.[6]

All technological ends, be they proximate or remote, have their origin in some object of human need or desire. Our capacities and desires, e.g. for communication, health, transportation, nourishment, security, entertainment, shelter, comfort etc., will ultimately constitute the hermeneutic grid in terms of which the point of any technology can be understood. In this sense, though technology may generate possibilities that we have not envisioned, its significance derives ultimately from our nature and values. However, when those values become ends of technology, they are translated into the realm of technics, and various branches of technology coalesce around them, e.g. mechanical engineering, electronics, civil engineering, agriculture, etc. And, when those ends become the guiding criteria for the various sectors of technology, the ends and the technologies associated with them will form a relatively autonomous domain. The technologically rational gaze is guided by an end that has been articulated in terms commensurate with the particular technology in question. For instance, in medicine one typically speaks in terms of halting the progress of a specific biomedically defined disease rather than, say, in terms invoking the concept of health, where health is understood to involve social and cultural as well as medical dimensions.

Technological rationality is a pure rationality of function, focused exclusively on the relation of means to ends. Technology's animating rationality restricts the scope of its deliberation to means–end thinking, to a species of calculation dedicated to maximizing economy and efficiency, with respect to time and effort, in the realization of ends. So "technological rationality" refers to that view of reason which focuses its attention exclusively upon the adequacy of means for the realization of ends, where those ends are not themselves subject to non-strategic rational adjudication, and to the notion of progress that is consistent with this view.

We can think of technology itself as a social phenomenon that embodies at once a distinctive cognitive style or orientation, a distinctive mode of action, and a distinctive way of taking up with the world. Accordingly, a useful core characterization of technological rationality is to think of it as a species of problem-solving rationality whereby we make use of the environment to satisfy our wants and desires. Worldly objects, and time itself, are instrumentally interpreted as potentially manipulable units to be orchestrated in the interest of achieving the goals at hand.[7] The set of knowledge, skills and instruments that are the most efficient and effective at problem-solving are the distinctive products of this mode of rationality.[8] We can characterize the way technology addresses its problems, or the technological approach, in the following way: a need is made explicit, or an opportunity, made available by scientific or perhaps other technological developments, is articulated; within the context of the need or opportunity, a clear and determinate goal is specified; the major steps to be taken and the major pieces of work to be done are identified; the plan is constantly made responsive to "feedback" from the results of the work; and, typically, the work is organized so that each major segment is apportioned within a division of labor.[9] This way of putting it highlights the important point that the end that technology seeks to realize as efficiently and effectively as possible is one that is specifiable and determinate beforehand. It further highlights the importance to the technological enterprise of planning, of the rational orchestration of procedure. The rationality of technology aims at the reduction of contingency and uncertainty via the mastery of instrumentalities and time through planning and ordering.

Hence, while there are historically contingent features of technological practices, we can, without unduly essentializing technology, also locate features that are, at least relatively speaking, historically invariant, features that survive social and historical transformations, features that enable us to identify and re-identify a practice or some aspect of it as technological in virtue of an underlying rationality. Among these are: (1) the separation of means and ends and (2) the rationalization of the means for the efficient procurement of ends. To summarize, we might think of technology, then, as the set of purposively rationalized practices aimed at putting the future at our disposal.

To say that technology can be viewed as that constellation of knowledge, processes, skills and products whose aim is rationally to control and transform is to raise the question of the relation between technological and scientific rationality. We often think that technology's promise of control is fulfilled by cashing in on the cognitive achievements of science. But what, exactly, is technology's relationship to science? An adequate account of *this* distinction will have to acknowledge that there is considerable overlap between what persons identified as scientists and those identified as technologists do. It has been remarked that it is often difficult to differentiate research scientists from research engineers based upon observation of them at work.[10] So, if our demarcation criteria are to be sensitive to actual practice, it would be advisable to think perhaps in terms of a spectrum of activities, interests and kinds of knowledge rather than in terms of sharp dichotomies and to acknowledge that the science/technology "border" is rather fluid. The end points of such a spectrum should be understood then to designate features more akin to those of an ideal type than to those of an actual practice. But those termini will be useful for talking about scientific or technological *aspects* of a practice or in speaking of a more or less scientific or technological practice.

The most useful and least contested way of characterizing what lies at the end points is to do so in terms of ultimate aims. Scientific practice aims at increasing our knowledge of the natural and social worlds by offering explanations of phenomena. Technological practice aims at solving the material problems of human life by increasing our power to transform those worlds. An adequate attempt to differentiate between the scientific and the technological, then, must take its orientation from an acknowledgment that science's aim is primarily cognitive, while technology's is primarily practical.[11]

We turn, finally, to the conception of progress that is consonant with the account of technological rationality presented here. The primary measure of technological progress is granted by the imperative to maximize effectiveness (reliability, durability, strength, ease of use, etc.) and efficiency in the securing of a given end. (Increased efficiency can be achieved either through the discovery of more productive ways – yielding more for a given "cost" or input – or more "economical" modes – providing the same yield for less input – of securing an end.) A further and highly salient mark of technological progress is the abbreviation of the time necessary for such a securing.[12]

Social constructivists will point out that the evolution of technology itself is underdetermined by the principle of technological rationality articulated here. For that principle is reached by abstracting or disembedding technology from the contexts wherein particular technologies are actually deployed. To render a full account of such contexts of use, socially and historically informed analyses that examine the social and historical specificity of technological systems must also be brought to bear.

## Notes

1. See, for instance, Feenberg (1995), Feenberg (1999) and Ihde (1990).
2. Leiss (1972).
3. Habermas (1970), p. 92.
4. Zvelebil (1984), p. 314, cited in DeGregori (1985), p. 14.
5. See also DeGregori (1985), pp. 14 ff.
6. Simpson (1995), p. 4.
7. On the idea of encountering the world as a resource for manipulation and use (*Bestand*), see Heidegger (1977).
8. DeGregori (1985), p. 37.
9. See Kranzberg and Pursell (1967), p. 18.
10. Hughes (1976), p. 651; and O. Mayr (1976), p. 667. Further complicating this problem is the fact that what at a given time is taken to be the science–technology distinction may be in part a social construction, may be determined by what society judges to be practical and irrelevant to practice at a given time. See Reingold and Molella (1976), p. 629, and Mayr (1976), p. 664.
11. See Bunge (1972), pp. 63, 68–70. Those who would reject the salience of the cognitive/practical distinction here – and that would include both those whose view of science is

informed by some version of instrumentalism or pragmatism and those influenced by some trends within the Frankfurt School of critical theory or in the thought of Husserl, Heidegger and Max Scheler – and who would claim that science itself is but a device for technical control and manipulation, face the challenge of giving an adequate account of the different criteria of success that characterize what are generally acknowledged to be the distinguishable enterprises of science and technology. Though social values may influence what gets brought under scientific scrutiny, the purely scientific will is ultimately "disinterested" in the specific sense that it is not wed to a particular experimental outcome. For it, the "pressures of life" are bracketed or neutralized (though they may not be for an individual scientist). The technological will is not disinterested in this sense. Even fundamental engineering research – basic scientific research with an eye to practical payoff – is committed to finding corroborated scientific claims that may prove *useful* (see Agassi [1980], p. 93). If we, with Karl Popper, agree that science progresses by, and ultimately seeks, falsifications or refutations, then we can distinguish the criteria of scientific success from even those of fundamental engineering research. The commitment to truth on the part of the scientific community is sufficiently strong (at least in principle and ideally) to redeem the self-negation of a refutation. Though a post-empiricist such as Thomas Kuhn might contest this claim, my point is that at least it can be *argued* in the case of science, because of its cognitive commitment. But it cannot be argued in the case of technology, because of its commitment to success in reliably altering the world. While refutations are cognitive achievements, and are for this reason "suffered" by science, they signify failure in the practical arena (see Popper [1963], pp. 112–14, and Agassi [1980], pp. 94–8).

Tendencies to conflate science and technology are often predicated upon an uncritical identification of truth and usefulness. For example, often the distinction is not made between the success of laboratory operations and the success of practical operations in the overdetermined world outside the laboratory. The practical, real-world success or failure of a scientific theory is not, in general, an index of its truth, or even of its warranted assertibility. There are many cases of false scientific theories being of great practical use. One need think only of the usefulness of Ptolemaic cosmography for navigational calculations. Or of N. A. Otto's successful internal combustion engine which turned out to be based upon false theoretical assumptions (see Bryant [1966]). There are a number of reasons for this: (1) either the false part of the theory is not used in the deduction that informs the technological application or the false part has no practical consequences; (2) because the emphasis in technology is upon using knowledge to achieve a real-world goal rather than on "stepping back" in order to achieve cognitive security, the levels of precision demanded in practice are often far lower than that demanded in scientific research, where precision is an element of a theory's falsifiability; and (3), in real situations, relevant variables are seldom adequately known and precisely controlled, for in the domain of practice timely and effective action is much too strongly urged to permit the detailed study necessary to isolate and assess relevant independent variables (see Bunge [1972], pp. 65–6). Theory choice in science, no matter how little it is algorithmically governed or how much it is value-laden, remains an epistemic affair. Technology's concern with extra-epistemic values such as reliability, safety, standardization and speed at the possible expense of depth, scope, accuracy, and fruitfulness for further research programs make its criteria of success rather different from those of science (see Bunge [1972], p. 76). An epistemically promising new theory may well be rejected in favor of a less promising but less risky alternative.

Even if one argues, as was Habermas' wont, that the technical interest underlies science's projection of its object domain, we can still acknowledge the distinction of the two enterprises at the level of their self-understanding, a distinction that accounts for different criteria of success and hence observable differences in institutional dynamics. This is a distinction that our universities neglect at their peril in the current rush toward corporate sponsorship of research. For a fuller discussion of some of the issues broached here, see Simpson (1983).

12. See Skolimowski, H. (1972), p. 44.

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# 34

# Phenomenology and Technology

## IAIN THOMSON

As a distinctive philosophical tradition, phenomenology was founded by Husserl and then developed further – into the domain of technology – by Husserl's most original and important student, Heidegger. Let us begin with this standard view and then develop and refine it as our needs require and space allows.

The watchword of Husserlian phenomenology is: "To the things themselves!" According to Heidegger, phenomenology – a word derived from the Greek *phainomenon* ("what shows itself from itself") and *logos* (understood as a "making manifest" of the way things hang together) – requires "letting what shows itself from itself be seen in the very way in which it shows itself from itself."[1] For both Husserl and Heidegger, phenomenology seeks to describe the way things show themselves to consciousness – or, better, *Dasein*, our mere "being-here" – when we do not distort matters with theoretical interpretations drawn from outside the experience of these phenomena themselves.[2] Phenomenology's ideal (virtually regulative, but sometimes achievable) is thus a type of *pure description*, the pursuit of which requires phenomenologists to struggle vigilantly against our usual tendency to force the square peg of recalcitrant experience into the round hole of ready-made conceptual categories. For, in so far as the concepts we use to make sense of our experience remain uninterrogated as to their own built-in interpretive biases, we tend not even to notice when inappropriate conceptual projections lead us to a distorted or inadequate apprehension of the phenomena at issue. The phenomenologist must thus be a "radical beginner," as Husserl liked to say, because phenomenology seeks to neutralize our pervasive but unnoticed conceptual biases by critically inspecting and carefully reconstructing our conceptual toolkit – a process meant to help us understand what our philosophical concepts conceal as well as what they reveal.

Phenomenology's methods remain widely applicable, but it was not developed in order to describe just any phenomena. Phenomenology is primarily concerned with phenomena that remain "hidden in plain sight" because they are either (1) masked by the distortions of inappropriate theories (as Othello, viewing his wife through the lenses of Iago's jealousy, sees only a demon in Desdemona) or else (2) concealed by their very immediacy (like the feel of the clothing on our bodies), ubiquity (like water to the fish or, increasingly, technology to us), or obviousness (like Poe's eponymous purloined letter). The "first law of phenomenology," the "law of proximity" (drawn from Gestalt psychology),

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states that, paradoxically, what is closest to us in our everyday worldly endeavors remains furthest from us in terms of our ability to take it up explicitly and understand it critically. Phenomenology's fundamental concern is thus to uncover, understand and, when necessary, contest and seek to transcend the underlying principles of vision and division which – like lenses we see through but do not see – tacitly inform and frequently distort our basic sense of ourselves and our worlds.

By understanding phenomenology in this way, we can trace the path leading from its roots in Kant and Hegel to its branches in Husserlian and Heideggerian critiques of technology. Kant's *Critique of Pure Reason* famously distinguishes the faculty of *intuition*, which passively receives sensory information, from the faculty of *understanding*, which actively organizes that sensory data into the stable form of conscious "mental representations."[3] According to Kant's *discursivity thesis*, the faculties of intuition and understanding work together subconsciously to generate the world of experience.[4] The understanding, employing its twelve basic cognitive categories (to data already shaped by the two "pure forms of intuition," the proto-categories of space and time), spontaneously sorts and organizes the manifold content of intuition, thereby bestowing the form of stable mental representations on to the stream of sensory data. This continuous combination of intuition and understanding (or *receptive spontaneity*) happens beneath the level of conscious experience, so I simply seem to perceive, for instance, a blue-and-gold book before me, unaware that this stable representation is already the product of my mind's subconscious conceptual organization of the manifold flux of sensation into the form of *this* substance with *these* particular properties.

Husserl thought that Kant's view – that there are only twelve categories tacitly organizing the spatio-temporal deliverances of intuition – faced an insurmountable problem. Recall the example of the book lying before me. For Kant, the mind subconsciously employs a combination of the twelve basic categories in order to arrive at the representational judgment that, of all the multifarious substances with similar properties, this one is a blue-and-gold-colored book, and not a blue-and-gold journal (or, for that matter, just an empty dust-jacket or even a hologram). Where, however, do I get the general idea of "blueness," of "gold," or of a "book"? Husserl did not think such ideas could be explained solely through a combinational application of Kant's twelve categories. (In this, Husserl effectively revives an objection Aristotle's empiricism had raised against Plato's proto-rationalistic theory of *ideas*: How can an idea pre-exist the entire class of entities that instantiate that idea?) Instead, in one of his distinctive theoretical innovations (but one which has proved problematic for Husserlian approaches to the phenomenology of technology, as we shall see), Husserl postulates the existence of an *eidetic intuition*, that is, a capacity to receive the very idea of something (that is, to experience *what* something is) along with other sensory information about it. From a Kantian perspective, however, Husserl thereby seems to blur the boundaries between intuition and understanding. For, on Husserl's view, the contours of my experience of the world do not just reflect the fixed conceptual structures that my mind has already tacitly supplied to the world. Rather, my experience of the world gives me categories (via eidetic intuitions) that the fixed structure of my mind did not first give to the world. Whether that seems like good phenomenology or else a "pre-critical" (or even "mystical") move depends on how rigidly Kant has shaped one's philosophical intuitions.[5]

Kant believed, further, that the cognitive categories subconsciously organizing the sensory manifold into stable representations were simply part of the fixed structure of the human mind.[6] From the beginning, however, Hegel rejected Kant's view that the categories by which the mind makes sense of the world were fixed for all time. Instead, Hegel's *Phenomenology of Spirit* sought to capture the inner, "dialectical" logic responsible for the historical emergence of humanity's progressively more satisfying cognitive categories. We could thus say that the phenomenological tradition really begins with Hegel's *Phenomenology*. For, in the *Phenomenology* – originally titled "The Science of the Experience of Consciousness" – Hegel attempts to supplement and historically ground Kant's discursivity thesis (which holds that the conceptual scaffolding of our minds tacitly constitutes the limits of our world) by attending to the actual experience of first-personal awareness, which Kant ignored in his logical analysis of the categorial structures conditioning experience beneath the level of conscious awareness. Hegel argued that by carefully describing the structure of first-personal conscious experience we can come to understand not just the emergence of our particular form of self-consciousness (which Kant treated ahistorically) but also the necessary path of consciousness's historical unfolding and even its final political destiny.

The first philosopher to call himself a "phenomenologist," Husserl, independently reinitiated Hegel's "scientific" attempt to describe the structure of first-personal experience. Yet some of Hegel's most radical insights – into not just (1) the incompleteness of Kant's categories (their failure to account for the experience of first personal awareness) but also (2) the historicity of experience (the fact that humanity's basic sense of reality changes with time), (3) the ineliminable absence at the heart of self-consciousness (the fact that consciousness cannot be conscious of itself and of the world simultaneously) and (4) the idea that the historical destiny of humanity is determined by the nature of our understanding of the relation between our selves and the world (such that our fundamental sense of ourselves changes history and vice versa) – did not jointly re-enter the phenomenological tradition until Heidegger, who brought them powerfully together in his historical understanding of the phenomenon of technology.

Indeed, the essential difference between Husserlian and Heideggerian phenomenology is nowhere more perspicuous than in the phenomenology of technology; for Husserlians and Heideggerians give subtly but importantly different answers to the question of whether and in what sense technology has an essence. Not surprisingly, their views originally converged. The later Husserl (of *The Crisis of the European Sciences*) and the early Heidegger (of *Being and Time*) both thought that the positive development of the empirical sciences, in which each science presupposes an understanding of the essence of *what* it studies and then generates empirical results on the basis of that understanding, effectively buries the philosophically crucial prior question of the adequacy of each science's original, guiding understanding of the essence of the class of objects it studies.[7] Both thus thought that phenomenology, by providing a clarified grasp of these essential foundations guiding each scientific discipline, would allow philosophy to regain its throne as the queen of the sciences. As I have shown in detail elsewhere, however, the later Heidegger outgrew this politically disastrous view, refining it in a way that brought it closer to Hegel's insight into historicity (coming to recognize the historically dynamic nature of our understanding of essences) but in a way that rejected Hegel's teleological understanding of historical progress.

To simplify a complicated story, the mature Heidegger came to the view that the positive sciences are guided not by a historically immutable understanding of the being of all entities, a "fundamental ontology" (or understanding of "the meaning of being in general") that phenomenologists needed only recover in order to set the sciences aright (and so unify the broader cultural understanding the sciences guide). The later Heidegger continued to believe that an understanding of the being of entities implicitly guides all the various knowledge domains. (Heidegger believes this because he maintains a form of ontological holism: Everything is, so changing our basic conception of *isness* eventually changes our conception of everything. As we saw at the beginning, moreover, phenomenology is fundamentally committed to the Kantian insight that our conceptions of things structure their very intelligibility, shaping the way things reveal and conceal themselves.) But Heidegger came to think that this guiding understanding of being changed with time, arguing that this "history of being" derives at the most fundamental conceptual level from a historically variable understanding of the being of entities which has an *ontotheological* structure. Our current sciences are thus guided implicitly by the same ontotheology that increasingly shapes our entire historical constellation of intelligibility.

This implicitly Nietzschean, "technological" ontotheology understands the being of entities as eternally recurring will-to-power, that is, mere forces coming together and breaking apart with no end beyond the self-perpetuating accumulation of those underlying forces. (When philosophers of biology proclaim that life *is* a self-replicating system, for instance, they seem to confirm Heidegger's insight.) In Heidegger's view, this technological ontotheology is leading us increasingly to understand, and so treat, all entities, including ourselves, as intrinsically meaningless "resources," mere *Bestand*. As this historical transformation of beings into intrinsically meaningless resources becomes more pervasive, it increasingly eludes our critical gaze. Indeed, we late-moderns come to treat even ourselves in the nihilistic terms that underlie our technological refashioning of the world: No longer as modern subjects seeking to master an objective world, but merely as one more intrinsically meaningless resource to be optimized, ordered and enhanced with maximal efficiency, whether cosmetically, psychopharmacologically, genetically, or even cybernetically.[8]

I mentioned that Husserl's phenomenological method developed in part to help afford phenomenologists with an eidetic intuition of the essence of a phenomenon.[9] Ironically, however, Husserlian phenomenologists have tended to avoid the difficult question of the essence of technological phenomena.[10] Owing to this omission, Husserlian phenomenology tends to join forces with the other contemporary "anti-essentialist" approaches to technology found in the sociology of science and in social constructivism (Latour, Pinch and Bijker, and the like). Such anti-essentialists tend to focus their critical analyses on the social normativity embedded within particular technological devices (rather than on the broader effects of technology *per se*). They might reveal, for example, the way red-light cameras reinforce a normative social order marked by the efficiency and immediacy of brute obedience to the law rather than the neo-enlightenment project that would seek to educate citizens about the rationality of traffic laws, for example, in order to secure their autonomous consent to such laws. Such analyses might note that red-light cameras accept the permanent alienation of subjects from the law and so reinforce that "panopticization" which reifies the carceral surveillance society Foucault warned against, but they will tend (because of their prior commitment to anti-essentialism) to be extremely cautious about following Foucault by extrapolating from such interlocking technological trends back to an underlying historical "episteme" or broader framework of "power-knowledge." Here Foucault himself, however, was following Heidegger. Indeed, Foucault's revealing analyses of contemporary "biopower" applied and developed Heidegger's critique of our "technological" understanding of being, which increasingly reduces all entities to the status of intrinsically meaningless resources to be efficiently ordered and optimized for further ordering.

Nice examples of such technological "enframing" can be found in the ubiquitous phenomenon of television's laugh-track and, even more poignantly, in the similar but less noticeable technology of "room tone," in which different types of "silence" (actually different kinds of low-level background noise) are recorded and stored for use in making the audio component of film and television recording seem less artificial.[11] Still, Heidegger was concerned less with the normativity embedded in particular technological devices than with the ontohistorical trend toward increasing *technologization*, that is, with the disturbing and increasingly global phenomenon (manifest with particular clarity in exemplary technologies such as the autobahn and the Internet, and so rightly called "technological") by which entities are transformed into intrinsically meaningless resources standing by for optimization. The ultimate goal of Heidegger's phenomenology of technology is thus to help us become aware of these nihilistic ontotheological lenses implicitly structuring our basic sense of ourselves and our world so that we can contest and transcend them.[12]

## Notes

1. Heidegger, M. (1962). *Being and Time.* Trans. J. Macquarrie and E. Robinson (New York: Harper & Row, p. 58; see also E. Husserl (1969). *Formal and Transcendental Logic*. Trans. D. Cairns (The Hague: Martinus Nijhoff), p. 234: "experienced being 'is there,' and is there *as what* it is, with the whole content and mode of being that experience itself, by the performance going on in its intentionality, attributes to it." See also Inwood, M. (1999). *A Heidegger Dictionary* (Oxford: Blackwell), pp. 159–60; and Moran, D. (2000). *An Introduction to Phenomenology* (London: Routledge), p. 6.
2. Radicalizing Husserl's project, Heidegger argued that Husserl's understanding of consciousness as an immanent sphere of intentionality was itself an example of a theoretical model inappropriate to the phenomenon it seeks to describe. Seeking to eradicate Husserl's residual Cartesianism, Heidegger proposes his notion of *Dasein* or "being-here" – i.e., the making-intelligible of the place in which one finds oneself – as a maximally neutral description of the phenomenon that Husserl's "consciousness" seeks to describe.
3. "Mental representation" is a doubly dubious concept phenomenologically, because I do not typically experience *representations* at all, let alone as taking place *in* my "mind," as if consciousness were some sort of container for representations of a world exterior to consciousness. As Husserl already recognized, "experience is not an opening through which a world, existing prior to all experience, shines into a room of consciousness; it is not a mere taking of something alien to consciousness into consciousness" (*Formal And Transcendental Logic*, p. 232). Heidegger sharpens Husserl's point, writing that "the perceiving of what is known is not a process of returning with one's booty to the cabinet of consciousness after one has gone out and grasped it" (*Being and Time*, p. 89).

4. See Allison, H. (1983). *Kant's Transcendental Idealism: An Interpretation and Defense* (New Haven, Conn.: Yale University Press), pp. 65–8.
5. In more contemporary terms, Husserl's eidetic intuition seems to resuscitate a belief in what orthodox Kantians – who subscribe to a scheme/content dualism by treating sensory "intuition" and conceptual "understanding" as dichotomous – would call a *myth of the given*. But the neat dichotomies assumed by the orthodox Kantian view, long challenged by phenomenologists, are now under siege from numerous quarters, including the holism and neo-pragmatism of Davidson and Putnam, the neo-Kantianism of McDowell, and the neo-Hegelianism of Brandom. I develop some of the important ethico-political implications of this fundamental ontological disagreement in Iain Thomson, "Environmental Philosophy," in H. L. Dreyfus and M. A. Wrathall (eds) (2006), *A Companion to Phenomenology and Existentialism* (Oxford: Blackwell).
6. In other words, Kant's categories look like the type of "hard-wired" conceptual structures that, if they possess a discernible neurophysiological correlate, a future neuroscientist should in principle (or even in practice – say, with a time machine and suitably advanced brain imaging technology) be able to uncover them in any conscious human being from any point in history.
7. See Husserl, E. (1970). *The Crisis of the European Sciences and Transcendental Phenomenology.* Trans. D. Carr (Evanston, Ill.: Northwestern University Press), pp. 46–53. This is a late Husserlian work, and clearly shows the influence of Husserl's critical reading of Heidegger's *Being and Time*, as argued in Ihde, D. (1987). *Instrumental Realism: Interface between Philosophy of Science and Philosophy of Technology* (Bloomington, Ind.: Indiana University Press).
8. Heidegger is deeply worried that within our current technological constellation of intelligibility, the post-Nietzschean epoch of enframing, it is increasingly becoming the case that: "Only what is calculable in advance counts as being." For our technological understanding of being produces a "calculative thinking" which quantifies all qualitative relations, reducing entities to bivalent, programmable "information," digitized data ready to enter into what Jean Baudrillard aptly describes as "a state of pure circulation" on the Internet. See Heidegger, M. (1998). "Traditional Language and Technological Language." Trans. W. T. Gregory, *Journal of Philosophical Research*, 23: 136, 139; Heidegger, M. (1966). *Discourse on Thinking*. Trans. J. Anderson and E. Freund (New York: Harper & Row), p. 46; and Baudrillard, J. (1993). *The Transparency of Evil: Essays on Extreme Phenomena.* Trans. J. Benedict (London: Verso), p. 4. See also Dreyfus's important (2003) monograph, *On the Internet* (London/New York: Routledge).
9. Among other phenomenological reductions, Husserl taught his students to practice an "eidetic reduction" in order to help them learn to discern the eidetic intuitions mentioned earlier. See also Moran, *Introduction to Phenomenology*, pp. 134–6.
10. The point is perhaps best-illustrated with an anecdote. I vividly recall Don Ihde, the leading Husserlian phenomenologist of technology, performing Husserlian "phenomenological variations" in which he compared (1) a technologically advanced virtual fish-tank I discovered in the lobby of our Tokyo hotel (the simulacra was so realistic that several days passed before I noticed that the fish-tank was a fake, although we all walked by it numerous times on our way in and out of the hotel – a nice illustration of the "hiding in plain sight" predicted by phenomenology's law of proximity, which technology reinforces by bringing the distant near and so distancing the near from us) with (2) a real fish-tank Ihde encountered in a restaurant soon after I pointed out the fake one to him. Ihde sought in this way to identify the essential structures common to the idea of fish-tank as such, isolating these structures from the contingent properties instantiated in the technological simulacrum and the random fish-tank. In his obvious mastery of this Husserlian task, Ihde

showed a real knack for discerning patterns instantiated across the minutiae of concrete differences between technologies (and, not surprisingly, Ihde's work has been extremely insightful about the way advances in technological instrumentation drive conceptual revolutions, and not simply the reverse). Yet this very strength, this knack for discerning shared patterns across concrete differences, seemed to come with a weakness as well, for it left the Husserlian without any non-question-begging means of approaching the much larger and more abstract question of the essence of technology as such. (Even if it were not an untenably enormous task, one could not gather together all the different technological devices in order to examine them phenomenologically without some prior criterion for what makes all and only these devices *technological* in the first place.) A Heideggerian, by contrast, would abandon the systematic and scientific pretensions of Husserlian phenomenology and instead accept the unavoidable hermeneutic circularity involved in the attempt to distinguish the technological from the non-technological phenomenologically. (On the Heideggerian approach, the ordinary fish-tank looks like a typically modern artifact, an instance of the human subject's control over an objective world, whereas the technological fish-tank appears as a late-modern technological object, an instance of our reduction of all entities to intrinsically meaningless resources increasingly caught up in an endless cycle of efficient optimization.) Heidegger thus suggests that we should understand the emergence of "technology" in terms of its more than two millennia history, as an eventual eclipse of *poiesis*, bring into being, by one of its species, *techne*, a making which imposes a pre-given form on matter without regard for its intrinsic potentialities. The difference can be starkly illustrated by comparing the woodworking artisan, who decides what to make out of a piece of wood by closely studying it in order to discern its intrinsic potentialities, with the contemporary furniture mill, which reduces all the different wood to sawdust, pastes it back together as particle board, and then ships it to mass suppliers for use in a maximal variety of building applications. That human beings now treat each other like such particle board is, for Heidegger, technology's "greatest danger." For more on this point, see "Understanding Technology Ontotheologically; or, The Danger and the Promise of Heidegger, an American Perspective," in J. K. B. Olsen, E. Selinger and S. Riis (eds), *New Waves in the Philosophy of Technology* (New York: Palgrave Macmillan, 2008).

11. On this enframing of silence, see Baudrillard, J. (2006). *Cool Memories V*. Trans. C. Turner (Cambridge: Polity Press), p. 29: "First victim of the screen: silence. No living silence on television ever again, but minutes of artificial silence, of dead silence, stocked like spare parts or replacement organs, for the needs of the program." Another important philosopher of technology who, along with such French thinkers as Foucault, Baudrillard, de Certeau, and Lyotard, applies and so revealingly develops Heidegger's critique of technologization is Albert Borgmann; see his (1997) *Technology and the Character of Contemporary Life: A Philosophical Inquiry* (Chicago, Ill.: University of Chicago Press).
12. For a much more careful development of the arguments summarized here, see Thomson, I. (2005). *Heidegger on Ontotheology: Technology and the Politics of Education* (New York: Cambridge University Press).

# 35

# Expertise

## EVAN SELINGER

Dating back at least as far as Plato's writings on *techne*, issues of expertise have been vexing for quite some time. Today, they have become inter-disciplinary topics that are widely acknowledged as having profound social and political consequences as well as decidedly epistemic and normative dimensions.

For example:

Questions about how to identify experts and when to defer to them remain daunting. The problem of whether genuine expertise can be distinguished from its social markers cuts across and even reshapes disciplinary boundaries. The conundrum of how to classify and organize different kinds of expertise traverses descriptive and prescriptive terrain.

While scientific and technological authority remain at the forefront of the expertise debates, phenomenological concerns, such as the nature and scope of skill acquisition and embodied action, also occupy a central role. Matters of discretionary power, media bias, litigation and shared governance occupy center stage as well. Here's why.

In the abstract, it is easy to see experts as special kinds of people whose relation to knowledge, skill and experience entitles them to respect. In an increasingly specialized age in which information is rapidly proliferating and scientific research is delegated to teams of inquirers, it seems rather difficult for people to acquire in-depth understanding of multiple specialized fields. And, while the division of labor makes it incumbent to diversify and proliferate talents, skills, interests and training, individuals appear to benefit from the ease of consumerism – from being able to use electronic and mechanical devices, as well as applied medical technologies, without obtaining a sophisticated understanding of how the means of production and distribution relate to the ends of use and habituation.

Despite the gains that result from managing "resources" and "ignorance" in this way, experts have increasingly become subject to critical scrutiny and distrust. Scandals, such as that surrounding Hwang Woo Suk's false claims about cloning research, have reminded the public that integrity can be marred by competition, and that the standards maintained by the current peer-review process are imperfect. Beyond blatant instances of unethical conduct, more subtle problems concerning bias and ideology remain. By considering the following problematic but widely discussed cases, some of these issues can be crystallized.

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Recent debates over global warming and "natural" disasters highlight the difficulty of disentangling scientific judgment from political ideology. When considering the same "evidence," some find economic motivations and racism at play, while others counter that such accusations are rooted in a misunderstanding of natural causes. This tension is not relegated to esoteric academic musings. Caustic versions abound in mainstream media coverage of the Kyoto Protocol, Hurricane Katrina and other related topics.

Controversy between advocates of intelligent design and natural evolution has raised anew questions about how science and religion might be demarcated from one another. The complexities of these debates have even called into question what counts as a secular and what counts as a religious perspective. In challenging scientific authority, some have gone so far as to denounce proponents of natural selection as "high priests of Science." Moreover, heated exchange has been prompted over the role that public opinion should play in shaping the curriculums that guide taxpayer-funded education.

The issue of medical objectivity continues to grab headlines, with particular emphasis being given to psychological diagnoses and alternative medical therapies. With hot topics such as cancer, depression, Attention Deficit Disorder, chiropractic care, and homeopathic remedies, the problem of how to distinguish sound clinical classification from economic motivation and cultural bias seems destined to be caught in interminable dispute. So, too, does the difficulty of deciding how to evaluate first-person accounts of successful treatment that differ from reports derived from more "objective" "evidence-based" approaches. Indeed, the financial success of Airborne – a dietary supplement "invented" by a former elementary-school teacher that putatively helps fight cold symptoms – illustrates that, in some instances, people are less interested in independent scientific evidence than they are in "folksy" markers of trust. Suspicion of the greed exhibited by the mainstream pharmaceutical industry – fanned, for example, by the recent Vioxx lawsuits and trials – may be pertinent here as well.

With respect to legal matters, the famous 1993 US Supreme Court case, *Daubert v. Merrell Dow Pharmaceuticals* was an attempt to construct a practical solution to the difficult problem of screening out junk science. Unfortunately, questions about its effectiveness remain. Some claim that it has had a tendency to produce expensive and time-consuming pretrial hearings that discourage the kind of sound gatekeeping that the decision was intended to establish. Others worry that the case inadvertently created new obstacles for sorting through competing claims made on behalf of frontier and mainstream researchers. Beyond these issues, additional reflections have questioned whether due process itself is compromised by the manner in which juries assess expert testimony. Finally, phenomenologists have questioned whether expert testimony, in general, is predicated upon a performance in which intuitive understanding remains hidden and rationalization dominates.

The expertise debates continue to generate momentum in discussions about the advantages and disadvantages that have arisen in connection with new computer practices of acquiring and disseminating information. For example, long-standing convictions about credentials are being challenged by advocates of *Wikipedia*, an online encyclopedia that is not driven by content experts, and whose entries can be altered by essentially anyone who desires to change them. While instances of error and even fraud have been discovered, *Nature* recently concluded that *Wikipedia* and the *Encyclopedia Britannica* have nearly comparable levels of accuracy. Furthermore, as debates about reports occurring on blogs have allegedly brought traditional reporting to the threshold of a crisis, intrigue into the collaborative categorization of information by means of using social software to "index" information instead of "classifying" it has raised powerful questions concerning who has the right to manage data. At the heart of these debates may very well be confusion about fundamental relations between knowledge, skill and experience. This is evidenced by the fact that questions about the prerequisites for expert judgment are now being raised. How much firsthand experience is necessary to be an expert? What kind of training is required to be an expert? These queries are, perhaps, only in their embryonic stages. They should shape the debates for some time to come.

Finally, it should be noted that, in some of the literature on indigenous culture, the very notion of expertise has become synonymous with Western imperialism. The central idea conveyed in this context is that, even when well intentioned, much of the "development" work that is undertaken to address the poverty of "developing" regions remains chauvinistic. As a consequence of advocating particular models of efficiency, it is alleged, the traditional skills are unfairly devalued and traditional forms of life are mischaracterized as backward. Moshoeshoe II expresses this point clearly in the context of interventions in Africa when he writes:

> "Experts" have shown a total disregard and ignorance of Africa's long-established and successful methods to ensure their survival and well-being. . . . Such "experts" have also failed to understand either the social or ecological base of the cultural practices on which they seek to impose their externally derived solutions, constructed in an entirely different socioeconomic and ecological context. The result is that many of their agricultural strategies and environmental solutions have proved disastrous for the people, wildlife, and natural environment of Africa.

# 36

# Imaging Technologies

## DON IHDE

A major group of technologies in the contemporary world is unquestionably that of the imaging technologies, so important for artistic, scientific, communication and entertainment activities. The production of images by humans can be traced at least back to the Ice Ages – excellent images of animal life 34,000 BP were found in Chauvet, France. And, since, in this entry, both visual and auditory image technologies will be featured, a bear-bone flute associated with a Neanderthal site has been dated back to 45,000 BP. These visualizations and acoustic sounds were "hand produced" with minimalist technologies such as pigments and brushes and the bear-bone musical instrument.

More complex imaging processes arise in antiquity, and the best-known of these imaging processes – at least in the West – is probably the shadow theater imagined by Plato and known as the "allegory of the cave." Here a light source (fire) casts the shadows of cut-out objects upon the cave wall (screen) somewhat like an Indonesian puppet shadow theater. And, although it is unknown whether Plato knew of the *camera obscura,* Aristotle and Euclid did (2350 BP); and Mo-Tzu, a Chinese mathematician, knew of it and described it approximately a century earlier (2450 BP), although its complete description and the science of its optics was described later by the Arab philosopher Al Hazen (1070 BP).

The *camera obscura* and its variants stand at the beginnings of a very long and complex technological trajectory of image-producing machines. The *camera* – early examples were usually room-sized – depends upon an external light source (sun or artificial), an aperture (at first hole, later with lenses) and a blank screen upon which is cast an upside-down image in two dimensions. And, although known in antiquity, possibly used to view eclipses, such devices became a popular part of the optical toolkits of the Renaissance in Europe. Alberti, da Vinci and many other artists of the fifteenth century used a *camera.*[1] Indeed, one tendency in the Renaissance seems to have been the increased instrumentalization of many human practices. The *camera* and other visual framing devices assisted in the development of so-called Renaissance perspective, but in music the earlier and mostly *a cappella* vocal music sung in sacred contexts was in this same period undergoing much instrumental development as well, with all the main families of instruments – brass, winds, strings and percussion – represented.

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Thus what we call early modern science in the seventeenth century arrived in an already instrumentalized culture. Early science, too, had its visualization technologies, most notably optical ones with the adaptation of earlier lens uses such as eyeglasses, later compounded into telescopes and microscopes.[2] Now, in a strict phenomenological sense, telescopes and microscopes, particularly if hand-held and without some added imaging device, are not yet fully imaging technologies. The "images" of Galileo's new telescopic discoveries – (*a*) the mountains of the Moon, (*b*) the satellites of Jupiter, (*c*) the phases of Venus – were produced as images through his own drawings thereof (and Galileo had a rather remarkable hand at drawing). The one exception – (*d*) sunspots – was produced by his invention of a *helioscope*, that is the casting of an image through the telescope on to an attached small screen, thus turning the telescope into a *camera obscura* variant. The seventeenth century also saw considerable development of acoustic inventions and experimentation. Large, separated hearing horns helped for long-range and stereo-directed hearing, echo chambers and spy devices were architecturally designed, as well as further musical instrumentation development.[3]

The eighteenth century produced yet more variants upon the *camera*, including the additions of focusable lenses, but also the replacement of a lens by a prism by Isaac Newton, producing spectra instead of isomorphic images, which, with the nineteenth century development of a slit instead of a round hole or its lensed variant, led to spectroscopy by the nineteenth century.

The nineteenth century then accelerates the continuum of imaging technologies. *Camera obscurae* undergo developments as "box" devices, lensed and focusable; and, although preceded with a few experiments to "fix" *camera* images with silver salts, Louis Daguerre improves upon the earlier processes and the *photographic camera* is invented and its processes publicized in 1839.[4] Not far behind are acoustic imaging processes which can *record* sounds – Thomas Edison invents the first cylinder mechanical recording technology in 1877. Both photography and phonography are quickly adapted to art, science, entertainment and communication practices in the entire industrial world.

It should be noted at this point that both visual and auditory imaging processes remained limited to *optical light* for vision and to the humanly hearable range of sound waves for recordings. The next plateau is reached once electricity becomes manipulatable. By the 1830s experimentation in electromagnetic processes yielded the first *dynamos* or electric current generators, thus laying the basis for electric and electronic imaging processes. Manipulation of what came to be known as the electromagnetic spectrum (EMS hereafter) opened the way to levels of emission detection both above and below the previous imaging ranges. Radioactive wave propagation through the use of cathode tubes led Wilhelm Roentgen to the discovery of X-ray imaging in 1895.[5] Noticing a glow from his cathode ray tube, he discovered that this strange light-like source could actually pass through his hand and cast a shadow-like image of his hand bones upon a plate – he later used a "shadowgraph" of his wife's hand with her ring to advertise his discovery.

This brings us to the twentieth century and what can now be recognized as the century beginning an explosive image technology revolution. Still photography evolved into cinema – later, with audio-visual combinations, to become "talkies" – to which one must add early radio and improved electrically produced sound recordings. By mid-century one can add television to cinema, many varieties of sound recording to radio and records, and communication versions of imaging technologies such as cable (wired) and radio (wireless) imaging. Then, later in the century, the further development of the electronic computer with its variant versions also becomes widespread. By century's end the "screen" is omnipresent.

Contemporary imaging technologies are qualitatively different in capacity from the predecessor technologies into the nineteenth century. Four such distinctive capacities may be noted:

Contemporary imaging technologies and the associated systems of emission detection – at least since the capacity to detect and image EMS frequencies beyond human optical light and human auditory perception – can now detect and image, with particular technologies, the full known range of the EMS. This capacity is probably most important in the sciences. For example, until the twentieth century *all astronomy was limited to observations within the optical light spectrum.*[6] With the accidental discovery of radio astronomy earlier in the century, and then the later imaging processes now possible, ranging from very short gamma ray to very long radio wave detection and imaging, the entire picture of the cosmos has changed. And, while early photography made time manipulation possible through faster exposure times – from Muybridge's time studies to Edgerton's stroboscopic images – it was not until X-rays and other "penetrating" technologies such as ground-penetrating radar that imaging could show interior structures. Today, this capacity is particularly important in medicine with the range of imaging running from X-ray to Magnetic Resonance Imaging (MRI) to Positron Emission Tomography (PET). At this now breaking of human perceptual limits, typical imaging is developed from "slices" of the EMS. In astronomy, for example, the Hubble Space Telescope contains a number of different cameras, attuned to different slices of the EMS. There is also the Chandra X-ray source telescope and others in a list too long to mention. Results are the now familiar images of Martian water erosion, Venusian mounts, and the ice surface of Europa. It is to be noted, however, that all such imaging from beyond human perceptual limits *translates* its imagery back into experienceable visualizations which include gestalt shapes, and "false colors."

The second capacity of contemporary imaging arises from the simultaneous development of computational technologies embodied in the electronic computer. The capacity to transform data into image, and its reversibility to transform image into data, produces a new set of imaging possibilities. A space probe taking any number of image technology slices – say, of a Martian surface – has the result first transformed into transmissible data to send back to the earthbound receiving station; and, once received, the data is transformed back into an image. More mundanely, this is also the process familiar to those who send digital photos over the Internet. Data, however, can also be reconstructed according to algorithms – as in fractal and chaos phenomena – to produce images which were not previously "imaged."

Third, contemporary imaging has a wide range of *constructibility* built into it. Computational processes include *tomography,* such that, for example, one can at one level "dial in" different sets of frequencies. MRI scans are typically taken of multiple slices through a brain, for example, at different frequencies and composed into the multiple images used by the neurologist. Or one can also do a *composite* through tomography of MRI, PET and CAT imaging to produce a more complete three-dimensional image of a possible brain tumor. Also included in such constructibility are both the rotational and slice capacities such that virtual anatomy and other virtual practices may be undertaken on the basis of imagery manipulation. One may add here, too, the development of holography and other three-dimensional imaging which is under current development.

The final contemporary imaging capacity to be noted here is what could be called *complexity* imaging, which is precisely what is also known as *modeling* and *simulation.* First used in the modeling of a complex atomic reaction during the development of the atomic bomb (Monte Carlo simulations), modeling and simulation is today a rapidly growing set of practices which include graphic modeling of global warming, hurricane simulation models, complex industrial processes and a whole range of similar complex phenomena visualized in computational gestalts.

Although this entry has concentrated on scientific imaging, the burgeoning of similar imaging in the arts, communications, contemporary media and entertainment is parallel. Indeed, artists using such imaging processes have also discovered that the capacity to transform data to image, and its reversal, also has a different potential. One can turn data into *either* a visualization *or* an acoustic image. Thus various performance artists have turned hurricane models into "music," and others have with time compression and data into acoustic form produced sound patterns of weather "songs" and the like.[7]

## Notes

1. David Hockney's *Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters* (New York: Penguin Putnam, 2001) may have shocked some of the art world in its claims concerning the use of the *camera obscura* in Renaissance art practice, but historians of technology had been familiar with this fact as a commonplace for decades.
2. Lenses for uses in eyeglasses were common in Europe by the thirteenth century and, similarly, were also in use in China.
3. An interdisciplinary group located at the Free University of Berlin produced a major study of instruments in both art and science in the seventeenth century; see Ludgar Schwarte, Helmar Schrum and Walther Lazarzig, *Instrumente in Kunst und Wissenschaft* (Berlin: Walter de Greuter, 2006).
4. Joseph Niepce had used silver salts to fix photographic images before Daguerre, but Daguerre perfected the process and published his results in 1869 – photography as a technology was immediately adopted in the industrial world of the time and its use in science through connecting a photographic camera to both standard and spectroscopic telescopes occurred within a year of Daguerre's publication.
5. A full account of medical imaging, from the X-ray on, may be found in Betty Ann Kevles, *Naked to the Bone* (Reading, Mass.: Addison-Wesley, 1998).
6. See Nigel Henbest and Michael Marten, *The New Astronomy*, 2nd edn (Cambridge: Cambridge University Press, 1996). The new astronomy is a term applied to EMS frequencies beyond the optical spectrum.
7. Andrea Polli from Hunter College developed the technique of turning model data into acoustic recordings, and Felix Hess has developed a series of time-compressed acoustic records of both natural and socially produced imaged sound.

## References and Further Reading

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# 37

# The Critique of the Precautionary Principle and the Possibility for an "Enlightened Doomsaying"

### JEAN-PIERRE DUPUY

All the fears of our age seem to have found shelter in one word: precaution. Yet the conceptual underpinnings of the notion of precaution are extremely fragile.

Let us recall the definition of the precautionary principle formulated in the Maastricht treaty:

> The absence of certainties, given the current state of scientific and technological knowledge, must not delay the adoption of effective and proportionate preventive measures aimed at forestalling a risk of grave and irreversible damage to the environment at an economically acceptable cost.

A first serious deficiency which hamstrings the notion of precaution is that it does not properly gauge *the type of uncertainty* with which we are confronted at present. The very formulation of the precautionary principle makes it clear that it places itself from the outset within the framework of epistemic uncertainty, i.e. a form of uncertainty that resides in the mind of the knowing subject rather than in the objective properties of the outside world. The presupposition is that we know we are in a situation of uncertainty. It is an axiom of epistemic logic that if I do not know *p*, then I know that I do not know *p*. Yet, as soon as we depart from this framework, we must entertain the possibility that we do not know that we do not know something. In cases where the uncertainty is such that it entails that the uncertainty itself is uncertain, it is impossible to know whether or not the conditions for the application of the precautionary principle have been met. If we apply the principle to itself, it will invalidate itself before our eyes.

Moreover, "given the current state of scientific and technological knowledge" implies that a scientific research effort could overcome the uncertainty in question, the existence of which is viewed as purely contingent. It is a safe bet that a "precautionary policy" will inevitably include the edict that research efforts must be pursued – as if the gap between what is known and what needs to be known could be filled by a supplementary effort on the part of the knowing subject. But it is not uncommon to encounter cases in which the progress of knowledge comports an increase in uncertainty for the

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decision-maker, something which is inconceivable within the framework of epistemic uncertainty. Sometimes, to learn more is to discover hidden complexities that make us realize that the mastery we thought we had over phenomena was in part illusory.

However, the most important reason that leads us to deem the precautionary principle an insufficient tool if we are to confront the new threats that put the survival of humankind in jeopardy is that, by placing the emphasis on scientific *uncertainty*, it utterly misconstrues the nature of the obstacle that keeps us from acting in the face of catastrophe. The obstacle is not uncertainty, scientific or otherwise; the obstacle is *the impossibility of believing that the worst is going to occur.*

Even when it is known that it is going to take place (think of global warming), a catastrophe is not credible: that is the principal obstacle. On the basis of numerous examples, an English researcher identified what he called an "inverse principle of risk evaluation": the propensity of a community to recognize the existence of a risk seems to be determined by the extent to which it thinks that solutions exist. To call into question what we have learned to view as progress would have such phenomenal repercussions that we do not believe we are facing catastrophe.

In addition to psychology, the question of future catastrophe brings into play a whole metaphysics of temporality. The world experienced the tragedy of 11 September 2001 less as the introduction into reality of something senseless, and therefore impossible, than as the sudden transformation of an impossibility into a possibility. The worst horror has now become possible, one sometimes heard it said. If it *has become* possible, then it was not possible before. And yet, common sense objects, if it happened, then it must have *been* possible.

French philosopher Henri Bergson describes the weird feeling of easiness and relief he experienced on 4 August 1914 when he learned that Germany had declared war on France. This uncanny familiarity contrasted sharply with the feelings that prevailed *before* the catastrophe. War then appeared to Bergson "*at one and the same time* as probable and as impossible: a complex and contradictory idea, which persisted right up to the fateful date."

In reality, Bergson deftly untangles this apparent contradiction. The explanation comes when he reflects on the work of art: "I believe it will ultimately be thought obvious that the artist *creates the possible at the same time as the real* when he brings his work into being," he writes. This reflection is no less valid in the case of a catastrophe.

Catastrophes are characterized by a temporality that is in some sense inverted. As an event bursting forth out of nothing, the catastrophe becomes possible only by making itself possible while becoming real. And that is precisely the source of our problem. For, if one is to prevent a catastrophe, one needs to believe in its possibility *before* it occurs. If, on the other hand, one succeeds in preventing it, its non-realization maintains it in the realm of the impossible; and, as a result, the prevention efforts will appear useless in retrospect.

It is this spontaneous metaphysics of the temporality of catastrophes that is the chief obstacle to the definition of a form of prudence adapted to our time. The concept of "enlightened doomsaying" proposes a solution founded on an antidote to that same metaphysics. The idea is to project oneself into the future and look back at our present and evaluate it from there. This temporal *loop* between future and past defines the metaphysics of *projected time*. It makes sense only if one accepts that the future is not only real but also fixed. The possible exists only in present and future actuality, and this actuality is itself a necessity.[1] More precisely, before the catastrophe occurs, it can *not* occur; it is in occurring that it begins to have always been necessary, and therefore that the non-catastrophe, which was possible, begins to have always been impossible. This metaphysics consists in *projecting oneself* into the time following the catastrophe, and in retrospectively seeing in the latter an event *at once necessary and improbable.* The (im)probability of a necessary event is no longer the measure of an ignorance that might have some chance of being only provisional (*uncertainty*). It is an element of reality, a reality that is not entirely determinate (*indeterminacy*).

The paradox of "enlightened doomsaying" presents itself as follows. To make the prospect of a catastrophe credible, one must increase the ontological force of its inscription in the future. But to do this with too much success would be to lose sight of the goal, which is precisely to raise awareness and spur action so that the catastrophe *does not take place.*

In projected time, the future is taken to be fixed, which means that any event that is not part of the present or the future is an impossible event. It immediately follows that, in projected time, prudence can never take the form of prevention (of which precaution is just a particular instance). Prevention assumes that the undesirable event that one prevents is an unrealized possibility. The event must be possible for us to have a reason to act; but if our action is effective it will not take place. This is unthinkable within the framework of projected time.

To foretell the future in projected time, it is necessary to seek the loop's fixed point, where an expectation (on the part of the past with regard to the future) and a causal production (of the future by the past) coincide. The predictor, knowing that his prediction is going to produce causal effects in the world, must take account of this fact if he wants the future to confirm what he foretold. Traditionally, which is to say in a world dominated by religion, this is the role of the prophet, and especially that of the biblical prophet. However, we are speaking of prophecy here in a purely secular and technical sense. The prophet is the one who, more prosaically, seeks out the *fixed point* of the problem, *the point where voluntarism achieves the very thing that fatality dictates*. The prophecy includes itself in its own discourse; it sees itself realizing what it announces as destiny.

The French planning system as it was once conceived by Pierre Massé constitutes the best example of what it means to foretell the future in projected time. It "aimed to obtain through consultations and research an image of the future sufficiently optimistic to be desirable and sufficiently credible to trigger the actions that would bring about its own realization."[2] It is easy to see that this definition can make sense only within the metaphysics of projected time, whose characteristic loop between past and future it describes perfectly. Here coordination is achieved on the basis of an *image* of the future capable of ensuring a closed loop between the causal production of the future and the self-fulfilling expectation of it.

The paradox of the doomsayer's solution to the problem posed by the threats hanging over humanity's future is now in place. It is a matter of achieving coordination on the basis of a negative project taking the form of a fixed future *which one does not want.* One might try to transpose the former definition into the following terms: "to obtain through scientific futurology and a meditation on human goals an image of the future sufficiently catastrophic to be repulsive and sufficiently credible to trigger the actions that would block its realization" – but this formulation would seem to be hobbled from the outset by a prohibitive defect: self-contradiction. If one succeeds in avoiding the undesirable future, how can one say that coordination was achieved by fixing one's sights on that same future? The paradox is unresolved.

The problem is to see what type of fixed point is capable of ensuring the closure of the loop that links the future to the past in projected time. We know that the catastrophe cannot be this fixed point: the signals it would send back toward the past would trigger actions that would keep the catastrophic future from being realized. If the deterrent effect of the catastrophe worked perfectly, it would be self-obliterating. For the signals from the future to reach the past without triggering the very thing that would obliterate their source, there must subsist, inscribed in the future, an *imperfection in the closure of the loop.* The maxim for a rational form of doomsaying becomes: "to obtain . . . an image of the future sufficiently catastrophic to be repulsive and sufficiently credible to trigger the actions that would block its realization, *barring an accident*."

One may want to quantify the probability of this accident. Let us say that it is an epsilon, $\varepsilon$, by definition weak or very weak. The foregoing explanation can then be summed up very concisely: it is because there is a probability $\varepsilon$ that the deterrence will not work that it works with a probability $1-\varepsilon$. What might look like a tautology (it would obviously be one in our usual metaphysics) is absolutely not one here, since the preceding proposition is not true for $\varepsilon = 0$. The discontinuity at $\varepsilon = 0$ suggests that something like an indeterminacy principle is at work here. The probabilities $\varepsilon$ and $1-\varepsilon$ behave like probabilities in quantum mechanics. The fixed point must be conceived as the *superposition* of two states, one being the accidental and preordained occurrence of the catastrophe, the other its non-occurrence.

The fact that the deterrence will not work with a strictly positive probability $\varepsilon$ is what allows for the inscription of the catastrophe in the future, and it is this inscription that makes the deterrence effective, *with a margin of error* $\varepsilon$. Note that it would be quite incorrect to say that it is the *possibility* of the error, with the probability $\varepsilon$, that saves the effectiveness of the deterrence – as if the error and the absence of error constituted two paths branching out from a fork in the road. There are no branching paths in projected time. The error is not merely possible, it is actual: it is inscribed in time, rather like a slip of the pen. The future is written but it is partially indeterminate. It includes the catastrophe but as an accident.

## Notes

1. The metaphysics of projected time rests on a novel solution to one of the oldest problems in metaphysics: Diodorus' Master Argument. See Vuillemin, J. (1996). *Necessity or Contingency: The Master Argument* (Stanford, Calif.: Stanford University, CSLI Publications).
2. Guesnerie, R. (1996), *L'Economie de marché* (Paris: Flammarion). The phrasing reflects the spirit of rational expectations.

# 38

# Technology and Metaphysics

## JEAN-PIERRE DUPUY

The positivist philosophy that drives most of modern science and technology (and much of contemporary philosophy) takes "metaphysics" to be a meaningless quest for answers to unanswerable questions; but Karl Popper, following the lead of Emile Meyerson, showed that there is no scientific (or, for that matter, technological) research program that does not rest on a set of general presuppositions about the structure of the world. To be sure, those metaphysical views are not empirically testable and they are not amenable to "falsification." However, that does not imply that they are not interesting, substantial, and that they do not play a fundamental role in the advancement of science. Those who deny metaphysics simply render it invisible, and it is very likely that their hidden metaphysics is bad or inconsistent. To the amazement of those who mistook him for a positivist, Karl Popper claimed that the philosopher or historian of science's task was twofold: first, unearth and make visible the metaphysical ideas that lie underneath scientific programs in order to make them amenable to criticism; second, proceed to a critical examination of those metaphysical theories, in a way that is different from the criticism of scientific theories, since no empirical testing is here possible, but nevertheless rational.

Two major philosophers from the seventeenth and eighteenth centuries can be said to have fleshed out the metaphysics underlying the new science the budding of which they were witnessing: René Descartes and Giambattista Vico. Descartes saw science and technology as aiming at making man master and possessor of nature and of himself. More subtly, Vico gave the postulate of the "new science" (1725) a celebrated formulation: *Verum et factum convertuntur* ("The true and the made are convertible"). This means that we can have rational knowledge only about that of which we are the cause, about that which we ourselves have made. The principle of *verum factum* was originally understood as implying a want or lack on the part of human beings: we can never know nature in the way that God does, for God created what we can only observe. Quickly, however, the principle acquired a positive sense more in keeping with the growing affirmation of modern subjectivism: what human beings make can be rationally – that is, demonstratively and deductively – known despite the finiteness of human understanding. Among the branches of knowledge, ranked in descending order according to their degree of perfection, mathematics by this criterion of course comes first, followed, however, not by the natural sciences but by

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the moral and political sciences, supposed to be more scientific because they deal with the products of human activity.

As regards the science of nature, however, its first principle, according to Hannah Arendt, had to be that one can know only in making or, rather, in remaking. Despite his human limitations, the scientist "nevertheless from the outset approached it [nature] from the standpoint of the One who made it."[1] This explains not only the scientist's emphasis on the "how" of physical processes rather than on the being of things, but also the considerable role assigned by science to experiment.

With the looming advanced technologies, we shall be one big step further. I am thinking in particular of the so-called Nano-Bio-Info-Cogno (NBIC) convergence which presents itself as the ultimate culmination of the *verum factum*. It is no longer merely by doing experiments on it, it is no longer merely by modeling it, that men will now come to know nature. It is by *remaking* it. But, by the same token, it is no longer nature that they will come to know, but what they have made. Or, rather, it is the very idea of nature, and thus of a given that is exterior to the self, which will appear outmoded. The very distinction between knowing and making will lose all meaning with the NBIC convergence, as will the distinction that still exists today between the scientist and the engineer. Already today, in the case of biotechnologies, the distinction between discovery and invention, on which patent law rests, is proving increasingly tricky to maintain, as the debates about the patentability of life forms demonstrate.

Under this general heading, we can include what some philosophers call "the artificialization of Nature" and, in particular, of Life and the Mind. The metaphysical program that drives the NBIC convergence, a Promethean project if ever there was one, is to turn man into a demiurge or, scarcely more modestly, the "engineer of evolutionary processes." Biological evolution, with its clumsy tinkering, has often botched the job, and it cannot be especially proud of its latest handiwork, man. It is up to man himself, then, to try to do better. This puts him in the position of being the divine maker of the world, the demiurge, while at the same time condemning him to see himself as out of date. We are dealing here with an extraordinary paradox of the coincidence of opposites, which such philosophers as Martin Heidegger, Hannah Arendt or Günther Anders have brought out: the overweening ambition and pride of a certain scientific humanism leads straight to the obsolescence of man. It is in this broad perspective that we must always set the specific questions which are termed "ethical" and which touch on the engineering of man by man.

The human condition is an inextricable mixture of things given and things made. This means that man, to a great extent, can shape that which shapes him, condition that which conditions him, while still respecting the fragile equilibrium between the given and the made. Now, already in the 1950s, Arendt prophesied a human rebellion against the given. She wrote:

> For some time now, a great many scientific endeavors have been directed toward making life also "artificial," toward cutting the last tie through which even man belongs among the children of nature. . . . This future man, whom the scientists tell us they will produce in no more than a hundred years, seems to be possessed by *a rebellion against human existence as it has been given*, a free gift from nowhere (secularly speaking), which he wishes to exchange, as it were, for something he has made himself.[2]

Indeed, the metaphysics of the NBIC convergence dreams of overcoming once and for all every given that is a part of the human condition, especially the finiteness of a human life – its mortality and its beginning in birth. If immortality has always had a place in man's thoughts or dreams, it is only very recently that death has come to be considered a "problem" which science and technology can solve by eliminating it. As for birth, the fact that we are born into the world without our having had anything to do with it has become a source of shame (Günther Anders). We discover that we have been *thrown* (the Heideggerian *Geworfenheit*) into the world and we feel abandoned. We experience forlornness when we realize that we are not the foundation of our own being. Technology fantasmatically promises a remedy for this feeling of nausea: (re)designing ourselves, partially or totally, as if we were our own machines.

At the heart of the metaphysical research program that drives much of contemporary technology, there is an enormous paradox. The metaphysics in question clearly wants to be *monist*: one would no longer say today that everything in the universe proceeds from the same *substance*, but one will say that everything is subject to the same *principles of organization*: nature, life and the mind. The watchword of cognitive science is "*naturalizing* the mind." It is a matter of fully restoring the mind (and life) to their proper place within the natural world. Now, it happens that the principles of organization supposed to be common to everything that exists in the universe are mechanistic principles. A device that processes information according to fixed rules, that is, the algorithm, constitutes the sole model of everything that exists. Chronologically, and despite what certain preconceptions might suggest, the mind was first to be assimilated to an algorithm (or Turing machine: McCulloch and Pitts's model, 1943); next was the turn of life, with the birth of molecular biology (Max Delbrück and the "phage group," 1949); and only later came the thesis that the laws of physics are recursive (or *Turing computable*). The naturalization of the mind thus merges with the mechanization of the mind.

Is the ambition to (re)make the world tantamount to *controlling* it, in keeping with Descartes' metaphysics? Thinking so would mean that one remains blind to a fundamental shift in the philosophy of contemporary technology. It is often the case that the philosophy implicit to a new field is given away, admittedly in a crude way, by its visionaries and ideologues. On this score it is difficult to be more explicit than Kevin Kelly when he writes: "It took us a long time to realize that the power of a technology is proportional to its inherent *out-of-controlness*, its inherent ability to surprise and be generative. In fact, unless we can worry about a technology, it is not revolutionary enough."[3]

In 1948, the great American mathematician John von Neumann, the inventor of game theory and automata theory, but also a major contributor to the design of the A- and H-bombs, prophesied that soon the builder of automata would find himself as helpless before his creation as we feel ourselves to be in the presence of complex natural phenomena. He was thus founding the so-called *bottom-up approach* that has become the landmark of nanotechnology. In keeping with that philosophy, the engineers of the future will no longer be the ones who devise and design a structure capable of fulfilling a function that has been assigned to them. The engineers of the future will be the ones who know they are successful when they are surprised by their own creations.

The paradigm of *complex, self-organizing systems* envisioned by von Neumann is stepping ahead at an accelerated pace, both in science and in technology. It is in the process of shoving away and replacing the old metaphors inherited from the cybernetic paradigm (the one whose main concept is "control"), like the representations that treat the mind or the genome as computer programs. Complexity has already become a catchword in biology.

The time has not come – and may never come – when we manufacture self-replicating machinery that mimics the self-replication of living materials. However, we are using more and more living materials and their capacity for self-organization to mimic smart machinery or perform mechanical functions. We are manufacturing self-organization and soon we shall be able to unchain complexity, that is, create irreversible processes that would never have existed without human intervention. The height of this ambition will be reached when or if we become able to manufacture life itself – not necessarily the kind of life that emerged spontaneously on this planet one billion years ago and evolved into ever more complex forms, but organizations that have the basic properties which we attribute to life: self-replication and self-complexification.

It will then be an inevitable temptation, not to say a task or a duty, for the technologists of the future to set off processes over which they have *no control*. The myth of the sorcerer's apprentice must be updated: it is neither by error nor by terror that Man will be dispossessed of his own creations but *by design*.

## Notes

1. Arendt, H. (1958). *The Human Condition* (Chicago, Ill.: University of Chicago Press), p. 295.
2. ibid., pp. 2–3.
3. Kelly, K. (in progress). "Will Spiritual Robots Replace Humanity by 2100?," in *The Technium*, http://www.kk.org/thetechnium/

# 39

# Large Technical Systems

## ERIK VAN DER VLEUTEN

## Background

The notion of Large Technical Systems (LTS) refers both to an *approach* to understanding and analyzing sociotechnical change, and to a *class of phenomena* – large infrastructural and production systems – which are particularly suited for analysis by an LTS approach.

LTS thinking finds its roots in the American historian Thomas P. Hughes's book *Networks of Power: Electrification in Western Society 1880–1930* (1983). In the late 1980s, the LTS approach was positioned among the promising "new directions in the sociology and history of technology" next to the Social Construction of Technology (SCOT; see Chapter 15) and Actor-Network Theory (ANT; see Chapter 64).

Simultaneously, an LTS literature emerged to investigate large infrastructure and production systems. Since then, the conceptual framework and the empirical range of inquiry have steadily expanded.

LTS-informed work is best-presented not as a coherent theory in a strict social science sense, but rather as comprising a variety of narratives, concepts and research strategies that can inspire inquiry. These are usually guided by two original concerns.

A first important original concern was to criticize and transcend the customary focus upon artifacts or machines in history and sociology, routinely investigating the lightbulb, locomotive, motorcar or assembly line as loci of technological change and harbingers of major social changes. Such artifacts, however, were only the most visible of many interacting elements that jointly formed entire "systems" for electricity supply, transportation, or industrial production. In electricity supply systems, for instance, the designs of steam engines, generators, distribution networks, and consumer appliances were mutually adapted and aligned into one functioning whole. Such systems constitute true frontiers of twentieth-century technical change as well as important "deep structures" in modern societies. Therefore, in LTS research, systems, not their most visible elements, form the primary unit of inquiry.

A second original concern is that explaining the development, functioning and societal implications of such systems demands understanding their *sociotechnical* nature (a concern shared with SCOT and ANT). In the case of electricity supply systems, design properties also interacted with non-technical system elements as company structures, financial possibilities and obligations, negotiated government concessions,

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and consumer practices. Traditional analytic categories apriori separating the "technical," "political" and "economic" obscure such sociotechnical intertwinement. Worse, they may superimpose analytical boxes that obscure the sociotechnical fabric from view. Hughes and others therefore developed alternative concepts to inquire how the sociotechnical fabric is woven, how it works, and how it intertwines with broader societal changes.

These concerns inspired historical narratives of the development of specific systems and the history of large technical systems as a category *sui generis*; the development of strategies for building and managing systems; and the intertwinements of LTS development and the shaping of cities, nations and regions. For reasons of space, I shall here focus on the LTS *approach* and key concepts informing the inquiry of LTS dynamics and its societal implications.

## Concepts for Examining LTS Dynamics

As the most common denominator, studying technologies from an LTS perspective, whether electricity supply, uranium supply chains, steamboats, or weapon production systems, means bringing into vogue their systemic and sociotechnical aspects. Beyond that, there is no consensus on defining words like "large," "technical" and "system." It is true that early LTS studies often presupposed centralized control over all system elements and excluded anarchistic systems like road and water transport. Later studies, however, examined exactly self-regulation and coordination mechanisms in "loosely–coupled" large technical systems. Likewise, some authors have defined large technical systems by function (communication, transport, energy supply), while others investigated challenges and problems due to their multifunctionality (again, particularly in water-based and road systems).

A number of concepts aim to spotlight the systemic and sociotechnical character of LTS development. Most of them were first introduced by Hughes. Regarding overall system development, Hughes identified a "loosely defined" pattern of LTS development with "overlapping yet discernible" phases. In an *invention phase* a new technological system emerges around radical inventions. In a *development phase* this nascent system is adapted to economic, political and social characteristics needed for survival in the "use world," typically at test sites. An *innovation phase* adds further system components relating to manufacturing, sales and service facilities, enabling the system to enter the market. In a phase of *competition and growth* the system expands and adapts in competition with rival systems. In a *consolidation phase* a system has acquired so much "momentum" that it is difficult to change, creating an appearance of autonomy from its environment. A *technology transfer phase* may occur at any time during a system's history. Here it is exported to different environments, for instance different countries, and adapted to new natural, social and technical contexts. Finally, other authors soon added a phase of *stagnation* or decline, which was lacking in Hughes's original publications.

Several concepts specify driving forces behind such system development. First, the concept of *system-builders* brings human agency into the analysis of sociotechnical system development (which was ignored in earlier system theories, most notably general systems theory). The concept refers to individuals and (later) organizations that mold and align technical and non-technical elements into a sociotechnical whole; they do the sociotechnical weaving. The concept suggests studying key actors not as heroic inventors, but as dedicated builders of sociotechnical systems: Thomas Edison was not so much concerned with "inventing" the lightbulb as with designing and selling entire electricity supply systems, which demanded simultaneous work on a commercial vision, contracts with local governments and financiers, setting up new companies, marketing, and new generator, distribution network and lightbulb designs.

Often, system-builders work by identifying *reverse salients* – elements lagging behind and restraining total system development – and translate these into *critical problems* that may (or may not) be solved. Such reverse salients and problems can be of a technical or non-technical nature; system-builders engage in *trans-disciplinary problem-solving*. Furthermore, different types of system-builders dominate different phases of system development. *Inventor-entrepreneurs* such as Edison are crucial during invention, development and innovation, while *manager-entrepreneurs* (e.g. Henry Ford setting up his automobile production system) preside over the growth phase. *Financier entrepreneurs* and consulting engineers are the main players in the consolidation phase. System-building approaches also varied in time: *modern system-building* refers to top-down hierarchical organization structures and micro-management in the pre-Second World War period, while *postmodern system-building* of the 1990s reflects counterculture values such as horizontal organization and participative system-building – giving stakeholders access to the design process. *Ecotechnical system-building* refers to restoring and redesigning natural systems like river or forest systems.

Hughes's original concept paid scarce attention to one important human attribute – conflict. It emphasized how system-builders manipulated and aligned system elements in a rather top-down fashion. Later studies, by contrast, often examine system-building as a game involving many actors, full of negotiation and possibly conflict, producing winners as well as losers. They study system-builders as a methodological move to gain access to the systemic, sociotechnical and contested character of sociotechnical change.

Other concepts point at structural drivers of system development. The concept of *technological style* expresses how the designs of systems and their interrelated technical and non-technical elements change when transferred to other social, natural or technical environments.

By contrast, the concept of *momentum* articulates the apparent autonomy of mature large technical systems, resisting pressures for change. This physics metaphor suggests a "mass" (again, in terms of interrelated technical and non-technical elements as invested capital, actor commitment, employment, user habits, etc.) traveling with a certain "speed" in a certain "direction" (e.g. geographical expansion or scale increase). The concept is broader than comparable concepts of "path dependency" and "lock-in" in the economics of innovation. Large-scale electricity supply had reached considerable momentum by the 1930s; the trajectory of scale increase proved difficult to change since.

Related concepts explaining growth and momentum address economic performance. Next to economies of scale and scope, Hughes introduced the concepts of *load factor* and *economic mix* from the electricity supply world. A high load factor denotes a stable system load, allowing better usage of the available machinery and thus a quicker return on investment. An economic mix denotes the pooling of production facilities with different characteristics so as to optimize production costs at any given moment.

Later research has further nuanced these insights. In particular, Arne Kaijser and his Swedish collaborators have developed a wealth of concepts differentiating between systems with different technical, geographical, economic and institutional properties, with due implications for their development patterns. For instance, systems with artificial or *specific links* like railroads or electricity supply networks are less easily changed than systems using *nature-based links* like maritime navigation or air transport, or already *existing links* like the postal system. In the Baltic countries after the transition, air connections were predominantly reoriented to the West, while train and electricity connections remained focused on Russia and the Ukraine. Systems vary geographically on their local, provincial, national or international scale and their representation by dots (like self-generating electricity units), lines (like railroads) or fields (like radio systems). Economic criteria include financing and pricing methods, while institutionally systems diverge on forms of government control and forms of cooperation between key actors like operators, equipment suppliers and users.

Much work has been done on the issue of system stability and change, particularly in the light of a desired transition toward more sustainable transport and energy systems. If mature large technical systems are characterized by a large momentum and resist change, only extreme external conditions like warfare, oil crises, environmentalism and government interference may change the development trajectory. The policy implication is that, to assist change, policy-makers should set up protected spaces or “niches” where new systems can be invented and grow, protected from the established system until they are able to compete. Another strategy is to generate innovative views on future system developments in the minds of the main stakeholders using participative technology assessment methods. Current policy tools for sustainable technological development as Strategic Niche Management and sociotechnical scenario development partly lean on LTS insights.

Some authors, however, dismiss the assumption that mature systems cannot change. Closed systems can open up and adapt to new internal and external circumstances. In this vein, ongoing work on system innovations is developing a taxonomy of transition paths originating either from within or outside existing systems.

## Societal Implications of LTS

LTS authors see large technical systems as “deep structures” shaping individual and social life. Conceptualization of LTS’s societal (in the broadest sense) implications has been limited, though, mainly because of a general concern to steer clear of Technological Determinism. Only recently it was commonly accepted that the technological shaping of society can be investigated in non-determinist ways.

The notion of sociotechnical system-building, of course, already encourages inquiry of several LTS-related societal changes, namely those that are part and parcel of the sociotechnical construction process. For instance, electricity supply systems made light and power omnipresent, Swedish or Norwegian hydropower systems secured national energy independence, and the Australian interstate power grid should break the state-owned utility monopolies that kept prices up – and break coal-miner strikes that were organized at the state level.

Other approaches bring into vogue indirect, often unanticipated and long-term societal changes related to LTS development. Once built, *users* may use large technical systems in multiple, sometimes surprising ways. Users, too, are agents of indirect LTS-related societal changes. Large-scale industries used electric drive to design even larger factories; medium- and small-size industries, however, employed electric drive to improve their competitive position relative to large factories. Households helped shape the meaning of electricity and gas supply systems in the home. *Institutional users* such as the military, the food sector or the health sector built their own systems (so-called *second-order large technical systems*) for defense and warfare, food supply, and organ transplantation on top of existing transport and communication systems.

Finally, some changes follow the *intrinsic properties* of large technical systems. Electricity supply and automobility systems initially greatly reduced urban reduction, but in the long run their massive diffusion created new forms of regional and global pollution such as acid rain and the greenhouse effect. System properties also may enhance new consciousness and mental spaces; space exploration systems inspired a rediscovery of a fragile blue planet Earth and the concept of the biosphere, train travel interfered with perceptions of the landscape, etc. Such LTS-related changes may have a deterministic character, whether as a natural science cause-and-effect relation (effects on the natural environment) or as a "force field" favoring some changes above others (in the social world), but remain too important to be excluded from critical analysis as undesirable "Technological Determinism."

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# 40

# Sociotechnical Systems

MAARTEN FRANSSEN AND PETER KROES

The core of technology is the design and realization – which includes manufacture, implementation and maintenance – of technical artifacts. The prototypical artifact is a single material object designed to be used by a particular person for a particular purpose. There is an important class of artifacts, in the sense of man-made constructs, that cannot be seen as a single connected material object, nor as having a single user or even a sequence of single but distinct users. Typical examples are the infrastructures that form the backbone of our societies: the air and road transportation systems, the electricity and gas networks. Such artifacts have a diffuse multitude of users, a multitude that is, moreover, heterogeneous in that the purposes for which the users participate in its use may be quite different. It is increasingly being recognized that artifactual constructs of this sort have particular properties that set them apart from other artifacts, and pose special problems to the people who are involved in designing and implementing them, which has led to their being referred to by the special term *sociotechnical systems*.

Sociotechnical systems are, first of all, systems. The notion of system, however, is extremely general. Any single-user consumer artifact is a system in that it consists of various components, where the behavior of the overall artifact results from a careful matching of the input–output relations between these components. Still, these components are all similar in being material objects for which a scientific description is available that enables engineers to investigate, predict and control their input–output behavior.

Sociotechnical systems, in contrast, are hybrid systems, consisting of, or involving, "components" or "elements" that, by the description we have available for their behavior, belong to other domains than just the domain of the material objects described by natural science. Among these components or elements we may distinguish individual people, but also corporate actors such as business companies and governmental bodies, and more abstract social entities such as institutions, and laws, regulations and other rules.

It is important to recognize that people can be involved in artifactual systems, through their relations to the material objects that are in a straightforward sense components of such systems, in two different ways. On the one hand, there are people who use the system, through their use of material components of the system, in the

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way the people who drive their car to go to work use the road transportation system, and the people who connect their television set to the socket in their house use the electric-power system. On the other hand, there are people who are involved in the operation and maintenance of the system. In the case of the road transportation system they include road workers, traffic police, petrol-station personnel, and so forth; in the case of the electric-power system they include the operators of power stations, repair and maintenance workers in the field, and the personnel of the companies that sell electricity to customers. There may also be cases where it is difficult to decide to which category someone belongs. A taxi driver, for example, or an employed chauffeur, seems to participate in the traffic system just like any other car driver. However, these people do not use the road transportation system to satisfy their goal of being transported from one place to another. Presumably they participate for some purpose of their own – to earn a salary or make a profit, or to live a fulfilling life – but this purpose bears no logical relation to the function of the system they "use" for this purpose.

The contrast between these two ways people are involved in sociotechnical systems can be accentuated by considering that in their facilitating role people can in principle be replaced by – intelligent – machines. It would make no sense, however, to consider automating the users of a sociotechnical system, that is, the people who use the roads and petrol stations to drive their car to work or who use the power sockets in their home to watch television. Were these people to be replaced by machines, there would no longer be any point to the system. This shows that, whereas the intentionality of the user of a system is necessary for the conception of the system as performing a function in the first place, the intentionality of the people who are active in the operation, facilitation, maintenance and repair of the system is only an accidental property of these "system components."

Hardware components and people fulfilling certain roles do not exhaust the ingredients of sociotechnical systems, however. Institutions and the related rules and regulations are also essential, beyond the extent to which there is an institutional background to all technical artifacts. This institutional background consists partly of the rules that constitute corporate actors, such that business firms can own, buy and sell objects and be held liable in case of misconduct, and partly of the rules defining misconduct, i.e. the safety, health and environmental protection regulations to which the design, manufacture and use of all artifacts is subject. Sociotechnical systems additionally require rules defining ownership, regulating the distribution and billing of costs, regulating the mutual effects of consecutive use by different users. Although arguably a road transportation system could exist even in the absence of any traffic rules, the road transportation system as we know it functions only thanks to the existence of traffic rules and of a legal system – itself functioning largely on the basis of rules – that sees to it that these rules are maintained and effective. Similarly the electric-power system as we know it functions only given a set of rules that determine how much an individual user is charged for the share of electric power he or she took, and given a legal system that sees to it that these rules are implemented. It is only on the basis of this regulatory apparatus that individual "customers" develop the sort of trust in the system that is necessary for them to be prepared to use it.

A special place among these rules is taken by the rules that define the roles of the human "components" of a sociotechnical system. Such rules specify what a traffic policeman or the operator of the control room of a power station is supposed to do, given the circumstances. The individual traffic policeman or control-room operator serves his or her individual purpose of earning a living best by following those roles as meticulously as possible. When these human components of the system are replaced by machines, these machines must be engineered or programmed to operate in accord with these rules; they incorporate these rules, so to speak, in the way an ordinary thermostat can be seen as incorporating the rule "Keep the room at a temperature of $x$°C." It could be argued, however, that in this way the rules lose their character as rules. A rule is a normative concept: it is not true or false but applies or does not apply, and whether or not it is actually followed does not affect whether or not it applies. Following a rule follows upon a judgment that the rule applies. The machines replacing the humans supposedly cannot judge that they are in a situation in which they ought to apply the rule they incorporate, nor can they break the rules they incorporate; that is precisely what the incorporation amounts to. The considerations that specify when a particular rule applies are themselves of the form of rules and therefore presuppose considerations when they in their turn apply and when not. If this is true, it is in principle impossible to replace all human components in a sociotechnical system by machines that incorporate the rules defining the corresponding roles. A naturalist, however, would argue that human beings themselves are just as little capable of exhaustively fulfilling these roles, and accordingly there would then be no principled limit to the automation of human roles. This issue is of interest to disciplines like safety science but also has an ethical dimension, concerning, for example, the notion of responsibility.

The previous considerations point to the particular difficulties that sociotechnical systems pose to engineering design, in particular the question of the engineer's control of the system. In the classical approach to engineering design an engineer aims to construct an artifact such that, as long as certain conditions prevail that include the conditions of the environment in which the artifact is to be used and the specific manipulations that are involved in its use, the behavior of the artifact can be predicted with certainty. This can be achieved thanks to the engineer's investigation of and subsequent knowledge of the law-like behavior of the materials and components applied in the specified circumstances and to the controlled linking of the components to each other, but also, of course, thanks to the engineer's ability to prescribe precisely to any future user the required manipulations and environmental conditions. This does not necessarily presuppose a single user; the artifact's designer could specify the coordinated manipulations of an exact number of users. If a user chooses to deviate from these prescriptions, the artifact's behavior is no longer the responsibility of the designer, although it has increasingly become a part of engineering design to limit the possibilities of the user to deviate in cases where such deviations would cause a hazard to the user or his or her environment, whereby the scope of the engineer's control of the artifact's behavior is extended even more.

In the case of sociotechnical systems, this "control paradigm" can no longer be upheld. Sociotechnical systems have an indefinite, constantly changing number of users who are generally anonymous to each other and cannot coordinate their use of the system except in limiting cases of close contact, even though they may anticipate the system's use by others and the consequences for their own use, such as traffic queues during rush hours. This difficulty of coordination is repeated at the system level of managers and operators: decisions to open or close motorway lanes and access roads, or to expand power-generating capacity, to decouple stations, or to purchase extra capacity, are equally distributed over various roles, even internationally, and therefore involve problems of coordination. Finally, control is limited by the importance of the institutional level. Legal and regulatory changes may limit or expand the freedom of operators to take measures as defined for their roles, and changes in traffic law or insurance law may cause considerable changes in the way the users of the system behave. Owing to these limitations to the control of the system, classical engineering design criteria like optimality and efficiency become very hard to operationalize. Instead criteria like flexibility and robustness seem the more important ones.

Even taking into account that sociotechnical systems evolve and are constantly redesigned, rather than designed in one stroke, an adequate conceptualization of the system is of first importance for the professionals involved in designing such systems. Here, engineering design also faces a major challenge. In contrast to traditional artifacts, where all elements are material objects related by causal laws, it is unclear how the various elements or components involved in sociotechnical systems – hardware, people in various roles, and laws, rules and regulations – must be seen as making up the system, and in particular by what relations these elements are linked. Since the behavior of people is described with intentional rather than causal concepts, and since rules are abstract rather than concrete things, these relations must cover a much wider spectrum than just the causal laws of natural science.

Part of the problem of conceptualizing sociotechnical systems is the problem of where to draw their boundaries. It is an important aspect of the character of sociotechnical systems that the scope of design includes all types of elements. Designing a sociotechnical system will therefore involve designing specific roles and tasks for people to fulfill to match the hardware components, and also rules to define and regulate these roles and tasks. The road-transport system, for example, contains coordinating devices such as traffic lights; but, for such technical devices to contribute adequately to the overall functioning of the system, laws that punish those who ignore them are essential, as are police patrols to detect such cases. Maintaining the system then includes not just checking that the lights still work, but also checking that drivers' estimates of the chance of getting caught when skipping the lights are still large enough, and that the fines are still high enough to deter them. Engineers may come up with sophisticated technical solutions for particular problems, such as special lanes for carpoolers to reduce traffic-jams; but, if the law forbids any discrimination among car drivers on public roads, the technical solution itself is ineffective, and the design should include an accompanying change of law. It depends on the circumstances whether such changes can indeed be considered during the design process – which would include the government as a party to the design – and whether the boundaries of the system should be (re)drawn accordingly. For any sociotechnical system, however, the technical, human-operational and institutional levels all contribute to its adequate functioning and must all be taken into account in its design and implementation.

# 41

# Information Technology

## LUCIANO FLORIDI

Information technology (IT), also known as information and communication technology (ICT), has shaped human life so profoundly that, in the middle of the nineteenth century, the word "prehistory" was introduced to classify civilizations that lacked written records and hence could be studied only on the basis of their artifacts. It seems that history begins with the availability of some IT, but the nature of IT has also evolved through history, to the point that, at the beginning of the twenty-first century, IT has become so pervasive as to make it difficult to determine its specific nature. In order to clarify in this article what counts as IT, it is useful to concentrate on the three fundamental functions exercised by IT: *recording*, *communicating* and *elaborating* information (Floridi 1999). With some approximation, each of them has characterized a different stage in the evolution of IT.

## The Evolution of IT

According to a broadly inclusive understanding of IT, the invention of alphabets, numerical notations and writing systems represents the earliest and most fundamental stage in the development of information technologies. This was certainly Plato's view when he notoriously complained against written records in favour of a dialectical understanding of what is eternal and immutable (*Phaedo* 275a and ff.). Writing makes possible the diachronic accumulation of information as non-biological memory. But, if writing is the first step, it is then natural to interpret the invention of printing as its completion and hence as the following major revolution in IT. The mechanization of text reproduction made the accumulated information widely available to a potentially endless number of people. After the fifteenth century, universal alphabetization – that is, the translation of availability of information into its accessibility – came to be considered, for the first time in the history of human civilization, a feasible project.

The evolution of IT from Plato to Gutenberg is therefore largely understandable as the evolution of recording technologies. Then, from Leibniz to the *Encyclopédie* (1751–80), IT was at the center of a vast process of reorganization and restructuring of huge amounts

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of recorded information increasing exponentially. But. when the nineteenth century came to be dominated by the telegraph (Standage 1998), and IT became associated with communication technologies, the impression was that the original function of recording technologies had been replaced by the new function of communication (Headrick 2000). It is indicative that the Cooke and Wheatstone electric "Five Needle Telegraph," patented in London in 1837, had no means of recording messages and that Morse judged this a major shortcoming. History proved him right; IT was to develop by accumulating functions, not by replacing them. The following inventions, especially cinema, radio, telephone and television, all belong to the communication era of IT. This is why they are considered mass media, i.e. media of mass communication, although they are also media of massive recording.

The third and last stage begins only in the middle of the twentieth century, with the invention of the computer (Goldstine 1972). Between 1941 (Zuse Z3, Germany) and 1948 (ENIAC, USA), IT acquired its new meaning, the one we currently associate to it, as it came to refer to any technology used to elaborate information by processing data electronically and automatically. For a few decades, IT was once again supposed to have replaced its previous function (communication) with a new one, elaboration. Shifting from analog to digital solutions, the invention of new languages and new physical supports gave the impression that the old function of recording could now be joined by the new processing capacities. Communication was no longer in view. This proved to be, once again, a mistake. By the end of the twentieth century, the evolution of the Internet, of the Worldwide Web, of email communication, of mobile phones and of other digital technologies of information exchange and dissemination had shown that IT continues to comprise and cross-fertilize all of the three functions listed above: information recording, communication and elaboration (Cyganski et al. 2001).

## Understanding IT

The sketchy summary just provided lends credibility to the following approach: a fruitful way of understanding IT is by focusing not on the specific and contingent features of the constantly and ever-changing technologies that go under that label, but on the more stable nature of the object with which they deal, namely information. From this perspective, IT includes any technology used to treat information in one or more of the phases in its life cycle: occurrence (discovering, designing, authoring, acquiring, creating, etc.), processing and management (collecting, validating, modifying, organizing, indexing, classifying, filtering, updating, sorting, storing, networking, distributing, disseminating, displaying, accessing, retrieving, transmitting, transferring, etc.) and usage (monitoring, modeling, analyzing, explaining, interpreting, planning, forecasting, decision-making, instructing, educating, learning, etc.). The focus on the information life cycle explains why abacuses, cameras, faxes and photocopiers are forms of IT and why IT was poised to become the technology that would determine the transition from prehistory to history and, within history, from pre-information to post-information societies.

## IT in the Information Society

What we call "the information society" has been brought about by the fastest-growing technology in history. No previous generation has ever been exposed to such an extraordinary acceleration of technological power and corresponding social changes. Total pervasiveness and high power have raised IT to the status of the characteristic technology of our time, both rhetorically and iconographically. No wonder that the computer, the quintessential IT product, has become a symbol of the new millennium, playing a cultural role comparable to that of mills in the Middle Ages, mechanical clocks in the seventeenth century, and the loom or the steam engine in the age of the industrial revolution (Ifrah 2001). The computer as the information machine is a defining technology.

The most developed post-industrial societies now literally live by information, and IT is what keeps them constantly oxygenated. Information has matured into an asset of growing value, with marketable quantities and prices. It is the new digital gold and represents one of the most valuable resources. Such modifications in the growth, the fruition and the management of information resources and services concern four main IT sectors: computation, automatic control, modeling, and information management. This sequence follows a conceptual order and only partially overlaps through time.

"Computation" seems to be a sufficiently intuitive concept, but as soon as one tries to provide a clear and fully satisfactory definition of it one immediately realizes how difficult the task is. According to different perspectives, computation may be described as a logical or physical process of generation of final states (outputs) from initial states (inputs), based on:

(1) rule-governed state-transitions, or
(2) discrete or digital rule-governed state-transitions, or
(3) a series of rule-governed state-transitions for which the rule can be altered, or
(4) rule-governed state-transitions between interpretable states.

There are some difficulties with these definitions. (1) is too loose, for it also applies to devices such as printers and washing machines, physical systems that we do not include in the class of computational systems or IT; (2) is perhaps too strict, for it excludes forms of analog computation, which one may wish to include in the definition of IT; (3) is either vague or too strict, for there are computational systems, like pocket calculators, with embedded rules (non-programmable algorithms); (4) seems to be the most satisfactory, as it makes the interpretable representation of a state (i.e. information) a necessary condition for computation.

Although computation has remained a major area of application, it would be shortsighted to think that the impact of the technological innovations brought about by the diffusion of IT has been limited just to straightforward numerical problems, and hence to important but quite specific sectors of mathematical applications. For not only have computers helped us to read some of the most complex chapters in the "mathematical book of nature"; they also have put us in a position to control a large variety of physical and bureaucratic processes automatically (office automation and electronic data processing). Today, the complex functioning of an increasing number of manufacturing and administrative operations requires the constant intervention of microprocessors and other IT devices. Following on from the process of mechanization, IT has caused a second industrial revolution through the implementation of massive automation. As industry has moved from a low-technology, unspecialized and labor-intensive stage to a highly mechanized, automated (electronics), AT-intensive (advanced technology) and more specialized stage, it has become extensively information-based and hence more and more IT-dependent.

The mathematical description and the digital control of the physical environment have provided the solid premises for its potential replacement by mathematical models (systems of differential equations) in scientific computing and virtual reality environments. Digital computing has become crucial whenever it is necessary to simulate real-life properties and forecast the behavior of objects placed in contexts that are either not reproducible in laboratory situations or simply not testable at all, whether for safety reasons, for example, or because of the high cost of building and testing physical prototypes, or because we need non-invasive and non-destructive techniques of analysis, as in medical contexts. Indeed, every area of human knowledge whose models and entities – whether real or theoretical no longer matters – can be translated into the digital language of bits is, and will inevitably be more and more dependent upon, IT capacity to let us perceive and handle the objects under investigation, as if they were everyday things, pieces on a chess board that can be automatically moved, rotated, mirrored, scaled, magnified, modified, combined and subjected to the most diverse transformations and tests (Baeyer 2003).

The IT-based description and control of the physical environment, together with the digital construction of a synthetic world, is, finally, intertwined with a fourth area of application, represented by the transformation of the encyclopedic macrocosm of data, information, ideas, knowledge, beliefs, codified experiences, memories, images, artistic interpretations and other mental creations into a global *infosphere* (Floridi 2004). The infosphere is the whole system of services and documents, encoded in any semiotic and physical media, whose contents include any sort of data, information and knowledge, with no limitations either in size, typology or logical structure, and hence ranging from alphanumeric texts (i.e. texts including letters, numbers and diacritic symbols) and multimedia products to statistical data, from films and hypertexts to whole text-banks and collections of pictures, from mathematical formulae to sounds and videoclips. As regards the infosphere, the symbolic-computational power of IT tools is employed for ends that go beyond the solution of complex numerical problems, the control of a mechanical world or the creation of virtual models. IT provides the new means to generate, manufacture and control the flow of digital data and information (which is also being generated, in increasingly huge quantities, by the three areas of application just mentioned) thus managing its life cycle.

## Conclusion

Information is the sap of contemporary societies, and IT provides the essential tool for its generation, recording, flow, management and usage. The corruption, wanton destruction, illegal or unethical use of information may easily undermine the basic processes on which the life of individuals and their complex societies depends (Brown and Duguid 2002). In light of their importance, the whole life cycle of information – from collection or generation through storage and manipulation to usage and possible erasure – is often protected, at different stages, by legal systems in various ways and in many different contexts. Examples include copyright and ownership legislation, patent systems, privacy protection laws, fair use agreements, regulations about availability and accessibility of sensitive data, and so forth. The more societies develop into information-based societies, the more concerned and careful they need to become about their very foundation. Unsurprisingly, in recent years ethical and political concerns about the correct and fair usage of IT have begun to address the challenging ethical issues raised by the new data-based environment in which advanced societies grow (Floridi 2007).

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# Part IV

# Technology and Environment

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# 42

# Technology and Environment

## MARY TILES

The "Inconvenient Truth"[1] we face in the twenty-first century is that our reliance on fossil fuel technologies for the previous two centuries has had an impact on our global environment. Combustion of fossil fuels has increased the level of carbon dioxide in the earth's atmosphere to the point at which the occurrence of global warming has had to be acknowledged even by determined skeptics in the White House. The publicity given to this issue, and the politicization of the science surrounding it, means that it has come to frame many discussions of the relationships between technology and the environment. In the mid-twentieth century, during the period of the Cold War, the hazards of nuclear technology and of the widespread use of insecticides (such as DDT) in agriculture occupied similar roles. In the nineteenth century it was the transformation and degradation of landscapes by steam-powered industrial technology, as reflected in, for example, the work of William Blake ("England's dark satanic mills"), that framed the context of debate.

These are the contexts of environmental politics, of the clash of values between enthusiasts viewing technological development as an essential indicator of human progress and detractors who have seen technology as a vehicle of domination over both the natural environment and large sectors of humanity. When the terms "technology" and "environment" are juxtaposed in such contexts there is a tendency to assume that the discussion to follow will be framed in terms of the divide between Man and Nature. Technology is seen as the material expression of Man's ambition to dominate Nature, with the subjugated natural environment the victim of its detrimental impacts.

Here, in brief, we see the ideological load borne by juxtaposition of the terms "technology" and "environment" and the near-impossibility of entering into any discussion of their relationships from an ideologically neutral standpoint. Many environmentalist critiques of technology have shared with their tacitly or explicitly faith-based opponents an acceptance of the Man–Nature divide. Questions are then framed as questions of environmental ethics and as disputes over the fundamental locus of moral values.[2] This ideological/political burden of "The Environment," particularly in the United States, creates a chasm across which it is difficult to conduct a policy dialogue, let alone construct policy bridges in response to the challenges potentially presented by a changing climate. As in most such standoffs, the opposed positions rest on a shared assumption, in this case that humans and their environments, or Man and The

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Environment, are independently constituted and stand in an external relationship; absolute values can have a basis on one or the other, but not on both.

Recognizing that such deep ideological differences are unlikely to be resolved either by philosophical debate between the opposed positions or by political or moral evangelism, it would seem that it is past time to challenge the idea that there is any such thing as The Environment standing in an external relation to humans, their histories and their technologies. In other words, it is time to become reacquainted with human *environments* and our dependencies on them as well as with the extent to which they are *human* environments, formed over the course of a history of human habitation. An examination of the role of technology in creating environments, through its function as an intermediary that creates human–natural hybrids, is one route to such re-acquaintance. An environment is simply a surrounding, a context, a milieu, hardly anything with enough stability or definition to become an object of scientific investigation or of philosophical or political concern. I shall begin by illustrating the manner in which technologies play a constitutive role in relation to many of our environments. On this basis I shall propose that there is a need to extend the conception of an ecosystem and of ecology to industrial, technological and social ecosystems and ecologies.

Because ecology is very unlike sciences such as physics and chemistry, a policy debate informed by an extended ecological perspective could be expected to view policy objectives in a rather different way than would be the case were the debate informed by the perspective of the more traditional sciences.

First, however, it is worth briefly mentioning two contexts that lend credence to and serve to reinforce use of the technology–environment opposition as a surrogate for the Man–Nature opposition and its construal of this as an external relation. The first is that of mining and manufacturing, and the second is that of the military–industrial model of technological development.

Mining and manufacturing technologies are those that have most frequently been portrayed as threats to the environment because they have most dramatically illustrated the capacity of human technologies to create environments that are hostile to many life-forms, human included. Their development is also intimately intertwined with the development of energy and transport technologies. Mining is a paradigm example of an activity that is locally unsustainable, exploitative and hugely disruptive of the natural and social environments in which it begins to operate. Mineral deposits occur in limited quantities that will sooner or later be exhausted and the extraction of which becomes increasingly uneconomic. Extraction, whether open-face or by tunneling, wreaks dramatic physical changes on the landscape. Communities of miners and their associated equipment move into regions that may have been sparsely populated and largely agricultural or pastoral. Roads or waterways have to be built to supply the mines and to transport materials to and from them.[3] The extraction of metals from mineral ores requires mechanical energy for crushing, and heat for smelting; and the by-products, frequently toxic, migrate into the surroundings, possibly continuing for many years to leach out of large spoil heaps that remain long after a mine's closure. Early mines were severely limited by the available technology for pumping water out of mine shafts. This was the context driving the development of the use of steam for power, with the large beam engines used first for pumping out water, and then to haul material and men up and down shafts whose increased depth was now possible, then to drive steam hammers for crushing and steam engines for hauling carts horizontally along rails. The synergistic development of coal-mining and the burning of coal to power steam engines was the spur to the industrial revolution that transformed the rural countryside of central England into the Black Country, wreathed in smoke and soot that clung to buildings and the inside of people's lungs – these were the dark satanic mills. The transformation in manufacturing capacity associated both with improved transportation and with a seemingly inexhaustible supply of energy transformed the economy and society. It laid the foundations of the environment – physical, social economic and political – in which we now live, even though the era of steam has passed, those mills are now silent, the mines are mostly closed and their mining communities dispersed. It began our dependence on the intensive use of fossil fuel in quantities the global impact of which we have only belatedly come to recognize. It gave rise to a chemical industry that has transformed our lived environment in ways too numerous to mention, but also in ways that we are far from understanding. It has created and continues to create local environments surrounding mines, oil-drilling operations, refineries and chemical plants that are toxic to most life forms. So it is natural, if this is our image of technology, to put it in opposition to Nature since one of the side-effects of its operations has been to create wastelands devoid of anything much in the way of organic life.

A different kind of oppositional relationship is revealed in the context of the military–industrial development of technology. This has been equally important in shaping conceptions of the technology–environment relationship, and is a relationship that has enormous significance for the forging of the science–technology relation. As Serres (1982) notes (crediting Lucretius with a similar insight), military applications have frequently been the spur driving the use of science in technological development. In contrast the history of mining technology, including the early development of the steam engine, was not theory-driven but was craft- and trade-based. The development of military capacity, whether defensive or offensive, was perceived by those in power as a necessary instrument for their continued survival and/or hold on power; and, because possession of technological devices not available to opponents was believed to confer a military advantage, there is an internal dynamic favoring investment in innovation. The fact that military applications have played such a role in technological development is of no minor significance for the manner in which the environment has been impacted by the development of technology or for the way in which the technology–environment relation has been conceptualized.

Whether in the remains of ancient China or in those of the ancient Roman Empire, one can see evidence of the impact of the military impetus toward regimentation, imposed for the sake of efficient and predictable operation, on the technologies used and on the built infrastructure required for their use. Armies need standardized equipment with standardized parts that can be on hand in any location. Army engineers developed standardized methods for the construction of structures such as roads or fortifications, for carriages and ships, for armor and weaponry, methods and specifications developed ahead of time with people trained to deploy them in any required location. Stretches of road used by the Romans to move their troops and supplies rapidly across the outposts of their empire can still be identified by their straightness and by their lack of concern for local topographical or land-holding patterns. Military engineers used geometry to assist in the design of fort walls and ramparts as defenses against anticipated forms of attack (themselves conditioned by available technology) and replicated them across the territory to be defended.

Particularly for large imperial powers, military efficiency and effectiveness is linked to the requirements of bureaucratic techniques of administration, techniques that require standardization in modes of operation allowing for centralized design and planning and allowing personnel and equipment to be moved from one location to another without significant retraining or redesign. This has two effects. It allows design to become a theoretical process, carried out according to general principles, and separated from actual construction; and it requires that local environmental variations be made irrelevant. They can be made irrelevant either by insulating devices to be used from external impacts that might affect their designated function (the design of a ship's chronometer – a mechanical timepiece designed to keep accurate time through the pitching and rolling of a ship and through the wide variations in temperature that might be experienced on a long sea voyage[4] is one instance where there is documentation of the long sequence of efforts explicitly undertaken to address this challenge) or by altering the local environment to conform to conditions under which the device functions well (build roads for carriages, deforest and flatten areas around forts[5]) or some combination of both.[6] The aim is to create an environment favorable to forward planning that relies on being able to predict the degree to which actions will have their desired effects. Where there is uniformity there is also much more predictability; but that uniformity has to be created by eradicating or externalizing relevant variations. The close interconnections, both historically and in contemporary society, between the military drive for technological innovation and large private corporations (the bureaucracies of the military–industrial complex[7]) have ensured that it is this conception of technology, with its deliberately designed insensitivity to environmental variations and to its own environmental impacts that has been another lens focusing attention on the relation between technology and environment as one of opposed and competing interests and values. This has left in the shadows, and relatively invisible until recently, the factors ignored when concentrating attention in this way.

One of the areas to have exposed weaknesses in the approach that assumes that local environmental variations can either be ignored or eliminated is that of the design and use of agricultural technologies under the move to an "industrial" agriculture. It has frequently been pointed out that one of the most significant shifts in the way humans sought to secure their basic needs was when they made the transition from being nomadic hunter-gathering groups to becoming place-based agricultural societies. It has been through the development of agriculture and technologies to support it that humans traditionally have most altered and created the environments in which they live. Agricultural technology made possible the rise of cities, with their large urban populations and built environments. These in turn needed to be defended both against other groups of humans and against the forces of nature; they required extraction of material sources for their construction and for the manufacture of the tools and artifacts that became the trappings of "civilization" – the goods that can be accumulated in settled dwelling places.

Agriculture is undoubtedly the locus of the most immediate and most necessary interaction between humans and their physical/biological environment. Where the story of the rise of agriculture was once told as part of the long epic of human progress, some more recent tellings have been more ambivalent.[8] They have documented the decline in human health as a result of increased dependence on grain in the diet. They have also emphasized that opting for agriculture and a more settled existence marked an irreversible choice for a society. Increased food availability leads to population levels that cannot be supported without agriculture; population pressure acts to spur technological innovation and motivates the drive to bring more land under cultivation, thus changing the face of ever wider swathes of the landscape. This is a technological treadmill from which there is no voluntary release.

Currently there are concerns that, although we have used new technologies to increase global agricultural yields to levels once thought unattainable, and have thus, so far, roughly kept pace with population increases (although it has to be acknowledged that distribution is far from equitable), this has been done on an unsustainable basis. The massive increases in production since the Second World War have been the result, first, of the increased use of fertilizers resulting from chemical production, ultimately dependent on oil. This technological shift allowed grain production to expand without the need of inputs of manure from animal husbandry and allowed elimination of elaborate crop rotations and periods of fallow. However, this amounts to turning fossil fuel (oil) into grain. As fears mount about the limits of oil production having been reached, and because of all the other demands on oil, some worry that the current configuration of our large agricultural systems will not remain viable.[9] The second important stimulant to agricultural production, spurred by the availability of nitrogen fertilizers was the so-called "green revolution" – the development of hybridized grain crops that can take up more nitrogen and grow more grain rather than more leaf and stalk. Seeds from hybrids cannot be saved for replanting because they will not reproduce the original hybrid; and, in any case, the new varieties have, for the most part, been patented by large corporations. Widespread use of a limited number of varieties results in mono-cropping, thus eliminating local genetic variation, and assumes that such genetic variation is irrelevant to crop success in different locations or even in a single location from year to year.

These crops also required more water if they were to produce consistently higher yields. In many parts of the world the acreage of land under irrigation was dramatically increased. In some cases this has been the result of dam-building projects, but in others the same prospecting and drilling technologies that served the oil industry were used to locate and tap underground aquifers. Some of these aquifers contained "fossil" water (water trapped many years ago and receiving no significant current replacement) while others are replenished much more slowly than the current rate of pumping. Technology has allowed us to exploit these resources, but further technological innovation seems the only possible route to maintaining current levels of agricultural production as aquifers and rivers begin to run dry. This is the sense in which embarking on the agricultural path has put human beings on a technological treadmill. And that treadmill has caused us to (re)shape, wittingly and unwittingly, vast regions of the land surface of the globe.

Water-control technologies have been hugely important for the expansion of cultivated land and the provision of sufficient food surpluses for the emergence of non-agricultural sectors of human activity. Water is also important for human consumption, health and hygiene. On the other hand, it poses a threat to human life when there is too little, when there is an overabundance and when it is contaminated with disease-causing organisms or toxic chemicals. The need and ability to control water provides one of the most striking examples of the way in which physical environment prompts development of certain kinds of technologies that then shape and constrain the societies that come to depend on them. The ancient "hydraulic" civilizations of India, the Middle East, South America, China and Bali provide examples.[10] Although the technical details of hydrological challenges and the technologies available to deal with them are location, time and region specific, there are common features of dependence on water management. As water-control technologies are put in place in the service of agriculture, continued production of food depends on continued water control, and this in turn can impose very high maintenance burdens. On continental land-masses, as opposed to relatively small islands, river networks extend over many miles and usually through several countries. Water projects undertaken upstream will almost certainly impact those further downstream.[11] The development of modern engineering technologies that make possible the construction of ever bigger dams has introduced the potential for major political conflict as larger proportions of a river's flow can be diverted for irrigation or other uses well before it reaches the sea.[12]

Water can be a problem when there is too much as well as when there is too little. Technologies have been developed and deployed to prevent rivers causing damage by bursting their banks and flooding agricultural land or towns, villages or cities, and to prevent the sea encroaching and causing similar damage. Just as in regions of water shortage those with access have sought to retain water for their own use without consideration of the downstream consequences, similarly in regions subject to flooding the tendency has been to find ways to hasten the water's flow away, passing it on as quickly as possible to lower reaches. Rarely was thought given to the impact of either approach on coastal ecosystems when rivers reach the sea. Some rivers no longer do so; in other cases they do so but without depositing the burden of silt that maintained and fertilized delta regions,[13]; in yet others they are carrying silt out into ecosystems, such as coral reefs, that will be disrupted by its presence. All of this is teaching us that, when water is regarded as a commodity to be shifted around at will, our environments are transformed in ways we may or may not have intended or foreseen. At a time when fresh water is projected to become an increasingly scarce commodity in many regions, and sea water, with a predicted rise in sea levels, poses a greater threat to many inhabitants of coastal regions, it is perhaps particularly important to learn from the impacts of past technologies of water management and to think in a more integrated way about the role of water in constraining the ways in which we can live and about the role of water systems in shaping our environments on a number of scales (local to global), below ground as well as above.[14]

Similarly there is a need to think beyond agriculture and its technologies to the larger systems in which they are embedded. For example, the widespread use of seed-breeding technology, and now genetic modification, was accompanied by the rise of large seed companies and a transformation of agriculture favoring large farms over small holdings facilitated by the development of farm machinery, in turn made possible by the internal combustion engine.

The displacement of human energy in agriculture made possible by reliance on oil-based technologies has changed our societies and our environments in another way.

There are now sparsely populated agricultural landscapes, ever growing cities, suburban sprawl and unplanned slums created by the movement of people off the land.

Technology has displaced people – has moved them from environments in which they have a relatively close relationship to the land and to other life forms to another, much more obviously man-made environment, one where people, their activities and the by-products of those activities dominate. Of course, none of this separation of population concentrations from their sources of food would be possible without transportation networks, trade agreements, refrigeration and food-processing technologies. This illustrates the sense in which technologies do not stand alone but themselves exist and thrive or face extinction depending on other environmental (technological, natural, social) conditions. Large farm machinery is of little use in cultivating small patches of land clinging to hillsides or nestling in valley bottoms. US pork production can be concentrated in the huge hog farms of the Carolinas only if there are ways to bring that meat to distant consumer markets and only if regulatory structures permit the widespread use of antibiotics in farm animals and the accumulation of manure in open lagoons (in a manner that would not be permitted for human waste). The rise in meat consumption worldwide, made possible by industrial-scale livestock operations, is in turn having an impact on the atmosphere and thus on climate.[15] Much of the history of technology has been written as a history of technological devices (the plow, the combine harvester, the steam engine . . . ). Attention has also been given to the potential of such devices for changing human environments (living and working conditions) as well as "natural" environments (landscapes, wildlife and their habitats, water, air . . . ). But, as I hope the all too brief discussion above has indicated, if we are concerned about the interactions between technological devices and environments, it is equally important not only to think about the actual and potential effects of deployment and use of the devices, but also to look at the economic conditions, processes, labor and materials required for their manufacture and successful use as well as the effects of disposal at the end of their useful life. In other words, we need to borrow techniques and concepts from ecology to think in terms of industrial or technological ecology[16] that can focus on the webs of interdependence between different technologies and the ways in which they form environments for each other as well as for human and other living organisms.

The idea of ecology as a potential science arises in the context of Darwin's theory of evolution. It was first mooted and labeled by Haeckel in 1866 (seven years after the appearance of *The Origin of Species*). Three years later he explained it in the following terms:

> By ecology we mean the body of knowledge concerning the economy of nature – the investigation of the total relations of the animal both to its organic and to its inorganic environment; including, above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly into contact – in a word, ecology is the study of all those complex interrelations referred to by Darwin as the conditions of the struggle for existence.
>
> (quoted in Cooper 2003: 4–5)

At the time no such study existed, in part because the need to take environments into account does not, on its own, indicate how they can become "objects" of scientific investigation and knowledge.[17] They have to be acknowledged as complex, but also treated as quasi-organic wholes, wholes whose characteristics cannot be understood as any simple aggregation of properties of the parts since the whole motivation from evolutionary biology is to attempt to understand the *interactive* relations between a given part – the life form in focus – and the remainder, the environment that constitutes its dynamic backdrop. Already in Haeckel's "definition" we can see the potential problem for the construction of a unitary discipline. He refers to both organic and inorganic environments. The problem here is that the biological study of organisms in communities and the applied physics and chemistry used to study ecosystems bring fundamentally different categories and methods to bear. For example, where one deals in the dynamics and statistics of populations the other looks at flows of energy and materials. So there is considerable heterogeneity within ecology as it has come to be practiced. None the less there are some important reorientations in the way to think about human environments that can emerge from reframing the discussion by starting from an evolutionary perspective.

The evidence brought forward in favor of theories of the evolution of the human species, whether Darwinian or Lamarckian, crucially includes the fossil record, and interpretation of that record is part of the development of geological accounts of the history of planet Earth.[18] This story of our origins is inseparable from the history of the planet, the place that "gave birth" to humans as to all other living creatures that now and in the past have populated it. But the history of that planet, the character of its sedimentary rocks, its coal and oil deposits, etc., is equally inseparable from the story of the life forms evolving on it. If we believe Darwin's version of our origins, we must recognize ourselves as products of selection pressures, exerted by the environments of our ancestors, on the variations thrown up by random genetic mutation. This perspective starts from a view of life as a dynamic process in which each living organism interacts with and thereby affects, to a lesser or greater extent, its surroundings, and those surroundings include all other living organisms. The cut between organism and environment is determined by the focus of attention; it does not rest on any metaphysical divide between Man and the rest of Creation. In order to understand how or why creatures have evolved as they have, attention must be paid to the physical and biological characteristics of the environments with which they had to contend in order to survive; and, in turn, those environments have to be recognized as themselves changing partly in response to their living inhabitants and as a result of the chemical and physical processes set in train by deposition and decomposition of their leavings.

Entering environmental discussions via the biological nature of human existence is thus one way of revealing the stake that all humans, in common with other living organisms, have in their environments. Through their reproductive potential, living organisms, even very small ones, have collectively the potential to affect the earth's ecosystems in significant ways if they exist in sufficient numbers.[19] From the point of view of any living being, its surroundings take on a value-laden significance – they may be conditions conducive to the flourishing of that life form, conditions that threaten its continued existence or somewhere on a gradient in between.[20] If one were to pursue this discussion further, it would be necessary to distinguish between individual and species. An individual's continued existence may be threatened or enhanced by others of its own kind. The existence of a whole species may be threatened or enhanced by environmental changes – loss or extension of habitat, invasion by competitor species or other organisms. The evolution of "higher" organisms has resulted in a complex tangle of interdependencies between life forms.

Humans, however, have needs beyond those related to their continued biological existence and reproduction. Humans in societies have formed conceptions of their own nature, and of what constitutes human well-being and flourishing, and through the vehicles of religion, philosophy, politics and law in a wide variety of combinations have developed cultural and commercial structures that allow at least some fractions of society to live a life that they themselves conceive to be conducive to their well-being (in their own interests). Humans deploy their cognitive capacities to evaluate the situations in which they find themselves as threatening or as conducive to flourishing and have, over thousands of years developed, forgotten about and redeveloped ways of trying to protect themselves from threats and provide themselves with conditions under which they can thrive, but they have not always agreed about what constitutes human flourishing or about the role of technology in contributing to or detracting from it.

Given that conceptions of human flourishing typically extend beyond mere biological well-being, the situations being evaluated are, for the most part, not evaluated as purely natural situations; they are already hybrid[21] natural–social–man-made situations. Moreover, given the limited nature of our knowledge at any given time, we do not always correctly evaluate situations or conditions, nor in our attempts to change our surroundings in ways that suit us are we fully aware of the possibly detrimental side-effects or long-term consequences of our actions. All of this is as true for ancient societies and civilizations as for modern ones. A vast panoply of technologies has been developed by human beings in their pursuit of the "good" life, whether for themselves or for the larger human community with which they identify (clan, village, city, nation, religious sect, or whatever).

Environments circumscribe the range of possible human actions, and our relationship to them is interactive; we shape and are shaped by them. The impacts of past human actions contribute to the rural (more "natural") as well as the urban (more man-made) environments of subsequent generations (the Norfolk Broads, old canal networks, ruined castles, the hedgerow or drystone-wall enclosure of fields, town squares, government buildings and institutions, paper money and banking systems . . . ).[22] Once our sights are turned in this direction, it becomes natural to pay attention to technologies in the form of large infrastructure networks (irrigation systems, power grids, sewer systems, the Internet, roads . . . ) that become inseparably woven into the environment that frames our existence and will leave their mark on the environments of future generations, whether or not they are sustained to serve their original purposes. These networks are essential to manufacturing and trade, and to the continued utility of many technological devices. (How useful is an automobile without a supply of gasoline and a road to run on, or a refrigerator without a supply of electricity?) Once installed, these networks cease to be the focus of attention and are taken for granted until disrupted; we tend to forget that such systems are not self-sustaining and that the burden of maintaining them can be so high as to render the whole system vulnerable to collapse in the medium to long term.[23] The variety and global extent of such infrastructure networks is what perhaps most strikingly marks our current situation. At an accelerated pace, we are continuing to lay down webs of wires, pipes, sewers, roads, railways, and filling the airways with flight paths and communication channels all of which need to be maintained in order to sustain lifestyles as we know them and whose contributions to the environment that supports those lifestyles is largely invisible to and certainly incompletely known and understood by most of us. These infrastructure networks are the life-support systems creating environments favorable to the effective functioning of many of our technological devices; it takes energy and money and labor to maintain them. To the extent that our day-to-day existence is mediated by and dependent on the devices that depend on such networks, infrastructure networks have become factors in the human "struggle for existence." Thus they need to be included in any accounting of the ecosystems that together make up our human environments.

But, if there was a problem integrating the languages, methods and models of organic and inorganic perspective on ecosystems, inclusion of multiple technological, economic and cultural networks will only exacerbate the problem. Yet it does serve to highlight where our problem lies – in figuring out how to bring the perspectives and skills of the various scientific and technical disciplines to bear on environmental problems – and to underscore the point that the role of science cannot be expected to be that of supporting the traditional conception of problem-solving through instrumental reasoning, where science provides predictions of the consequences of actions. It was the realization that predictability and control could be secured by creating uniformity and externalizing natural environmental variations that set us down the path of creating environments for technological devices. To avoid being locked in by our own infrastructure dependencies and their associated maintenance costs would require moving back in the direction of place-based technological solutions, using locally available materials where possible, with devices designed either to be relatively impervious to environmental variation or pervious by design – designed to be able to take advantage of features specific to a local environment.[24]

Global warming is a statistical phenomenon since the globe does not have a temperature. Each locality will be affected differently. The rise in concentrations of atmospheric carbon dioxide affects all regions, but human actions generating such emissions (and those of other greenhouse gases) are concentrated in localities and do not occur uniformly around the globe. Globalization has meant that for some purposes there is no distinction between global and local. The challenge is how to retain some of the benefits of global interconnectedness while weaning ourselves off dependence on those connections the maintenance of which is both economically and environmentally the most burdensome. Globally the strategy would be to give serious consideration to variations in local conditions in our effort to reduce global greenhouse gas emissions and to create more sustainable human environments.

## Notes

1. The term is borrowed from the title of Al Gore's documentary film on climate change, released in 2006.
2. See Latour (2004), Whiteside (2002) and Norton (2005) for more detailed and nuanced elaboration of this point.

3. Such enduring marks of past mining operations can be seen for example in Cornwall, Cumbria and South Wales in the UK or in Colorado in the US. Africa provides many examples of the devastation and disruption caused by ongoing mining and oil-extraction operations.
4. See, for example, John Harrison's various painstaking efforts to achieve this as narrated in Sobel (1995).
5. See, for example, Ferguson (1992).
6. As Latour (1988) notes (p. 90), these are the conditions on which science is able to get out of the laboratory and into application. The application of general principles often requires creation of a suitably controlled environment.
7. Walt Disney and Ray Krock, the founder of McDonald's, both transferred their experience of military organization and regimentation to the world of private business. Multinational corporations can now relocate and replicate manufacturing plants around the world frequently ignoring not only the natural environment but also the local social impacts as on the border between the US and Mexico.
8. See, for example, Diamond (1999): "Archaeologists have demonstrated that the first farmers in many areas were smaller and less well nourished, suffered more serious diseases, and died on the average at a younger age than the hunter-gatherers they replaced. If those first farmers could have foreseen the consequences of adopting food production, they might not have opted to do so" (p. 105).
9. See, for example, Kunstler (2005), pp. 157–66.
10. See, for example, Elvin (2004), Pearce (2006) and Lansing (1991).
11. As Elvin (2004) comments, "Water control systems are where society and economy meet the environment in a relationship that is more often than not adversarial" (p. 115). Moreover he notes that the different needs for water, such as irrigation, transport, power and drinking, have often come into competition with one another. Elvin gives two examples to "suggest the complexities of hydraulic histories and show how Chinese hydraulic engineering both changed its environment and was, in turn, constrained by it, and even – sometimes – broken by it" (p. 120). He documents the huge amounts of money, labor, materials and administrative skill required to build and then maintain a water control system. He also illustrates the way in which a society can become locked into maintenance – even at very high cost – of such a system because the costs of not doing so would be socially and economically disruptive.
12. One striking example is the diversion of water for irrigating cotton grown in the Aral Sea basin. The result has been that the Sea has shrunk to about 10 percent of its former size (800 m acre-feet of water). See Pearce (2006), ch. 23.
13. As in the case of the Mississippi delta, which used to give some protection against storm surges to New Orleans.
14. Pearce (2006) is an example of a broad, systematic examination of water issues.
15. Steinfeld et al. (2006). The livestock sector accounts for 18 percent of anthropogenic global greenhouse gas emissions measured in $CO_2$ equivalent.
16. This term is borrowed from Rosen (2003); she explains: "Biologists examining natural ecosystems observe that in nature living organisms are knit together with one another and with the natural world, drawing nourishment from the bodies and wastes of other organisms as well as from the water and minerals in the soil and the energy produced by the sun. So it is for industrial ecologists. They see that business is also woven into the natural world. Business enterprises feed on natural resources found in the earth, or energy ultimately derived from the sun, wind or geological forces deep within the earth, and on the manufactured inputs of their industrial supply chains. They return their wastes to the earth the seas, and the atmosphere" (p. 320). I would want to add that business is

also thoroughly woven into the human world and that its inputs also include human labor, management and economic capital.

17. As that time this was a case of what Canguilhem (1988) would call a scientific ideology: a scientific ideology comes to an end when the place that it occupied in the encyclopedia of knowledge is taken over by a discipline that operationally demonstrates the validity of its claims to scientific status, its "norms of scientificity" (p. 33). A scientific ideology is an explanatory system that strays beyond its own borrowed norms of scientificity and precedes the establishment of a science (p. 38).
18. See, for example, Gillispie (1951).
19. For example, termites exist in sufficient numbers to contribute 11 percent of the annual emission of methane from natural sources, about 20 Tg/yr. www.epa.gov/methane.
20. See Canguilhem (1985), p. 154.
21. This term is borrowed from Latour (1993).
22. Cronon (1983) importantly points out that "human groups often have significantly *unstable* interactions with their environments. . . . An ecological history begins by assuming a dynamic and changing relationship between environment and culture, one as apt to produce contradictions as continuities. Moreover, it assumes that the interactions of the two are dialectical. Environment may initially shape the range of choices available to a people at a given moment, but then culture reshapes the environment in response to those choices" (p. 13).
23. An example of such a collapse is one of the factors Davis (2001), pp. 309–10, cites for the severity of the famines in India and China in the nineteenth century. Lack of financial support for maintenance of irrigation systems led to what he calls an irrigation deficit leaving agricultural production highly vulnerable to ENSO cycles.
24. For example the British Soil Association recently proposed that food that has been transported by air-freight should not in future be certified as organic. This is part of a campaign to reduce the distance between producers and consumers of food and thus the amount of fossil fuel required to get food from one to the other.

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## 43

# The Precautionary Principle

### ANDY STIRLING

## General Background

Few issues in contemporary technology policy are as momentous (or contentious) as the precautionary principle.[1] The topic features prominently in mainstream political discourse[2] as well as in academic literatures on risk,[3] environmental science,[4] economics,[5] social science[6] and international law.[7] Originating in the earliest international initiatives for environmental protection in the 1970s,[8] it first came to legal maturity in German environmental policy in the 1980s.[9] Since then it has been championed by environmentalists[10] and strongly resisted by some of the industries they oppose.[11] Diverse formulations proliferate across a variety of international instruments,[12] national jurisdictions[13] and policy areas.[14] From a guiding theme in EC environmental policy,[15] it has become a general principle of EC law[16] and a repeated focus of attention in high-stakes international disputes.[17] Applying especially in areas like food safety,[18] chemicals regulation,[19] genetic modification,[20] telecommunications,[21] nanotechnology,[22] climate change[23] and general health protection,[24] it remains particularly controversial in the US.[25] Elsewhere, however, its influence has extended from environmental regulation,[26] to wider policy-making on issues of risk,[27] science,[28] innovation[29] and world trade.[30] As it has expanded in scope,[31] so it has grown in profile and authority[32] and in its general implications for the governance of technology.[33]

An early classic formulation (which has been widely accepted, even by many otherwise skeptical states such as the US[34]) neatly encapsulates the key minimal features and illustrates the central role of precaution in wider concepts of sustainability.[35] According to Principle 15 of the 1992 Rio Declaration: ". . . *Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*"[36] Other instruments are variously more stringent[37] or more far-reaching.[38] Sometimes generally characterized as an injunction that "*it is better to be safe than sorry,*"[39] even such a simple expression of the precautionary principle actually holds rather more specific implications. First, it hinges on the presence of two quite particular qualities: a potential for irreversible harm and a lack of scientific certainty. Second, the normative presumption is also quite particular: favoring the interests of the environment (and human health) rather than economic, sectoral or strategic institutional interests.[40] Third, it refers to

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the reasons for action, not to the substance of the possible actions themselves.[41] Fourth, it applies in principle symmetrically to all technological or policy alternatives in any given context.

At root, the precautionary principle involves a particular normative distillation of more than a century of experience with the unexpected consequences of new knowledges and technologies.[42] As such, it bears close relationship with other parallel principles (with which it is sometimes compared and elided), like those concerning "prevention,"[43] "polluter pays,"[44] "no regrets"[45] and "clean production."[46] Like them, precaution serves to enrich and reinforce appreciations of the duties of care on the part of commercial firms[47] and of the responsibilities of sovereign governments[48] and associated regulatory administrations.[49] In short, the precautionary principle requires more explicit and rigorous attention to the implications of incomplete knowledge than is routinely provided in the conventional regulatory assessment of "risk."[50]

## Critical Debate

Given the nature of the issues and the powerful interests at stake, it is not surprising that the precautionary principle has been subject to a wide array of criticisms.[51] One frequent concern is that it is *ill-defined.*[52] In the formulation given above, for instance, how "serious" is "serious"?[53] What exactly does "irreversible" mean? Does "full scientific certainty" ever exist? Such concerns seem well founded if the precautionary principle is presented as a sufficient, comprehensive or definitive procedural rule.[54] Yet legal scholars point out that, as with any general legal principle (like "proportionality" or "cost-effectiveness"), precaution is not a decision rule in its own right.[55] Just as these other principles rely on methods like risk assessment and cost–benefit analysis in order to make them operational, so, too, can precaution simply be seen as a general guide to the development and application of more detailed complementary methods and processes. This point is returned to in the next section.

A further criticism is that the inherently normative character of the precautionary principle renders it intrinsically *irrational.*[56] In one form, this concern rests on the (usually implicit) assumption that conventional "science-based" procedures manage to transcend normative content.[57] However, this neglects the ways in which practical applications of methods like risk assessment and cost–benefit analysis also require the exercise of evaluative judgments. For instance, these are intrinsic to the setting of levels of protection, the weighing of different forms of harm and their balancing with countervailing benefits.[58] Beyond this, an extensive literature documents how such apparently "science-based" methods are typically subject to divergent "framings."[59] As a consequence, the results obtained in areas such as climate,[60] energy,[61] chemicals,[62] genetic modification[63] and industrial regulation[64] often display strong sensitivity to assumptions that can vary radically across different, equally authoritative studies.[65] When analysis is acknowledged to be "framed" in this way by value judgments, there is an argument that the explicit normativity of precaution is actually more, rather than less, rational.

A variant of the charge of irrationality rests in the particular orientation of the *normative presumption* of precaution in favor of the environment.[66] Under evaluative positions prioritizing economic competitiveness or favoring the particular technologies or institutions that are subject to challenge, this contrasting presumption can appear self-evidently unreasonable.[67] Such positions are, of course, entirely legitimate in a plural democratic society. They represent one of the main reasons for the controversial status – and, indeed (to some), necessity[68] – of the precautionary principle. Yet it is difficult to claim that these evaluative positions have a monopoly on rationality itself. Instead, such criticisms may be seen not as refuting the rationality of precaution, but as a salutary reminder that it should not be invoked as a means to suppress or divert deliberation, argument or dissent. In short, these criticisms reflect disagreement with the normative values underlying precaution, not a refutation of its rationality.

A related set of concerns focus on the *political implications* of the precautionary principle. Cases are sometimes cited in which it appears to have been applied in an expedient fashion, in order to achieve outcomes that are actually pursued for rather different reasons – like the rejection of particular technologies or the protection of national industries from international trade competition.[69] Where precaution is invoked selectively or opaquely with respect to a particular policy, there are dangers that the alternatives or substitutes thereby implicitly favored[70] may actually turn out perversely to present more serious environmental or health threats.[71] Finally (and somewhat in tension with the preceding concern), there are fears that precaution is often motivated by – or might lead to – a blanket rejection of all new technological innovation.[72]

In considering such concerns, it is wise to reflect on the fundamental features of the precautionary principle highlighted in the last section. As we have seen, the principle is *not undiscriminating* in its application – but explicitly applies only under specific conditions (for instance) of serious or irreversible threat over which there is a lack of scientific certainty. This does not render it immune to expediency, but does help militate against arbitrary usage. It is important to recall here that there is also no shortage of examples of the expedient usage of conventional risk assessment as a means to protect favored technologies or inhibit their competitors.[73] A wide literature shows this to be endemic in regulatory politics.[74] Critics and proponents therefore hold tacit common ground here, in aiming for a situation in which the particular methods adopted in the implementation of precaution are more rigorous, systematic and transparent about challenges of incomplete knowledge and potentially irreversible harm than is currently the established practice in regulatory assessment.

With respect to worries over *blanket rejections of technology*, the key point is that the precautionary principle focuses on the reasons for intervening, not on the substance of the interventions themselves. These may as readily take the form of strengthened standards, containment strategies, licensing arrangements, labeling requirements,[75] liability provisions or compensation schemes[76] as the feared bans or phase-outs. Since the principle properly applies symmetrically both to a given technology and to its potential substitutes, there is no more reason why it should lead to perverse outcomes than is the case in conventional risk assessment. Concerns that precaution is generally "anti-technology" are also countered by observing how restraints on any one technology typically act in practice to favor other innovations. For instance, some of the major opportunities for renewable energy, energy efficiency, ecological agriculture or green chemistry rest in precautionary measures aimed at the incumbent technologies with which they compete. In this way, it is not precaution that appears as political rhetoric, but the selective branding of concerns over *particular* technologies as if they were undifferentiated general "pro" or "anti" technology positions.[77]

This leads on to a final series of criticisms of the precautionary principle, from a rather different quarter. These relate not to the feasibility but to the sufficiency of what is held to be the relatively *narrow technical focus* of precaution.[78] Some such concerns are informed by growing appreciation of the open,[79] indeterminate,[80] and path-dependent[81] nature of scientific and technological change. Others draw on contemporary social theory[82] concerning the structural dynamics[83] of late-modern governance institutions[84] and the wider "risk society."[85] Either way, current "risk" controversies appear far more open in their implications than narrow precautionary concerns over reversibility, safety or even scientific certainty and the environment.[86] Instead, they can be seen to reflect much wider and deeper tensions around competing cultural discourses, distributional inequities and the exercise of power in the politics of technology choice and knowledge production.[87] In this view, contemporary preoccupations with regulatory risk are part of a process in which these more substantive and intractable issues are reduced, marginalized and eclipsed.[88] At worst, the precautionary principle can thus be seen as an unhelpful simplification, distracting both attention and accountability from the real issues.

## Practical Implications

A major outcome of these critical debates is a recognition that the substantive significance of the precautionary principle rests largely in the specific institutional frameworks, deliberative procedures and analytical methods through which it is implemented.[89] *In other words, precaution is more important as a process than as a "decision rule."*[90] The purpose of this precautionary process is to help address a lack of scientific certainty by expending more effort in "social learning"[91] – exploring a wider range of salient knowledges. This is an important point, because much of the ostensible support currently afforded to the principle by governmental bodies – like the European Commission[92] – is explicitly predicated on the qualification that precaution is a risk "management" (rather than "assessment") measure. This point is also relevant to countervailing concerns from bodies such as the US government[93] (among others) to the effect that precaution implies a rejection of conventional "science-based" risk assessment. In considering these concerns, the resulting questions focus on the precise nature of the broader and more rigorous appraisal process implied by precaution – and the associated demands on money, attention, time and evidence.

A detailed understanding of these practical implications rests on an appreciation of the relationships between the precautionary principle and conventional "science-based" risk assessment.[94] Here, an especially significant contribution has been made by an extensive literature in the social and policy analysis of science.[95] This shows that a "lack of scientific certainty" can take many forms, extending well beyond the narrow technical characterization of "risk" routinely employed in risk assessment.[96] In risk assessment, multivalent complexities are reduced to two parameters. First, there are the *magnitudes* of the things that may happen ("hazards," "possibilities" or "outcomes"). Second, there are the *likelihoods* (or probabilities) associated with each. These are then aggregated across all possible dimensions, contexts, aetiologies and perspectives. The resulting "reductive–aggregative" style[97] lends itself to an apparently transcendent quantitative idiom,[98] which can then be asserted as objective authority.[99] This can in turn be used as a means to justify decisions,[100] channel accountabilities[101] and manage blame.[102] What is typically neglected in conventional risk assessment, however, is that both of these parameters may each be subject to variously incomplete or problematic knowledge, of a kind that can (by definition) not be addressed by probabilistic analysis.[103]

Under the strict state of *uncertainty*, for instance,[104] we can be confident in our characterization of the different possible outcomes, but the available empirical information or analytical models simply do not present a definitive basis for assigning probabilities.[105] Under the condition of *ambiguity*, it is not the probabilities themselves but the characterization of associated outcomes that is problematic.[106] It arises where there are "contradictory certainties,"[107] applying even for events that have occurred already.[108] Disagreements may exist, for instance, over the selection, partitioning, bounding, measurement, prioritization or interpretation of different forms or understandings of benefit or harm.[109] Finally, there is the condition of *ignorance*.[110] Here, neither probabilities nor outcomes can be fully characterized.[111] It is where "we don't know what we don't know,"[112] thus facing the ever present prospect of "surprise."[113]

In order to emphasize the practical relevance to established risk assessment, Figure 43.1 represents these contrasting states of knowledge as logical permutations under the two basic parameters structuring risk assessment: "outcomes" and "likelihoods." In practice, of course, these four "ideal–typical" states typically occur together.[114] The scheme is thus not a taxonomy but a heuristic distinction between different "*aspects*

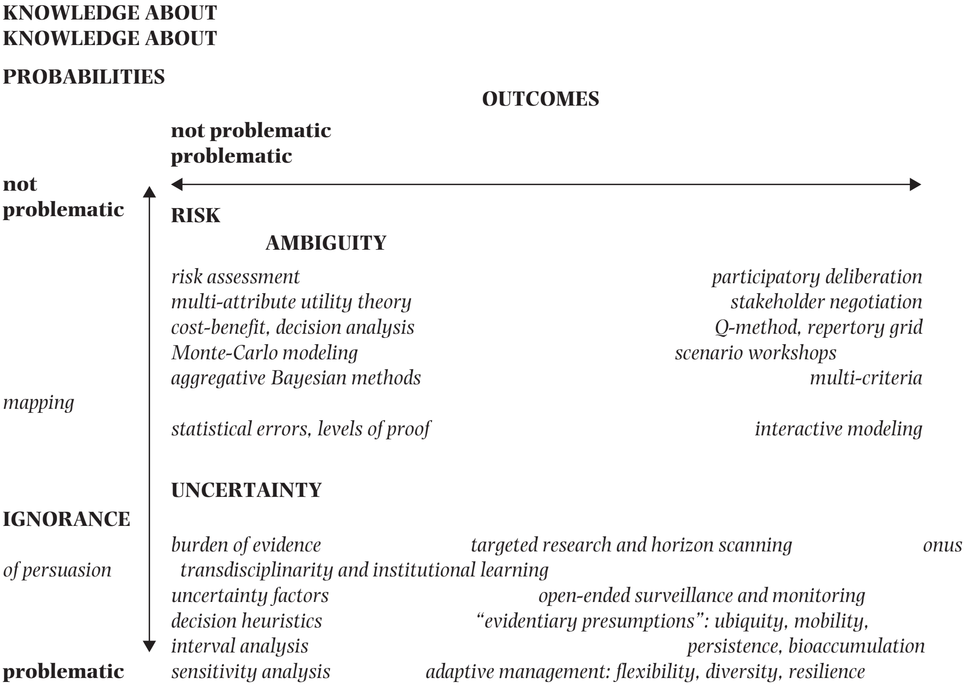

**Figure 43.1** Responses in technology appraisal to different aspects of incertitude

*of incertitude*"[115] – each spanning a variety of specific implications,[116] contexts[117] and causes.[118] For practical purposes, the crucial point is that each aspect is susceptible (in overlapping ways) to treatment by different kinds of institutional framework, deliberative procedure or analytical method. Most of these are less reductive or aggregative than those that are appropriate under the strict condition of "risk." But these are no less systematic or "scientific" in nature than is risk assessment. By drawing attention to this diversity of practical responses in appraisal, we can readily appreciate how precaution is directly relevant not just to the management but also to the assessment of risk. We can also see the consistency of precaution with fundamental principles of scientific rigor. In particular, it is clear that precaution does not imply a general rejection of risk assessment. Instead, it prompts attention to a variety of alternative methods that are more rigorously applicable under uncertainty, ambiguity and ignorance.

A key challenge of precaution thus lies in considering how to implement this greater diversity of approaches, and articulate them together in a more broad-based process of appraisal. Drawing on a body of recent theoretical,[119] empirical[120] and methodological[121] work, Table 43.1 summarizes a series of key considerations, which together help in responding to this challenge. Each represents a general quality, of a kind that should be displayed in any truly precautionary process of technology appraisal. Each is briefly illustrated by reference to an example drawn from regulatory experience.[122] In many ways, the qualities listed in Table 43.1 are simply common sense. As befits their general nature, they apply equally to the implementation of any approach to technology appraisal,[123] including risk assessment. This underscores the understanding that precaution represents an enhancement, rather than a contradiction, of accepted principles of scientific rigor in this field.

Important questions do arise, of course, over the extent to which it is possible in existing institutional contexts always fully to implement the array of methods identified in Figure 43.1, in a fashion that displays all the qualities summarized in Table 43.1. By contrast with conventional narrow forms of risk assessment, the associated demands on money, attention, time and evidence can look onerous indeed.[124] Although raising a number of unresolved issues, such questions suggest a focus for more constructive discussion than that which is evident in the more polarized areas of the precaution debate discussed earlier. Here, a number of frameworks have emerged in proposals from different legal,[125] environmental science,[126] public health[127] and technology policy[128] perspectives. Recent work for European risk governance bodies may serve to illustrate some of the resulting practical possibilities.

Adapted from a series of stakeholder deliberations, Figure 43.2 is a schematic outline of a general compromise framework for the articulation of precaution with conventional risk assessment of a kind that builds on the analysis discussed here.[129] This addresses concerns over proportionality, through envisaging an initial screening process. Only the most appropriate issues are thereby allocated to treatment by more broad-based (and onerous) processes of precautionary appraisal. Subject to a set of detailed screening criteria applied in stakeholder deliberation, other cases are variously allocated to more inclusive and participatory forms of appraisal (in the case of ambiguity) or more straightforward and familiar forms of risk assessment (where these are held to be sufficient). In this way, established notions of proportionality are reconciled with precaution through the employment of more targeted approaches to appraisal. Since

**Table 43.1** Key features of a precautionary appraisal process

independence from vested institutional, disciplinary, economic and political interests;
*as long constrained attention to problems caused to industrial workers by asbestos.*

examination of a greater range of uncertainties, sensitivities and possible scenarios;
*as addressed in early attention to risks of antimicrobials in animal feed, but later neglected.*

deliberate search for "blind spots," gaps in knowledge and divergent scientific views;
*as with assumptions over the dynamics of environmental dispersal of acid gas emissions.*

attention to proxies for possible harm (e.g. mobility, bioaccumulation, persistence);
*as encountered in managing chemicals like the ostensibly benign fuel additive MTBE.*

contemplation of full life cycles and resource chains as they occur in the real world;
*like failures in PCB containment during decommissioning of electrical equipment.*

consideration of indirect effects, like additivity, synergy and accumulation;
*of a kind long neglected in the regulation of occupational exposures to ionizing radiation.*

inclusion of industrial trends, institutional behavior and issues of non-compliance;
*the latter featuring prominently in the large-scale misuse of antimicrobials in animal feed.*

explicit discussion over appropriate burdens of proof, persuasion, evidence, analysis;
*for instance around the systematic neglect of "Type II errors" in risk assessment.*

comparison of a series of technology and policy options and potential substitutes;
*a topic neglected in the over-use of diagnostic X-rays in health care.*

deliberation over justifications and possible wider benefits as well as risks and costs;
*as insufficiently considered in licensing of the drug DES for pregnant mothers.*

drawing on relevant knowledge and experience arising beyond specialist disciplines;
*like the knowledge gained by birdwatchers concerning the dynamics of fish stocks.*

engagement with the values and interests of all stakeholders who stand to be affected;
*as with experience of local communities on pollution episodes in the Great Lakes.*

general citizen participation in order to provide independent validation of framing;
*as was significantly neglected in checking assumptions adopted in the management of BSE.*

a shift from theoretical modeling toward systematic monitoring and surveillance;
*which would help address conceptual limitations, such as those affecting regulation of PCBs.*

a greater priority on targeted scientific research, to address unresolved questions;
*as omitted for long periods over the course of the development of the BSE crisis.*

initiation at the earliest stages "upstream" in an innovation, strategy or policy process;
*helping to foster cleaner innovation pathways before lock-in occurs to less benign options.*

emphasis on strategic qualities like reversibility, flexibility, diversity, resilience;
*these can offer ways partly to hedge against even the most intractable aspects of ignorance.*

*Source:* After G. Gee, P. Harremoes, J. Keys, M. MacGarvin, A. Stirling, S. Vaz and B. Wynne, *Late Lesson from Early Warnings: The Precautionary Principle 1898–2000* (Copenhagen: European Environment Agency, 2001).

the screening applies to all cases, the resulting analytic–deliberative framework as a whole remains precautionary.

Under the final set of criticisms of precaution discussed in the last section, these kinds of "practical" framework can look highly simplified, instrumental and even potentially counterproductive. The fear is that their compatibility with existing practices simply serves to reinforce current institutional inadequacies. However, a counterargument is that such frameworks might alternatively be seen as a tactical means to introduce into existing mainstream policy discourses and institutional procedures concerned with

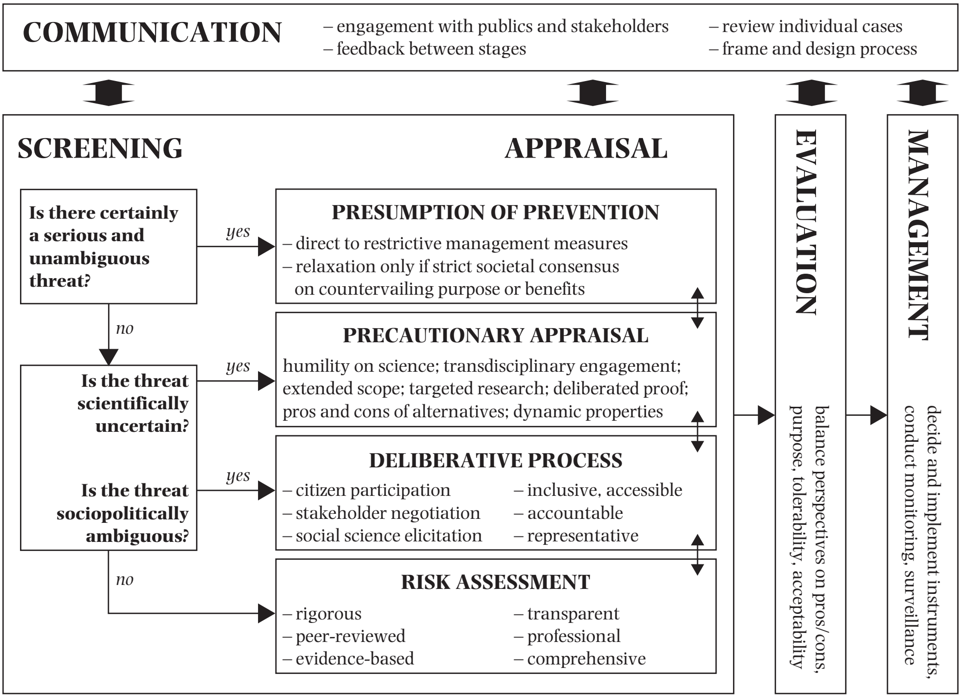

**Figure 43.2** A framework articulating risk assessment and precautionary appraisal
*Source:* Adapted from A. Stirling, O. Renn and P. van Zwanenberg, "A Framework for the Precautionary Governance of Food Safety: Integrating Science and Participation in the Social Appraisal of Risk," in E. Fisher, J. Jones and R. von Schomberg (eds) *Implementing the Precautionary Principle: Perspectives and Prospects* (Cheltenham: Edward Elgar, 2006), pp. 284–315.

regulation and innovation the wider political issues raised earlier concerning the governance of knowledge production and technology choice. Under this agenda, the adoption of an instrumental idiom on precaution is a sign not of naïve or expedient simplification, but of strategic sophistication. In this way, the implementation of more broad-based precautionary processes of appraisal may themselves help catalyze the development of more reflexive institutions[130] – going well beyond the ostensibly marginal reform of existing administrative practices implied in the apparently reductive and instrumental diagrams. By opening the door to recognition of the full implications of uncertainty, ambiguity and ignorance, these kinds of framework for the practical implementation of the precautionary principle in technology appraisal may help to nurture the emergence of a richer and more vibrant, deliberate and equitable general politics of technology.[131]

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## 44

# Boundary-work, Pluralism and the Environment

JOZEF KEULARTZ

Unfortunately, most environmental problems appear to be difficult to handle. Nowadays, this intractability is no longer exclusively ascribed to some inherent features of the environmental problems themselves, like complexity. There is a growing awareness that the intractability of environmental problems can at least in part be explained by the social context in which these problems arise and should be solved.

## The Tension between Sustainability and Diversity and the Quest for Unity

Climate change, air pollution, deforestation, loss of biodiversity, stratospheric ozone depletion, land and freshwater degradation – all these environmental problems have effects that transcend national boundaries; they cannot be solved by the unilateral decisions of individual states but require international cooperation. Moreover, these problems are interconnected and cannot be solved in isolation but require an integrated approach. But such an approach is frustrated by the existing multiplicity of communities with diverse and sometimes diverging ethical visions and moral vocabularies. Hence there is a strong tension between the diversity of actors that have a stake in sustainable development and the need for a close cooperation between these various stakeholders. There is a general tendency to resolve this tension by a forced striving for unity. This quest usually takes one of the following directions: it is aimed at one world community without borders, at a new comprehensive worldview, or at a universal scientific method.

### *One world community*

Because environmental problems usually transcend state borders and are closely interrelated, they require an integrated approach. It seems that such an approach can only succeed if world politics loses the anarchistic character that is inherent to the system of sovereign states that gradually spread around the world after the Treaty of Westphalia in 1648. That, at least, is the opinion of Peter Singer. In an era of globalization, Singer insists in his book *One World*, we should abandon the idea of

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sovereign states and replace it with "a sense that we really are one community" (Singer 2004: 7). We should go beyond the existing state boundaries and develop an ethics without borders – a "one-world-ethics."

However, the process of globalization that Singer so positively refers to goes hand in hand with a process of decentralization and fragmentation in most states: the restriction of state power and state control "from above" is accompanied by a restriction "from below." But this picture is far from complete – because the locus of power, control and decision-making has moved not only "upward" and "downward" from the state level, but also sideward, partly to the market and partly to civil society. So, actually, we have to do with a double shift in governance: a *vertical* shift from the national level to more global and to more local levels, and a *horizontal* shift from the state to the market and to civil society. These worldwide shifts in governance have led to a significant increase in levels of decision-making (*multi-level governance*) and to a considerable growth of the number of private and public players (*multi-actor governance*). Instead of the advent of Singer's single-world community we actually witness an ongoing multiplication of communities. Increasingly, policy-makers are dealing with a wide array of groups which do not necessarily speak each other's language or share similar conceptions of the world. With that many voices and vocabularies and that many interests at stake, the specter of the Tower of Babel looms large. Especially in contested matters such as scarce natural resources, multiple conflicts arise. At the same time, the sustainable management of these natural resources requires an integrated approach and a close cooperation among all groups involved. So, again, the question is: How should the tension between sustainability and diversity be resolved?

## *One worldview*

Both environmental philosophers and activists tend to resolve this tension by developing a new comprehensive worldview that would provide the unifying power that seems indispensable for dealing with the environmental crisis. Most environmental philosophers and activists agree with Martin Heidegger's criticism of the anthropocentrism of Western metaphysics. If man sets himself up as the measure and master of all things, nature will appear solely as "material" that he can control and command as he pleases. This metaphysical disease can only be cured with the help of a different metaphysical worldview. To prevent the environmental crisis from ending in catastrophe, we should turn away from anthropocentrism and convert to some sort of biocentrism or ecocentrism: we should no longer treat nature in terms of her instrumental significance for our survival and self-preservation but instead acknowledge and respect her intrinsic value. Typically, such a new metaphysics evolves along holistic lines and bears an ecological stamp, according to the slogan that the whole is greater than the sum of its parts and that everything is connected to and dependent on everything else.

However, the way to resolve the tension between sustainability and diversity through a new, comprehensive and unifying worldview turns out to be a blind alley as well. Since Emmanuel Kant, modern philosophy has left the road from diversity to unity and has taken the opposite road: the road from unity to diversity – to differentiation, decentering, dissemination, deconstruction, dissensus and discontinuity, to name a few of the terms in circulation to describe this process. This road from unity to diversity culminates in the work of Jean-François Lyotard, who with a great fanfare has proclaimed the end of the grand narratives (*meta-écrits*). The aversion of contemporary philosophers to grand narratives is only too understandable. Such narratives have an ethnocentric character because they are products of a specific time and place. Furthermore, recent history demonstrates that such narratives, exactly because of their claims to totality and unity, show terrorist features – they suppress and destroy everything that is incompatible with these narratives. This is also the case with ecologically inspired narratives of the future ("green utopias") that enjoy great popularity among environmental philosophers and activists. So we had better stop the quest for grand narratives and try to accept and live with the multitude and variety of ethical visions and moral vocabularies. But, then, again, the question arises: how is cooperation possible at all under these pluralist conditions?

### *The universal scientific method*

The third way to answer this question is "science." This pathway is frequently taken because the supposed universal character of science looks like a watertight guarantee for the unity that seems essential for a collaborative solution to global environmental problems. But, again, this solution, too, turns out to be a mock-solution. The image of science as an objective and impartial provider of the empirical facts and rational explanations upon which politicians and policy-makers can safely rely has become outdated. Especially in the case of very complex problems like climate change, biotechnology or genomics, this traditional image no longer matches reality. With these disciplines we find ourselves each time in a situation in which "the facts are uncertain, values in dispute, stakes high and decisions urgent."

Under these conditions the puzzle-solving strategies of "normal science" (in the Kuhnian sense) are no longer appropriate and we have to switch over to what Silvio Funtowicz and Jerome Ravetz have called "post-normal science." The most prominent feature of post-normal science is the extension of the peer community and the inclusion of an ever growing set of scientific and non-scientific stakeholders. The boundaries between science and society are becoming more and more blurred, with the result that all existing societal conflicts are penetrating the heart of science itself. So science no longer exists as an independent and impartial agency outside or above society, and is therefore no longer able to provide politicians and policy-makers with objective rules and universal guidelines.

## Boundary-work

The different ways to handle the tension between diversity and sustainability mentioned so far boil down to the search for a new unity, and to the limitation and finally to the elimination of political, ideological and scientific diversity. They all turned out to be blind alleys: the striving for one single world community without borders is as unrealistic as the striving for one single metaphysical worldview or the appeal to science as the sole arbitrator with whom all parties should comply. But, if we abandon all efforts to reduce or eliminate diversity once and for all, and if we acknowledge plurality without any reservations, then the question of the possibilities for cooperation for a sustainable management of natural resources becomes all the more urgent.

A promising answer to this question is "boundary-work," i.e. the constructive effort to support communication and coordination across the fences that separate communities. Here one can take inspiration from philosophical pragmatism and from scientific disciplines that are strongly influenced by philosophical pragmatism like Public Policy Studies and Science and Technology Studies. This should not come as a surprise because, from the start, pragmatism has promoted the issues of communication and collaboration under pluralist conditions to key issues. Three pragmatic methods of boundary work will be discussed in some detail: the overcoming of dualisms by *gradualization*, the transformation of problematic situations by *reframing*, and the creation of space for shared problem-solving by the formation of so-called *boundary objects*.

## *Gradualization*

A common pragmatic strategy to make persistent conflicts manageable is breaking up dualisms. Pragmatism is an anti-dualistic movement of thought. Both Western philosophy and Western common sense are dominated by dualisms like theory and practice, fact and value, body and mind, nature and culture, instrumental and intrinsic value. These dualisms encourage "black-and-white" thinking, which brings conflicts to a head and leads debate to reach a total deadlock. One method to break up dualisms is gradualization: thinking in terms of degrees instead of boundaries.

One example of this is the debate between animal protectionists and nature conservationists about the moral problems associated with the introduction of large grazing animals in Dutch nature reserves. These animals are basically domesticated species that are derived from hoofed animals that were once wild, such as cattle, horses, sheep and goats. They are subjected to a process of "de-domestication" and have to learn to fend for themselves. The management policies of de-domestication, which entail minimizing supplementary feeding and veterinary assistance, have been most controversial. There is a lot of debate over the question whether these animals should be seen and treated as domesticated or as wild. While the majority of the animal protectionists view the released horses and cattle as domesticated animals to be cared for as individuals, most nature conservationists prefer to treat them the same as wild animals. As a result of this discord, people exhaust themselves in unproductive boundary disputes in which both sides claim an exclusive "moral jurisdiction" over large grazing animals.

This deadlock can be overcome by replacing the notion of a clear-cut borderline between nature and culture with the idea of a broad continuum or scale. Then the status of grazing animals introduced into nature reserves is no longer a question of "either–or" but of "less or more." These animals do not simply cross a distinct dividing line between culture and nature; they do not walk from domestication into the wild, that is, from a moral domain of individual care to one of concern for the ecological whole. They gradually move from a thoroughly cultural context to one that is increasingly natural. In this de-domestication process, both animal protectionists and nature conservationists will be indispensable. Thus, the gradualization strategy can help to bridge the rift between these groups and can open up new possibilities for communication and cooperation.

### *Reframing*

Another pragmatic strategy to make conflicts manageable is what Dewey has called "reconstructive thinking." Within Public Policy Studies, this method is developed by pragmatist Donald Schön. According to Schön, the difficulties in handling intractable problems have more to do with problem-setting than with problem-solving. Conflicts become difficult to solve if the problem at hand is framed differently by the opponents. Such conflicts require what Schön calls "frame restructuring." Hereby "we respond to frame conflict by constructing a new problem-setting story, one in which we attempt to integrate conflicting frames by including features and relations drawn from earlier stories" (Schön 1979: 270).

A good example of reframing is the notion of "sustainable development." Environmental problems, too, become intractable because different parties frame these problems differently. In the industrialized North, environmental degradation is considered a result of overproduction and overconsumption. Hence the slogan "Limits to Growth," as the famous Club of Rome has called their first report from 1972. In the South, environmental degradation is framed quite differently, as a consequence not of too much material wealth but of too much poverty. Hence the fierce protests of developing countries against the possible limits on their industrial development and their exploitation of natural resources.

The notion of "sustainable development" was introduced to bridge this gap in the perception of environmental degradation. It meets both the industrialized and the developing countries halfway. It acknowledges the necessity to transform the economy and at the same time it recognizes the need for poverty alleviation and social equality. It is a good example of successful reframing because it brought together two competing frames in a new frame that opened up new possibilities for communication and cooperation.

### *Boundary objects*

Yet another pragmatic strategy concerns the formation of so-called "boundary objects." This notion was introduced by Susan Leigh Star and James Griesemer within the context of Science and Technology Studies. Boundary objects are objects

> which both inhabit several intersecting social worlds *and* satisfy the informational requirements of each of them. They are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They have different meanings in different social worlds, but their structure is common enough to more than one world to make them recognizable.
>
> (Star and Griesemer 1989: 393)

Let us turn to climate change, the "quintessential environmental problem," for an example of a successful boundary object: the so-called Clean Development Mechanism (CDM). This is one of the so-called "flexibility mechanisms" established under the Kyoto

Protocol: market-based mechanisms that allow industrialized countries flexibility in meeting their commitment to reduce greenhouse gas emissions by taking action outside their own borders. The Clean Development Mechanism enables industrialized countries to invest in emissions-reducing projects in developing countries. CDM projects should address the need for sustainable development of the host country and generate credits for the donor country.

CDM offers many benefits for the diverse group of stakeholders involved. Donor countries will receive carbon credits to meet their commitment at the lowest possible costs. Corporations in these countries will try to acquire carbon credits for reasons of cost-effectiveness, but they may also view a CDM project as a means to create markets for their products, or as a way to enhance their corporate image. Other investors will also benefit. Institutional investors will be able to further portfolio diversification and to promote socially responsible business. A foundation or NGO may invest in a CDM project as a means of putting carbon credits out of commercial circulation.

Host countries will benefit as well. They receive new and additional investment to foster sustainable development, in line with their own priorities. They will also be able to profit from the transfer of low- or no-carbon-emitting technologies. CDM projects can have a positive effect on the local environment, by reducing air pollution and groundwater contamination, and by protecting or restoring biodiversity. They can also have a positive effect on the local economy and on employment, on poverty alleviation and on capacity-building.

CDM projects bring together various persons and parties who formerly had no contact with each other, and create a widespread collaboration between them. By enabling communication and cooperation between diverse parties and countries, CDM can help build and enhance the trust that is an indispensable precondition for the acceptance of and compliance to new or further commitments, especially by the developing countries. In this way it can help overcome the profound differences in the moral perception and framing of environmental problems.

## Conclusion

An important precondition for successful boundary-work is what Schön and Rein have called "double vision": "the ability to act from a frame while cultivating awareness of alternative frames" (Schön and Rein 1994: 207). We should learn to "squint," so to speak, in order to see things from different angles simultaneously. The notion of "double vision" is meant to make students, teachers, researchers and policy-makers more aware of and sensitive to difference. Such an awareness and sensitivity are crucial if we want to foster and facilitate collaborative conflict resolution and integrative problem-solving to prevent further degradation of our natural resources.

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# 45

# Global Warming

SIR JOHN HOUGHTON

Global warming is often described as the most important problem the world faces in the twenty-first century. It is an example of *global pollution.* Emissions of the gas carbon dioxide into the atmosphere from the burning of fossil fuels – coal, oil and gas – to which we all contribute, are leading to damaging climate change – so affecting everyone in the world. *Global* pollution demands *global* solutions. This article will outline the scientific basis for human-induced climate change, then summarize the main impacts on human communities and ecosystems, and finally mention the action that needs to be taken to mitigate the change and adapt to it.

## The Science of Global Warming

By absorbing infra-red or "heat" radiation from the earth's surface, "greenhouse gases" present in the atmosphere, such as water vapor and carbon dioxide, act as blankets over the earth's surface, keeping it warmer than it would otherwise be. The existence of this natural "greenhouse effect" has been known for nearly two hundred years; it is essential to the provision of our current climate, to which ecosystems and we humans have adapted.

Since the beginning of the industrial revolution around 1750, one of these greenhouse gases, carbon dioxide, has increased by over 35 percent and is now over 380 parts per million (ppm) – a higher concentration in the atmosphere than for many hundreds of thousands of years. Chemical analysis demonstrates that this increase is due largely to the burning of fossil fuels – coal, oil and gas. If no action is taken to curb these emissions, the carbon dioxide concentration will rise during the twenty-first century to two or three times its pre-industrial level.

The climate record over past centuries shows a lot of natural variability arising from external factors (such as changes in the sun's energy or the influence of volcanoes) or from internal variations within the climate system. However, the rise in global average temperature (and its rate of rise) during the twentieth century is well outside this range of known natural variability. The twelve warmest years in the instrumental record that goes back to 1860 have occurred since 1990. A more striking statistic is that each of the first eight months of 1998 was the warmest on record for that month. There is

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very strong evidence that most of the warming over the last fifty years is due to the increase of greenhouse gases, especially carbon dioxide.

Over the twenty-first century the global average temperature is projected to rise by between 2 and 6°C (3.5 to 11°F) from its pre-industrial level; the range represents different assumptions about greenhouse gas emissions and the sensitivity of the climate. For *global average* temperature, a rise of this amount is large. Its difference between the middle of an ice age and the warm periods in between is only about 5 or 6°C. So, associated with likely warming in the twenty-first century will be a rate of change of climate equivalent to, say, half an ice age in less than a hundred years – a larger rate of change than for at least 10,000 years. Adapting to this will be difficult for both humans and many ecosystems.

## The Impacts of Global Warming

Talking in terms of changes of global average temperature, however, tells us rather little about the impacts on human communities. There will be some positive impacts – for instance a longer growing season at high latitudes. But most impacts will be adverse.[1] One obvious impact will be due to the rise in sea level (of about half a meter [20 inches] a century) that is mainly occurring because ocean water expands as it is heated. This rise will continue for many centuries – to warm the deep oceans as well as the surface waters takes a long time. This will cause large problems for human communities living in low-lying regions. Many areas – for instance in Bangladesh, southern China, islands in the Indian and Pacific oceans, and similar places elsewhere in the world – will be impossible to protect, and many millions will be displaced.

There will also be impacts from extreme events. The extremely unusual heatwave in central Europe during the summer of 2003 led to the death of over 20,000 people. Careful analysis leads to the projection that such summers are likely to be average by the middle of the twenty-first century and cool by the year 2100.

Water is becoming an increasingly important resource. A warmer world will lead to more evaporation of water from the surface, more water vapor in the atmosphere and more precipitation on average. Of greater importance is the fact that the increased condensation of water vapor in cloud formation leads to greater release of latent heat of condensation. Since this latent heat provides the largest source of energy driving the atmosphere's circulation, the hydrological cycle will become more intense. This means a tendency to more intense rainfall events and also less rainfall in some semi-arid areas. The most recent estimates indicate by 2050 a typical increase in many places of around a factor of five in the risk of the most extreme floods and droughts.[2] Since, on average, floods and droughts are the most damaging of the world's disasters, their greater frequency and intensity is bad news for most human communities and especially for those regions such as Southeast Asia and sub-Saharan Africa where such events already occur only too frequently. These sorts of events provide some credence for the comparison of climate with weapons of mass destruction.

Sea-level rise, changes in water availability, and extreme events will lead to increasing pressure from environmental refugees. A careful estimate has suggested that, owing to climate change, there could be more than 150 million extra refugees by 2050.[3] The rapidity of climate change will also have a large impact on ecosystems and lead to substantial loss of biodiversity.

In addition to the main impacts summarized above are changes about which there is less certainty, but if they occurred would be highly damaging and probably irreversible. For instance, large changes are being observed in polar regions. If the temperature rises more than about 3°C (~5°F) in the area of Greenland, it is estimated that meltdown of the ice cap would begin. Complete meltdown is likely to take many centuries, but it would add 7 meters (23 feet) to the sea level.

## Can We Believe the Evidence?

How sure are we about the scientific story I have just presented? It is largely based on the assessments by the world scientific community carried out through the work of the Intergovernmental Panel on Climate Change (IPCC).[4] I had the privilege of being chairman or co-chairman of the Panel's scientific assessment from its beginning in 1988 to 2002. Many hundreds of scientists from many countries were involved in its work. No assessments on any other scientific topic have been so thoroughly researched and reviewed. In June 2005, the Academies of Science of the world's eleven most important countries (the G8 plus India, China and Brazil) issued a statement endorsing the IPCC's conclusions.[5]

Unfortunately, there are strong vested interests that have spent tens of millions of dollars on spreading misinformation about the climate change issue. They first denied the scientific evidence and more recently have argued that its impacts will not be large, that we can "wait and see," and in any case we can always "fix" the problem if it turns out to be substantial. The scientific evidence cannot support such arguments.

## International Agreement Required

Global emissions of carbon dioxide to the atmosphere from fossil fuel burning are currently approaching 7 billion tonnes of carbon per annum and rising rapidly. Unless strong measures are taken, they will reach two or three times their present levels during the twenty-first century and climate change will continue unabated. To halt climate change during the twenty-first century, global emissions must be reduced to a small fraction of their present levels before the century's end.

Because of the work of the IPCC and its first report in 1990, the Earth Summit in Rio de Janeiro in 1992 was able to address the climate change issue and the action that needed to be taken. The Framework Convention on Climate Change (FCCC) – agreed by over 160 countries, signed by President George Bush, Snr, for the USA and subsequently ratified unanimously by the US Senate – agreed that Parties to the Convention should take "precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects. Where there are threats of irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures."

More particularly, the Objective of the FCCC in its Article 2 is "to stabilise greenhouse gas concentrations in the atmosphere at a level that does not cause dangerous interference with the climate system" and that is consistent with sustainable development. Such stabilization would also eventually stop further climate change. However, because of the long time that carbon dioxide resides in the atmosphere, the lag in the response of the climate to changes in greenhouse gases (largely because of the time taken for the ocean to warm), and the time taken for appropriate human action to be agreed, the achievement of such stabilization will take at least the best part of a century.

One of the largest challenges faced by the international community is how emissions of carbon dioxide can be shared fairly between nations. Currently great disparity exists between emissions by rich nations compared with those by poorer ones. Expressed in tonnes of carbon per capita per annum, they vary from about 5.5 for the USA, 2.2 for Europe, 0.7 for China and 0.2 for India. Further, the global average per capita, currently about 1 tonne per annum, must fall substantially during the twenty-first century. A proposal by the Global Commons Institute[6] is that emissions should first be allocated to everybody in the world equally per capita, with transfer of allocations then being allowed through trading between nations. The logic and the basic equity of this proposal is in principle compelling; in practice, it will not be easy to achieve.

The Kyoto Protocol agreed by the FCCC in 1997 finally came into force in 2005. It represents a beginning for the process of mandatory reduction in greenhouse gases, averaging about 5 percent below 1990 levels by 2012 by those developed countries that have ratified the protocol. It is an important start, demonstrating the achievement of a useful measure of international agreement on such a complex issue. It also introduces for the first time international trading of greenhouse gas emissions so that reductions can be achieved in the most cost-effective ways.

Serious discussion is now beginning about international agreements for emissions reductions post-Kyoto. These must include all major emitters in both developed and developing countries. Regarding a target level for stabilization of greenhouse gases in the atmosphere, most proposals[7] now fall within the range of 450 to 550 ppm in terms of equivalent $CO_2$,[8] which means 400 to 490 ppm in terms of $CO_2$ alone. This implies a reduction in global carbon dioxide emissions from the current level by over 50 percent by 2050. The UK government, for instance, has taken a lead and has agreed a target for the reduction of greenhouse gas emissions of 60 percent by 2050 – a target that recognizes that developed countries need to make greater reductions to allow some headroom for developing countries.

Those in the developed countries have already benefited over many generations from abundant fossil fuel energy. As is recognized by the FCCC, the realization that the adverse impacts of climate change will fall disproportionately on poorer nations creates a strong moral imperative for urgent action by industrialized countries.

## What Actions Can Be Taken?

First, it is essential that all countries and communities begin to prepare to adapt to the climate change to which the world is already committed and which will become more apparent over the next few decades.

Regarding mitigation, three sorts of actions are required if the reductions mentioned above are to be achieved. First, there is energy efficiency. Very approximately, one-third of energy is employed in buildings (domestic and commercial), one-third in transport and one-third by industry. Means are available to double the efficiency of energy use in all three sectors, in many cases with significant savings in cost. Second, a wide variety of non-fossil-fuel sources of energy are available for development and exploitation – for instance, biomass (including waste), solar power (both photovoltaic and thermal), hydro, wind, wave, tidal, geothermal energy and nuclear. Third, there are possibilities for sequestering carbon that would otherwise enter the atmosphere either through the planting of forests or by pumping underground (for instance in spent oil and gas fields). The opportunities for industry for innovation, development and investment in all these areas are large. Technology transfer from developed to developing countries is also vital if energy growth in developing countries is going to proceed in a sustainable way.

What about the cost of action, and how does it compare with the likely cost of damage if no action is taken? A recent review of the economics of climate change by Sir Nicholas Stern provides estimates of both. The likely cost of climate change impacts is estimated at up to 3 percent of global world output for a warming of 2–3°C and up to 10 percent (over 10 percent in many poor countries) if warming rises more than 5°C as is likely to occur next century if no action to reduce greenhouse gases is taken. These estimates in terms of loss of GDP do not take into account the human cost in terms of death, dislocation, misery, lack of security, etc., that would also accompany large-scale climate change. The annual costs of stabilization of atmospheric carbon dioxide within the range quoted above are estimated to be around 1 percent of world GDP by 2050, a number broadly in agreement with those estimated by the IPCC in its 2001 Report and much less than the cost of taking no action. These conclusions present a very large challenge to governments, industry and indeed to everybody to contribute urgently to the mitigation of human-induced climate change.

Sir John Houghton was co-chairman of the Scientific Assessment for the IPCC from 1988 to 2002. He was previously chairman of the Royal Commission on Environmental Pollution (1992–8), chief executive of the Meteorological Office (1983–91) and Professor of Atmospheric Physics, University of Oxford (1976–83). He is currently chairman of the John Ray Initiative, a trustee of the Shell Foundation and Honorary Scientist at the Hadley Centre.

## Notes

1. A modern, well-illustrated account of climate change and its impacts is that of Gore, A. (2006). *An Inconvenient Truth* (New York: Rodale).
2. See, for instance, on floods in Europe, Palmer, T. N. and Raisanen, J. (2002), *Nature*, 415: 512–14, and, on global extreme droughts, Burke, E. J., Brown, S. J. and Christidis, N. (2006), *Journal of Hydrometeorology*, 7: 1113–25.
3. Myers, N. and Kent, J. (1995). *Environmental Exodus: An Emergent Crisis in the Global Arena* (Washington, D.C.: Climate Institute).

4. *Climate Change 2001* in four volumes, published for the IPCC by Cambridge University Press, 2001. Also available on the IPCC website www.ipcc.ch. My book, Houghton, J. (2004). *Global Warming: The Complete Briefing*, 3rd edn (Cambridge: Cambridge University Press), is strongly based on the IPCC reports. Further, a review I have recently written (Houghton, J. [2005]. *Global Warming*, Reports Progress in Physics, 68, pp. 1343–1403) provides a concise summary of the science and associated impacts.
5. <www.royalsoc.ac.uk/document.asp?id=3222>
6. For more details, see <www.gci.org.uk>
7. See, for instance, the Stern Review commissioned by UK government, published by Cambridge University Press, 2006.
8. Equivalent $CO_2$ (often written as $CO_2e$) includes the effect of increases from pre-industrial in the other greenhouse gases ($CH_4$, $N_20$), etc.) – assumed here to be constant at their 1990 levels – expressed as an additional amount of $CO_2$ that would give the same radiative forcing; 450 ppm $CO_2$ is equivalent to about 510 ppm $CO_2e$.

# 46

# The Reinvention of $CO_2$ as Refrigerant for Both Heating and Cooling

JAN HURLEN

## The Breakthrough of the Refrigerant System

In 1862, the French engineer F. Carré presented a refrigeration machine based on ammonia and water. Based on his principles, several new areas of application for refrigeration systems were found in the nineteenth and twentieth centuries, and many of the technical problems were solved. However, there were still problems – especially in connection with toxic refrigerants. Accidents with refrigerants such as sulfur dioxide and methyl chloride could be fatal. Ammonia leaks could also have toxic effects, and throughout the twentieth century scientists endeavored to find a non-toxic, non-flammable, efficient refrigerant.

## $CO_2$ Makes a Brief Appearance

$CO_2$ – or carbon dioxide – has been used as refrigerant for cooling and freezing since approximately 1870, and was particularly popular with the military and with the shipping industry because it was neither toxic nor flammable.

But, in the 1940s, $CO_2$ disappeared from the market, mainly owing to technical problems. Containing the high-pressure charge inside the system was problematic, and leaks were common. Besides, the new "wonder working fluids" CFC and HCFC had come on the market and, backed by a prosperous chemical industry, proved tough competition for the old $CO_2$ technology.

Both CFC (chlorofluorocarbon) and HCFC (hydrochlofluorocarbon) contain chlorine – a chemical that later in the 1970s was proved to be a strong ozone-depleting substance.

## The New Wonder Refrigerants

As early as the 1890s, Belgian scientists experimented with chemical compounds containing the elements chloride, fluoride and carbon, known as chlorofluorocarbons

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(CFCs). These compounds are chemically highly stable and transport heat well. They were consequently selected for a wide range of technological applications, including refrigeration.

The technology was adopted by industry in the 1930s. During the 1950s and 1960s it was applied in cars, fridges and freezers – all products of postwar affluence.

In the mid-1970s, the environmental effects of CFC gases came into question. Research indicated that these gases depleted the ozone layer and contributed to global warming. The following years saw a heated debate on the possible harmful effects of these substances, and intensive research for alternative refrigerants began.

## The Area of the HFC Gases

In the early 1980s it became technically and financially possible to develop substitutes for CFC gases that did not harm the ozone layer. Hydrofluorocarbons (HFCs), consisting of hydrogen, fluorine and carbon, quickly became a popular substitute for CFC gases. The great advantage of HFC compounds was that they were safe and efficient working fluids, like CFC gases, and could be used in more or less the same systems, but did not affect the ozone layer. HFC gases soon became the dominant working fluid in refrigeration systems. But, like CFC, HFC was a very powerful greenhouse gas, and the refrigeration industry was under continual international pressure to find new and more environmentally friendly products. The quest for the ultimate refrigeration system was not yet over.

## A New Technology Is Born – in Norway

In response to the 1987 UN Montreal protocol on substances that depleted the ozone layer, a team of scientists from the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) joined the quest. They studied natural working fluids like ammonia, hydrocarbons, water and carbon dioxide ($CO_2$), and they immediately saw many clear advantages of using $CO_2$ as a refrigerant, but now in a transcritical condition implying an operating pressure of over 100 bar.

First, $CO_2$ was a natural substance, which meant that nothing synthetic or harmful would be introduced to the environment. Second, the substance was neither toxic nor flammable and was therefore safe to work with. Finally, it was a cheap and easy source as it was an industrial by-product. The many requirements for the perfect refrigerant seemed to be met. The question was whether $CO_2$ technology requiring a very high operation pressure of more than 100 bar could become an economically realistic competitor to existing solutions.

The company Norsk Hydro entered the scene as main industrial sponsor and partner to the further development of the transcritical $CO_2$ system in the early 1990s, being a major worldwide producer and distributor of $CO_2$ gas as well as a leading producer of aluminum micro-tubes. The latter products could be advantageously applied in high-pressure heat exchangers to reduce volume and weight – an absolute requirement in automotive applications.

Hence Norsk Hydro – in a long-term perspective – believed that such a technology could add to its commercial interest in both the $CO_2$ and aluminum area.

The new technology was named SHECCO Technology – *S*ustainable *HE*ating and *C*ooling with *CO*$_2$ – and is successfully commercialized and traded worldwide under this brand name (www.shecco.com).

Besides, the name resembles a gekko – an animal that has shown its sustainability by its existence for millions of years and has an ideal and efficient control of its body temperature by continuously adjusting it to the surrounding air temperature.

## The SHECCO Transcritical $CO_2$ Circuit

The SHECCO flow circuit shown in Figure 46.1 comprises the same elements as a standard cooling or heat pump circuit. It is separated into a low-pressure part and a high-pressure part. The compressor draws superheated low-pressure vapor from the Internal Heat Exchanger. Vapor is generated by heat absorption in the Evaporator and the Internal Heat Exchanger. After increasing the pressure and the temperature, the compressor discharges high-pressure gas into the Gas Cooler. Here, the supercritical $CO_2$ gas is cooled (heat is released to the surrounding medium – water or air).

Condensation does not occur since the pressure is supercritical. Thus, the gas is cooled and its density increased. After the Gas Cooler, the fluid is further cooled in the Internal Heat Exchanger, giving off heat to the low-pressure vapor. The fluid is then throttled to low pressure by an expansion device – for instance a valve or a similar device – giving a liquid–vapor mixture at the Evaporator inlet. Liquid is vaporized owing to

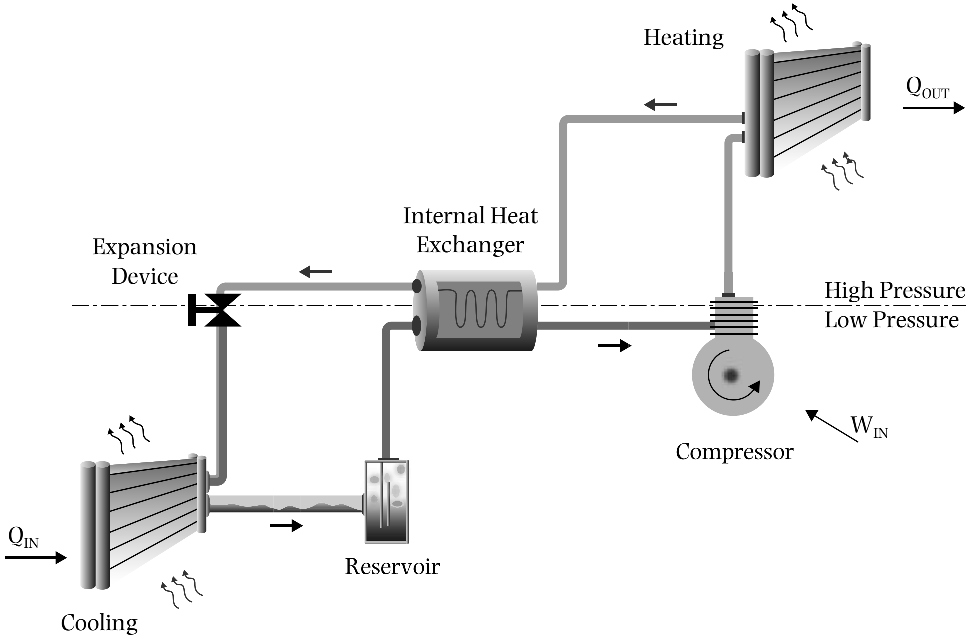

**Figure 46.1** The SHECCO flow circuit

heat absorption in the Evaporator, giving a saturated or slightly wet outlet which is buffered in a reservoir.

When using $CO_2$ in a transcritical cycle, the high-side pressure is supercritical (that is above the highest pressure under which liquid and vapor can coexist) of 7.4 MPa.++ Owing to the moderate critical temperature of $CO_2$ (31°C), transcritical cycle operation is needed in air-cooled refrigeration or air-conditioning applications and heat pumps or heat recovery applications where water or air is heated to a high temperature.

In general the system efficiency is significantly better with $CO_2$ than with HFC when applied for heating purposes, and at least as efficient as HFC when applied for cooling/freezing purposes.

## The $CO_2$ Paradox

As the global warming potential (GWP) of $CO_2$ is 1 – compared to 1300–1500 for the HFC gases widely used for cooling, freezing and warming applications in today's systems – substituting HFCs with $CO_2$ represents a substantial reduction in the global warming potential.

Hence $CO_2$ – ill-reputed in connection with all global warming debates – may actually be used to *reduce global warming.*

# 47

# Environmental Science and Technology

MARY TILES

Because technologies develop apace and continue to find new applications, and because environmental science is currently an academic growth area, any attempt to catalog examples of mutual influence is doomed to incompleteness from the outset. An alternative approach is to consider three principal questions one can ask about the connection between technology and any scientific area and then to ask how the answers will be distinctive in the case of at least some of the environmental sciences. The three questions are:

1. Does technological development drive the research agenda? If so, how and to what extent?
2. In the long term, can successful research be expected to lead to innovative technological development? If so, how?
3. To what extent and in what ways is empirical investigation dependent on technology and technological development?

Answers to the questions, especially once one gets to any level of detail, will differ for different areas of scientific investigation; but there is reason to think that, even when working at a relatively high level of generality, there are some distinctive ways in which the answers for environmental sciences will differ from those given for more traditional, laboratory sciences such as physics, chemistry and biology.

First, however, there should be some clarification of what is included under "environmental science," even though there is no unique, clearly agreed definition of this term. One useful broad indication is that it covers "all those disciplines which are concerned with the physical, chemical, and biological surroundings in which organisms live" and that it is "especially concerned with changes wrought by human activities, and their immediate and long-term implications for the welfare of living organisms."[1] The introduction to environmental science from which these quotes are taken covers earth sciences and the study of physical resources, the biosphere and the study of biological resources, and environmental management. The author also points out that one of the distinctive features of environmental science is that its conduct frequently involves assembling a team of specialists from different disciplines to address a particular issue.[2] Another introductory text, without any claims to completeness, gives a table

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listing twenty-six kinds of environmental issue of current concern as a way of indicating the broad scope of environmental science.[3] These issues range from concerns about pollution through resource depletion and waste disposal to global warming.

What this tells us is that the research agenda of contemporary environmental science is significantly driven by impacts of technological development that have become matters of public concern rather than by theoretically generated research problems.[4] The impetus to study many aspects of "the environment" as environment arose both from concern about the impact of industrial and agricultural technologies and from a desire to utilize natural resources efficiently and effectively without causing their disappearance through overexploitation. And the possibilities of overexploitation increase as more effective exploitative technologies are developed. Concern might be over the disappearance of particular wildlife species in a given area, obvious air or water pollution or feared, less obvious radiological or chemical contamination. Just as the research agenda of medical science is significantly driven by the need to address human health issues, the research agenda of environmental science is significantly driven by the need to address issues of the "health" of the environmental systems on which our lives, and those of other organisms, depend, particularly where it seems that humans have had a hand in causing the problem through their deployment of new technologies or techniques. There is a tacit assumption at work that if human beings, through their activities, including their use of technology, have caused a problem there should be a way of remedying it by changing what we do or the way in which we do it. So, to the extent that environmental science can indicate the causes of a problem and develop an understanding of the systems involved, it can at least set the stage for proposed technological and/or behavioral fixes and would continue to play a role in evaluating their success. But its research would not *per se* provide a basis for devising technology to provide the fix; it would merely set the parameters of the technological problem.

A brief and oversimplified account of the issue of acid rain illustrates one way in which this can work. In the 1950s air pollution from power stations was a concern of communities living near them. In response to local pressures, energy companies built higher smokestacks dispersing the pollution over a wider region and diverting it from the local population. In the 1960s and 1970s people living and working in forested regions well away from obvious point-sources of pollution noticed dramatic die-off of trees. Environmental scientists (in the role of environmental detectives) determined that this was a result of acid rain, itself a result of sulfur and nitrogen dioxide emissions from tall power-station smokestacks.[5] Prevention of acid rain then becomes a technological and political problem – how to reduce emissions (design and install "scrubbers" to reduce the sulfur and nitrogen dioxide content of smokestack emissions), and how to require power-generating companies (possibly in a state or country other than that experiencing the damaging effects of acid rain) to install scrubbers.

However, it would be misleading to suggest that environmental science is always driven by reaction to already recognized negative impacts of technology. Now that people have been alerted to the fact that deployment and use of technology can have unexpected and unintended effects on surrounding ecosystems, public works in many countries cannot be approved without an environmental impact assessment having been conducted. So one significant role for environmental scientists is the production of environmental impact assessments for proposed new developments.[6] Equally, as these sciences have developed their own research base and have acquired the resources to gather increasing amounts of data on an ongoing basis, scientists themselves have increasingly sought to raise public awareness of negative environmental impacts of our use of technology that they have detected and that they believe have the potential to pose serious threats if not addressed. This has been the case, for example, with the effect of CFCs (chlorofluorocarbons, used in refrigerators and aerosols) on the ozone layer, of female hormones (used in birth control pills and hormone replacement therapy) on the reproductive systems of fish, and the global warming effect of increased use of fossil fuels. In such cases, environmental science becomes a basis for setting a technological agenda, since very often people would rather find a technological solution than cease engaging in the activity the problem technologies support.

Any science is dependent on technology for its instrumentation, for constructing experimental set-ups, performing analyses or routine tests, making measurements, and collecting and processing data. Technological development enhances existing procedures and creates the possibility of whole new kinds of empirical investigation. In this respect technologies form part of the conditions of possibility for the existence of the empirical study of ranges of phenomena to which they afford access. Certainly environmental sciences have this in common with other natural sciences. However, theoretical developments in basic sciences – physics, chemistry, molecular biology – often lead to technological innovation and the development of technological devices some of which prompt development of new scientific instrumentation – the history of microscopes from early low-resolution optical instruments to electron scanning microscopes and other scanning devices provides just one sequence of examples. Because the environmental sciences, for the most part, do not have the revelation of fundamental laws, processes or entities as their goal, but rather draw on the resources provided by physics, chemistry and biology, it is not to be expected that work in these sciences will lead to the kind of technological innovation that would result in new scientific instrumentation. However, there are always exceptions, and one famous exception is the development of the cloud chamber, used by physicists for the detection of fundamental particles and the results of their collisions. This had its origins in attempts to reproduce clouds in the laboratory with a view to demonstrating that rain can be caused by an electrical discharge in the absence of particulate matter.[7]

Because the environmental sciences must deal with and seek to integrate understanding of phenomena occurring on wildly different temporal and spatial scales, the range of technologies on which they depend for data collection and integration is much broader than that of standard laboratory sciences. The history of Global Environmental Science (predominantly interdisciplinary earth systems analysis), for example, is closely interwoven with the history of the development transport, communication and military technologies and with technological ambitions to manipulate our earthly environment on a grand scale. But such global studies could not themselves develop without the development of modern communication, command, control and information technologies (computers, satellites, automated remote sensing devices). In order for phenomena exhibited on a global scale to become objects of scientific study and investigation, there have to be ways of revealing and studying phenomena on that scale.

Early meteorology was a matter of keeping systematic daily, weekly, monthly and yearly records of such things as temperature, atmospheric pressure, wind speed and direction, rainfall, cloud cover and visibility on a local basis, and of recognizing patterns in these records on the basis of which to attempt to produce short- and medium-term forecasts. With the expansion and development of shipping and then air transportation, accurate short-term forecasting became increasingly important. As Monmonier says, "Maps that could warn of storms and cold waves were a triumphant collaboration of science, technology, bureaucracy and cartography."[8] The requisite technology was the electric telegraph that for the first time made possible the rapid collection of perishable data from widely separated weather observers and the subsequent communication of forecasts. Bureaucracy was required to provide the institutional framework and funding for the system of weather stations and weather observers.

Here we see one of the challenges of constructing empirically derived representations of global phenomena: data collection, coordination and processing for dynamic conditions on such a scale is no trivial matter and was in many cases impossible before the development of modern electronic, computer and satellite technologies, and even now this enterprise faces significant challenges. Routine data collection on such a scale requires international coordination and cooperation, and very considerable financial investment. The sheer size of global data sets used by climatologists means that they would yield nothing intelligible to a human being were it not for the existence of fast computers programmed to process them and render them usable.

Global environmental sciences depend on and continually push the limits of computer processing capacity for another reason – there is no way that most hypotheses about the nature and function of global systems can be tested empirically. The Earth is not a convenient experimental object and is, so far as we know, the only accessible one of its kind. For this reason, computer modeling has become a vital part of Earth systems research. But early computer development was itself shaped by recognition that development of numerical methods for handling the equations of fluid dynamics and of devices that would then handle the resulting mass of computations would provide a crucial tool for use in atomic energy and weapons development, oil and gas exploration and weather forecasting. Von Neumann and Edward Teller both viewed the Earth as a newfound object of technological manipulation and control, thanks to the potential of nuclear technology. Project Plowshare, created in 1958 and funded by the US Congress in 1964, was to explore the possibilities of using nuclear explosions for the creation of harbors and a sea-level replacement for the Panama Canal and even to modify the climate of North America. A history of this project (Kirsch 2005) contains the comment that "In the laboratories and proving grounds of the Project Plowshare, the histories of experiment and environment meet." Some of the tools developed here made global environmental science possible and created the technological possibility of detecting and monitoring global effects of human activity and even, paradoxically, of revealing the complete impracticality of proposals to control the Earth's climate. Early attempts to construct a computer model of the Earth's climate system opened the door to the systematic study and recognition of non-linear systems and the limits that these place on our capacity for prediction and control. In this respect, the pursuit of global environmental science has prompted a reframing of some technological ambitions and a rethinking of the technology–environment interface.

## Notes

1. Allaby (1996), p. 2.
2. ibid., p. 3.
3. Hadlock (1998), pp. 6–8.
4. This is not to say that the latter do not exist, but that – to an extent greater than for basic sciences – environmental science exists at the interface between techno-political–economic practical problems and theoretically based research sciences.
5. In the US at least, this episode illustrated another not untypical pattern of development in environmental science research. In response to the acid rain problem, Congress in 1980 funded a ten-year scientific research program (NAPAP) in their desire to have the authority of science behind a planned new regulatory policy. Lots of good scientific research was done within different academic specializations, and the systems involved were much better understood as a result, but the specialists involved did not coordinate their research efforts around the policy problem, and as a result the work could not be integrated to form the basis of any policy recommendations. (See Rubin, Lave and Morgan 1991.)
6. At the University of Hawaii the Environmental Center was legislative-funded precisely to perform this function for the State of Hawaii.
7. See Galison (1997) for details.
8. Monmonier (1999), p. 7.

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# 48

# Agriculture and Technology

## JOHN R. PORTER AND JESPER RASMUSSEN

Agriculture is the human practice of cultivating the land and domesticating animals to produce food, fiber and energy. In a narrow sense, agriculture refers simply to production of these essential human commodities; in a wider sense, it refers to a human activity system that connects social and natural systems such that it is practically impossible to isolate changes in agriculture from changes in socio-economic and cultural conditions. Agriculture is a uniquely human activity and is perhaps the first activity for which humans developed technology. Technology, understood as the use of farming tools and techniques, is an indispensable component in agriculture. In the most general sense, technology permits humans to increase the capture and efficient utilization of solar radiation that drives primary plant production that is the basis of the human food and fiber chain.

Humans have cultivated the land since about 10,000 years ago when the global population reached 1 million. Before that time, and for the preponderance of human history, humans had hunted and gathered their food, fiber and energy since *Homo sapiens* diverged from its ancestors about 200,000 years ago (Evans 1998). The transition from hunting and gathering to agriculture, represented by the Neolithic Revolution, was adopted by various independent prehistoric human societies, in various locations. This transition created major social change, including the organization of hierarchical communities, settlements and higher population densities. In the 10,000 years leading to AD 1000, the human population increased a hundredfold from 5 million to 500 million people. In the second millennium, the effect was even more profound in absolute terms as 500 million people became 6,000 million. Both the hypothesis that human population growth drove the need for increased food production and thus agriculture and its obverse, that cultivation permitted population increase, have been suggested. It is probably the case that multiple causes rather than a simple causal relationship link land cultivation to population growth.

Today more than 75 percent of the land area of Europe is cultivated for crops, grassland or forestry production, and humans appropriate about 40 percent of global terrestrial net primary productivity for their own use. In rich, demographically stable countries the effects of agriculture and forestry on biodiversity and the cycles of carbon, nutrients and water are social and political issues that are rarely out of the news. Land cultivation, and particularly its management intensity, is the most influential human

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practice for the dynamics of the terrestrial landscape and thereby the atmospheric, biogeochemical and water cycles of the Earth system. The current production of food affects the main global biogeochemical cycles and is heavily reliant on inputs of fossil fuel energy and technology. Farmers use such products of fossil fuels as nitrogen fertilizer, herbicides and pesticides and machinery to increase the proportion of solar energy that is captured by crops to drive dry matter production and thereby harvested yield. It is only in the past 250 years out of the 10,000 years that human beings have cultivated the land for food that they have been able to swap the toil of long hours in the field, to increase solar energy capture, for less humanly demanding methods.

The base of the human food chain is largely formed by the grasses rice, maize, wheat and tropical species such as sorghum and millet. Wheat provides a clear example of the modern link between technology and agriculture. Wheat has been bred not to shed its seeds, to have a high yield index, to have a high response to nitrogen fertilizer, to need the protection against weeds and diseases afforded by chemicals, and is harvested by enormous machines driven by one person and is the most globally traded crop being carried around the world in large ships. The importance of wheat as a crop for humans is such that, of the 1.4 billion hectares of land (Evans 1998) devoted to arable cultivation, wheat is harvested from about 15 percent of it; direct consumption of wheat contributes 20 percent of the calories and 22 percent of the protein in the human diet (Amthor 2001). As more than 30 per cent of harvested wheat is fed to animals and thence to humans as milk or meat, the place of wheat as the most important human food source is unrivalled.

Technology in agriculture probably started with the stone ax that was used to clear forest trees and fire that was used to release the nutrients in the wood and thereby provide a rich soil for food plants. This was shifting cultivation and was the first step, beyond hunter-gatherer communities, in the settlement of human societies. The Neolithic revolution saw the domestication of crops and animals, and the consequent necessity for social stability to guard these precious resources. The act of harvesting the wild grains changed them genetically. A small percentage of wild grass plants have seeds that cling to the stalk even when ripe, rather than separating easily. Humans collecting wheat or barley seed would thus gather a disproportionate amount of the clinging mutant in each harvest, and plants were thereby domesticated.

Later animals were domesticated to be draught animals, which led to a large increase in the power available for cultivation. In the animal-powered agriculture, the main technological developments were plows, harrows, carts and wagons. Oxen were domesticated as draught animals 6,000 years before the present. Animal-powered agriculture increased in efficiency in the Middle Ages, when horses replaced cows as draught animals, and the first primitive European plow dates from about 3,500 years ago. These primitive scratch-plows consisted of a frame holding a vertical wooden stick that was dragged through the topsoil. In the Middle Ages, plows were fitted with wheels and shares that inverted soil. The wheel plow changed little until the 1700s when the swing plow was invented with fittings and a coulter made of iron and a moldboard and share covered with an iron plate. The use of the swing plow was closely linked to new crop management practices in the 1700s, which started modern Western agriculture. For example, in Northern Europe, the horse-driven swing plow was linked to the introduction of a crop rotational system with fodder crops that comprised temporal rotations of root crops, two cereals, clover and grass, with the clover being the "driver" of the system via its symbiotic ability to fix nitrogen into the soil from the air. This rotation replaced a three-year crop rotation that had been practiced since the Middle Ages rotating rye or winter wheat in year one, followed by spring oats or barley in the second year, and followed by a third year of fallow. The abolition of fallow lands and the introduction of legume-based fodder in crop rotations increased agricultural production and mechanization. The agrarian revolution of the 1700s is a clear example of how technology was linked to agricultural change and how, at the same time, this underpinned other changes in society such as industrialization and the beginnings of the metropolitan life. The same period also saw the start of the chemical control of plant and animal diseases, and the start of systematic plant-breeding and selection based on the later discoveries of the principles of genetics by Mendel.

The next major technological change in agriculture involved the increased use of fossil fuels in direct and indirect ways, and this occurred in the early to middle years of the 1900s. Between the collapse of the New York stock market in 1929 and the end of the Second World War the number of tractors in use on farms in the USA increased from 1 million to 2.5 million, while the number of horses fell from 20 million to 12 million over the same period (Evans 1998). Cheaper nitrogen fertilizers were also produced based on the Haber process, dependent on access to abundant and cheap sources of fossil energy. Synthetic chemicals based on analogs of plant hormones were also being invented for weeds, and neurological toxins were used for pest control. Food became and has remained as much a matter of eating oil-produced energy as solar energy fixed by photosynthesis. Globalized agriculture followed the revolution in fossil-fuel-dependent transportation in the 1800s and 1900s. In globalized modern agriculture, animal husbandry has developed into industrial-like plants, where the animal production is separated from fodder inputs that may now originate a long distance from where they are consumed.

There are many connections between agriculture, technology and philosophy. Agriculture was mainly based on traditions and traditional knowledge systems and indigenous knowledge until the 1700s, when agriculture was influenced by scientific progress and the philosophy of the Enlightenment that confirmed faith in man, reason and progress. One of the first theories of the new scientific agriculture stated that more forage meant more cattle that meant more manure and thus more cereals. This thinking resulted in the growing of forage crops in the crop rotation, which led to the decline of the old agro-pastoral system.

Questions such as whether technological agricultural developments drive population increase or vice-versa, the nature of the agricultural production paradigm such as between conventional and organic farming, and the very question of what should be the function of agriculture – for example food or energy production – each represent a differently weighted interplay between technology and philosophy in agriculture. The role of technology in food production has been twofold; first, and most basically, to increase the proportion of photosynthetically active solar energy that is utilized by crops, thereby raising crop yields that form the basis of the human food chain. More recently, technology has been used to alter the composition of food and to change its nutritional and processing properties. Recent attempts to alter genetically the make-up of plants used for food production have met resistance, mainly in Europe, whereas many emerging economies have embraced biotechnology with enthusiasm. One important issue raised by the advent of biotechnology has been the question of ownership and intellectual property protection. The private and exclusive ownership of technological products and processes in agriculture has been extended to include plant and animal varieties. These have traditionally either been part of a social and cultural heritage, and thus freely available, or have been under legal protection designed to foster their utilization by non-owning others. Such developments in ownership, fostered by the application of gene technology to agriculture, will have profound consequences for a human activity that forms the basis of human society.

In summary, except in the most "primitive" societies, humans have always found means to harness their intellects to solving the problem of having enough food to eat. In the time that humans have cultivated the land they can be said to have escaped the Malthusian logic of population regulation two and a half times – in the mid-1800s when the population rose above 1 billion for the first time and in the mid-1900s when the population reached 3 billion. The Green Revolution of the mid- to late 1900s (the "half") represented the cultural export of the agricultural lessons learned in the energy-rich postwar Western world to the developed world. As L. P. Hartley wrote at the start of his novel *The Go-Between*, "The past is a foreign country: they do things differently there"; and, thus, how far the future of agriculture can repeat its past successes in a world of limited and not limitless cheap energy combined with a global population of 9–10 billion is one of the great challenges of the 2100s.

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# 49

# The Built Environment

## CHRISTIAN ILLIES

## 1. Environmental Impact

The built environment, the world of houses and cities, is considered responsible for two-fifths of the world's energy consumption. In the United States, it is estimated that one-sixth of all energy is used for air-conditioning alone on hot summer days; this can go up to 43 percent of the peak power load.[1] The impact on the environment is obviously enormous. The US Department of Energy estimates that heating and cooling systems in the United States emit each year over half a billion tons of carbon dioxide and generate about a fourth of the sulfur dioxide that goes into the atmosphere (sulfur dioxide is the main ingredient in acid rain).[2] According to the World Resources Institute, heating, cooling and lighting buildings together make up 12 percent of US greenhouse gas emissions (which amounts to about 3 percent of global warming gases).[3]

A telling metaphor for the environmental impact of the built environment is its "ecological footprint." The term was introduced by William Rees in 1992 to indicate the bioproductive land and water area that is required to support a human population with food and timber products and to assimilate wastes and emissions such as carbon dioxide. The ecological footprint is expressed in terms of "global hectares" (gha) and "global hectares per person" (gha/cap). Herbert Girardet has calculated the footprint of London in 1996 when it had around 7 million inhabitants and was covering a surface area of 158,000 ha.[4] Given prevailing technology, on average 1.2 ha per person are required for food production and 1.5 ha per person for fuel production (needed for carbon sequestration) – that amounts to 8,400,000 ha and 10,500,000 ha respectively. If we add a forest area of 768,000 ha (required for wood products), it adds up to around 19,700,000 ha. Thus, London's footprint is 125 times its surface area – and nearly all of Britain's productive land (around 21 million ha).[5] But, of course, the environmental effects of London are not limited to the United Kingdom; its footprint "stretches to far-flung places such as the wheat prairies of Kansas, the tea-gardens of Assam, the forests of Scandinavia and Amazonia, and the copper mines of Zambia."[6]

It should not come as a surprise that in many countries the environmental impact of cities is increasing owing to their rapid growth. In 1950 only Greater London and New York City had a population of more than 8 million;[7] today there are around

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thirteen such "Mega Cities." In 2000, twenty-three principal agglomerations contained more than 10 million inhabitants, and the World Bank estimated that twenty-seven Mega Cities will reach this size by 2015. The most obvious causes for this development are population growth and the rural exodus in many, especially developing, countries (in particular in Africa and Asia). Population growth is a well-known and -documented phenomenon. In 1950 the world's population was 4 billion, in 2000 it was 6 billion, and it is projected to be 9 billion in 2050. Although the growth rate of the human population has been steadily declining since the 1970s, the world population increases currently by more than 200,000 every day. As a consequence, more and more housing is needed. In addition, a rural exodus happens in many places, mostly where people in the countryside live below the poverty line and migrate to cities in order to find employment. (Mostly these are *also* the places with highest population growth, so that the effects of the two causes accumulate.) In many Mega Cities, the rapid growth of the urban population cannot be controlled, let alone planned, and leads to slum and squatter settlements. Most of these fall outside the realm of urban infrastructural projects and have inadequate roads, electricity and (most importantly) water supply. Although the absolute number of people with access to safe water and sanitation becomes bigger, population growth exceeds their number – WaterAid estimates that between 1990 and 2000 "an extra 900 million people were born in places without water and sanitation."[8] Not surprisingly, the urban poor can be much worse off than the rural poor – the economic gains of moving to the city are often paid for by diseases such as diarrhea and other infections stemming from inadequate hygiene. (The infant mortality rate in the slums of Bangladesh is 142 per 1,000 live births, compared to the rural rate in India of 93.) Further, most of these places face critical environmental degradation as a result of overload on water sources and the uncontrolled extraction of water from depleted aquifers, improper waste disposal, and the contamination of ground water and rivers through poor sanitation measures. Yet improving the situation is often fighting a losing battle since many cities face an ever increasing demand while the quantity and quality of available water declines. In addition, there are often inadequate pollution controls and a lack of administrative order and political will.

While subdevelopment settlements are to be found mainly in developing countries, some cities in industrial nations are spreading in face of a stagnating population (or even while losing inhabitants); this happens mainly in Australia and the United States, but also in Europe – for example in Brussels, Copenhagen, Frankfurt, Munich and Zurich.[9] This expansion is labeled (critically) as "urban sprawl": cities expand geographically in the form of suburbs of low-density housing, typically with *single-family homes* on big lots, separated by *lawns* and *roads.* They are distant to the city center and to industrial and commercial zones. The impact of low-density suburbs on the environment is twofold. On the one hand, there is more urbanized land, and thus more land surface rendered impervious by development that was formerly open and of a greater environmental value. On the other, these new developments are only possible because of – and are dependent on – personal cars as the main means of transportation. While cities before the middle of the nineteenth century were built around walking and other methods of transit, this is no longer practical. Jeff Kenworthy and Peter Newman coined the term "automobile dependence" in order to explain how modern cities inevitably lead to more automobile use. While an average inhabitant from central Melbourne makes

2.12 trips per day by car, an inhabitant of the fringe uses his car 3.92 times. Similarly, an inhabitant of the suburbs of New York needs more than five times the amount of gasoline than someone in its center.[10] The central point is that population density is needed to make public transit possible: "Urban design, reflected chiefly in population and job densities, emerged as the most significant determinant of the travel patterns in cities around the world."[11]

Not only the operation of the built environment but also its construction – that means all activities such as development or demolition and disposal – have a major impact on the environment. Taken together, building construction and operations consume directly or indirectly around 54 percent of all energy generated in the United States.[12] In 1999, according to the United Nations Environment Programme, construction activities are estimated to contribute over 35 percent of total global carbon dioxide emissions – more than any other industrial activity.[13] No other sector uses more raw materials than construction; it accounts for an estimated 40 percent of all resource consumption. This point is illustrated when we look at cement concrete that is used in the construction of every part of the built environment (buildings, roads, bridges, etc.). Besides requiring crushed stone, gravel, sand and water, the central ingredient of cement concrete is cement; it is, on a per-unit basis, the component with the strongest impact on the environment. Globally 1.45 billion Mg of cement are produced every year requiring 2 percent of global primary energy and responsible for 5 percent of global carbon dioxide emissions.[14] In the United States, 0.6 percent of the energy goes into cement production, though it is only 0.06 percent of the GNP.[15] The construction industry is also the cause of enormous amounts of waste. In Australia, Finland, Germany, the Netherlands and the United States, for example, the waste of construction and demolition adds up to 13–29 percent of solid waste entering landfills.[16] If one includes greenhouse gas emissions, the construction industry produces about 40 percent of all waste.[17]

Again, the effects obviously depend on the technology used. According to a report on California's construction industry, older equipment is a particular problem.[18] Toxic diesel particulate matter pollution from older diesel tractors and bulldozers can cause severe cardiovascular and respiratory illnesses, asthma attacks and acute bronchitis. (For every additional 10 micrograms of 2.5 micron particles per cubic meter of air, an 18 percent increase in heart-attack deaths has been found.[19]) In 2005 at least 1,100 premature deaths in California (of which 731 were in Los Angeles and its suburban areas) were likely to have been caused by emissions from outdated construction equipment (there are an estimated 250,000 to 300,000 of such machines in California[20]). In 2005, the estimated public health cost due to California's construction industry was around $9.1 billion.

## 2. Built Environment versus Environment?

The story of the built environment is part of man's domination of nature. A city as any building is a place that had to be wrested out of nature: forests must be rooted out, land cleared, and much that was hitherto part of a vital ecological system becomes covered by asphalt, concrete and brick. Le Corbusier called architecture an "assault on nature" – and thought that he was complementing the city by doing so.[21] Yet the often described dichotomous separation of humans (and in particular their technological artifacts) from nature in Western culture has seldom been radical in the built environment. New York's Central Park, urban sprawl, and every flowerpot on the windowsill show our "biophilia," that is, our deeply rooted fascination with nature and things that are alive.[22] Even Etienne-Louis Boullée, whose abstract geometric style is far from showing any link to organic forms, did not reject nature entirely, his (never built) cenotaph for Isaac Newton being designed as a gigantic sphere embedded in a circular two-levelled base but topped with cypress trees.

Why, then, has the built environment turned inimical toward the un-built environment? A primary reason is surely ignorance and the difficulty in predicting future consequences of technical innovations and of the built environment; quantitative as much as qualitative consequences. In 1896, when New York City introduced asphalt paving in place of brick, granite and woodblock, no one could have foreseen that Houston (Texas) would build an asphalt highway that is in places eighteen lanes wide. And when the German engineer Carl Benz invented the car in 1886 he could not have anticipated the development of modern cities, which Peter Droege has baptized "Fossil Cities" (because their "very existence, form and growth dynamics are explained by the logic of the fossil fuel economy"[23]). After all, *Technology Assessment* is a relatively new term (coined in 1966) as much as a new science. *Environmental Impact Assessment*, a formal process used to predict the environmental consequences of a development project, was not introduced as a planning and decision-making tool before the late 1960s – in the United States in the National Environmental Policy Act of 1969. (Ethical concerns about negative consequences of modern urban developments had, however, been raised much earlier – for example by Lewis Mumford in the late 1930s.)

Another factor is the difficulty of discerning many very slow destructive influences. The waste production or resource consumption of a small hamlet does not matter much, and only when the settlement grows do environmental impacts accumulate. After the 1913 opening of the aqueduct that allowed Los Angeles to bloom from a semi-arid desert, it took some decades (and the filling of many swimming pools) before Owens Lake had dried up and turned into a toxic wasteland. Slow and gradual processes are not merely difficult to predict but also easily escape our attention. It might be an inborn optimism or general laziness that makes humans blind to negative effects when they come upon us step by step. This has been described as the "Boiled Frog Syndrome."[24] If a frog is in a pot of water that is gradually being heated, then the frog adjusts and continues to adjust its body temperature. The frog does not seem to feel uncomfortable – until, ultimately, it is boiled alive. Humans, like the frog, keep adjusting to the increasing health and ecological hazards, so that they often do not realize (or at least act against) the destruction of their environment and health, even if it becomes dramatic (Owens Lake) or highly dangerous (Mexico City averages 30 micrograms of fine particles per cubic meter of air).

Another, rather intricate reason for neglect of the environment could be added: it is often a result of applaudable attempts to satisfy human needs in an efficient way and on a large scale. To provide solid shelter, warm housing, or sufficient water and energy for everyone are rightly seen as *moral* demands. As Friedrich Schiller remarks on this point: "To nourish give him, to shelter./Have ye the naked bedecked,/Dignity comes on its own."[25] The human right to housing is also explicitly stated in the Universal Declaration of Human Rights: "Everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including food, clothing, housing and medical care."[26] Many ecologically (and psychologically) disastrous developments were built to provide housing for the socially weak and the needy among the population.

Yet things have changed. We have experienced the ambiguous nature of many developments, such as that of our fuel-based transportation technology and of cities based upon it. The apparent domination of man over nature turned out to be a self-destructive illusion. We understand that regard for the environment and for future generations is an essential part of our *moral* obligation; the happiness and comfort of present and proximate generations should not be bought with the misery (or even nonexistence) of future ones. This radicalized universality of ethics has been expressed by Hans Jonas in his *Imperative of Responsibility*: "Act so that the effects of your action are compatible with the permanence of genuine human life!"[27] Many are willing to listen to this imperative. To name but two examples: "Promoting Sustainable Human Settlement Development" has been spelled out as an important political goal in the *Agenda 21* (ch. 7), and "The Sustainable Cities Programme," a joint UN-HABITAT/UNEP facility, was established in the early 1990s. It seems that mankind is about to write a new chapter in the story of the built environment, called "The Sustainable City." We possess most of the technological skills needed to erect cities that are not inimical to the environment but are a vital part of it. However, such a transformation requires us changing some ideas about how we should live, ideas about traveling and about the space and energy that we think we need. And, if we are not willing to change them, the next chapter might never be written.

## Notes

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5. Depending on what is included in the footprint, it can be seen as being even higher. The WWF et al. (2006) ("Counting Consumption: $CO_2$ Emissions, Material Flows and Ecological Footprint of the UK by Region and Devolved Country") calculate the ecological footprint of the Southeast population as approximately 6.3 gha/cap (which is seen as the highest in the UK) with food and agriculture 1.14 gha/cap, transport 1.26 gha/cap, and domestic energy and construction 1.3 gha/cap. (This equates to twenty-five times the actual land area.)
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22. Which might even be a genetically given preference (though surely refined through experience and culture); cf. Wilson, E. O. (1984). *Biophilia* (Cambridge, Mass.: Harvard University Press).
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24. See, for example, Saunders, T. (2002). *The Boiled Frog Syndrome: Your Health and the Built Environment* (Chichester: Wiley-Academy).
25. In *Die Würde des Menschen* (1796).
26. Article 25. It should be added that, again, this is a human right that is not everywhere duly respected. The UN Centre for Human Settlements estimates that 100 million people worldwide are homeless and over 1 billion people live in inadequate housing.
27. Jonas, H. (1984). *The Imperative of Responsibility* (Chicago, Ill.: University of Chicago Press), p. 43.

# Part V

# Technology and Politics

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# 50

# Technology and Politics

## EVAN SELINGER

Technological concerns are central to political history, political theory and political action. Since democracy requires a well-informed citizenry, civic responsibility is abdicated when the public does not make a concentrated effort to understand the conceptual and material links that connect technology and politics. Of course, the responsibility for being well informed does not fall solely on citizens themselves. Since information is presented and received in contextually specific ways, injustice occurs when the following events transpire: public education fails to prioritize the relevant issues; media bias diverts attention from matters of genuine concern and clouds real issues through spin; governments make bad-faith appeals to secrecy and security; and inequitable access to data marginalizes individuals and groups. In short, without a deep understanding of how ideas about and decisions concerning technology impact political processes, and without a sophisticated grasp of how political processes impact the development, distribution and use of technology, neither global nor local affairs can be comprehensively grasped or intelligently evaluated.

Given the profound inter-relation between technology and politics, as well as the difficulty of finding rigorous and appropriately critical frameworks to illuminate the central issues, the articles found in this section should not be seen as mere academic summaries. While they synthesize vast bodies of literature, they collectively transcend exegesis and offer political tools that citizens across the globe should find essential to their pursuits of justice and the good life.

Put in more specific terms, this section contains analyses of technology and politics that address topics most people have strong opinions about. It traverses issues concerning how technology relates to progress, power, culture, globalization, capitalism, energy, management, strategy, comparative governance, and gender. To ensure that the philosophical dimensions of all these issues shine through, we shall begin by discussing the more explicitly abstract ideas.

"The Idea of Progress" clarifies the fundamental problem of innovation. On the one hand, nations would not put significant resources into technical research and development if they did not believe that progress – economic, medical, military, environmental and recreational – would result. Progress is a widespread regulative ideal, and a commitment to progress is essential for motivating collaboration and structuring social cohesion.

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On the other hand, citizens do not always benefit equally from the emergence of innovative practices. In some cases, the limited availability or high price of new technology facilitates hierarchical practices with painful exclusionary costs. In this context, calls for justice are often framed in terms of demands for better access and usability. Other instances of disenfranchisement, however, contain greater subtlety. In these cases, efforts to promote justice occur over long periods of time and begin with the laborious process of clarifying hidden harms.

Furthermore, as the history of unintended consequences demonstrates, technological change rarely follows the patterns of development that designers anticipate. Sometimes, technological use engenders new problems that are so complex that cost–benefit assessment cannot be used as an uncontested standard for determining whether progress has been achieved. In light of this history, judgments about whether innovation generally ameliorates pervasive social ills or ushers in disaster remain bounded by seemingly ineliminable ambiguity.

Finally, while modern market economies depend upon constant consumption, and secure this dependency by promoting the idea that the happiness can be obtained by purchasing new devices, empirical studies of the hedonic treadmill point to the opposite conclusion. The increase in satisfaction that new technology provides is, at best, temporary. Above a fairly minimal threshold, innovation does not enhance overall levels of well-being.

"Technology and Culture" is a contribution that addresses the problem of alienation – a problem that has long been the Achilles heel of technology advocates. For example, Martin Heidegger worried that modern technical activity is, at bottom, an attempt to master nature. If Heidegger is right, then it would seem that modern tools and techniques are designed in such a way as routinely to foster practices that adversely impact the environment. From this perspective, the very idea of "green technology" would be an oxymoron. Contrary to the technocratic hope of relying upon innovation to pave the way for a more sustainable future, people like Heidegger view a shift in ontological orientation as a prerequisite for saving the planet from destruction. To take another powerful example in which alienation is an issue, we need only consider how cultural conservatives somewhat ironically appropriate one of Karl Marx's early insights. Modern technology's capacity to remake nature has enabled developed countries to refashion their worlds in thoroughly artificial ways that challenge both natural and traditional approaches to dealing with other people. From the conservative perspective, innovation (especially in the domains of communication and transportation technology) erodes the fabric of traditional civility because it undermines tradition.

The discussion of André Leroi-Gourhan's central ideas in "Technology and Culture" clarifies why traditional concerns about alienation can be understood as poorly framed problems. For Leroi-Gourhan, such poor framing comes from two sources. The first source is reductive theories that view culture as arising from a material base in a wholly determinate manner. The second source is reductive theories that view culture as the end result of rational minds devising plans for transcending nature. At the heart of Leroi-Gourhan's conception of technology are ideas about general anthropology and invariant uses of technology to accomplish the goal of "exteriorization" that challenge the theoretical prejudices just listed. These ideas: (1) clarify why traditional conceptions of technology-induced alienation are themselves artifacts of an impoverished theoretical imagination, and (2) detail why contemporary social scientific trends of rejecting evolutionism and raising the status of cultural relativism to a dogma impede our capacity to understand how cultural change occurs.

Ultimately, the review of Leroi-Gourhan's ideas is not offered as a means of justifying a particular political agenda. Rather, readers are presented with these ideas as a corrective that remedies mistaken conceptions of how technology and culture relate. In this sense, the reader is exposed to arguably more accurate conceptions of how real political change occurs and why certain political anxieties about technology are given more credit than they deserve.

"Technology and Power" makes the case that, because our species is competitive and inventive by nature, technology and power co-evolve synergistically.

1. Technology augments the human ability to exert control over people, places, and things.
2. Technology influences the ever-expanding goals that humans select as worth trying to gain control over.
3. Technology transforms how both individuals and collectives understand their comparative worth.

While these patterns of change are invariant, a noticeable historical shift, one that lies at the center of contemporary debates about globalization, began to occur hundreds of years ago. Whereas innovation once had a geographically and temporally erratic character – even with trade and knowledge transfer being long-standing features of human interaction – over time it has taken on an accelerated and markedly cosmopolitan form. Given the current interdependencies entailed by technologically mediated labor and trade practices, migration patterns (both short and long term) and geographically dispersed environmental pollution, the traditional notion of the "nation-state" may no longer be viable. With its demise go long-standing conceptions of how technology can be best put in the service of military and economic power.

Moreover, as the recent US "War on Terror" demonstrates, advances in technological resources cannot be equated *a priori* with political might. The strategies of resistance displayed in Iraq against US intervention show: high-tech military technology can be disrupted by local environmental conditions; religious conviction can enable low-tech weapons to be used to yield high causalities; and democracy cannot be relied on to neutralize historical and cultural influences. Given the complexities just outlined, it seems that the traditional distinction between "knowledge" and "wisdom" remains valid. Despite increasing knowledge of how to make powerful technologies, we still lack the wisdom to recognize how best to apply our creations.

"Technology and Globalization," "Technology Transfer" and "Technology and Capitalism" are inter-related entries that expand upon some of the concerns just articulated. "Technology and Globalization" clarifies some of the ways in which innovation renders spatial and temporal differences increasingly obsolete for communicative and travel purposes, and helps pave the way for what some theorists see as the emergence of cosmopolitan sensibilities. Information technology plays an especially important role in this process because it does more than speed up traditional business practices and render them more efficient. Crucially, information technology enables new industries, types of work, management styles and financial markets to emerge – and, along with them, the introduction of new goods, services and priorities. Phrases like "knowledge workers" and the "information economy" designate the historical shift in practice and expectation that demarcate the present from material conditions associated with the Industrial Revolution.

Accompanying this change in modes of production and distribution are new political problems and new resources for political adjudication. At the international level, controversies rage over how best to regulate the manner in which workers are treated, goods are created, shared and converted to intellectual property, and toxins are contained, mitigated against and disposed. As national and global interests compete with one another, the very institutions and policies that have been constructed to deal with the ensuing conflicts, such as the World Trade Organization, find themselves objects of controversy. Even within local communities, citizens around the world find themselves increasingly polarized about jobs that are being exported to other countries and about the populations of migrant workers who are now offering services that the "information economy" has rendered "low skill."

As "Technology Transfer" clarifies, in order to grasp many of the political issues that are proving contentious in the context of contemporary globalization, it is useful to understand the fundamental ontological dimensions that structure technological experience. According to pragmatists and phenomenologists, the human experience of technological activity is both embodied and cultured. While material constraints and engineering principles are crucial components of technology, the experience of technology is shaped by background conditions that include skills, knowledge, techniques, norms and perceptions that personal and collective histories can influence. Differences in background conditions can prevent technology from being transferred successfully from one area to another. Indeed, smooth operations can become catastrophes when devices take on new meanings and functions. Ultimately, these ideas provide the basis for the crucial thesis of "technological relativity": technologies can transform into different devices through geographic and temporal circulation.

"Technology and Capitalism" provides the historical background needed fully to appreciate many of the issues detailed in the previous two entries. For, in order to grasp the complexities that link global economic activity with problems of injustice, one needs to understand the role that both technology and regulation have played in the historical shifts that mark the transitions from:

- the mercantilism of Europe that transpired during the sixteenth to eighteenth centuries,
- the first and second industrial revolutions of the eighteenth and nineteenth centuries respectively,
- the development and implementation of Taylorism and Fordism that typified early-twentieth-century practices,
- the recent activity of so-called "late capitalism."

"Energy, Technology and Geopolitics" clarifies some of the paradigmatic ways in which relations to technology and energy influence (1) the types of identities that nations adopt and (2) the routine patterns of engagement that they exhibit when conducting affairs with other countries. In this context, a summary of Huntington's taxonomic conception of geopolitical formations and types of contemporary civilizations is presented and contextualized in terms of historical energy needs and energy policies. Such analysis reveals the complex ways in which addiction to limited energy resources can – to use an appropriate metaphor – fuel economic, social and political tension.

The chapters "European Politics, Economy and Technology," "Asian Politics, Economy and Technology" and "US Politics, Economy and Technology" provide a comparative map for understanding the geoculturally distinct relations between the three crucial and repeating variables found in each title. Of particular interest is the light they shed on the following perplexing questions. Why does the US public tend to view scientific and technological innovation in a predominantly positive light, whereas Europeans often see innovation as an ambivalent phenomenon, one that gives and takes at the same time, offering the benefits of modernity and progress by threatening to undermine long-standing and valuable cultural and political traditions? Do substantive differences between US and European views on technology determine whether a given innovation will be subject to protest and skepticism? How do differences between Chinese and Indian policy reveal the flexible ways in which tensions between the urge to modernize and the desire to preserve national identity can be explored in both theory and practice?

Not only are these questions crucial to public policy; they also hold a particular significance for philosophers of technology. The early history of the philosophy of technology was replete with metaphysical characterizations of the essence of technology. These characterizations either presumed that geocultural differences are of minor consequence with respect to the matter of determining what technology most fundamentally is or they depicted the basic features of technology in geoculturally specific terms through a misleading rhetoric that gave their accounts the appearance of transcending localized ideals. In light of the complex cultural differences that these three chapters reveal, it becomes clear that the early philosophical approaches to technology are no longer viable.

In "Technology Management" we gain additional insight into the merits of using a comparative approach to analyzing technology. Notably, the concept of "technology management" is clarified through general discussion of its defining features, and emphasis is placed upon similarities and differences between US and Chinese approaches to the issue. The complex patterns that conceptually link organizational and governmental decisions concerning technology are developed further in "Technology Strategy." Here, discussions of successful and unsuccessful partnerships between China and Germany prove exceptionally illustrative.

Through emphasis upon the following issues, "The Politics of Gender and Technology" brings the virtue of comparative analysis to bear on the topic of how technology and gender mutually influence one another. Because certain technologies are perceived as masculine and others as feminine, artifacts have been used to maintain as well as challenge expectations about gender roles and definitions. Additionally, conceptions of gender have also helped determine who gets to design a new technology. Moreover, gender stereotypes have influenced the manner in which technologies are designed – that is, tastes and patterns of behavior associated with gender have factored into decisions about aesthetics and function. And, since certain professions are associated with distinct technologies, gendered stereotypes about those technologies have impacted the extent to which men and women participate in those professions and affected how they are treated once embedded in the correlative professional norms.

## 51

# The Idea of Progress

## DANIEL SAREWITZ

Among those who have given serious consideration to the idea of progress, virtually every conceivable position has been staked out: from the inevitability of progress to its impossibility; from its invention as a modern ideal to its persistence throughout history; from its embodiment in scientific truth-seeking, technological advance, moral improvement, or the amelioration of human suffering, to its social construction as nothing more than a contextual illusion that justifies particular ways of being and acting.[1] This diversity of perspectives reflects two attributes of the idea of progress. The first is that all human action is in some sense guided by an expectation of progress toward the intended goal of that action. The second is that these goals or endpoints of progress are themselves the subject of disagreement.

Ideas of progress address three types of non-trivial goals or endpoints. The first is truth, as approached by religious insight, philosophical reasoning, or scientific inquiry. The second is the variety of normative ideals whose achievement, even if partial, may be said to constitute an improvement of the human condition. These ideals encompass notions of both individual virtue and accomplishment (generosity, tolerance, piety, self-actualization, etc.), and measures of collective good (social justice, freedom, equality, etc.). The third type of goal pertains to concrete, specifiable outcomes toward which progress can be measured using context-independent, and thus typically quantitative, metrics – for example reduced human suffering from disease morbidity and premature mortality.

For each of these categories, disagreement arises over definitions of the goals toward which effort should be directed, over the proper means of pursuing progress toward those goals, and over determination and interpretation of the metrics by which progress toward the goals can be assessed, including timescales. Any assertion of progress (or its lack), therefore, is incoherent without an accompanying statement of beliefs and assumptions about how the goals of progress are recognized and how distance from those goals is evaluated.

Science and technology, however, have seemed to offer a stable frame of reference from which directional change – progress – could be recognized and measured. The idea that science makes progress toward truth has been a powerful, widely shared notion in Western societies since the Enlightenment. This power has reflected not an abstract commitment to the ennobling value of truth, but the notion that the acquisition of more

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scientific truth leads to more human well-being by enabling action in the world that is both morally defensible (because it is based on truth) and practically effective (because it is based on reliable knowledge about nature). The coherence of this idea of progress, however, can no longer be sustained – owing not so much to the insights of philosophers and historians about the contingent nature of science and truth as to the very success of science itself in continually generating new insight into the intricacies and complexities of the world. For, just as science yields new facts, it simultaneously expands the realm of the unknown and in turn continually casts doubt on, and raises questions about, the meaning of those facts that it has already created.

The most fundamental truths generated by science, sometimes called "laws of nature," actually describe phenomena that can be observed only in the controlled environment of laboratories, experiments and engineered artifacts. Such laws do not have reliably predictive power in the complex and uncontrolled world of human affairs, and are likely as not to mislead if applied as "truth" to guide human action.[2] When science is applied to the understanding and guidance of human affairs, its results – while often useful – are contextual, contingent and ephemeral. Weather forecasts, disease diagnoses and economic models, for example, represent – at best – a very weak notion of truth, and are better-understood as heuristics whose effectiveness depends as much on social institutions and human judgment as on scientific truth.[3] In total, scientific claims of truth-making are strongest when the truths themselves are the most divorced from real-world contexts. The idea of scientific progress toward ultimate truth must therefore largely be relegated to the domain of philosophical abstraction.

Scientific truth does make itself strongly felt in human affairs – not as truth *qua* truth, but through its embodiment in technology. Technologies work because they take advantage of the predictability and reliability of controlled physical, chemical and biological phenomena. But they need not depend on an understanding of the underlying truths – only on the necessity that such truths actually exist. The special claim on progress that can be made on technology's behalf is one of directionality, accumulation and effectiveness. Technology's evolution through time moves away from simplicity, transparency, closedness and discreteness toward complexity, inaccessibility, ubiquity, interconnectedness. Because technology embodies reliable action in the world – rather than reliable knowledge as an abstraction or a rarified phenomenon of the laboratory experiment, as is the case for science – those who can link what a technology or technological system does to their own interests may reasonably say that their ability to pursue their desired goals or endpoints has improved: they can make a reasonable, if parochial, claim to progress. When such claims are strongly tied to uncontested and widely distributed increases in human well-being – as, for example, with indoor plumbing, more productive crop varieties, obstetric forceps, childhood vaccines, and antibiotics – it would be churlish to deny some directional betterment of the human condition, some progress, for those who have gained access to such artifacts.

The case for technological progress is more complex, however, than the simple accretion of artifacts that are individually deployed for human betterment. For one thing, in modern technological societies, most new technologies are not aimed directly at overcoming important obstacles to an improved quality of life. Rather, they aim at expanding economic productivity, competitiveness and consumer choice, and in so doing catalyze the creation of new wealth that in turn allows proliferation of, and access to, new technologies among ever greater numbers of people. Economic growth thus becomes a proxy for progress. Within the resulting affluent and technology-saturated societies, it becomes impossible in most cases to isolate simple cause–effect relations between any given technology and human betterment. For example, the best predictor of good human health in affluent countries is not access to the latest medical knowledge and technologies but a range of social determinants including education level and standard of living.[4] Moreover, technological change always creates losers as well as winners, for example those whose jobs and skills are displaced by machines with enhanced functionality and autonomy. Progress for some is erosion for others. We are back to disagreement.

The idea of technological progress is also confounded by the complexities that accompany technological change. While technologies are intended to solve particular problems within a restricted context, almost any widely adopted technology will have consequences, unintended and sometimes undesirable, outside that context. Automobiles (and the technological infrastructure that they require and enable) are an obvious example, on the one hand allowing a quantum increase in autonomous human mobility, but on the other contributing to transformation of domains as disparate as the social fabric of communities and the chemistry and physics of the atmosphere. Similarly, the huge benefits of antibiotics are now being undermined by the looming threat of antibiotic-resistant infections. One might even observe that nuclear weapons, which have brought to humans the capacity to annihilate their own societies, were in fact a strong stabilizing force in the second half of the twentieth century that arguably led to radically reduced loss of life from organized, international violence following the carnage of two world wars.[5]

Yet the point that technological change leads to consequences both good and bad is obvious and trivial. The deeper point is that, while the intent of all technologies is to exercise more certain and reliable control over some circumscribed facet of reality, the cumulative effect of more technology continually being integrated into complex human and natural systems is the creation of more complexity and contingency in the world. Just as science in its production of knowledge creates new realms of the unknown, so does technology in its exercise of local control open new terrains of unreliability and unpredictability.

Thus, three centuries of continual expansion of scientific knowledge and technological capability do not add up to a concomitant increase in the capacity accurately to predict the future of human affairs. This should be surprising because the proliferation of reliable scientific knowledge and reliable technological control might reasonably be expected to create a growing capacity to, on the one hand, characterize and, on the other, create desired future outcomes. The problem is that the social–natural systems in which science and technology act are unbounded (at least relative to our capacity to understand and to act), so knowledge and consequences radiate and interact in ways that cannot possibly be anticipated.

Predictability, or its absence, is central to the idea of progress because statements about progress are necessarily informed not just by comparison with the past (itself a contentious enough task) but with expectations for the future as well. There is something that sounds very much like directional change in the fact that today people can, with considerable reliability, manage information and communication networks that span the globe, an electric utility grid for a city of 10 million people, or a global agricultural system that produces sufficient food for 6 billion people (distributional problems aside) – capabilities that were literally unthinkable as recently as half a century ago, and that were acquired incrementally and cumulatively over time. Yet it was precisely the acquired ability to manage reliably a complex global air transport system that created the technical conditions that allowed the terrorist attacks of 11 September 2001, themselves the stimuli for complex subsequent geopolitical events. So, are technological trends extendable into the indefinite future, or do they bring society closer to cascading disasters caused by, say, cultural conflict, environmental collapse, or a combination of both? Is technological society a sturdy edifice or a house of cards? Ideas of scientific and technological progress are strongly influenced by expectations of the future that must always have a considerable irrational component.

The idea of progress thus carries with it an inherent contestability. And yet, in a sense that is at once definitional and tautological, a commitment to progress is also bound up in all human action. Human decisions, at the individual or collective level, are made to achieve an aim, and thus they predict a state that the decision-maker desires to achieve. It is true that the outcomes of decisions are often different from those that were intended or desired, but this does not alter the logical reality that the intent of decisions is to make progress toward a goal via the action that the decision initiates. Notions of agency and ascertainable cause-and-effect relations, which lie at the core of modernity, are thus logically tied up with commitments to progress.

Indeed, the idea of progress is essential to the sustainability of modern high-technology, market-oriented societies. Political stability in such societies appears to be strongly dependent on a continual process of wealth creation which in turn is made possible by continual technological innovation and, crucially, continual societal adoption of the products of that innovation. Yet people do not use new technologies as part of some social contract to help create new wealth and civil stability; they use them because they believe they will somehow improve their life. The avid consumption of the products of innovation is a statement of belief in progress.

The result of this belief is a continual remaking of the appearance, mechanics and dynamics of daily existence, from the way people enjoy music to the way they eat and work and fight wars and have sex. Finally, then, even within the restricted context of affluent societies with their implicit commitment to technological change, the idea of progress must encounter how such change actually makes people feel. The data on this subject are strong and unambiguous: within affluent nations, people's level of subjective well-being, of how they perceive their own quality of life, is remarkably stable, unperturbed by rapid technological change and accumulating wealth.[6] In other words, the data – measured in surveys from many countries over several decades – demonstrate that people don't like living in the latest version of the world any more (or less) than they liked living in previous ones. Levels of happiness, satisfaction and wellness, it turns out, are coupled to technological change and economic growth only via the commitment to pursuing a more satisfying future that never arrives. Yet, if society gave up on technological consumption as the road to a better life, then the centrifugal force that holds modern market economies together would dissipate. The idea of progress is thus essential to social cohesion in modern societies; the reality of progress will always, however, remain a contested and elusive domain of the human imagination.

## Notes

1. For example, see: R. Nisbet, *The Idea of Progress* (New Brunswick, N.J.: Transaction Publishers, 1980/1998); C. Lasch, *The True and Only Heaven: Progress and Its Critics* (New York: W. W. Norton, 1991); and *Daedalus, Journal of the American Academy of Arts and Sciences*, special issue *On Progress*, Summer 2004.
2. e.g. N. Cartwright, *The Dappled World: A Study of the Boundaries of Science* (New York: Cambridge University Press, 1999).
3. D. Sarewitz, R. A. Pielke, Jr, and R. A. Byerly, Jr (eds), *Prediction: Science, Decision Making, and the Future of Nature* (Covelo, Calif.: Island Press, 2000).
4. e.g. R. Evans, M. Barer and T. Marmor, *Why Are Some People Healthy and Others Not: The Determinants of Health of Populations* (New York: Aldine de Gruyter, 1994).
5. R. Rhodes, R., "Technology and Death," in A. Lightman, D. Sarewitz and C. Desser (eds), *Living with the Genie: Essays on Technology and the Quest for Human Mastery* (Covelo, Calif.: Island Press, 2003), pp. 129–38.
6. e.g. E. Deiner and E. Suh, *Subjective Well-Being across Cultures* (Cambridge, Mass.: MIT Press, 2000).

## 52

# Technology and Power

### DANIEL SAREWITZ

Power is the projection of human intent over other people, animals or things. Technology magnifies intent and makes it more reliable. If we say that an artist has power over his medium, we mean that the artist successfully translates creativity and virtuosity to the work of art via a technology such as brush, sculpting tool or camera. Yet the artifact of the camera clearly embodies more of the artist's power than the brush or the tool. Michelangelo spoke metaphorically in saying that in producing his sculptures he was merely liberating the form that resided in the block of marble. For the photographer, however, the metaphor becomes reality; the image actually does reside in the camera. This increased taking on of the essence of power by the technology tells us less about the skill of the artist than about the capacity of the technology to translate the skill of a practitioner into something that could not exist without it – to expand the realm of plausible intent. Thus, a longbowman provides both skill and power in launching an arrow toward its intended mark perhaps – if the bowman has great skill – a hundred meters away. A technician on a missile cruiser presses a button and launches a computer-guided cruise missile that strikes a five-foot-wide target a hundred (or a thousand) miles away. In the case of the sculptor compared to the photographer, and the bowman compared to the sailor, more of the cause-and-effect connecting intent to power is embodied in the technology, though all these practitioners may require a high degree of skill to fulfill their intent.

Politically and militarily dominant societies have almost always been those that have chosen to take seriously the pursuit of technological advantage. Indeed, history can be told as a story of evolving technology applied to the exercise of power. David's slingshot, the Trojan Horse, the longbows of Agincourt, British ships-of-the-line, the tanks of the Blitzkrieg, and the A-bomb at Hiroshima are the mythically familiar instantiations of the relation of technology and power. Of course, technology has also been applied to the exercise of power through means that are not explicitly military, such as superior modes of transportation, communication and information dissemination, production of goods, and production of energy for doing various kinds of work more efficiently. Yet advances in these realms have also often supported the exercise of martial power.

Power and technology grow together; they co-evolve. The competitive nature of humans and societies, and the incremental essence of technological innovation feed

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back on each other and are mutually enhancing. That is, the quest for power is inherently served through the adoption and improvement of technologies that can increasingly embody that power. Throughout much of history this feedback process was temporally spasmodic and geographically specific; over the past several centuries it has become rapid, continual and increasingly cosmopolitan.

Military power and economic power are especially closely tied together through the role of technology. Historically, superior technology in arms and transport allowed the geographic projection of military and political power that in turn catalyzed economic power largely via control of natural resources (ore; arable land; spices) and trade routes, as exemplified by the far-flung European colonies, and Chinese colonies before that. But industrialism – the apparently limitless indigenous wealth-creating capacity created by the application of technological innovation to production of goods and services – has amplified and accelerated the synergies between military and economic power. This interdependence reached its most conspicuous high point in the Cold War, during which the United States and the Soviet Union (as well as their respective allies) invested significant proportions of their wealth in the development of both military and non-military technologies as part of a competition for global military and economic supremacy. The obvious product of this competition was the arsenal of increasingly powerful and accurate nuclear weapons capable of destroying the world many hundreds of times over. But transformational advances in computing and information technologies, materials, communications, biotechnologies, and avionics and aeronautics were also products of the Cold War and the linking, both direct and indirect, of military and non-military technological innovation processes. For example, the utter pervasiveness of computers in society today is an outgrowth of evolving networks of government military, private-sector industrial, and academic research institutions that were knitted together during the Cold War and which could simultaneously serve goals of national defense, wealth generation, and knowledge creation. Indeed, the more rapid, pervasive and all-encompassing technological change enabled in the West through linking innovation to competitive economic markets was arguably a key element in the West's Cold War victory – a victory that was achieved, needless to say, without actually employing the weaponry the devastating power of which was the symbolic technological product of that contest.

The Cold War, that is, ought to have made completely clear the reality that power in its military, political, economic and cultural guises, while intimately related, are not the same things, and that the successful linking of technology to power in one of these realms does not automatically confer dominance in the others.

Yet deep confusion about technology and power remains a key attribute of world affairs, and is on conspicuous display in the ongoing war in Iraq. The United States, owing to its absolute supremacy in military technology, vanquished the Iraqi army in short order and with few US casualties. But the subsequent "mission accomplished" pronouncement by US president George W. Bush, standing on the deck of an aircraft carrier – itself a palpable symbol of the wedding of power and technology – can now be understood as an inadvertent testimony to the limits of the technology–power nexus. The proximal objectives enabled by a technology – killing a soldier or destroying a building, for example – say little if anything about the power of that technology to facilitate broader outcomes – the compliance of one society to the will of another, for example.

Technology and power are inextricably linked to each other through the competitive and inventive nature of the human species. This synergistic essence seems not, however, to be matched by an evolving wisdom as to the proper and effective application of technologically enabled power in human affairs.

## 53

# Technology and Culture

### LUCIEN SCUBLA

The impressive development of techniques over the course of the last few centuries has not been accompanied by a better understanding of what technical activity entails. Whereas Aristotle saw in it an "imitation of nature," modern thought readily pictures it as a demiurgic power: the power to "make oneself master and possessor of nature" (Descartes), to capture or "enframe" it (Heidegger), sometimes even to destroy it. Although a Samuel Butler or an André Leroi-Gourhan had no trouble showing that every technique, ancient or modern, is a natural extension of the living organism, the opposite view tends to prevail. Conventional wisdom no longer places man *within* nature, but *face-to-face* with it, the author of his own essence and able to reshape it at will, replacing it, for better or worse, with a wholly artificial world. This vision was embraced by the young Marx, elaborated by existentialist philosophers, and even sanctioned by a certain anthropology which, reviving the old distinction between *nomos* and *phusis,* sets up an opposition between "Culture" as the totality of specifically human creations and "Nature" conceived as an alien reality.

This resurgence of the Sophists' point of view in the contemporary world is a reminder that the Promethean conception of *Homo faber* has roots deep in the past. It is not due to a belatedly achieved awareness of the "essence of technique," but rather to a perennial misapprehension that is exacerbated in our day by the scientific division of labor. Although it might have served to maintain a close link between man and the rest of the natural world, technology, by becoming autonomous, separates its object from the other components of culture and further expands the gap between the sciences of man and the sciences of nature. As a result of specialization, ethnographers may describe a people while ignoring its material culture, and theoretical anthropologists may neglect even to mention technology. Whereas Marx reduced the most original features of culture (religion, politics, law, etc.) to mere reflections of material production, social anthropology, having attained its independence, may fall into the opposite error of elevating human institutions to the status of pure products of the human mind.

This disciplinary isolation is all the more detrimental to the knowledge of man in that technical activity lends itself better to objective observation than do other kinds of activity, and it is more specifically human than organized social life, which is common to other species. A widespread intellectualist prejudice gives language and

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representations precedence over technique and actions. In reality, man objectifies his potentialities in his tools no less than in his words, and if language is the pre-eminent locus of reflexivity, doubtless a defining feature of human thought, it is not the only one, for, just as words are used to speak of other words, so tools are used to manufacture other tools.

The study of *Homo faber* and of material culture gives not only a richer but also a more exact idea of *Homo sapiens* and of culture as a whole. By establishing precise homologies between technical activities and biological activities, the works of a Leroi-Gourhan undermine assumptions that have governed anthropology for decades: the unreserved rejection of evolutionism, which discredits any morphogenetic approach to culture; cultural relativism which, elevated to a dogma, obstructs any large-scale comparative analysis; not to mention the overdrawn opposition between nature and culture, which rules out the existence of principles common to cultural and natural forms and makes the very idea of transcultural invariants problematic.

A few elementary truths suffice to rectify these ideas. Against those tempted to reject any form of evolutionism, cultural technology reminds us of the fact that tools cannot appear or succeed one another in any random order: for instance, the use of a wood-chisel presupposes the acquisition of two different types of percussion, since the steady pressure of the chisel pushing against the wood must be combined with the hurling force of the hammer swung through the air to pound it. Against relativists, inclined to regard cultures as “incommensurable,” it demonstrates that the structural and functional properties of technical objects are universal, and that the different “technical milieux” in which they are found can be partially ordered, in the mathematical sense of the term, by inclusion. Far from establishing a radical break between nature and culture, it shows technical objects to be projections and extensions of the organism – the throwing-stick, for example, adds a third immovable element to the upper arm and the forearm, writing an external memory to that of the brain, and the computer an external calculator to those inherent in neural networks – and, without calling into question the specificity of human technical capability, it reveals that certain animal species, such as ants, invented elaborate forms of breeding or agriculture before we did.

Last but not least, against those who make culture out to be a pure product of the human mind, technology exhibits numerous invariants that derive from geometrical and topological properties totally independent of men’s intellectual capacities or even of their biological features. This is true for different modes and types of percussion (diffuse, linear or pointed; pushing or hurling; longitudinal or transversal, etc. – cf. Leroi-Gourhan, *L’Homme et la Matière,* 1943) characterizing technical objects; for different ways of plaiting or weaving; for the limited number of elementary decorative motifs, etc.

The evolution of techniques, which Leroi-Gourhan so aptly described in terms of successive “liberations” – those of tools, gestures, forces and programs (cf. *Le Geste et la Parole,* 1966: 35–62) – lends support to this idea and even suggests a certain ontological autonomy of cultural phenomena. Not, of course, that, from the most modest chopping instrument to the most complex automatic machine, technical objects could have come into being on their own, unaided by human intelligence and will: but because, over the long run, their appearance and development seem ultimately to be guided, irrespective of men's motivations, by an internal logic that gives the lie both to the utilitarian doctrine that techniques are born of need, and the otherwise more cogent opposing views that make them the products of desire (Bachelard) or of ritual necessities.

The contribution of technology is not confined to the bounds of material culture. Studying techniques and technicians gives us a better grasp of culture as a whole and of man in general. It suffices to compare human techniques with those of animals in order to shift from cultural technology to general anthropology, for it is probably the surest means of determining what, in man, is properly human.

What such a comparison demonstrates is not that artificial production is fundamentally distinct from natural production, or that the procedures employed by men are always or even often original. In reality, they rarely or never are, for we have good reason to suppose that there is always less in a machine, however complex it may be, than in an organism – much less, for example, in a computer than in the brain of its inventor. No, as Aristotle taught long ago, and as Leroi-Gouhran so carefully established, what characterizes human techniques is their exteriorization, their progressive "implementation" in inert matter. It is the feat that consists in getting technical objects to carry out operations which man initially accomplished himself using nothing but his own organism. It is an activity which, in a sense, amounts to "rediscovering" and "redoing" in the external world operations which he previously had to be able to do in order to construct his own organism, the machine of his own body – and, therefore, to projecting an ever more complete self-image into the world outside this organism.

This process of exteriorization has two consequences: it sets man at a distance from the world, through the intermediary of the technical objects that he interposes between his hand and the material he fashions, and it sets him at a distance from himself, by allowing him to contemplate his own image in the objects he produces.

Remarkably, the same type of setting at a distance is accomplished by writing and, even earlier, by speech, both of which give thought an objective form: language is, in this sense, less a means of communication than a means of interrupting communication (cf. Raymond Ruyer, *L'Animal, l'Homme, la Fonction Symbolique,* 1964: 97) by interposing words between us and the world, thereby creating a barrier against the alienating effects of fascination (cf. René Thom, *Paraboles et Catastrophes,* 1983: 154) or mimetic contagion that we may experience when exposed to the immediate presence of things or fellow human beings.

Technical activity and language thus appear as two different aspects of a selfsame capability that is constitutive of the humanity of man and that could be called, in accordance with anthropological usage, the "symbolic function" – provided that the word "symbolic" is defined in such a way as to preserve the meaning implicit in its etymology. Here we are thinking of the rite associated with the *sumbolon,* which consisted in establishing a bond between two individuals through the intermediary of an object cut into two parts. In other words, the symbol should be defined as that which unites and separates at once, through its twofold capacity to render present things that are absent, and to set at a distance things that are present.

The close kinship between technical activity and language, which Leroi-Gourhan demonstrated, leads us to look for more general connections between cultural technology and social anthropology. The aim is not to reduce social institutions and structures to the status of by-products of material culture, but rather to conceive of them as specific techniques, subject to common principles. In this way, we might regard social organizations as "techniques for territorial control" (in Pierre Gourou's phrase) or as systems for the self-regulation or "self-domestication of man" (in René Girard's phrase), and conjecture that what is called the "symbolic" efficacy of rituals is, as in the case of tools, primarily a function of their form, that is to say, of their topological and geometrical properties (the position and structure of ceremonial sites, the spatial distribution, gestures and movements of the actors, etc.).

Let us take as an example investiture, a ritual found the world over in which an individual acceding to a new function (especially that of king, priest or judge) dons a ceremonial garment. It would be a mistake to say that this rite "expresses" a change in status. Rather, by concealing from the eyes of the public the body of the new office-holder, investiture turns him into an *arbiter* in the original sense of the term, meaning one who *sees without being seen,* and can therefore act as a third party, standing outside the face-to-face confrontations of common mortals. In short, it does not "symbolize" the arbiter's function; it *creates* the antisymmetrical relationship which makes this function possible in a society ruled by a principle of reciprocity.

Or let us take a unanimous oath, such as the *Serment du Jeu de Paume* sworn by the deputies of the Third Estate during the French Revolution: such an oath immediately creates a unified group solely in virtue of the fact that all must simultaneously raise their arms in the same direction. They need not share a belief in any divinity; the simple convergence of their hands is enough to designate a site destined to become a transcendent pole to which the group may periodically return in order to re-establish its unity.

Or, finally, let us take a type of sacrifice, quite widespread in Africa, in which the body of the sacrificial victim is cut in two in order to terminate an incestuous relationship or a vendetta. The object of this ritual is not to mark the end of an illicit liaison between two relatives or the end of hostilities between two rival groups, but rather to *obtain* this result by re-creating the borderline and the distance necessary to improve relations between the parties concerned. It follows that sacrifice, contrary to what famous definitions would lead one to believe, is less a rite of communion than of separation, maintaining men and gods (whose wrath must be kept at bay by offering them the expiatory victim) at the right distance from one another. In all of these examples, the so-called symbolic efficacy of the rite depends on the precision of the technical gesture, on which responsibility for the regulation of actions and representations rests.

Let us come back to language. Since ritual forms turn out to be less arbitrary than one might have believed, one is tempted to challenge the dogma of the conventional nature of signs which, from Aristotle to Saussure, has dominated the history of Western thought. Such a revision would find support in the work of Pierre Guiraud. In an article summarizing an exhaustive French vocabulary study (*Langue française,* 1969, 4: 67–74), this linguist showed that the great majority of words designating the act of "striking a blow" are formed on the basis of a very small number of onomatopoeic roots. One counts more than 500 terms constructed around the element TK, and distributed across the vocal oppositions TIK–TOK–TAK, depending on whether the blow is piercing, cutting or contusing. Here we encounter once more the three great modes of percussion defined by Leroi-Gouhran: pointed, linear and diffuse, analogically represented by the sounds TIK, TOK and TAK. Hence everything occurs as if the same reasons led us to have three types of teeth (canines, incisors and molars), to manufacture three types of tools and to create three classes of words to designate the different types of blows: not because cultural forms are a mere extension of living forms, but because both human institutions and living organisms are subject to certain universal formal constraints which no matter or substratum may elude.

For, to borrow a famous phrase, it is not a question of explaining feudal society by the hand-mill and state society by the steam-mill – in other words, of denying the specificity of human institutions and of social anthropology – but only of suggesting that a "technological detour" could help anthropology better grasp the organization of cultural phenomena while approaching closer, in a non-reductionist spirit, to the other sciences of nature.

We do not have space enough to show how esthetic phenomena interact with technical phenomena to give each ethnic group its singular identity. Here, again, a Leroi-Gouhran, by demonstrating that phenomena of the same type (e.g. plumage and songs in the case of birds, ornaments and musical rhythms in that of people) serve as operators of identity in both species and ethnicities, is able in our view to account at once for the unity and the cultural or specific diversity displayed by both the human and the animal worlds.

Translated by Mark R. Anspach.

# 54

# Technology Management

RICHARD LI-HUA

## What Is Technology Management/Management of Technology (MOT)?

Technology management can be viewed from many different perspectives since the word "technology" itself is subject to various interpretations. However, the author of this thesis approaches the topics from different experiences that are associated with different environments and backgrounds. It is hoped that this thesis will present the many facets of technology management. The two words "management" and "technology" not only carry the burden of many different meanings but also present additional sophistication owing to the anthropological diversity. To many, MOT means managing engineering and technology. To others, MOT indicates managing knowledge and information, managing research and development, managing manufacture and operation, managing the activities of engineers and scientists, or managing the functional activities without concern for the total of activities that encompass the business-concepts-to-commercialization process. According to Gaynor (1996), these interrelated activities must be integrated into a technology system. MOT means not only managing the system but also managing the pieces, which involves integrating the "pieces" into an acceptable "whole" by focusing attention on the interdependence of the pieces. However, these elaborations are only part of the process of MOT by this thesis.

According to the 1987 workshop report of the National Research Council (NRC) of the USA, "Management of Technology" is the hidden competitive advantage bridging "the knowledge and practice gap" between science, engineering and business management (Khalil 2001). Management of Technology (MOT) as a field links "engineering, science, and management disciplines to plan, develop, implement technological capabilities to shape and accomplish the strategic and operational objectives of an organisation." The NRC report summarizes important contributions to industry that management of technology knowledge can make as follows:

How to integrate technology into the overall strategic objectives of organization;
How to get into and out of technologies faster and more efficiently;
How to assess/evaluate technology more efficiently;
How best to accomplish technology transfer;

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How to reduce new product development time;
How to manage large, complex and inter-disciplinary or inter-organizational projects/systems;
How to manage the organization's internal use of technology;
How to leverage the effectiveness of technical professionals

To put it in a simple way, technology management is about getting people and technologies working together to do what people are expecting, which is a collection of systematic methods for managing the process of applying knowledge to extend the human activities and produce defined products. Effective technology management synthesizes the best ideas from all sides: academic, practitioner, generalist or technologist.

## Significance of Technology Management

It is argued that there are three major factors strategically in modern organizations that underpin the creation of competitive advantages. The first of these is strategic leadership. The effective leadership ensures that the enterprise will develop itself in the right direction and the production of product will meet the demand of the market. The second factor is having a staff with motivation and empowerment. They are the driving forces of the organization. The third factor is the proper management of technology. It is important that the company's technology be appropriately and properly managed so as to achieve effective and competitive status (Harrison and Samson 2003).

Leadership and motivation of employees have been widely recognized as success factors. There have been significant additions to theories and practice regarding improvement in the management of people. Therefore, strategically, the remaining battlefield being competitive depends on proper management of technology. To put it differently, the strategic issue will be how a company could develop, acquire, share and manage technology appropriately and effectively.

It is interesting that this argument has been in congruence with the American historical experience. The United States of America experienced an increasing global competition which resulted in loss of market share in several industry sectors in the 1970s and 1980s. This became a concern not only to industries but also to government and educational interests. To identify reasons for the decline in US industrial competitiveness, and to formulate a response to the challenges within global competition, serious work and efforts had been contributed in the search for explanations and solutions. Discussions were initiated by major establishments such as the National Research Council (NRC), the National Science Foundation (NSF), the American Association of Engineering Societies, the Accreditation Board for Engineering and Technology, the American Assembly of Collegiate Schools of Business, Oak Ridge Associated Universities and others. A series of workshops were organized and attended by experts for the discussion of changing paradigms in business and technology (Khalil and Bayraktar 1988). A resulting consensus was that great attention and a significant amount of effort should be directed toward making improvements in the management of technology and in conducting research and developing educational programs in this emerging field of knowledge.

Khalil (2001) highlights that efforts to improve the US position in the global economy were being influenced by the understanding that more organizations, including government agencies, higher educational institutions, enterprises and founding agencies become aware of issues involved in the international arena. Today, rapid changes in the technology and business environment continue to occur. These changes require continuous updating of methods and techniques of business practice. For example, measuring the value of a business according to assessment of physical assets or based on traditional accounting or finance formulas is inadequate in the knowledge economy. Education and training institutions need to take into consideration the changing environment in technology and business, and respond by changing their programs accordingly. Khalil (2001) argues that international business and engineering schools need to give consideration to incorporating into their curricula educational modules recognizing the importance of the knowledge era and the technology revolution. The intangible assets such as intellectual capital, intellectual properties, service innovation, information technology and many of today's rapidly growing arenas should be recognized. Furthermore, many of the existing models and the traditional programs need to take into account the appropriateness and effectiveness of technology and innovation as well as the volatilities of the environment in which the technology is created and applied.

In addition, in the twenty-first century, technology assumes great importance in advancing every aspect of human endeavor. MOT assumes even greater importance in the capacity-building of countries, companies and individuals to embrace technological changes in order to advance their competitive status in a global marketplace. It has been recognized that interest in the field of management of technology has mushroomed since the inception of the movement to introduce MOT as a new field of study and research in the 1980s. The application of MOT principles has made a significant impact on the wealth-creation ability of the US and a large number of other countries.

## New Endeavors in Management of Technology

It has to be acknowledged that there are a number of endeavors to embrace the challenges that the world is facing in terms of management of technology. The International Association for Management of Technology (IAMOT), founded in the early 1980s, has become the leading and largest international professional association solely devoted to the promotion of management of technology education, research and application. IAMOT is currently undertaking a major initiative to create guidelines for academic programs in MOT and certification/accreditation guidelines to recognize the quality of academic programs. This promises to be a strong step toward establishing formal management of technology education globally on a sound academic basis.

In addressing the Chinese experience in terms of management of technology, Li-Hua and Khalil (2006) argue that appropriate infrastructures, strategies and mechanism for management of technology need to be established in order to support the diffusion of management of technology principles throughout China. The conceptual framework for the future direction and needs has been proposed based on the US research and education experiences over the past two decades. It is debatable whether business and engineering schools need to introduce MOT curricula following the US model or develop a new model shaped by the Chinese culture. It draws upon the experience of the US in management of technology over the past two decades and projects what may be needed for China to continue its development and economic growth in the future.

It is, however, evident that the current situation in China in terms of MOT presents both opportunities and challenges not only to Chinese business but also to Western business. Today, increased levels of competition discussed in this thesis in the wake of China's entry into the WTO have resulted in experimentation and risk-taking as ways of doing business in China. However, the uncertainties and ambiguities prevalent in the Chinese business environment – in particular, in the area of technology management – are neither well understood nor effectively negotiated by the international investment community. In addition, the complexities of technology and knowledge transfer have led to misunderstanding in the operation and the implementation of international joint-venture projects in China (Li-Hua 2006). Therefore, as to the international investors, China's business environment continues to present many challenges, particularly in how to manage effective business networks and ensure smooth knowledge transfer, especially in international joint-venture projects.

In response to these challenges and opportunities, there is an initiative that, following the successful launching of the *Journal of Technology Management in China*, in late 2005 the China Association for Management of Technology (CAMOT) was established. CAMOT is an international organization committed to encouraging and supporting researchers and professionals who are engaging in research in management of technology in China. CAMOT aims to establish national, regional and international collaborative research programs in the field of technology management, technology innovation, technology transfer as well as knowledge transfer by engaging government agencies, funding agencies, educational institutions, state-owned enterprises (SOEs) as well as private sectors in China. CAMOT stresses the importance of keeping up with the fast pace of technological change and the emerging new global paradigms of the business environment. Management of technology (MOT) is an important strategic instrument to improve competitiveness and create prosperity in China. CAMOT believes that there is a need to address the existing gaps in the process of technology management, which will assist in implementing more a sustainable arrangement for successful technology transfer and development.

The vision of CAMOT is to inspire excellence for management of technology and promote the appropriate diffusion of management of technology principles throughout China.

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# 55

# Technology Strategy

## RICHARD LI-HUA

Technology strategy is no doubt an important but often ignored link in the strategic formulation system. Compared with the position of development and marketing strategy, technology strategy appears to be in a fragmented, piecemeal fashion. However, it has been hoped that this thesis addresses the significance of technology strategy in the process of the creation of competitive advantage and highlights the crucial issues concerning technology strategy, such as the definition, brief history, features, principles, processes and steps of formulation of technology strategy.

A strategy of a nation is a means by which the internal strengths and weaknesses are linked with the opportunities and threats provided by its environment. Technologies by themselves do not establish the overall strengths of a nation. However, the appropriate and effective technology strategy is a key component and driving force in attaining competitive advantage. By integrating proper technology strategy into its overall strategy, a nation can develop a well-defined technology policy toward technology development and innovation (De 2004).

Technology strategy is a relatively recent concept in the area of technology management. After the Second World War, firms in the US such as Westinghouse and General Electric pursued paths of diversification through internal research and development (R&D) efforts (Narayanan 2001). Though the concept of technology strategy was not prevalent at that time, the origin of the concept can be traced to the R&D activities and the argument about technology strategy adopted to manage R&D in large diversified firms.

Porter (1988) describes "technological strategy" as "a vehicle for pursuing generic competitive strategies aiming at fundamentally different types of competitive advantages" in trying to establish a conceptual link between technological change and the choice of competitive strategy by the individual firm. He further elaborates that technological strategy must be a broader concept of overall competitive strategy, which is an integrated set of policies in each functional activity of the firm that aims to create a sustainable competitive advantage. Technological strategy is but one element of an overall competitive strategy and thus must be consistent with and reinforced by the actions of other functional departments. Maidique and Frevola (1988) define "technological strategy" as "the pattern of choices that the firms make regarding technology direction." In their view, technological strategy addresses a distinct set of

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decisions; it should be differentiated from other manufacturing strategies. Furthermore, it is concerned with choices between alternative new technologies, the manner in which they are implemented into new products and processes, and the utilization of resources that will allow their successful implementation. Rosenbloom (1993) regards "technology strategy" as "the revealed pattern in the technology choices of firms, which involve the commitment of resources for the appropriation, maintenance, deployment, and abandonment of technological capacity." These technological choices determine the character and the extent of the firms' principal technical capacities and the set of available product and process platforms.

According to Narayanan (2001), in reflection of these definitions, technology strategy should have the following features:

Technology strategy focuses on the kinds of technologies that a firm selects for acquisition, development, deployment, etc.;

Technology strategy requires commitments surrounding technology selection;

Technology strategy is not confined to high-technology industries. Even a capacity-driven or a customer-driven industry requires a technology strategy. Such strategies may be implicit and may not reflect the conscious decisions by executives, but none the less they determine the choice of the technical capacities and available product and process platforms of the firms. For example, a banking firm or a hotel in a service industry may decide to invest in information and communication technology (ICT) as a way of communicating and interfacing with their customers;

Technology strategy has to embrace both the hardware and software elements of technology. It is specially the case in these days.

With consideration of these features, therefore, there are four major types of technology strategy. These include technology leadership, niche, technology follower and technology rationalizer.

Technology leadership strategy consists of establishing and maintaining through technology development, innovation and deployment a pre-eminent position in the competitive domain in all the technologies for a dominant market position. In general, the well-developed countries often follow this strategy.

Niche strategy consists of focusing on a selected number of critical technologies to seek leadership. Technology innovation and development are selective and oriented to build technological capacity in order to create competitive advantage. For example, the newly developed countries often follow this technology strategy.

Follower strategy is often adapted by the developing countries in order to avoid the risk of basic research.

Technology rationalization involves maintaining adequately only a selected set of technologies.

Narayanan (2001) proposes that there are four steps in formulating a technology strategy. The first step consists of diagnosis, understanding the environmental context and the firm's strategic position. Second, it involves the commitment of resources to certain technology choices. Third, it has to consider the mode of implementation, intellectual property protection plans and organization for execution of the technology choices. Finally, it involves the execution of the choices and the implementation of the technology strategy.

Faced with a turbulent business environment, collaborative arrangement of technology strategy has become a trend these days. Collaborative arrangement involves two or more firms in which the partners wish to involve technology transfer and to learn from each other the technologies, skills and knowledge that are not otherwise available. The partners may range from suppliers and customers to even competitors.

One of the major features in the collaborative arrangement is knowledge transfer, which is viewed as strategically important. The collaborative arrangement is often determined because of the strategic reasons. Though partners may try to avoid competition in their day-to-day operations, however, many technology-related collaborative arrangements are actually between competitors. Take Shanghai Automobile for example. The factory once was the flagship of China's car manufacturing industry, which produced the first car in 1958. In the early years of China's economic reform, the first joint venture was established in 1991 between Shanghai Automobile and Volkswagen, which to some extent takes a leading role in China's car industry. The technology collaboration between Shanghai Automobile and Volkswagen begun in the early 1990s has brought the company into the top 500 in the world. It has been recognized that there has been close and successful collaboration between the two strategic partners. However, when Shanghai Automobile wished to create its own brand and intended to acquire core technology from its German partner this was rejected by Volkswagen. This clearly indicates that Shanghai Automobile and Volkswagen are pursuing different technology strategies.

In this thesis, we use the term "technology strategy" to describe the strategically important technology choices made by a firm or a state. It is a strategic instrument in achieving sustainable competitive advantage. Thus, the cooperation in Maglev railway in Shanghai between China and Germany is another case of collaborative arrangement of technology strategy. In 2003, the German technology of magnetic trains in Shanghai had created the fastest speed (500 kilometers per hour) on the first magnetic railway in the world. Known as the Maglev (magnetic levitation), China's flagship transport system takes eight minutes to hurtle along a 28.5 kilometer track through the paddy fields surrounding Shanghai Pudong International Airport. This journey normally takes up to one hour by car. From the point of view of technology strategy, Germany's Maglev technology was testified and made known through technology collaboration, while China has sorted out its transportation problem from Shanghai Longyang Station to Pudong International Airport. This is a so-called win–win solution. Furthermore, the Chinese government is currently considering an extension into the city and possibly further to the neighboring city of Hangzhou, in time for Shanghai's hosting of the World Expo in 2010. As the German technology being transferred to China has had a positive effect, the Maglev is now having followers across the world. According to Clark (2005), Germany wants to build one Maglev for an airport link in Munich. The US government is also evaluating Maglev schemes. More realistically, the UK government plans to build a Maglev from London to Scotland, which will cost at least £16 billion.

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# 56

# Technology and Globalization

DAVID M. KAPLAN

Globalization typically refers to the process by which a capitalist world system spreads across the globe and consolidates the economic, cultural and political order of nations into a world society. Globalization involves the expansion of global linkages, the liberalization of trade and currencies, the dominance of Western cultural life, increased international travel and immigration, and proliferation of information technologies leading to the interdependence of nations and, eventually, a single global community. Since the 1970s, the industrialized world has established progressively closer contact with and involvement in the developing world, thanks to a combination of new technologies and specific economic and political policies. Local events are shaped by distant events, and vice versa. As a result, distance is becoming less important, time is accelerating, and political communities are losing their traditional authority as fundamental changes in the laws, economies and cultures occur within every society. Globalization refers to a number of phenomena related to the social and political integration of geographically remote locations.

## Technology and the Global Political Economy

Technological innovations have, in large part, fueled globalization. Innovations such as jet airplanes, wireless telephones, email, computers and global telecommunications infrastructure allow money, technology, raw materials and finished products to move freely across national borders. Information and communication technologies, however, stand out as the most important technologies driving globalization. The increasing speed of social interactions and the decreasing distances among people depend on the presence of information and communication technology. The generation and transmission of technological knowledge is also transformed by globalization, which has made the world seem smaller and more interdependent as people who were previously separated by great distances are now able to share in the same economic, political and social forms of life.

Information technology (IT) is arguably the key to the process of globalization. Innovations in computer hardware and software in the early 1990s allowed for a tremendous increase in the scale of information gathering, storage, and speed of distribution. At

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the same time, improvements in telecommunications technology allowed for increased access to information, creating more effective, and less expensive, means of communication. The ability to process information and communicate in digital form has driven the "IT revolution." Microprocessors, the tiny devices that power digital technologies, progressively increased their processing power and speed while becoming smaller and less expensive. Microprocessors power personal computers and computer networks, cellular telephones and communications networks, televisions, video games and visual displays, and are increasingly found in more ordinary devices, like automobiles and refrigerators. Innovations in fiber optics allowed data to be transformed into digital form, converted into impulses of light, and then transmitted at great speeds over great distances, markedly increasing the capacity of telecommunications networks. Improvements in wireless networks allowed for greater flexibility in communications and information-processing over distances. Advances in IT facilitate the transfer, storage and processing of information, and help to further the process of globalization.

IT technology has had a profound influence on globalizing business practices. The Internet, for example, has transformed the nature of exchanges between buyers and sellers, eliminating the need for face-to-face interactions, and allowing consumers more access to retailers and business to expand their market share. Businesses use the Internet for "e-commerce" to find other businesses to buy or sell their products or services. "Business-to-business" commerce streamlines the interactions between wholesalers, retailers, producers and distributors of goods within and among business enterprises. E-commerce facilitates communication and access to markets on a scale previously unrealized.

IT technology has created new industries, fostered new kinds of work, and transformed the nature of management, manufacturing, distribution and services. It has created the demand for new computer hardware and software development, technical expertise and support, information management and "knowledge workers." IT technology changes the nature of the global workforce as it eliminates the need for workers in outdated industries and demands workers with the knowledge and training required for jobs in computing and telecommunications. Changes in the nature of the workforce, away from physical work to knowledge work, in turn push the demand for high-tech workers, high-tech machinery, and the infrastructure necessary to support them. As IT-driven sectors of the economy create new service jobs and destroy old manufacturing jobs in advanced industrialized nations, the nature of economies and workforces change in developing nations as well. Part of the dynamics of IT technology and globalization is the intimate relationships now afforded by computing and telecommunication to coordinate commerce across national boundaries, creating new patterns of economic activities while eliminating others, both domestically and internationally.

IT technology is a key ingredient in "lean production," the manufacturing system that characterizes the late-capitalist ("post-Fordist") global system of production and distribution. Lean production aims at streamlining manufacturing to eliminate excesses and inefficiencies related to overproduction, inflexible design, slow product development, excessive inventory, unresponsive management, lack of information, and a host of other problems associated with Fordist mass production. IT-based inventory systems help manufacturers coordinate to reduce the time, waste and costs of production by reducing product assembly and delivery times, and by reducing product inventories held in warehouses in between the factory and retail outlets. The technique is known as "just-in-time" production, a strategy of reducing inventory before and after manufacturing in order to reduce costs, maximize profits and improve return on investment. Just-in-time improves the flow of goods by managing the segments of the supply chain in a business (what materials are used, how much, delivered when and where, for what exact purpose) co-coordinated with knowledge about the demand for a particular product. Just-in-time production depends on fast and accurate information-sharing up and down the supply chain. Late-twentieth-century developments in IT technology helped to establish lean production as a central ingredient in a global economy.

Another area profoundly impacted by information technology is financial markets. Fast, reliable information is vital for all interactions among banks, financial institutions and lenders with individuals, investors, shareholders and borrowers. Marketplace institutions have benefited from improvements in IT technology, including the stock market, bond market, futures markets, options market, foreign exchange market, to name just some among many instruments for buying, selling, borrowing, lending and investing in important segments of financial markets. IT innovations in information-processing speed, storage, memory, data analysis capacity, and security have allowed financial market to become international. IT innovations in information-gathering and -management allow actors separated by great distances to have information and coordinate actions based on information on a new, increasing scale. The result is a global financial market in which individuals and institutions have access to more information more rapidly than before, and greater access to previously remote banks, lenders, governments and foreign markets to invest or raise capital. The currently existing global financial market owes its existence to a combination of IT innovations and international regulatory reforms that have opened up financial markets to foreign (i.e. global) participation.

## The Global Political Economy and Technology

Technology is a necessary but not sufficient condition for globalization. A variety of national and international laws, policies, practices must also be in place. The most important conditions include the dominance of capitalist markets, increasing influence of international financial markets over national policies, a decreasing influence of the State over international finance and commerce, privatization of services, deregulation of economic activities, and an increasing role of private actors and business corporations in social and economic life.

The most powerful and important organization dealing with global economic regulations among nations is the World Trade Organization (WTO). The purpose of the WTO is to provide a negotiating forum for nations to form agreements to lower trade barriers to ensure that trade flows as freely and predictably as possible. In addition to trade in goods and services, the WTO regulates banking and finance, intellectual property, dispute settlement, and trade policy reviews. For the 150 member nations, the WTO is the most influential institution of international commerce.

The WTO aims to lower trade barriers such as customs duties, import bans or quotas, as well as limits to non-tariff trade barriers that nations may implement and enforce, such as domestic laws regulating product standards and liability, environmental protections, use of tax revenues for public services, and other domestic laws regulating investment and trade. Through the WTO Dispute Settlement Process, nations can challenge each other's laws on behalf of their commercial interests if they believe barriers to trade exist. If member nations do not conform to WTO regulations, they face possible economic sanctions.

Many of the WTO agreements affect the science and technology laws and practices of member nations. The Sanitary and Phytosanitary Measures Agreement (SPS) sets food safety and animal and plant health standards, including quarantine, inspections, and testing requirements. The aim of the SPS Agreement is to establish standards based on accepted science to allow countries to set reasonable health and safety regulations but only to the extent necessary to protect human, plant, or animal life or health. The SPS agreement prevents countries from using higher sanitary and phytosanitary measures in order to protect domestic producers. The result is an enforceable procedure for establishing global health standards and acceptable scientific practice.

The Agreement on Technical Barriers to Trade (TBT) ensures that product standards, regulations, testing and certification on all goods, including industrial and agricultural products, do not become obstacles to trade. The TBT Agreement sets limits on the standards governments may enforce to achieve social, environmental, consumer, or public health objectives. The aim is to prevent national technical regulations and industrial standards from being used for protectionism and instead to foster the development of singular, globally accepted regulations and standards.

The Agreement on Trade-Related Aspects of Intellectual Property (TRIPs) establishes the levels of protection governments have to give the intellectual property rights of other governments. The agreement covers copyright, trademarks, geographical indications, industrial designs, patents, trade secrets, and integrated circuit layout designs. TRIPs extends intellectual property rights to include pharmaceuticals, plant varieties, human and plant cell lines, micro-organisms, and genes. The agreement defines what counts as intellectual property, how governments should enforce rights, and how to settle disputes over rights between member nations. Through these agreements and others, the WTO functions as the single most important institution enabling the globalization of science and technology practice.

Proponents of the WTO and economic globalization maintain that lowering import tariffs and "harmonizing" the international rules of commerce will make trade more competitive and more beneficial for all nations, especially less developed nations. Opponents worry that its agreements privilege private corporate and financial interest goals over public interest goals of sovereign nations. As a result, the process of globalization tends less toward positive "harmonization" of international policies and more toward negative "homogenization" of regional cultural and environmental differences that are sacrificed for the sake of free trade in goods, services and investment. Other theorists believe that the impact of globalization is greatly exaggerated and that most of the world's population remains immune from technological innovations and international economic institutions and financial markets. Despite the controversies surrounding globalization, there is widespread agreement that the combination of new technologies and the expansion of financial and economic markets is challenging local and national boundaries with far-reaching implications for humanity.

# 57

# Technology Transfer

EVAN SELINGER

The phrase "technology transfer" has multiple meanings. The two dominant uses concern anticipatory thinking: one refers to employees working in offices of technology transfer who attend to patenting and licensing inventions so that new scientific discoveries can be transformed into technological applications; the other refers to people working on development projects who try to discern and implement new applications for technologies that already exist.

Given the enthusiasm for accelerating the pace of technological progress in developing countries, it is the latter endeavor – particularly when designed to assist impoverished regions to "leapfrog" from a pre-modern milieu into the digital age – that is at the forefront of many private and public programs.

Even when well intentioned and carefully orchestrated, the use of technology transfer as a development tool routinely provokes international critique in addition to praise. This is because the standards for judging regional success and the feasibility for expansion through replication are subject to debate – debate that typically contains ontological, ethical and political dimensions.

In order to understand the central motifs around which many of the debates revolve, it will be useful first to discuss how to understand technology transfer *qua* practice. Owing to anthropological diversity, the thesis of technological relativity holds the key to this endeavor. According to this thesis – expressed by pragmatists such as John Dewey and phenomenologists such as Don Ihde – technological activity is an embodied experience that has ineliminable cultural dimensions. Not only does the scope of technology include machines, artifacts and engineering principals; it also extends to background conditions, including skills, knowledge, techniques, social norms, and perceptions that are shaped by personal and collective histories. In short, without the regulating structure of practice, artifacts and machines would simply be useless junk – or, at best, material entities that could, some day, potentially become technologies. Indeed, even the effective use of "found" or "proto" technologies, such as the tubes of grass that chimps use to coax insects out of the ground, requires users to possess viable techniques – and these techniques, in turn, are typically acquired through the disciplining of natural talent through habituation.

When it comes to importing a new technology, some simple contexts, such as eating and drinking, are widespread; as a consequence, they often transfer easily. Other

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contexts, however, are more complex; in these cases, technology transfer can prove difficult. In some instances, technologies that a particular culture finds useful cannot be transferred at all; here, differences in background conditions tend to be at the root of the discrepancy. For example, as Hubert Dreyfus notes, it would be difficult to imagine, given the way material culture embodies and shapes cultural identity, a traditional Japanese tea ceremony occurring around Styrofoam cups. Styrofoam cups are not aesthetically pleasing; and their primary function, managing temperature efficiently, is achieved in a disposable and interchangeable form. By contrast, "the tea cup does not preserve temperature as well as its plastic replacement, and it has to be washed and protected, but it is preserved from generation to generation for its beauty and social meaning."

Cases like the latter suggest that, when it comes to understanding and assessing technology transfer, categories such as "cultural specificity" are likely to be more relevant than what often turn out to be primarily ergonomic matters of "simplicity" and "complexity." Since a transferable technology can count as being adopted only once its components are instantiated into cultural practices through "integration" as well as "translation," new agendas and novel usage can always turn a given artifact, machine, and even system into a different "being."

Two examples of technology transfer can prove illustrative here. First, consider the widespread use of text-messaging. It may be tempting to imagine that this trend has become ubiquitous owing to universal proclivities. Perhaps it is human nature to want to avoid genuine intimacy while simultaneously generating the illusion of intersubjective bonding. But, in addition to being culturally insensitive, such grand speculation would be difficult, if not impossible to prove.

In order to explain the popularity of text-messaging in China, for example, one would need to examine how the prospect of leaving a text-message accords with or challenges extant perceptions of hierarchical behavior. For example, it has been alleged that, owing to traditional values, many people in China view text-messaging as a communicative act that can preserve dignity. This is because they consider it rude to leave voice-mail messages, and they further view the prospect of conversing with an intended recipient's assistant to be undignified. Thus, while text-messaging may be primarily a general technology of idle chatter or emergency contact in one cultural context, it can be primarily a dignity-preserving technology in another.

The second example to consider is the Village Phone Program. Created under the auspices of the Grameen Bank in 1997, this endeavor uses micro-credit principals to loan Bangladeshi women money for acquiring mobile phones that can be rented out to villagers on a call-by-call basis. This program has already made it possible for women living in a predominantly Muslim and explicitly patriarchal society to gain new levels of income, respect and geographic mobility. It has also enabled the mostly illiterate Bangladeshis to acquire improved "connectivity" that, in turn, has helped merchants of all sorts conduct more efficient and informed business transactions, helped people stay in touch with relatives who moved abroad (primarily to acquire employment), and helped people improve their access to medical advice and medical treatment. As a consequence of these gains, neo-classical economists typically characterize the project as producing "empowered" and, comparatively speaking, "independent" agents. Indeed, if such a description were unproblematic, the Village Phone Program would deserve unqualified praise for effectively promoting two of the United Nations Millennium Goals: combating extreme poverty and promoting gender equality through the empowerment of women. And, even if the Village Phone Program is more complicated than the dominant development narratives acknowledge, it still makes sense to characterize mobile phones as "weapons against poverty" in this context, but not in others. Again, the critical point here is that culturally specific reasons explain why mobile phones have become development tools in Bangladesh but not in US slums and ghettos.

Having briefly detailed the relativistic dimension of technology transfer, it will be useful to discuss some of the leading ethical and political issues. For the sake of continuity, Bangladesh and China will again be used as paradigm cases.

With respect to the transfer of chemicals, nuclear power and biotechnology, one of the central problems that developing countries have faced is *contextual insensitivity* on the part of the developers. One illustrative case is discussed by Bill McKibben in *Enough: Staying Human in an Engineered Age* (2000). There he analyzes the impact of the 1960s Green Revolution in Gorasin, Bangladesh, judging the project to be an instance of Western *hubris*.

At the program's inception, compliance was achieved by informing the Bangladeshis that, if they imported new high-yield rice strains produced in "Western labs," progress would be made in combating the rampant hunger problem; indeed, the predicted outcome was abundant and consistent food sources. What the developers did not sufficiently consider, however, is that Bangladesh is "as much water as it is land" and also experiences floods regularly. As a consequence, by planting more " 'improved' seeds instead of dozens of different varieties," the inhabitants of Gorasin would come to acquire an increased need for pesticides, and people as well as animals were exposed to dangerous toxins.

Because the women who collected water for the village came into direct contact with harmful chemicals, they developed gastric and skin problems. The cows and fish became diseased as well – and this proved to be a significant blow to Bengali diet and cultural identity. In order to prevent further devastation, it was decided that the high-tech agenda needed to be revisited. In McKibben's parlance, the Bangladeshis said "enough" to a technology that could not be successfully integrated into their local norms. About a decade ago they imported low-tech organic farming zones in the hope of moving toward a more sustainable solution. The general lesson that McKibben draws from thinking about Gorasin is that the very pursuit of a developmental goal (e.g. improving health) can, ironically, inhibit that goal (e.g. fostering disease). Since comparable examples of dramatic and unforeseen results arising from technology transfer abound, the task of creating an empirically sensitive development ethics, one that deals appropriately with both techno-scientific uncertainty and multi-cultural sensitivity, remains an important priority.

On the more explicitly political side of the spectrum, human rights issues are also taking center stage in current discussions about technology transfer. While some of the paradigm cases concern the techno-economic erosion of indigenous values, others emphasize a problem at the other end of the political spectrum. In these instances, critics are concerned about techno-economic forces entrenching unjust local norms.

For example, Microsoft's decision in early 2006 to shut down the MSN Spaces website of a popular Beijing journalist – Zhao Jing (alias Michael Anti) – became mired in controversy. Chinese censors were concerned about the subversive content that was being displayed on his blog; and Microsoft, in turn, responded by touting a corporate ethos that emphasized client autonomy and cultural relativism. Brook Richardson, a group product manager at MSN, noted that Microsoft and other multinational companies are obligated to ensure that their "products and services comply with local laws, norms, and industry practices." Because such policy is being enacted during a time in which China already exhibits strict – if not repressive – guidelines for Internet use, concern is being expressed that American companies may not simply be ignoring human rights violations but could, in fact, be fortifying them. Yahoo, for example, recently provided Chinese authorities with the name of an "anonymous" emailer who had disseminated an opinionated message about Tiananmen Square. As a consequence, that person is serving a ten-year prison term. Furthermore, MSN's filter for Chinese use prevents certain controversial phrases, including "Dalai Lama," "human rights," "freedom" and "democracy," from being included in prominent places, such as blog headers. In light of such evidence concerning China's commitment to curbing "cyberdissidents," some critics suggest that multinational corporations need to become "better corporate citizens." Steps need to be taken, they insist, to ensure that fundamental human rights are privileged over profiteering. For instance, Reporters Without Borders, an international non-governmental organization, argues that corporations should adopt codes designed to enable the freedom of expression and the free flow of information.

The problem of digital information and human rights can be expected to continue to generate controversy. For example, although Google is known for its corporate mantra "Don't be evil," it is too early to predict what its long-term search engine policy will be in China.

# 58

# Technology and Capitalism

## DAVID M. KAPLAN

Capitalism is an economic system based on the private ownership of the means of production, a market system for the distribution and exchange of goods and services, and an allocation of resources also based on the market. Capitalism is typically justified by an appeal to the rights of individuals or groups of individuals acting as "legal persons" (or corporations) to buy, sell, trade or give (as gifts) products, labor, money in an economic system that is relatively free of government control. A capitalist economic system is dedicated to production for profit and the accumulation of value and market share by individuals or corporate business entities. Capitalism has been the dominant system in the Western world since the decline of mercantilism in the eighteenth century and the rise of the industrial revolution in the nineteenth century.

Technology has been vital to the development and success of a capitalist economy from its beginnings and continues to be so today.

## Technology and the Development of Capitalism

Early capitalist economic practices appeared throughout Europe from the sixteenth to the eighteenth centuries during a period known as "mercantilism" or "merchant capitalism." Mercantilism was a system under which nations traded for profit by exchanging manufactured goods for gold and silver bullion. Mercantilism relied on extensive state regulation of economic activity, the establishment of colonies for raw materials and labor, and manufacturing and trade geared toward a surplus of exports over imports. The mercantilist era helped give rise to capitalism through the creation of strong national states, uniform monetary and legal systems, and the accumulation of vast amounts of capital. Mercantilism was criticized, most famously, by Adam Smith in his *The Wealth of Nations* (1776) for supporting too strict controls over the economy, for maintaining protectionist tariffs, and for focusing on manufacturing and money supply rather than on consumption and trade. Mid-eighteenth-century economic theories and the rise of political liberalism, with its emphasis on individual liberty, helped to transform European economies from mercantilist to capitalist.

Perhaps even more important to the rise of capitalism than conceptual developments in political economy and trade liberalization was the development of a number of key

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technologies. Advances in mechanized agriculture, steam-powered machinery and semi-automatic factories fueled the European industrial revolution and transformed the nature of production from manual to mechanical. Industrialized production was made possible by such innovations as the steam engine, improved iron-smelting (based on coke rather than on charcoal), and machine tools. These innovations led to the mechanized production of textiles, coal-mining, and factory-based manufacturing. Later innovations in transportation (railways, canals) and communication (telegraph) led to expansion and trade which advanced and spread the industrial revolution through Europe and the United States.

As the new productive forces of the industrial manufacturing system replaced feudalism, agrarianism and guilds, a new social class emerged: the bourgeoisie and their political order. The bourgeoisie supplanted the aristocracy as the dominant economic and political class in industrialized nations. They acquired their wealth and power from profits accumulated during production, or, as Karl Marx explains it, from surplus value appropriated from unremunerated wages of workers who generate wealth. The bourgeoisie and workers (also known as capitalists and proletariat, or capital and labor) are defined by their different relations to the means of production: capitalists own the means of production, hire workers in exchange for wages, and strive for profits and increased market share; proletariats sell their labor power, receive wages, and produce surplus value for the capitalists. Surplus value is the key to Marx's critique of capitalism. Profit (along with rent and interest) is derived from unpaid surplus labor performed by the proletariat for the capitalist. It is value accumulated beyond the costs of raw materials and machinery (constant capital) and wages (variable capital). It is capital, not particular capitalists, that is responsible for constantly expanding wealth and markets.

The industrial revolution and capitalism developed alongside one another. Industrial manufacturing relies on cheap, available, unskilled labor and thus depends upon the division of labor (i.e. the commodification of labor) for its success. The transformation of labor into a commodity, in turn, presupposes a complex network of social, political and technological preconditions including the availability of machinery for factory manufacturing, a reliable supply of labor, the legal sanction for private ownership of the means of production, the social sanction for wage labor, and so on. Early capitalism was geared toward the production of commodities, using commodified labor, mechanical technical production apparatus, oriented to the production of surplus value.

Technological innovations, while not the cause of the development of eighteenth-century capitalism, were, along with various social and political conditions, essential to its creation and subsequent success.

The so-called "second industrial revolution" occurred near the end of the nineteenth-century, and further transformed the economies of Europe, the Americas and much of the world. Important developments of this time include the internal combustion engine, which led to the automobile, motorcycle, boats, pumps, machinery and factories; steel-making improved to make large quantities available inexpensively; innovations in the chemical industry and chemical engineering led to developments in the production of sulfuric acid, sodium bicarbonate, ammonium, and nitrogen compounds, including explosives and fertilizers; advances in petroleum-processing and -drilling led to the production of fuels, lubricants and other petrochemicals; the development of the electricity industry led to the replacement of gas lighting, heating and industrial power; and communication technologies such as the telegraph, the telephone, the gramophone, the radio and the cinema further contributed to mass production and the formation of a mass society.

In addition to technological innovations, several developments in techniques of production developed alongside widespread social change. One such technique was "scientific management," popularized by Frederick Taylor's *The Principles of Scientific Management* (1911). Also known as "Taylorism," the aim of scientific management was to improve productive efficiency, maximize output and develop techniques to motivate employees. Taylor introduced practices such as management standardization, task specialization, work design and work method analysis, and stopwatch timing of production activities. Subsequent research in scientific management included studies of human motion and the principles of motion economy, rational-economic incentive schemes for workers, and personnel management and human resources development.

Another important technique of production was the development of assembly-line manufacturing processes. In the assembly line, interchangeable parts are assembled by several different individuals in an ordered, routinized fashion to create a product. The aim of assembly-line manufacturing is to produce more units, faster, in a more cost-effective way than if an entire product were fashioned by a single person. In 1913, Henry Ford designed automobile factories using assembly-line production and is widely credited with perfecting, if not inventing, the practice.

Early twentieth-century capitalism is sometimes known as "Fordism," an economic system that espoused the virtues of high productivity, high profits, inexpensive products and high wages that would enable workers to purchase what they produced. Fordism depended on automated, standardized industrial production geared toward a mass consumer market. using the assembly line with relatively high wages compared to other economic sectors. Fordism intensified the accumulation of capital by value and further entrenched the division of labor by deskilling workers and heightening capitalist control over the means of production.

## Monopoly and Welfare State Capitalism

In the late nineteenth and early twentieth century, the ownership of large-scale industries became increasingly concentrated into industrial trusts or monopolies. At the same time, banks and financiers assumed increasing control over the production process and began to serve the interests of speculators and financial interests rather than the needs of producers and consumers. Banking systems, equity markets and stock exchanges were established in Europe and the United States, further transforming the aim of capitalism from a system of production toward a means of accumulating profit. In response to the rise of monopolies and large-scale financiers, which undermined capitalist growth, and rendered the economy volatile and prone to recessions and depressions, were two important social–political developments: the rise of the labor movement, and increased government intervention in economic activities.

The factory system of production, in spite of its Fordist pretensions, tended to produce a large population of underpaid workers, typically working long hours in poor conditions. In response, various trade unions began to form through the early-to-mid-nineteenth century. By the end of the century, labor movements throughout the industrialized world began to demand improved working conditions and a working day no longer than eight hours. As strikes and boycotts became more common, governments were forced to intervene, often by supplying military force to break strikes, but just as often by mediating conflicts and offering arbitration. The labor movement led to reforms in labor laws, occupational safety, collective bargaining rights, elimination of child labor, a shortened working week, and other progressive legislation designed to improve the lives of workers. The rise of labor movements internationally, coupled with the challenge to capitalism posed by communism and democratic socialism, compelled governments to regulate capitalist economies in order to maintain economic and political stability.

Welfare capitalism refers to the practice that appeared in the United States from the 1880s to the 1920s that provided private, employer-based social welfare services to workers. Welfare capitalism was a response to the widespread worker discontent and social reform activists in an attempt to placate employees while resisting government regulation of markets and union organization. Employers began to provide such things as meal plans, recreational activities, language classes, religious services, as well as more meaningful services such as retirement benefits, healthcare, and housing. The most extensive welfare capitalist projects were the short-lived "company towns" where companies owned and provided for everything workers needed in order to live, including housing, food, medical care, recreation and other necessities of life.

The Great Depression of the 1930s revealed inherent limitations of welfare capitalism, which could not provide adequate social welfare protection to nearly enough workers. President Franklin D. Roosevelt's New Deal programs (1933–7) in the United States were designed to rescue the collapsed capitalist economy while providing a vast social welfare system for citizens. New Deal programs provided direct relief to workers and farmers in the form of labor, food, housing and loans; recovery to the fragile capitalist economy through an "emergency budget" to overcome the effects of the depression; and national reforms to stabilize the economy, set minimum wages, manage agricultural production, insure banks, and protect the rights of workers to organize. Rather than nationalize banks, railroads and other major industries, Roosevelt attempted to balance the interests of workers and capitalists in a concept of government known as "welfare state capitalism," in which the state plays a crucial role in protecting the stability of markets, facilitating capitalist accumulation, and ensuring the economic and social welfare of its citizens. President Lyndon B. Johnson further extended the role of the welfare state with his Great Society programs, which included education, medical care, transportation, civil rights, environmental protections and the arts.

The welfare state also supported research and development in science and technology. In the United States, the National Institutes of Health provided medical research; the US Atomic Energy Commission nuclear and particle physics research; the National Aeronautics and Space Administration space science and exploration; the National Science Foundation general scientific and engineering research; and the Defense Advanced Research Projects Agency provided defense research. These are just some among many publicly funded programs geared toward advancing the development of science and technology.

Welfare state capitalist governments exist throughout the world. Germany is generally believed to be the first welfare state; other welfare states developed during the early twentieth century as a capitalist compromise between communism and fascism. Western Europe, Scandinavia, Canada, Australia and New Zealand are noted for having more extensive welfare provisions than the United States.

## Technology and Late Capitalism

By the 1970s a crisis had emerged in the global capitalist system measured by a decline in the general rate of profit owing to an increase in oil prices, increased competition from Asian markets, and a decline in welfare state economic protections while supporting increased privatization of goods and services. Fordism was plagued by high raw material costs, high inventory costs, and factory systems of production that were slow to respond to changes in the market; circulation time and costs were as slow as the machinery they used; technological research and development was sacrificed under Fordism for short-term profit; consumers were reacting against mass-produced, standardized products; and the relationships among suppliers, engineers, producers and distributors were too poorly integrated to innovate as rapidly as the market demanded.

What evolved was an economic system, found in most industrialized countries today, known as "late capitalism." Also known as "post-Fordism," the current mode of production is based on the widespread use of information technologies, a "just in time" system of production and distribution of commodities (i.e. fewer raw materials, more partially assembled parts), the elimination of non-"value-adding" positions in production (i.e. management, quality control), mass customization tailored to meet more individualized consumer desires, the creation of "knowledge worker" jobs, and cooperation among and within firms. The current trend in production is toward smaller, more specialized markets, flexibility designed into production and distribution systems, and integrated clusters of specialized firms.

Advocates of this form of "lean production" claim that it will greatly improve capital–labor relations, capital–consumer relations, and eventually capitalism itself. Critics of lean production maintain that, although its technical and social conditions differ from those of Fordism, it does not differ substantially with respect to the basic character of capitalism, and thus fundamental antagonisms continue to exist between labor and capital, consumers are not appreciably more empowered, economic power is more (not less) asymmetrical between capital and consumers, and the connection between economic expansion and global justice is, for better or worse, the same as it was in the Fordist production era.

## 59

# The Politics of Gender and Technology

ELISABETH K. KELAN

Although technologies are a pervasive part of our everyday life, we rarely think about technology as gendered. If we look at toys for children alone, it is very evident that boys tend to get game consoles and remote-control cars while girls get dolls to play with. From an early age, we are confronted with subtle messages about which technologies are deemed appropriate for which gender. While men tend to be associated with technologies like spacecraft, fast cars and advanced computing, the technologies associated with women are things like kitchen tools, which often do not qualify as real technology at all. In this article this politics of gender and technology is discussed.

The area of gender and technology studies has been flourishing in recent years, and scholars have developed sophisticated approaches to understand better the gender–technology relation (Gill and Grint 1995; Wajcman 1991, 2004). These approaches start from the assumption that gender and technology are co-produced and mutually shaping. This means that technology influences gender relations and gender relations influence technology. The notion of co-production of gender and technology needs some unpacking. Faulkner (2001: 83) distinguishes between the gender *in* technology and the gender *of* technology. The latter refers to the symbolic association between gender and technology. Certain technologies are perceived as masculine in society, such as computing technology, fast cars, spacecraft or construction tools; whereas other technologies, like kitchen tools or beauty tools, are commonly associated with femininity.

How people enact and use these technologies often reflects these gender associations. Research has found that men working in high-tech environments who see themselves as technologically well versed also construct themselves as technologically incompetent when it comes to operating the microwave in the home (Massey 1996). Another example is the telephone. The telephone was initially marketed for use by businessmen (at that time almost exclusively men) to communicate with the office while at home. However, women quickly took over the telephone and made it their own. This has meant that now the telephone is strongly associated with femininity (Rakow 1988). This can be illustrated through research which has shown that men describe their use of the telephone as more task-oriented than the chatty use which is associated with women (Lohan 2001). Through the association with technology, gender is enacted.

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Gender *in* technology refers in contrast to how gender enters the design of technology. Looking back in time, it appears that most inventors of technologies were men. Developing technology is an endeavor largely undertaken by men. When designing technologies people bring their personal experience with them, and this flows into the design of technologies. These mechanisms may be very subtle, in that designers use themselves as the template for the ideal user, as happened in the design of a digital city in the Netherlands (Rommes et al. 2001). This implicitly excluded women, and few women participated in the Internet forum.

The perceived gender of the user of technology has influenced how technologies develop. Even though users can subvert technologies by using them in ways not originally intended, designers have considerable power in inscribing gender to technical artifacts. This has been called "gender scripts" (Rommes et al. 2001). The construction of the user is often very flexible. Research by Hofmann (1999) shows how, in the design of interfaces, secretaries are either constructed as able to learn shortcut keystrokes, or as unable to navigate independently, and are therefore provided with menus. Webster (1996) in turn has demonstrated how the image of the female user of office technology meant that the first generation of word processors was developed from office equipment rather than from computing. These examples show that gender is highly relevant when technologies are designed.

Research on gender and technology has, however, shown that not all designers and innovators are men, and recent feminist research has started to uncover women inventors who have not entered the history books or whose inventions are not associated with them. An example of this can be found in early computing. Some of the earliest computer programmers were women, which is partly because at this time programming was seen as a clerical task and not of high status (Perry and Gerber 1990). However, as soon as the importance of computer programming rose, the stereotypical programmer became more a man than a woman. The contribution of women like Ada Lovelance to computing is increasingly recognized after much work has gone into uncovering her contribution to the design and construction of early computers (Stanley 1993). One dimension of the politics of gender and technology is therefore to uncover women inventors of technology who have been forgotten by history.

That women inventors are often written out of history reflects gender relations, as women are not associated with technologies, and ground-breaking technologies are commonly associated with men. That computer programming has changed gender from being associated with women to becoming a male endeavor is important as it reflects that during that time the economic potential of computers rose and important things in society are commonly associated with men. Technology reflects gender; but gender also shapes technology, and this is an important process to study as it tells us something about power relations in society.

In recent times much debate has arisen about how gender is relevant in the information and knowledge society. There was much discussion about women lagging behind in elements like Internet use and participation. It was perceived as a problem that more men than women were "online," and it has been suggested that men dominate computer-mediated communication and are said to exclude women through using crude language (Herring 2000). However, in recent times the figures for Internet use in many Western countries are more gender-balanced (for the USA, Fallows 2005). This could mean that gender and technology in relation to new technologies is no longer a problem as equal participation is supposedly ensured in the West. However, this would mean neglecting that access is not the only issue but how technologies are used is equally important (Henwood et al. 2000).

The design and use of technology is still gendered. Research on gender and technology has, for instance, found that women in technical education and professions distance themselves from technology, while men construct a close relationship with technology (Corneliussen 2004; Henwood 1998). When engaging with technology, people are enacting gender because it is commonly assumed that men are close to technology while women are not. These gender relations seem to re-establish themselves even when women have chosen technical education and professions. This assumption that people are "doing gender" while engaging with technology links well with current gender theories. In current gender theories, gender is perceived as something that is "done" in interactions. This means that men and women engage in certain activities that are gendered masculine or feminine to count as proper men or women.

This perspective may explain why women do not enter technical professions which are associated with masculinity. Although in earlier times it was not allowed that women enter technical education, or board spaceships for that matter, today despite the few institutionalized barriers for women's entry women often select non-technical professions. This can be interpreted as a move to count as a proper woman who is not interested in technology. As we have seen, this continues even in technical education and professions when women distance themselves more from technology by defining it as not part of their identity. Women therefore are still under-represented in technical fields which commonly attract high status, prestige and remuneration. It thus perpetuates gender relations in which, in general, the masculine side is valued over the feminine side.

This raises the question which politics may be useful to challenge and change these gender and technology relationships. Seeing gender and technology as mutually shaping means that gender and technology are constantly in flux and can be redefined. This redefinition takes place through practicing gender in such a way that it counteracts and potentially subverts current gender expectations in relation to technology. For instance, that women use certain technologies or are present in certain technical professions which are gendered masculine challenges the hegemonic gender order.

It is often expected that the goals of a new politics of gender and technology is to make men and women more alike and eliminate gender differences through this. However, the issue appears to be to open equal opportunities for men and women by allowing them to enact divergent relationships with technology. Rather than making women more like men or vice versa, one possible avenue for change would be to allow for multiple differences and similarities. This means to accept that men and women are not homogenous groups, but that there are differences between and among men and women. Individuals should be given the choice to enact different positions such as enjoying this technology or not, but these may not have to be linked to gender. It would then be possible to interrogate critically the gender–technology relationship and to seek ways to develop an alternative politics.

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# 60

# European Politics, Economy and Technology

## ERIK JONES

Technology plays an ambivalent role in European politics and economics. It is a source of modernity and progress but it is also a threat to tradition and to equality. Europeans celebrate the influence of technology on economic competitiveness and express concern about its impact on environmental sustainability. Technology has shaped the development of European political ideology, and it has threatened to undermine the legitimacy and overwhelm the capacity of the European nation-state.

Modern Europe is born of the technological advances which constitute the industrial revolution. The spread of industrial technology changed fundamentally the structure of the European economy and society in which it was embedded. New factories drew Europeans from the land into the city even as improvements in travel, communication and sanitation facilitated a gradual expansion of urban areas to match the new urban population. While dramatic and unprecedented, the transformation of Europe was less shocking perhaps than the impact of the industrial revolution elsewhere. The industrial revolution was grounded in Europe, and so Europe's economic and political transformation moved at the pace of technological change. This pace was revolutionary at the time and yet contrasts sharply with the sudden introduction of "industrialization" outside Europe and the consequent urban explosion experienced by the developing world today.

Even within Europe, the influence and timing of technological innovation was not everywhere the same. Moreover, the consequences of this differential development were historically important, as is clear in the writings of Alexander Gerschenkron. Gerschenkron argued that there were economic advantages to "backwardness," as later-developing countries benefit from the adoption of technological innovations made by early-industrializing nations. Moreover, the late developers can leap ahead by avoiding failed developmental trajectories and by investing in the most advanced productive machinery. This model explains not only the belated surge of Germany as an industrial power in the latter part of the nineteenth century but also the miraculous recovery of the German economy after the Second World War. By contrast, Great Britain, Europe's earliest and most established industrial country, experienced a relative decline in its Great Power rivalry with the German Empire in the late–nineteenth and early-twentieth centuries and a further relative decline during the first three decades after the Second World War.

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The link between technology and modernity in Europe was ideological as well as physical. The widespread adoption of Fordist manufacturing techniques in the early part of the twentieth century nurtured the rise of powerful trade unions, among both Christian Democrats and Social Democrats. In turn, these unions became deeply involved in the stabilization of macro-economic performance through concerted wage bargaining (usually at the national level) and in the development of the European welfare state. As a result, European conceptions of Christian and Social Democracy share a commitment to working-class solidarity both across society and over time. Such commitments go beyond rhetoric. Social solidarity can be seen in the wage compression across different categories of workers that results from nationally concerted bargaining. Solidarity over time is expressed on the Continent in terms of entitlements arising from the payment of social insurance premiums and in the United Kingdom in the willingness to finance welfare state benefits from general revenues.

The link between technology and modernity in Europe has not always been positive either in terms of ideological commitment or, more broadly, in terms of economic and social structure. The spread of mass manufacturing after the Second World War sparked a growth in consumption that dramatically increased standards of living and raised life expectations. At the same time, however, this consumerism whittled away at class distinctions – particularly those based on Marxist notions of relationship to the means of production. In turn, this weakened the political bonds holding voters to either Christian Democratic or Social Democratic political parties. The effects manifested in three different ways: through increasing competition between the traditional parties, through increased opportunities for new political movements to emerge, and through declining voter participation at election time. Traditional European political parties adapted by de-emphasizing their ideological appeals and instead focusing on issues and personalities. The results were only partly successful. While the major parties were able to stabilize their relative decline, they did so at the expense of longer-term voter identification and commitment.

The structural shift in economics was even more marked. A change in the industrial patterns from Fordist mass employment in mass manufacturing to a more capital-intensive and flexible "post-Fordist" paradigm presented European trade unions with two different challenges. The first was to adapt to the decline in the manufacturing share in employment relative to the public and service sectors of the economy. Since productivity is generally higher in manufacturing than in the public or service sectors, this relative decline in manufacturing employment created a rift between manufacturing employees who could demand higher wages and service-sector employees who could not. National trade unions that tried to put upward pressure on wages across both categories of workers soon found themselves in conflict with governments eager to hold down price inflation. Meanwhile, national trade unions that tried to maintain wage discipline faced defections from manufacturing unions and a loss of membership overall.

The second challenge for European trade unions presented by the shift from Fordist to post-Fordist manufacturing was to accommodate the increasingly differentiated nature of manufacturing work and the structural basis for manufacturing unemployment. Although European trade unions tried to maintain a commitment to worker solidarity, such commitment no longer translated easily into wage-bargaining claims even at the sectoral level let alone across the country as a whole. Instead, sectoral wage bargains gave way to wage drift as employers reclassified workers to reward highly productive individuals with implicit "efficiency" wages. The result was both to encourage wage differentiation (as opposed to wage compression) and to stimulate further investment in capital deepening and productivity growth. The number of manufacturing jobs declined even as manufacturing output continued to increase. European trade union membership and wage-bargaining coverage retreated as manufacturing technology continued to advance.

By the 1970s, Europeans began openly to question the merits of continued technological advance. Politicians expressed concern about the governability of their societies, employers complained about the militancy of the trade unions, labor leaders worried about the spread of structural unemployment, and economists began to debate the limits to growth. Development economists like Fritz Schumacher had particular influence in this context. Schumacher argued that economics should be recast "as if people mattered" and manufacturing should be based on "intermediate technologies" that treated material productivity as only one of many goals in manufacturing. Such claims resonated strongly within the nascent European environmentalist movement and played an important role in transforming that movement into political parties able to address a range of issues beyond environmental conservation.

The emergence of two new issues reinforced European ambivalence toward technology: the 1973 energy price shock and the introduction of intermediate-range nuclear weapons into the European theater of the Cold War. The energy price shock gave dramatic emphasis to concerns about the limits of growth, particularly as Europe is dependent upon imported hydrocarbons to meet its energy needs. Most European countries responded by promoting greater energy efficiency. In France, they also invested heavily in the development and expansion of civilian nuclear technology as an alternative energy resource. French promotion of nuclear energy was facilitated by the efforts made by previous governments to underscore the prestige advantages of France's independent nuclear deterrent. Other countries did not have this tradition for national grandeur or the aspiration to join the nuclear club, and so they resisted efforts to expand civilian nuclear use.

Resistance to nuclear technology increased dramatically once West Europeans discovered that the Soviet Union had installed intermediate-range SS-20 missiles in Central and Eastern Europe. These SS-20s threatened to undermine the delicate balance of East–West deterrence and so to trigger a destabilizing arms race in Europe. The North Atlantic Treaty Organization (NATO) responded with a double-track strategy of negotiating the withdrawal of the SS-20s and threatening to install a new generation of intermediate-range nuclear weapons in Western Europe should the negotiations fail. However, the success of this double-track strategy depended upon the willingness of two NATO allies – West Germany and Italy – to accept the installation of American intermediate-range nuclear weapons on their soil. Massive peace demonstrations broke out in opposition to this move both in the countries affected and across Europe as a whole. In turn, these anti-nuclear movements divided much of the European political left between those who were more concerned about traditional economic issues related to income and employment and those more focused on issues related to nuclear technology, the environment, and the limits to growth.

The division of the European left at the end of the 1970s coincided with a third phase in attitudes toward technology: moving from modernization, to conservation, to competition. The rise of Japan as a world-beating economy during the 1970s and early 1980s underscored the importance of technological innovation to European prosperity and employment. The jobs crisis was not just the result of manufacturing employers replacing workers with machines; it was also the consequence of low-cost and highly productive manufacturing competition from abroad. This new challenge could only be met through combined research and development. Hence European leaders – spurred by French president François Mitterrand – began efforts to promote greater "pre-competitive" research collaboration across European countries prior to a more general re-launching of the process of European integration. Mitterrand's argument was that national research efforts were no longer sufficient to achieve and maintain a competitive advantage in the global economy. Only combined European research efforts in a European single market would suffice.

This new attention to economic competitiveness did not resolve all of Europe's concerns about technology and yet it did pave the way for a re-prioritization of interests. Competitiveness through increased productivity is one issue where European manufacturing employers and trade unions could find common ground. Hence the 1980s saw a resurgence of concerted wage moderation in order to free up financial resources for productive investment. This trend was more pronounced in many of the smaller European countries than in the larger ones and it was also more evident on the Continent than in the United Kingdom (where wage moderation was enforced against the opposition of the trade unions).

As competitiveness became more important, other technological issues became less so. The progress of arms control in Europe both before and after the end of the Cold War sapped much of the concern for nuclear weapons. Meanwhile, European anxiety about the limits of growth softened to focus on broader notions of "sustainability," whether in reference to energy resources, the natural environment, or the welfare state. Concern for sustainability waxed with the growth of evidence about the effects of global warming and yet it never eclipsed the importance of technology for economic competitiveness in Europe. If anything, the revolution in information and communications technology and the resurgence of American competitiveness in the 1990s only reinforced the need for combined European investment in research.

Yet sustainability did not disappear as a focus for attention, either. Instead, the fusion of competitiveness and sustainability lies at the center of Europe's current consensus on technology – at least in broad economic and political terms. It can be found in the 1993 European Commission White Paper on Jobs, Growth, Competitiveness, and it is manifest in the March 2000 commitment at the Lisbon European Council summit to focus the energies of the European Union on building the world's most competitive and dynamic knowledge-based economy within the first decade of the twenty-first century.

The European Union is far from achieving the strategic objective it announced in Lisbon. In part this is due to the weakness of Europe's traditional political parties as they try to implement necessary market structural reforms. Although Europeans may have adapted their priorities in light of changes in technology, they have been slower to adapt their political structures. European democracy was institutionalized in the early days of the industrial revolution and consolidated in the age of widespread Fordist manufacturing. As a result, it is ill-suited to the requirements for dynamic flexibility of the information age. Political processes are too slow to hold on to the popular attention, and political parties are too weak, both organizationally and financially, to bring about any radical restructuring.

The gap between the technology that predominates in economics and institutions that frame European politics is growing and not shrinking. Even worse, the tension between technology and politics is slowing down the pace of technological adaptation elsewhere. This tension can be seen in the "digital divide" between those who have unfettered access to the information and resources made available via the Internet and those who do not. It is manifest in the sudden emergence and implosion of political movements like that surrounding the Dutch populist Pim Fortuyn. It is apparent in the widespread concerns arising about the permeability of national borders to foreign migrants. And it is underscored by the extreme difficulty of providing security in the context of a global war on terror.

The challenge Europeans face is to adapt political institutions in order to ensure that issues like those related to income distribution, political participation, migration and security can be properly managed. This challenge is both facilitated and complicated by the emergence of new technologies. Nevertheless, it is not a problem of technology itself. Europe's challenge goes beyond either sustainability or competitiveness to touch on the core legitimacy of the European national state. Technology's role in European politics and economics remains ambivalent.

# 61

# Asian Politics, Economy and Technology

KEEKOK LEE

## Introduction

"Asian," in this essay, refers primarily to China and India,[1] as Japan, since its regeneration after the end of the Second World War, counts as an honorary "Western" nation, a mature, developed economy with democratic politics. Furthermore, Japan's systematic transformation from agrarian feudalism to become a modern society and economy has a history of at least 150 years, beginning with the Meiji Restoration around 1868. By contrast, China and India, in spite of their very different histories, may be said only recently to be systematically en route to transforming themselves from an agriculture/peasant-based society/economy to become industrialized economies.[2] Each country has more than a billion people; between them, they are responsible for a third of the world's population.

## Recent History and Politics

India achieved independence with the withdrawal of the British Raj in 1947. China defeated the Japanese in the Second World War but was immediately engulfed in the last stages of a long-drawn-out civil war, ending with the retreat of the Kuomintang to Taiwan and the establishment of the People's Republic of China by the Chinese Communist Party led by Mao Zedong in 1949.

India is said to be the world's largest democracy and is celebrated as such by the Western press, although its democracy as well as its human rights record may be flawed in many aspects. In contrast, China is said to be the world's largest authoritarian as well as totalitarian state, and is often vilified as such.

Both countries may be said to have been scarred by their respective histories before independence. Some Indian elites resent(ed) having been colonized for two hundred years; however, the resentment could be said to be relatively muted, compared with that of their Chinese counterpart; the British Raj has left them a lasting legacy, the English language. The Chinese – elite or ordinary – felt and still feel humiliated by the unequal treaties entailing the loss of sovereignty during the period of the Opium Wars, the first of which was signed in 1842, the annexation of Chinese territory by Japan

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and other Western powers at the end of the First Sino-Japanese War in 1894–5, and then the invasion and formal occupation of northern and even parts of central China by Japan during the Second Sino-Japanese War (1937–41). Furthermore, many leading members of the Indian ruling élite – from Jawaharlal Nehru, to Indira Gandhi, to the present prime minister, Dr Manmohan Singh, are all Oxbridge-educated, whereas the Chinese ruling class, to a man or woman, are primarily home-educated products (Mao himself had never seen the need to leave China, unlike some of his colleagues who went for short, limited periods to study or work in foreign countries, such as Japan and Europe); hence so-called Western – political and economic – values, viewed as a package (colonialism, militarism, exploitation, capitalism, democracy, freedom) are perceived with far greater suspicion than in India, especially when the Chinese consider/considered their civilization/culture to be superior, as evidenced by the name "China," which means "the country at the center" of the world.

## The West: Politics, Economy and Technology

There is a commonly held simplistic view of the modern history of the West (Western Europe) that the triad of democratic politics, free-market capitalism and science-driven high technology went inextricably hand in hand. This is not the place to examine this thesis in depth. Suffice it to make the following brief observations: modern science may be said to have begun in seventeenth-century Europe, but it took two centuries at least before the fundamental discoveries of physics and chemistry induced what today we call high tech. Before that, far from science leading and invention following, inventions were autonomous of science; and, in one spectacular instance, it was the invention of the steam engine which led to the fundamental science of thermodynamics. Industrialization took off in Europe, on the whole, without the benefits of modern basic science and its application to industry. The first industrial revolution – water–wind–wood complex – rested on what may be called craft-based technology and inventions which found their way to Europe, in many instances, from China, via the Middle East. The second industrial revolution – steam–coal–iron complex – was similarly based. Science-led/-induced high tech did not make an appearance till the 1840s.[3]

The history of capitalism is as complex as that of technology. In brief, finance capitalism began as early as the Italian city states during the Renaissance which had nothing to do with the rise of Protestantism, Weber notwithstanding. *Laissez-faire* capitalism was/is, in any case, more associated with the Anglo-Saxon world than with continental Europe, especially France which has a strong tradition of *étatisme*.

The beginnings of mass democracy in the UK only occurred with the Reform Act of 1832, and full adult suffrage was not available until women were given the vote in 1928 – and, in Switzerland, only in 1971.

In other words, historically, capitalism in its various forms in the West needed neither science-induced technology nor democracy (universal adult suffrage), nor what we, today, call human rights to develop and flourish. Modern science in Western Europe began in the seventeenth century, a period not noted either for human rights or for democracy, while applied science leading to high tech, as already observed, did not take off till the mid-nineteenth century.

## Nationalism, Modernization and Westernization

The briefest historical outline of the various complex thematic developments given above shows that it would be imprudent to understand "Westernization" to mean that China (if not India) would be happy to buy "off the peg" Western political, economic and cultural values without further scrutiny. The case of China parallels that of nineteenth-century Japan – the Meiji reforms were not about Western values *per se*, but about modernization, that is, the attempt to restructure the feudal/agrarian organization of society based on the warrior *samurai* class to one which emphasized economic growth, industrialism and military power, this time resting not on the traditional sword but high tech. In this limited sense only, "Westernization" may be said to equal "modernization," how to bring one's country up to the economic strength of the West, so that it may be able to compete with the West on more or less equal terms and, therefore, to be respected by Western powers. In other words, modernization goes hand in hand with nationalism – in this project, India is as nationalistic as China, although it remains true that their respective nationalisms assume different aspects given the differences in their histories.

The intellectual debate about modernization in the context of nationalism in China as well as attempts at modernization began in the nineteenth and continued into the twentieth century, although the project was much interrupted, first by the Japanese and Western occupation of parts of China, and then later by the next wave of Japanese conquest which constituted the Second Sino-Japanese War, after the so-called "Lugouqiao (Marco Polo Bridge)" Incident, in 1937 to be followed in 1941 by China's formal entry into the Second World War after the Japanese bombing of Pearl Harbor. In 1949, the project was resumed in earnest, first by following the route of state capitalism (the command economy) and then, after the death of Mao, by the economic reforms associated with Deng Xiaoping.

Chinese intellectuals considered/consider modern science and its technology, though initiated by the West, as institutions and values which are detachable from the usually conceived package of "Western values" said to consist of mass democracy with its associated freedoms to form at least two political parties of more or less equal political/economic strength, to vote (intermittently) for them, to have some freedom in the media to express disagreements and criticisms of government policies, etc. In such an analysis, Western countries grow strong and powerful, economically as well as militarily, primarily through the discoveries of basic science and their induced technologies. It follows that one can follow the scientific/technological path in pursuit of modernization without necessarily jeopardizing more traditional cultural values – in the nineteenth century, the Japanese did just that and were successful. The intellectual debate which began during the late Qing Dynasty (1644–1911) threw up a "couplet" elegantly expressed in the traditional four-word format which sums up this spirit of development and modernization in the context of nationalism: *gu wei jin yong; yang wei zhong yong*, which freely translated means "Ancient knowledge/wisdom to serve contemporary interests; Western knowledge to serve China's interests." This expression was made popular when Mao adopted it and it became one of the much-cited slogans during the Cultural Revolution (1966–76); it remains abiding currency.

From such a perspective, the economic reforms of the last twenty-five years are less of a rupture from what has preceded than might appear at first sight. The first stage of modernization and development, which began with the establishment of the People's Republic of China, rested, by and large, on the command economy, a form of capitalism pioneered by the West in the form of the Soviet Union, and using in the main the high tech also developed by the Soviet Union. However, simultaneously, it also encouraged low-tech, labor-intensive activities. This stage paved the way for the next, when China outgrew the command economy/labor-intensive-low-tech model, and opted not so much for the *laissez-faire* free market/private enterprise model associated with the Anglo-Saxon economies as for the *dirigisme/étatisme* of the European continental model, in particular the French. This more recent borrowing is also in keeping with the spirit of the axiom cited above, to use Western tools, modifying them whenever and wherever necessary, in order to serve and promote Chinese needs and interests. To date, the Chinese government has seen no need to borrow the Western notion of mass democracy and some of its associated ideas to serve Chinese needs and interests (as perceived, at least, by the ruling elites). Whether it would ever do so remains the $64,000 question; Chinese intellectuals are busy trying to revamp traditional cultural, social, political ideas to cope with the China of the twenty-first century. Whether and how they will succeed is one of the most fascinating issues of this new century.

In India, Mohandas Gandhi formulated an alternative to the standard development route. However, India, after independence, did not follow that philosophy; instead, it pursued what may be called the Fabian socialist route, implementing import substitution, central planning with strict control of the private sector of the economy, foreign trade and foreign direct investment. The government, like the Chinese one during roughly the same epoch, pursued simultaneously capital-intensive/high-tech as well as subsidizing labor-intensive/low-tech (although the latter was on a limited scale, almost only as a token gesture to the Gandhian philosophy perhaps). However, by 1990, the economy was perceived to be in crisis, which led to a series of reforms centered on liberalization (the removal of regulatory constraints), privatization (reducing the roles of the State and the public sector in business) and globalization (facilitating the expansion and penetration of multinational corporations).

From the brief sketch above, it appears that China and India, in spite of obvious differences, have pursued broadly the same economic paths in transforming their respective countries from an agrarian to a more industrialized society and, as a result, are facing roughly the same kind of social problems, namely, an increase of inequality between the industrialized/urban parts and the non-industrialized/rural parts during a period of high economic growth. Both countries are well aware that this set of issues has to be addressed; the Chinese government in its recent five-year preview has explicitly set out certain remedial policies.

In the last fifteen years or so, India, capitalizing on its heritage of the English language, has chosen to enter the globalized market mainly via the service sector, welcoming the electronic outsourcing of Western enterprises to Bangalore and other centers of electronic excellence in the country. China, on the other hand, has opted to go down the manufacturing route, to become once again the so-called manufacturing center of the world, a position it had occupied for centuries until Britain (followed by other Western countries) began its second industrial revolution in the nineteenth century.

Like all developing economies in recent years (South Korea, Taiwan), China has climbed the ladder by concentrating in the first instance on cheap, low-quality products; but, as more recent experience shows, it is capable of learning fast and of manufacturing high-quality goods which rely not merely on its low labor costs but also on its grasp and implementation of high tech. (This same tendency also obtains in India.) Indeed, foreign firms wishing to invest in China must be prepared to do deals with the Chinese government regarding (cutting-edge) technology transfer; without willingness to enter into such agreements, the billion customers awaiting the foreign investor would forever elude them. It would be wise for them to bear in mind that the strategy the Chinese deploy is what one Chinese scholar, Li Yining, at Beijing University, has called *yi shichang huan jishu* – using the market as an exchange for technology.[4]

## Conclusion

The case of China shows clearly that "Westernization" at most equals "modernization" but always within the context of nationalism. Science and its technology are perceived to be detachable from the rest of the package of Western values/culture, including mass democracy and its associated practices. From this perspective, it would be naïve to imagine that China would simply unfold in the way that Marx has ordained, namely, that the superstructure would change in accordance with changes in the economic base. However, this should not be interpreted to mean that China would not necessarily, in the longer term, evolve to accommodate certain selected political/cultural features from the West; the direction and pace of such evolution would not be at the behest of the West (unless the West were, unwisely, to choose to impose them directly on China) but only in a way in which foreign values can be comfortably domesticated or "sinicized." China has a long history of such domestication and sinicization – witness, the absorption of Buddhist values into Chinese – Confucian and Daoist – culture and civilization. The long-standing intellectual debate involving the contest between *ti* (referring to the political and economic systems in this instance) and *yong* (referring to any useful knowledge, especially high-tech) continues apace today within a context whose spirit may be summed up by the outlook: Chinese learning as essence, Western learning as utility.[5] In this respect, India differs profoundly from China, as India, by virtue of its recent colonial past, has formally embraced democracy, and, as a result, its on-going debate (amongst its intellectuals) about this aspect of societal values differs somewhat from that of their Chinese counterparts.

## Notes

1. Some recent writings of interest are: James McGregor, *One Billion Customers: Lessons from the Front Lines of Doing Business in China* (London: Nicholas Brealey Publishing, 2005); Amartya Sen, *The Argumentative Indian: Writings on Indian History, Culture and Identity* (London: Allen Lane, 2005), chs 8 and 9; Pankaj Mishra, "The Western View of the Rise of India and China Is a Self-Affirming Fiction" http://www.guardian.co.uk/china/story/0,,1794502,00.html [published 10/06/06; accessed 10/07/06]

2. India did have thriving cottage industries such as in cotton which were, however, destroyed by the British Raj. Before the Opium Wars, China did have thriving commerce in Hong Kong, which then migrated to Shanghai (when Hong Kong was ceded to Britain) – as a result, Shanghai grew and developed to be the commercial and industrial center of China, until foreign invasions/occupations, wars and then civil war interrupted its growth and development.
3. For details, see Keekok Lee, *Philosophy and Revolutions in Genetics: Deep Science and Deep Technology* (Basingstoke: Palgrave Macmillan, 2005).
4. See Tan Chung, "China under the Impact of Modern Civilization," http://ignca.nic.in/cd_05006.htm [accessed 07/2006]
5. See also Li Hongtu, "China's Modernization: A Historical Survey," http://w1.ens-Ish.fr/colloques/chine2004/china_modernization.pdg http://66.102.9.104/search?q=cache:MQ663mRNGUUJ:w1.ens-lsh.fr/colloques/chine2004/china_modernization.pdf+Modernization+and+China&hl=en&gl=uk&ct=clnk&cd=7 [accessed 07/2006]

# 62

# US Politics, Economy and Technology

DAVID M. HART

Technological change is a social process. Individuals who are the agents of such change are generally embedded in organizations, which are themselves structured by institutions, which are in turn embedded in cultural systems of meaning and value. Together, these layers of governance regulate the pace of technological change and determine its direction. The layers interact continuously, usually reinforcing one another, thereby producing characteristic paths of development at the national level.

In the American context, governance in this broad sense conspires to foster relatively rapid and occasionally radical technological change. American culture tends to be accepting of new technologies and is often enthusiastic about them. These cultural biases and their expression in law and in public policy support what Nathan Rosenberg calls "economic experimentation,"[1] a diversity of private efforts to combine and recombine technological systems with organizational schemes for producing and exchanging new goods and services. The market generally decides which of these "experiments" deserve to be continued and which are to be relegated to the dustbin.

Until the twentieth century, the US federal government did little more than passively countenance this dollar-based process of generating and selecting new technologies. Since the country attained Great Power status, and especially since the Second World War, when it assumed a dominant role in the international system, the government has increasingly added to the diversity of experimentation and accelerated the pace of change. Exceptional cases notwithstanding, there are few signs that this acceleration has bumped up against cultural, political or economic limits in the early twenty-first century.

## American Liberalism

The US is at root a liberal society. Americans tend to value the individual over the collective interest and to privilege negative freedom over positive freedom – "freedom from," as Isaiah Berlin would have it, over "freedom to." Premodern status distinctions eroded more quickly in the US than in Europe and other European colonies; political rights and entrepreneurship trumped aristocracy and guild.

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To be sure, these ideals were often abridged, nowhere more so than in the slave-holding South of the pre-Civil War era. None the less, in the context of abundant natural resources and a shortage of labor, they helped to animate a relatively high level of popular engagement in what the patent clause of the US Constitution labeled the "useful arts." "The annals of American invention," writes B. Zorina Khan of the nineteenth century, "were not limited to the wealthy, corporate entities, or other privileged classes, but reflected a broad spectrum of society."[2]

The objective of such invention was usually to get rich quick. Machines that could do something new or better than before provided platforms for enterprises that could bank on a taste for novelty among buyers. As the pace of immigration quickened after the Civil War, newly arrived Americans reinforced the receiving culture's openness to novelty, shedding their traditional ways and adopting with alacrity the means supplied by the emerging mass-production sector.

The giant corporations that arose in the late nineteenth and early twentieth centuries to feed this mass market aroused some misgivings among Americans. Populists and Progressives gave voice to concerns about the destruction of traditions, livelihoods, and places like John Muir's beloved Hetch Hetchy Valley, near the present-day Yosemite National Park. Yet it was not the technologies *per se* that bore the brunt of these attacks, but rather the firms that produced them. Indeed, the short-lived Technocracy movement of the early 1930s revealed a deep-seated suspicion that big business was suppressing technological change and that solutions to the nation's problems could be found by unleashing it.

The technological enthusiasm of the Jazz Age of the 1920s, with its radios and automobiles, found expression once again in the post-Second World War consumer culture. For all the irony of "plastics," as whispered in the ear of "The Graduate" in the movie of that name, American consumers continued to find the pull of the new irresistible. The popular culture of technological production was renewed as well in the postwar period, especially with the appearance of hackers like the Homebrew Computer Club, which gestated the idea of the personal computer in the late 1970s in Silicon Valley.

Hacker culture came into full flower during the boom of the late 1990s, reinterpreting the American liberal creed once again. "Cyberlibertarians" construed the Internet as a new frontier for the imagination that was ungovernable not simply in practice but in principle as well. Even property rights, the collective capacity on which individual effort is based in Lockean theory, presented problems for some of them. Although the juxtaposition of extreme anti-statism and unbridled technological freedom of cyberlibertarianism never won over mainstream America, it distilled powerful tendencies that have always been latent within American society.

## The Constitutional System

The institutional framework that nurtured the liberal culture and its zeal for the new – and which was in turn reinforced by that culture – was set in place by the Constitution. The founders of the US polity divided governmental power horizontally and vertically, and diluted it by establishing individual rights against the State. These constraints on the federal government fostered political and economic competition that was often expressed in technological form.

The states within the Union competed for business from the start, subsidizing turnpikes and canals and, before long, steamboats and railroads. The federal government was precluded from investing in such "internal improvements" in the antebellum period. For instance, although Congress briefly supported Samuel Morse's research on the telegraph in the 1840s, it declined an opportunity to acquire and develop the finished invention. The lack of central direction and coordination made for chaos and duplication in the new technologies of transportation and communication, but also sped their deployment and diffusion as alternative approaches were tried out by entrepreneurs and their backers at the state level.

The Civil War removed some constraints on the federal government, as evidenced in 1862 by the beginnings of a unique partnership with the states to create "colleges for the benefit of agriculture and mechanic arts." Building on a tradition of widespread, locally governed public education, the "A&Ms" brought higher education to a broad stratum of the population. They also became valuable knowledge resources for local industries, engaging in targeted research as well as in education. Agricultural experiment stations, which were linked together and supported by the US Department of Agriculture, were joined at many public universities by state-funded engineering experiment stations.

The various "internal improvements" of the postbellum era knitted together the world's largest free-trade zone. This market stimulated private investments in productive capacity of unprecedented scale, along the way accelerating productivity growth in one manufacturing industry after another. The financial and legal instruments that evolved to enable and insure such risk-taking were in part products of competition within the federal system. Most notably, the generous laws of states like New Jersey and Delaware brought into being the private corporation as we know it. The long-term security and large-scale capital made possible by this institutional form enabled the creation of the corporate R&D laboratory, the hub of technological development in the early twentieth century.

The system of constrained and divided governmental power made it difficult for those harmed by technological change in the age of industrialization to get recompense, and pre-emptive action to head off such change was nearly unheard of. The courts were the primary venue for these kinds of claims, and they acted after the fact and slowly, if at all. Only at the end of the nineteenth century, after decades of political agitation, did Congress begin to create a federal administrative structure that even remotely resembled the ideal type of bureaucracy envisioned by Max Weber around the same time. The new agencies were frequently saddled with mixed promotional and regulatory missions, and proved vulnerable to "capture" by the industries that they oversaw.

Still, technologies to safeguard human health, public safety and the natural environment began to attract substantial public interest and support around the turn of the twentieth century. New communities of practice in such fields as public health and civil engineering explicitly aligned professional interest with the common good. These progressive engineers envisioned a society operating along scientific principles, reducing the "waste" (a word with diverse connotations) they saw as inherent in the market system that had dominated the century just past.

## Federal Patronage

Business in such a scientifically managed society would not be replaced by government, but would instead practice "self-governance" through the creation of a consensus that spanned the public and private sectors. The leading exponent of this view claimed the presidency in 1928. Unfortunately for President Herbert Hoover, the Great Depression derailed his attempt to implement such a vision. The New Deal state that emerged in its place under his successor, President Franklin D. Roosevelt, presumed tension, if not hostility, between business and government. And it shattered most of the remaining constraints on federal authority, carrying out programs of "internal improvement" in a variety of technological fields, such as rural electrification and soil conservation.

Although the New Deal drew many technical experts into public service, it was not as extensive or as focused on science and technology as cognate developments in Europe; the vast bulk of technological capability in the US remained outside the compass of the state. The Second World War changed that. Under Roosevelt's prodding and with the creative efforts of Hooverites like his science advisor Vannevar Bush, the US military moved from conservatism to a radical embrace of technology during the course of the war. Employing what pioneering science policy analyst Don K. Price later called "federalism by contract," the armed forces engaged the knowledge and skills of the country's most advanced firms and most prestigious universities.[3]

The Cold War that followed sustained these institutional innovations. Yet they did not amount to a "military–industrial complex" dominated by a "scientific–technological elite" that President Dwight D. Eisenhower spoke of with anxiety in his 1961 farewell address.[4] Military support for new technologies remained decentralized and pluralistic, not least because of the way that the Constitution divided power. The contractors favored by the new federal patrons included start-up firms as well as corporate giants. Technological know-how was widely diffused both for security reasons and because the liberal tradition seemed to demand it.

These policies, backed by a massive amount of federal spending, produced not only the "baroque arsenal"[5] of ICBMs (intercontinental ballistic missiles) and MIRVs (multiple independently targetable re-entry vehicles) but also the passenger jet, computer-controlled machine tools and, eventually, the Internet. Such civilian "spinoffs" from military R&D and the academic–venture-capital–entrepreneurship complex that they helped give rise to in places like Silicon Valley provided powerful impulses to the American high-technology economy in the postwar period.

Like their military counterparts, the main federal civilian science and technology agencies were born in the early Cold War, and they operated in a similar fashion with similar results. The National Institutes of Health (NIH) is paradigmatic in this regard. Opposition to federal patronage of biomedical research melted away during the Second World War, and by the 1950s the executive and legislative branches were competing to see which could propose a larger budget for this purpose. Meanwhile, individual members of Congress scrambled to build up research centers in their home districts. NIH's R&D spending stimulated rapid growth in the US pharmaceutical and medical device industries, spinning off the extraordinary new field of biotechnology in the 1970s and 1980s.

As in the late nineteenth century, technological change in the late-twentieth-century US was not without its critics. The "affluent society," as John Kenneth Galbraith characterized it,[6] provided them with more political resources and public support than their predecessors. In the 1960s and early 1970s, Congress responded to these "new social movements" with pioneering health, safety and environmental legislation that forced industry to adopt the "best available control technologies" and, in some cases, to develop new ones.

Nuclear power was the focal point of much of this criticism, and its diffusion was halted in the US in the late 1970s by public opposition and skyrocketing costs. But it would be a mistake to generalize from this unique case and this exceptional period to conclude – for better or for worse – that American institutions for governing new technologies had been transformed. Even as the Three Mile Island accident was putting the final nail in the nuclear coffin in 1979, recombinant DNA and the personal computer were capturing public enthusiasm, sparking entrepreneurship and spawning new millionaires.

## Looking Forward

Cross-national surveys conducted between 2000 and 2004 suggest that the US public continues to view science and technology more favorably than the European or Japanese publics. US government agencies, business, universities and charitable foundations continue to finance R&D at a record pace, still accounting for more than a third of the global total in 2000.[7] American policies and institutions that foster technology-based entrepreneurship are envied and emulated the world over. Even nuclear power is getting a new look, as policy-makers begin to explore the options for addressing climate change realistically.

Voices of dissent have become fainter in recent years, with one prominent exception. Christian fundamentalists have blocked federal funding for embryonic stem cell research, which they see as murder, for several years. Yet this success is quickly crumbling as other countries and even US states leap into the void. The liberal regime of international trade, investment and communication, of which the US has been the primary sponsor, has stripped from this country the power to control the pace and direction of technological change. To understand governance of technological change in the coming century, we shall need to understand culture, institutions, organizations and individual behavior on a global scale.

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# 63

# Energy, Technology and Geopolitics

JOHN R. FANCHI

Quality of life, energy supply, and the distribution of energy sources are important components of global politics. Geopolitics is the study of how the relationships between nations depend on geography, demography and economics. In this article, we discuss the relationship between energy, technology and geopolitics. This article is an extension of the discussion found in Huntington (1996) and Fanchi (2004, 2005).

Energy has had a significant impact on society. Deforestation in sixteenth-century England motivated the search for a new primary fuel: coal. The discovery that rock oil – as oil was called in the nineteenth century – could be used as an illuminant made rock oil a viable substitute for whale oil and reduced the need to hunt whales. The need for oil encouraged Japanese expansion throughout Asia in the 1930s and was one of the causes of the Second World War. The 1973 Arab–Israeli war led to the first oil crisis, with a short-term but significant increase in the price of oil. This oil price shock was followed by another in 1979 after the fall of the Shah of Iran. These oil price increases are considered shocks because they were large enough to cause a significant decline in global economic activity. Their global impact showed the interdependence of nations and the need to understand how nations interact.

The world has been undergoing a socio-political transition that began with the end of the Cold War and is continuing today. Huntington (1996) provided a view of this transition that helps clarify historical and current events, and provides a foundation for understanding the socio-political issues that affect energy demand.

Huntington argued that a paradigm shift was occurring in the geopolitical arena. A paradigm is a model that is realistic enough to help us make predictions and understand events, but not so realistic that it tends to confuse rather than clarify issues. A paradigm shift is a change in paradigm. Huntington identified four geopolitical models that let us order events and make general statements about reality. The models should help us understand causal relationships between events and communities. The communities can range in size from organizations to alliances of nations. Each geopolitical model should help us establish the importance of information in relation to the model, let us anticipate future developments, make predictions in some cases, and show us paths that might help us reach our goals.

The Cold War between the Soviet Union and the Western alliance led by the United States established a framework that allowed people to understand better the relationships

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**Table 63.1** Huntington's possible geopolitical paradigms

| | |
|---|---|
| 1 | One Unified World |
| 2 | Two Worlds (West versus non-West) |
| 3 | Anarchy (184+ nation-states) |
| 4 | Chaos |

between nations following the end of the Second World War in 1945. When the Cold War ended with the fall of the Berlin wall and the break-up of the Soviet Union in the late 1980s and the 1990s, it signaled the end of one paradigm and the need for a new paradigm. Several geopolitical models have been proposed. Huntington considered four possible paradigms for understanding the transition (Table 63.1).

The paradigms in Table 63.1 cover a wide range of geopolitical models. The One Unified World paradigm asserts that the end of the Cold War signaled the end of major conflicts and the beginning of a period of relative calm and stability. The Two Worlds paradigm views the world in an "us versus them" framework. The world was no longer divided by political ideology (democracy versus communism); it was divided by some other issue. Possible divisive issues include religion, rich versus poor (generally a North–South geographic division), and geographic access to natural resources (haves and have nots). The world could also be split into zones of peace and zones of turmoil. The third paradigm, Anarchy, views the world in terms of the interests of each nation, and considers the relationships between nations to be unconstrained. According to Huntington, these three paradigms – One Unified World, Two Worlds, and Anarchy – range from too simple (One Unified World) to too complex (Anarchy).

The Chaos paradigm says that post-Cold War nations are losing their relevance as new loyalties emerge. In a world in which information flows freely and quickly, people are forming allegiances based on shared traditions and value systems. The value systems are notably cultural and, on a more fundamental level, religious. The new allegiances are in many cases a rebirth of historical loyalties. New alliances are forming from the new allegiances and emerging as a small set of civilizations. The emerging civilizations are characterized by ancestry, language, religion and way of life. Table 63.2 presents some characteristics of major contemporary civilizations identified by Huntington. The existence of a distinct African civilization has been proposed by some scholars, but is not as widely accepted as the civilizations identified in the table.

The growth of multiculturalism in some states has established communities within those states that may not share the values and allegiances of the host state. A multicultural state in this context is a member state of one civilization that contains at least one relatively large group of people that is loyal to many of the values of a different civilization. For example, Spain is a member state of Western Civilization with a sizable Islamic population. After the collapse of the Soviet Union, some multicultural states (e.g. Yugoslavia and Czechoslovakia) that were once bound by strong central governments separated into smaller states with more homogeneous values.

Huntington considered the fourth paradigm, Chaos, to be the most accurate picture of current events and recent trends. He argued that the politics of the modern world

**Table 63.2** Huntington's major contemporary civilizations

| *Civilization* | *Comments* |
|---|---|
| Sinic | China and related cultures in Southeast Asia |
| Japanese | The distinct civilization that emerged from the Chinese civilization between 100 and 400 CE |
| Hindu | The peoples of the Indian subcontinent that share a Hindu heritage |
| Islamic | A civilization that originated in the Arabian peninsula and now includes subcultures in Arabia, Turkey, Persia and Malaysia |
| Western | A civilization centered around the northern Atlantic that has a European heritage and includes peoples in Europe, North America, Australia and New Zealand. |
| Orthodox | A civilization centered in Russia and distinguished from Western civilization by its cultural heritage, including limited exposure to Western experiences (such as the Renaissance, the Reformation and the Enlightenment) |
| Latin America | Peoples with a European and Roman Catholic heritage who have lived in authoritarian cultures in Mexico, Central America and South America |

can be best understood in terms of a model that considers relationships between the major contemporary civilizations shown in Table 63.2.

Each major civilization has at least one core state (Huntington 1996, ch. 7). France and Germany are core states in the European Union. The United States is a core state in Western Civilization. Russia and China are core states, perhaps the only core states, in Orthodox Civilization and Sinic Civilization respectively. Core states are sources of order within their civilizations. Stable relations between core states can help provide order between civilizations.

Within the context of the multi-civilization geopolitical model, the First World War and the Second World War began as civil wars in Western Civilization and engulfed other civilizations as the hostilities expanded. The two world wars in the twentieth century demonstrate that civilizations are not monolithic: states within civilizations may compete with each other. Indeed, the growth of multiculturalism and large migrant populations in some states is making it possible for states within a civilization to change their cultural identity as cultures within member states compete for dominance. The change in cultural identity can lead to a change in allegiance to a civilization.

The Cold War and the oil crises in the latter half of the twentieth century were conflicts between civilizations. Western Civilization has been the most powerful civilization for centuries, where power in this context refers to the ability to control and influence someone else's behavior. The trend in global politics is a decline in the political power of Western Civilization as other civilizations develop technologically and economically. Energy is a key factor in this model of global politics. This can be seen by analyzing the energy dependence and relative military strength of core states. For example, consider the relationship between Western and Islamic Civilizations.

Western Civilization is an importer of oil, and many states in Islamic Civilization are oil exporters. The result is the transfer of wealth from oil-importing states of Western

Civilization to oil-exporting states in Islamic Civilization. By contrast, the United States, a leading core state in Western Civilization, is the leading military power in the world with a large arsenal of nuclear weapons. Most core states in Islamic Civilization are relatively weak militarily and do not have nuclear weapons. The wealth being acquired by Islamic Civilization is being used to alter the balance of military power between Western Civilization and Islamic Civilization. Iran, a core state in Islamic Civilization, is using its oil wealth to improve its arsenal of conventional weapons and acquire nuclear technology from core states in other civilizations.

Ideological differences between civilizations can lead to a struggle for global influence between core states. The battlefields in this struggle can range from economic to ideological to military. The outcome of this struggle depends on energy.

Energy-importing states in one civilization rely on access to energy sources from energy-exporting states in other civilizations. If the relationship between energy-trading states is hostile, energy becomes a weapon in the struggle between civilizations. For example, the growth of non-Western civilizations, such as Sinic and Hindu Civilizations, has increased demand for a finite volume of oil. This increases the price of oil as a globally traded commodity and increases the flow of wealth between oil-importing civilizations and oil-exporting civilizations. Oil-importing nations may try to reduce their need for imported oil by finding energy substitutes or by conservation. The social acceptability of energy conservation varies widely around the world. In some countries, such as Germany, energy conservationists and environmentalists are a political force (the Green Party). In other countries, such as the United States, people may espouse conservation measures but be unwilling to participate in or pay for energy conservation practices, such as recycling or driving energy-efficient vehicles.

Energy production depends on the ability of energy producers to have access to natural resources. Access depends on the nature of relationships between civilizations with the technology to develop natural resources and civilizations with territorial jurisdiction over the natural resources. Much oil production technology was developed in Western Civilization and gave Western Civilization the energy it needed to become the most powerful civilization in the world. As Western Civilization consumed its supply of oil, it became reliant on other civilizations to provide it with the energy its states needed to maintain their oil-dependent economies. This dependence in times of stress between civilizations can lead to social turmoil and conflict between states that are members of different civilizations.

Energy is needed for quality of life, but it may also be a source of economic disparity and social stress between civilizations. The United Nations adopted a policy of sustainable development following a 1987 report prepared by the United Nations World Commission on Environment and Development under the leadership of chairwoman Gro Harlem Brundtland of Norway. The policy of sustainable development encourages society to meet its present needs while preserving the ability of future generations to meet their own needs (WCED 1987). We are living in the period of transition from energy being dominated by fossil fuels to an emerging energy mix. Some governments, especially in energy-importing nations, are encouraging or requiring the development of energy-conserving and alternative energy technologies.

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# Part VI

# Technology and Ethics

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# 64

# Technology and Ethics: Overview

## CARL MITCHAM AND KATINKA WAELBERS

Since the mid-twentieth century, technological change has increasingly led to public debate. Concerns have been raised about the legitimacy of nuclear deterrence, dangers of environmental pollution, informed consent in medicine, privacy and computing, the safety and desirability of genetic engineering, intellectual techno-property rights, and nanotechnological risks. Given the large and increasing number of these moral discussions, one could anticipate that any companion to the philosophy of technology would include analyses of a diversity of ethical issues. The twenty-three chapters included here, covering topics from agricultural ethics to water technology, confirm such expectation. New technologies, now affecting and affected by all aspects of the human lifeworld, open up and have become manifold opportunities for philosophical negotiation and critical reflection.

In the regionalized field of technology and ethics discussions, there are two distinct types of interactions. One focuses on the ethics of technical professionals, that is, the specialized ethical codes appropriate to physicians, engineers, computer scientists and the like. Critical reflection on how technological change influences such codes of conduct has become an increasingly prominent aspect of the ethics of technical professionals. Another focuses on how best to extend ethics in general from its traditional focus on human–human interactions to human–technology–world interactions, with the world including both humans and the non-human environment. Questions have also been raised about the possibility of specifically ethical dimensions to some human–artifact interactions, especially with artifacts that may be so complex or sophisticated as to acquire apparently human-like properties of intelligence or emotional responsiveness. A third and quite different interaction between technology and ethics has attempted to turn ethics itself into a technology. In the present overview, however, emphasis will be placed on general discussions, without meaning to deny the legitimacy and importance of professional technical ethics, human–artifact interactions, or efforts to create a technology of ethics.

There are nevertheless dangers in general ethical reflections, not just with regard to technology but in any moral assessment that too quickly interprets challenges in positive or negative terms – or even neutral ones. Any judgment deserves to be preceded by careful description. As the playwright Harold Pinter wrote, "To supply an explicit moral tag to an evolving and compulsive dramatic image [is] facile,

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impertinent, and dishonest" (Pinter 1998: 18). What the Nobel Prize-winning British author maintained with respect to his own plays applies equally well to dramatic unfoldings in the techno-lifeworld. As the essays collected here show, we are in the midst not only of major plot developments in the human condition but also of what might be called a relighting of the very world stage on which we "all play our parts." To give too quickly a determinate moral interpretation to this evolving and compulsive narrative would be facile, impertinent and dishonest. Indeed, philosophy must work to appreciate the enlightenments of history and the dramatic ideas being played out therein.

## 1. From Cultural Criticism to Cultural Lag

Two influential and related general descriptions of the new stage lighting in which we perforce assume our roles emerged in the late-nineteenth- and early-twentieth-century social sciences. In Europe, a key figure in the development of what became known as the cultural criticism of modern technics was Georg Simmel. As has been argued by José Luis Garcia (2005), Simmel's socio-philosophical study of money analyzed how what began as a simple enhancement of the means of exchange, through the monetizing of all exchanges, fundamentally altered socio-cultural life. This alteration, which Simmel identifies with the particular technical means known as money, applies even more to modern technics as a whole. The result of industrial production, mass consumerism, and "creative destruction" – to use Joseph Shumpeter's illuminating descriptor for the unification of the technical inventive and commercial impulses – nevertheless tempers any unqualified Enlightenment, liberal or socialist belief in progress. Technological progress appears to bring not only the goods of increased wealth, reduced physical labor and extended lifespan but also the more problematic, unintended and not easily controlled consequences of alienation, bureaucratization and intensified decision-making – not to mention environmental pollution and transformation. For Simmel, Max Weber, Walter Benjamin, Romano Guardini, Günter Anders and others, the combination was creating a new type of cultural life that appears incommensurable with all that has been known up to this point in human history and within which people thus struggled for moral orientation.

A related argument took more programmatic form in cultural lag theory, which can be found adumbrated in Marxist analyses of the need for a proletarian revolution to take full advantage of the liberating potential created by capitalism, but was given distinctly American formulation by sociologist William Fielding Ogburn and philosopher John Dewey. According to Ogburn (1922), social orders are constituted by semi-independent elements that normally reinforce one another, as when religion and science present compatible cosmologies or governments fund teaching respect for existing political arrangements. Maladjustment occurs when a cultural ecology experiences differential change in its elements such that disharmonies are introduced. Leading examples are associated with new inventions in material culture that no longer mesh easily with existing socio-cultural habits, which then require periods of sometimes difficult adjustment. One example of such technologically generated cultural lag (from Ogburn 1964) was the period during which the social institutions and customs of road-building and -use had to adapt to the increasing speed of automotive travel. Establishment of the US Food and Drug Administration (FDA) in the early part of the twentieth century provides another case; prior to the industrial processing of food and mass marketing of drugs, no governmental agency was necessary to supplement traditions of experience and personal assessment to inform patterns of use.

From the perspective of Dewey, cultural lag presents special challenges for democratic theory, which can easily fail to appreciate how the unity of the modern state depends on new transportation and communications technologies. As Dewey observed, "Political and legal forms have only piecemeal and haltingly, with great lag, accommodated themselves to the industrial transformation" (1927: 114). "Cultural lag" praise for and reliance on forms of schooling and freedom of the press that have been weakened or captured by special interests "is everywhere in evidence" (Dewey 1939: 48). Numerous other cases in which science and technology have outstripped the social, political or intellectual capacities of a culture have been documented by anthropological studies such as those collected by Edward H. Spicer (1952) and H. Russell Bernard and Pertti J. Pelto (1987).

One of the most pressing mid-twentieth-century examples was the advent of nuclear weapons, which presented an enormous leap in scientific knowledge and technological power prior to any political adjustments that would ensure wise or prudent use. As Albert Einstein put it, "The unleashed power of the atom has changed everything save our modes of thinking," thus calling for "a new type of thinking" – or, equally important, of acting. More generally, according to philosopher Hans Jonas, "Modern technology has introduced actions of such novel scale, objects, and consequences that the framework of former ethics can no longer contain them" (Jonas 1984: 6).

More positively, however, one can identify during the last half of the twentieth century in many Euro-American countries diverse pragmatic, institutional responses to techno-cultural imbalances. Recognition of the problem of environmental pollution, stimulated by publication of Rachel Carson's *Silent Spring* (1962), led to establishment of the Club of Rome (1968) – which produced an influential series of studies on the limits to growth (see Meadows et al. 1972 for the initial volume, and Simon 1981 for a vigorous response) – and the US Environmental Protection Agency (1970). Additionally, in the United States, the Congressional Office of Technology Assessment was created (1972–95) to "assist Congress with complex and highly technical issues that increasingly affect our society"; in Europe similar initiatives were both adopted and maintained, with the Dutch Rathenau Institute (1986–present) being one good case in point. In the 1980s, challenges associated with advancing biomedical technologies led to the development of Institutional Review Boards (IRBs) and Institutional Biosafety Committees (IBCs) to ensure the free and informed consent of human experimentation participants as well as the health and safety of those working in or affected by this expanding technological sector. Since the 1970s, professional ethics in science and engineering has also focused reflection on such issues. Finally, the funding of Ethical, Legal and Social Implications (ELSI) research as part of the Human Genome Project, and the development in Europe of new democratizing practices such as citizen participation projects (Netherlands) and consensus conferences (Denmark), witnessed creative efforts to bridge gaps between technological change and socio-cultural patterns of action and ideas.

Broadly speaking, much of the applied ethics movement – from environmental and bioethics to engineering, computer and nanoethics – can be interpreted as a response at the level of intellectual culture to technological changes in material culture. Post-1980, optimism about the ability of free markets to mediate adjustments can be read equally as an applied ethical–political theory about how to address cultural lag phenomena – an optimism that nevertheless deserves to be qualified, as much as the governmental response it seeks to replace, by the continuing emergence of problems associated with natural resource utilization, energy production and human-induced climate change.

Indeed, the sometimes ambiguous notion of cultural lag itself deserves to be qualified, in order to avoid assuming the primacy of technology. Is it not possible for intellectual culture to lead as well as follow material culture? Historical analyses of the rise of science and technology in Europe during the 1500s, such as Weber (1904) and Lynn White, Jr (1978) – as well as of the different trajectory of historical development in China (see, e.g., Needham 1954) – argue that ideas and ideals can be major influences on technological change. Thus it need not always be assumed that "lagging" aspects of culture must simply be altered in order to "catch up" with technology. When applied uncritically and interculturally, cultural lag theory can threaten to rationalize Eurocentric assumptions about "underdevelopment" and forced transfer of technology – in accord with the ideology of techo-economic development put forth by "point four" in President Harry Truman's 1949 inaugural address (see Truman 1949 and Sachs 1992).

To repeat: It may be intuitive that various aspects of culture change at differential rates. But this need not imply that one aspect (whether behavioral or intellectual) simply lags behind another or has failed to adjust to an inevitable or non-problematic change in material culture, as if there were no choice other than running to remain upright on the treadmill of technology. Futurist Alvin Toffler, for instance, has argued for recognition of a phenomenon he terms "future shock" or "the shattering stress and disorientation that we induce in individuals by subjecting them to too much change in too short a time" (1970: 4). Building off Ogburn's theory, Toffler suggests "there must be balance, not merely between rates of change in different sectors [of society], but between the pace of environmental change and the limited pace of human response" (1970: 5). Cultural lag theory can highlight the values of preserving proportionality, equilibrium and harmony (the right adjustment) among the parts of culture. For Toffler:

> The only way to maintain any semblance of equilibrium . . . will be to meet invention with invention – to design new personal and social change-regulators. Thus we need neither blind acceptance nor blind resistance, but an array of creative strategies for shaping, deflecting, accelerating, or decelerating change selectively.
>
> (1970: 331)

Achieving this selective change is no simple, technical issue of "catching up," but selective decision-making about what constitutes the good life and the ideal society. It may also happen that altered elements become interactive in some new and equally balanced way that awaits recognition.

## 2. Dramatic Tensions

On the stage lighted by technological change and its cultural concomitants there have emerged a number of not necessarily mutually exclusive dramatic ideas. Given their diversity, it is difficult to parse these ideas or to attach to them clear and distinct typological tags for tracking the emerging interactive narrative tensions. But consider enacting alternative responses to the following closely related questions: (*a*) To what extent do humans shape technological products or processes? (*b*) In what ways do technological products or processes shape human action and perception?

To the first question, responses run a gamut from beliefs that technologies are the free creations of humans to those emphasizing an inner logic or determination in technology. What might be called *voluntarism* argues that people freely create technological artifacts and see technological development as completely malleable. This, of course, tends to be a corollary to popular expressions of faith in creativity and innovation. By contrast, what is often called *determinism* sees technological development as following its own inner logic, with humans functioning as something like vehicles for its expression. Just as human beings are not free to think anything other than 2 + 2 = 4 (although they are, of course, free to *speak* otherwise), so they are not free to create a perpetual motion machine (however much they might *aspire* to do so). Such historical phenomena as repeated sequences of invention (stone ages always come before iron ages), multiple invention (the wheel) and simultaneous invention (the telephone, motion picture, and airplane were all independently invented at about the same time) suggest determinate patterns or autonomy to technological history.

To the second question, responses again spread out across a spectrum. What might be termed *substantivism* is the position that technological change strongly shapes or influences social, political or human affairs; all stone age cultures are basically the same, and, as technology globalizes, socio-cultural orders converge. By contrast, *instrumentalism* views artifacts as tools that can reflect and be used in many different ways by diversities of human lifeworlds; that Thomas Edison invented the telephone for business communications did not prohibit its subversive deployment for private talk. People shape their lives and cultures, then as individuals or groups incorporate and adapt technologies in whatever ways they choose – a perspective especially congenial with the research of Michel de Certeau (1980).

Combining these two spectra of ideas yields a two-axes matrix. One (the $x$-axis) would concern the extent to which humans shape technology; another (the $y$-axis) would focus on the extent to which technology shapes humans (Figure 64.1).

The better-known philosophical arguments have been in support of positions that fit most comfortably in quadrants II and III. Quadrant II involves a combined determinist interpretation of technological change and substantivist assessment of the influence of technology on society. The thought of Jacques Ellul, for instance, is typically interpreted as representative of this quadrant. Quadrant III, by contrast, involves some combination of a voluntarist interpretation of technological change and instrumentalist assessment of the influence of technology on society. Samuel Florman (1976), along with most engineers, not to mention most people, would place themselves in this quadrant.

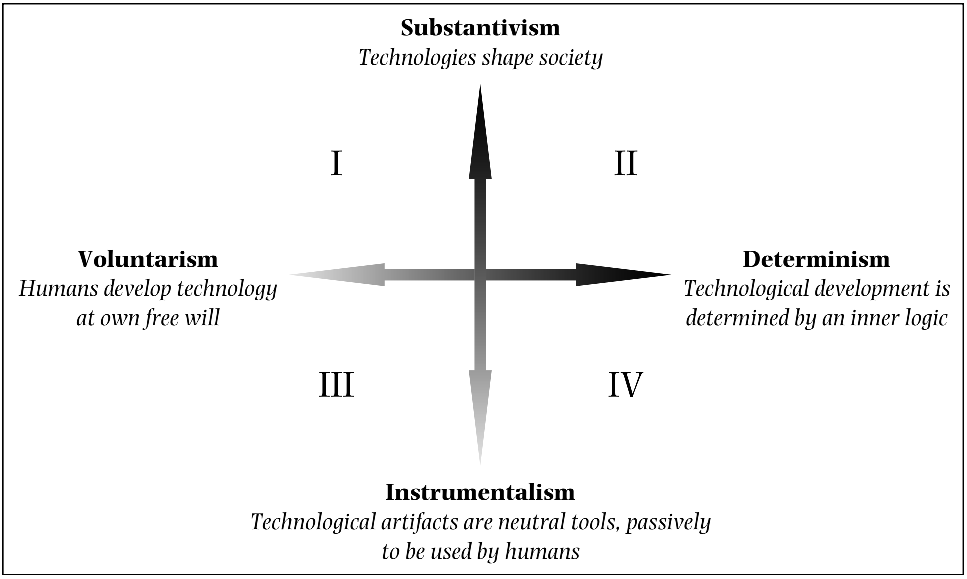

**Figure 64.1**

This does not mean that quadrants I and IV are empty. For instance, David Collingridge (1980) could be interpreted as representing the quadrant that combines a voluntarist position concerning the creation of technology but a substantivist position with regard to its societal influence, once created. What has become known as the "Collingridge dilemma" states that early in its development a new technology is quite malleable or subject to a free shaping by human beings, although, once created, the technology takes on a momentum and influence that can be difficult to alter. The construction of the interstate highway system in the United States is one example: there was considerable freedom in its initial design, but since being put in place it has strongly influenced landscape, commercial activities, and patterns of travel. Another philosopher who holds a similar position is Jonas, with his "contention that with certain [free] developments of our powers the nature of human action has [necessarily] changed," which "calls for a change in ethics as well" (Jonas 1984: 1).

As for the combination of determinism and instrumentalism, the thought of thinkers as diverse as Karl Jaspers, Donella Meadows and colleagues, Julian Simon and Nick Bostrom might serve to illustrate an idea that may initially seem anomalous. Jaspers, Meadows, Simon and Bostrom all argue that technology is a means that humans can use in many different ways, yet one that nevertheless exhibits a developmental logic all its own. For Jaspers (1949), the course of history manifests a degree of independence, but in its different stages and especially with the arrival of modern science and technology, most explicitly with the atomic bomb (Jaspers 1958), presents challenges to human freedom; in the present human beings must struggle to maintain *Technik als Mittel*, or technology as means. Meadows et al. (1972) and Simon (1981) both argue some degree of inevitability about techno-social progress, but divide radically on their interpretations of the human meaning and appropriate response. Bostrom (2005) argues for taking advantage of technological opportunities that have appeared for human self-transformation, to become transhumans.

Much ethics-relevant work in the interdisciplinary field of science, technology and society (STS) studies has nevertheless challenged the adequacy of one or more of the basic ideas constitutive of these quadrants. For instance, according to Ellul's adumbration of STS scholarship, analysis of the character of modern technology reveals it to be distinguished by such key features as automatism and self-augmentation. Technological decision-making exhibits a pursuit of efficiency such that when engineers see one technology as more efficient than another – that is, as increasing output relative to input, in relation to some context – their choice is determined; they automatically choose the more efficient technology. Moreover, what Ellul terms the technical system re-enforces itself in a quasi-determinist manner. New technologies often and unintentionally have consequences that only seem to call for the development of ever newer technologies. Examples are easy to find: classic industrial manufacturing technology caused environmental pollution, which then stimulated the development of clean-up technologies, medical treatment technologies to deal with health problems that arise, and new, less-polluting technologies. The extent and density of technological artifice seems only to increase. From industrial production to medicine to warfare, human activity becomes ever more technological and thereby to engender a technological milieu that replaces previous natural and social milieux.

What appears persuasive from one perspective has nevertheless been contested by another. Arguing the social construction of technology, subsequent STS scholars have described in detail how one technology does not always replace another simply because it is more efficient; technological adoption depends fundamentally on some degree of acceptance or appreciation by humans, be they engineers, marketers or consumers. Indeed, different groups of people are always redefining what counts as efficiency. According to one highly influential study of the historical development of the bicycle, for instance, its technical evolution was more a result of competition between social groups for how the bicycle was to be defined than the pursuit of anything that could be called the most efficient two-wheeled means of transportation (Bijker 1995). From this perspective, increases in the technological character of the human lifeworld are more the result of social commitments to technology than of any domination by technology. In the marketplace, some technologies succeed while others fail – but the reason choices keep being made between one technology and another rather than between more or less technology is simply that technologies themselves taken as a whole are socially desired.

At the same time, complementary STS studies have argued that technological development is not always as free as it may appear in the quasi-voluntarist accounts of social constructivism. Technological developments depend not just on the laws of nature but also on what have been identified as "orgware" and "hardware" (Smits and Leyten 1991). Orgware is constituted by the organizational and institutional conditions that influence the development and application of an invention, from engineering standards and governmental regulations to suppliers of materials, distributors and customers. Hardware is constituted by the physical technologies already invented, regulated, distributed and purchased. In sum, although efficiency may not determine everything, neither are the makers and users of technology as free as they might sometimes think.

Neither determinism nor voluntarism seems a fully adequate account of the complexities of the techno-lifeworld.

Related arguments have been brought to bear to question the substantivism-versus-instrumentalism divide. Substantivism appears to reify if not anthropomorphize technology. Instrumentalism is somewhat idealistic about the abilities of humans to understand what they are really making and doing. As an outgrowth of such contesting arguments, a number of theories have emerged that attempt to integrate or move beyond the particular insights of different quadrants.

## 3. Dramatic Theory

Ideational tensions in the ethics of technology, just like observations tensions in empirical science, are synthesized in dramatic theories; and, even though the dramas themselves are more rich than any theoretical models meant to capture them, the theories provide pathways to enhanced dramatic appreciation. Two major theorists of technology and ethics tensions who have also challenged the oppositions between the four quadrants defined by substantivism, determinism, instrumentalism and voluntarism are Langdon Winner and Bruno Latour. Given their influence across a wide variety of discussions, it is worth considering each in modest detail.

Winner aims to go beyond descriptions of making and using in order to "examine critically the nature and significance of artificial aids to human activity" (Winner 1983: 749). There is more involved with technology than commonly recognized in the ways inventors, engineers, operators, repair technicians and the like make and maintain artifacts that others can pick up, use and then set aside. For Winner, both voluntarist and instrumentalist views constitute a "technological somnambulism" in which we sleepwalk through and fail to recognize the extent to which technologies reshape human activity and its meanings. Adapting a term from Ludwig Wittgenstein, Winner argues that automobiles, electric lights and computers have become "forms of life" – creating a culture that is scarcely thinkable without them. Taking the example of television, Winner notes how "none of those who worked to perfect the technology . . . in its early years and few of those who brought television sets into their homes ever intended the device to be employed as the universal babysitter." Additionally, "if anyone in the 1930s had predicted people would eventually be watching seven hours of television each day, the forecast would have been laughed away as absurd" (Winner 1983: 257). But Winner is also critical of substantivism and determinism. Watching television is a choice, even when turning it off may not be as easy as instrumentalists customarily assert. Television is woven into the fabric of daily life with programs that are topics of office conversation and news sources and as the hearth around which household furniture is arranged. High-definition television was as much a creation of marketing, especially the marketing of sports programming, as of technical invention. Such observations invite consideration of what Carl Mitcham (2002), responding to arguments by Ivan Illich, has called technological asceticism.

With some nuance, Winner nevertheless observes how artifacts can "embody specific forms of power and authority" in at least two ways. In one, the invention, design or arrangement of a technology functions to enforce an often hidden political decision.

His example is bridges on a Long Island roadway that were made so low as to exclude the buses African Americans would most likely need to ride in order to access public beaches, thus effectively promoting segregation. (The particular example has been contested; but, even if some details are mistaken, the case well illustrates how artifacts can enforce political beliefs.) This case of what might be called a voluntary, instrumental substantivism is complemented by cases of what Winner calls "inherently political technologies" or technologies with a kind of existential influence. Assembly lines, for instance, demand that labor be broken down into simple, mind-numbing routines and require rigid workplace discipline; it is hard to imagine nuclear power not implicating authoritarian systems of control.

Winner's examples argue how social arrangements that precede artifacts can be reified in their design and how technologies can have their own social-ordering effects. In both cases, artifacts can be said to have politics. To cite another easily appreciated example, most stairs and curbs are serious obstacles for less mobile people. As Winner puts it, such artifacts are political in the sense that they have "power and authority in human associations as well as the activities that take place within those arrangements" (Winner 1980: 290). Such an argument falls between yet combines determinism, voluntarism, instrumentalism and substantivism. Yet Winner has provided little in the way of response, other than to call for more consciousness and public participation in the design and use of technologies.

Latour's development of actor network theory (ANT) can be read as another effort to provide a systematic framework for dealing with the kinds of issues to which Winner attends. Certainly it is the case that Latour strives to avoid "technological somnambulism" or deterministic pessimism – but in a way that, more dramatically than Winner, offers a new ontology of artifacts (or what he prefers to call an anthropology). Rather than seeking to steer a course between the Scylla and Charybdis of voluntarism-determinism and substantivism-instrumentalism, Latour rejects two basic assumptions shared by all four opposing positions.

Actor-network analysis focuses on the continuous reassembling of the social. In Latour's words, his concern is "how to resume the task of tracing associations" (Latour 2005: ch. 1). This concern devolves into two further questions, the first of which asks what is meant by associations. For Latour, technical and human associations cannot be distinguished from each other when it comes to their social or moral roles (Latour 2002). Both are agents, or what he prefers to term "actants," in so far as they both exhibit figuration (shape) and traceability (traces of making a difference). When it comes to figuration and traceability, the actions of humans and artifacts are associations that are themselves associated. In other words, Latour fundamentally (dis)solves arguments between voluntarism versus determinism and instrumentalism versus substantivism by simply denying the modernist presupposition that one can distinguish subjects and objects, and then argue about which influences the other to what extent.

A second question focuses on how to trace the trail of associations, and the continuous change of the social. Effective activity (that is, agency, whether of humans or of artifacts) is always found in a shifting network. Agencies continuously form, change and break off associations. Understanding the social role of anything requires appreciating how arrangements shift and interact. The presumption that the two axes of the matrix are separable (voluntarism-determinism versus instrumentalism-substantivism) is not tenable. There is no substantial distinction between technological and societal development. The trail of a technology changing shape is inextricably intertwined with the trail of societal change; social and technological evolution cannot be distinguished because the two are not distinct. Latour even denies the distinction between "making" and "using."

To summarize: Two arguments are central to ANT. First, a social role is granted to non-humans. The subject–object dichotomy is dissolved so that artifacts (and even natural objects) are conceived as agencies along with humans. Second, what is called the social never stabilizes, but is composed of associations that form, change, break off and re-form across time. The roles of different actants and the actants themselves are not fixed, but the network is a continuously co-evolving complexity.

## 4. Theory and Description

In actant-network theory, what are constitutive features of actant agency? As already noted, these are figuration and traceability – which neither singly nor together constitute autonomy, one of the foundations of modernist moral theory. Technological artifacts, just like people, become agents when they exist in a form that makes a difference in the existences and actions of others. To elaborate, Latour adapts an analysis from Marilyn Akrich (1992), who has argued that the designers of technical artifacts place in them *scripts* indicating their functions or uses. Engineers, inventors and others inscribe worldviews and thereby define actant artifacts with specific competences, motives, aspirations, political prejudices and more. But technical artifacts function like film scripts: they provide frameworks for interactions with other actants; they do not fully determine such actions. Like a piece of music or a drama, they require the interpretation of performance. When a technology is used or performed, it is also possible for de-scription to take place, with new associations between humans and non-humans leading to the emergence of new and often unpredictable agencies.

Artifacts and humans are described as co-shaping the social by means of multiple *mediations*: translation, composition, blackboxing and delegation. Mediation by translation occurs when a human actant, attempting to reach some end that it may lack – for instance, sufficient strength to achieve – utilizes another, often non-human, actant. But, when this detour toward an end takes place, the initial end of the original actant is changed by the involvement of the new actant, and both will reach their communal new goal instead of the first actant's original goal. In mediation by composition, many actions and actants are already the result of a collection of human and non-human actants. For instance, in the manufacturing of an automobile, multiple artifacts such as chassis, wheels and axles, engines, sheet metal, and more are combined. The development of these technologies (which are all actants) depends on multiple negotiations between different humans and non-humans.

Mediation by blackboxing is a process that makes the joint production of actants opaque. The acts of a driver (normally a human actant) are the result of the automobile, road construction, traffic laws, the behavior of other automobile compositions, and more. That a driver was in a hurry is an inadequate explanation for some act of speeding. Other users of the road can make speeding (im)possible, and so can the road and/or the car, all of which are typically placed in a mental black box, not to be considered. Being in a hurry is not even a necessary condition for speeding, since roads can be designed to keep traffic at a certain speed. In fact, the affordances designed into roads and many automobiles are scripts for speeding as defined by traffic laws. Finally, through the mediation of delegation, actants take on meanings in the sense that they produce special types of articulation that cross the boundaries between signs and things. Consider a comparison between a speed bump, a traffic sign and a police officer; the regulation of speed can be delegated from the policeman to a traffic sign or a speed bump.

Appreciating these four, interacting types of mediation introduces a shift in how action is perceived and described. The world comes to be seen as a constructed "concatenations of mediators" or as links of ever changing associations. Each point in the network represents an acting agent, like actors in a stage play or like puppets connected to their puppeteers. But there is no real author of the play. Nor is there a puppeteer who pulls the strings or a script that fully determines the play. The only scripts are the "programmes of action" of the different agencies (Latour 1994: 40). Action (or agency) "is distributed, variegated, multiple, dislocated and remains a puzzle for the analysts as well as for the actors" (Latour 2005: 60).

Summarizing again: In an actant network, the social role of technological artifacts is equivalent to that of humans. Relations between technologies and humans are comparable to relations between humans. Additionally, both humans and non-humans are agencies, but neither are autonomous agents. Actant agents act as they do as a result of associations with other agents, human and non-human. Human agents are not unique sources of action, but neither are non-human agents.

A brief but important aside: Although Latour is critical of modernism, he is not postmodernist. Postmodernism, on Latour's reading, seeks to deconstruct the modernist social project and argues against the possibility of formulating a theory of the social or of the technical. Social agency is not possible; and society and nature, if they exist at all, cannot be objectively understood or studied. Contrary to such postmodernist claims, the a-modernity of ANT "retraces the social and society by subtle changes in connecting non-social resources" (Latour 2005: 36). Within ANT, agency continues to exist but with new and different meanings.

Two other philosophers whose work intersects in critical ways with this new theory of descriptions, especially in so far as the descriptions contribute to advancing the regionalized field of technology and ethics, are Don Ihde and Peter-Paul Verbeek. Ihde's phenomenology of human-technology originated in primarily theoretical (instead of social theoretical) interests. Independent and in anticipation of Latour, Ihde thematized a set of human–technology–world mediations in which technology influenced not action but perceptions of world and self. In the two basic types of mediations, technology could be incorporated into the human or taken as part of the world. The former, symbolized by Ihde as "(human–technology)–world relations," with one example being the use of telescopes, constitute embodiment relations; the latter, symbolized as "human–(technology–world) relations," and illustrated by the thermometer, constitute hermeneutic relations. In embodiment mediations, a technology becomes a kind of extension of the body; in hermeneutic mediations, the technology has to be read or interpreted. Other mediations are constituted by alterity or otherness and background experiences of technology. But, more importantly, in embodiment and hermenutic mediations Ihde identifies an invariant amplification–reduction structure. The telescope amplifies perception of things at a distance while reducing the cone of vision; the thermometer amplifies accuracy of measurement while reducing sensory engagement with the world. All mediations, that is, are non-neutral in amplifying some experiences while reducing others.

Although Ihde does not develop the possibility, one could imagine an ethical argument for the pursuit of those technological amplifications in which reduction is itself minimized or exhibits a distinctly marginal character; in so far as amplification does not carry with it, human experience undergoes an unqualified enlargement. This would be analogous to efforts in risk–benefit analysis of technological actions to minimize risks while maximizing benefits. As a limit case, such amplifying technologies as eye glasses could become so integrated into body functioning that the (human–technology)–world relation would be better-represented as a technobody–world relation (eye glasses becoming contact lens "I-glasses") with humans as cyborgs (Haraway 1985).

Both Latour and Ihde are on record as seeing their theories of mediations for actions and for perspectives, respectively, as at odds (see Latour 1991, Ihde and Selinger 2003). For Verbeek, however, Latour can be read as picking up where Ihde leaves off, as moving from perception to action. Whereas phenomenology in general attacks the subject–object dichotomy by explaining how reality arises through relations between humans and their environment, Ihde's particular contribution to this tradition (which Ihde calls "post-phenomenology") is to note how these relations are mediated (co-shaped) by technological artifacts. Ihde's mediation of perception can be easily seen as complemented or extended by Latour's analyses of mediation in social action. "Technology mediates our behavior and our perception, and thereby actively shapes subjectivity and objectivity: the way in which we are present in the world and the world is present to us" (Verbeek 2005: 203).

The mediating role of artifacts should not be understood as intermediate between humans and the world. Instead, mediation constitutes both subject and object. "Humans and the world they experience are the products of technological mediation, and not just the poles between which the mediation plays itself out" (Verbeek 2005: 130). At the same time, Ihde and Latour seek to overcome the subject–object gap in quite different ways: Ihde bridges the gap not by denying it but by showing how mutual engagements constitute subjects and objects. In support of Ihde, Verbeek then argues that "it is indeed meaningful to make a distinction between someone who experiences and something that is experienced, someone who acts and a world in which action takes place – regardless of how interwoven and mutually constituted they are" (Verbeek 2005: 166).

## 5. Description Plus

This overview of technology and ethics began by drawing on an objection by Harold Pinter to those who would reduce dramas to moral didacticism, to suggest that to some extent moral judgments of technology ought also to be suspended in favor of careful observation. Descriptive ethics is a necessary prolegomenon to prescriptive ethics. However, in his Nobel Prize acceptance speech, Pinter (2005) makes a distinction between how, for him as a writer, morality must remain an open question, while for him as a citizen it cannot. In the play itself, "Sermonizing has to be avoided at all cost"; but in life, in contrast to art, sermonizing cannot be avoided. For Pinter, his point had to do with what he considered a responsibility to expose the lies and mendacity of United States foreign policy since the end of the Second World War. In like manner, analysts of the technology-ethics drama have often felt called to criticize modern technology on such grounds as its disruptions of traditional culture, alienation and the loss of human autonomy in mass society, destruction of a natural environment, multiple risks and dangers (material and political), or its dehumanizing (including post-humanizing) tendencies. In counterpoint, others have celebrated technology for its contributions to human welfare, freedom and progress.

Pinter has been lambasted for his moralistic sermonizing in terms that echo the castigation directed at many critics of technology for their alleged naïve romanticism of the past or idealistic and unrealistic proposals for such reforms as democratic participation in technical decision-making. (Interestingly enough, the celebrations of technology are much less commonly criticized for their naïve optimisms or unrealistic forecasts.) There nevertheless remains a philosophical obligation not only to move beyond the celebration of technological change with its attendant ideologies, but also to weave ethical analysis into normative discourse that can contribute to the abilities of citizens to appreciate benefits while exposing and delimiting or transforming wherever possible its self-regarding dominations or public and private harms. How to square moral philosophical analysis and reflection with normative assessment is as difficult as Pinter found it was to bridge the hiatus between art and politics.

The theories of ethical drama that have been associated here with Winner, Latour and their followers are cumulative products of a trajectory of dialogue on relations between technology and ethics that remain rich but largely descriptive in character. From Winner through Latour, challenges have been formulated to any narrative that would simply enact distinctions between voluntarism versus determinism or instrumentalism versus substantivism. The relation between humans and artifacts needs to be understood as a fluid network, in which a rigid distinction between the technological and the social disappears. But are there no down sides to such a sophisticated theory?

Winner himself has raised one when arguing the vacuousness of "opening the black box" of the social construction of technology in ways that can leave in place uncriticized existing power relations (Winner 1989). Another important objection is that Latour's symmetry between humans and non-humans at once anthropomorphizes artifacts and objectifies humans (Collins and Yearley 1992). If humans are co-constituted by non-humans, then it becomes unclear to what extent humans can form their own moral character, the idea of normative ethics withers, and any argument that actants should behave one way rather loses force. Moral responsibility seems to disappear. How could someone be praised or blamed for an action or intention if these are constituted by a continuously shifting network of associations?

One body of work that seeks to negotiate a clearer path from description to prescription – that engages descriptive complexities in the technology-ethics drama while arguing the need for normative orientation – can be found in the work of Albert Borgmann. In *Real American Ethics* (2006), for instance, Borgmann agrees with Latour that the insistent mediations of artifice undermine any simple autonomy as a precondition of ethics and proposes with Winner a politics based in what he proposes to call "Churchill's principle." In 1943, when the Nazi-bombed House of Commons needed to be rebuilt, Winston Churchill, as prime minister, argued against an architecture of the new and in favor of reconstructing what had been, on the grounds that "We shape our buildings, and afterwards our buildings shape us." As Borgmann also emphasizes, it is not the individual who shapes buildings; instead, "We do it together, after disagreements, discussions, compromises, and decisions" (Borgmann 2006: 5). Giving Churchill's principle a more general articulation, Borgmann continues:

> [T]he Industrial Revolution changed the stage of life from the ground up, and now the technological devices that surround us channel the typical ways we behave. Ethics has to become real as well as theoretical and practical. It has to become a making as well as a doing. Real means tangible; real ethics is taking responsibility for the tangible setting of life. Real also means relevant, and real ethics is grounding theoretical and practical ethics in contemporary culture and making them thrive again.
>
> (Borgmann 2006: 11)

Recalling the matrix that provided orientation to the dramatic tensions of technology and ethics narratives, it is possible to imagine an analogous situating of ethics itself. On the *x*-axis would be the extent to which humans voluntarily adopt their ethical guidelines or have these determined for them, if not by nature then by reason or social institutions. On the *y*-axis would be stretched out an opposition between substantive and procedural moralities. As with the previous matrix, it is the second and third quadrants that would seem best-populated. Conservative fundamentalists argue determination by some substantially delimiting moral code, liberal constructivists for an inclusive proceduralism adopted in something like a social contract. Borgmann, however, criticizes liberal proceduralism as itself manifesting a semi-determinist influence of the thin way of life typical of the culture of high-tech consumerism and aspires instead for the free affirmation of a more substantive vision of the good.

We must, Borgmann argues, recognize the extent to which human freedom is a reality that leaves us able – and even calls us forth – to argue about what constitutes the good life within that material culture associated with advanced and ever advancing technology. The proceduralism of public participation is not enough. In a series of works that began with his philosophical study of *Technology and the Character of Contemporary Life* (1984), Borgmann has argued repeatedly for a substantive view of the good as composed of engagement with reality in both nature and artifice, and has sought to spell this out with both descriptive richness and normative depth. At the same time, Borgmann recognizes that philosophy engages the good by way of neither the apodeictic causal explanations of science nor the deictic witness of poetry; instead, in ethics, philosophy can only present the good in a paradeictic or paradigmatic form that at once throws into unifying relief an apparently chaotic world with an attractiveness that perhaps can open the mind and heart to greater things.

For Borgmann, this greater good is the conscious design of an artifice that recognizes its own limitations and promotes instead not simply more human freedom and mastery of experience but what he calls focal things and practices such as those exemplified by well-wrought material objects and the festive meal. Ethics, in Borgmann's terms, is constituted by recognizing and responding to the claims of realities such as natural beauties and human virtues that, were they to be ignored, would diminish us as persons in our particularities as members of communities natural and social – that is, in landscape and country. In America, Borgmann finds real ethics dispersed in the new urbanism, environmentalist, and voluntary simplicity movements, and in his concept of focal reality he seeks thereby to concentrate and illuminate the multiple intuitions at their core. Even those who remain unpersuaded by Borgmann's own paradigm for the realization of a more substantive ethics in the midst of American technological prowess, who criticize it perhaps as a romantic idealization of the past, may still be attracted to his approach as providing a paradigm of descriptive sensitivity woven together with an enriched and enriching normative seriousness.

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# 65

# Agriculture Ethics

DAVID M. KAPLAN

Agriculture ethics is a branch of applied ethics that deals with a wide range of issues related to the farming of food, ranching and processing livestock, and the cultivation of crops for fiber, fuel and other products. The history of agriculture is inseparably linked to human history and the history of technology. It is widely believed that technological developments related to animal domestication, irrigation and storage once enabled farmers to establish permanent settlements. Stable communities were then able to develop measuring techniques, construction technologies, legal systems and other technologies and social practices necessary for permanent large-scale civilizations.

In the twentieth century, the methods and machinery of industrialization were applied to agriculture culminating in the "Green Revolution," a mid-to-late-century period of great increases in productivity in both the industrialized and the developing worlds. The Green Revolution brought great social and environmental changes and raised new moral questions in agriculture ethics related to appropriate use of the land, environmental harms, hunger and trade policy, agricultural biotechnology, and the ethical treatment of animals.

## Health and Environment

Twentieth-century agriculture introduced "intensive farming," a highly productive system based on the use of agricultural machinery, chemical fertilizers, pesticides and herbicides, mechanized processing, plant-breeding and monoculture crops. Intensive agriculture is a form of high-input agriculture, as opposed to low-input non-industrialized farming practices. While intensive agriculture has undoubtedly resulted in higher yields, increased productivity, greater availability and lower prices, it has also raised significant health and environmental concerns stemming from the use of chemical fertilizers, pesticides and herbicides, all of which can pollute the air and soil, and contaminate water supplies. These contaminants often enter the food supply and pose health risks to humans and animals, and threaten aquatic habitats and ecosystems.

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## Topsoil Erosion

Intensive agriculture also results in topsoil erosion. In addition to losses in arable land, erosion washes vast amounts of silt into bodies of water, damaging plant and animal life. Erosion increases the amount of dust, which carries infectious diseases and costs nations billions of dollars each year in productivity losses. Nutrients lost to erosion must be replaced, usually by chemical fertilizers. Excesses in phosphorus, potassium and, especially, nitrogen reduce water quality, reduce biodiversity, and diminish the availability and quality of the soil as demand for food and agricultural products continue to increase.

## Monocrops

The practice of planting monoculture crops, single crops grown over thousands of kilometers, reduces the genetic diversity of a region of land, creates an ecological vacuum that insects and disease exploit, reducing the quality of the soil while increasing the chance of crop failure. According to the United Nations Food and Agriculture Organization, the world has lost 75 percent of its crop diversity owing to agricultural monoculture. These reductions in biodiversity have consequences throughout the food chain. Farmers must increasingly rely on chemical fertilizers and pesticides to compensate for the lack of genetic diversity. Insects and disease, however, form resistance, necessitating further chemical intervention.

## Global Trade

Trade and the globalization of agriculture is increasingly “delocalizing” the origin of food and the political authority over food policy. Producers and consumers are often vulnerable to events that take place far away and subject to decisions over which they have little control. Transnational agribusiness, and the global political and financial institutions that support it, exercises tremendous influence over food production, often with great consequences for food security, food safety and the social fabric of communities. One social consequence of intensive agriculture is the consolidation of small farms into large, monocrop farms. As industrialized farming replaces human labor with machinery, millions of people every year are displaced, eradicating societies based on rural farming, where half of the world’s population still lives and works. These farms do not produce food for local people to eat, but instead grow single crops for export, usually luxury items like coffee, sugar, cotton, fruit and flowers. As farming communities dwindle in the face of competition, people are driven off their land and into poverty, usually settling in urban centers. Poverty, not the lack of food production, is widely believed to be the cause of food insecurity and famine.

## Genetically Modified Food

Genetically modified (GM) foods are plants and animals that have been altered using recombinant DNA technology which combines DNA molecules from different sources into a single molecule. Advocates of GM crops maintain that they pose neither health nor environmental risks. Critics warn that GM foods were prematurely determined by the Food and Drug Administration (FDA) to be no different from conventional foods and thus determined to be GRAS (generally regarded as safe) without having undergone independent safety testing. Critics also warn of potential cross-pollination triggering irreversible genetic contamination. Other critics are concerned that GM seeds are patent-protected, making it illegal for farmers to save and store seeds without paying royalty fees.

## Animals

The industrialized production of livestock, poultry and fish, also known as "factory farming," has many of the same benefits and harms associated with intensive farming. The benefits include efficiency, high yields, availability, low prices, and contributions to local and national economies. The harms of factory farming are animal welfare, environmental hazards, and health risks to farm workers and food safety risks to consumers.

Critics of intensive farming methods used in the production of eggs, poultry, pork, beef, dairy, veal and fish maintain that the practice is cruel and causes unnecessary suffering. Concentrated Animal Feeding Operation (CAFO) maximizes production by confining large numbers of animals indoors, limiting their space and movement. The diet of an animal in a CAFO is typically supplemented with hormones and antibiotics, and is unlike its natural diet, diminishing the health of the animals and of the food products. Livestock processing plants are notoriously hazardous workplace environments and are the most common source of foodborne illnesses and food safety risks.

CAFOs require large amounts of energy and water; they produce large amounts of animal waste and are among the principal causes of air pollution and water contamination.

## 66

# Architecture Ethics

## WARWICK A. FOX

Notwithstanding the massive impact that architecture and, more generally, the built, or human-constructed, environment has on people and the planet, serious attempts explicitly to address ethical issues associated with architecture and the built environment have thus far been few and far between, whether we consider approaches to this topic from the philosophical side or the design and architecture side. Thus the study of *architecture ethics*, the *ethics of architecture* or, more generally, the *ethics of the built environment*, the *ethics of the human-constructed realm*, or the *ethics of design*, is still in its infancy (see the introduction to Fox 2000 for more on this point as well as a fairly complete listing of the few books and paper-length contributions on architecture ethics that preceded that publication).

Why is this important field of architecture ethics so underdeveloped? On the architecture side, we can cite several possible reasons. First, we can note Fisher's (2000: 123) point that architecture "has long been viewed as a branch of aesthetics rather than ethics. If anything, ethics has been thought of as applying to architects and not to architecture, to the actions of professionals, not the traits of buildings." (Fisher immediately proceeds to warn that "Our profession, however, has not attended enough to the connection between buildings and ethics, and that has gotten us in trouble," and calls in his concluding chapter for "a conversation about ethics" within the architecture profession.) Second, to the extent that architects do think about ethical issues in their work, they might consider these issues to boil down to little more than the need to follow one's "common sense" or to comply with – or at least not fall foul of – a code of professional conduct such as that developed by the American Institute of Architects (AIA) or by the Royal Institute of British Architects (RIBA) (both of which are readily obtainable online). Third, and potentially in significant contrast with the second point, architects might consider some complex ethical issues – including the wider ethical implications of what they do – as too messy to explore in detail ("Let's not open *that* can of worms") or as a "luxury we can't afford" in the context of busy working lives. And, finally, to the extent that architects do wish "to open that can of worms" and enter into a serious "conversation about ethics," we can cite the fact that they are trained, obviously enough, in architecture, not in the formal study of ethics. Thus, although thoughtful architecturally schooled commentators will sometimes gesture in ethical directions in their lectures and writings, these gestures are generally viewed from the perspective of formally trained

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ethicists as amounting to little more than that. They are either not explicitly advanced within a developed ethical framework (such as those afforded by the major ethical theories) or, in any case, are not systematically argued.

Turning to the neglect of architecture ethics from the philosophical side, we can cite the fact that Western ethics has, at least for all earthly purposes (i.e. setting aside any putative duties we have in respect of God), been overwhelmingly focused on our obligations in respect of people. This anthropocentric focus of interest has run from the origins of Western ethics in Athens in the fifth century BC, through the Christian-dominated period (initiated by the Roman emperor Constantine in the fourth century) until the Renaissance and beyond, and on through the development of the more secular, rationally grounded forms of ethics that have characterized philosophical discussions from the eighteenth century to the present. Indeed, it is only since the 1970s that (some) philosophers have begun to devote serious, systematic attention to ethical questions in respect of non-human entities such as other sentient beings, living things in general, and ecological systems. These post-1970s developments have gone under the general name *environmental ethics*. However, in their concern to escape the anthropocentric legacy of Western ethics, environmental ethicists have been overwhelmingly concerned with the ethics of the *natural* environment (including non-human animals and other living things) and have largely ignored the *built* environment. Thus, just as the non-human world has constituted a major blind spot in theorizing associated with traditional, anthropocentrically focused forms of ethics, so the built environment has constituted a major blind spot in theorizing associated with the development of environmental ethics to date. The upshot is that the field of "environmental" ethics has not yet realized the full implications of its own name.

But, even if architecture ethics is still in its infancy as a formal field of inquiry, it is undeniable that the actual practice and products of architectural work do issue in a great many ethically relevant concerns. As Wasserman, Sullivan and Palermo (2000: 31) state in their first-of-its-kind textbook *Ethics and the Practice of Architecture*: "Architecture, in its many manifestations, is as much an ethical discipline as a design discipline."

If we think of ethics as being concerned with *the values we should live by*, then it is helpful to think of the kinds of ethical concerns that are raised by the practice of architecture as falling into at least six (not entirely exclusive and not always compatible) categories:

(1) Basic forms of professional conduct. This category covers issues that are relevant to professional life in general such as honesty, fair dealing, honoring commitments, gaining and maintaining sufficient skills to perform tasks competently, respecting and advancing the profession, and so on.
(2) Physical impact of the product of architectural practice (i.e. a built form of some kind) upon people who have direct contact with it (because they live or work in it, use it in other ways, or live close enough to be directly affected by it). Many of these kinds of issues are dealt with these days under the rubric of "health and safety."
(3) Psychological impact of the building upon people who have direct contact with it (again, because they live or work in it, use it in other ways, or live close enough to be directly affected by it). This category is concerned with such things as whether

a building is experienced in a quite straightforward way as, say, drab, dreary and depressing or inspiring and enlivening. Needless to say, these matters can affect people's "quality of life" just as surely as those covered in the previous category.

(4) What we might call "cultural fit" or "symbolic resonance" (e.g. building an immigration center – or any building for that matter – in the shape of a swastika would be widely regarded as deeply offensive). This is distinguishable from the previous point in that a building could be experienced as inspiring and enlivening were it not for – or perhaps even in spite of – its offensive cultural or symbolic resonances.

(5) Physical impact upon the environment. This concern is clearly of immense importance to the future of the planet and has spawned the burgeoning field of sustainable or "green" architecture.

(6) What we might call a building's "design fit," that is, the extent to which a building fits with its natural, social and built contexts when considered purely in terms of its design rather than in terms of its actual physical impact or even the preferences that people might have in regard to it.

What resources can the field of ethics bring to bear on these kinds of issues? The main approaches to ethics are referred to as *virtue ethics*, *deontological ethics*, and *consequentialist ethics* or just *consequentialism*. Virtue ethics is concerned with identifying the kinds of virtuous qualities of character that we ought to develop; deontological ethics (from *deon*, duty) is concerned with identifying those principles that we are obliged (i.e. have a duty) to respect in our conduct (independently of concerns about consequences); consequentialism is concerned with identifying the kinds of outcomes that we should strive to maximize (the best-known form of consequentialism is *utilitarianism*, which enjoins us to maximize the general happiness). These forms of ethics are all highly developed – especially in regard to inter-human ethics – and they can all be employed to address the above categories of issues. This does not mean that we simply crank an ethical handle and get an ethical answer; there is as much disputation in ethical discourse as in other high-level forms of discourse. (That said, this fact of intellectual life should not obscure the fact that, as in other high-level forms of discourse, from science to law, there are also substantial areas of agreement.) Rather, it means that we can address ethical questions within systematically developed frameworks of thought that enable us to offer well-developed reasons for our views and so enter into reasoned discussion with others.

In regard to the six categories of issues listed above, we can note that established, anthropocentrically focused forms of virtue ethics are especially (but not only) applicable to the issues covered by the first category, that is, the category of basic forms of professional conduct. Similarly, established, anthropocentrically focused forms of deontological and consequentialist ethics are especially (but not only) applicable to the second, third and fourth categories I have listed above, that is, the categories of direct physical impacts upon people, direct psychological impacts upon people, and impacts upon people that are more obviously culturally/symbolically mediated. The fifth category – that of physical impact upon the environment – can be addressed either *indirectly* by established, anthropocentric approaches to ethics (i.e. by focusing on the indirect impact that the built environment has on people through its direct impacts upon the wider natural environment) or *directly* by the approaches that are being developed within environmental ethics from animal welfare ethics to life-based ethics to (especially) ecological integrity based ethics.

At this point, however, a critic might say: "OK, I can see that the practice of architecture raises a great many kinds of ethically relevant questions, but it turns out that these questions can all be dealt with in terms of either established, anthropocentric approaches to ethics or the newer approaches being developed in regard to the ethics of the natural environment; so, although we need to discuss ethical questions concerning architecture, these questions do not confront the field of ethics itself with any genuinely new kinds of challenges. Questions concerning the ethics of architecture are simply *reducible* to other approaches to ethics such as those concerning our obligations in respect of other people, other sentient beings, other living things, or ecosystem integrity. Thus, architecture ethics cannot be thought of as a genuinely independent field of inquiry; it is just another field that is ripe for the *application* of ethical approaches that have been or are being developed elsewhere."

This criticism might have some force were it not for the sixth – "design fit" – category listed above. If people see a building that "sticks out like a sore thumb," they will often spontaneously exclaim words to the effect that "There ought to be a law against it" (and sometimes there is). Moreover, even if it turns out that the building has a relatively low environmental impact in measurable, physical terms and is, on the whole, accepted by others (e.g. perhaps other people "don't mind it" in part because it provides more car parking space than other buildings or perhaps they take some kind of perverse pride in the fact that it has helped to "put the place on the map"), someone might still object to this building *in principle* on the grounds that its design does not fit its context. Is this "just" an aesthetic reaction? Or is it a more strongly normatively laden reaction – as the expression "There ought to be a *law* against it" suggests? This is a key question for architecture ethics for this reason: if we agree that the values we should live by (which is to say, the *ethics* we should adopt) are such that we should object to this kind of building *regardless* of both the preferences of others and the (physical) environmental impact of such a building, then it means that the field of architecture ethics does indeed deal with questions that are not reducible to traditional, anthropocentric approaches to ethics or the newer approaches being developed in regard to the ethics of the natural environment (or, for that matter, aesthetics, since the stipulation that we are concerned with *the values we should live by* specifies that we are dealing with concerns that are, at base, ethical rather than aesthetic, or only aesthetic). It means, in other words, that architecture ethics must be considered as a field of inquiry in its own right. Indeed, it might even be that in tackling this theoretically challenging – but architecturally central – "design fit" issue ethicists are forced to develop new approaches not just to architecture ethics but to ethics in general (see Fox 2006 for an approach to ethics that proceeds on this basis).

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# 67

# Biomedical Engineering Ethics

PHILIP BREY

Biomedical engineering is the application of engineering principles and techniques to medicine. It combines expertise in engineering with expertise in medicine and human biology to develop technologies and techniques for healthcare and patient care. Biomedical engineering emerged as a field after the Second World War and has expanded ever since. As a field, it is very broad, with applications ranging from molecular imaging to the construction of artificial hearts. Biomedical engineering is, however, narrower in scope than *bioengineering*, or *biological engineering*, with which it is sometimes equated. Bioengineering focuses on the engineering of biological processes and systems in general, and includes not only biomedical engineering but also agricultural engineering, food engineering and biotechnology.

In part because biomedical engineering it itself a new field, there is currently no distinct academic field of biomedical engineering ethics. Ethical issues in biomedical engineering are currently studied in the fields of bioethics, medical ethics and engineering ethics. Yet professional ethical issues in biomedical engineering are often different from the ones traditionally discussed in these fields. Biomedical engineers differ from medical practitioners, and are similar to other engineers, in that they are involved in research for and development of new technology, and do not engage in the study, diagnosis and treatment of patients. Biomedical engineers differ from other engineers, and are similar to medical practitioners, in that they aim to contribute to good patient care and healthcare. The ethical responsibilities of biomedical engineers thus combine those of engineers and medical professionals, including a responsibility to adhere to general ethical standards in research and development of technology and to do R&D that adheres to the specific standards set forth by medical ethics and bioethics. Although biomedical engineers are not medical practitioners, one could say that they are indirect practitioners, since the technologies and techniques they develop co-determine medical practice.

## General Ethical Issues

In biomedical engineering, a distinction can be made between ethical issues in the R&D practice itself and ethical issues regarding the implications of developed techniques and

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devices for medical practice. Within R&D there are ethical issues regarding human and animal experimentation and the use of biomaterials, as well as general issues of R&D ethics like truthfulness and the avoidance of conflicts of interest. Next to such issues inherent to their own practice, biomedical engineers have a responsibility to anticipate the consequences of their designs for medical practice and to ensure that technologies and techniques are designed in a manner consistent with and supportive of ethical principles for medical practice. Such principles include beneficence (benefiting patients), nonmaleficence (doing no harm), patient autonomy (the right to choose or refuse treatment), justice (the equitable allocation of scarce health resources), dignity (dignified treatment of patients), confidentiality (of medical information) and informed consent (consent to treatment based on a proper understanding of the facts).

Particular ethical questions arise in relation to *human enhancement*. Whereas the devices and techniques developed by biomedical engineers are usually designed to support therapy or diagnosis, they may also be designed to enhance healthy human traits beyond a normal level. This is called human enhancement, and it is morally controversial because it moves traits beyond boundaries of the human species, and therefore has the potential to create superhumans. If medicine were to engage in human enhancement, it would move beyond its traditional mission, which is merely curative and preventive. Enhancement may even require the impairment of healthy human tissue or organs to fit augmentations. It therefore remains controversial whether biomedical engineers (and medical practitioners) should engage in human enhancement.

Let us now turn to some specific fields of biomedical engineering and consider major ethical issues in them.

## Cellular, Genetic and Tissue Engineering

These fields involve recent attempts to attack biomedical problems at the microscopic level.

*Cellular engineering* is a field that attempts to control cell function through chemical, mechanical, electrical or genetic engineering of cells. It attempts to understand disease processes at the cellular level and to intervene by means of miniature devices that stimulate or inhibit cellular processes at target locations to prevent or treat disease.

*Genetic engineering* specifically aims to control the genetic material in cells. Most research goes into *somatic cell therapy*, which is the genetic modification of bodily cells other than sperm or egg cells in order to replace defective genes with functional ones. It is being clinically tested to treat inheritable diseases, cancer, diabetes and various neurodegenerative disorders. There is now considerable agreement that somatic cell gene therapy to treat serious diseases is ethical.

*Germline engineering*, which is not currently used therapeutically but which is being studied, is a more controversial practice in which genes in eggs, sperm or very early embryos are modified. It is controversial because it leads to inheritable modifications of the genome that are passed on to future generations. The long-term side-effects of such engineering are currently unpredictable, and there are also concerns that such engineering violates the rights of future generations or amounts to “playing God.” Also controversial is genetic engineering to enhance human traits such as intelligence or strength, whether practiced on somatic cells or on germline cells. Such genetic enhancement is controversial for the same reasons that apply to other types of human enhancement.

*Tissue engineering* is a field that aims to restore, maintain or improve the functioning of tissues or whole organs by means of biological substitutes that repair or replace these tissues or organs. One of the goals of tissue engineering is to create artificially grown organs for patients that need organ transplants. Tissue engineering strongly depends on cellular engineering as well as on biomaterials science. Major moral controversies in tissue engineering concern the use of *xenogenic* (animal or vegetative) and *human embryonic tissue* (stem and germ cells). The use of xenogenic cells and cell material is controversial because species boundaries are crossed in the process: it involves the creation and medical use of cells and tissues that, by origin, are part human, part animal or plant. The use of embryonic tissue is controversial because cells are harvested from human embryos, which are destroyed in the process, or from aborted fetuses. It has been objected that it is unethical to kill or destroy human embryos and therefore to have a medical practice that involves it, and there are worries that a demand for human embryonic tissue promotes the large-scale cultivation of human embryos specifically for this purpose.

Other ethical issues in tissue engineering concern the question whether and how specific types of tissues can be patented, the question whether human donors of cells should be able to profit from their use (which is currently not the case) and whether donors have a right to informed consent for every use of their cells (which is currently the case). The protection of privacy of donors is another issue. Tissues of donors are stored in so-called biobanks, repositories for the storage of biospecimens that are used for clinical or research purposes. Public and private organizations that own such biobanks are responsible for protecting the privacy and confidentiality of donors, but there are disagreements about the extent and manner to which this should be done. A final ethical issue concerns the question of how to balance the prolonging of life with the quality of life in tissue engineering. To what extent should lengthening the lifespan of humans be a goal of tissue engineering, and how should such a goal be balanced against the goal of improving the quality of life, as these goals may sometimes conflict?

## Biomaterials, Prostheses and Implants

Several biomedical engineering fields have a partial focus on the development of prosthetic devices and implants. In the field of *biomaterials*, which is complementary to tissue engineering, non-biological synthetic or natural materials are developed and used to interface with biological systems to replace, treat, augment or support tissues, organs or functions of the body. The field of biomaterials contributes substantially to the development of prostheses and implants in biomedical engineering. The development and use of prostheses and implants is a major concern of *rehabilitation engineering*, a field concerned with developing technological solutions for problems of people with disabilities and function impairments. Prostheses such as artificial hips, artificial limbs, pacemakers, speech synthesizers and retinal implants are used to restore function.

The use of prostheses and implants raises issues of human identity and dignity because it involves the addition of artificial structures and systems to human biology, or even the replacement of human tissues and organs with artificial versions. The use of prostheses and implants, particularly ones that have functioning parts, makes humans into *cyborgs*: beings that are part human, part machine. Can the resulting person still be called fully human? Can the addition of artificial parts cause a transformation or even a loss of identity? Are humans still autonomous persons when they rely on electronic circuitry in their bodies? Should certain organs or functions not be replaced by artificial systems? In addition, the possibility that prostheses and implants are developed for human enhancement has also met with controversy. A more mundane issue concerns the use of biomedical devices and implants in clinical trials: what conditions must be met for the ethical and responsible testing of new biomaterial and prostheses in humans, and how thoroughly should materials and implants be tested before they go on the market?

## Biomedical Imaging and Optics

Biomedical imaging is the application of engineering methods to detect and visualize biological processes. Biomedical imaging techniques are used clinically, to detect and diagnose diseases, and in basic life sciences research, to study normal anatomy and function. Biomedical imaging is usually non-invasive or minimally invasive and involves the radiation or detection of a known physical quantity, like sound, ultrasound, radiation or magnetism. Electronic data processing and analysis is then used to generate visual images.

Biomedical imaging has obvious benefits for science and healthcare. Concerns have been raised with *diagnostic imaging*, however. It has been worried that imaging for this purpose may lead to an excess of diagnoses. Diseases may be revealed that were not under investigation or for which no therapy is available, or conditions may become visible that indicate an increased probability to develop a disease. This may confront medical specialists and patients with information and (moral) choices they may not wish to have. Patients may not want to know that they have a disease for which no good therapy is available, or be confronted with a painful uncertainty whether they have or could contract a certain disease. This raises moral issues about not only the use but also the design of imaging technologies: should they be designed, for example, so that bodily conditions are made visible selectively?

Moral controversy also extends to *brain imaging*, which is reaching the point that it can reveal information about a person’s mental states or plans for action. These developments raise significant privacy concerns and the frightening possibility that mind-reading is used to manipulate and control people.

A third and final ethical issue concerns the ethics of data manipulation in biomedical imaging. Images, whether for clinical study or for scientific analysis, are expected to be truthful and reliable, which requires that no imaging operations are performed that manipulate data and provide false information. Yet some imaging operations, such as brightness and contrast adjustments, are clearly acceptable and sometimes necessary. This raises the question what imaging operations are permissible and to what extent imaging operations must be reported to third parties.

## Neural Engineering

Neural engineering is a new field at the intersection of engineering and neuroscience that uses engineering techniques to study and manipulate the central or peripheral nervous systems. Its goals include the restoration and augmentation of human function. This is usually achieved via direct interactions between the nervous system and artificial devices. In *neuroprosthetics*, neural prostheses are developed that replace or improve neural function of an impaired nervous system. Another area of neural engineering is that of *brain–computer interfaces*, in which external computing devices are hooked up to the brain so that signals can be exchanged. Neural engineering also includes the development of *brain implants* for functional electrical stimulation of nervous tissue to restore function.

Besides involving controversial forms of animal and human subject research, neural engineering has raised ethical questions regarding the integrity and dignity of persons, as artificial neural devices may affect personal identity and make the human mind or brain partially artificial, thus turning humans into cyborgs. In addition, individual autonomy could be undermined as neural devices could be used to control cognition, mood and behavior. This also raises questions of responsibility: can humans still be held morally responsible for their behavior when their brain has been engineered by others to function in a certain way? The possibility of *neuro-enhancement* also raises significant ethical issues: should neural engineering be used to develop artificial devices that allow humans to have superior perception, cognition or motor control, or positive moods and attitudes?

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## 68

# Bioethics

PAUL B. THOMSON

The term "bioethics" is often credited to Van Rensalaer Potter (1911–2001), whose 1971 book *Bioethics: Bridge to the Future* argued that increases in technological power over the human body and the Earth's natural processes make it necessary to develop new normative understandings of biology at organismal, regional and global scales. Potter linked advances in medical technology and nutrition to the rapid growth of human population, foreseeing the need to develop a new domain in ethics that would articulate a conception of ethical responsibility for reproductive processes at a global scale. Potter's conception of bioethics was developed in the context of already thriving debates on population and world hunger in which Garrett Hardin (1915–2003), Paul R. Ehrlich (b. 1938) and Joseph Fletcher (1905–91) were prominent figures. Hardin and Ehrlich took an ecological perspective on population growth, stressing the notion of carrying capacity (the number of individuals in a given species that could be supported by a given region). They noted a tendency for many species to enjoy temporary surges in population that would exceed long-term carrying capacity, leading eventually to widespread diebacks.

The nexus between technology and ethics in these debates is rooted in the views of nineteenth-century philosopher Thomas Malthus (1766–1834), who postulated the law that population would naturally increase at a geometric rate, while technology would increase resource availability at only an arithmetic rate, necessitating human suffering due to starvation, disease and warfare over resources. The twentieth-century ecological view represented by Hardin and Ehrlich tended to see technological advance – especially in the medical sciences – as a primary cause of population growth. Fletcher adapted utilitarian analyses to social issues such as abortion and euthanasia, using the term "situational ethics" to describe his approach. His role in the population debates was in support of Hardin's view that it was immoral to give food to populations that had already exceeded the technical carrying capacity of their local environment.

These global resource debates of the 1960s and early 1970s were pursued in the work of Hans Jonas (1903–92), who was also a founding figure in bioethics. Jonas's book *The Imperative of Responsibility: In Search of an Ethics for the Technological Age* (1984) offered an early statement of the precautionary principle. However, technology's impact on specific medical procedures has proved to be a more enduring model for linking

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bioethics and technology. Bioethicists have conducted vigorous philosophical debates on the ethical acceptability of procedures such as *in vitro* fertilization, cloning and stem cell research, as well as on drugs (such as misoprostol and mifepristone) that can be used to terminate pregnancy or drug protocols for euthanasia. Each of these procedures has become the subject of debate within the medical profession only in the wake of technological developments that have vastly improved its efficiency and reliability, but the nature or trajectory of technological innovation in medicine has not generally been taken to be a significant theme in these debates. Instead, each procedure has been discussed in terms of the ethical justifiability of the medical end being sought. Technical means have been seen as relevant only to the extent that they involve risks that might offset intended benefits.

For example, *in vitro* fertilization is a procedure that requires a number of distinct technical achievements including ovarian stimulation (a hormonal injection technology), oocyte retrieval (an ultrasound-guided surgical technology), intracytoplasmic sperm injection (a laboratory micromanipulation technology) and embryo transfer (a surgical deployment of flexible plastic catheters), as well as attendant drug, hormone and acupuncture technologies intended to improve success rates. Each of these specific technologies has involved the development of both materials and techniques, but it is only with their combination that so-called "test-tube babies" have become a reality. As such, it is a classic example of what Thomas P. Hughes (1983) has characterized as a technological system supported and developed by networks of actors, as theorized by Michel Callon and Bruno Latour (1981). Within bioethics, however, *in vitro* fertilization is debated primarily either in terms of the ethical acceptability of "bypassing natural conception" (a phrase that implies a clear distinction between nature and technology) or in terms of unintended consequences that are causal consequences of technical means, but that are viewed as having ethical significance largely independent from technical practices in themselves.

Intrinsic objections to *in vitro* fertilization include worries about the moral status of embryos created through intracytoplasmic sperm injection and the fate of embryos that are not eventually implanted through embryo transfer. Concerns about its unnatural character invoke traditional notions of family and motherhood. Debates over unintended consequences begin with birth defects, multiple births and risks to women during research, but move quickly to unequal access to medical technologies and impact on the allocation of scarce resources for medical research and treatment (Heitman 1999). Abortion, euthanasia, end-of-life medicine and stem cells are each associated with an extensive literature recounting both intrinsic objections to the medical goals sought by the procedure and their tendency to view human life or life processes as a means to achieving these ends, as well as an extensive literature weighing risks and benefits of the procedure, including broad social impact on healthcare delivery. This discussion of *in vitro* fertilization is an exemplar for a veritable avalanche of bioethics writings on other technically based medical procedures.

The pattern for framing technological issues in terms of a contrast between intrinsic objections to a technical practice and consequentialist or rights-based analysis of a technology has been especially important as bioethics has moved to consider genetics and the possibility for genetic engineering. Some literature in this domain focuses on specific technical applications such as genetic testing for susceptibility to disease and the potential for misuse of genetic databases. Here, philosophical analysis may begin with a cost–benefit-style accounting of possible consequences. Benefits include enhanced medical diagnosis and the potential for better risk management, while risks include invasion of privacy, the use of genetic information for discriminatory purposes, and the potential for racial, gender or ethnic stereotyping. As with *in vitro* fertilization, concerns about equitable access are quickly added to this list, but in the case of genetic testing and databases this harm is portrayed as having the potential to inscribe economic inequalities in the genetic characteristics of future generations: the "genetic divide." Philip Kitcher has argued that beneficial applications of genetic technology should be pursued only under the condition that social institutions to mitigate these risks accompany it (Kitcher 1996).

Along with direct germline genetic engineering, such impacts are seen as having such pervasive impact on human nature as to constitute the basis for an intrinsic objection to genetic technology. A 2002 statement from the Vatican holds that "Changing the genetic identity of man as a human person through the production of an infrahuman being is radically immoral." Philosophers such as Mary Midgely (1991), Leon Kass (2001) and Francis Fukuyama (2002) have assembled a battery of arguments intended to suggest that such extensive genetic change in any portion of the human population is intrinsically wrong, whether brought about intentionally or through the cumulative result of otherwise unobjectionable practices. This line of argument is opposed by bioethicists, who view these arguments as similar to protests about the unnatural character of racial mixing, women in the workforce and various forms of sexuality, or as a new form of the genetic determinism that arose in the era of eugenics. In its place, philosophers such as Allan Buchanan, Dan W. Brock, Norman Daniels and Daniel Wikler (2001) have interposed philosophy that draws upon utilitarian and rights-based arguments which claim that, while there must be social policies to guard against abuse, denying access to those desirous or needful of genetic technologies is consistent neither with social utility nor with basic liberty.

In short, medical bioethics has evolved a pattern in which neo-Kantian, religious and tradition-based views of intrinsic value and the natural order are set against more liberal philosophies that utilize either straightforward utilitarian weighing of cost and benefit, on the one hand, or rights-based theories for conceptualizing distributive justice, entitlements or non-interference rights, on the other. While technological innovations and networks may be acknowledged as having given rise to the specific circumstances that stimulate debate, the philosophical terms in which they are conducted are derived from the most venerable philosophical and theological traditions of the modern era. Analysts of ethical issues associated with pharmaceuticals and medical procedures tend to interpret the work that precipitates their debates in terms of *science,* rather than of technology. The implicit assumption is that these technological capabilities exist as forms of knowledge: as theories and beliefs that reside in the mind where they may be held in abeyance awaiting the determination of a discrete ethical inquiry that precedes action. As such, while mainstream medical bioethics has been the site for extended philosophical analysis of specific tools and techniques, practitioners have not engaged in or been much influenced by views on the nature and significance of technology that have derived from the views of technological essentialists such as Martin Heidegger, social theorists such as Karl Marx or Max Weber, or even the global technological development concerns of their own founding figures such as Potter, Hardin and Jonas, much less more recent work in phenomenology, critical theory and the social construction of technical systems.

This framing has extended beyond the medical bioethics field in philosophical debates over agricultural biotechnology or so-called GMOs, an acronym for "genetically modified organisms," that has been widely used to indicate products of genetic engineering in the agrifood sector. Following the pattern in medical bioethics, philosophical analysis of the debate has interpreted resistance to GMOs as a reflection of intrinsic values and objections to their "unnatural" character. Philosophers such as Michael Reiss and Roger Straughan (1996) or Gregory Pence (2002) regard such concerns as flatly incoherent or at best religious, tradition-bound and often reflecting the same strand of non-reflective conservatism that medical bioethicists associate with unnatural practices in human social or sexual practice. Mary Midgely (2000) has defended the idea that the "monstrous" nature of these foods is a sufficient reason to oppose them.

In the case of GMOs, however, it may prove more appropriate to see biotechnology as a cluster of techniques and applications that has the ability to mobilize fairly complex networks of actors in pursuit of diverse and potentially fluid social goals. Thus the timing of key innovations in plant transformation coincides with changes in intellectual property law, creating an opportunity for mergers between pharmaceutical companies, agro-chemical companies and seed suppliers, on the one hand, and for active entry into patent activity by non-profit agricultural research agencies, on the other. This consolidation of power precipitated a new alliance among civil society groups focused on consumer, environmental and rural development. This consortium utilized a form of risk-based micro-politics (in the mode described by Ulrich Beck) to mobilize resistance to GMOs as a counterweight to the industry–university alliances forming around the agricultural/pharmaceutical biotechnology complex. On this view, the bioethics of GMOs has little to do with the classic philosophical oppositions of modern philosophy where religious beliefs join the forces of tradition to oppose "unnatural" behavior while progressives utilize consequentialism and human rights to promote enlightenment. Instead, technology mobilizes the formation of networks and counter-networks to produce contingent and inherently unstable dialectics. Only a detailed and empirical study of the actual technical capacities existing within real social contexts can adequately address the ethics of agricultural biotechnology (Thompson 2007).

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# 69

# Biotechnology: Plants and Animals

BART GREMMEN

Biotechnology can be defined as the science and technology aimed at understanding and using living organisms or parts thereof to improve the organism for specific human uses or to make or modify a product. In this setting, many human activities should be considered part of the realm of biotechnology, but this is too general. So we shall use the more specific term "genetic modification": the science and technology aimed at introducing any alteration of genetic material (DNA or RNA) of an organism by means that could not occur naturally through mating or recombination. The resulting organisms are called transgenic organisms or genetically modified organisms (GMOs).

In 1996 the first genetically modified crops appeared, thirteen years after the first description of this technology. This year in countries like the US, China and India more than 85 million hectares are covered with genetically modified crops, like soya, cotton and maize. The total market value is estimated to be $4.5 billion. The first GMO crops, developed by Monsanto, were resistant against the herbicide of this company. Nowadays there are also all kinds of insect- and virus-resistant crops in many parts of the world with the exception of Europe. Transgenic animals are used in medical research, and there are only a few examples of transgenic animals in agriculture (for example transgenic salmon), while there is a worldwide ban on transgenic humans.

Only within the last few decades, developing transgenic organisms has become routine and has raised a lot of ethical concerns. Because genetic modification may be used in different kinds of agriculture, it will have to face all the ethical, moral, social and technical issues associated with agriculture in general. Genetic modification contributes to important societal values like sustainability, biodiversity and health. This is done by research on drought and salt resistance, the reduction of pesticides and viruses. Basic ethical questions are about intrinsic value, environmental and health risks, and the problem of human hunger and benefit-sharing.

## Intrinsic Value

Fundamental ethical concerns of biotechnology, like respect for nature, and naturalness, often are called "intrinsic" because genetic engineering of organisms is thought to be problematic in itself. Intrinsic value refers to the qualities of life, freedom and health.

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Therefore it belongs to the deontological part of ethics in which general values serve as principles. During the last agricultural crises involving animals in Europe, like BSE and pig diseases, many groups in society criticized the policy of the government and the EU using their own version of intrinsic value. The concept is now also applied in discussions on the genetic modification of plants, where it is invoked to criticize genetic modification. For example, the adherents of organic agriculture consider the introduction of transgenic material in a plant as a violation of its intrinsic value.

The concept of intrinsic value, formerly strictly reserved for humans, is only recently well established in animal ethics. The concept means that animals have an ethical status, a value of their own, independent of the instrumental value for humans. In the Netherlands the concept of intrinsic value is even incorporated in the law on the protection of animals. Without the intrinsic value of nature, environmental ethics becomes a particular application of human-to-human ethics. In this traditional kind of ethics the term "intrinsic value" is used to refer to certain conscious experiences of humans, and is thus anthropocentric. In this view there is a central difference between humans and non-humans: only humans have moral relevance, and everything else has instrumental value.

Warwick Fox argues that it makes a huge practical difference when we grant intrinsic value to nature. In that case the burden of proof would shift from the conservationists to the people who are destroying nature. People would have to go to court seeking permission, for example, to fell trees. As a consequence, people would also have to seek permission to perform activities like genetic modification. With the rise of environmental ethics at the end of the 1960s, the term "intrinsic value" was also applied to the so-called "higher" animals (closest to humans) that also have a conscious awareness because they can experience pain. That is why humans only need to show respect to sentient animals and also why animal husbandry that makes use of transgenic animals violates the intrinsic value of animals. Because plants are not sentient animals, it is also in this view impossible for plant biotechnology to violate the intrinsic value of plants. The next step in the development of the concept of intrinsic value is an enlargement of the domain of intrinsic value to all living beings. In this extreme view, shared only by a minority of people, intrinsic value is an absolute value, without degrees, and not connected to subjective human experience. This means that all GM activities in agriculture would violate the intrinsic value of all living beings in those activities.

## Environmental and Health Risks

Straughan refers to ethical concerns about the consequences of the development and use of genetically modified organisms, like environmental risks and health risks, as "extrinsic" concerns. They belong to the teleological part of ethics which focuses on the consequences of our actions. At the moment there is global consensus that the environment deserves moral consideration. The environmental risks are about the release of GMOs in the field. Some people have called this "genetic pollution" because of the possible transgenic gene flow into farming and natural environments. The use of herbicide-resistant crops has led to questions about the effects of herbicide residues and the possibility of the development of "killer" weeds that have become resistant to herbicides. The use of male sterility in crops could reduce the gene flow into the environment. This would also help organic agriculture in its struggle to remain free of GMOs, because, surrounded by GMO fields, it is difficult for organic farmers to guarantee consumers a free choice between organic and GM products. Also, in the case of transgenic animals, gene flow into the wild population is likely to occur when the net fitness of, for example, a transgenic fish is equal to or higher than the net fitness of a wild mate. May we allow a lasting genetic effect on wild animals? Kaiser even describes the so-called "Trojan gene scenario" which suggests that enhanced mating success coupled to reduced adult viability would result in a rapid decline of the wild population. The number of uncertainties about the environmental effects in these debates is high, and the assessment of these risks entails an implicit value stance. According to Kaiser, this follows directly from what kind of harm one is willing to test for and implies that the methods employed necessarily display some kind of bias. The kind of need that is satisfied, and who benefits, are crucial aspects for ethical acceptance. Although people expect a certain level of safety for GM animals, other considerations, like medical benefits for humans, often prevail over animal welfare.

## Human Hunger and Benefit-sharing

According to some calculations, the world population will have grown to 10 billion people in 2050, while at the moment there is food for 6.4 billion people. The demand for more variety in food will increase in China and India, and also 42 percent of the crops will be lost because of pests, drought, salt, heat and cold. Genetically modified organisms could be one of the important ways to meet this challenge, by using the same amount of land in worsened circumstances. In this respect, genetic modification may be called a global technology. Individual countries cannot develop and use this technology on their own. International cooperation and networks are necessary to keep the development of this technology going. Countries will have to make large long-term investments to participate in genetic modification, and Third World countries will not be able to participate.

There are two conditions that have to be fulfilled in order for Third World countries to be able to join genetic modification: the building of an infrastructure and the ownership of genetic resources. The poor countries cannot fulfill the first condition because their very restricted budget does not allow equipping laboratories with advanced and expensive computers and all kinds of machines. Although many poor countries have abundant genetic resources, they are not able to profit because these genetic resources also are present in other countries (like potato and tomato in the Andes), and there are also large collections of genetic resources in the gene-banks of the developed world. In debates on the protection of biodiversity, the Third World countries keep insisting on a fair compensation for the use of "their" genetic resources. An international treaty of 2004 (FAO) regulates the compensation in case of patents, but in the case of "breeders' rights" there are still ethical questions like: What is the benefit of the farmers when they have the right to use the seeds of the companies in the West and they lack the specific knowledge and means to use these seeds in their plant-breeding? If these farmers cannot develop seeds of their own, can they use the seeds from the biotechnology industry?

This is often difficult because genetic modification, until now, has only developed seeds that are important in the economy of the West and not local "orphan" seeds that are important in Third World countries.

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# 70

# Computer Ethics

PHILIP BREY

Computer ethics is a new field of applied ethics that addresses ethical issues in the use, design and management of information technology and in the formulation of ethical policies for its regulation in society. For contemporary overviews of the field, see Tavani (2007), Weckert (2007), Spinello and Tavani (2004), and Himma and Tavani (2007). Computer ethics, which has also been called *cyberethics*, emerged in the 1980s, together with the rise of the personal computer. Early work in the field, however, had already started in the 1940s, soon after the invention of the computer. The birth of computer ethics as a field is often fixed at 1985, the year that saw the appearance of seminal publications by Jim Moor (1985) and Deborah Johnson (1985). The field is sometimes also defined to be a part of a more general field of *information ethics*, which includes computer ethics, media ethics, library ethics and bio-information ethics.

Why would there be a need for computer ethics, while there is no need for a separate field of ethics for many other technologies, like automobiles and appliances? Jim Moor (1985) has argued that the computer has had an impact like no other recent technology. The computer seems to impact every sector of society, and seems to require us to rethink many of our policies, laws and behaviors. According to Moor, this great impact is due to the fact that computers have *logical malleability*, meaning that their structure allows them to perform any activity that can be specified as a logical relation between inputs and outputs. Many activities can be specified in this way, and the computer therefore turns out to be an extremely powerful and versatile machine that can perform an incredible amount of functions, from word processor to communication device to gaming platform to financial manager.

The versatility of computers is an important reason for the occurrence of a computer revolution, or information revolution, that is now transforming many human activities and social institutions. Many important things that humans do, including many that raise moral questions like stealing from someone, defaming someone, or invading someone's privacy, now also exist in electronic form. In addition, the computer also makes substantially new types of activities possible that are morally controversial, such as the creation of virtual child pornography for which no real children were abused. Because many of the actions made possible by computers are different and new, we often lack policies and laws to guide them. They generate what Moor has called *policy vacuums*, being the lack of clear policies or rules of conduct. The task of computer ethics, then,

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is to propose and develop new ethical policies, ranging from explicit laws to informal guidelines, to guide new types of actions that involve computers.

Computer ethics has taken off since its birth in the mid-1980s, and has established itself as a mature field with its own scientific journals, conferences and organizations. The field initially attracted most interest from computer scientists and philosophers, with many computer science curricula nowadays requiring a course or module on computer ethics. However, given the wide implications for human action sketched by Moor, computer ethics is also of interest to other fields that focus on human behavior and social institutions, such as law, communication studies, education, political science and management. Moreover, computer ethics is also an important topic of debate in the public arena, and computer ethicists regularly contribute to public discussions regarding the use and regulating of computer technology.

## Approaches in Computer Ethics

Computer ethics is sometimes defined as a branch of *professional ethics* similar to other branches like engineering ethics and journalism ethics. On this view, the aim of computer ethics is to define and analyze the moral and professional responsibilities of computer professionals. *Computer professionals* are individuals employed in the information technology branch, for example as hardware or software engineer, web designer, network or database administrator, computer science instructor or computer-repair technician. Computer ethics, on this view, should focus on the various moral issues that computer professionals encounter in their work, for instance in the design, development and maintenance of computer hardware and software.

Within this approach to computer ethics, most attention goes to the discussion of ethical dilemmas that various sorts of computer professionals may face in their work and possible ways of approaching them. Such dilemmas may include, for example, the question how one should act as a web designer when one's employer asks one to install spyware into a site built for a client, or the question to what extent software engineers should be held accountable for harm incurred by software malfunction. Next to the discussion of specific ethical dilemmas, there is also general discussion of the responsibilities of computer professionals toward various other parties, such as clients, employers, colleagues and the general public, and of the nature and importance of ethical codes in the profession. A recent topic of interest has been the development of methods for *value-sensitive design*, which is the design of software and systems in such a way that they conform to a desired set of (moral) values (Friedman, Kahn and Borning 2006).

While the professional ethics view of computer ethics is important, many in the field employ a broader conception that places the focus on general ethical issues in the use and regulation of information technology. This approach may be called the *philosophical ethics* approach to computer ethics. This conception holds, following Moor (1985), that computer ethics studies moral issues that are of broad societal importance, and develops ethical policies to address them. Such policies may regulate the conduct of organizations, groups and individuals, and the workings of institutions. The philosophical approach focuses on larger social issues like information privacy and security, computer crime, issues of access and equity, and the regulation of commerce and speech on the Internet. It asks what ethical principles should guide our thinking about these issues, and what specific policies (laws, social and corporate policies, social norms) should regulate conduct with respect to them.

Although most ethical commentary in the philosophical approach is directed to the *use* of computers by individuals and organizations, attention has also started to be paid to systems and software *themselves*, as it has been recognized that these are not morally neutral but contain values and biases in their design that must also be analyzed. Approaches that emphasize this angle include *values in design* approaches (Nissenbaum 1998) and *disclosive computer ethics* (Brey 2000). Another development in the field that is of more recent origin is the emergence of *inter-cultural information ethics* (Capurro 2007), which attempts to compare and come to grips with the vastly different moral attitudes and behaviors that exist toward information and information technology in different cultures.

## Topics in Computer Ethics

### *Privacy*

Privacy is a topic that has received much attention in computer ethics from early on. Information technology is often used to record, store and transmit personal information, and it may happen that this information is accessed or used by third parties without the consent of the corresponding persons, thus violating their privacy. Privacy is the right of persons to control access to their personal affairs, such as their body, thoughts, private places, private conduct, and personal information about themselves. The most attention in computer ethics has gone to *information privacy*, which is the right to control the disclosure of personal data. Information technology can easily be used to violate this right.

Privacy issues play, amongst others, on the Internet, where cookies, spyware, browser-tracking and access to the records of Internet providers may be used to study the Internet behavior of individuals or to get access to their PCs. Privacy issues also play in the construction of databases with personal information by corporations and government organizations, and the merging of such databases to create complex records about persons or to find matches across databases. Other topics of major concern include the privacy implications of video surveillance and biometric technologies, and the ethics of medical privacy and privacy at work. It has also been studied whether people have a legitimate expectation to privacy in public areas or whether they can be freely recorded, screened and tracked whenever they appear in public.

### *Security and crime*

Security has become a major issue in computer ethics, because of rampant computer crime and fraud, the spread of computer viruses, malware and spam, and national security concerns about the status of computer networks as breeding grounds for terrorist activity and as vulnerable targets for terrorist attacks. Computer security is the protection of computer systems against the unauthorized disclosure, manipulation or deletion of information and against denial of service. Breaches of computer security may cause harms and rights violations, including economic losses, personal injury and death, which may occur in so-called safety-critical systems, and violations of privacy and intellectual property rights.

Much attention goes to the moral and social evaluation of computer crime and other forms of disruptive behavior, including *hacking* (non-malicious break-ins into systems and networks), *cracking* (malicious break-ins), *cybervandalism* (disrupting the operations of computer networks or corrupting data), *software piracy* (the illegal reproduction or dissemination of proprietary software) and *computer fraud* (the deception for personal gain in online business transactions by assuming a false online identity or by altering or misrepresenting data). Another recently important security-related issue is how state interests in monitoring and controlling information infrastructures the better to protect against terrorist attacks should be balanced against the right to privacy and other civil rights (Nissenbaum 2005).

### *Free expression and content control*

The Internet has become a very important medium for the expression of information and ideas. This has raised questions about whether there should be content control or censorship of Internet information, for example by governments or service providers. Censorship could thwart the right to free expression, which is held to be a basic right in many nations. Free expression includes both freedom of speech (the freedom to express oneself through publication and dissemination) and freedom of access to information.

Several types of speech have been proposed as candidates for censorship. These include pornography and other obscene forms of speech, hate speech such as websites of fascist and racist organizations, speech that can cause harm or undermine the state, such as information on how to build bombs, speech that violates privacy or confidentiality, and libelous and defamatory speech. Studies in computer ethics focus on the permissibility of these types of speech, and on the ethical aspects of different censorship methods, such as legal prohibitions and software filters.

### *Equity and access*

The information revolution has been claimed to exacerbate inequalities in society, such as racial, class and gender inequalities, and to create a new, digital divide, in which those who have the skills and opportunities to use information technology effectively reap the benefits while others are left behind. In computer ethics, it is studied how both the design of information technologies and their embedding in society could increase inequalities, and how ethical policies may be developed that result in a fairer and more just distribution of their benefits and disadvantages. This research includes ethical analyses of the accessibility of computer systems and services for various social groups, studies of social biases in software and systems design, normative studies of education in the use of computers, and ethical studies of the digital gap between industrialized and developing countries.

### *Intellectual property*

Intellectual property is the name for information, ideas, works of art and other creations of the mind for which the creator has an established proprietary right of use. Intellectual property laws exist to protect creative works by ensuring that only the creators benefit from marketing them or making them available, be they individuals or corporations. Intellectual property rights for software and digital information have generated much controversy. There are those who want to ensure strict control of creators over their digital products, whereas others emphasize the importance of maintaining a strong public domain in cyberspace, and argue for unrestricted access to electronic information and for the permissibility of copying proprietary software. In computer ethics, the ethical and philosophical aspects of these disputes are analyzed, and policy proposals are made for the regulation of digital intellectual property in its different forms.

## Moral Responsibility

Society strongly relies on computers. It relies on them for correct information, for collaboration and social interaction, for aid in decision-making, and for the monitoring and execution of tasks. When computer systems malfunction or make mistakes, harm can be done, in terms of loss of time, money, property, opportunities, or even life and limb. Who is responsible for such harms? Computer professionals, end-users, employers, policy-makers and others could all be held responsible for particular harms. It has even been argued that intelligent computer systems can bear moral responsibility themselves. In computer ethics, it is studied how the moral responsibility of different actors can be defined, and what kinds of decisions should be delegated to computers to begin with. It is studied how a proper assignment of responsibility can minimize harm and allows for attributions of accountability and liability.

## Other Topics

There are many other social and ethical issues that are studied in computer ethics next to these central ones. Some of these include the implications of IT for community, identity, the quality of work and the quality of life, the relation between information technology and democracy, the ethics of Internet governance and electronic commerce, the ethics of trust online, and meta-ethical and foundational issues in computer ethics. The constant addition of new products and services in information technology, and the coming into being of new uses and new social and cultural impacts, ensures that the field keeps meeting new challenges.

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# 71

# Consumerism

## EDWARD J. WOODHOUSE

Consumerism is a way of life combining material affluence with symbolic–emotional attachments to shopping, possessions and "waste." Scholarly commentary tends to depict global consumerism as culturally corrosive (Satterthwaite 2001) and environmentally unsustainable (Crocker and Lindman 1998, Rosenblatt 1999). Even those skeptical of such claims must acknowledge that consumerism is linked inextricably with science and technology.

Studies bearing on consumerism began with Thorstein Veblen (1899) a century ago, took firm root in the mid-twentieth century (Riesman 1950, Potter 1954, Frazier 1957, Galbraith 1958), built gradually thereafter thanks especially to Baudrillard (1968, 1970), and then burgeoned after the fall of the Soviet Union left affluent democracies as the primary occupants of the political–economic stage. Contemporary scholarship ranges from updates on conspicuous consumption (Varul 2006), to the ethos of consumers (Ci 2006), to debates about whether a zero-growth economy would be technically feasible and morally superior (Daly 1977). The literature includes general meditations on the role of technology in the good life (Higgs et al. 2000) as well as specific critiques implicating consumerism in "identity morphing, aesthetization of life, and a denial of life's tragic dimensions" (Brinkman 2006: 92) and as an "ideology enabling and supporting U.S. capitalism" (Wolff 2005: 223). Issues connected with consumerism include McDonaldization, the rationalization of everything (Ritzer 2004), and Disneyization, the prepackaging of leisure and entertainment (Bryman 2004). Although the variegated scholarship has not yet coalesced into a coherent subfield, there are at least five questions political philosophers can help humanity pose so as to clarify and possibly reform the dynamics of consumerism.

First, given that scientists and technologists created the possibility of widespread material affluence, is one logically forced to trace problems of consumerism partly to technoscientific institutions and practices (Swearengen and Woodhouse 2001)? For example, ought chemists and chemical engineers to be considered culpable for helping populate homes, landfills and even oceans with plastic artifacts and toxic chemicals? What is to be made of the fact that electronic engineers and information technologists were crucial to the distribution of advertising, pornography and trivial entertainments via mass media? How might a commendable civilization arrange to

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hold technoscientists accountable for such secondary and tertiary consequences of their work?

A second set of questions pertain to gross inequalities among citizen consumers. The most affluent 20 percent – concentrated in the US, the EU and Japan – have approximately a hundred times the spending power of humanity's least affluent quintile. The privileged minority effectively determines the "consumer demand" stimulating businesses to innovate, and purchases by the affluent substantially reshape everyday life for everyone else. These same people provide the tax revenues and voter expectations that encourage government officials in affluent nations to provide generous support for scientific research and pre-competitive technological R&D. The affluent likewise are best-positioned to use new knowledge and technical capacities, by reading about popularized science or by upgrading to the latest gadget – meaning that scientific inquiry and technological innovation typically maintain or exacerbate inequalities (Sarewitz and Woodhouse 2007). Are there lines of philosophical inquiry that can justify such a state of affairs, or is a philosopher of technology bound to advocate redistribution of income, wealth and political power within and among nations (Hayward 2006)?

Third, along with affluent consumers, it is business executives who are the proximate decision-makers of consumer culture. They routinely act in ethically indefensible ways, as by deceiving and seducing buyers, and otherwise placing private values over public ones. One need not disparage R&D-driven productivity gains, consumer liberties and contemporary affluence to recognize that businesses in market-oriented societies make money by finding willing buyers, not by attending to the needs of the general public. Government regulation once was believed an answer to the problem, but political scientists and economists have convincingly shown that "government failure" is almost as big a problem as market failure. The electoral-political, legislative, bureaucratic and other obstacles to implementing appropriate regulation are sufficiently systematic and severe that it makes sense to look for supplemental approaches: How can business executives be incentivized to meld their concerns for sales and profits with equivalent concerns for the public sphere (Woodhouse 2006)?

Fourth, inasmuch as most adults are both consumers and workers, how might a commendable civilization structure negotiations between our consumer-selves and our worker-selves? The workplace is a more important source of life satisfaction and cognitive development than the marketplace (once a person's basic needs have been met), so a utilitarian might urge developing workplace technologies and practices that increase worker satisfaction even at high expense. Yet consumers actually undermine workers' well-being by making purchases at stores offering the lowest prices, which puts pressure on business executives to cut costs, which contributes along with other factors to underinvesting in worker satisfaction (Lane 1991). A huge irony, little remarked (but see Cohen 2003 on changing incarnations of the consumer/citizen/taxpayer/voter). Clarifying the problem and options for addressing it may be one of the more important tasks that scholars of consumerism could tackle.

Fifth, in a lengthy encyclopedia covering technology as a social phenomenon, it is striking that no entry pertains directly to the subjective experience of life in contemporary civilization. Does anyone doubt that the rapid pace of technoscientific change helped create the conditions for psychosocial stress and for the widely shared sense that there is "no time" (Menzies 2005)? To reach such issues, we may need new approaches to science and engineering ethics, because the unintended speed-up of everyday life is not a matter of malfeasance by individuals; rather it is a systemic phenomenon partially beyond anyone's current understanding or control.

In conclusion, far from being simply a matter of more versus less stuff, consumerism involves all the major institutions and processes of contemporary civilization. It therefore belongs near the core of philosophical inquiry regarding technology. Can high levels of consumption and production be made compatible with stronger community, more effective democracy, more sustainable environment and, most generally, a *satisfying* way of life? How ought political–economic institutions be designed to promote reflective, public-regarding, just, and environmentally sustainable public and private choices about goods and services? Even those who believe that material affluence is wonderful arguably have a responsibility to inquire into how humanity might move toward wiser and fairer consumerism.

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# 72

# Development Ethics

## THOMAS KESSELRING

Development aid policy (DAP) takes place at the point of intersection of a number of ethical issues:

(1) What does "development" mean and in which direction does it point?
(2) What purpose does development cooperation (DC) have, what role do rights and obligations play, and what motives is it based on?
(3) Who has to support whom with development aid?
(4) Which goals should development aid policy aim at?

This article leaves aside issues about individual development and about pedagogy (i.e. concerted support of individual development) and concentrates on DAP.

At (1). Involvements in development cooperation presuppose a gradient between the cooperating groups. Members of a society considered higher developed (donor) support one or more groups of a society considered less developed (recipient). The aim of the support is to minimize the development deficit. In practice the question then arises who defines direction and aim of the development process. From an ethical as well as a practical standpoint, it stands to reason that the groups involved take joint action. DC in the strict sense presupposes a symmetrical relation and a joint decision-making process. Otherwise the relation is asymmetrical (i.e. "development aid"), and the recipients remain heteronomous. For instance, development aid based on conditions is asymmetrical.

Development is frequently equated with economic growth and judged by the gross national product (The World Bank: World Development Reports). Accordingly, development means increase in material prosperity by construction of an industrial service sector as well as political – particularly democratic – institutions. This conception competes with two others which were introduced more recently: (*a*) in 1990 the development program of the UN created a subtly differentiated index for *human development* (United Nations Development Program, UNDP) based on several factors – namely (i) gross national product per person (as an indicator of living standard), (ii) life expectancy (in which healthcare, nutrition and hygiene find expression), and (iii) rate of primary school enrolment and rate of literacy (expressing educational level); (*b*) The concept of sustainable development was introduced into the discussion

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in 1987, when the Brundtland report (World Commission on Environment and Development 1987: ch. 1, § 27) was published. Sustainable development "ensure[s] that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs." Because technology and lifestyle of industrial nations do not meet this definition, the level of development of these nations loses its exemplary character. The realization of the development aid policy program of the 1960s, scheduled for all "underdeveloped" countries, that they should catch up on the development would inevitably lead to ecological collapse. The task of bringing together human development and sustainable development remains a challenge for all societies – especially for those societies that are highest developed according to the old definition.

At (2). DC has been subject to ethical discussions time and time again since the 1960s. At first criticism concerned the non-intended side-effects of DC: it is not free of corruption, it makes the partners dependent, and presenting Western lifestyle awakens their craving for emigration (Kesselring 2003: ch. 11). But ethical controversy has also broken out about the aim of DC itself. In this controversy, four positions can be distinguished:

(*a*) The adherents of the first evaluate DC positively on ethical grounds, but hold that nobody is obliged to participate in DC. This means at the same time that no underdeveloped society has a legally enforceable right to foreign help. Somebody who helps others is admittedly doing something good and praiseworthy, according to a (supererogatory) virtue, but he does not thereby follow a moral imperative. This goes well with the fact that the UN recommendation to the industrial nations in the 1960s to spend at least 0.7 percent of their GNP on DC never was obligatory and very few countries complied with it. Most of the countries confined themselves to half of this quota and even cut back their commitment further during the 1990s. Motives for voluntary commitment to DC are, e.g., *solidarity*, *charitable attitude* or *sympathy for the disadvantaged* (cf. "option for the poor" acknowledged by the Latin American bishops' conference at their general assembly in Medellin in 1968).

(*b*) According to a second position, it is the obligation of prosperous societies (or their citizens) to become committed to the relief of poverty or to make financial contributions to development cooperation. This obligation conforms to a moral (but not legally enforceable) right of the disadvantaged for assistance. This thesis is advocated by utilitarian (Singer 1979, Unger 1996) as well as non-utilitarian oriented authors (Pogge 1987). The most radical views are defended by Singer and Unger, who classify failure to give assistance as murder. This opinion is not held by any party in the practice of development policy. At best the practice of church welfare organizations in some countries comes close to it. According to O'Neill (1986) and Rawls (1999), in the end no private individual but rather states are obligated to DC.

(*c*) A utilitarian view opposed to (b) is held by the biologist Hardin (1977): development aid should be omitted, because its results are counterproductive: By stimulating population growth in poor countries, it contributes to making the situation for the next generation(s) considerably worse than it is today. However, since the 1970s this thesis has become outdated: first, because family planning itself constitutes a primary concern of many development aid programs; and, second, since many governments of receiving countries actively pursue a population control policy often carried through more rigorously if they themselves take the initiative than if they are forced to do so by external financial backers.

(*d*) Today's most common position is a fourth: There is neither an obligation to DC nor to its omission. Nevertheless there are a number of rational motives for becoming involved in development aid policy which are based on well-understood personal interests. For instance, DC opens up new markets. During the Cold War, DC also served Western powers and Eastern-bloc states to extend or consolidate their political power. Today some multinational companies, too, invest – directly or via foundations – in development aid programs and humanitarian projects. Such investments have a positive impact on the image of the firm, although the contributions are often plainly under 0.7 percent of the net profit.

Development aid policy does also become more and more significant in the context of "Global Governance." In particular, it is of increasing importance for coping with a series of challenges that rich as well as poor nations face equally, such as ecological crisis, climate change, atomic radiation, AIDS, risks of unstable financial markets, and terrorism. These challenges depict factual constraints which relativize the significance of national borders, reduce the latitude of national politics, and restrict the sovereignty of states (Messner et al. 2005). A growing number of problems individual states are facing – pressure by migration, unemployment, weather damage conditioned by climate change, drinking-water shortage – demand also for their solution a coordinated international effort ("*Global Governance*"). Obviously, poor nations have to be involved in the collective fight against world problems, too. Development aid policy has especially to be orientated toward them – though without focusing only upon those poor countries from which the largest contributions to the solution of international problems are to be expected.

At (3). Agents within development aid policy are usually either states or non-governmental organizations (NGOs), clerical or other religious groups or private persons.

Many industrial nations maintain very close corporate relations regarding development aid policy to certain developing countries. The choice of those countries normally does not provoke any ethical debates. Notwithstanding aid does apply selectively – despite the universal validity of the demand to help. If there occurs urgent need of help somewhere, the UN with its organs usually gets active, and often a lot of governments commit themselves spontaneously, but often these initiatives are driven by national interests. After the tsunami catastrophe of 26 December 2004 the Western donor countries almost competed with each other regarding the amount of their donations. Nine months later, however, after the earthquake in Islamic Pakistan (October 2005) the necessary money hardly came in.

It is more likely that people are willing to help their family members or close relatives than non-related persons, even if the latter are much more in need of help. It is no coincidence that, in the parable, the Samaritan who came to the assistance of a Jew who had been assaulted, and rendered him first aid, even though he himself was a member of a group of ethnical foreigners, is portrayed as exemplary and worthy of admiration (Luke 10: 29–37). Apparently it already surpassed customary practice and expectations in those days. Something similar is valid for redistribution: in small, manageable groups or societies with strong community spirit it is easier to enforce than in pluralistic societies without a clear unity. Redistribution of goods across national borders is even less capable of consensus, since a common conception of justice is often missing (Walzer 1994). Involvement in development aid policy is therefore more likely capable of obtaining a majority if it applies to groups related ethnically, close trading partners or allies.

At (4). For DAP a clarification of prioritized goals is perempting. Rawls addressed this issue in two of his latest papers (1993, 1999). In particular, he formulated a *principle of assistance* stressing that the obligation to support disadvantaged societies is restricted to the establishment of conditions in agreement with human rights. This principle corresponds to the first of three criteria of justice which he proposed as part of national-state rules – a system of equal fundamental rights and liberties for everyone guaranteed by the society or state. At an international level, this criterion is satisfied if all states respect the human rights – or at least its hard kernel. Obtaining this goal, though, presupposes states with an assertive government and with financial resources sufficient to carry out the corresponding tasks. According to Rawls, international support aimed at increasing prosperity beyond the protection of fundamental rights cannot be the goal of development aid.

At the international level, Rawls attaches no significance to the principle of difference (stating that of two social orders the one is more just in which the group of disadvantaged is better off). He gives two reasons for this: On the one hand, not all states agree with this principle and, on the other hand, material aid or redistribution of goods is only demanded if it is required in order to establish a social order guaranteeing elementary human rights for everyone. For instance, from a society which has achieved prosperity by means of successful demographic measures we cannot demand that it has to make financial contributions to another society which consciously has refrained from family planning and for that reason has remained poor (Rawls 1999: 118). Such aid would be counterproductive and unsuitable for changing the causes of poverty.

Rawls also denies equality of opportunity (i.e. his second criterion for social justice) to have any significance at the international level. This is related to the fact that he conceives international economic relations one-sidedly as a cooperative system and does not take into account that economic exchange takes place on the basis of a global (ousting) competition and, moreover, that the power of decision-making with respect to political issues is distributed unequally. Beitz (1985) and Pogge (1989) therefore demand that we should hold on to the principle of equality of opportunity at the international level, too. This principle could indeed get relevant at two places: (*a*) when decisions on concerns of global interest are at stake, and (*b*) in the case of integrating individual countries into the world economy. If it is admitted that not all states can have the same influence on decisions regarding the regulation of international concerns and affecting all human beings, then the principle of difference may be applied for establishing different degrees of international justice: the better the chances are that even the weakest states (presupposing that their governments convincingly represent the interests of the people) can make themselves heard and their legitimate interests are taken into account, the more just is the political world order. And, analogically, the better the integration of the economically weakest countries into the world market, the more just is the economic world order (Kesselring 2006).

The attitude of Amartya Sen (1999) to development aid policy is directed more strongly toward the needs of the involved people than Rawls's. Sen has criticized Rawls for restricting transnational obligations toward development aid policy to the aim of (re-)establishing a system of human rights. Persons, Sen demands, must have at their disposal the abilities and the material prerequisites that are necessary for exercising their fundamental rights. For instance, a paralytic person cannot exercise her freedom of movement unless she has means of transport at her disposal. Hence she is in need of more resources than non-disabled persons. This example can be generalized. The fundamental right, say, to get an education is only beneficial for the person concerned when there exist schools within reach and when the way to school is safe. Moreover, fundamental rights are only of use if they are legally recoverable – this needs efficient executive bodies, incorruptible attorneys, fair courts, competent legal advice, and the access to these services has to be affordable for everyone. Development means for Sen something like an expansion of freedoms (cf. the title of his major work, *Development as Freedom*). Contrary to Latin American liberation theology, Sen understands "freedom" not only in the negative sense as the absence of obstacles but also positively as the disposal of "capabilities," i.e. abilities, knowledge, information, social influence, access to resources and infrastructure. The most important *capability* is self-determination – it is an indispensable precondition for the responsible use of all other abilities and fundamental rights. Obviously the acquisition of these special abilities is even more demanding than the protection of Western fundamental rights.

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# 73

# Energy Ethics

## KIRSTEN HALSNÆS

Energy is a key factor in economic development and human well-being, and energy provision therefore has many ethical dimensions. Furthermore, energy consumption has many indirect impacts on the environment.

The ethical dimensions of energy consumption include various elements. Energy generally supports economic growth, and is a key production factor that enhances the productivity of labor, machinery and land. At the same time, energy is a key element in the well-being of individuals and households; it provides lighting, comfort, entertainment services, cooling, warming, and reduces manual work. Energy consumption also has inter-generational impacts when exhaustible resources are used.

The ethical dimensions of energy also include various environmental impacts and risks. They can be intra-generational impacts where pollution externalities influence other people's utility function, and/or can be inter-generational impacts exemplified by global warming that emerges from atmospheric greenhouse gas concentrations with up to a hundred-year lifetime.

Considerations about energy ethics related to these dimensions depend on the equity paradigm applied. Some of the paradigms that have been applied to the assessment of energy ethics are:

Utilitarian-based approaches to equity that focus on the consequences of energy consumption on well-being. This approach is the backbone of welfare economics including the use of cost–benefit analysis and various energy economic models.

Right-based approaches that are based on the view that social actions are to be judged on whether or not they conform to a "social contract" that defines rights and duties of individuals in society.

Capability-based approaches, as for example represented by Amartya Sen who argues that options should be judged not only in terms of their consequences but also in terms of procedures (Sen 1999). Capabilities focus on the extent to which individuals can choose a life that one has reason to value.

In what follows we shall provide a number of examples of the ethical consequences of energy consumption and show how assessment will depend on the equity approach taken.

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## Energy and Economic Growth

Energy is a key production factor, and empirical research confirms this role (Halsnæs and Garg 2006). Based on this, developing countries today have energy security in terms of reliable supply and low costs as a major policy priority. However, energy security is challenged by the volatility of international oil markets, and by international requests for cleaner energy sources in order to prevent global warming and other environmental impacts. These international requests could imply depressed energy supply and increasing costs if domestic sources like coal are excluded. Seen in relation to the perspective of energy access and affordability of private consumers, environmental concerns can be in conflict with energy demand. It is here important to recognize that in particular low-income households presently have low energy access, so there is a special equity dimension related to access. Furthermore, energy expenditures are a relatively high share of household expenditures of low-income families, which can make it controversial to increase energy costs seen from an equity perspective (Halsnæs and Garg 2006).

A utility-based equity approach would in this context focus on the welfare consequences of increased energy consumption at macro-economic level and in relation to households. These consequences can be measured in terms of GDP impacts, and costs and benefits to households and companies of increased energy consumption versus the costs and benefits of environmental impacts. Altogether, this will provide an estimate of whether there is a net social[1] deficit or gain of increased energy consumption. Based on the distribution of the consequences, equity arguments could be used to suggest that the ones that gain from increased energy consumption should compensate those that suffer from environmental impacts. Such a principle is sometimes talked about as "the polluter pays principle."

A right-based approach differently could argue that a given energy consumption per capita is a basic right, and people living in developing countries should be allowed to increase their consumption, and thereby their pollution, up to a certain level before they are forced to take environmental targets. Several suggestions have been forwarded along this line of thinking in relation to global warming and energy consumption including the basic needs approach and equal per capita emission rights.

In terms of capabilities, energy access can be understood as an option that should be available to individuals, but the equity outcome of the availability will depend on the capability of the individuals to use the energy and the role it plays in his/her well-being. Among other factors, this will depend on the education, possibilities for income generation and employment, and on the availability of various energy-consuming technologies.

## Transportation Access

Energy in terms of transportation is a key component in the demand for mobility including freight transport, market access, transport to work, and all sorts of transport for private purposes. If we here focus on road transport, there are a number of equity dimensions of this activity.

Mobility, on one hand, in itself has many equity dimensions in terms of who has access to transport and how this access is influencing various dimensions of human well-being. At the same time, transportation causes many externalities including environmental impacts as well as accidents and noise. Those who suffer from these externalities in many cases are different from those who enjoy the benefits of transportation. A recent study about air pollution from transportation in New Delhi concludes that in particular poor families suffer from high mortality and morbidity rates because they live in heavily polluted areas and have poor health conditions, though they do not benefit from the transport that is causing the pollution (Garg 2006). Only about 38 percent of the households owned cars and/or motorcycles in Delhi and most of them are high-income families.

A utility-based approach would here focus on the net social costs and benefits of the mobility versus externalities from transport. In case there is a net surplus, traditional cost–benefit analysis can conclude that the winners can compensate the losers, and the activity therefore has a positive impact on social welfare. Whether this compensation actually is given to the losers will often be understood as an equity issue or a political issue that is beyond the scope of cost–benefit analysis.

Differently, a right-based approach could argue both from the perspective of the users of the transport and from those that are affected by externalities. The first group could argue that transportation is a basic right, and the affected could argue that clean air, quietness and low risks are a basic right for people living in a given area. In the case where property rights are well defined for the environmental quality, an agreement can be established through bargaining among the involved (based on the so-called Coase Principle: Coase 1960).

The capability approach in this case would suggest that transportation should be available for all income groups, and they can choose to use this option if it serves their needs – so they are not only allowed to use transportation options; they are also able to do it because it is accessible and affordable. Along the same lines of thinking, people should have access to safe and clean livelihoods without serious health impacts from transportation.

## Exhaustible Resources

Energy consumption influences the welfare of future generations when it is based on fossil fuels that are exhaustible, since they will have less energy resources available than current generations.

Issues like that are addressed in the very rich international literature on sustainable development. This literature to a large extent emerged as a reaction to the growing interest in considering the interactions and potential conflicts between economic development and the environment. Sustainable development was defined by the World Commission on Environment and Development in the report *Our Common Future* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987).

A core element in the economic literature on sustainable development is the extent to which different capital forms can substitute each other. In the case of exhaustible energy resources, the issue is to what extent fossil fuels in the future can be substituted by other energy sources, and the costs of these alternatives. In practice the equity dimension of welfare economics will then suggest that, if exhaustion of fossil fuels imposes higher energy costs on future generations, non-declining consumption possibilities can be maintained if investments that offset the exhaustion enable future availability of low-cost options. In this way, current generations should transfer resources to future generations for equity reasons.

It is more difficult to interpret what a right-based equity approach would recommend here. It does not make much sense to suggest that all future generations should have the right to use exactly the same amount of fossil-fuel resources as current, since that will not work for infinity.

Finally, the capability approach could in this context be interpreted as a recommendation of both access to energy resources and affordability including fossil fuels and substitutes for current and future generations.

## Note

1. Social costs and benefits include the value of all environmental impacts and are measured from the society's point of view.

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# 74

# Engineering Ethics

CHRISTELLE DIDIER

## 1. The Birth of a Discipline

Engineering ethics is an academic research field which can be first traced back to the United States at the end of the 1970s. In this specific context, this discipline has taken its roots in a former ethical reflection developed by professional organizations. Following the model of the British Institute of Civil Engineers, the American associations drafted numerous "codes of ethics" at the beginning of the twentieth century (AICE in 1911, AiChE and AIEE in 1912, ASME and ASCE in 1914). They also attempted, unsuccessfully, to reach an agreement on a common text. In the middle of the 1970s, most of them converged on the code put forward by the Engineers' Council for Professional Development (now the Accreditation Board for Engineering and Technology [ABET]).

The end of the 1970s marked a turning-point for engineering ethics, thanks to the financial support of the National Science Foundation (NSF), which allowed the creation of teams made up of philosophers and engineers. These teams achieved the first specialized conferences (CSEP of the Illinois Institute of Technology in 1982: Weil 1983), published manuals (Baum and Flores 1978, Schaub and Pavlovic 1983, Martin and Schinzinger 1983–95, Harris et al. 1995, Whitbeck 1998) and essays (Unger 1994, Davis 1998). They put on line many codes of ethics (CSEP) as well as case studies for pedagogical use (Murdough Center of Texas A&M University 1992, CSES Western Michigan University 1995). The NSF also contributed to the creation of a website which has become a reference in the domain (onlineethics.org).

This discipline also developed outside the United States. In Canada, where professional ethics has the force of law, several works were published with the support of the professional associations: the Engineers' Order of Quebec (Racine et al. 1991) and the provincial Association of Ontario (Andrews and Kemper 1999). In France (and in Europe more generally), the publications are more recent than in North America: *Ethique industrielle* (Didier et al. 1998) is a collection of classic and original texts and case studies selected by a fellowship of teachers and engineers. It prolongs the reflection conducted in the form of an essay by an engineer and philosopher who had discovered the field of engineering ethics in the USA (Hériard Dubreuil 1997). Books are also published in other European countries such as Spain and the Netherlands.

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Several projects supported by the European Commission (SOCRATES program) have led to the organization of conferences (European Ethics Network since 1996) and the publication of works (Goujon and Hériard Dubreuil 2001). One of the chapters of *Philosophy in Engineering* (Christensen and al. 2007), also an outcome of a SOCRATES program, explicitly concerns engineering ethics.

With regard to research, the presence of active teams, particularly in the Netherlands at the 3TU Ethics and Technology Center (www.ethicsandtechnology.eu), can be noted. In France, the major work of the CETS researchers of the Institut Catholique d'Arts et Métiers (www.cets.groupe-icam.fr) bears upon technical democracy. Those of the ethics department of the Université Catholique de Lille (www.univ-catholille.fr) also take an interest in the articulation between engineers' ethics, sustainable development and corporate social responsibility. In Japan, one can find evidence of the emergence of the discipline in view of the participation of Jun Fudano and others scholars in international conferences such as the one organized in 1999 in Cleveland by Caroline Whitbeck, and more recently the WPE (Workshop on Philosophy and Engineering) organized by the Delft Technology University in the Netherlands. The works of Martin and Schinzinger, Harris et al., and also Whitbeck were translated in Japan. Several works were also published by Japanese authors (Saito and Sakashita 2001, Ohnuki et al. 2002, Nakamura 2003).

Concerning publications, we can quote the presence of articles on engineering ethics in professional journals of engineers (*IEEE Technology and Society Magazine*) or related to engineers' training (ASEE's *Journal of Engineering Education*, SEFI's *European Journal of Engineering Education*, the journal of the *Japanese Society of Engineering Education*) and in journals on general ethics (*Journal of Business Ethics*, EEN's *Ethical Perspective*). Since 1995, many articles have been published in *Science and Enginering Ethics*.

If the existence of a more and more visible active scientific community can be pointed out, engineering ethics as an academic discipline remains underestimated, criticized or even disputed. Technologies can raise moral problems to the society (this is not much questioned) without posing any to the engineers who contribute to their development.

## 2. Status and Stakes of Engineering Ethics?

### *2.1 Professional, applied ethics or something else*

In the United States, *engineering ethics* is often classified among "professional ethics." The great majority of North American *engineering ethics* manuals explain why students should rank engineers among the "professionals." In fact, this insistence on re-demonstration shows the difficulty in defining the status of engineers. In order to understand this discussion, it is necessary to place it in its legal context: the Taft–Hartley law (1947). This law distinguishes, in the United States, the attributes and the prerogatives of the "professions" by opposing them to mere "occupations." Nevertheless the existence of ethical stakes bound to the practice of the engineering profession has perhaps no link with the fact that engineering is or is not a "*profession.*" It was already the opinion of Karl Pavlovic (1983), who considered it a "parasitic" question.

In Canada (at least in some regions), Spain, Portugal and Italy, where engineers need to be registered, there is no doubt that engineers are "true professionals." In France and Germany, the question does not arise because it is not relevant: there is neither a legal status nor a specific social recognition for the so-called "professionals." The stake of engineers' deontology differs according to the cultural and legal contexts: in Québec the code of ethics has a legal status, but not in the USA, the Netherlands or France; there is no code of ethics in Spain and Italy. Ethical stakes, on the other hand, are very often similar.

To classify *engineering ethics* among the "applied ethics" has other drawbacks (which are not specific to this field). This option implies that it would be possible to define beforehand "the" moral theory or the code article which is advisable to use. It also supposes that the work of ethics consists in solving problems. This is the position of certain authors: according to Harris et al. (1995), it is a question of applying codes; according to Martin and Schinzinger (1983), it is a matter of applying moral theories. As for Mitcham (1997), he considers that the role of *engineering ethics* is neither to promote respect for a professional ethics and behavioral righteousness nor to apply theories. It is a reflective work concerning a specific context of "human actions": engineering. The focal point of *engineering ethics* is neither a status (a "profession") nor a knowledge ("techno/logy," "engineering sciences"), but a "practice," a form of action.

### *2.2 What are the specific traits of this practice?*

Engineering presents the characteristic of being both scientific *and* economic: the test of the engineers' work does not take place in the laboratory, but on the market (Layton 1986). It is also a combination between the work and the capital (Downey and Lucena 1995). It is finally a "situated practice," both technical and non-technical, which contributes to building up a "conceptual and political network" (Bijker and Law 1992). Engineering must be understood as a hybrid (social and technical) form of action developing in a complex context (and not merely complicated) where political, social and economic stakes are intermingled.

Although having something to do with the sciences, the engineer's work is not that of the scientific researcher: engineering is a "social experimentation" (Martin and Schinzinger 1983). The product of engineering is not knowledge, but an object which transforms the world: "when science takes the world into its laboratory, engineering takes the world for a laboratory" (Mitcham 1997: 138). Engineering generates all kinds of risks: social, sanitary, political, environmental, economic. It is characterized by potential power and its uncertain impacts on its natural and human environment, today as well as in the future.

Finally, engineering is not a simple resolution of problems: it is an art which requires imagination and creativity (Davis 1998). The activity of industrial design is considered by most researchers as the central and most specific engineering act. The activity of design is the process by which ideas, objectives or functions take shape in the plans for implementing an object, a system or a service, aiming at attaining the objective or performing this function.

### *2.3 Each of these characteristics raises ethical questions*

Complexity: where are the spaces for freedom in these intermingled decisions? What are the spaces where ethical acts remain possible? How to assume a responsibility that is diluted in the mass? How to define the limits of human responsibilities in action?

Impact and irreversibility: on what grounds should we accept the existence of risks resulting from the multiple "social experimentations" which surround us? Who can and who must decide on it? What is a socially and morally acceptable risk?

Design: how to estimate the "ethicality" of the creative acts which are at the heart of engineering and consist in transforming ideas into forms, objects, programs, processes? How are values and standards embodied in these objects, programs and processes?

## 3. The Moral Responsibility of Engineers

Engineering designates a type of action which takes place in a complex social and technical network, jeopardizing multiple animate and inanimate beings and consisting fundamentally in transforming ideas into concrete forms. The designing act entails a specific responsibility of its authors because society is dependent on engineers in this domain. The intensity of this responsibility is proportional to the number of beings whose existence, health, quality of life – even life expectation – are at stake.

Certainly, the engineers' obligation is difficult to apprehend owing to the engineering context. Dennis Thompson (1980) gave the name of "problem of *many hands*" to the phenomenon of dilution of the individual responsibility in large organizations where it is difficult to identify who is morally responsible, because many different persons in various manners contribute to the decisions. Nevertheless engineers, owing to their training, their mission and their position in the social space, contribute collectively to the creation of phenomena whose effects on the social and natural environment are important, and sometimes irreversible.

To draw the borders of the engineers' moral responsibility amounts to raising three questions: What is their specific knowledge? What are their concrete "degrees of freedom"? What is their moral legitimacy to take into account the engineering ethical stakes within the framework of their professional activities?

### *3.1 The knowledge of engineers*

One cannot be held responsible for what one does not know, but some gaps in knowledge are more morally acceptable than others.

The impacts of technologies are partially uncertain. Many manufacturers are worried about the extravagant plea for a "precautionary principle" which would consist in restraining any innovation for fear of possible undesirable consequences. Engineers have no vocation to be transformed into experts in ethics. On the other hand, they probably have the moral obligation not to be ignorant of the debates upon the controversies aroused by the projects in which they take part. They probably have the obligation to be among the best-informed of their fellow citizens. More generally, they can be expected to have an opinion on the goals of the company employing them.

Finally, given the intrinsically risky nature of engineering, they can also be expected to have an opinion on the important issues raised by our "risk society": Are the parties exposed volunteering and properly informed? What are social profits worth in view of the resulting social costs? Is the distribution of risks fair?

### *3.2 The engineers' power*

Another reason for claiming that there is no place for ethics in engineering practice rests upon the fact that the engineers' status as employees would not give them enough freedom. This old-time argument is evoked, either to state that, on principle, the position of employee is incompatible with the practice of a professional ethics, for lack of autonomy, or to say that it is often true in practice. (Nader 1967, Noble 1979).

The working context of engineers is nearly always a large company or an organization working for one or several big companies. The problem of "many hands" can lead to the development of a feeling of impunity. The responsibility dilution is all the more likely as there is not always a continuity in the projects. The decisions are sometimes passed on from one individual to another occupying the same post successively.

Engineers are not always there to witness and assume the consequences of the decisions in which they took part. . . . Moreover, certain choices have repercussions in new timescales. Nevertheless engineers can be expected to feel accountable for their activities, to feel concerned even if they are not liable, and not to benefit from the difficult traceability of the decisions to lose interest in the (short- and long-term) consequences of their professional work.

The space of freedom within organizations employing engineers may not be so narrow. The real power of engineers, which binds their moral responsibility, is to be looked for beyond its most visible aspects, i.e. the set of authority relations. Wiebe Bijker and John Law compare engineers to "social activists" because they design the societies and organizations so that they adapt to machines. Langdon Winner (1989) observed that the conception of nuclear power stations had implications on the very structure of societies, on social roles and their distribution.

### *3.3 The legitimacy of engineers*

The American engineer and essayist Samuel Florman is very skeptical about the obligation imposed on engineers, through the most recent American codes of ethics, to protect the public from the harmful effects of technical developments, particularly in the domains of hygiene, health, safety and damage to the environment. According to him, engineers are no more qualified than novelists, dentists or philosophers to determine what it is advisable to do (Florman 1987: 30). "A feast is to be appreciated by the guest, not by the cook," already said Aristotle (*Politics*, bk 3).

If all the actors – technical, economic, political or even social – have a role to play in technical development, engineers stand in a position which generates quite specific obligations.

At the beginning of the development of any new device, there is a wide palette of possible technological choices, each responding to the interests of one or several groups concerned (the contractors, their customers, the engineers, the political leaders). The definition of the option which will be retained is the object of a negotiation between these groups. In the end, the technology chosen becomes a "black box." Engineers have no legitimacy to decide for the others but stand in this technical dead angle. They do not know everything, but sometimes know things that they are the only ones to know.

One of their obligations perhaps will be in extreme cases to be *whistleblowers.* In a more trivial way, society is entitled to expect them to take an active part in the debates on technical choices in the diverse scales where they take place, inside as well as outside the companies which employ them. There are numerous places where the engineers' words are absent, though quite justifiable, beside those of other "stakeholders" of technical development.

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## Abbreviations

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| AICE | American Institute of Consulting Engineers |
| AIChE | American Institute of Chemical Engineers |
| AIEE | American Institute of Electrical Engineers |
| ASCE | American Society of Civil Engineers |
| ASEE | American Society for Engineering Education |
| ASME | American Society of Mechanical Engineers |
| CSEP | Center for the Study of Ethics in the Professions |
| CSES | Center for the Study of Ethics in Society |
| EEN | European Ethics Network |
| IEEE | Institute of Electrical and Electronics Engineers |
| JSEE | Japanese Society for Engineering Education |
| NSF | National Science Foundation |
| SEFI | Société Européenne pour la Formation des Ingénieurs |

# 75

# Environmental Ethics

THOMAS SØBIRK PETERSEN

## 1. Introduction

Our use of technology has changed and continues to change the natural environment. While technology – medicine, transportation technologies and information technology and so on – can help us to prosper, there is also no doubt that the production and use of technology can have a negative impact on the environment and therefore on us. The pollution of rivers, oceans and the air poses an immediate threat to the *health* of humans; and the build-up of greenhouse gases, depletion of the ozone layer, and deforestation may each pose a threat, not only to the health of humans, but also to the *survival* of the human species. On the other hand, innovation within technology can also be used to *remove* or *mitigate* some of these man-made threats, and to *minimize the impact* of some non-man-made threats such as huge meteors, volcanoes, earthquakes, tsunamis and diseases.

Our impact on the natural environment, and the way in which this affects humans, other animals and plants, raises important ethical questions. These questions, which are often dealt with under the heading of *environmental ethics*, include: Is human welfare all that matters morally when we evaluate, say, deforestation or the elimination of a species? Should we aim to decrease the number of humans on our planet in order to make other species flourish? Should a company be allowed to open a mine in a national park? What ought we to do about global warming?

The relevance of environmental ethics is obvious. Since the 1960s such ethics have had a more or less strong foothold in most societies. They are now part of the international political agenda, the Kyoto treaty being a clear example here.[1] Almost every political party and large company has formulated policies on treatment of the natural environment.[2] Furthermore, journals dedicated to environmental ethics have emerged,[3] as have NGOs like Greenpeace and Earth First.

Environmental ethics is a multidisciplinary activity. It draws on expertise in physics, biology, economics, law, sociology, psychology and philosophy. Roughly speaking, we can distinguish between *descriptive* and *normative* environmental ethics. The descriptive aim is to describe and explain what attitudes people have to questions like those mentioned above. This part is usually undertaken by sociologists and anthropologists.[4] The normative aim is to assess critically the attitudes people have on these issues.[5] This

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task depends on scientific knowledge and philosophical considerations about logic, value theory, normative ethical theory and the clarification of central concepts like those of *welfare, value* and *nature*. In line with the title of this *Companion*, the focus in this entry will be on some of the philosophical perspectives on environmental ethics.[6] In what follows, then, "environmental ethics" refers to discussions of how humans ought to treat the built and natural environment.[7]

## 2. The Axiology of Environmental Ethics

Among philosophers and environmentalists, much discussion has centered on the problem of what matters morally in evaluating acts with an impact on the environment. Is it only the *humans* that matter, or is it also *other sentient beings*? Alternatively, should moral concern be extended to *all living things* and perhaps also to *mountains* or even *ecosystems*? These questions concern what we can call the axiology (or value theory) of environmental ethics. At first glance, this endeavor may seem to be of purely academic interest. But it is not. One's view of what matters morally has a critical bearing on the way in which one will argue in discussions about the ethical aspects of pollution, global warming or the extinction of species. To some extent, it affects the conclusions one will reach. For instance, if one believes that all living things have value in themselves, a normative discussion about the preservation of a forest will not be wholly contingent on what effect preservation (or non-preservation) can be expected to have on human welfare.

The axiological literature contains a great variety of positions, but these fall under three general headings: anthropocentrism, sentientism and ecologism. According to *anthropocentrism* (or human-centered ethics),[8] only humans have intrinsic value.[9] This means that humans should not care directly about non-human entities, although they may care if this will further their own interests (e.g. in respect of welfare or rights). Thus anthropocentrists are only concerned with the non-human part of nature in an *instrumental* way: the pollution of a river is only of moral concern if it sets back the interests of humans; so, if the fish in a river die, that is only morally problematic if people are thereby harmed in some way – e.g. by eating them. Note, however, that it is wrong to assume that anthropocentrism readily justifies the pollution of rivers or the destruction of wilderness – at any rate, as long as we agree (as we surely should) that wilderness can bring humans many deep, lasting and wonderful experiences.

A central challenge for anthropocentrism is to give a convincing answer to the question: Why are humans all that matter? One answer is to say that human welfare is alone in having value in itself because humans have a morally relevant feature that differentiates humans from other beings. That feature might be rationality. The challenges to this kind of answer are many. For instance, it follows from this view that humans who are not rational (newborn infants, people with dementia, etc.) do not have moral value in themselves. Furthermore, some animals, like apes or horses, seem to be more rational than a one-day-old infant, so why not include these animals?

Another answer is to say that only humans have value in themselves, because they belong to the species *Homo sapiens*. But this seems like a form of unjustified discrimination. If human welfare, say, is what matters morally, then what is so special about humans that we should only take the welfare of humans into account? Why not include animals that have the neurophysiological capacity to experience welfare?[10] Considerations like this have led some to adopt *sentientism*, which claims that sentient beings capable of enjoying welfare (and the opposite) are the only subjects that have intrinsic moral worth.[11] When it comes to the value of the non-sentient part of nature, sentientism coincides with anthropocentrism, as both positions imply that the non-sentient part of nature only has instrumental value.

Some objections to sentientism ask how we know that animals have welfare and, in keeping with one way of defining welfare, are able to feel pleasure and pain. But, although we cannot directly experience the pain or pleasure of others, including other animals, we can observe whether they behave in a way that is evidence of pain or pleasure. Alternatively, from our scientific knowledge of the nervous system we can infer that all mammals and birds with a nervous system like ours can experience pleasure and pain. As we have no reason to claim that plants can feel pain, humans have, according to the sentientist, no direct moral obligations toward plants.[12] Others have argued that the notion of harm to an entity is not captured properly by assuming that the entity in question must have the capacity to experience pain or a reduced level of pleasure. On this view, it makes perfect sense to claim that a plant can be harmed if, say, through pollution or vandalism it is prevented from flourishing according to its telos (Greek *telos* = goal) or its potential for biological development.[13]

Dissatisfaction with anthropocentrism and sentientism has led to a variety of positions falling under the general heading “ecologism.” Ecologists believe that, apart from humans and animals, we should also be concerned with nature for its own sake. Biocentrism (life-centred ethics) implies that only living organisms have inherent value.[14] Ecocentrism (Earth-centred ethics) implies, roughly speaking, that entities such as rainforests, rivers and mountains have inherent value.[15] Some ecocentrists believe that the whole biosphere has value.[16]

A serious challenge for ecologists is to infer, in a plausible way, from the sensible-looking idea that trees and ecosystems can have setbacks according to their natural potential for development (thus, in one sense, being harmed) to the claim that they have intrinsic moral value. By analogy, my computer can break down, and an aeroplane can crash, and in that sense they can be said to have been harmed. But would it follow from these considerations that the computer or the aeroplane has value in itself? Elaborating this challenge, we might add that it is not at all easy to know when a part of nature has been harmed. Is grass harmed when a lawn is mowed? If the grass is harmed, because it has value in itself, does it follow that we have a moral reason *not* to mow the lawn? And how, in any case, could it be argued that only natural entities have moral value in themselves? What about artifacts like paperclips or pools of spilt milk? Can they also be harmed? Again, if we say that they can, do we have a moral reason not to harm (bend out of shape?) paperclips?

## 3. Normative Theories and Environmental Ethics

In order to have a fully developed environmental ethics, it is necessary to combine one’s preferred axiology with a normative theory that tells us how to act. For axiology is concerned with what kinds of thing are of value, and why, and not, at least directly, with how we ought to act. In other words, axiology points to kinds of things that we have a moral reason to be concerned about, but it has nothing to offer on the question how we ought to act all things considered. And, although it is not always obvious, people who engage in normative debate about the environment often base their reasoning on some kind of normative theory which, in more general terms, tells us how we ought to act. Normative theories are usually divided into three categories: consequentialism, deontology and virtue ethics. Consequentialism is the view that an agent is morally required to perform the act with the best consequences. Many consequentialists are utilitarians. They focus on welfare and insist that the best consequences are those containing maximum welfare. But consequentialism can be combined with any of the axiologies mentioned above.[17] A biocentric consequentialist could, for example, claim that the best outcome of an action or policy is the one in which there is the most fully realized equality (of potential to flourish) between humans and other living creatures.[18]

Deontology, on the other hand, is the view that certain types of act (e.g. harming innocents or, perhaps, rendering a species extinct) are morally forbidden even when the performance of those acts would bring about the best consequences. In principle, deontologists can disagree over whether the deontic rules function as absolute prohibitions[19] or are somewhat weaker and can be broken if enough is at stake. They can also, of course, dispute the *kinds* of action that are morally forbidden. And, like consequentialism, deontology can be combined with any of the axiologies sketched above. In the literature on environmental ethics, deontology has been combined with anthropocentrism[20] and with biocentrism.[21] A biocentric deontologist might claim that we are morally forbidden from killing living organisms intentionally.

In virtue theory, the focus is not so much on what kinds of act are right, but on what a virtuous person would do. In environmental ethics, the virtue ethicist might claim that the moral evaluation of something like deforestation cannot be based exclusively on consideration of what consequences that would have, or on the question whether there is a constraint on acts which lead to deforestation. Instead we must look at the *character* of the person who performs the act. If deforestation is a result of vandalism or vicious egoism, it is the kind of action a virtuous person would not engage in. Ecofeminism can be interpreted as a kind of environmental virtue ethics. One can see this when its defenders suggest that our despoliation of the environment points up problems with “male character,” with its tendency to dominate, and with its limited capacity for caring and appreciation of the aesthetic beauty of nature.[22]

This overview of the ethical positions available in environmental ethics will, I hope, make it easier to understand why people disagree over the ethics of the environment. A major source of disagreement is, of course, *scientific* dispute over empirical facts – e.g. the causes and consequences of ozone depletion. Is depletion of the ozone layer caused by human activity, or just part of a natural process in which human emission of carbon dioxide does not matter at all? But, as philosophical discussion in environmental ethics has shown, there is plenty of room for ethical debate even if people agree on the relevant empirical data. Those engaged with environmental issues might benefit, therefore, from raised awareness of their axiological and normative commitments. These tend to be less apparent than the science, and in environmental matters, as elsewhere, the first step toward a fruitful dialogue is usually to locate the source of disagreement.

## Notes

1. The Kyoto treaty is an agreement reached under the United Nations Framework Convention on Climate Change (UNFCCC). The 164 countries (as of July 2006) which have ratified the Kyoto Protocol are, among other things, committed to reducing their emissions of carbon dioxide and five other greenhouse gases, or to engage in emission trading if they maintain or increase emissions of these gases. For details of the protocol, see: http://unfccc.int/resource/docs/convkp/kpeng.html or http://en.wikipedia.org/wiki/Kyoto_Protocol
2. Consult, e.g., the UK Labour Party official website http://www.labour.org.uk/environment04. See, e.g., www.shell.com (Shell's official website) for examples of their views on environmental issues.
3. e.g. *Environmental Ethics*, *Environmental Values* and *Journal of Agricultural and Environmental Ethics*.
4. See, e.g., W. S. Kempton, J. M. Boster J. A. Hartley (1997) *Environmental Values in American Culture* (Cambridge, Mass.: MIT Press, 1997).
5. See, e.g., A. Light and H. Rolston (eds), *Environmental Ethics: An Anthology* (Oxford: Blackwell, 2002), or R. Elliot (ed.), *Environmental Ethics* (Oxford: Oxford University Press, 1995).
6. For an excellent introduction to the debate about the scope and different varieties of environmental ethics, see A. Light, "Environmental Ethics," in R. G. Frey and C. H. Wellman (eds), *A Companion to Applied Ethics* (Oxford: Blackwell, 2003), pp. 633–49.
7. For a defence of the view that cities and not only the non-built part of the environment should fall under the heading of environmental ethics, see A. Light, "Urban Ecological Citizenship," *Journal of Social Philosophy*, vol. 34 (2003), no. 1, pp. 44–63.
8. Anthropocentrism is a central part of western Christian thinking: see Genesis 1: 26–8. Modern adherents of anthropcentrism include L. Ferry, *The New Ecological Order* (Chicago, Ill.: University of Chicago Press, 1995), originally published as *Le nouvel order écologique: L'arbre, l'animal et l'homme* (Paris: Bernard Grasset, 1992) and R. G. Frey, *Rights, Killing and Suffering* (Oxford: Blackwell, 1983).
9. An important issue that divides anthropocentrists (as well as sentientists) is the moral status of future generations. Should the welfare of future generations be taken into account in environmental ethics and, if so, how? Should their welfare be subject to a kind of discount rate? For a discussion of these questions, see D. Parfit, *Reasons and Persons* (Oxford: Oxford University Press, 1984), and J. Broome, *Counting the Cost of Global Warming* (Newbury: The White Horse Press, 1992).
10. For criticism of anthropocentrism, see e.g. P. Singer, "Equality for Animals?," in *Practical Ethics* (Cambridge: Cambridge University Press, 1993).
11. See, e.g., P. Singer, "Environmental Ethics," in ibid.
12. ibid.
13. See, e.g., R. Attfield, "The Good of Trees," *Journal of Value Inquiry*, vol. 15 (1981), pp. 35–54 and P. Taylor, *Respect for Nature* (Princeton, N.J.: Princeton University Press, 1986).
14. Influential biocentrists include Taylor, *Respect for Nature*, and A. Schweitzer, *Civilisation and Ethics*, 2nd edn (1929).
15. See, e.g., Elliot "Faking Nature," in *Environmental Ethics*.

16. See, e.g., J. Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 1978).
17. This also goes for utilitarianism! See, e.g., T. Sprigge's utilitarian defence of ecocentrism in "Are There Intrinsic Values in Nature?," *Journal for Applied Philosophy*, vol. 4 (1987), no. 1, pp. 21–8; reprinted in B. Almond D. H. Hill (eds), *Applied Philosophy: Morals and Metaphysics in Contemporary Debate* (London/New York, Routledge, 1991), pp. 37–44.
18. The movement known as "left biocentrism" is, as far as I can see, a consequentialist position which, unlike utilitarianism, says that we ought to be concerned about the *distribution* of what is valuable. For references to literature on left biocentrism see P. Curry (2006) *Ecological Ethics: An Introduction* (Caambridge: Polity Press, 2006).
19. The German philosopher Immanuel Kant is a well-known defender of this position: see his *Grundlegung zur Metaphysik der Sitten*, 1785.
20. See, e.g., Ferry.
21. See, e.g., Taylor.
22. For an example of ecofeminism, see V. Plumwood, "Nature, Self, and Gender: Feminism, Environmental Philosophy, and the Critique of Rationalism," in Elliot (ed.) *Enviromental Ethics*.

# 76

# Food Ethics

DAVID M. KAPLAN

Food ethics is a branch of applied ethics that deals with a wide range of issues related to the production, distribution and consumption of food. In addition to providing nourishment, food has relevance for the moral character of our lives, for our obligations to others, to animals and to natural environments. As food-manufacturing becomes increasingly industrialized, food and food ethics also become increasingly bound up with food science and technology. Several issues highlight the moral dimensions of food, science and technology, and policy.

## Food Safety

Nearly 2 million people die each year, mostly children, from food- and water-borne diseases as a result of unsafe food production, processing, preparation and distribution. Technologies play a pivotal role in ensuring safety. They are needed to keep food and water clean, to cook food thoroughly, to keep food at safe temperature, to extend shelf life, and reduce spoilage and contamination. Food safety is important for ensuring the nutritional quality of food, preventing food-borne disease, health hazards, and for preventing malnutrition and starvation. Proper food safety management is vital to public health, human welfare and economic development. The responsibility for ensuring food safety is shared not only by producers and consumers but also by policy-making institutions. Local, national and international institutions can play a crucial role by setting regulatory processes that ensure food safety standards are met. Although some contend that free-market mechanisms can ensure public health and consumer protection, most agree that food safety requires at least some regulatory regimes. Policy-makers must balance competing needs, interests and values of food producers, distributors and consumers using scientific knowledge, technologies, and ethical judgments.

## Food Processing

Almost everything humans eat has been processed in some way using technologies and techniques to alter raw ingredients or animals into food. Food-processing techniques

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include cooking, drying, fermenting, slicing, peeling and butchering. More technologically complex processing includes pasteurizing, canning, freezing, irradiating and artificially sweetening. Some processed food involves food additives, substances designed to help prevent spoilage or contamination, or to make food look and taste better. Additives are things like flavor enhancers (MSG), artificial colors and flavors, preservatives, stabilizers, sulfites and nitrates. Some processed foods include dietary supplements, additional ingredients with nutritional properties, such as vitamins, minerals, proteins, herbs, enzymes or extracts. The benefits of food-processing include improved preservation, increased distribution potential, fortification, consumer choice, and convenience. The harms and risks often associated with processed food are reduced nutritional value and adverse health effects. Heavily processed foods with (chemical) artificial ingredients and high-fructose corn syrup, like carbonated beverages and fast food, have been linked to the rise in obesity, type II diabetes, and heart disease. Ethical questions about processed food hinge on consumer sovereignty and the right to choose, government regulation and the duty to protect, and corporate responsibility and liability.

## Genetically Modified Food

Genetically modified (GM) foods are plants and animals that have been altered using recombinant DNA technology which combines DNA molecules from different sources into a single molecule. The purpose of genetic modification is to produce new and useful traits otherwise unattainable through conventional techniques. The most common (98 percent) GM foods are corn, soy, canola, and cotton seed oil. Most often foods are genetically modified to contain their own pesticides or to be herbicide-resistant. Occasionally they are engineered to be nutritionally enhanced, for example, Vitamin-A-enriched rice that reduces blindness in malnourished children, milk and peanuts that are allergen-free, tomatoes with added lycopene, carrots and potatoes with vaccines for hepatitis-B and cholera respectively. Controversy has surrounded GM foods since their introduction in the late 1990s. Critics warn of unknown health risks from allergens, and unknown environmental consequences, such as genetic transfer and new forms of pesticide- and herbicide-resistant weeds. Critics also worry about the abuse of intellectual property rights laws to privatize and patent life forms.

## Functional Food

A functional food, or “nutraceutical,” is a food-based product that has added ingredients believed to provide additional health benefits. Functional foods are designed to assist in the prevention or treatment of disease, or to enhance and improve human capacities. They include products like vitamin-fortified grains, energy bars, low-fat or low-sodium foods, and sports drinks. Functional foods have existed since the early 1900s when iodine was first added to salt to prevent goiter. Vitamin D has been added to milk since the 1930s, extra vitamins and minerals to breakfast cereals since the 1940s, and water fluoridated shortly thereafter. The difference between older fortified foods and newer functional foods is that the latter are designed to replace medicine with food, or sometimes to eliminate qualities from the food to make it more nutritious. The key moral issue with functional foods is the way in which they claim to function as medicine, blurring the boundaries between food and drugs. Public health and social justice questions remain about their appropriate use, distribution and regulation. Currently, each nation may determine what kind of health claims a functional food product is allowed by law to make. Typically, food companies can produce items that make *general* health claims (to promote health) so long as they make no *specific* claims (to treat diseases). There is no legal definition for functional foods in the United States, and neither pre-market approval for safety nor proof of general health claims is required.

## Food Nanotechnology

Nanotechnology deals with objects that are measured in nanometers, or a millionth of a millimeter in size. Nanotechnology is being applied to food production and food packaging. Applications of nano-particles to food include antimicrobial filters to improve food safety; Smart (spatially directed, time-controlled release, intelligent control) delivery of nutrients, proteins and antioxidants directly to targeted body parts and cells; food products that remain fresh longer and that inhibit the absorption of harmful elements; and improved food packaging to increase shelf-life and decrease spoilage and contamination. Nanotechnology, however, might pose a potential danger when introduced into the air, water, soil and food precisely because of its minute size. Safety to persons and environments remains the most important ethical question about nanotechnology. Currently, nanotechnology in food-manufacturing is more poorly regulated in the United States, Europe and Japan than conventional food.

# 77

# Future Generations

## JESPER RYBERG

Development of new technology, and political decisions about implementing it, may have an impact on the lives of many people and other living creatures. In fact, those whose lives may be affected are not limited to people presently existing. New technology may affect the lives of many generations to come. Using technology to counter depletion of the ozone layer or to reduce the increase in global warming may have long-term effects. But even technologies introduced for more immediate purposes may have consequences reaching far into the future. An ethical assessment of technology, therefore, gives rise to several related questions concerning the moral status of future generations.

1. Do we have an obligation to future generations? Some theorists have defended the view that the answer should be in the negative. Arguments to this effect have been based on the premise that parties to whom we have obligations must be able to claim their rights or that moral obligations presuppose certain personal relations which cannot be obtained with presently non-existing persons (De George 1981, Macklin 1981). Another argument to the same effect, sometimes presented under the rhetorical heading "What has posterity ever done for us?," is to hold that moral obligations should be regarded as some sort of mutual exchange presupposing reciprocity of actions (Heilbroner 1981). Despite these arguments, it is fair to say that most theorists today defend the view that we do have an obligation to future generations. The fact that future people's lives may be affected for the worse or the better by present acts, combined with the view that mere temporal distance *per se* is considered morally insignificant, provides the ground for which an affirmative answer is advocated (Kavka 1978, Laslett and Fishkin 1992, De-Sharlit 1995).
2. How should the interests of future people be weighed relatively to the interests of presently existing people? In the realm of economics it is standard procedure to access the value of costs and benefits relatively to their temporal location. More precisely, the standard device used to handle questions of inter-temporal economic benefits and costs is time-discounting. However, besides discounting economic benefits and costs, economists also frequently employ what is sometimes referred to as a *pure discounting*, that is, they discount future well-being (Broome 1994). A pure discount rate indicates the rate at which the value of well-being decreases as we

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look forward in time from the present. Such a discount rate may have a significant effect, for instance, in the assessment of new technology which contributes with an immediate gain in terms of well-being for the present generation but which may – owing, for instance, to long-term effects of pollution – threaten the well-being of future generations. The philosophical discussion of a pure discount rate concerns the moral legitimacy of this kind of discounting. For instance, it has been argued that traditional arguments in support of time-discounting of economic benefits and costs – for instance, based on considerations of opportunity costs or time preferences – cannot be extrapolated to, and thereby justify, a pure discount rate (Parfit 1984, Cowen and Parfit 1992, Broome 1994).

3. Do possible people have moral standing? When we consider present obligations to future generations there is apparently a tendency to imagine future people whose lives may be affected by present actions. If we act in one way, they may be better off; if we act in another way, they may be worse off. However, if this is how we think of future people, then it is obvious that we have missed an important point, namely that the identity of future generations may itself be contingent on present actions and decisions. A couple's decisions as to whether or not they will procreate, or whether they will do so at one point in life rather than at another, are obvious examples of how decisions can affect the identity of future people. Another example is the invention and implementation of technologies designed specifically to assist or prevent reproduction. Moreover, on reflection it is obvious that there are many political decisions concerning technology, which on the surface have nothing to do with procreation, which may nevertheless have impact on who will exist in the future. If one bears in mind that major power cuts in capital cities can be registered in the birth statistics nine months later, then it no longer seems mysterious that decisions concerning new technology – e.g. as part of a new energy policy – which have a much larger impact on society than a temporary power cut may have a significant impact on the identity of future generations. If we define possible people as those who will come into existence if we act in one way but who will not come into existence if we act in another way, then we are left with the question as to how possible people should figure in our technological decision-making.

According to one view on the matter, there is no ground for taking the effects on possible people into account when we consider how to act. The reason is that if a person will exist if we act in one way but not if we act in another, then this person, if actually brought into existence, cannot properly be held to be worse off (or better off) than he would have been had we acted differently (i.e. if one assumes that coming into existence cannot benefit or harm someone). The alternative for this person would have been nonexistence. Thus, on the ground of the view that what matters morally is whether individuals are benefited or harmed from our actions, possible people do not have moral standing (Narveson 1973, 1978; Heyd 1992; but also Roberts 1998). In fact, this view has been used to defend the conclusion that we need not care at all about the non-immediate future (Schwartz 1978).

An alternative answer is to adopt what has been referred to as the "no-difference" view, namely that changes of identity between possible outcomes do not make a difference with regard to how they should be assessed (Parfit 1984). For instance, this would be the case if one holds that the best outcome is the one producing the greatest quantity of whatever makes life worth living. Though this position seems appealing in many non-identity cases, it suffers from the apparent drawback that it implies that for any population of people with a very high quality of life there must be some much larger population whose existence would be better, even though its members have lives that are barely worth living. This implication is known as the Repugnant Conclusion (Parfit 1984, Arrhenius 2000, Ryberg and Tännsjö 2004). The question as to how one should morally deal with cases involving changes in identity and in the number of people from different outcomes constitutes a major challenge which has been the object of much discussion over the latest few decades, usually considered under the heading *population ethics*.

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# 78

# Genethics

## NILS HOLTUG

## 1. Genes, Identity and Ethics

The genetic revolution has brought us technologies such as genetic screening, genetic pre-implantation and pre-natal diagnosis, gene therapy, cloning and genetic pharmacology. Such technologies raise all sorts of ethical issues. Some of the most profound issues pertain to the impact of genetic technologies on the identity of human beings. For instance, perhaps gene therapy and genetic pharmacology may be used to treat severe diseases such as cystic fibrosis, Tay-Sachs disease and Huntington's chorea, and even to enhance human characteristics in the "normal" range, including height, memory and intelligence. Such genetic interventions will affect the identity of their recipients in that they will give them certain properties (say, better health or memory) that they would not otherwise have had. But where exactly do we draw the line for such genetic interventions?

Some uses of genetic technology will affect human identities in a deeper sense than this. If a person is successfully treated for, e.g., Huntington's chorea, this will improve his health and so give him certain new qualities, but it will still be *he* who receives these new qualities. In other words, his numerical identity is not affected. But now suppose instead that a pre-natal diagnosis reveals that a fetus carries the gene for Huntington's chorea, and his parents therefore decide to have an abortion and try to have another (healthy) child later. Here, one child is *replaced* with another that has different properties (and, in particular, is not disposed to develop Huntington's chorea), implying a change in both qualitative and numerical identities. Therefore, such a genetic intervention raises separate ethical issues.

## 2. Identity-affecting Genetic Interventions

I shall call genetic interventions that affect *who* (in the numerical sense) comes to exist *identity-affecting* and those that do not *identity-preserving* (although they will, of course, affect the recipient's qualitative identity). Both pre-implantation and pre-natal diagnosis may be identity-affecting because they may lead to selective implantation and selective abortion respectively. Likewise, perhaps certain forms of gene therapy would, if performed

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on a conceptus or embryo, have such massive effects on its – or the resulting child's – properties that a numerically different child would be caused to exist.

Medical interventions usually aim to benefit their recipients but, setting aside cases of "wrongful life" (see below), identity-affecting genetic interventions will often not achieve this. For instance, a fertilized egg that is not implanted because it has the gene for cystic fibrosis or a fetus that is aborted because it has the gene for Huntington's chorea will not benefit from these procedures. But things may be different if, e.g., a fertilized egg is implanted after a diagnosis reveals that it is healthy.

Some will object to certain genetic interventions because they involve the killing of a fetus (fertilized egg, embryo). Others will argue that such beings have no moral standing and that killing them can be justified on the basis of the interests of the parents (and perhaps societal interests as well).

But, even if we concede that the interests of the fetus or child should be taken into consideration, this does not automatically speak against such interventions. Thus some argue that the healthy child that the parents may have instead of the child with a serious genetic disease is likely to benefit from coming into existence, and more so than the unhealthy child would. Others deny that it can benefit a child to come into existence, but claim that the interests of the child can nevertheless be taken into account "impersonally," i.e. in terms of the welfare this child contributes to the world.

A similar question arises in relation to so-called "wrongful life" cases, where, e.g., a child sues her parents for bringing her into existence with a terrible disease rather than aborting her. Some have argued that such cases make no sense because the child cannot be harmed by being caused to exist (Heyd 1992: 29–33). However, others argue that it may in fact benefit or harm a person to come into existence (Holtug 2001), so that, in so far as a child has a life that is worse than no life at all, she is harmed by existing.

Identity-affecting interventions raise a further issue of whether some forms of "selection" amount to objectionable discrimination. It may be argued that to select against a fetus (fertilized egg, embryo) that will develop a disability is to discriminate against her and/or to express a demeaning view of the disabled. There are several issues that need to be addressed here. Do fetuses (fertilized eggs, embryos) have a moral standing that makes them capable of being discriminated against? Does selection necessarily express a demeaning view of the disabled, or might it just express that health is better than disease? Also, it has been argued that at least some of the arguments for why we discriminate if we select *against* disability implausibly imply that it should be permissible to select *for* disability (McMahan 2005).

## 3. Identity-preserving Genetic Interventions

Except perhaps in exceptional cases, genetic pharmacology and gene therapy will be identity-preserving. Therefore, such interventions usually benefit their recipients. For this reason, many will consider them less controversial technologies, at least as long as they are considered sufficiently safe, do not pass on genetic modifications to future generations, and aim only to treat disease.

One worry that some nevertheless have about genetic pharmacology and gene therapy is that they are a slippery slope toward less acceptable forms of genetic intervention, say, memory or intelligence enhancements. This raises two separate but related issues. One is how strong this slippery-slope argument is as a general argument against genetic pharmacology and gene therapy. Perhaps some time in the future (brain) surgery may also be used to enhance memory or intelligence, but it is doubtful if this is a good reason to ban surgery (Holtug 1993: 417).

The other issue is what sort of genetic interventions should be considered morally impermissible and so possible undesirable end-results of a slippery slope. Some have drawn a distinction between the treatment of disease, on the one hand, and enhancements, on the other, where a disease may be defined as a departure from species-typical normal functioning. It is then claimed that only the former interventions are permissible. Nevertheless, such a claim would rule out at least some interventions that may seem rather desirable, for instance a genetic vaccine against HIV that would *enhance* the recipient's immune system because it would give her a property that humans do not normally (or naturally) have (Holtug 1998: 211).

## 4. Justice

According to luck egalitarianism, we should compensate victims of the genetic lottery to the extent that they have acquired a set of genes that renders them worse off than others. Thus we should compensate at least some people who have genes that cause them to have a disease. Usually, luck egalitarians have aimed to redistribute social assets (e.g. money) to achieve this, but genetic technologies have made it possible to compensate by distributing natural assets instead. Furthermore, luck egalitarianism would seem to require not only the treatment of disease but also *enhancements*, namely in so far as there are properties that are not departures from species-typical functioning but may nevertheless render people worse off than others (Holtug 1999). An example of this may be a boy with a predicted adult height of 160 centimeters (5 feet 3 inches).

Some egalitarians have nevertheless given a qualified defence of the treatment/enhancement distinction (Buchanan et al 2000: chs 3–4). They argue that, while justice requires compensating victims of the social lottery, it requires only limited compensation of victims of the genetic lottery. The latter should only be restored to the level of "normal" (not equal) competitors for advantages, where normal competitors may well suffer disadvantages that come from normal but not optimal or even average capabilities. Roughly, this means that justice requires genetic treatments, not genetic enhancements. Luck egalitarians, on the other hand, will insist that victims of the social and the genetic lottery suffer the very *same* form of injustice. They are worse of than others through no choice or fault of their own. Nevertheless, such egalitarians may agree that treatments should generally have priority over enhancements because it is most urgent to benefit the worst off, including people with serious diseases.

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# 79

# Technology and the Law

## RICHARD SUSSKIND

The technology that has exerted the greatest impact so far on the practice of law and the administration of justice is information technology (IT). It is both intuitively obvious and jurisprudentially sound to recognize that the law, with its heavy dependency on documents, information services and knowledge resources, is a fertile application area for IT. However, the full potential of IT has not yet been realized in most legal systems, partly because of underinvestment by governments and private-sector legal businesses and also because lawyers, in general, are often late adopters of new technology.

In recent years, there has been growing uptake of IT by legal practitioners, including lawyers who work in law firms, advocates who specialize in court work, and legal advisers who operate in-house within businesses and governments. In the 1970s and 1980s, the dominant uses of IT by these lawyers were in the back office – for word processing, accounting and administrative purposes. It was later recognized, in the 1980s and since, that information systems could be used to capture and share the collective know-how and experience of a legal team, so that databases of standard-form documents and legal opinions were developed and made easily accessible to lawyers from their desktops. As elsewhere, however, it was the advent of the Internet that led to IT becoming mainstream amongst practicing lawyers. Since the late 1990s, email has become the dominant way in which lawyers communicate with their clients, while hand-held machines are used extensively (some would say obsessively) to maintain contact while out of the office. The Worldwide Web and Google have transformed the information-seeking habits of lawyers, with legal resources and information about organizations and markets now being readily available. The next step in the evolution of legal technology is online systems that actually undertake legal tasks – providing legal updates, drafting documents, offering advice, and solving legal problems. The most widely used of these so far are automatic document-assembly systems.

Judges in most advanced legal systems are also using IT. Email and word processing by judges are now firmly established applications. Many judges use a wide variety of online research resources, while some are benefiting from judicial intranets as a mechanism for sharing information with one another. Where the courts are suitably equipped, judges may also have access to case-management systems, which enable them to monitor and progress the cases before them. Courtrooms are increasingly being

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equipped with IT, including document- and exhibit-display systems, wall-screen and large monitors, video-linking for remote evidence, computer-assisted realtime transcription, wireless networks with Internet access, and tools (from computer graphics to virtual reality) for the presentation of evidence. More ambitious and controversial is the idea of the virtual hearing or online dispute resolution – some lawyers and legal technologists are challenging the assumption that court work requires the gathering of parties in a single, physical space and are developing systems to allow litigants to present evidence and arguments via online systems. Currently, these submissions are adjudicated upon remotely by human beings, but artificial intelligence specialists continue to speak about computers replacing judges.

Legal education and research are also being significantly affected by IT. The emergence of multimedia e-learning systems (from webcasts through to virtual legal environments) are complementing traditional teaching and sometimes replacing methods of the past. Students can attend and replay online lectures and tutorials at their convenience. And they have a wealth of primary materials (legislation and case law) and secondary materials (articles and books) at their disposal on the Worldwide Web. Legal scholarship is also undergoing substantial change. Aside from unprecedented access to legal sources, legal academics also enjoy easy access to fellow scholars around the world. While conventional conferences and symposia remain important for personal contact, ongoing dialogue by email is now pervasive.

The citizen, too, is a beneficiary of legal technology. In the past, citizens generally had to consult lawyers if they wanted advice on most legal problems. Today, these non-lawyers can obtain legal guidance on a wide range of legal issues from websites developed, amongst others, by consumer bodies, trade associations and government agencies. While the counsel provided by these sites may be less tailored and rigorous than that offered by traditional lawyers, they can provide useful briefings for people before they seek formal legal advice. And, where it is not feasible for citizens to obtain lawyers' help directly, these websites are generally far more useful than having no guidance at all.

One aspect of the legal system that has remained relatively untouched by technology is the legislative process, even though law-making could be substantially supported by IT. Various emerging technologies could be used to invite greater participation in legislating by all members of society. Historically, in representative democracies, citizens have elected politicians to represent their interests in parliaments. It was not practicable in the past for the individual views of citizens to be solicited and then reflected in policy-making and legislating. However, there are now techniques and technologies (blogs, wikis and other social software) that are designed precisely to enable and encourage Internet users to express their views, discuss their values and arguments, build communities of interest, and convey these positions to those who make new and change old law. In broad terms, this is known as e-democracy; and while there are understandable concerns about the reliability and security of related systems, especially online voting, there are strong arguments in favor of investing considerable resources in systems that enhance democratic participation. Another underexploited application of technology for use in legislating is computer-assisted drafting. There was considerable academic interest in this field in the 1980s, when various scholars pointed to the similarities between drafting legislation and writing software and suggested that programming techniques, if applied to the law, could bring about more consistent, less ambiguous and better-structured legislation. However, this early promise has not yet been fulfilled.

As IT advances, more applications for lawyers and citizens will emerge. With sufficient investment and careful planning, IT could greatly enhance the efficiency of lawyers and substantially increase access to justice.

# 80

# Media Ethics

## DENI ELLIOTT

Media ethics is the study of (1) how media practitioners act when making decisions that affect other people, species or natural systems, and (2) how media practitioners should act in making these decisions. The first is descriptive ethics; the second is normative ethics. Choice of actions may be examined on an individual practitioner (micro) level or on an organizational or institutional (macro) level.

Judgments of what is ethically prohibited, permitted, required and ideal in a specific situation are based on understandings from philosophical theory as well as on professional conventions and codes. New technologies that afford opportunities outside traditional boundaries complicate the development of and adherence to professional conventions because new technologies allow for behaviors that are not anticipated or addressed by assumed conventions.

Philosophical theories that serve as the foundation for media ethics draw first on libertarian doctrines that emphasize freedom of expression as essential for self-governing citizens. However, theories that focus on freedoms are paired with those that emphasize social responsibility and communitarian concerns, owing to the harms that can be caused to individuals and vulnerable groups by mass communication.

Two thousand years of Western moral philosophy can be summed up as philosophers finding different ways to articulate a single mantra: "Do your job and don't cause unjustified harm." Philosophical theories articulate determinations for what counts as doing one's job, i.e. articulating the special role-related responsibilities associated with a particular profession. For example, the special job of journalists is to seek and provide information that citizens need for self-governance.

The theories also help practitioners to clarify harms that can be caused by those within their professions and how to differentiate harms that are justified from those that are not. It is justified, for example, for journalists to cause harm to corrupt politicians through media exposure because information about corruption among governmental leaders is essential for citizens to have to make educated choices for self-governance.

Traditionally, media practitioners, and their ethical issues, could be distinguished from one another by their intent of medium use: to inform, to persuade, or to entertain. Role-related responsibilities of practitioners derived from the intent. Professional standards and conventions adhere to the means and products that come from acting on those intents.

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Journalistic practices and products were judged by how well practitioners and organizations did in providing timely, non-biased accounts to a mass audience. Public relations and advertising practices and products were judged by how well practitioners and organizations provided opinion without falsity. Broadcast television and radio, films and music, books and magazines intended for enjoyment were judged ethically by how well they entertained without causing harm to vulnerable subjects or audiences.

Technology in the late twentieth and early twenty-first century has strained traditional concepts of media intent and with it the traditional ways of judging media ethics. New media, including satellite technology and the Worldwide Web have provided the opportunity for every individual to produce visual and textual messages for mass consumption and to access messages without the involvement of media organizations and their gatekeepers. Bloggers, for example, simultaneously provide information, express opinion, and secretly embed paid advertisements in their copy. Websites such as Youtube entertain, advertise, inform and provide access to a world of opinions. Virtual communities, such as Second Life, are used for entertainment and education, as well as providing the formation of groups for those with shared opinions.

The fluidity of communication has led some to argue that media practitioners – journalists in particular – are no longer necessary. Others note that bloggers are developing standards of conduct that bring their conventions more in line with traditional journalists. Virtual communities require participants to follow rules that promote social order.

Technology has created tensions for the practice of mass communication so that conventional standards are currently in flux. Practitioners in traditional media struggle with the expectation that they will follow conventional standards when non-professional practitioners are not.

Despite the blurring of lines among the three media intents, and the blurring of lines between professional and amateur information-givers and gatekeepers, common areas of ethical concern can be identified that have persisted over time and technology.

Those who wish to have credibility as information-givers – journalists – need to be aware of conflicts of interest that may bias or appear to bias their presentations. They need to avoid falsification and fabrication, and provide news products that are balanced, accurate, relevant and complete. Journalists must also be protective of the means by which they acquire their stories. Confidentiality to sources should be maintained, if promised; subjects and sources ought not to be deceived.

Opinion-givers, such as public relations and advertising practitioners, as well as those producing editorials in various media, should articulate their loyalties and be clear with the audience about the reason for the loyalty, whether it be purchased or personal conviction. They ought not to lie in the process of presenting their message; but, unlike journalists, they are not ethically compelled to provide a complete accounting that might dilute their message. They should be aware of any special vulnerability of audiences that they address.

Those who use media primarily as a vehicle for entertainment also need to be aware of the vulnerability of the audiences that they address. Fare that contains sex, violence, or acceptance of drugs or other harmful products is more suitable for controlled consumption (such as cable or satellite) than it is for broadcast. Those who have power have an ethical responsibility to use that power judiciously.

Law provides the minimal requirements to which media practitioners must adhere, but ethics addresses behaviors that rise above the legal minimums. No one could live well in a community in which others adhered only to the legal minimum. Ethics provides a basis for the development of voluntary standards for self and for industry. Because of democracy's commitment to free expression, government regulation of mass communication is to be avoided when possible. In recognition of the power of mass communication and to forestall governmental interference with free expression, media practitioners, whether acting on their own or through industry, share an obligation to uphold ethical standards rather than push the envelope of legal limitations.

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# 81

# Medical Ethics

SØREN HOLM

Medical ethics is that branch of applied ethics that is concerned with the ethical problems of healthcare professionals and healthcare systems. It is a subset of bioethics, and can itself be further divided in medical ethics (narrowly defined), nursing ethics, public health ethics, research ethics, management ethics, etc.

There are extensive overlaps between the field of medical ethics and cognate fields such as the ethics of genetics (genethics), the ethics of new technologies, and professional ethics in general.

## History

The history of medical ethics can be traced to two sources. The first of these is the professional ethics of the medical profession, its internal rules of conduct. The second is general moral philosophy and theology. Although there has been mutual influence between these two lines of thought and practice throughout history, strong interaction between moral theory and medical ethics is a relatively recent phenomenon.

Within medical historiography some have tried to trace an unbroken line of rules or principles of conduct from the Hippocratic Oath (see Box 6.1) attributed to the Greek physician Hippocrates (c. 460–370 BC) to current rules of conduct, often in order to be able to claim that medicine stands in an unbroken Hippocratic tradition and should follow the principles in the oath (e.g. its prohibition against prescribing abortifacients). Some even seem to think that all doctors still swear the Oath. But both claims are fallacious. Only a minority of modern doctors swear the Hippocratic Oath, and even within Western medicine there have been long periods in which the Oath played no role in setting the standards for medical conduct.

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### Box 6.1 The Hippocratic Oath

I swear by Apollo Physician and Asclepius and Hygiea and Panaceia and all the gods and goddesses, making them my witnesses, that I will fulfill according to my ability and judgment this oath and this covenant:

To hold him who has taught me this art as equal to my parents and to live my life in partnership with him, and if he is in need of money to give him a share of mine, and to regard his offspring as equal to my brothers in male lineage and to teach them this art – if they desire to learn it – without fee and covenant; to give a share of precepts and oral instruction and all the other learning to my sons and to the sons of him who has instructed me and to pupils who have signed the covenant and have taken an oath according to the medical law, but no one else.

I will apply dietetic measures for the benefit of the sick according to my ability and judgment; I will keep them from harm and injustice.

I will neither give a deadly drug to anybody who asked for it, nor will I make a suggestion to this effect. Similarly I will not give to a woman an abortive remedy. In purity and holiness I will guard my life and my art.

I will not use the knife, not even on sufferers from stone, but will withdraw in favor of such men as are engaged in this work.

Whatever houses I may visit, I will come for the benefit of the sick, remaining free of all intentional injustice, of all mischief and in particular of sexual relations with both female and male persons, be they free or slaves.

What I may see or hear in the course of the treatment or even outside of the treatment in regard to the life of men, which on no account one must spread abroad, I will keep to myself, holding such things shameful to be spoken about.

If I fulfill this oath and do not violate it, may it be granted to me to enjoy life and art, being honored with fame among all men for all time to come; if I transgress it and swear falsely, may the opposite of all this be my lot.

From Ludwig Edelstein, *The Hippocratic Oath: Text, Translation, and Interpretation*, Baltimore, Md.: Johns Hopkins Press, 1943

The history of modern medical ethics is usually traced back to the publication by the British physician Thomas Percival in 1803 of a book entitled *Medical Ethics* (to what extent this is a result of academic linguistic Anglo-centrism is a matter for debate), but it is probably more accurate to say that the current form of medical ethics debates had their beginning in the 1960s and early 1970s (for views on the history from the two sides of the Atlantic, see Campbell 2000, Jonsen 1998). At that time, general social developments made it legitimate to criticize the medical profession for its paternalism and argue for a greater role for patients in decision-making, and the development of new medical technologies created new moral problems such as "Who should have access to kidney dialysis if not all can get it? And who should decide this?" and "What should we do in a situation where respirators can keep people in a coma alive indefinitely?"

In the 1960s and 1970s two partly overlapping conservative streams were evident in medical ethics, one religious and one based on a secular skepticism toward medical technology and the "medico-industrial complex," but these have become less and less prominent over time in academic medical ethics. Today liberal arguments are much more prevalent, especially in North America and Northern Europe. The liberal arguments often draw on elements from American pragmatism, classical political liberalism and modern preference consequentialism.

## Specific Features of Medical Ethics

Medical ethics differs from other branches of applied ethics in some respects. A number of ethical frameworks have been developed that try to mediate between abstract ethical theory and healthcare practice by providing a simple and structured method for analyzing and evaluating moral issues. The most prominent of these frameworks is the four-principles approach developed by Tom Beauchamp and James Childress (Beauchamp and Childress 2001). According to Beauchamp and Childress, four principles are central to medical ethics:

Respect for autonomy
Non-maleficence
Beneficence
Justice

These principles are mid-level in the sense that they are at a level between ethical theory and concrete moral decisions. They are both justified from above – any plausible ethical theory will support some version of each of the four principles – and from below – critical reflection on our day-to-day decision-making will show that it adheres to these principles. Although there is disagreement at the level of ethical theory, and at the level of unreflective day-to-day decision-making, these four mid-level principles can therefore form a relatively stable ground for resolving ethical conflict. When healthcare professionals encounter a moral problem they should therefore identify all the relevant actors, analyze how the problem engages each of the four principles and reach a decision based on balancing the four principles against each other in the concrete situation.

Many papers on ethical issues in general medical journals use this or other similar approaches rather uncritically and will therefore often seem very simplistic to someone with a background in moral philosophy.

Critics of the four-principles approach and other similar approaches have pointed out that the claimed agreement on the four principles is not an agreement on their content or substance, but only an agreement at the level of labels (Holm 1995). We can all agree that we should do good – the principle of Beneficence – but we do not agree on what this actually entails. Another common criticism is that the procedure for balancing the four principles against each other is vague and will not lead to determinate results.

Another specific feature of modern medical ethics is that it has developed in an intensive interplay with regulatory efforts, first in the area of research ethics and more recently in the areas of human (assisted) reproduction and end-of-life decision-making. This has meant that many quasi-legal concepts and modes of argumentation have entered medical ethics, especially in US medical ethics because of the practical importance of US Supreme Court decisions in these fields (the right to abortion in the US, for instance, comes from a Supreme Court decision not from legislation passed by Congress). Concepts like "privacy," "freedom of speech" and "separation of church and state" have thus been pressed into service in ethical arguments, instead of concepts that are more basic to ethical theory and political philosophy like "liberty" or "liberalism."

## Recent Developments

In recent years many have argued that medical ethics has been too preoccupied with the ethical issues actualized by modern technologies, and with the ethical problems that are common in affluent healthcare systems. There has therefore been a call to globalize medical ethics and focus more on issues of justice, power and exploitation relevant to the developing world.

The emerging debate on these issues has shown that there is an underlying individualism in the most prominent approaches to medical ethics that makes it difficult to engage with more systemic issues. Many medical ethicists agree that the distribution of resources in the world is grossly unjust and inequitable, and that this should be rectified, but still defend the right of those who have resources (the rich) to engage in exchanges with those who lack them (the poor) where the resource disparities are used by the rich to extract much better bargaining outcomes for themselves than they could have extracted under conditions of justice.

Another recent development is the formal international codification of medical ethics, often under the label of bioethics. The Council of Europe agreed on the "Convention for the Protection of Human Rights and Dignity of the Human Being with Regard to the Application of Biology and Medicine: Convention on Human Rights and Biomedicine" in 1997, and the General Assembly of UNESCO adopted the "Universal Declaration on Bioethics and Human Rights" in 2005. The development of these formal documents is seen by some as part of a widening split between official and academic medical ethics.

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# 82

# Nanoethics

## JOHN WECKERT

Nanoethics is the ethics of nanotechnology or, better, of *nanotechnologies*. What is called nanotechnology is a set of enabling technologies that are used, for example, in materials, medical technology and electronics.

Is nanoethics a branch of applied ethics similar to, for example, bioethics or computer ethics? It can be argued, quite plausibly, that it is not, but it is not clear that this matters. Swierstra and Rip, for example, argue that, while there might not be a nanoethics, there is an ethics of new and emerging technology (NEST ethics), and Schmid et al. argue that the ethical issues that arise in connection with nanotechnology are, by and large, not new ethical problems but nevertheless must be examined because they can arise in new or more urgent ways (Schmid et al. 2006: 433).

One difficulty is that many of the ethical issues in nanotechnology are in areas where there has as yet been little development, so discussion of them must be based on prediction, which of course is notoriously unreliable, and this is particularly true of predictions about the directions of scientific and technological developments. However, while it must be done with care, some prediction about the development and likely impacts of nanotechnology is both necessary and possible, and this in itself has become a topic in nanoethics.

While it is true that most, perhaps all, of the ethical issues raised by nanotechnology are not new, and many involve prediction of future developments, it does not follow that we should not talk about *nanoethics*. There is a cluster of ethical issues surrounding nanotechnologies that are both important and interesting and that require examination. One of the most pressing current ones is concern about possible risks, both to health and to the environment, associated with nanoparticle toxicity. The ethical considerations arise in connection with the level of risk that should be tolerated. The problem is not so much that there are known to be dangers but rather that, because of the wide range of different nanoparticles with different properties, there are inherent difficulties in assessing risks and in formulating regulations to control them. There is debate, too, about whether current regulations are adequate to cover materials at the nanoscale or whether new regulations are required.

Many other problems will be exacerbated and made more urgent by developments in nanotechnology. A good example is privacy. Given the fact that nanotechnologies will enable more sophisticated monitoring and surveillance technology, particularly

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in the form of more sensitive and much smaller sensing devices together with increased computing power, both processing speed and memory size, the capacity to collect information on individuals, and generate information through data-mining, will increase and with it implications for civil liberties.

Nanotechnology is promising many medical benefits, for example, new lab-on-a-chip technology for diagnosis, and targeted drug delivery. While these are undoubtedly to be welcomed, associated risks must be assessed, and so must the issue of the diagnosis of diseases for which there are no cures.

There is a growing literature, too, on the moral issues involved in human enhancement and longevity that is at least partially enabled by nanotechnology. Therapeutic implants – for example, computer chips to overcome blindness and some psychiatric conditions – will almost certainly be further enabled by developments in nanotechnology and most likely lead to implants for enhancements. There is already research on cognitive enhancement involving memory and reasoning ability and new learning techniques; the enhancement of our senses; direct brain-to-brain communication, and brain-to-machine communication.

Most of the current developments in nanotechnology are in rich countries, and perhaps these developments will only help the rich, thereby creating a nanodivide. One of the issues here concerns intellectual property. If most patents are held in rich countries, developing countries may have only limited access to potentially extremely beneficial products and technologies.

Various potential military uses of nanotechnologies are of concern and perhaps could lead to another arms race. Examples of such weapons include weapons with some ability to make autonomous decisions, tiny missiles of perhaps only a few millimetres in length, enhancement of soldier performance through implants, sensors and so on, and small animals or insects with sensor or even explosive implants.

Finally, other ethical problems arise from a more radical and much contested view of nanotechnology: molecular manufacturing, a view where mechanical engineering principles and self-replication could be used at the nanoscale to build inexpensively just about any product. Uncontrolled self-replication, however, some believe, could lead to the so-called "grey goo" problem. There is, however, skepticism that this is a real problem.

Given that developments in nanotechnologies are still in their infancy, there is considerable discussion regarding both the direction that research and development should take and how nanoethics should be done. Regarding the former, there have been various calls for the precautionary principle to be applied to certain research and development, and much opposition to these calls. This raises issues about who, if anyone, should control or regulate the direction of research or development in nanotechnology and what responsibilities scientists have for the consequences of their research. Nanoethics, therefore, currently includes examination of the control and regulation of research directions and the responsibility of nanotechnology scientists and developers, and discussion of methodologies for assessing future developments, as well as issues such as those mentioned previously.

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## 83

# Nuclear Ethics

KOOS VAN DER BRUGGEN

## Introduction

For more than forty years (1945–89) most of the world was divided in a bipolar power system: on the one hand, the United States with its allies in the "Western or free world"; on the other hand, the Soviet Union with its allies in the "communist world."

In the same year, 1945, that the world became divided, a new weapon was invented: the nuclear bomb. The weapon was used twice during the end of the war against Japan. Hiroshima and Nagasaki were completely destroyed. From the beginning of the nuclear era the atomic bomb gave rise to vehement political and ethical disputes. Just after 1945, different opinions rose about nuclear weapons:

*Just another weapon*. The atomic weapon of course is much stronger than the weapons that had existed until then, but its function and its possibilities are not essentially different: it is "just another weapon."

*A counterforce weapon*. This weapon should (only) be used to destroy the weapons of the enemy.

*A weapon of terror*. As was seen in Hiroshima and Nagasaki, nuclear weapons are weapons of terror that destroy populations.

*A weapon under international control.* The American diplomat Bernard Baruch presented a plan to the International Atomic Agency in which he proposed to put the knowledge of atomic weapons under international control. The Russians rejected this proposal.

*A weapon of deterrence*. It was Bernard Brodie who was the first one to say that the atomic weapon could only be a weapon of deterrence: its only function could be to prevent other states from using their nuclear weapons.

## Ethics and the Use of Nuclear Weapons

Moral thinking about weapons, so about nuclear weapons as well, implies moral thinking about war. That is why the "just war" tradition is a starting-point for many considerations on nuclear weapons and nuclear deterrence. "Just war" tradition has

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a history of centuries and has its roots in religion and theology, philosophy, knighthood tradition and (international) law. It has two main elements: *ius ad bellum* and *ius in bello*.

The *ius ad bellum* deals with moral conditions for starting a war. The main criteria are:

*legitimate authority:* only sovereign states are allowed to wage war;
*just cause:* in line with the UN Charter, only a reaction to foreign aggression and actions that are sanctioned by the Security Council are seen as a just cause;
*chance of success:* the consequentialist argument that a war that cannot be won should not be waged;
*last resort:* no other solution is still possible;
*proportionality of war:* the means should be in a proportionate relation to the goals of war.

The *ius in bello* deals with moral considerations that have to be respected during a war. Main criteria of the *ius in bello* are:

*proportionality in war:* actions during a war must be in a proportionate relation to the goals of that action and of war as such;
*discrimination or non-combatant immunity:* direct or indirect threat or violence against the civil population is not allowed.

Applying "just war" criteria to the use of nuclear weapons leads almost inevitably to the conclusion that such a use is morally unacceptable: it is disproportional, the weapons destroy what they should protect; non-combatants are almost by definition victims; the damage can last decades. But what if nuclear weapons are used as a counterforce weapon (and not directed at non-combatants; what if it is only a "mininuke," a nuclear weapon with a small nuclear device and because of that less devastating; and what if using a nuclear weapon is seen as the only way to end an ongoing war (Hiroshima argument)?

Although these considerations are to be weighed carefully in each individual case, most ethicists conclude that none of these considerations is compelling enough to make the use of nuclear weapons morally acceptable. The foreseen and unforeseen consequences are too great; collateral damage is almost unavoidable; there is the risk of escalation and retaliation.

So there are strong reasons to stick to an unconditional No to the use of nuclear weapons! And history since 1945 seems to confirm that politicians share this view. For, despite all declaratory policy, a taboo has grown on using nuclear weapons. Until now nobody has dared to break that taboo: not one of the so-called rogue states (Iran, North Korea), nor the US or any of the other nuclear states. Having nuclear weapons seems to be more a political than a military goal.

## Ethics and the Possession of Nuclear Weapons

If using nuclear weapons is morally unacceptable, what about *having* nuclear weapons? At first sight it seems evident that possessing nuclear weapons should be unacceptable, too. But reality is not that simple. Nuclear weapons exist, and the knowledge to make them will always continue to exist. These weapons cannot be "uninvented."

Moreover, in line with the prophetic words of Bernard Brodie, the nuclear weapon has above all become a weapon of deterrence: preventing other states from using their nuclear weapons. Some even say that having nuclear weapons as such is deterring already. Nuclear weapons imply deterring, preventing others from using nuclear weapons. If this is the case, possession could be morally acceptable. But immediately the next question rises: Is the risky game of deterrence really working? And there is always the issue of accidental use of nuclear weapons. So the crucial question remains: Is deterring with nuclear weapons morally acceptable if using them is morally unacceptable?

## Toward a Theory of Justified Deterrence

For a considered moral judgment on the possession of and deterrence with nuclear weapons, an ethical theory is needed that can catch the paradoxes that "just war" criteria cannot catch. Such a theory of justified deterrence has parallels and differences with "just war" tradition. A parallel is the distinction between a *ius ad dissuasionem* (the right to initiate a situation of deterrence) and a *ius in dissuasione* (rights and duties in a situation of deterrence). Possible criteria:

*ius ad dissuasionem*
Only a legitimate authority may carry out a policy of deterrence.
Deterrence should be aimed only at preventing military aggression by other states or non-state actors.
*ius in dissuasione*
The strategy and means of deterrence must be such that the effect of the threat of deterrence is maximal (principle of effectiveness).
The strategy and means of deterrence must be such that after a possible failure of deterrence the level of violence is minimal or at least proportionate to the goals of the war to be fought (principle of external proportionality).
Quantitatively and qualitatively the means of deterrence have to be minimal or at least proportionate to the goals of deterrence (principle of internal proportionality).
In any threat of deterrence a distinction should be made between military and non-military targets. Civilians may not become the target of a threat (principle of discrimination).
The threat of deterrence may not be misleading or ambiguous.

These criteria are not to be seen as unchangeable and not debatable. Like the "just war" criteria, these criteria are no dogmas. They are and should be adapted to new military, political and technological circumstances.

## Applying Justified Deterrence Theory

Can nuclear deterrence during the Cold War be justified in retrospect, when applying the theory of justified deterrence? Looking at the criteria, this is very doubtful. In fact only three criteria are more or less respected: both criteria of the *ius ad dissuasionem* criteria and the principle of effectiveness. In a consequentialistic way of reasoning, this principle of effectiveness is the most important one. Even for non-consequentialists it may be a defensible thesis that from a moral point of view nuclear deterrence during the Cold War was not by definition unjustified, if it can be shown that this deterrence indeed was effective in preventing a real nuclear war, which always would have been a greater evil.

But can having nuclear weapons be justified in the post-Cold War and post-9/11 world? Bipolar deterrence does not provide any legitimation any more. But some form of deterrence still exists. Having is deterring, even if that is not expressed. And having is providing status in international relations. That is one of the main reasons for countries such as North Korea and Iran to become a member of the nuclear club, but the paradoxical effect is that the more members this club has, the greater the chance of intended or unintended use of nuclear weapons. This risk may even increase if non-state actors such as terrorist groups get nuclear weapons.

Given the impossibility of "uninventing" nuclear weapons, the world will never completely get rid of them. But applying the criteria for justified deterrence there surely are some moral prescriptions in the post-9/11 era. Measures should be taken to make the chance of intended or unintended use of nuclear weapons as small as possible. Such measures are the prevention of the further spread of nuclear weapons, and an ultimate goal could and perhaps even should be to replace the present multipolar deterrence by the development of a kind of a new Baruch plan for a new supra-national deterrence structure.

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# 84

# Religion and Technology

## CARL MITCHAM

The relation between religion and science has been the subject of extended philosophical discussions, that between religion and technology much less so. When religious belief (in one European version) is bound up with an Earth-centered cosmology or theology of creation and opposed by heliocentric astronomy or evolutionary biology respectively, problems readily arise. Either the belief needs purification or the science is mistaken; boundaries must be adjudicated and interactions analyzed. Yet, in so far as technology is simply an instrumental means, any opposition would seem to be downgraded from the level of analysis to one of temptation to misuse – with temptations being adequately addressed simply with more resolute faith. Existentially, however, technologies can be designed to appeal to lower or higher human inclinations in ways that enhance one over the other, so that in practice, if not in theory, there can exist problematic relations between religion and technology. In addition, there is the problematic claim that one particular religion (namely Christianity) contributed uniquely to the rise of technology in its modern form.

To restate, from the perspective of ethics alone: Both historically and culturally, moral practice is closely associated with religion. This is true in two senses: Many people find it difficult to imagine a morality that is not religiously based. Virtually no one can imagine religions that do not include substantive components of morality, even if their adherents may fail to live out the moral ideals to which they are committed. Indeed, virtually all religions seem to pose some degree of tension or conflict between alternative ways of life and to argue for one of these ways as higher or superior. In so far as technology itself can constitute a way of life, it is thus subject to religious or spiritual assessment. To some extent, then, the question of the relation between religion and technology can be considered as a special version of the relation between moral theory or ethics and technology.

Religion and technology, like ethics and technology, can be analyzed in terms of historical traditions, basic features, or particular issues. In terms of historical traditions, it would be necessary to consider what different religions, from Hinduism to Islam, might have to say about technology. In terms of basic features, religion and technology are, in different senses, fundamentally related and opposed, so that the key philosophical challenge is to identify and assess these different relations. With regard to particular issues, from industrialization to nuclear weapons, environmental pollution, artificial

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contraception, medicalized abortion and euthanasia, computerized communication, and space travel the discussion could easily expand beyond the confines of an introductory overview.

## Historico-theological Debates

One prominent instance of analyzing what historical traditions have to say about technology centers around the question of whether Christianity made a distinctive contribution to the rise of modern technology. The relation between Christianity and technology was initially broached in scholarly form by the social scientist Max Weber (1864–1920), who focused on the contribution of Protestant Christianity to the development of capitalist industrialization. By attributing to Christianity some responsibility for the rise of techno-capitalist civilization, Weber popularized a criticism previously advanced by philosopher Friedrich Nietzsche (1844–1900), that bourgeois culture was simply Christian morality write large.

Prior to the initial stirrings of distinctly modern attitudes, most religious philosophies were at least minimally wary of what is now called technology. The argument was fundamentally quite simple: that the pursuit and practice of technics distracts from higher things. This idea can be found in the Jewish–Christian scriptures as well as in Daoist and Buddhist teachings. In the first case, one may cite the stories of a conflict between the shepherd, Abel, and the builder of cities, Cain (Genesis 4), and of the attempt by humans to aggrandize themselves through the technical construction of a tower that would undermine dependence on the divine (Genesis 11: 4–9). In the second, a story from China relates that the sage Chuang Tzu (fourth century BCE) once saw a peasant irrigating his garden with a bucket and explained how irrigation could be done more easily with a machine called a shadoof. The old peasant declined the advice, contending that “where there are ingenious machines, there are sure to be crafty actions [and] a scheming mind [that undermines] simplicity. . . . The unsettled spirit is not the proper residence of the Dao” (see Muller 1891: bk 12, sect. 11).

With conscious opposition to such traditions, modernity arose during the long sixteenth century in association with arguments for the priority of technology in human affairs. These arguments at once tended to criticize traditional religious beliefs and reinterpret them in radical ways. For instance, Francis Bacon (1561–1626) argued that the practice of Christian charity required pursuit of the control of nature for relief of the human estate. Weber’s *The Protestant Ethic and the Spirit of Capitalism* (1904–5) found in Calvinist theology another source of commitment to this-worldly transformation.

According to Weber, cultures are characterized by the presence of numerous techniques. “There are,” Weber observed, “techniques of every conceivable type of action, techniques of prayer, of asceticism, of thought and research, of memorizing, of education, of exercising political or hierarchic domination, of administration, of making love, of making war, of musical performance, of sculpture and painting, of arriving at legal decisions” (*Economy and Society*, Vol. 1, p. 65). In premodern cultures these techniques are never evaluated solely in their own terms, that is, in terms of effectiveness or their “rational” relation to some well-defined material product. The technique of butchering, for instance, was customarily oriented not solely toward the preparation of meat, but also involved placating the gods or acting in harmony with various ritual prescriptions. Only with the rise of Protestantism did religion, economics, politics, the arts, and other dimensions of culture get spun off into semi-autonomous spheres, thus making possible an assessment of their techniques in strictly rational terms – and thereby giving birth to what we now appropriately call "technology."

The Weber thesis has been criticized by those suspicious of mono-causal explanations and uneasy with giving such strong weight to "ideal types" and personal agency. While Robert Merton (1938) offered complementary confirmation to Weber, others have challenged Weber's understanding of Protestantism, which privileged interpretations on the basis of their influence not their orthodoxy. In reality, according to the Christian sociologist Jacques Ellul, "The technical movement of the West developed in a world which had already withdrawn from the dominant influence of Christianity" (1954: 35).

Just as the Weber debate seemed to have exhausted itself, the historian of technology Lynn White, Jr (1907–87) expanded analysis of the Christianity–technology relationship by pushing the argument for a positive relationship between certain kinds of religious asceticism and the pursuit of technical prowess back into medieval Latin Catholicism and criticizing not its promotion of bourgeois values but as a cause of the environmental crisis. White excluded only Eastern Orthodox Christianity because of its interpretation of Christian teaching as more a *gnosis*, or spiritual enlightenment, than a disciplining of the will, and its resistance to the contamination of sacred space with mechanical devices such as the organ and the clock. His essay on "The Historical Roots of Our Ecologic Crisis" (1967) credited Western Christianity with a large measure of responsibility for environmental pollution because of its emphasis on active conformity to God's will and a sympathy for power technologies.

The impact of White's criticism, especially in so far as it was used to develop a pro-pagan environmentalism critical of Christianity (contrary to White himself, who argued for a reform Christianity with appeal to Franciscan respect for nature), was the stimulation of a double defense. One defense challenged White's characterization of Christian theology, the other his assumptions about the environmental crisis. Against White's claim that Christianity promoted technological exploitation of nature and was thus to blame for the environmental crisis, a spectrum of theologians from Catholic to evangelical replied, in arguments reminiscent of earlier responses to Weber, that White had failed to distinguish true Christianity from its cultural perversions. The authentic Christian teaching, such apologists maintained, was environmental stewardship. A second defense argued against White that technology was not properly characterized as causing an environmental crisis, but instead had done more to benefit humanity in ways consonant with the requirements of Christian charity than all environmentalists together – and was actually overcoming the alleged environmental problems attributed to it. No book has better documented the pro-technology response than David Noble's *The Religion of Technology* (1997).

## From History to Philosophy

The historiological problem of accounting for the uniquely European origins of modern technology remains a somewhat parochial discussion in regard to the attitudes of various world religions toward technology. A broader discussion of religion and technology attempts to analyze and consider intrinsic affinities or tensions between the two key phenomena, the definitions of which manifest their own problematics. Indeed, arguments have even been made that there is no such thing as either religion or technology, that there are only religions and technologies. Yet even to apply the terms in their plural forms implies something in common among the diverse phenomena so named. In each case it is thus reasonable to inquire about the unifying features.

Consider, first, the case of technology, because it is slightly easier. Technology – whose etymology derives from a combination of the Greek *techne*, art or skill, and *logos*, speech or reason – has been variously understood to be restricted to or to include technique or technics, machines and structures, the mechanical arts and crafts, applied science, invention, engineering, the pursuit of power or efficiency, any means to an end, and more. One unifying feature thus readily appears to be physical objects made and used by human beings, with an important distinction to be maintained between premodern or handcraft technics and modern engineering or mass-production technology. Nevertheless, the strict demarcation of technology as the making and using of artifacts in any of its manifesting modes as object, knowledge, activity and intention from other types of object (such as natural ones?), knowledge (versus scientific?), activity (versus play?) and intention (versus aesthetic?) remains difficult (Mitcham 1994).

With "religion," even the etymology is contested. Cicero derived the Latin *religio* from *re*, "again," plus *legere*, "to read," thus referencing the repetitious reading of sacred texts; Augustine from *re* plus *ligare*, "to connect," meaning to reconnect humans to the divine or to bind them in community through a common commitment to the sacred. The English term has been differentially identified with faith, belief system, or human behaviors related to the sacred, divine or supernatural. One synthetic definition can be adapted from Ninian Smart (1984): A religion is a set of socially institutionalized rituals (activities) expressing and/or evoking experiences of the transcendent understood in terms of myths and doctrines (knowledge) and implicating morals (intentions). As Smart further remarks, the myths and rituals also engender symbolic products in art, music, poetry and architecture (artifacts).

These two conceptual analyses suggest at least four modalities in which religion may intersect with craft technics or scientific technology, possibilities summarized (and modestly expanded) by means of Table 84.1.

**Table 84.1** Opportunities for collaboration and opposition

| | *Religion* | *Craft technics* | *Scientific technology* |
|---|---|---|---|
| Physical objects | Particular temples and paintings | Hand-crafted pots | Mass-produced cars or computers |
| Types of knowledge | Revelations and teachings | Intuitive skills | Engineering sciences |
| Forms of activity | Praying and worshipping | Holistic processes: constructing and using | Analysis and synthesis: constructing and using |
| Intentions | Transcendence | Particular products | Mass production and consumer products |

It is thus possible to consider in turn possible arguments, often of an existential character, between various aspects of religious experience and different modes of the manifestation of technology, highlighting opportunities for collaboration and opposition. Among the more systematic philosophical efforts to explore a spectrum of interactions are those by Carl Mitcham and Jim Grote (1984), William Jones and Warren Matthews (1990), Frederick Ferré (1993), Jay Newman (1997) and others. Drawing on these and related approaches, while keeping in mind the distinction between craft technics and scientific technology, one can venture a number of observations about relationships that play out across an indefinite number of particular issues.

With regard to those material objects or artifacts constructed and used as ritual instruments or structures for worship, one would expect little if any opposition between religion and technics – except in so far as technics can on occasion have unintended consequences. The replacement of such crafted ritual instruments by scientifically engineered products, however, as when candles are replaced by electric lights imitating candles, may pose questions. Indeed, since artifacts – as well as knowledge, activity and intention – can, alongside unintended consequences, serve as vectors for diverse explicit or implicit restructurings of the world, these dimensions of technology run the chance of transforming or opposing religious experience. Attempts to adapt technological products, processes and systems to facilitate religious practices have nevertheless been pursued especially by orthodox Jews (see Gerstenfeld and Wyler 2006) and Protestant Christians (see Spyker 2007).

Consider also the issue of technological knowledge. Here, too, there is probably less room for concern at the level of craft knowledge, although such knowledge is often hedged in by religious mores, as when medical or alchemical knowledge is embedded in religious traditions as diverse as Hinduism and Islam. In the modern world, although the engineering sciences may not be logically at odds with revelation or worship, there are certainly individuals who have known what might be described as existential tensions between the spirit engaged in the meditative reading of sacred texts, the conduct of worship, or efforts to open oneself to transcendent experiences of the self or world and those human experiences manifest and drawn forth by advancing, say, fluid mechanics, or in utilizing fluid mechanics in design work. Some engineers and inventors certainly experience the act of invention and design as itself involving a kind of self-transcendence. (For some papers that touch on this topic, see Mitcham and Richardson 1999.)

Issues with regard to activity are perhaps the most extensive. First, at the craft level, religious activities often overlap with technique. But at the level of technological activities – as with industrialized production and consumption; the design, construction and operation of technological systems; and the development of diverse technoscientific practices – numerous questions arise. Religious activity itself may be said to take three primary forms: ritual performance, prayer or contemplation, and good works (meaning especially works of compassion and charity). With regard to ritual performance, competitions arise between the demands of life in a technological society and those of ritual; there is not always sufficient time for both. With regard to prayer and contemplation, not only are there time competitions, but also the practices of technological work, from the industrial to service and information sectors, can tend to undermine the habits and attitudes on which they depend. For instance, prayer and contemplation seem quite compatible with the slow place of plowing a field, but not with assembly-line labor or fast food preparation and customer delivery.

With regard to good works, issues of social justice become prominent. Indeed, Christian socialism was one of the primary drivers to address economic inequities and the sufferings of the working class during the industrial revolution. For Gandhi, Hinduism (despite its own problems with the caste system) served as a resource for addressing political injustice closely associated with technological exploitation in the form of colonialism and provided inspiration for a vision of craft technics revival. At the same time, many Hindus, Jews, Christians, Muslims and others have argued that the mass production of goods and services is a practical realization of spiritual concern for the welfare of others. This same tension appears equally dramatically in the realm of medical practice as transformed by advances in medical science and therapeutic practice. On the one hand, there are those who see all medicine, from low- to high-tech, as the exercise of love and concern for others; on the other, there are selected critics from virtually all religious communities who see at least certain techno-medical practices (e.g. artificial birth control and medicalized abortion) as inherently evil.

The intention at work in technology has been variously characterized as the pursuit of power or efficiency. No matter how it is described, clearly technology in its most obvious forms aims at transforming the physical world. It is difficult not to see this intention as deeply at odds with the aspiration for transcendence found at the heart of many religions. Take Buddhism as a case in point. The way of the Buddha is summarized in the teaching of the Four Noble Truths. First is the truth that all life, not just human life, is *Dukkha*, suffering or lack of satisfaction. Second is the truth that suffering has an origin in craving or desiring. Third is the truth that suffering can cease or fade away with the abandonment of craving and desiring. Fourth is the truth of the Noble Eightfold Path that can lead to the abandonment of craving and desiring. The Noble Eightfold Path involves the practice of right view, right intention, right speech, right action, right livelihood, right effort, right mindfulness, and right concentration. In Buddhism it is difficult not to detect a deep opposition to technology, in so far as technology aims not to abandon desires but to satisfy them through more effective views and actions. This is an opposition, for instance, on which E. F. Schumacher has drawn in his essay “Buddhist Economics” (1973), in support of a notion of alternative technology. By contrast, of course, as has already been mentioned, in the Christian tradition there would seem to be intentional commitments to caring for others physically that would be able to make common alliance with technology. Similar intentions can be argued as present in other religions of the book, that is, in Judaism and Islam.

## Conclusions

In so far as the religion–technology relation is linked to the ethics–technology relation, what might the religion–technology add? There are at least two possibilities. First, because religion adds to ethics both affective and institutional components, it provides supplementary resources for dealing with the moral challenges of technology. Religion has, for instance, made significant contributions to dealing with the moral issues and substantive threats raised by nuclear weapons and environmental pollution. Of course, at the same time, religion has often complicated secular approaches to other moral issues such as population control.

Second, and perhaps more important philosophically, critical religious reflection on technology can widen and deepen ethical perspectives. Most perspicaciously, critical religious thought can examine the extent to which technology itself might function as or attempt to replace religion. Such an approach might moderate some religious enthusiasms with regard to technology.

Finally, it is worth considering which religious traditions might offer the best complements to ethics from any number of perspectives. Such reflections (as in, e.g., Szerszynski 2005 and Waters 2006) might well function as a creative contribution to the multiple dimensional encounters between religions that are enfolded in the globalization that is itself promoted by technology.

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# 85

# Technology and Personal Moral Responsibility

## JESPER RYBERG

The development of new technology gives rise to several ethical questions concerning the moral responsibility of those who carry out the development, i.e. the scientists (obviously, such work may involve traditional scientists, engineers and several other groups; however, for reasons of ease in exposition I shall here use “the scientists”). One type of question concerns the moral legitimacy of the scientific work itself. For instance, to what extent is it acceptable to perform experiments on animals or humans? What is the proper behavior when scientists are competing with other scientists? How and to what extent ought new results to be presented? Such questions have over the last decades been treated within different fields of ethics such as the ethics of animals, medical ethics and, more recently, what has become known as research ethics (see Erwin, Gendin and Kleiman 1994). Another type of question, however, concerns not the scientific process itself, but the application of the results of the scientific research. The fact that the scientific work, especially the work that leads to new technology, may end up having a severe impact on many people’s lives raises the question concerning the extent to which scientists should be regarded as personally responsible for the consequences of their work. This is the question to be dealt with here.

Shortly after the end of the Second World War a correspondence took place between Albert Einstein and the American Quaker A. J. Muste (see Chalk 1989). The background for this correspondence was an appeal in which Einstein urged the public for donations to support scientists in their attempts to develop controls limiting the use of nuclear weapons. The point made by Muste was that if the appeal were to be taken seriously, then what Einstein and other scientists should do would be to renounce any involvement in constructing such weapons in the first place. He concluded by asking: “As for the masses, how can they be expected to believe that atomic weapons are as worthless and horrible as the scientists say they are, when the scientists continue to make the things . . . ,” and, furthermore, he declared that this “cannot make sense to ordinary human beings” (Chalk 1989: 61).

The question that constitutes the core of this correspondence, and one which has often later been posed, is: Do scientists have a moral responsibility for the consequences of their work – for instance, the death of people that might follow from the construction of certain types of weapons? Naturally the question can be posed positively, such as whether there is an obligation for the scientist to take part in research

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that will be to the benefit of many people. However, since scientists usually have various incentives – for instance, what J. R. Oppenheimer once referred to as the "sweetness" of scientific problems or simply their salary – to engage in scientific work, the question has typically been phrased negatively, such as whether there exists a moral obligation to abstain from carrying out or participating in certain kinds of research.

According to one stand, this question should be answered in the negative. In academic discussions, as well as in broader public discussions, several arguments have been presented to this effect. Following one such argument, the idea of the moral responsibility of scientists rests on misrepresentation of the nature of scientific work. Correctly perceived, scientific inquiry is an activity that seeks to eliminate an undesirable characteristic of a situation. However, since the scientist cannot foresee the specific truth his work will yield – otherwise why should he have engaged in inquiry in the first place? – it makes no sense to hold him/her responsible for results that follow from the research (see Hoffman 1975). To this argument it might be objected that, even though some scientific research is pure or fundamental, in the sense that from the outset it is not clear what the precise purpose of the inquiry consists in, there is also scientific work that is "mission-oriented," in the sense that the scientist has a very good idea of what he/she is looking for. This is especially the case when it comes to the development of new technology: one often knows what one is aiming at, but not how to reach or construct it (Belsey 1978). Moreover, even though scientific work sometimes produces totally unexpected results, this does not indicate whether or not the scientist ought to communicate his/her results (Ryberg 2003).

Another argument to the effect that the scientist should not be held morally responsible proclaims that questions of right and wrong are state matters, not matters that lie in the hands of individual scientists. This argument was presented by several scientists in their objection to Muste's appeal. For instance, W. Higginbotham contended: "We believe in government of the people . . . if scientists were to walk out on all military projects they would be taking the law into their own hands just as surely as the Ku Klux Klan" (Chalk 1989: 69). More generally, the view is that morality should be handled by the state. This argument raises several questions. For instance, is it not the fact that there are many cases where we have a personal moral responsibility independently of what a state decides? And does the argument presuppose that state decisions are always right? If so, are there not many examples in our history that bring this assumption into question?

Perhaps the argument which most naturally comes to mind is the one that claims that scientists should not be held responsible, for the simple reason that they do not decide how the results of their work should be applied (Hoffman 1975). Responsibility for use is rightly ascribed to whoever formulates a policy and whoever makes the decisions, and this group almost never includes scientists but rather politicians. This argument leads one to wonder whether the fact that one could have prevented a certain undesirable outcome from happening is not sufficient for the ascription of responsibility, no matter whether other people's decisions intervene in the series of events leading to this outcome (Ryberg 2003).

A further argument worth mentioning has been referred to as the "replaceability argument" (see Lackey 1994). In short, the argument says that "If I did not do it, someone else would" and, therefore, "I did not really do anything wrong." If an undesirable outcome follows from a scientist's work, but this work would have been carried out by another scientist had the first rejected it, then, the argument goes, the first scientist had not made things worse than they would have been, and he/she should therefore not be held responsible. One way of challenging this argument would be to hold that there are certain acts that are wrong to perform independently of the consequences they produce.

As well as the above-mentioned arguments, other arguments have been presented in defence of the view that scientists do not have moral responsibility (Lackey 1994, Ryberg 2003). If one instead leaves aside the negative answers in favor of the outlook that the initially mentioned question should be answered in the affirmative, the number of arguments is much more limited. The main argument, of course, is that in so far as scientists engage in work that may have important consequences for other people's lives they do carry a moral responsibility. One of the practical challenges that follows from this point of view is that it may be very difficult for the individual scientist to foresee the consequences of his/her work. To stick to general rules such as that it is wrong to contribute to the development of military technology is probably much too simplistic. Weapons and other military technologies may be used to protect people and to prevent undesirable consequences. Moreover, technologies may turn out to have consequences that reach far beyond the more narrow purpose for which they were initially constructed. For instance, it is well known that, while nuclear power, and also drugs, pesticides, aircraft, radar, processed food, satellites, computers, transistors, lasers and many other technologies have been developed for military purposes, they have had obvious beneficial civilian applications as well. Thus transforming more general considerations on responsibility into something that can guide the individual scientist in his/her daily work may well be a complicated challenge.

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# 86

# Value-sensitive Design

## JEROEN VAN DER HOVEN AND NOEMI MANDERS-HUITS

Value-sensitive design (VSD) is an approach to systems development and software engineering which was first introduced in the last decade of the twentieth century as an approach for incorporating human values into the design of (information) technology. VSD was developed by Batya Friedman and others, building on insights of the human–computer interaction community (HCI) to draw attention to the social and moral dimensions of design. Other initiatives had also been studying the social implications of computer technology, such as computer ethics, computer-supported cooperative work (CSCW) and participatory design (PD). Some of these research communities, like value-sensitive design, have also tried to incorporate values into the design of technological systems at an early stage; however, whereas these approaches tend to focus on functional and instrumental values (e.g. user-friendliness), value-sensitive design focuses *primarily* on addressing values of *moral* import, such as privacy, trust and autonomy. Although building a user-friendly technology might also increase a user's sense of autonomy or trust, in value-sensitive design the attention for moral values is the primary goal. According to Friedman:

> Value-Sensitive Design is primarily concerned with values that center on human well-being, human dignity, justice, welfare, and human rights. Value-Sensitive Design connects the people who design systems with the people who think about and understand the values of the stakeholders who are affected by the systems. Ultimately, Value-Sensitive Design requires that we broaden the goals and criteria for judging the quality of technological systems to include those that advance human values.
>
> (Friedman and Kahn 2000)

Several authors in the field of value-sensitive design drew attention to human and moral values as an integral part of the conception, design and development of technological artifacts and systems. These include design for values (Camp 2007), values at play (Flanagan, Howe and Nissenbaum 2005; Flanagan, Howe and Nissenbaum, in press), value-sensitive design (Friedman 1999; Friedman, Kahn and Borning 2002) and disclosive computer ethics developed by Philip Brey (2000). Each of these frameworks seeks (1) to broaden the criteria for judging the quality of technological systems to include the advancement of moral values, and (2) to promulgate the proactive influencing of

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the design of technologies to account for such values during the early phase of the design process.

System developers, information architects and designers in other disciplines are traditionally primarily interested in functional requirements (e.g. speed, capacity, cost, durability, robustness) and related values such as usability, efficiency, reliability and affordability. Value-sensitive design draws attention to the impact technologies have on human well-being and the quality of human lives. The underlying idea of value-sensitive design is that technology is not value-neutral. Technology is bound to have moral and political implications for those affected by it. Furthermore, much of our technology is not merely enabling but constitutive. It shapes our practices and institutions in important ways. It changes our way of life and the way we think, in education, business, healthcare and science, van den Hoven argues (2005). Decisions made in design determine future opportunities and possibilities of those who work with it. As Friedman points out, however (Friedman and Kahn 2003), values are neither solely designed into technology, nor solely conveyed by social drivers and forces. Influence is exerted bi-directionally. New technologies may be applied and used for purposes other than those intended in design, and technologies are adjusted and changed in a dynamical development process. This is what is called an interactional position. An adequate account of technology needs to accommodate both design and social context and the interaction between them (Friedman and Kahn 2003).

Many social and philosophical scholars of technology have attempted to expose the social and political biases embedded in technical systems and artifacts (see, for example, Berg 1998; Latour 1992, 1985; Mumford 1964; Winner 1980). They argue that technologies tend to promote certain ideologies, while obscuring others. Scholars in ethics of information technology have extended this research into questions of how information technologies specifically exemplify *ethical* and *value* biases (see, for example, Friedman 1997, 2005; Moor 1985; Nissenbaum 2001; Tavani 2004). Value-sensitive design recognizes that the design of technologies bears “directly and systematically on the realization, or suppression, of particular configurations of social, ethical, and political values” (Flanagan, Howe and Nissenbaum 2005).

In order to do justice to these moral and political implications, value-sensitive design is employed as a methodology of systems design that “seeks to design technology that accounts for human values in a principled and comprehensive manner throughout the design process” (Friedman and Kahn 2000). It is at the same time, as pointed to by van den Hoven (2005), “a way of doing ethics that aims at making moral values part of technological design, research and development.” Several value-sensitive design initiatives share a similar methodological structure, an integrative and iterative tripartite methodology consisting of conceptual, empirical and technical investigations (see Friedman, Kahn and Borning 2002, 2006; or Flanagan, Howe and Nissenbaum 2005). Each of the conceptual, empirical and technical investigations and analyses are carried out iteratively, mutually informing and being informed by the other investigation. These interdependencies are metaphorically described by Nissenbaum as “balls in play” (Flanagan, Howe and Nissenbaum 2005), where attention to three different modes (balls) of investigation must be maintained and balanced for successful implementation. “Conscientious designers must juggle and keep in the play the results of at least three modes," i.e. the results of empirical, conceptual and technical research (Flanagan, Howe and Nissenbaum 2005).

The first "ball," the conceptual analysis, is informed by ethics and moral philosophy regarding particular value constructs relevant to the design in question. This connects to the development in ethics termed "The Design Turn in Applied Ethics" by van den Hoven (2007). This refers to the way in which moral philosophers are starting to think about the way in which their analyses can be successfully implemented and expressed in institutional arrangements, infrastructure, artifacts and systems, and can thereby contribute to desirable moral changes in the real world. "Value-Sensitive Design provides us with the opportunity to deal with these ethical issues in a new and fresh way: by 'frontloading ethics' by means of proactive integration of ethical reflection in the early stages of design" (van den Hoven 2005).

The second ball in play is the empirical mode of investigation, providing empirical data in support of the values investigated in the conceptual mode, as well as empirical data providing feedback in support of the technical investigation of a particular design. Finally, the third ball, the technical analysis, investigates particular technical design specifications and variables that might promote or obscure given values within the context of the technology being designed. Decisions during the design process knowingly or unknowingly determine to a large extent the moral and political implications a technology may have in practice. Any particular design enables features, opportunities and possibilities, while playing off others. In the technical analysis the focus is primarily on how technologies can support or compromise human values. Subsequently, it tries to incorporate the results of the conceptual and empirical phases into designing in a proactive manner (Friedman 2004).

The values at play (VAP) approach offers a similar tripartite methodological framework consisting of discovery, translation and verification phases (Flanagan, Howe and Nissenbaum 2005). The goal of the discovery phase is to identify the values that might be relevant to the design of a particular technology, including those explicit in the aspirations of the technology's designers, as well as those that only emerge when the technological design process is underway. The translation phase of VAP is the activity in which designers translate the value considerations identified in the discovery phase into the architecture and features of the technology. The final phase is verification, ensuring that the designers have successfully implemented the values identified throughout the discovery process. In both the VSD and VAP versions, these three modes of investigation are intended to form an integrative and iterative methodological framework for embodying human and moral values into the design of technology.

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# Part VII

# Technology and the Future

*A Companion to the Philosophy of Technology* Edited by J. K. B. Olsen, S. A. Pedersen and V. F. Hendricks
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# 87

# Technology, Prosperity and Risk

SVEN OVE HANSSON

## 1. Introduction

Owing to the increasing pace of technological innovation, every generation is more aware than its predecessors that the world they leave behind will be different from the one they took over. Technology radically changes the human condition, and it does so in ways that we cannot foresee. Can we gain more control and foresight in this process?

Two major attempts have been made to deal systematically with the uncertainties that technology gives rise to, namely risk analysis and technology assessment. They both arose in the 1970s in response to public concern with negative aspects of new and emerging technologies.

Risk analysis and technology assessment are two perspectives on the same basic problem, namely our lack of knowledge about the effects of technology. They are usually dealt with by different groups of experts, and one seldom sees them treated in one and the same context. In this section, they will be juxtaposed and combined in a series of chapters that reflect the wide range of ongoing philosophical discussions about the uncertainties associated with current and future technologies.

## 2. Technological Risks

### *2.1 What is risk?*

The most basic philosophical question in connection with risk is of course: What is risk? Unfortunately, this question is far from easy to answer, since the term "risk" has several well-established usages. Often, "risk" is used to denote, in general, a situation in which something unwelcome may or may not occur, but we do not know whether or not it will. This is how we use the term when we say, for instance, that smoking is a major health risk.

On other occasions, "risk" denotes the probability of an unwelcome event. This is how you use the word, for instance, if you ask a doctor how large the risk is that a treatment will fail. This is also the standard meaning of the term in decision theory; by "decision under risk" is meant "decision with determinate probabilities."

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A third usage is common in professional risk analysis. In that discipline, "risk" often denotes a numerical representation of severity that is obtained by multiplying the probability of an unwanted event with a measure of its disvalue (negative value). When, for instance, the risks associated with nuclear energy are compared in numerical terms to those of fossil fuels, "risk" is usually taken in this third, technical sense.

In all the different senses of "risk," references to risk involve a subtle combination of knowledge and lack thereof. When there is a risk, there must be something that is unknown or has an unknown outcome. But, for this lack of knowledge to constitute a risk for us, something must be known about it. To have knowledge about a risk means to know something about what it is you do not know. This is therefore an unusually difficult type of knowledge to assess and to act upon.

## 2.2 *Risk and uncertainty*

In discussions on the effects of technology, the term "uncertainty" is equally important as "risk." The distinction between these two terms originates in decision theory. A decision is said to be made "under risk" if the relevant probabilities are known, and "under uncertainty" if they are unknown. In one of the most influential textbooks in decision theory, the terms are defined as follows:

> We shall say that we are in the realm of decision making under:
>
> (a) *Certainty* if each action is known to lead invariably to a specific outcome (the words prospect, stimulus, alternative, etc., are also used).
> (b) *Risk* if each action leads to one of a set of possible specific outcomes, each outcome occurring with a known probability. The probabilities are assumed to be known to the decision maker. For example, an action might lead to this risky outcome: a reward of $10 if a "fair" coin comes up heads, and a loss of $5 if it comes up tails. Of course, certainty is a degenerate case of risk where the probabilities are 0 and 1.
> (c) *Uncertainty* if either action or both has as its consequence a set of possible specific outcomes, but where the probabilities of these outcomes are completely unknown or are not even meaningful.
>
> (Luce and Raiffa 1957: 13)

Three additional comments are in place about the notion of uncertainty. First, uncertainty differs from "risk" in not implying undesirability. We can have uncertainty, also in this technical sense, about desirable future events. Second, it is common to use "uncertainty" in lieu of "risk or uncertainty," i.e. to define uncertainty as lack of knowledge (whether probabilistic or not) and risk as a species of uncertainty. Third, the term "uncertainty" often also covers decision-making under unknown possibilities, i.e. cases with ignorance about what the possible outcomes are. When discussing the effects of future nanotechnology, our problem is not that we do not know what probabilities to assign to the possible effects. Instead the problem is that we do not even have a workable list of these effects. This type of decision-making has been called "decision-making under great uncertainty" (Hansson 1996).

## *2.3 Is risk subjective?*

As we have already seen, "risk" denotes something undesirable. The tourist who hopes for a sunny week talks about the "risk" of rain, but the farmer whose crops are threatened by drought will refer to the possibility of rain as a "chance" rather than a "risk." Since the notion of risk includes a component of undesirability, it is value-laden. This value-ladenness is often overlooked since the most discussed risks refer to events such as death, diseases and environmental destruction that are uncontroversially undesirable. However, from a philosophical point of view, it is important not to confuse uncontroversial values with no values at all.

It is equally important not to confuse value-ladenness with lack of factual or objective content. Risk is not only value-laden; it is also fact-laden. The statement that you risk losing your leg if you tread on a landmine has both a factual component (landmines tend to dismember people who tread on them) and a value component (it is undesirable that you lose your leg). The propensity of these devices to mutilate is no more a subjective construct than these devices themselves.

There are discussants who deny this double nature of risk. Some maintain that risk is "objective," devoid of any subjective component. Others claim that risk is plainly a "subjective" phenomenon, not concerned with matters of fact. These are both attempts to rid a complex concept of much of its complexity. Neither is successful. Any notion of risk that connects in a reasonable way to the conditions of human life will have to admit the double nature of risk, and not try to make risk either value-free or fact-free.

## *2.4 Are the risks increasing?*

In many discussions of risk, including some of the contributions to this volume, it is taken for granted that we live in a society with increasing risks. But is this really so? Have we not always lived with tremendous uncertainties? Is not the current attention to risk and uncertainty the result of a shift in focus rather than a real increase in risks?

This is not an easy question to answer. Clearly, technological developments have imposed new risks on humanity. Most of the risks that we discuss today did not exist fifty or a hundred years ago – GMOs, nuclear power plants, organic pesticides, air-traffic accidents, etc. Others, such as global warming, have only relatively recently become sufficiently understood.

But, on the other hand, many risks have a decreasing trend. For good reasons, we pay more attention to increasing than to decreasing risks. In the industrialized parts of the world, famine is no longer a serious threat, and neither are a large number of previously incurable diseases for which cures have now been found. When some risks are increasing and others decreasing, how do we measure the total amount of risk? One reasonable measure, as far as health risks are concerned, is life expectancy. Measured in that way, total risks have decreased in the richer parts of the world since we tend to live longer. Would it perhaps be more adequate to characterize our time as one in which we have fewer risks than before, but are more aware of them?

Not necessarily so. In addition to the individual risks of everyday life, we also have to consider the collective risks that affect the future existence of humanity. A nuclear holocaust was the first such risk to be publicly discussed on a broad scale; global warming is currently the one most debated. If such large-scale global risks are taken into account, we are undeniably in a new situation, as compared to a couple of generations ago.

## 2.5 *Probabilistic risk analysis*

In professional risk analysis, risk is usually taken in the quantified sense referred to in section 2.1, namely as the statistical *expectation value* of an unwanted event that may or may not occur. In other words, risk is identified with the measure that is obtained by multiplying the probability of an unwanted event with a measure of its disvalue (negative value). If only death risks are considered (which is a surprisingly common restriction), this means that risk is identified with the statistically expected number of deaths caused by a possible event or class of possible events. Hence, if 200 deep-sea divers perform an operation in which the individual risk of death is 0.1 percent for each individual, then the expected number of fatalities from this activity is $0.001 \times 200 = 0.2$. Expectation values have the important property of being additive. Suppose that a certain activity is associated with a 1 percent probability of an accident that will kill five persons, and also with a 2 percent probability of another type of accident that will kill one person. Then the total expectation value is $0.01 \times 5 + 0.02 \times 1 = 0.07$ deaths.

Although expectation values have been calculated since the seventeenth century, the use of the term "risk" to denote them is relatively new. It was introduced into risk analysis in the influential Reactor Safety Study (WASH-1400, the Rasmussen report) from 1975 (Rechard 1999: 776). Today it is the dominant technical meaning of the term "risk." Some authors even claim that this is the only rational approach to technological risk:

> The only meaningful way to evaluate the riskiness of a technology is through probabilistic risk analysis (PRA). A PRA gives an estimate of the number of expected health impacts – e.g., the number of induced deaths – of the technology, which then allows comparisons to be made with the health impacts of competing technologies so a rational judgment can be made of their relative acceptability. Not only is that procedure attractive from the standpoint of scientific logic, but it is easily understood by the public.
>
> (Cohen 2003: 909)

PRA is increasingly often combined with the economic discipline of risk–benefit analysis, in which risks are weighed against the economic gains of taking them (or risk reductions against the costs of achieving them) (Hansson 2007a). This approach has the advantage of being simple, operative and mathematizable. It reduces problems of technological risk from issues of social contest to optimization problems – or at least it tries to do so. Unfortunately, this reduction is problematic on several accounts.

## 2.6 *The tuxedo fallacy*

In real life, uncertainties are much more common than (probabilistic) risks. Few, if any, decisions in actual life are based on probabilities that are known with certainty. Strictly speaking, the only clear-cut cases of "risk" (known probabilities) seem to be idealized textbook cases with devices such as dice, coins or roulette wheels that are supposedly known with certainty to be fair. The gambler's decisions at the roulette table are as close as we can come to decision-making under risk, i.e. with known probabilities. Given that the wheel is fair, the probabilities of various outcomes – gains and losses – are easily calculable, and thus knowable, although the gambler may not take them into account.

For an example of a decision under uncertainty, think of an explorer who considers entering a distant part of the jungle, previously untrodden by human foot. There are many dangers in the jungle, but no estimates better than guesses can be given of their probabilities. In addition, there may be unknown dangers about which we know nothing.

There is a strong tendency in decision-supporting disciplines, including risk analysis, to proceed as if reasonably reliable probability estimates were available for all possible outcomes. This has been called the *tuxedo fallacy*. It consists in treating all decisions as if they took place under epistemic conditions analogous to gambling at the roulette table. The tuxedo fallacy is dangerous since it may lead to an illusion of control and to neglect of uncertainties that should have a significant impact on decisions.

In the analysis of well-known technologies, probabilistic risk analysis can often be performed with reasonable accuracy. When there is statistically sufficient experience of an event-type, such as a machine failure, then we can determine its probability by collecting and analyzing that experience. However, for new and emerging technologies, this is often not the case. As one example of this, the future risks – and future possibilities – of the convergence of nano- and bio-technology cannot be expressed meaningfully in probabilistic terms. What future technologies offer us is much more similar to an adventure in the jungle than to a visit to the casino.

Even for well-established technologies, data are often insufficient to determine the frequencies of unusual types of failures. As one example of this, there have (fortunately) been too few severe accidents in nuclear reactors to make it possible to estimate their probabilities. In particular, most of the reactor types in use have never been involved in any serious accident. It is therefore not possible to determine the risk (probability) of a severe accident in a specified type of reactor.

## 2.7 *The ethics of risk*

Assessments in terms of "risk" in the technical sense, as the product of probability and severity, have the obvious advantage that two important factors in a risky situation, namely the probability and the severity of damage, are both taken into account. However, if strictly applied, this mode of assessment also leads to the exclusion of other factors that might influence a risk management decision. Risks are inextricably connected with morally relevant interpersonal relationships. As an example of this, it makes a big difference if a person risks her own life or that of somebody else in order to earn a fortune for herself. Person-related aspects such as agency, intentionality, consent, voluntariness, equity, etc., will have to be taken seriously in any reasonably accurate general format for the assessment of risk (Hansson 2003).

The strong focus in PRA on probabilities and outcomes, to the exclusion of ethical factors that could legitimately influence decisions, may well be a major reason why risk analysis has had such great difficulties in communicating with the public. Instead of blaming the public for not understanding probabilistic reasoning, risk analysts should learn to deal with the moral and social issues that the public so often – rightly – puts on the agenda.

## 3. Future Technology

### *3.1 Technology assessment*

Attempts to predict future technologies are at least as old as science fiction. (The beginning of science fiction is a contested issue; perhaps the first novel with an uncontested science fiction status is Mary Shelley's *Frankenstein* from 1818.) However, systematic attempts to predict technology in a scientific manner are of rather recent origin. The term "technology assessment" was introduced in 1966 by Philip Yeager, who worked for the American Congressman Emilio Q. Daddario (Ropohl 1996). Daddario proposed the creation of a Congressional agency that would help identify consequences of new technologies in advance, so that negative effects could be avoided or limited, and positive effects amplified and promoted. As a result of his endeavors, the American Office of Technology Assessment (OTA) was established in 1972. Its task was to analyze and predict the consequences of future technological development. In 1995, when OTA was closed down for political reasons, it had published over 700 reports on a wide variety of topics related to science and technology. OTA assessments were based on extensive research, involving scientists from a wide variety of disciplines. Typically, the reports did not offer specific recommendations, but instead presented alternative options and appraisals of their consequences.

Today, the main scene for TA activities is in Europe, perhaps in particular Germany. Several European countries have their own parliamentary TA offices, and since the beginning of the 1990s the importance of TA activities has also been emphasized within the European Parliament, resulting in its official TA organ Scientific Technological Options Assessment (STOA) and in the European Parliamentary Technology Assessment Network (EPTA). The European Technology Assessment Network (ETAN) was initiated by the European Commission.

Technology assessment (TA) started as an attempt to gain political control over the potential negative effects of technological development. It was expected to reveal future consequences of new technology that would not otherwise have been foreseen. However, the original optimism with respect to technological predictions was not substantiated. Technology assessors have been able to highlight important aspects of technological development and to bring them out for public discussion – which is important enough – but they have not been able to predict future technologies.

In practice, TA has retreated from the ambition to predict. The focus has largely shifted to careful analysis of specific aspects of existing technologies. One variant of TA that does this is environmental impact analysis (EIA).

### *3.2 Why we cannot predict future technology*

There are four major sources of uncertainty that combine to make future technologies unpredictable.

The first is the inherent uncertainty in the behavior of the technological device itself. As an example, consider a proposal to develop a nanotechnological device that can be injected into the body of a cancer patient, where it will be triggered by the cancer cells to release a substance that kills them. This is one of many potential uses of nanotechnology that has been proposed. Since the technology is hypothetical, and not yet specified in its details, it is difficult to identify the possible dangers that may be associated with it. Therefore, a discussion in terms of quantitative approaches to risk would be premature, and the relevant risk concept is rather that of event types. Although a meaningful list can be made of negative event types (types of device failure), there is no way to know that such a list is complete.

The second source of uncertainty is the behavior of individual users of the technology. As one example of this, users sometimes "compensate" for improved technical safety by more risk-taking behavior. Drivers are known to have driven faster or delayed braking when driving cars with better brakes (Rothengatter 2002).

The third source of uncertainty is the development of new social and cultural patterns in response to the technology. Experience shows that social and cultural developments are almost impossible to predict. A famous example is the reply a chief official of the British Post Office gave to the House of Commons in 1879 concerning the possible future of the telephone. He predicted that the telephone would have very little use in Britain since there was no shortage of messenger boys in the country (de Sola Pool 1983: 65). Today it takes some reflection to understand why such an answer could at all be given by an intelligent and well-informed person. The reason is that the telephone conversation, today a major form of human communication, was yet unknown. The telephone was therefore first seen as a more convenient version of the telegraph. Similarly, in the early days of television its potential use for living-room entertainment was not realized (de Sola Pool 1983: 99).

The fourth source of uncertainty is the interaction of technologies with complex natural systems, in particular ecosystems, that are also in practice unpredictable. Many environmental problems are the result of such unpredicted interactions with natural mechanisms. Two of the best-known examples are the effects of organohalogen compounds on the ozone layer and of greenhouse gases on the global climate.

## 4. Dealing with Technological Uncertainty

We have seen that the two traditional methods for dealing with technological uncertainties both have severe limitations. Risk analysis, in its traditional form, is based on quantitative measures of risk in the form of expectation values. In order to obtain these measures, probability values that are required are often unavailable even for technologies in use, and always unavailable for future technologies that differ in their basic structures from the technologies already in place. Technology assessment, as originally conceived, should foresee the development of new technologies and their social consequences. It has not delivered such predictions, although it has contributed to public discourse on technology in many other useful ways.

We therefore need to develop new frameworks that can provide policy guidance in the difficult issues that technological development gives rise to. In what follows, three possible beginnings for such developments will be mentioned. The first of them may be a surprise since it is much older than technology assessment or risk analysis. It may nevertheless have some of the answers for which we are searching.

### *4.1 Safety engineering*

Since the nineteenth century, engineers have specialized in workers' safety and other safety-related tasks. But, although safety engineering is taught at technological colleges and universities, it has a much lower profile than risk analysis. One of the reasons may be that whereas risk analysis is programmatically unified, covering all sorts of risk with the same methodology, safety engineering is fragmented between different areas of technology. But a closer study will reveal that the various forms of safety engineering exhibit similar ways of thinking about risk and safety. Here, we shall show this by presenting three (of the many) principles that are applied by safety engineers.

*Inherent safety*, also called primary prevention, consists in the elimination of a hazard. It is contrasted with secondary prevention that consists in retaining the hazard but reducing the risk associated with it. For a simple example, consider a process in which inflammable materials are used. Inherent safety would consist in replacing them by non-inflammable materials. Secondary prevention would consist in removing or isolating sources of ignition and/or installing fire-extinguishing equipment. As this example shows, secondary prevention usually employs add-on safety equipment. Safety engineers, in particular in the chemical industry, have developed methods to achieve as much inherent safety as possible in an industrial plant. Proponents of inherent safety maintain that, other things being equal, if we have a choice between eliminating and managing a hazard, then elimination is the better option. The major reason for this is that, as long as the hazard still exists, it can be realized by some unanticipated triggering event. Even with the best of control measures, some unforeseen chain of events can give rise, for instance, to a fire. Even the best add-on safety technology can fail, or be destroyed in the course of an accident. Even if the calculated risk is very low, this calculation may be uncertain, and this uncertainty can be sufficient reason to eliminate the hazard.

*Multiple safety barriers* are based on principles that are at least as old as the fortresses of antiquity. If the enemy manages to pass the first wall, there are additional layers that protect the defending forces. Some engineering safety barriers follow the same principle of concentric physical barriers. As one example of this, modern nuclear reactors have a series of physical barriers against radioactive leakage. In other cases, the safety barriers are consecutive in a temporal rather than a spatial sense. Consider, for instance, the protection of workers against a dangerous gas, such as hydrogen sulfide, that can leak from a chemical process. The first barrier consists in constructing the whole plant in a way that excludes uncontrolled leakage as far as possible. The second barrier is careful maintenance, including regular checking of vulnerable details such as valves. The third barrier is a warning system combined with routines for evacuation of the premises in the case of a leakage. The fourth barrier is efficient and well-trained rescue services. The basic idea behind multiple barriers is that, even if a barrier is well constructed, it may fail, perhaps for some unforeseen reason, and that the next barrier should then provide protection.

*Safety factors*, finally, are numerical factors that are used to dimension a safety reserve. The use of safety factors originates in the latter half of the nineteenth century. Safety factors now have a central role in structural mechanics and in its many applications in different engineering disciplines. Elaborate systems of safety factors have been developed, and specified in norms and standards. Most commonly, a safety factor is expressed as the ratio between a measure of the maximal load not leading to the specified type of failure and a corresponding measure of the applied load. Hence, we may choose to build a bridge so that it resists twice the highest load that we predict that it will be subjected to. We have then used a safety factor of 2. According to standard accounts of structural mechanics, safety factors are intended to compensate for five major categories of sources of failure: higher loads than those foreseen, worse properties of the material than foreseen, imperfect theory of the failure mechanism in question, possibly unknown failure mechanisms, and human error (e.g. in design) (Knoll 1976, Moses 1997). The last three of these failure types are errors in our theory and in our application of it. Thus, safety factors aim not only at calculable risk but also at non-numerical uncertainties. (It is not in practice feasible to adjust a calculation to compensate self-referentially for an estimated probability that the calculation itself may be wrong.)

As we saw in section 2.2, in the assessment of new and emerging technologies, uncertainty is often more important than calculable risks. Therefore, it speaks much in favour of safety engineering that its major guiding principles are aimed at coping not only with risks but also with uncertainties. For a further example, suppose that a ship-builder comes up with a convincing plan for an unsinkable ship (much better than *Titanic*). A probabilistic risk analysis shows that the probability of the ship sinking is incredibly low. Based on the PRA, a risk–benefit analysis is performed. It shows that the cost of lifeboats would be economically indefensible. The risk–benefit analysis therefore clearly shows us that the ship should not have any lifeboats. Would a safety engineer accept the probabilistic analysis and exclude lifeboats from the design? The answer is no, if she follows the traditions of her profession, and this for a very simple reason: the calculations may possibly be wrong, and if they are, then the outcome can be disastrous. The additional safety barrier in the form of lifeboats (and evacuation routines and all the rest) should not be excluded, in spite of the probability estimates showing them to be uncalled for.

## *4.2 Scenarios and contingency planning*

In military planning, there is a long tradition of testing alternative scenarios, based on possible strategy choices by the enemy. In the 1950s, the use of alternative scenarios in order to prepare for different possible futures was developed in American think-tanks such as the RAND corporation. In the 1970s the Royal Dutch/Shell company took up this methodology and started to use scenarios in the strategic planning of the company. Brainstorm seminars, with participants from different management levels, were used to develop the scenarios. This participation was considered important to ensure that the scenarios will be considered relevant by those supposed to use them in planning activities.

In addition to brainstorming, several more methods have been developed for the construction of plausible scenarios. One such method is to develop, separately for recombination, (1) internal elements, consisting in developments that the planning entity (the company) has in its own control, (2) transactional elements, consisting in developments that the planning entity has influence but not full control over, and (3) contextual elements such as the development of the global economy that the planning entity has at most marginal influence over. Other methodologies have been developed for the combinatorial combination of such elements into full scenarios (Dreborg 2004: 24–8).

It has been reported that Shell, using scenario methodology, was able to foresee the oil crisis in 1973 and therefore made adjustments that put them at advantage in relation to competitors during this crisis. Other companies, and some public agencies, have taken up the same methodology and developed it for their own purposes. Although it has on occasions been applied to issues of technological risk, this is yet largely an unexplored application area for scenario-based planning.

### *4.3 New deliberative processes*

In the 1980s, *participatory Technology Assessment (pTA)* came up as an alternative to traditional TA, foremost in Denmark and the Netherlands. This was a response to demands for a more socially oriented approach to technology and for increased public influence and participation in decision-making. Typically, pTA involves a broader spectrum of actors than traditional TA, such as politicians, NGOs, trade unions, journalists, scientists, technology developers, and lay people. At the same time, risk communication developed into a major branch of risk analysis. Risk communicators have developed procedures for dialogue that aim at decreasing the distance between decision-makers and the public.

What has usually been missing in these discussions is a systematic approach to planning for the future. Procedures need to be developed that facilitate deliberation on risk and uncertainty. A recent proposal is to base such discussions on hypothetical retrospection, i.e. on procedures in which we place ourselves hypothetically in the future in order to find out how we might in the future come to evaluate what we do now (Hansson 2007b).

One way to organize hypothetical retrospection is through convergence seminars. This is a procedure containing two phases of discussions based on future scenarios. In the first phase, the participants are divided into scenario groups. Each such group is assigned the task of discussion of one particular scenario. The different scenarios coincide up to a point in time at which a risk-related decision is made, but they differ in what decision is made and in what happens after the decision. Hence, in a discussion on medical enhancement, one group may discuss a scenario in which a decision is made to allow new enhancement methods such as drugs that improve mental faculties, and as a result of this decision new social patterns develop that give rise to severe tensions between social groups. Another group discusses a scenario in which the same decision is made, and some of the enhancement methods turn out to have severe side-effects, but large segments of the population still feel a pressure to use them. A third group can discuss a scenario in which the new enhancement methods are instead forbidden, but an uncontrolled black market results in much more dangerous practices than would otherwise have been the case. The discussions in these groups are based on questions structured to clarify standpoints about the decision in question.

In the second phase, the participants are regrouped into convergence groups, each of which contains participants from the different scenario groups. In these groups, each participant reports the discussion in the scenario group of which she was a member. After that the group discusses the issue at hand, again with the help of questions structured to clarify standpoints about the decision. To finish off, a joint session is held with all the participants from different groups, and here each convergence group reports its conclusions.

This methodology can be seen as a further development of the scenario methodology described in section 4.2, adjusting it specifically to deal with the subject matter of technological risks. Convergence seminars have been tried out with good results in discussions on the possible risks and benefits of future nanotechnology (Godman and Hansson, in preparation). It should be observed that this method goes in the opposite direction to that taken in commonly used decision tools such as risk analysis. Risk analysis abstracts from individuals and their relationships and counts statistical lives of non-identified persons. In contrast, hypothetical retrospection adds concreteness so that our deliberations will be based on “the full story” rather than on curtailed versions of it. More specifically, this procedure brings to our attention interpersonal relations that should be essential in a moral appraisal of risk and uncertainty, such as who exposes whom to a risk, who receives the benefits from whose exposure to risk, etc. It is only by staying off such concreteness that standard risk analysis can remain on the detached and depersonalized level of statistical lives and free-floating risks and benefits.

## 5. How Special Is Technology?

It is a common view among risk analysts that all risk issues should be treated with uniform criteria. If this is done, then risk management decisions can be so adjusted that the (marginal) price paid for a saved life is the same in all social sectors. This may seem fine in theory, but in practice any attempt to implement this idea will run into severe difficulties. Risk issues are dispersed over the whole social agenda; more often than not, they are parts of various larger and more complex issues. Traffic safety is closely connected to issues of traffic and community planning. It is often impossible to divide the costs of a traffic investment in a non-arbitrary way between costs of improved safety and costs of improved accessibility. Workplace safety issues are similarly integrated with issues of industrial productivity, etc. In short, the risk issues of different social sectors all have important aspects that connect them to other issues in their respective sectors. Therefore, we cannot base risk decisions on a unified calculation for all social sectors without introducing a far-reaching system of central planning for all these sectors.

The more general lesson to be learned from this is that issues of risk and our technological future cannot be isolated from other social issues. They have to be treated in the same decision procedures as other issues. In particular, there is no reason to refer them to more technocratic or expert-dominated forums than other policy issues. Instead we need methods to include the special characteristics of risk-related issues in our general decision-making processes. This may sound trivial, but it runs contrary to the received view in the risk sciences.

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# 88

# World Risk Society

## ULRICH BECK

Modern society has become a risk society in the sense that it is increasingly occupied with debating, preventing and managing risks that it itself has produced. That may well be, many will object, but it is indicative rather of a hysteria and politics of fear instigated and aggravated by the mass media. On the contrary, would not someone, looking at European societies from outside, have to acknowledge that the risks which get us worked up are luxury risks more than anything else? After all, our world appears a lot safer than that, say, of the war-torn regions of Africa, Afghanistan or the Middle East. Are modern societies not distinguished precisely by the fact that, to a large extent, they have succeeded in bringing under control contingencies and uncertainties, for example with respect to accidents, violence and sickness? Recent events have once again reminded us, with the Tsunami catastrophe, the destruction of New Orleans by Hurricane Katrina, the devastation of large regions in South America and Pakistan, how limited the claim to control of modern societies in the face of natural forces remains. But even natural hazards appear less random than they used to. Although human intervention may not stop earthquakes or volcanic eruptions, they can be predicted with reasonable accuracy. We anticipate them in terms both of structural arrangements as well as of emergency planning.

As true as all such observations may be, they miss the most obvious point about risk: that is, the key distinction between risk and catastrophe. Risk does *not* mean catastrophe. Risk means the *anticipation* of catastrophe. Risks exist in a permanent state of virtuality, and only become "topical" to the extent that they are anticipated. Risks are not "real"; they are "*becoming real*" (Joost van Loon). At the moment at which risks become real – for example, in the shape of a terrorist attack – they cease to be risks and become catastrophes. Risks have already moved elsewhere: to the anticipation of further attacks, inflation, new markets, wars or the reduction of civil liberties. Risks are always events that are threatening. Without techniques of visualization, without symbolic forms, without mass media, etc., risks are nothing at all. In other words, it is irrelevant whether we live in a world which is in fact or in some sense "objectively" safer than all other worlds; if destruction and disasters are anticipated, then that produces a compulsion to act.

This in turn conceals an irony – the irony of the promise of security made by scientists, companies and governments, which in wondrous fashion contributes to an

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increase in risks. Finding themselves accused in public of countenancing risk, ministers jump into rivers or get their children to eat hamburgers, in order to "prove" that everything is "absolutely" safe and under control – from which follows, as surely as night follows day, that every doubt cast, every accident violates the basis of the unshakeable right to security that appears to be promised.

In my first publication, in 1986, I described *Risk Society* as "an inescapable *structural* condition of advanced industrialization" – and criticized the "mathematicized morality" of expert thinking and public discourse on "risk profiling." While policy-oriented risk assessment posited the manageability of risks, I pointed out that "even the most restrained and moderate-objectivist account of risk implications involves a hidden politics, ethics and morality." Risk "is not reducible to the product of probability of occurrence multiplied with the intensity and scope of potential harm." Rather, it is a socially constructed phenomenon, in which some people have a greater capacity to define risks than others. Not all actors really benefit from the reflexivity of risk – only those with real scope to define their own risks. Risk exposure is replacing class as the principal inequality of modern society, because of how risk is reflexively defined by actors: "In risk society *relations of definition* are to be conceived analogous to Marx's relations of production." The inequalities of definition enable powerful actors to maximize risks for "others" and minimize risks for "themselves." Risk definition, essentially, is a power game. This is especially true for world risk society where Western governments or powerful economic actors define risks for others.

Risk makes its appearance on the world stage when God leaves it. Risks presuppose human decisions. They are the partly positive, partly negative, Janus-faced consequences of human decisions and interventions. In relation to risks there is inevitably posed the highly explosive question of social accountability and responsibility, and this is also true where the prevailing rules allow for accountability only in extremely exceptional cases. The acknowledged, decision-governed social roots of risks make it completely impossible to externalize the problem of accountability. Someone, on the other hand, who believes in a personal God has at his disposal a room for maneuver and a meaning for his actions in the face of threats and catastrophes. Through prayers and good works people can win God's favour and forgiveness, and in this way actively contribute not only to their own salvation but also to that of their family and community. There is, therefore, a close connection between secularization and risk (Joost van Loon). When Nietzsche announces that God is dead, that has the – ironic – consequence that from now on human beings must find (or invent) their own explanations and justifications for the disasters which threaten them.

The theory of world risk society maintains, however, that modern societies are shaped by new kinds of risks, that their foundations are shaken by the global anticipation of global catastrophes. Such perceptions of global risk are characterized by three features:

*De-localization:* Its causes and consequences are not limited to one geographical location or space; they are in principle omnipresent.

*Incalculableness:* Its consequences are in principle incalculable; at bottom it is a matter of "hypothetical" risks, which, not least, are based on science-induced not-knowing and normative dissent.

*Non-compensatibility:* The security dream of first modernity was based on the scientific utopia of making the unsafe consequences and dangers of decisions ever more controllable; accidents could occur, as long as and because they were considered compensatible. If the climate has changed irreversibly, if progress in human genetics makes irreversible interventions in human existence possible, if terrorist groups already have weapons of mass destruction available to them, then it is too late. Given this new quality of "threats to humanity" – argues François Ewald[1] – the logic of compensation breaks down and is replaced by the principle of *precaution through prevention.* Not only is prevention taking precedence over compensation; we are also trying to anticipate and prevent risks whose existence has not been proved.

World risk society is faced by the awkward problem of having to make decisions about life and death, war and peace, on the basis of more or less unadmitted not-knowing. Because the dilemma lies also in the fact that the option which relies on there being no danger is equally based on not-knowing and is equally high-risk, in the sense that terrorists really could acquire weapons of mass destruction, and do so precisely because we believe in not being able to know and hence do nothing. In other words: The non-compensatibility comes to a head in tragic fashion; if risks are held to be non-compensatible, the problem of not-knowing is radicalized. If catastrophes are anticipated whose potential for destruction ultimately threatens everyone, then a risk calculation based on experience and rationality breaks down. Now all possible, more or less improbable scenarios have to be taken into consideration; to knowledge, therefore, drawn from experience and science there now also has to be added imagination, suspicion, fiction, fear.[2] The boundary between rationality and hysteria becomes blurred. Given the right invested in them to avert dangers, politicians, in particular, may easily be forced to proclaim a security which they cannot honor, because the *political* costs of omission are much higher than the costs of overreaction. In future, therefore, it is not going to be easy, in the context of state promises of security and a mass media hungry for catastrophes, actively to limit and prevent a diabolical power game with the hysteria of not-knowing. I do not even dare think about deliberate attempts to instrumentalize this situation.

*From trustee to suspect:* Global risks are the expression of a new form of global interdependence, which cannot be adequately addressed by way of national politics, nor of the available forms of international co-operation. All of the past and present practical experiences of human beings in dealing with uncertainty now exist side by side, without offering any ready solution to the resulting problems. Not only that: key institutions of modernity such as science, business and politics, which are supposed to guarantee rationality and security, find themselves confronted by situations in which their apparatus no longer has a purchase and the fundamental principles of modernity no longer automatically hold good. Indeed, the perception of their rating changes – from trustee to suspect. They are seen no longer only as instruments of risk *management* but also as a *source* of risk.

*Tragic individualization:* As a consequence, everyday life in world risk society is characterized by a new variant of individualization. The individual must cope with the uncertainty of the global world by himself or herself. Here individualization is a default outcome of a *failure* of expert systems to manage risks. Neither science nor the politics in power, nor the mass media, nor business, nor the law or even the military are in a position to define or control risks rationally. The individual is forced to distrust the promises of rationality of these key institutions. As a consequence, people are thrown back on to themselves, they are alienated from expert systems but have nothing else instead. *Disembedding without embedding* – this is the ironic–tragic formula for this dimension of individualization in world risk society. For example, responsibility for the decision on genetically modified foods and their unforeseeable, unknowable long-term consequences is ultimately dumped on the so-called "responsible consumer." (Consumer choice rules.) The appeal to "responsibility" is the cynicism with which the institutions whitewash their own failure. However – and this is also part of the tragic irony of this individualization process – the individual whose senses fail her in the face of ungraspable threats to civilization, who, thrown back on herself, is blind to dangers, remains at the same time unable to escape the power of definition of expert systems, whose judgment she cannot yet must trust. Sustaining an individual self of integrity in world risk society is indeed a tragic affair.

*World risk society produces new lines of conflict:* Unlike the national industrial society of first modernity, which was marked by socio-economic conflicts between labor and capital, and unlike the international conflict constellations of the East–West conflict, which were characterized by questions of political security, the lines of conflict of world risk society are *cultural* ones. To the extent that global risks evade calculation by scientific methods, are a matter of not-knowing, then the *cultural perception*, that is, the post-religious, quasi-religious *belief* in the reality of world risk assumes a key significance.

Central, however, are not, as with Huntington, traditional religiously grounded "civilizations," but opposing risk belief religions. We are dealing – to adapt Huntington – with the *clash of risk cultures, risk religions*. So, for example, the dominant risk belief and risk tendencies of Europe and the US government are drifting very far apart; because the risk religions contradict one another, Europeans and Americans live in different worlds. For Europeans, risk belief issues like climate change, perhaps even the threats which global financial movements pose for individual countries, are much more important than the threat of terrorism. While, as far as the Americans are concerned, the Europeans are suffering from an environmental hysteria, many Europeans see the Americans as struck by a terrorism hysteria. The reversal of the terms "secularism" and "religiosity" is also striking. It seems that religious cultures are marked by a "risk secularism." Whoever believes in God is a risk atheist.

Like religious wars in pre-modernity or the conflict of interest between capital and labor in first modernity, that is, class conflicts, the clash of risk cultures is the fundamental conflict of second modernity:

(1) this is a matter of life and death, not of individuals or individual nations, but potentially of everyone;
(2) precisely these decisions central to the physical and moral survival of mankind have to be made within a horizon of more or less admitted and disputed not-knowing, and they are socially not assignable.

(3) In many areas the experimental logic of trial and error breaks down. It is impossible to permit just a small amount of genetically modified food, just a small amount of nuclear energy, just a small amount of therapeutic cloning. Given the cultural differences in risk perception, the question is posed: How much tolerance in the face of the ignorance of others can we afford? Or: How can binding procedures and standards of regulation be agreed given cultural differences in perception and not-knowing with respect to the consequences of decisions, which change the anthropological character of being human? Here two contradictory risk philosophies come into conflict: The philosophy of *laissez-faire* – it is safe as long as it has not been proved to be dangerous; and the philosophy of precaution – nothing is safe as long as it has not been proved harmless.

BSE is an explosive reminder of the inability of both nation-states and transnational decision-making bodies like the EU to manage risk in a chaotically interacting world risk society. But this is only the beginning. In developing the technologies of the future – genetic technology, nanotechnology and robotics – we are opening up a Pandora's Box. Genetic modification, communications technology and artificial intelligence, now also being combined with one another, undermine the state's monopoly of the use of force and leave the door wide open to an individualization of war – unless effective measures are taken soon at global level to bolt it shut.

*Let me summarize*: The theory of world risk society addresses the increasing realization of the irrepressible ubiquity of radical uncertainty in the modern world. The basic institutions, the actors of first modernity – science and expert systems, the state, commerce and the international system, including the military – responsible for calculating and controlling manufactured uncertainties are undermined by growing awareness that they are inefficient, their actions even counterproductive. This does not happen haphazardly, but systematically. Radicalization of modernity produces this fundamental irony of risk: science, the state and the military are becoming part of the problem they are supposed to solve. This is what "reflexive modernization" means: We are not living in a *post*-modern world, but in a *more*-modern world. It is not the crisis but the *victory* of modernity which through the logics of unintended and unknown side-effects undermines basic institutions of first modernity.

## Notes

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2. ibid.

## 89

# Risk Analysis

## SVEN OVE HANSSON

In the late 1960s, increased public attention to technological risks gave rise to a wave of academic activities related to risk. Scientists and scholars from a wide range of disciplines, often in new interdisciplinary combinations, started to investigate risks and risk-taking in new perspectives. Much of the focus was on chemicals and on nuclear technology, the same risk factors that public opposition had targeted. The new field was institutionalized as the discipline of "risk analysis," with professional societies, research institutes and journals of its own. The major journal in the field, *Risk Analysis*, was launched in 1981. The leading professional society, the Society for Risk Analysis, sees risk analysis as "broadly defined to include risk assessment, risk characterization, risk communication, risk management, and policy relating to risk" (www.sra.org).

Risk analysis has several subdisciplines. *Probabilistic risk analysis (PRA)* is primarily devoted to the analysis of technological systems. One of its major tools is fault tree analysis, in which the various chains of events that may lead to an accident are identified, and their probabilities estimated. The major problem with this methodology is of course that there is no method by which we can identify all chains of events that may lead to a major accident, for instance, in a nuclear reactor or in any other complex technological system. In spite of this, the construction and analysis of such event chains can be an efficient way to identify weaknesses in a complex technological system.

*Health risk analysis* identifies the risks that various health hazards, such as chemicals, radiation, unhealthy diet, etc., can give rise to. In most cases, health risk analysis begins with hazard analysis, i.e. an inventory of possible negative health effects of the agent in question. This is followed by an estimate of dose–response relationships, i.e. of what effects can be expected at different levels of exposure. In some cases, estimates of hazards and dose–response relationships can be based on studies of exposed human populations, but more commonly animal experiments provide the best available data for these estimates. Finally, exposure analysis is an indispensable part of health risk analysis. In order to determine the risks to exposed humans, both the exposure and the dose–response relationships have to be known.

*Ecological risk assessment* identifies the risks to wildlife and to ecological systems from exposure to chemical substances. The major scientific disciplines that contribute to ecological risk assessment are ecotoxicology, which investigates the effects of chemical

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substances on non-human organisms, and environmental chemistry, which investigates the fate of chemicals in the natural environment.

*Risk–benefit analysis* is a subdiscipline of economics that makes calculations that can be used to weigh risks against benefits. The study of economic risk-taking (where the risks are economic losses) is part of mainstream economics and is usually not counted as part of risk analysis.

*Risk perception* is a subdiscipline of psychology, devoted to studies of how people perceive the severity of different types of risk and of the factors that influence their appraisals of risk.

*Risk communication* is another behavioral subdiscipline in risk analysis. It investigates the effects of various types of communication on the public's perception of risk. In recent years, there has been a shift of focus in risk communication studies from one-sided to dialogical communication.

Practical applications of risk analysis to decision-making have usually been based on a thought model that has been developed out of attempts to systematize the work carried out by regulatory agencies and summarized in an influential 1983 report by the American National Academy of Sciences (NAS) (*Risk Assessment in the Federal Government: Managing the Process*). The characteristic feature of this approach is the division of risk decision procedures into two distinct parts to be performed consecutively. The first of these, commonly called *risk assessment*, is a scientific undertaking. It consists of collecting and assessing the relevant scientific and other factual information and on this base characterizing the risks. The second procedure is called *risk management*. Contrary to risk assessment, this is not a scientific undertaking. Its starting-point is the outcome of risk assessment, which it combines with economic and technological information pertaining to various ways of reducing or eliminating the risk in question, and also with political and social information. Based on this, a decision is made on what measures – if any – should be taken to reduce the risk.

This consecutive model has served the important purpose of systematizing a previously much too unsystematic undertaking. In particular, it has served to defend the integrity of science and to prevent improper practices such as letting estimates of risk depend on whether or not risk reduction is considered feasible. On the other hand, a rigid implementation of this model also has several disadvantages. Perhaps most importantly, the model has often been interpreted as saying that risk assessment must be "completed" before risk management can start. This can sometimes lead to unnecessary delays of risk abatement. Modifications of the model that facilitate decisions based on preliminary conclusions can increase the efficiency of risk management.

## 90

# Prosperity and the Future of Technology[1]

## WILLIAM SIMS BAINBRIDGE

From the very beginning of human history, technological progress has been an essential precondition for economic development, and prosperous societies have had the resources to invest in a wide range of new technologies. However, the historical connections among technological change, prosperity, and human well-being have been complex and often indirect. What was true in the past may not be true in the future, and some critics have suggested that scientific and technological innovation may be coming to a halt, even as others argue that it is nearing a singularity at which the conditions of human life will change utterly, perhaps through a combination of information technology and nanotechnology.

### Economic Prosperity and Innovation

*Prosperity* has economic connotations, but its dictionary definition is broader, referring to thriving and success rather than to just monetary riches. For most of prehistoric days, prosperity meant living in a benign climate with ample wild game, abundant plant resources, and security from attack by other bands of humans. The *Neolithic revolution*, as classically described by V. Gordon Childe, was launched by the invention of agriculture, leading to population growth, political and military institutions to defend land, division of labor producing a greater variety of goods and services, and cultural advances such as writing and organized religion. Occurring first around ten thousand years ago, the Neolithic revolution gradually built the technical, demographic and economic basis for the industrial revolution, starting around 250 years ago. If prosperity is the greatest good for the greatest number, then the millennia-long progress of technology symbolized by these putative revolutions has increased human prosperity by something like a million times, from a hunter-gatherer population of ten or twenty thousand at the dawn of humanity to 6 billion today, roughly two-thirds of whom could be described as fabulously wealthy by ancient standards.

It is not at all clear that technological progress is faster today than decades ago, nor that innovation is currently playing a greater role in promoting prosperity. A case can be made that household electrification in the early twentieth century was more important in transforming life than the spread of the Internet at the end of the century,

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and that the introduction of telephones and automobiles was more important than email. The rate of increase of the lifespan was greater a century ago than today in industrial nations. Alexander Field has argued that the 1930s were the decade in which technological innovation had the greatest impact on American economic growth. John Horgan offers evidence that the science on which technological innovation is based has neared its limits in many fields. Granting that we cannot be certain about such matters, what technological factors might affect prosperity in the future?

Evan Schofer, Francisco Ramirez and John Meyer have shown that science, and thus technologies based on it, can have contrary effects on economic growth. Notably, science can retard short-term economic growth when it energizes policy reforms about environmental pollution, human rights, and welfare. On the other hand, major innovations can create entirely new industries that cause a wave of economic advance until they have become well established, for example saturating the market with their products. Kenneth Brown has examined what would happen if American investment in science were to decline markedly. Because other factors, such as savings and capital investment, promote growth, the lack of new technologies might not seem significant at first. Scientific and technological stasis would set a ceiling on long-term economic growth, however.

Economists generally believe that international trade helps underdeveloped nations grow toward prosperity, and globalization depends upon modern transportation and communication technologies. A crucial factor causing growth in poor but economically open countries may be the influx of scientific and technical knowledge that comes along with international trade. Impoverished, poorly educated nations must import their science if they are to have any at all. Knowledge enters an open nation through the technology brought in by foreign companies, across the imported train tracks and phone lines, in the minds of students sent abroad for their education, and even in the pages of foreign books and on the Worldwide Web. Thus, the technologies that already exist could support many decades of continued economic progress on the global scale.

## The Information Age

People should be wary of anyone who proclaims the dawn of a new era. The “Atomic Age” and the “Space Age” were quickly forgotten when the technologies after which they were named stalled in the 1960s and 1970s. The same innovations that gave us nuclear power plants and space satellites also gave us atomic warheads on intercontinental ballistic missiles, perhaps to the net harm of humanity. Thus we can doubt whether the Information Age is a real revolution in the basic conditions of human life, or, if it is, whether it is on balance a benefit for prosperity and well-being.

Economists have come to recognize the value of information in markets. Companies need to distinguish good from poor potential employees, and so the educational system acts as the credentialing institution. Consumers want reliable means of identifying products that meet their own cost–quality tradeoff, so brand loyalty arises. Information is costly, both directly to the person seeking it and indirectly through the cost of societal institutions like schools that support it. Brand loyalty is costly because brands demand a premium price. There is some question whether markets could function if everybody has perfect information. For example, if online reputation systems like that used by eBay work very well, then competing manufacturers and distribution companies may not be able to charge enough to provide profits to their owners, in a race to the bottom in which the lowest price attracts all consumers seeking products or services they easily learn are equal in quality.

In 1983, Wassily Leontief noted the transformation that information technology had begun to achieve, and predicted: "As soon as not only the physical but also the controlling 'mental' functions involved in the production of goods and services can be performed without the participation of human labor, labor's role as an indispensable 'factor of production' will progressively diminish" (p. 405). He argued that humans could be treated as horses were when gasoline-powered vehicles took over their tasks: dispensed with. The result could be increased unemployment, or underemployment when people take very low-paying service jobs in preference to no jobs at all. At some point in this process of devaluing human work, a large enough fraction of consumers could be poor enough to put the brakes on economic growth. Alternatively, the wealthy classes could keep their own prosperity growing by investing in large projects that operated above the mass consumer economy, such as architectural extravaganzas, lavish vices, or military campaigns.

A more recent perspective holds that the effect of new technologies on work organization, and the effects that work has on human lives, is contingent upon a number of factors, including policy decisions about how the roles of technology and workers are defined with respect to each other. This may be why research on the introduction of computers into the work environment gives complex and often contradictory results, notably the paradox that productivity does not automatically increase.

In the title of his 1964 book, *Psychotherapy: The Purchase of Friendship*, William Schofield approached but did not quite comprehend a major insight. All service industries involve the purchase of friendship. Mutually beneficial human cooperation has been the foundation of society since long before *Homo sapiens* evolved; but, as George Homans pointed out long ago, human nature expects practical services and emotional friendship to be combined, in the dynamics of small human groups. Thus it is possible to argue that service industries should first offload all repetitive tasks on machines, and then intentionally use human labor in an "inefficient" manner, such that a doctor or auto mechanic behaves like a real friend to the client.

## The Nanotechnology Age

At the dawn of the twenty-first century, the "next big thing" was nanotechnology, the engineering of matter at the scale of individual complex molecules. Visionaries like Eric Drexler suggested that a historical singularity might be approaching, when self-reproducing nanoscale robots could perform previously impossible manufacturing tasks at practically no cost, thereby producing essentially infinite prosperity.

In 2000, and again five years later, the US government convened major conferences of leading experts to consider the societal implications of nanoscience and nanotechnology. The notion that nanobots or some other single nano innovation would soon transform the economy was unanimously rejected by scientists knowledgeable with the technical challenges. However, they identified a very large number of industries where methods based on nanoscience could markedly improve the performance of products, whether or not they could also achieve lower cost. The transformation of industry would be widespread but gradual, allowing graceful adjustment of employment and investment patterns. Rather than causing a revolution, nanotechnology is expected to sustain conventional technology-based economic growth for several decades in the advanced nations, with benefit diffusing gradually around the world.

The very diversity of nanotechnologies makes them very difficult to monopolize, thus buffering their impact on the organization of work and financial power. To some extent they could reverse the trend toward an information and service economy that Daniel Bell called *post-industrial society*. At the same time, nanotechnology could facilitate a shift toward greater use of solar energy, the use of hydrogen or other synthetic fuels instead of gasoline, and improvements in the effectiveness and efficiency of healthcare. In 2004, the National Cancer Institute announced a five-year $144 million initiative to apply nanotechnology to the cure of cancer, a problem that has resisted other approaches for a century. Thus, health and environmental benefits could improve well-being, facilitating long-term economic growth.

Information technology could combine with nanotechnology, or with larger-scale methods developed as spinoffs from nanotechnology, to allow manufacturing industries to transcend the distinction responsible for the industrial revolution. As Broadberry (1994: 291) defines it: "In mass production, special purpose machinery and resources are substituted for skilled labour to produce identical products, while craft production methods make extensive use of skilled labour to produce customized output." Now, computer-controlled fabrication machinery can efficiently produce a line of products in which each item is customized to the user's needs and desires. Precision manufacture using synthetic materials could be done locally with local materials, thus detaching industry from the global economy and embedding it back in the community of users.

## Conclusion

Arguably, major social forms that emerge during the course of human history may be temporary, rather than becoming the permanent underpinning of an increasing complex social order. For example, complex, extended kinship structures and landed aristocracies were necessary during agrarian society, because of the need to hold and cultivate land, in competition with other communities who would like to seize it. Prior to agrarian society, kinship structures were smaller and more fluid, and the same is true today. Similarly, widespread markets trading manufactured goods are the dominant economic institutions today, but may fade into relative insignificance in an information society.

Given secure but modest housing and nutritious but temperate food, most of a person's well-being will consist of warm social relations and information resources. Already more than enough fine novels have gone out of copyright and been published on the web to last a reader a lifetime, so we can imagine a time not many years hence when the entertainment industries collapse, replaced by this trove of Internet culture and by semi-professional local artists. Manufacture can be carried out by skilled local craftsmen, using fabrication methods shaped by information technology and nanotechnology. Services will be performed by friends whose expertise gives them an honored status in the society, but who are never merely doing their job. This is only one of many possible scenarios for a future created by technology, describing a society that is more prosperous than today, but with far less money.

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1. The views expressed in this essay do not necessarily represent the views of the National Science Foundation or the United States.

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# 91

# Converging Technologies[1]

## WILLIAM SIMS BAINBRIDGE

A cultural movement has arisen within science and technology aimed at the unification of theories, methods and goals across fields. This convergence has tremendous potential in the so-called "NBIC" fields of nanotechnology, biotechnology, information technology and new technologies based on cognitive science. A series of conferences, some organized officially by the United States government but others organized by scientists and engineers separately from government support, have especially examined how convergence could leverage developments in the National Nanotechnology Initiative to transform the conditions of human life.

## The NBIC Fields

*Nanotechnology*, as conventionally defined, is a very general term for engineering materials, structures and devices in which at least some dimensions are less than 100 nanometers (billionths of a meter). By the end of the twentieth century, visionaries and science-fiction writers had convinced many people that self-reproducing nanoscale robots or automatic nanoscale factories for molecular manufacturing would soon be developed. When the United States government organized the first serious examination of the societal implications of nanotechnology in 2000, however, the consensus of expert opinion was that these dreams were at least fifty years in the future, but nanotechnology could have a great impact through incremental performance improvements across a wide range of existing technologies. Thus, "nano" would not be a revolution but an enabler, assisting progress through convergence with other technologies.

Already, computer hardware exploits the speed and efficiency of transistors with components less than 50 nanometers across, and nanoscale layers give hard disks significantly increased data capacity. As computing becomes ubiquitous and mobile, components must become smaller and lighter. Sensor networks will identify individual molecules for such applications as environmental monitoring, medical diagnosis, and defense against biohazards. Thus, nano–info convergence is not only taking place but also reaching in the direction of biotechnology.

Nano–bio convergence is evident in the concepts and methods used to study the nanoscale machinery inside living cells, and it joins with information technology to

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enable rapid gene sequencing and genetic engineering. The nervous systems of animals and humans depend upon many phenomena that operate at the nanoscale, from the reaction of pigment molecules like rhodopsin as they respond to light in the eye, to the flow of neurotransmitters across the gaps between neurons. Thus convergence reaches beyond nanotechnology, information technology and biotechnology toward cognitive technology.

The inclusion of cognitive science is controversial, in part because there still exists considerable cultural opposition to the very idea that the human "soul" or "spirit" can be studied scientifically, reflected in far lower levels of public financial support for research in the behavioral and social sciences than in the physical or biological sciences. There also exists considerable political opposition, especially in the United States where Republican administrations currying favor with evangelicals and conservatives continually seek to suppress the social and cognitive sciences on the theory that they are mere left-wing ideologies. While this criticism is poorly grounded, it is true that NBIC convergence is likely to undercut traditional beliefs, values and institutions.

## Philosophical Implications of Convergence

The technologies cannot unite unless the sciences also do so. This means that converging fields must develop shared languages, theories and educational curricula. The ultimate result could be the emergence of a universal set of scientific principles, the consensus of science about how the universe functions and the universal toolkit employed by engineers to transform the material conditions of human life. For example, the biological concept of evolution by natural selection from random variation has been adapted by computer scientists in genetic algorithms and evolutionary computing methods.

Importantly, the scientists and engineers who participated in the landmark NBIC and nano conferences expect substantial changes in human nature to result. Note the titles of two of the conference volumes: *Converging Technologies for Improving Human Performance* and *The Coevolution of Human Potential and Converging Technologies*. In order to compete with each other, individuals, corporations and nations may need to embrace convergence, with the unintended consequence that the rules of competition may constantly change as human nature is altered by the NBIC technologies.

Already, in such areas as human–computer interaction and robotics, major fields of information technology research and development, the distinction between human and machine cognition is blurring. Smart machines from videogames to office information systems are progressively designed to think more like humans, whereas the humans who use them come to mirror the machine's mental habits as well. Arguably, one machine is already more intelligent than any human, and its name is Google; but Google is smart only because it exploits the judgments of literally millions of people. At the same time, cyberinfrastructure (supercomputers, digital libraries, and research collaboratories) is transforming all modes of scientific data analysis and theorizing into subsets of computer science.

The new "technorthodoxy" could gain great social power from effective technologies based on it, notably genetic engineering and artificial intelligence. Influential sociobiologist Edward O. Wilson advocates scientific unification, calling it *consilience*, and predicts that religion will find itself left out of this grand convergence. One could argue that a worldwide, coherent scientific culture could become the technical basis for cultural pluralism in the humanities, social systems and matters of faith. Thus, it is unclear whether religion and the arts would be subordinate to science or independent from it. When everything that could become possible is actually possible, humans will need to decide what they really want.

## Conclusion

The fundamental fact about scientific consilience and technological convergence is uncertainty. Perhaps science and engineering are undergoing a major phase change, after which everything will be different. Perhaps political opposition will prevent unification, at least for a long time, allowing non-technical factors considerable scope to shape human destiny. However, one way to describe today's world is to say that old technologies are consuming natural resources and polluting the environment at an accelerating rate, while terrorists seek weapons of mass destruction and imperialists develop privacy-destroying information systems. From that perspective, it will be necessary to achieve convergence quickly, unifying humanity as well as science and technology before they destroy each other.

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# 92

# Nanotechnology

## ALFRED NORDMANN

There are at least two ways of defining nanotechnology. On the one hand, it is the seemingly unlimited technical potential that will arise from at present still rudimentary capabilities of visualizing and manipulating molecular structure. On the other hand, it is an umbrella term for a variety of nanotechnological research programs that aim for functional materials, for targeted drug delivery, for molecular wires and faster computers, for lab-on-a-chip sensors, for extremely fine filters, for smart textiles, for tagging and monitoring, and much more.[1]

There are also at least two ways of posing the question regarding prosperity and risk. One can ask what our nanotechnological future has in store for us, what benefits and risks will come with the development of nanotechnology. One can also ask how our current societal or environmental problems might be addressed with the help of this or some other nanotechnological research program.

In both cases, we either refer to an unspecified future in which a vast but vague potential may or may not be realized, or we remain in the present by referring to ongoing funded research programs, including the visions of a better society that may or may not inform them. In the former case, nanotechnology is promise and threat all wrapped into one; in the latter case, specific nanotechnological research is justified to the extent that it builds on presently demonstrable capabilities and contributes to the solution of well-defined problems.

The tension between futurist and presentist conceptions of nanotechnology is unresolved. The dynamic of nanotechnological development feeds on this unresolved tension. Reflection on this dynamic is therefore a major theme in nanoScience and Technology Studies (nSTS).[2,3,4,5,6,7] The futurist conception has come under pressure not only for the obvious epistemological problem that one cannot predict the future, but also for, broadly speaking, ethical and political reasons: Is there an ethically defensible standpoint from which to judge future technologies? Does a discourse about broad but vague prospects detract from particular choices that need to be made now? Reflections on issues of prosperity, risk, justice, or sustainability require a conceptually manageable presentation of nanotechnological programs. The price to pay for this is to give up the illusory hope that one could now worry about or prepare for a remote, unknown and unknowable future.

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There are further reasons to intervene in the systematically ambiguous rhetoric of "nanotechnology" and to disambiguate futurist and presentist conceptions. These reasons involve specific limits of knowledge and technical control of nanoscale phenomena. Here, nSTS scholarship has focused on the very conceptions of uncertainty or risk and the emergence of nanotoxicology.

Jean-Pierre Dupuy and Sven Ove Hansson highlight the distinction between known and unknown risks, between epistemic uncertainty and objective indeterminacy.[8,9] Epistemic uncertainty concerns our current state of knowledge: Given what is presently known, we cannot exclude, for example, that some chemical substance might pose a risk to human health. Accordingly, epistemic uncertainty serves as an index on propositions, hypotheses, or beliefs, indicating the incompleteness of knowledge. This uncertainty is oriented toward a future state at which greater certainty can and will be achieved: Once the data on exposure, on frequency and severity of incidents have been collected, a definitive judgment on the risks posed by the substance will be possible.

In contrast, objective indeterminacy is an irreducible property of a physical system. The system behaves in such a way that one cannot attain any assurance that would exclude a catastrophe from happening. If one takes the claims made on behalf of nanotechnologies seriously, there is good reason to expect that nanotechnological risk assessment takes place under conditions of objective indeterminacy. Dupuy points to the emphasis on "bottom-up engineering." Nanotechnologies are said to harness processes of self-organization which allow them to build structures through the self-assembly of molecules. Self-organization is frequently associated with non-linear dynamics and conceptions of ordered states emerging from chaotic states – this, of course, is also called "catastrophe theory." Indeed, at the tipping-point of self-organizing systems there is objective indeterminacy whether the emerging state is catastrophic collapse or a desirable state of greater complexity.

While it is an open question whether nanotechnological bottom-up engineering actually involves such a strong conception of self-organization, the argument regarding objective indeterminacy does not depend on it.[10,11] Even the most general definitions of nanotechnology refer to scale-dependent discontinuities. Nanotechnological research seeks to exploit the fact that familiar substances have different properties when they are scaled down to the point at which a great proportion of their atoms are close to their surface. Bulk matter is appropriately characterized by chemical composition alone, and its surface can usually be neglected. When materials are dominated by surface properties, however, their behavior depends not on chemical composition alone but also on size, surface characteristics and structure. The expected behavior is therefore highly sensitive to a whole variety of factors that are difficult to control individually, let alone at once. And, even if it were possible to achieve such control and a physically robust exploitation of some novel property, it is hard to limit the scope of this novelty. A nanoparticle might be engineered for its specific ability to absorb light; but, while an entire field of scientific research is built around the toxicity and biocompatibility of chemical properties, there is no such science for engineered properties and functionalities. Not surprisingly, therefore, the analogy to asbestos has been invoked repeatedly, since it was the structure of asbestos fibers rather than their chemical composition that proved to be hazardous.[12] As with asbestos, it may be difficult to gain definitive knowledge until after the fact, that is, until results are available from long-term epidemiological studies of sufficiently large populations with significant levels of exposure. Unlike the case of asbestos, however, early warnings are not being ignored and ways are being sought to deal with questions of risk in a situation characterized by objective indeterminacy.[13]

Currently predominant views of risk and precaution are epistemic in that they depend on what is currently known about hazards, exposures, incidence, and what one would need to know before giving a green light to further research or market distribution. When this road is not available under conditions of objective indeterminacy, the best of our knowledge is still taken into consideration, still needs to be updated and improved. However, toxicological and epidemiological information can only contribute to a more broadly conceived process of testing, observing and monitoring the robustness of a technical system. Indeed, a desideratum for nSTS is to develop criteria for the robustness of socio-technical systems in their environments. While these criteria will not be formally stringent like those proposed for the assessment of propositional knowledge-claims, they will include social robustness, that is, how firmly nanotechnological research-programs are entrenched within the larger aspirations of a society.[14]

The demand for a socially robust method of continuous justification, observation, research and deliberation is particularly strong in the emerging field of nanotoxicology. Here chemical toxicology, occupational health, inhalation toxicology and various other subfields come together to strengthen a disciplinary identity that is based on the traditional tools and methods that have served well in the development of regulatory mechanisms for fine particles and chemical substances. The fact that these traditional tools and methods reach their limits at the nanoscale could threaten disciplinary identity.[15] Instead, it apparently provides an added opportunity for the emerging field to reinvent itself as a nanoscience.[16,17] On the one hand, toxicology might move from the position of being a merely reactive testing science to a proactive knowledge-provider that paves the way for biocompatible nanotechnology. It can do so by informing nanotechnological research and development of relevant strategies for selecting its building blocks, the treatment of surfaces, etc.[18] At the same time, toxicology might further expand its interdisciplinary character by including the social sciences and becoming a social science of nature.[19] Epidemiological vigilance would be framed by deliberations on the societal benefits and institutional arrangements that might justify the assumption of unknown risks.

The term “social science of nature” was coined in the 1980s in the context of the so-called finalization thesis.[20] Its point of departure was the recognition that technoscientific research does not represent a unique and unchangeable nature but pursues as its program the shaping and reshaping of a world that is already the product of technical interventions.[21] If nature is no longer just natural but also social, the science of nature is also no longer natural but also social. As a science of judging how nanotechnical materials and devices can function in a socially and technically robust manner, nanotoxicology can show the way for the larger ambitions of embedding nanotechnological research within a convergence of enabling technologies (“converging sciences and technologies for bio- and sociocompatible technical systems”).[22]

In the discourse of technology and the future, the notions of prosperity and risk play a highly reductive role. In light of the many unknowns that the future may hold, they signal the presumed certainties that technological innovation leads to prosperity, that the most serious obstacle to this is perceptions of real or imagined risk. In this context the meaning of these terms is limited to their rhetorical and epistemological function in a public discourse that is oriented toward assurances of a "sustainable" future. However, in the context of the problems, technical capacities and needs of the present, prosperity and risk are implicated in the piecemeal transformations of highly complex socio-technical systems. Richly contextualized, these terms no longer serve to orient discourse to impoverished conceptions of protection from physical harm and growth of GNP. As Brian Wynne has shown for nanoethics, the evaluation of nanotechnological development moves from calculated impacts to social imagination when it is informed by lay ethics, by recognition of silent "others," by various sources of expertise and deliberative processes. Beyond the presumed benefit/presumed risk calculus, a social science of nature requires imagination for the ways in which nanotechnologies might alter the fabric of human relations.[23]

Brian Wynne's critique of "risk" is matched by Joachim Schummer's work on "prosperity" as the envisioned aim of nanotechnology. To be sure, visions of "global abundance" have informed futurist visions of nanotechnology from the beginning.[24] The arguments for public investment in nanotechnological research invariably refer to growing numbers of patents, anticipated increases in market-share and volume of nanotechnological products. These arguments have been shadowed by a concern whether the developing world can profit from these developments or whether they will widen existing gaps.[25] Schummer's review of nanotechnologies for the developing countries is sobering and highlights the magnitude of the task.[26] In the mean time, funding for nanotechnology raises questions of distributive justice: Who benefits and who pays?[27] In particular, this question might be addressed to nanomedical research that is focused not on infectious diseases but primarily on cancer and thus on an incremental extension of already-high life-expectancy in an affluent ageing population. And a variant of this question arises with respect to the environmental promises that are made on behalf of nanotechnologies. On futurist conceptions, environmental problems will take care of themselves once waste-free and resource-efficient modes of manufacturing are in place. By holding nanotechnological research and development to the demands and ecological problems of the present, one might insist that public investment in nanotechnology should be proportionate to its promises of environmental remediation.

Questions of risk and of prosperity and risk can thus become richly contextual once we realize that nanotechnology's storyline is not primarily that of human progress toward greater wealth, global abundance, ever expanded scientific understanding and technical control – but that its storyline is that of globalization: sailing under the flag of "nanotechnology," we are presently embarked upon the conquest of nanospace and thus upon a contentious project to reform the web of human relations and the world of lived experience.[28]

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## 93

# Energy Forecast Technologies

JOHN R. FANCHI

An energy mix is emerging to meet anticipated twenty-first-century energy demand (Fanchi 2004, 2005). This article discusses methodologies that are designed to forecast the role different energy technologies may take in the twenty-first century.

The demand for energy is driven by factors such as increasing global population and energy consumption, the finite availability of fossil fuels, and climate change associated with industrialized society. The ability to meet the demand for energy depends on such factors as energy density, price volatility, supply availability, and efficiency of energy use.

Energy density is the energy contained within a volume of material. Historically, energy density was one of the most important factors considered in selecting a fuel. A fuel is a material which contains one form of energy that can be transformed into another form of energy. Coal and oil have relatively large energy densities and were often preferentially chosen as the raw fuel that was input to power plants. Raw fuels such as oil, coal, natural gas, and uranium are present in nature and can be used to provide primary energy.

Primary energy is energy contained in raw fuels. It has not been obtained by anthropogenic conversion or transformation where the term "anthropogenic" refers to human activity or human influence. Primary energy is often converted to secondary energy, such as electrical energy, for more convenient use in human systems.

The energy types that contributed most to the energy mix in the latter half of the twentieth century were wood, coal, oil, natural gas, water and nuclear. The emerging energy mix includes renewable and non-renewable energy resources. Renewable energy is energy that is obtained from sources at a rate that is less than or equal to the rate at which the sources are replenished. Renewable energy sources may be classified as traditional renewable energy sources and newer renewable energy sources. Traditional renewable energy sources include hydroelectric power and wood (a biomass). Newer renewable energy sources include wind energy and solar photovoltaic energy.

Non-renewable energy is energy that is obtained from sources at a rate that is greater than the rate at which the sources are replenished. In the following, we adopt the view that fuels such as coal, oil and natural gas are non-renewable fuels and we refer to these fuels as fossil fuels. The term "carbon-based fuels" includes any fuel that

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contains carbon, such as fossil fuels and biomass. Biomass refers to modern wood and other plant or animal matter that can be burned directly or can be converted into fuels.

## Hubbert's Oil Supply Forecast

The emergence of an energy mix is motivated by environmental concerns and by the concern that the production of a dominant non-renewable resource, oil, is coming to an end. M. King Hubbert studied the production of oil, a non-renewable resource, in the continental United States (the forty-eight contiguous states of the United States) as a non-renewable resource. Hubbert (1956) found that oil production in this limited geographic region could be modeled as a function of time. The annual production of oil increased steadily until a maximum was reached, and then began to decline as it became more difficult to find and produce oil. The maximum oil production is considered a peak. Hubbert used his method to predict that peak oil production in the continental United States would occur between 1965 and 1970, and that global oil production would peak around 2000. Crude oil production in the continental United States peaked at 9.4 million barrels per day in 1970. A second peak for the United States occurred in 1988 when Alaskan oil production peaked at 2 million barrels per day. Many experts consider the 1970 oil peak to be a validation of Hubbert's methodology. Analyses of historical data using Hubbert's methodology typically predict that world oil production will peak in the first quarter of the twenty-first century.

Forecasts based on an analytical fit to historical data can be readily prepared using publicly available data. Figure 93.1 shows a fit of world oil production (in millions of barrels per day) from the United States EIA database. The fit is designed to match the

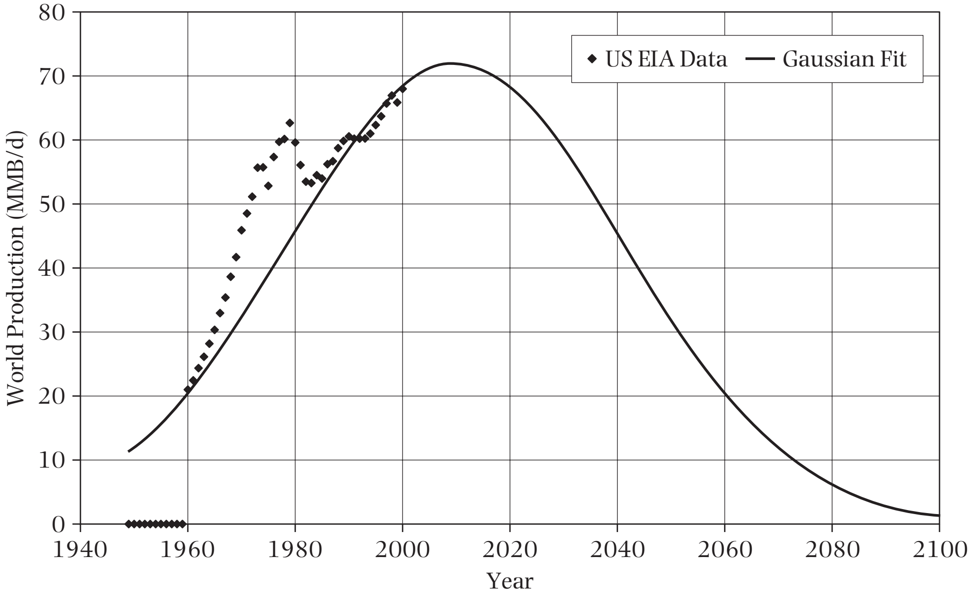

**Figure 93.1** Oil forecast using Gaussian Curve

most recent part of the production curve most accurately. This gives a match that is similar to results obtained by Deffeyes (2001: 147). For this fit, peak oil production rate in Figure 93.1 occurs in 2010.

## Energy Forecast Methodology

Future energy demand is expected to grow substantially as global population increases and developing nations seek a higher quality of life. Energy forecasters predict how this demand will be met. The forecasts vary from a scenario that relies on nuclear energy (Hodgson 1999) to a scenario that relies on renewable energy (Geller 2003). Other forecasts of the twenty-first-century energy mix show a gradual transition from the current dependence on carbon-based fuels to a more balanced dependence on a variety of energy sources (Schollnberger 1999, Edwards 2002). These forecasts illustrate the range of perspectives that must be considered in deciding global energy policy and are summarized here.

### *Nuclear energy forecast*

Hodgson (1999) presented a scenario in which the world would come to rely on nuclear fission energy. He defined five Objective Criteria for evaluating each type of energy: capacity, cost, safety, reliability, and effect on the environment. The capacity criterion considered the ability of the energy source to meet future energy needs. The cost criterion considered all costs associated with an energy source. The safety criterion examined all safety factors involved in the practical application of an energy source. This includes hazards associated with manufacturing and operations. The reliability criterion considered the availability of an energy source. By applying the five Objective Criteria, Hodgson concluded that nuclear fission energy was the most viable technology for providing global energy in the future. According to Hodgson, nuclear fission energy is a proven technology that does not emit significant amounts of greenhouse gases. He argued that nuclear fission reactors have an exemplary safety record when compared in detail with other energy sources. Breeder reactors could provide the fuel needed by nuclear fission power plants, and nuclear waste could be stored in geological traps. The security of nuclear power plants in countries around the world would be assured by an international agency such as the United Nations. In this nuclear scenario, renewable energy sources would be used to supplement fission power, and fossil energy use would be minimized. Hodgson did not assume that the problems associated with nuclear fusion would be overcome. If they are, nuclear fusion could also be incorporated into the energy mix.

### *Renewable energy forecast*

The nuclear fission scenario articulated by Hodgson (1999) contrasts sharply with the renewable energy scenario advocated by Geller (2003). Geller sought to replace both nuclear energy and fossil energy with renewable energy only. An important objective of his forecast was to reduce greenhouse gas emissions to levels that are considered safe by the Kyoto Protocol. The Kyoto Protocol is an international treaty that was negotiated in Kyoto, Japan, in 1997 to establish limits on the amount of greenhouse gases a country can emit into the atmosphere. Carbon dioxide is a greenhouse gas. The accumulation of greenhouse gas in the atmosphere tends to trap heat energy in the atmosphere. Many scientists believe that the additional heat is increasing the temperature of the atmosphere and is causing global warming.

The Kyoto Protocol has not been accepted worldwide. Some countries believe the greenhouse gas emission limits are too low and would adversely impact national and world economies without solving the problem of global warming. Another criticism of the Kyoto Protocol is that it does not apply to all nations. For example, China is exempt from greenhouse gas emission limitations in the Kyoto Protocol even though it has one of the world's fastest-growing economies and the world's largest population. Research is underway to develop the technology needed to capture and store greenhouse gases in geologic formations as an economically viable means of mitigating the increase in greenhouse gas concentration in the atmosphere.

## *Energy mix forecasts*

Forecasts of the twenty-first-century energy mix show that a range of scenarios is possible. The first energy mix forecast discussed here is based on Schollnberger's (1999) forecasts, which were designed to cover the entire twenty-first century and predict the contribution of a variety of energy sources to the twenty-first-century energy portfolio.

Schollnberger considered three forecast scenarios:

A. "Another Century of Oil and Gas" corresponding to continued high hydrocarbon demand;
B. "The End of the Internal Combustion Engine" corresponding to a low hydrocarbon demand scenario; and
C. "Energy Mix" corresponding to a scenario with intermediate demand for hydrocarbons and an increasing demand for alternative energy sources.

Schollnberger viewed scenario C as the most likely scenario. It is consistent with the observation that the transition from one energy source to another has historically taken several generations. Leaders of the international energy industry have expressed a similar view that the energy mix is undergoing a shift from liquid hydrocarbons to other fuel sources.

Schollnberger's scenario C shows energy consumption increasing from about 400 quads in 2000 to approximately 1600 quads in 2100.

Edwards (2002) presented the energy mix in terms of energy supply rather than consumption. His forecast is based on the assumption that global population increases from about 6 billion people in 2000 to about 10 billion people in 2100. It also assumes that energy demand is met by the energy supply. Edwards's forecast shows energy supply increasing from about 400 quads in 2000 to less than 600 quads in 2100. His forecast results in a much lower energy requirement in 2100 than Schollnberger's scenario C. For comparison, Geller's forecast shows that energy consumption in 2100 will be approximately 75 per cent greater than energy consumption in 2000. These three forecasts illustrate the range of results that can appear in energy forecasts.

### *Validity of energy forecasts*

We can assess the validity of energy forecasts by comparing the early period of the forecast with actual data. For example, one important test of the validity of a forecast is to compare the predicted peak of world oil production with actual world oil production. Edwards (2002: 43) presented several predictions of the year when annual global oil production would peak. The forecasts ranged from 1997 to 2040, with most of the forecasts predicting an annual global oil production peak occurring in the first quarter of the twenty-first century.

Forecasts of world oil production peak tend to shift as more historical data are accumulated. Laherrère (2000) pointed out that curve fits of historical data are most accurate when applied to activity that is "unaffected by political or significant economic interference, to areas having a large number of fields, and to areas of unfettered activity" (p. 75). Furthermore, curve fit forecasts work best when the inflection point (or peak) has been passed.

## Energy Forecast Trend

Most forecasts show the eventual displacement of fossil fuels by renewable energy sources. The demand by society for fossil fuels is expected to continue at or above current levels for a number of years, but the trend seems clear. The global energy portfolio is undergoing a transition from an energy portfolio dominated by fossil fuels to an energy portfolio that minimizes or eliminates the use of fossil fuels.

The emerging energy mix is expected to become a sustainable energy supply that will meet future demand. The goal is to create a sustainable energy system: a system that satisfies present energy needs while preserving the ability of future generations to meet their needs.

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# 94

# Biotechnology

## JENNIFER KUZMA

Some argue that biotechnology began thousands of years ago when crops were first bred for specific traits or micro-organisms were used to brew beer. The term "biotechnology" was first used in 1917 for processes using living organisms to make a product or run a process, such as industrial fermentation.[1] Others consider the beginning as the emergence of techniques allowing researchers precisely to manipulate and transfer genes from one organism to another. Genes are made up of deoxyribonucleic acid (DNA) and are expressed into proteins, which do chemical work and form structures to give us specific traits. In the 1970s, scientists discovered and used the power of natural "scissors" – proteins called restriction enzymes – specifically to remove genes from one kind of organism and put them into related or unrelated organisms. Thus recombinant DNA (rDNA) technology, or "modern biotechnology," was born. Most definitions of biotechnology focus broadly on the manipulation and use of biological systems for a purpose. However, there are numerous definitions which vary in their inclusion of modern techniques.

The pioneers of biotechnology could not have envisioned our current abilities to engineer plants to resist disease, animals to produce drugs in their milk, and small particles to target and destroy cancer cells.[2,3] However, biotechnology is more than engineered products – it is also a set of tools for understanding biological systems. Genomics is based on these tools and is the study of genes and their functions. We have determined the composition of, or "sequenced," the entire set of genes for humans and several other organisms using biotechnology. Genomic information is helping us to evaluate better the commonalities and diversity among organisms and human beings, and to understand ecology, evolution and disease.

Within these uncanny abilities, biotechnology poses both risks and benefits, and important social and ethical issues. Society drives and regulates technology, attempting to minimize costs and risks, and maximize benefits. From a utilitarian perspective, this balance is the most important consideration for technology governance. However, a utilitarian framework for decision-making can lead to choices that many would consider "unethical."[4] Natural and physical scientists tend to focus on "science-based" risks and benefits for oversight and prefer to maintain separation between social and ethical concerns and scientific ones. Recent controversies over the use of genetically engineered organisms in food and agriculture have illustrated that this boundary is not clear.[5]

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Others argue that tighter interactions among government, industry, academe and non-profits necessitate a more "socially robust" approach to science and technology.[6] Not only are there safety concerns about biotechnology, but there are also individual and cultural differences in acceptance of the applications and products.[a] The issue of whether diverse cultural views should be considered in formal oversight remains contentious. Individuals, regions and nations approach this question in various ways. In

**Table 94.1**

| *Ethical argument* | *Description* | *Examples for medical biotechnology* | *Examples for agricultural biotechnology* |
|---|---|---|---|
| Intrinsic | "Playing God," or creating life forms that nature would not have made, is wrong. | Cloning human beings or gene therapy directed at early human embryos is morally wrong. | Genetic engineering of animals for pharmaceutical production is morally wrong. |
| Consequentialist | Benefits to humans, animals or environment must outweigh harm. | The life-saving benefits of xenotransplantation using virus-free pig organs in humans is worth the transplantation risk to the patient and harm to the pig. Patents on life-saving drugs stimulate innovation and are worth the cost of limited access for other researchers and developing countries. | Benefits of reduced pesticides of Bt cotton in China outweigh harm to ecosystems. Economic harm to small farmers is less than economic gains of other sectors. |
| Rights/Consent | People have a right to know and choose. They should have autonomy. | There should be good informed consent during clinical trials of rDNA-derived drugs. Early testing for genetic disease should be a choice for patients. | Consumers have a right to know that food comes from genetically engineered organisms – products should be labeled. |
| Structural/ Procedural | The system is unethical or not fair. | Sharing of genetic susceptibility information with third parties should not occur. Scientists with conflicts of interest perform clinical trials. | Safety studies on genetically engineered crops should be available in public domain. Lack of transparency and access to information is not just. |

*Note*: Based on framework discussed in J. Burkhardt, "Ag Biotech Ethics at 25: What Have We Learned and Not Learned?," First International IFAS Conference on Food and Nanotechnology, *What Can Nano Learn from Bio?*, Michigan State University, 24–5 September 2005, http://www.ifas.msu.edu/presentations/Jeffrey_Burkhardt.pdf. In many ethical arguments, there is overlap among the paradigms. For example, the system might not be fair because consumers or patients do not have a right to choose.

the case of stem cell derivation and therapies, religious views often, but not always, align with national policies for their promotion or prohibition.[7]

Biotechnology applications are also layered with the philosophical question of the right of humans to interfere with basic natural processes. Other ethical questions include the rights of consumers or patients to choose their own level of acceptance (for example, informed consent to gene therapy or labeling of genetically engineered foods) and the rights of the poor to benefit from biotechnology applications (for example, access to rDNA-derived HIV treatments) (Table 94.1).[8] There seem to be no easy, universal solutions to addressing risk, societal and ethical issues in governance of emerging technologies, and it is even more challenging to consider all of these in local, national and international decision-making.

## Decision-making about New Technologies

Most agree that biotechnology itself is not inherently "risky" or "safe," but its products are. Decision-makers are faced with having to fit regulations to numerous types of products with unique risk and benefit profiles. This is especially challenging when products transcend disciplinary, sector and agency borders. These types of applications and products are categorized as "convergent technologies" (Figure 94.1). In 1986 the US Coordinated Framework for the Regulation of Biotechnology did not include guidance for the oversight of emerging or future products, leading to uncertainty as to how today's products like genetically engineered insects, fish and animals will be regulated and stalling these applications.[9,10] This highlights the need to anticipate and prepare for the future in decision-making for new technologies.[11]

Perception issues with convergent and novel applications abound. The public is more likely to perceive risks as unacceptable if they lack information about, experience with, and control of technologies.[12] Risk conversion factors have been formulated based on acceptability criteria, including whether technological risks are voluntary or involuntary, ordinary or catastrophic, natural or man-made, old or new, controlled

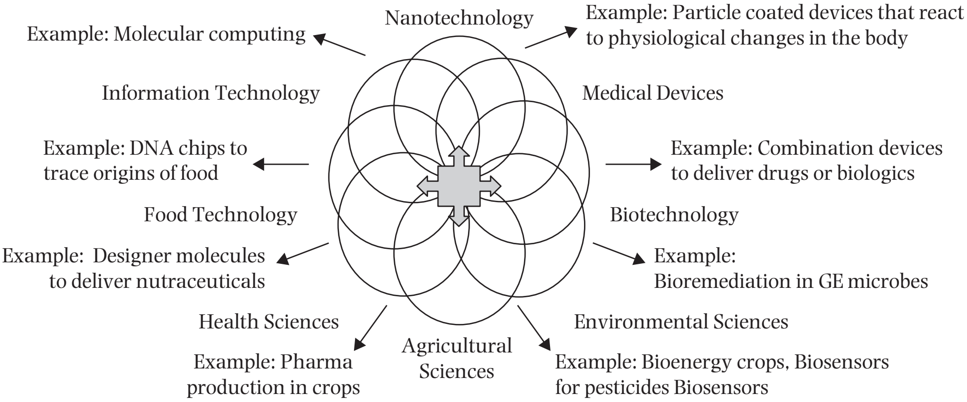

**Figure 94.1** Convergence technologies to improve health and the environment
*Note*: Examples at the intersection of circles are related to the use of biotechnology as broadly defined. Biotechnology, narrowly defined as rDNA techniques, also stands on its own as a circle in the diagram.

or uncontrolled, and delayed or immediate.[13,b] In fact, quantitative risk (severity of hazard combined with exposure) is just one of the many factors that citizens consider when they choose what is acceptable to them.

Why, then, is there such a push in the US and elsewhere for "science-based" oversight? Many believe that, in the face of the diversity of cultural, social and religious views and the goals of different organizations, it is impossible to accommodate them all. Science is viewed as the "rational," fair and objective way to approach products of new technologies. Yet, from a social constructionist viewpoint, technology does not drive its own existence, and humans create it within a social context.[14,15] The subsequent section will focus on the potential scientific risks and benefits of selected applications of biotechnology as well as the social impacts.

## Case Studies for Biotechnology

Biotechnology can be channeled to address challenges in energy, medicine, security, food and agriculture, environmental sustainability, and industrial products (Table 94.2). For example, fossil fuels are a finite energy resource, and we are expending them more quickly than nature can replenish. Researchers are using biotechnology to engineer better cellulases – enzymes that can break down plant material into biofuels such as ethanol. Better cellulases could eventually lead to the more cost-effective production of sustainable fuels.[16] Other examples of the environmental applications of biotechnology include micro-organisms engineered to produce hydrogen gas from organic waste; plants engineered to make biodegradable polymers; molecular machines based on plant photosynthetic proteins to harness energy from the sun; bacteria engineered to break down environmental pollutants; and biosensors developed to detect harmful environmental contaminants rapidly. The environmental applications of biotechnology are often overlooked and underfunded, yet the sustainability of our planet in the face of an increasing population is an issue of utmost importance.

Biotechnology has taken off in areas of food and agriculture. For example, cotton, soybeans, maize and other crops have been engineered to contain proteins from the bacterium *Bacillus thuringiensis* (Bt) that protect them from insect pests. The cultivation of Bt cotton in China has significantly reduced the use of chemical pesticides that are dangerous to human health, benefiting rural farmers.[17] On the other hand, there have been concerns associated with Bt crops. Starlink was a Bt maize variety approved only for animal feed in the United States, given questions about its potential to be a human allergen. However, it eventually contaminated some maize-based products in the human food supply.[18] Also, the genes for Bt proteins have been discovered in Mexican maize varieties, although Mexico has a moratorium on planting Bt maize.[19] This contamination has caused concern because Mexico is the geographic center of diversity for maize, and many want to preserve native varieties for cultural and agronomic reasons. Therefore, in order to reap the benefits of genetically engineered crops, it is important that good biosafety regimes be developed to avoid future mishaps and enhance confidence in the use of these crops.

Stem cells and cloning have gained unusual prominence in national and international politics.[20] Stem cells are the early-stage cells in an organism that have been

**Table 94.2**

| *Application* | *Potential health and environmental benefits* | *Potential health and environmental risks* | *Positive social impacts* | *Negative social impacts* |
|---|---|---|---|---|
| Genetically engineered bacteria for bioremediation | Reduced organic or inorganic pollution; preventing species decline or human toxicity. | Decline in native microbial fauna; negative effects of ingestion on other wildlife or humans. | Better environmental health leads to better quality of life; fewer illnesses from pollution and more time to work and play. | Displacement of other clean-up industries. Social unease with engineered life forms in environment. |
| Pre-implantation genetic diagnostics | Health of mother improved by avoiding pregnancies that will result in miscarriage. | Harm to healthy embryos by removing cells for testing. | Improved psychology of mothers with history of multiple miscarriages in past during pregnancy. | Misuse for traits that are not life-threatening or that lead to disability. Societal view of disability as something to be avoided. Inequitable distribution of technology for those who can afford it. |
| Stem cell therapy | Prevention or treatment of disease. | Destruction of human embryos; health risks of cell transplants (e.g. infection). | Better quality of life for many ill people. Improvement of life for people dealing with Alzheimer's. | Lack of access to therapies in poor rural areas around world. Disregard for human life in some religious and moral frameworks. |
| Pharmaceutical production in GE plants | Prevent disease that otherwise could not be prevented. | Impacts of gene flow to wild relatives, or contamination of general food supply. Risks to non-patients via these exposures. | Improved quality of life, especially in developing countries where cold storage of vaccines is a problem. More time for work, play and education. | Lack of trust in oversight systems due to previous co-mingling. Inaccessible to poor given intellectual property rights and high cost. |
| Herbicide-tolerant GE crops | Herbicides used on fields generally more benign to human health and the environment. | Impacts of gene flow on weedy relatives could lead to uncontrollable weeds in fields. | More free time and less production cost to farmers, improving their quality of life. | Monopolization of technology by few companies, leading to negative economic effects on small companies. |
| Engineered cellulase enzymes for biofuel processing | Reduce greenhouse gas emissions leading to many positive impacts | Chemical or energy inputs into enzyme production could be harmful to health or the environment. | Energy security for rural farm areas. Economic development for farmers. | Limited access of technology systems or biofuels to poor and energy-deprived areas. |
| DNA-based sensors for pathogens | Early detection of food or environmental contamination, preventing illness or death. | False negatives leading to mitigation measures that may actually increase risk. | Early response to bioterrorist attacks. Feeling of security. Fewer illnesses from food supply leading to better quality of life. | Psychological response to false alarms. Economic impacts of unnecessary recalls or decontamination. Military advantage for rich countries. |

*Note*: This table is not an exhaustive list, but provides just a few examples.

shown to give rise to different kinds of tissues. They have successfully replaced or repaired damaged tissue in animal models, and they hold promise for treating human diseases such as Alzheimer's and diabetes.[21] Although the vast majority of people agree that cloning to produce humans (reproductive cloning) is unacceptable, therapeutic cloning, in which the cloning process is used only to harvest stem cells, is hotly debated.[22] Therapeutic cloning could supply stem cells that exactly match a patient, minimizing the serious risks associated with tissue rejection. However, associated ethical, cultural and policy issues associated with them will continue to occupy scientists and politicians in the foreseeable future.

A fundamental application of biotechnology to medicine is in drug discovery. Humans have discovered drugs from natural sources by trial and error since the beginning of history. Now genomics and its companion field for proteins – proteomics – have allowed us to discover drugs more systematically. The automation of biochemical binding assays in small chips called micro-arrays enables scientists to screen thousands of chemical compounds for their effectiveness against disease-causing proteins in a very short time.[23] These assays can also explore an individual's responsiveness to treatment. There are concerns that this type of personalized genetic information could be used by insurance companies to deny coverage for pre-existing conditions or to patients who are less "treatable."[24]

Gene therapy, in which genes are delivered to specific diseased organs or tissues in the body to overcome metabolic deficiencies or other disease, is another area of great promise. The use of viruses to deliver genes has shown risks to human health, making trials with these viruses controversial.[25] The convergence of nanotechnology[c] with biotechnology will allow for safer gene delivery methods that are not based upon viruses. Chemically synthesized nanoparticles that carry genes or therapeutics specifically to diseased cells are being tested in animal models.[26]

Biotechnology also plays an important role in preventing disease. Vaccines produced by recombinant DNA methods are generally safer than traditional vaccines because they contain isolated viral or bacterial proteins, as opposed to killed or weakened disease-causing agents. However, many citizens in developing nations do not have access to any vaccines, let alone ones derived from biotechnology. Currently, most vaccines require cold storage and professional administration through injection. Therefore, researchers are working on genetically engineered plants to deliver vaccines through food. Production costs of plant-derived vaccines are estimated to be significantly less than for vaccines currently produced in bioreactors.[27] However, as with Bt crops, there are concerns about pharmaceutical crops because of inadvertent cross-pollination with food crops.[28]

## Guidance from the Public

Investments in science and technology will likely bear economic fruit. However, investments to address the social, political, cultural and ethical issues surrounding applications of biotechnology are equally important. There are good ways to foster open dialogue on societal issues surrounding emerging technologies among experts, stakeholders and citizens.[29] Many shy away from these activities, as it is impossible to accommodate everyone's preferences. However, if groups and their members are heard, and their input is considered, not only will they be more likely to accept decisions, but also better decisions will be made.[30]

We should neither ignore the potential health and environmental risks of biotechnology, nor dismiss its promise. However, the arguments for or against applications will be trusted only if the sources are.[31] We need to fund independent studies of impacts. Too often there is polarized debate because information presented comes from groups entrenched in their positions. Neutral think-tanks, academe, and respected organizations that do not have conflict of interests or large stakes in the outcomes, and where biases can be balanced, seem like good places for dialogue, policy analysis and safety research. Currently, there are few incentives for public engagement or the independent study of regulatory policy.

Likewise, there are few incentives for companies to provide information on the development and safety of potential products. Public and state access to information is difficult at best,[32] yet many have highlighted the need for transparency to increase public trust and procedural fairness.[33] Regulatory policy is largely negotiated between industry and federal regulators. We need a shift in attitude and willingness to work with all groups to resolve differences. With this, good governance,[d] and increased awareness of the social context of biotechnology and commitments to resolve existing issues, biotechnology can be harnessed responsibly for all.

## Notes

*a* For example, genetic testing of children prior to birth might be right for some, but not for others; likewise, some consumers might not want to eat genetically engineered food given their belief systems.

*b* For example, "voluntary" risks are accepted at a level of 1,000 times more in comparison to "involuntary" ones.

*c* The formal definition of nanotechnology includes the "understanding and control of matter at dimensions of roughly 1 to 100 nanometers (nm or 10−9 meters)." US National Nanotechnology Initiative. *What is Nanotechnology?* http://www.nano.gov/html/facts/whatIsNano.html (last visited 17 July 2006).

*d* For a discussion of good governance, see Commission of the European Communities, *European Governance: A White Paper* (25 July 2001) *available at* http://eur-lex.europa.eu/LexUriServ/site/en/com/2001/com2001_0428en01.pdf (last visited August 15, 2006).

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## 95

# Transportation

## JONATHAN L. GIFFORD

Transportation systems, like all technological systems, hold great promise for future prosperity, and also harbor great risks for the future. They facilitate cultural and economic exchange, specialization of production, access to opportunities for education, employment, worship, shopping and social interaction. Ease of transportation is a hallmark of advanced societies.

Yet transportation systems also consume scarce fossil fuels, produce greenhouse gases, fragment habitat, and act as vectors for disease and invasive species. Social and economic interaction facilitated by transportation can lead to erosion of cultural identity and to cultural homogenization.

Today efficient movement of people and goods is a key to prosperity and social well-being. Yet expansion of the benefits of affordable and reliable transportation services to a broader spectrum of global society also requires careful consideration of social, economic and environmental impacts.

## The Transportation System

The transportation system is a complex set of structures, devices, procedures and institutions. One scholar has called it a complex, large, integrated open system, or CLIOS (Sussman 2000). The transportation system is typically conceived of as consisting of several "modes": road, rail, water, air and pipeline. However, the shape and size of each mode varies considerably depending on the context, from horse and foot trails in remote areas to multilane limited-access highways in more developed locations.

One characteristic of the transportation system is its division into separate components of vehicles, infrastructure and operating protocols (Gifford and Garrison 1993). The automobile-highway system consists of automobiles and other vehicles, the road infrastructure upon which it travels, and the policies, norms, institutions and practices that govern its use. Similarly, the air transportation system consists of aircraft, airports and operating protocols and institutions. In many cases, the separate components are designed, operated, maintained and retired by well-defined professional groups, with financing provided through links to capital markets and governmental funding programs. Thus, the stakeholders in any single mode or industry are often very numerous.

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**Table 95.1** Measures of transportation infrastructure per capita – selected regions (km/million inhabitants)

| | *Intercity rail* | *Urban rail* | *Roads* | *Motorways* |
|---|---|---|---|---|
| EU 15 | 415 | 18 | 9,330 | 125 |
| Central and Eastern European countries | 635 | 50+ | 7,880 | 24 |
| United States | 140*/890 | 7 | 23,900 | 325 |
| Japan | 210 | 6 | 9,200 | 51 |
| World | 210 | 4 | 4,750 | 35 |

*Source*: European Commission (2000).
* Only 38,000 km in passenger service.

One indicator of the extent of the transportation system is the quantity of infrastructure per capita, as shown in Table 95.1. The US is by far the best-supplied with roads and motorways, with 23,900 and 325 km per million inhabitants respectively, compared with 9,200 and 51 respectively in Japan, and 4,750 and 35 respectively worldwide. Yet the US has far fewer miles of intercity passenger rail than the world average. Comparable measures of infrastructure supply in seaports, airports and pipelines would show similarly high relative supply in developed countries with less relative supply in developing countries. Another indicator is distribution of vehicles, as shown in Table 95.2. The patterns of supply are similar. The US had more than 800 vehicles per 1,000 residents, for example, compared with 20 in the East Asia Pacific region.

**Table 95.2** Number and type of vehicles (per 1,000 people) – selected regions*

| | *Motor vehicles* | | *Passenger cars* | |
|---|---|---|---|---|
| | *1990* | *2003* | *1990* | *2003* |
| East Asia and Pacific | 9 | 20 | 4 | 14 |
| Europe and Central Asia | 97 | 170 | 79 | 142 |
| Latin America and Caribbean | 100 | 153 | 72 | 108 |
| Middle East and N. Africa | 36 | .. | 24 | .. |
| South Asia | 4 | 10 | 2 | 6 |
| USA | 758 | 808 | 573 | 482 |
| Europe EMU | 429 | 570 | 379 | 502 |
| World | 118 | 141 | 91 | 100 |

*Source*: 2006 World Development Indicators, World Bank
* Motor vehicles include cars, buses, and freight vehicles but not two-wheelers. Passenger cars refer to road motor vehicles, other than two-wheelers, intended for the carriage of passengers and designed to seat no more than nine people (including the driver). Europe EMU is European Monetary Union.

## Transportation System Benefits, Harms and Hazards

At its most basic level, the transportation system's primary benefit is the reduction in cost of moving people and material between two locations. Absent a transportation system, people and material would be impossible or very difficult to move from place to place. Indeed, in some African countries, "head transport," generally by women, is a common form of moving water, food and other materials. Even head transport requires footpaths, although these may not be the product of systematic design and deliberate improvement and maintenance, but may have emerged through routine use over time.

As one reduces transportation costs, opportunities for economic and social exchange expand. Expanded exchange often allows specialization of production. The common textbook example is two nearby villages that require pottery (to cook and store food) and corn (to consume) for their sustenance. Without transportation, and hence without exchange, each village must produce enough pottery and corn to sustain itself. If transportation allows exchange, and if economies of scale are sufficient to offset transportation costs, then one village may evolve to specialize in production of pottery, the other corn, with the two villages trading with each other to achieve sustenance. Overall resources devoted to production and transportation of corn and pottery will decline under such conditions, and surplus income will allow both villages to be better off.

As illustrated by this example, transportation can have a significant influence on economic development. In *Transport Investment and Economic Development*, the author observes that "Transportation plays a many-faceted role in the pursuit of development objectives" (Fromm 1965). It may affect where or how much regional growth occurs, or it may create its own demand by stimulating industrial activities in a region (Kraft, Meyer and Valette 1971).

Thus transportation is the foundation for trade in modern society. Good transportation services allow the utilization of resources and markets in an extensive region. In that sense, "transportation 'creates' raw materials by making otherwise unusable commodities accessible" (World Business Council for Sustainable Development 2004). For instance, because of efficient and economical transportation services, companies may draw their workforces from and expand their markets to broader areas; productivity may increase based on more efficient combinations of labor and raw materials; and production costs may also be reduced because of economies of scale. A transportation network with a higher speed and larger scope has positive effects on distribution of population, industry and incomes (Fromm 1965, Queiroz and Gautam 1992, Fernald 1999).

The transportation of people is fundamentally important as well. Personal travel is central to many social and economic processes. In developed economies, the workforce often travels significant distances to jobs using either public transport or private vehicles. Personal travel is central to other social and economic activities as well, including travel to worship, shopping, school and entertainment.

Personal travel is highly income-elastic, that is, individuals often choose to spend proportionally more of their income on transportation as their income rises. In developing economies, expenditures on personal travel often rise rapidly with development, proceeding from human-powered modes like walking and cycling to motorized means like motor scooters, motor cycles and personal automobiles.

Yet demand for both personal travel and goods movement is for the most part "derived," that is, it arises out of demand for goods, services or activities located at the endpoint of the trip. Some travel is undertaken for its own sake, however – for recreation or exercise, for example.

Different spatial configurations may give rise to different patterns of transportation use. The modern American suburban subdivision is often criticized for fostering automobile dependence, in contrast to urban designs that facilitate pedestrian and bicycle transportation (Duany, Plater-Zyberk and Speck 2000). Thus the key to well-being is not transportation per se, but access to goods, services and activities. Access, in turn, can arise from use of transportation, or through community *design* (Levinson and Krizek 2005). Indeed, the United Kingdom has begun to assess how different transportation and development proposals foster or reduce "social exclusion," by which is meant the tendency of certain configurations of land-use and transportation to exclude certain social groups, such as those who do not own automobiles (see, for example, Dobbs 2005).

Notwithstanding the tremendous benefits that can arise from safe and efficient transportation systems, they also confer significant harms and hazards on society. A brief catalog of these would include: tailpipe emissions of toxic substances and greenhouse gases, dependence on foreign sources of energy (itself a product of the efficiency of the fossil fuel distribution system), injuries, fatalities and property damage visited upon pedestrians, motorists and collateral parties, fragmentation of habitat, and polluted runoff. Less widely agreed upon, but still a concern to many, are land-use arrangements (i.e. "urban sprawl"), community preservation, social isolation and exclusion, and sedentary lifestyles that contribute to obesity.

Concerns about these harms and hazards are heightened by the voracious social appetite for motorized transport in both the developed and the developing world. If vehicles, roadways and parking facilities are to be expanded to meet rising demand, what is the cost in habitat, natural resources and disrupted communities?

## Conclusions and Further Questions

Here, then, is the central philosophical question posed by the transportation system of the future: How may society discover the right tradeoffs between its obligation to pass on to future generations a healthy and wholesome world, on the one hand, and the needs and desires of the current global population on the other? This is the question posed since the release of the Bruntland report in 1987 by those concerned with the sustainability of the transportation system (Bruntland 1987).

Beyond its obligation to future generations, how should society discover the right allocation of resources across its current population? Few would begrudge the African woman engaged in head transport an improved road and a vehicle to use for ferrying water, food and other resources to and fro. But how best to provide that roadway and vehicle, whether by wringing efficiencies out of other parts of the system, or by reallocating resources from haves to have nots, remains a pressing issue.

Fundamentally it is an institutional question. Are markets robust enough to mediate these decisions? And, if not, to what extent should the focus be on improving the functioning of markets or alternatively resorting to non-market mechanisms.

Many economists would suggest establishing clear property rights and effective processes for protecting them, and letting markets take care of the rest. Yet no economist would disagree that, in much of the transportation domain, prices are way out of alignment and property rights are badly defined and poorly protected, perhaps more so in the developing world.

So how best, then, to bring the benefits of appropriate transportation to those in need, and manage the harms and hazards thereby arising? To focus on improving the conditions that allow markets to work efficiently, or to promote non-market mechanisms?

There is far from universal agreement on this question. Many view the developed world, and especially the US, as profligate energy-users and polluters, consuming far more than their fair share of global resources. Yet transportation cannot be examined in isolation from other domains. It is inextricably interwoven with matters of global trade, and hence with debates about how trade fosters or harms global well-being. And how should "Western" ideals of freedom, democracy and self-determination weigh in the balance?

Thus the transportation sector can have enormous impacts on future prosperity and future risks. It probably makes most sense to emphasize correct pricing and clear and well-protected property rights, while recognizing that the institutions needed to make markets work well are not present in many places with potentially large opportunities for both benefit and harm. Because of poor property rights definitions and protections, winners in the market system often do not compensate losers, which creates enormous losses of social welfare.

Yet there are no easy answers. The tradeoffs across today's populations, and between today's population and future generations are very difficult to resolve. Institutions hold the key to discovering the way forward, since there is no universally agreed upon technical standard, and since values play such an important role in making choices.

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# 96

# Global Challenges

## JENNIFER KUZMA

Since the industrial revolution, the economic importance of technological change has been widely accepted,[1,2] and science is now being viewed by many as a "vital precondition," rather than a luxury, for economic development.[3] Alongside this shift in thinking, over 180 UN member states adopted the 2000 Millennium Declaration to free the world of extreme poverty. These nations pledged to meet certain goals, called the Millennium Development Goals (MDGs), by the year 2015 (Box 7.1).[4] The goals are designed to address extreme poverty, hunger, disease, lack of adequate shelter, and exclusion, while promoting education, gender equality, and environmental sustainability. To date, significant progress has been made in meeting some MDGs, such as poverty reduction, increased primary education and gender equality, and lower child mortality. However, less progress has been made in fighting global disease and improving environmental sustainability.[5] Malaria and AIDs rates are increasing in many areas,[6] and greenhouse gas emissions continue to rise.[7] Historical and economic evidence suggests that science and technology (S&T) can contribute to all of the goals, and there is increasing attention to the need to link MDGs with global agendas for S&T.[8]

However, there are significant challenges to this linkage. Technology does not chart its own course toward social good. It is often developed by the private sector, whose main goal is to increase profits. Leaders at companies may want to promote environmental quality and larger societal benefits, but ultimately their success is measured by financial gains. There are few incentives for companies to focus technology development on problems that disproportionately affect the poor, as solutions to these are not big money-makers. Foundations led by philanthropists, such as the Bill and Melinda Gates Foundation, have contributed greatly in the area of global health.[9] Their efforts are commendable, but are not enough to meet the MDGs and will take time to come to fruition. Development assistance has recently increased from 2002 to 2005, however, most developed countries still contribute much less than 0.7 percent of their Gross National Incomes, the amount estimated to be required to meet the MDGs.[10,11]

Even with sufficient funds and assistance, there are other issues to address. The UN Millennium Project lists four major reasons for the lack of progress toward the MDGs – poor governance, including corruption, mismanagement, and citizen abuse; poverty traps, in which people are too poor to make use of investments; pockets of poverty, such

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## Box 7.1 The Millennium Development Goals

1. Eradicate extreme poverty and hunger.
   Reduce by half the proportion of people living on less than a dollar a day.
   Reduce by half the proportion of people who suffer from hunger.
2. Achieve universal primary education.
   Ensure that all boys and girls complete a full course of primary schooling.
3. Promote gender equality and empower women.
   Eliminate gender disparity in primary and secondary education, preferably by 2005, and at all levels by 2015.
4. Reduce child mortality.
   Reduce by two thirds the mortality rate among children under five.
5. Improve maternal mortality.
   Reduce by three quarters the maternal mortality rate.
6. Combat HIV/AIDS, malaria, and other diseases.
   Halt and begin to reverse the spread of HIV/AIDS.
   Halt and begin to reverse the incidence of malaria and other diseases.
7. Ensure environmental sustainability.
   Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources.
   Reduce by half the proportion of people without sustainable access to safe drinking water.
   Achieve significant improvement in the lives of at least 100 million slum dwellers by 2020.
8. Develop a global partnership for development.
   Develop further an open trading and financial system that is rule-based, predictable, and nondiscriminatory. Include a commitment to good governance, development, and poverty reduction – nationally and internationally.
   Address the least developed countries' special needs. This includes tariff-free and quota-free access for their exports; enhanced debt relief for heavily indebted poor countries; cancellation of official bilateral debt; and more generous official development assistance for countries committed to poverty reduction.
   Address the special needs of landlocked and small island developing states.
   Deal comprehensively with developing countries' debt problems through national and international measures to make debt sustainable in the long term.
   In cooperation with the developing countries, develop decent and productive work for youth.
   In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries.
   In cooperation with the private sector, make available the benefits of new technologies – especially information and communications technologies.

as slums and other social groups that are excluded from the benefits of investment; and policy neglect, in which policy-makers are unaware of what to do or ignore core issues.[12] Although science and technology cannot solve these problems, it can lead to reliable, appropriate and cost-effective interventions that alleviate conditions that cause extreme poverty. Yet stability and capacity are essential for taking advantage of investments and assistance related to S&T.[13]

In 2003, UN secretary-general Kofi Annan called for a mobilization of the scientific community to help meet global challenges:

> much of that science–in the realm of health, for example–neglects the problems that afflict most of the world's people. This unbalanced distribution of scientific activity generates serious problems not only for the scientific community in the developing countries, but for development itself. It accelerates the disparity between advanced and developing countries, creating social and economic difficulties at both national and international levels. The idea of two worlds of science is anathema to the scientific spirit. It will require the commitment of scientists and scientific institutions throughout the world to change that portrait to bring the benefits of science to all.[14]

The 10/90 Gap is one illustration of the current inequities. Only 5–10 percent of global health research funding is directed toward health problems that affect 90 percent of the world's population, and only a small proportion of this funding goes to researchers in developing countries.[15]

In an effort to steer the course of science and technology toward great societal challenges, the Interacademy Council, composed of the heads of fifteen world scientific academies, signed a statement calling on the world's scientific, medical and engineering experts to identify and promote ways to reduce poverty and advance the MDGs. The statement was delivered to heads of state at the opening of the UN General Assembly in September 2005.[16] Their specific recommendations include better local infrastructure for applying scientific and technological knowledge to national problem-solving; good connectivity to the Internet for all scientists and academic institutions; centers of research and development excellence in countries where the university sector is weak; promotion of local enterprises for better meeting the needs of the poor; and investment of international funds to support innovative capacity in developing countries.

The vision of S&T for the betterment of all seems to be in place among the world's experts and leaders; however, the path to achieving it seems difficult. The following sections explore the challenges of an S&T agenda that is more closely tied to achieving the MDGs and summarize recommendations for doing so.

## Cases of S&T Applied to the MDGs

There have been several reports outlining the contribution of S&T to the MDGs.[17,18,19] Some recommendations seem out of reach, in light of the lack of basic infrastructure in the world's poorest regions. For example, how can genomics play a role in diagnosing illness early on, if there is not basic medicine and doctors in many rural areas? Yet, in their optimism, they give us a picture of what the future should be. There has been a call for a "global genomics partnership," with high participation and leadership from the global South, to focus specifically on development needs.[20] Many argue that without advanced technology for developing countries they will only continue to lag behind.[21]

Local technology development is essential to building long-term capacity and appropriate solutions for developing countries.[22] For example, an Indonesian research team developed a real-time immunochemistry-based assay that detects *Salmonella typhi*, the causative agent of typhoid fever.[23] This test can be performed without laboratory facilities, as the reagents are stable and it is simple to conduct. The Indian company Shantha Biotechnics developed a recombinant hepatitis B vaccine, which sells for twenty times less per dose than the US vaccine.[24] Medical and healthcare technologies developed locally are more likely to take into consideration local financial and infrastructure challenges and conditions of affected communities.

Environmental sustainability is lagging behind other MDGs. One of the biggest threats to our planet is climate change induced by anthropogenic greenhouse gas emissions and climate change. Climate change is expected to affect the poor disproportionately, causing, among other things, crop loss and flooding in areas already stressed by natural disasters.[25] There is a need for all countries to reduce greenhouse gas emissions, especially developed countries that are primary contributors, such as the US. Although there are good arguments as to why developing countries should be able to base economies on fossil fuels, like the developed world has over the past few centuries,[26] renewable energy systems in developing countries can accomplish multiple goals. For example, diesel generation systems have been employed in West Africa to improve energy access.[27] With better technologies for fuel extraction and engines, these systems could eventually be run on local sources of biodiesel such as the *Jatropha curcas* shrub.[28] If properly deployed, locally based, renewable systems will boost local economies, mitigate climate change, and provide energy services to rural areas.

Access to energy is essential to meeting most of the MDGs. For example, with lighting, electric-powered machinery, and better cooking fuels, more time can be dedicated to education and income-generating activities. This increased time is especially important for women, who do most of the food preparation, cooking and farming in developing countries. Lives will also be improved with electric pumps for water, lower crime rates due to lighted areas, and reduced indoor air pollution from cleaner fuel sources for cooking.[29] There is need to link economic development better with distributed, sustainable energy systems in developing countries.

Applications of science and technology to water availability and shortages, food and agriculture will also be needed. The UN Environment Program lists freshwater shortages as one of the greatest environmental problems for the twenty-first century.[30] Drought- and salinity-tolerant crops tailored to developing countries could greatly enhance food security in areas where a combination of natural disasters and marginal land are sure to lead to famine in a given year. Through genomics and modern biotechnology, we are getting closer to understanding, identifying and engineering the many traits that control water use and salt utilization in plants. For example, at the International Maize and Wheat Improvement Center (CIMMYT), a branch of the Consultative Group on International Agricultural Research (CGIAR) system,[a] researchers are developing drought-resistant maize for Mexican and other farmers.[31] CGIAR has been a cornerstone for agronomic research in developing countries, but its centers have been significantly underfunded, and many of its centers and programs are in jeopardy.[32]

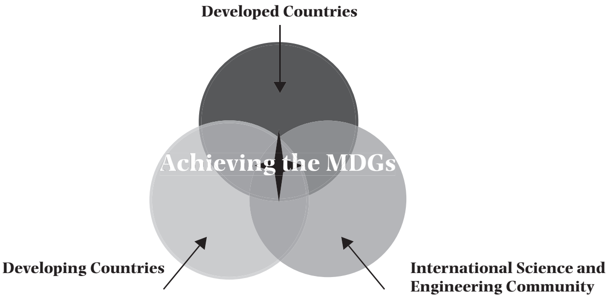
Healthier and more nutritious foods are also being developed via technology. More than 100 million people are affected by vitamin A deficiency (VAD), which is responsible for hundreds of thousands of cases of blindness annually. Researchers have engineered a variety of rice to supply the metabolic precursor to vitamin A. This "golden rice" is being bred with local varieties to enhance its properties for growth in developing countries.[33] At least sixteen research institutions in India, the Philippines, China, Bangladesh, Indonesia, Vietnam and South Africa are licensees and contribute to seed development as a consortium, termed the Golden Rice Network. Intellectual property hurdles have been overcome to distribute the rice free to subsistence farmers[b] – this is especially important because the cost of seed could otherwise be prohibitive. Although golden rice will likely not be a panacea for VAD, once the rice comes to market it is expected to reduce significantly the health burden and lead to other social benefits. For example, one case study in the Philippines estimated a 5.7–31.5 percent reduction in the health burden and $16–88 million worth of social benefits per year from adoption of golden rice.[34]

## Ways Forward

As described above, there are good examples of success in connecting the MDGs with S&T innovation. However, there is a long way to go. The UN's Task Force on Science, Technology and Innovation recommends a focus on platform technologies (ones that have broad impacts on economies); infrastructure development through indigenous engineering and construction firms; improvements in universities with a focus on development research; higher education for more young people, especially women; and government incentives and procurement for new technologies.[35] Currently, there is a significant drain of talent from developing countries to the developed world, given better economic opportunities and political stability abroad.[36] Developing countries, in partnership with developed ones, need to create climates to retain their scientists and engineers. The global S&T community needs to provide incentives for work on local issues, as researchers who work on important regional problems often cannot publish their findings in mainstream international journals.[37] One way to address this problem is for governments to fund competitions to address national challenges. The Venezuelan National Science and Technology Council has done this to focus research on challenges with the oil industry, urban violence and the cacao crop virus.[38]

Global public–private partnerships (PPPs) are on the rise for combating disease. Big pharmaceutical and smaller biotechnology companies are partnering with government and academic groups to combat global health threats with funding coming mainly from foundations.[39] As of December 2004, there were sixty-three projects of this nature, whereas a decade ago there were none. Although the companies involved are not expected to make money from the drugs they develop for neglected diseases, benefits to them include covered or reduced expenses for clinical trials, a better public image, and introduction to developing-country researchers. However, great caution must be taken with performing large-scale clinical trials in developing countries – these

- Governments
    - Provide at least 0.7% of GNP to MDGs
    - Provide incentives for businesses and scientists to work with developing-county experts
    - Link development with environmental goals
- Business
    - Invest in projects in developing countries in partnerships with local owners and developers
    - Donate enabling technologies and grant licenses for free
    - Provide medicines at low to no cost in disadvantaged areas
- Other
    - Private foundations to continue to fill the funding and research gaps
    - Citizens and NGOs to continue to demand political will to achieve the MDGs



- Governments
    - Invest in universities and education especially for children and women
    - Work towards political and economic stability
    - Develop infrastructure to utilize loans and assistance and provide incentives
- Industry
    - Engage in international collaborative projects
    - Focus R&D and products on local needs
- Others
    - Focus on education of children
    - Promote equality of women in society
    - Link development with environmental goals

- Provide incentives for developing world scientists to work on local problems
- Forge international collaborations to address pressing global challenges
- Donate intellectual property to the developing world
- Highlight the need for increased multi-sector funding to reach the MDGs
- Focus individual and collaborative research on meeting MDGs

**Figure 96.1** Achieving the MDGs
*Note*: This is not a complete list of recommendations for all sectors.

trials must be conducted with the same ethical and safety standards as in the developed world.[40,41]

There seems to be the will within the leadership of the S&T community to align S&T with the MDGs. However, in order to do so, more of the recommendations of premier international bodies need to be implemented by all sectors of society (Figure 96.1). Creativity in the design of policies and implementation of programs should be encouraged. With increased political, social and economic commitment, achieving the MDGs, while advancing S&T for all nations, seems within reach.

## Notes

*a* CGIAR is a strategic alliance of countries, international and regional organizations, and private foundations supporting fifteen international agricultural centers that work with national agricultural research systems and civil society organizations including the private sector. The alliance mobilizes agricultural science to reduce poverty, foster human well-being, promote agricultural growth and protect the environment. The CGIAR generates global public goods that are available to all. Excerpted from http://www.cgiar.org/who/index.html.

*b* Defined in this case as those who make under US$10,000 per year.

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# 97

# Chemicals

## BRUCE E. JOHANSEN

Artificial chemicals usually are invented, manufactured, sold and used under advertised assumptions that they will provide humankind with benefits, such as the eradication of harmful pests. In some cases, however, the use of such chemicals has been found to provoke various side-effects, which, like some drugs, inflict problems for people and the environment that outweigh their benefits. In several cases during the last century, the use of chemicals has been restricted or banned because of their malodorous (and often unanticipated) effects.

During the early 1960s, for example, a furor followed disclosure by Rachel Carson in *Silent Spring* (1962) of DDT's effects on the environment, largely on birds. Use of the chemical was then banned in the United States and other industrialized countries, although it continues to be used in areas where malaria-bearing mosquitoes are a major health risk.

During the 1970s and 1980s, the use of CFCs (chlorofluorocarbons) as refrigerants and propellants was found to be eroding stratospheric ozone, which shields human life from cancer-inducing ultraviolet radiation. Use of CFCs was subsequently banned under international law during the late 1980s. Restoration of stratospheric ozone has been much slower than expected under the ban, however, as scientists have discovered that many of the chemical reactions which cause CFCs to erode ozone are cold-activated. As carbon dioxide, methane and other greenhouse gases near the Earth's surface retain larger amounts of heat there, the stratosphere has cooled steadily since the 1980s, accelerating ozone depletion by remaining CFCs. Thus solution of ozone depletion depends to an important extent on human success in combating global warming.

A number of "persistent organic pollutants" (POPs) also have been banned or restricted by the Stockholm Protocol, following disclosure that they have been damaging human and animal life, most notably in the Arctic. Polychlorinated biphenyls (PCBs) and dioxins are two of the most widespread chemicals that concentrate in the Arctic owing to prevailing wind and ocean currents. They lodge in the body fat of mammals, and increase sharply in potency (bio-magnify or -accumulate) up the food chain. The Inuit, at the top of the Arctic food chain, would eventually have faced extinction if these chemicals had not been banned. Even with the ban, Inuit mothers have been told not to breast-feed their infants, and to restrict their consumption of some fish and land mammals which constitute the traditional Inuit diet.

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## Toxic Chemicals in the Arctic

"As we put our babies to our breasts we are feeding them a noxious, toxic cocktail," said Sheila Watt-Cloutier, a grandmother who has also served as president of the Inuit Circumpolar Conference. "When women have to think twice about breast-feeding their babies, surely that must be a wake-up call to the world" (Johansen 2000: 27).

Many residents of the temperate zones hold fond stereotypes of a pristine Arctic largely devoid of the human pollution that is so ubiquitous in the industrial world. To a tourist with no interest in environmental toxicology, the Inuits' Arctic homeland may seem as pristine as ever during its long, snow-swept winters. Such scenery may seem pristine, until one realizes that the polar bears' and seals' body fat are laced with dioxins and PCBs.

To the naked, untutored eye, the Arctic still *looks* pristine. In Inuit Country these days, however, it is what you *cannot* see that may kill you. The toxicological due bills for modern industry at the lower latitudes are being left on the Inuit table in Nunavut, in the Canadian Arctic. Native people whose diets consist largely of sea animals (whales, polar bears, fish and seals) have been consuming a concentrated toxic chemical cocktail. Abnormally high levels of dioxins and other industrial chemicals are being detected in Inuit mothers' breast milk.

Dioxins, PCPs and other toxins accumulate with each succeeding generation in breast-feeding mammals, including the Inuit and many of their food sources. Airborne toxic substances are absorbed by plankton and small fish, which are then eaten by dolphins and whales, and other large animals. The mammals' thick subcutaneous fat stores the hazardous substances, which are transmitted to offspring through breast-feeding. Sea mammals are more vulnerable to this kind of toxicity than land animals, so the levels of chemicals in their bodies can become exceptionally high. The level of these toxins increases with each breast-fed generation.

Inuit infants have provided "a living test tube for immunologists" (Cone 1996: A-1). Owing to their diet of contaminated sea animals and fish, Inuit women's breast milk contains six to seven times the PCB level of women in urban Quebec, according to Quebec government statistics. Their babies have experienced strikingly high rates of meningitis, bronchitis, pneumonia and other infections compared with other Canadians. One Inuit child out of every four has chronic hearing loss due to infections.

POPs have been linked to cancer, birth defects and other neurological, reproductive and immune-system damage in people and animals. At high levels, these chemicals damage the central nervous system. Many of them also act as endocrine disrupters, causing deformities in sex organs as well as long-term dysfunction of reproductive systems. POPs can also interfere with the function of the brain and endocrine system by penetrating the placental barrier and scrambling the instructions of naturally produced chemical messengers. These tell a fetus how to develop in the womb and post-natally through puberty; should interference occur, immune, nervous and reproductive systems may not develop as programmed by the genes inherited by the embryo.

"We are the miner's canary," said Watt-Cloutier. "It is only a matter of time until everybody will be poisoned by the pollutants that we are creating in this world" (Lamb n.d.). "At times," said Cloutier, "we feel like an endangered species" (Personal communication, 28 March 2001).

The bodies of some Inuit thousands of miles from the sources of chemical pollution have the highest levels of PCBs ever detected, except in victims of industrial accidents. Some Native people in Greenland, for example, have more than seventy times as much of the pesticide hexachlorobenzene (HCB) in their bodies as temperate-zone Canadians (Johansen 2000: 27).

Pesticide residues in the Arctic today may include some used decades ago in the southern United States. The Arctic's cold climate also slows decomposition of these toxins, so they persist in the Arctic environment longer than at lower latitudes. The Arctic acts as a cold trap, collecting and maintaining a wide range of industrial pollutants, from PCBs to toxaphene, chlordane to mercury, according to the Canadian Polar Commission (PCB Working Group n.d.). As a result, "Many Inuit have levels of PCBs, DDTs and other persistent organic pollutants in their blood and fatty tissues that are five to ten times greater than the national average in Canada or the United States" (PCB Working Group n.d.).

## Stratospheric Ozone Loss and Global Warming

A dozen years after CFCs were banned, the area of depleted stratospheric ozone over the Antarctic formed earlier and endured longer during September and October of 2000 than ever before – and by a significant extent. Figures from NASA satellite measurements showed that the area of severely depleted ozone (popularly called the "ozone hole") covered an area of approximately 29 million square kilometers in early September, exceeding the previous record during 1998. During early September 2003, the area of depleted ozone over Antarctica was again approaching near-record size. By the end of the month, the area of severely depleted ozone was the second-largest on record, at about the size of North America.

Why has stratospheric ozone been so slow to heal, even years after CFCs were banned? Scientists have discovered that many of the chemical reactions that deplete ozone are cold-activated; the colder the temperature in the stratosphere, the more severe the ozone loss. Rising levels of carbon dioxide, methane and other trace gases provoked by human burning of fossil fuels hold heat near the surface, inhibiting its radiation into space through the stratosphere. Thus, the stratosphere cools as the surface warms.

The effect of global warming on ozone depletion is significant enough that the rate of ozone depletion may not decrease even as levels of CFCs decline, according to Markus Rex of the Alfred Wegener Institute for Polar and Marine Research in Potsdam, Germany, and his colleagues. "I was surprised to see these results," said Drew Shindell, an atmospheric scientist at NASA's Goddard Institute for Space Studies, New York. "We never suspected the [existing] models were this far out of whack," he said (Rex et al. 2004 Ball 2004).

As scientists probe the connections between surface warming and stratospheric cooling, they find more potentially dangerous complications. For example, a team of atmospheric scientists has discovered large particles inside stratospheric clouds over the Arctic that could further delay the healing of the Earth's protective ozone layer.

Atmospheric chemist David Fahey of the National Oceanic and Atmospheric Administration's office in Boulder, Colorado, led a team of twenty-seven colleagues who concluded:

> Arctic ozone abundances will remain vulnerable to increased winter/spring loss in the coming decades as anthropogenic chlorine compounds are gradually removed from the atmosphere, particularly if rising concentrations of greenhouse gases induce cooling in the polar vortex and trends of increasing water vapor continue in the lower stratosphere. Both effects increase the extent of Polar stratospheric cloud formation and, thereby, denitrification and the lifetime of active chlorine. The role of denitrification in these future scenarios is likely quite important.
>
> (Baumgardner et al. 2001: 1030)

Fahey and his colleagues estimated that ozone depletion in the Arctic stratosphere may not reach its peak until the year 2070, even with a steady decline in chlorine levels.

While most of the area covered by the Antarctic ozone "hole" is uninhabited, a similar Arctic ozone-depletion zone could affect parts of densely populated Europe, Asia and North America. In addition to severe ozone losses over Antarctica, stratospheric ozone levels, too, have generally been declining in the Arctic for several years.

Jonathan Shanklin of the British Antarctic Survey, one of the three scientists credited with discovering severe ozone depletion over Antarctica, has warned that global warming threatens to deplete stratospheric ozone over the Arctic in a manner similar to the ozone "hole" over the Antarctic (Kirby 2000). Solar flares and frigid stratospheric temperatures during the winter of 2003–4 provoked the worst depletion of ozone above the Arctic since records have been kept, according to a team of scientists reporting in the 2 March 2005 issue of *Geophysical Research Letters* (Brohede et al. 2005).

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### 98

# The Future of Humanity

### NICK BOSTROM

The future of humanity has traditionally been a theological topic. All the major religions have teachings about the ultimate destiny of humanity or the end of the world. Eschatological themes have also been explored by philosophers, including Hegel, Kant and Marx. Science fiction authors, too, have had plenty to say on the subject. Very often, the future has served as a projection screen for our hopes and fears, for entertaining drama, morality tales, and reflections of tendencies in contemporary society. Only rarely is humanity's future taken seriously as a subject matter on which it is important to try to have factually correct beliefs.

Most important differences between ourselves and our forebears are ultimately related to technology. In the early days of our species, technological progress was slow. Tens of thousands of years would pass without much accumulation. Only within the last couple of hundred years could a person expect to experience significant technological change within her lifetime. Inventor and writer Ray Kurzweil argues that technological development is still accelerating. On the basis of exponential trends in a number of high-tech areas, he predicts a technological "singularity" before the middle of this century (Kurzweil 2005).

Technology in a wide sense (including not only gadgets but also methods, techniques and institution design principles) is the fundamental cause of long-term economic growth. Economic growth is what has enabled the world population to increase to over 6 billion people; up from the 4 million or so that inhabited the planet when humans lived as hunter-gatherers. Economic growth has also enabled cities and labor specialization, and hence indirectly all the phenomena made possible by high-density population centers with skilled laborers – including, significantly, a much faster pace of innovation.

Pessimists about the future often focus on the environmental problems facing the growing world population. They worry that our current wasteful and polluting ways are unsustainable and threatening to human civilization. Paul Ehrlich's *Population Bomb* (1968) and the Club of Rome's report *Limits to Growth* (1972), which sold 30 million copies, predicted economic collapse and mass starvation by the 1980s or 1990s as a result of population growth and resource depletion (Ehrlich 1968, Meadows and Club of Rome 1972). The basic idea of population growth as the nemesis of human welfare goes back to the English demographer and political economist Thomas Robert Malthus (1766–1834). Malthus argued that the lower classes could never permanently be lifted

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out of poverty, because as their condition improved they would have more surviving children and more mouths to feed. Over time, population would outgrow food supply, starvation would occur, and the majority of men would again be reduced to subsistence-level incomes (Malthus 1798).

In the long run, average income can only increase if economic growth is faster than population growth. Long-term economic growth is determined by technological progress. The predictions of Malthus and his latter-day followers failed because economic growth has been faster, and population growth slower, than they expected. Malthus would have been surprised to find that fertility has declined dramatically in high-income countries. Global population growth is currently just over 1 percent, while global economic growth over the last three decades has averaged about 3 percent per year (US Census Bureau 2007; Maddison and Organization for Economic Co-operation and Development. Development Centre 2003: 257–63).

The human species is not in an evolutionary equilibrium. Our current reproductive instincts and child-rearing preferences are not fitness-maximizing. It takes many generations for biological evolution to reshape our behavioral tendencies. If the present fitness landscape remained unchanged for a long time, we should expect *Homo sapiens* to evolve new dispositions that promote fitness under modern conditions – such as an aversion to contraceptives, a strong desire for big families, and perhaps a disinclination to fitness-reducing choices such as extended education. Memetic evolution might produce these results faster. Some groups, such as the Hutterites, an Anabaptist sect, have been growing despite high defection rates because of their extremely high fertility rate – an average Hutterite woman gives birth to nine children (Lang and Gohlen 1985). The Hutterites oppose birth control and see high fertility as a sign of divine blessing. Both in biological and memetic terms, human evolution is still occurring – probably at an unusually fast pace since our habitat has changed so much in recent times. If the human socio-economic habitat were magically frozen in its present state, Malthus would eventually be vindicated.

Not all pessimists focus on environmental problems or Malthusian scenarios. Many other catastrophe scenarios have been proposed. Of these, one can distinguish an especially severe subset: *existential risks* (Bostrom 2002b). An existential disaster is one which would either cause the extinction of Earth-originating intelligent life or permanently and drastically curtail its potential. Such an event would completely and irreversibly destroy humanity's future.

Existential risks have not received as much scholarly attention as they deserve. In recent years, there have been three serious books and one major paper on this topic. John Leslie, a philosopher, puts the probability of humanity failing to survive the next five centuries at 30 percent, partly based on the controversial "Doomsday argument" (Leslie 1996, Bostrom 2002a). Sir Martin Rees, an astronomer and president of Britain's Royal Society, is even more pessimistic, thinking the odds that we shall survive the twenty-first century are no better than 50 percent (Rees 2003). Richard Posner, an eminent American legal scholar, offers no numerical estimate but rates the risk "significant" (Posner 2004). Nick Bostrom, in the paper that introduced the concept of existential risk, maintained that assigning a probability of less than 25 percent to existential disaster in this century would be misguided (Bostrom 2002b). It is possible that a publication bias is responsible for these alarming opinions. Presumably, people who think the threats are severe are more likely to write books on the topic. It is nevertheless unsettling that those who have done research in this area seemingly agree that there is a serious risk that humanity's journey will come to a premature end.

The greatest existential risks arise from human activity. Our species has survived volcano eruptions, meteor impacts and other natural hazards for tens of thousands of years. It seems unlikely that any of these old risks should exterminate us in the near future. By contrast, human civilization is introducing many novel phenomena into the world, ranging from nuclear weapons to designer pathogens to high-energy particle colliders. The most severe existential risks of this century derive from expected technological developments. Advances in biotechnology might make it possible to design new viruses that combine the easy contagion and mutability of influenza with the lethality of HIV. Molecular nanotechnology might make it possible to create weapons systems that dwarf both thermonuclear bombs and biowarfare agents in destructiveness (Drexler 1985). Superintelligent machines might be built, and their actions could determine the future of humanity – and whether we shall have one (Yudkowsky 2007). Many of the existential risks that now seem to be among the greatest were conceptualized only in recent decades, and there might well be others that we have not yet become aware of.

The same technologies that pose these risks will also enable us to reduce some risks. Biotechnology can help us develop better diagnostics, vaccines and anti-viral drugs. Molecular nanotechnology could offer even stronger prophylactics (Freitas 1999). Superintelligent machines would be the last invention that human beings need to make, since a superintelligence would by definition be far more effective than human brains in all intellectual endeavors, including strategic thinking, scientific analysis and technological creativity (Bostrom 1998). In addition to creating and mitigating risks, these powerful technological capabilities would also affect the human condition in many other ways.

Supposing we avoid existential disasters, what then might become of humanity? Looking back, developments such as language, agriculture and perhaps the industrial revolution may be said to have fundamentally changed the human condition. There are at least a thousand times more of us now; and with current world average life expectancy at sixty-seven years we live perhaps three times longer than our Pleistocene predecessors. The mental life of human beings has been transformed by developments such as language, literacy, urbanization, division of labor, industrialization, science, communications, transport, and media technology. What developments can we foresee that would alter the human condition at least as profoundly as these past transitions?

One view is that there will be no fundamental change. Many people appear to hold an implicitly static conception of the human condition. On such a conception, there will surely be changes in politics, culture and gadgetry, but the basic parameters of life and human nature will remain unchanged.

The static view, however, is implausible. It would imply that we have recently arrived at the final human condition, even at a time when things seem to be changing faster than ever. It would also imply a radical break with several long-established trends. If the world economy continues to grow at the same pace as in the last half century, then by 2050 the world will be seven times richer than it is today. World population is predicted to increase to just over 9 billion in 2050, so average wealth would also increase dramatically (United Nations Population Division 2004). Extrapolating further, by 2100 the world would be almost fifty times richer than today. A single modest-sized country might then have as much wealth as the entire present world.

Over the course of human history, the doubling time of the world economy has been drastically reduced on several occasions, such as in the agricultural transition and the industrial revolution. Should another such transition occur in this century, the world economy might be orders of several magnitudes larger by the end of the century (Hanson 2000).

Another reason for assigning a low probability to the static view is that we can foresee that various specific technological advances will give humans important new capacities. Virtual reality environments will constitute an expanding fraction of our experience. The capability of recording, surveillance, biometrics and data-mining technologies will increase dramatically, making it possible to keep track of what is going on in physical reality to an unprecedented extent (Brin 1998). Nanotechnology will have wide-ranging consequences for manufacturing, medicine and computing. New institutions such as prediction markets might improve the capability of human groups to forecast future developments (Hanson 1995). The impacts of these and other technological developments on the character of human lives are difficult to predict, but that they will have such impacts seems a safe bet.

History shows a long-term trend toward increasing scales of integration of human society: from tribes, to villages, to city states, to kingdoms, nations, empires; and, more recently, regional organizations such as the European Union, and some very partial and limited forms of global governance (Wright 1999). One possibility is that humanity will eventually emerge as a singleton, a world-order where at the highest level there is only one independent agent (Bostrom 2007). A singleton could overcome international coordination problems that now plague our species, such as wars, arms races, and free-rider behavior resulting in underproduction of global public goods (Kaul 1999). It might also increase some risks. In the past, if one country or culture adopted policies that stopped growth, development would continue in other countries which would eventually attain such advantages that they could either invade the laggard country or force it to reform. In a singleton, there would be no outside competitor. Perhaps new technologies for surveillance and law enforcement could also make it immune to internal revolt. Even the direction of evolution could be controlled by a singleton (Bostrom 2005).

Among the most important potential developments are ones that would enable us to alter our biology directly through technological means. Such interventions could affect us more profoundly than modification of beliefs, habits, culture and education. If we learn to control the biochemical processes of human senescence, healthy lifespan could be radically prolonged. A person with the age-specific mortality of a 20-year-old would have a life expectancy of about a thousand years. The ancient but hitherto mostly futile quest for happiness could meet with success if we develop safe and effective methods of controlling the brain circuitry responsible for subjective wellbeing (Pearce 2004). Drugs and other neurotechnologies could make it increasingly feasible for users to shape themselves into the kind of people they want to be – their personality, emotional character, mental energy, romantic attachments and moral character.

Cognitive enhancements might deepen our intellectual lives (Bostrom and Ord 2006, Bostrom and Sandberg 2007).

Those who believe that such developments will not occur should consider whether their skepticism is really about ultimate feasibility or merely about timescales. Some of these technologies will be difficult to develop. Does that give us reason to think that they will never be developed? Not even in fifty years? Two hundred years? Ten thousand years? If we avoid existential catastrophe, humanity could have a long future, and it would seem myopic to assume that human nature will not eventually be technologically transformed into some kind of "posthuman" nature (Bostrom 2003b).

If and when artificial intelligence advances to the point where it matches the human mind in general reasoning abilities, superintelligence is likely to follow swiftly from further improvements in software and hardware (Vinge 1993, Bostrom 1998). The creation of superintelligent machines would be the most momentous event in the history of our species. Humanity's remoter future might be dominated by artificial minds, our "mind children" (Moravec 1988).

It could be possible for biological human beings to become non-biological by "uploading" their minds to computers. Uploading could be done by gradually replacing parts of the brain with prosthetic chips, or (more likely) by creating a detailed three-dimensional map of the neuronal network in a particular brain and emulating this computational structure on a powerful computer. A human upload could have an indefinitely long lifespan as it would not be subject to biological senescence. Periodic backup copies could be created for security. Speed-up of thought processes would result from implementing the upload on a faster computer, so an upload might, for instance, experience a year of subjective time over the course of one hour. Uploads could live in virtual reality or they could use a robotic body to interact with the physical world. Since uploads could create an unlimited number of copies of themselves, a Malthusian situation could quickly arise unless reproduction were limited (Bostrom 2005, Hanson 1994).

It could also be possible to create vast numbers of conscious computer-simulated people with experiences similar to those typical of an early-twenty-first-century human, raising the possibility that we ourselves might now be inhabiting a computer simulation created by a posthuman civilization. Important coherence constraints on tenable views about the future prospects of our species have recently been derived from this consideration. The so-called Simulation argument purports to show that *either* nearly all human-level civilizations go extinct before becoming posthuman, *or* there is a strong convergence among posthuman civilizations so that almost none of them is interested in creating this kind of ancestor simulation, *or* we are almost certainly living in a computer simulation (Bostrom 2003a).

With machine intelligence and other technologies such as advanced nanotechnology, space colonization should become economical. Such technology would enable us to construct "von Neumann probes" – machines with the capability of traveling to a planet, building a manufacturing base there, and launching multiple new probes to colonize other stars and planets (Tipler 1981). A space colonization race could ensue (Hanson 1998). Over time, the resources of the entire accessible universe might be turned into some kind of infrastructure, perhaps an optimal computing substrate ("computronium"). Viewed from the outside, this process might take a very simple and predictable form – a sphere of technological structure, centered on its Earthly origin, expanding uniformly in all directions at some significant fraction of the speed of light (Moravec 1999). What happens on the "inside" of this structure – what kinds of lives and experiences (if any) it would sustain – would depend on initial conditions and the dynamics shaping its temporal evolution. It is conceivable, therefore, that the choices we make in this century could have extensive consequences.

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# Index

Page number in *italics* refer to figures; those in **bold** to tables.

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