Taxidermy

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For other uses, see Taxidermy (disambiguation).

A mounted tiger at the Brigham Young University Life Sciences Museum

Taxidermy (from the Greek for *arrangement of skin*[1]) is the art of preparing, stuffing, and mounting the skins of animals (especially vertebrates) for display (e.g., as hunting trophies or museum display) or for other sources of study (like species identification) or simply the preservation of a beloved pet. Taxidermy can be done on all vertebrate species of animals, including mammals, birds, fish, reptiles, and amphibians.

Primate and pachyderm taxidermy at the Rahmat International Wildlife Museum and Gallery, Medan, Sumatra, Indonesia.

A person who practices taxidermy is called a taxidermist. Taxidermists may practice professionally for museums or as businesses catering to hunters and fishermen, or as amateurs, such as hobbyists, hunters, and fishermen. A taxidermist is aided by familiarity with anatomy, sculpture, painting, and tanning.

Contents

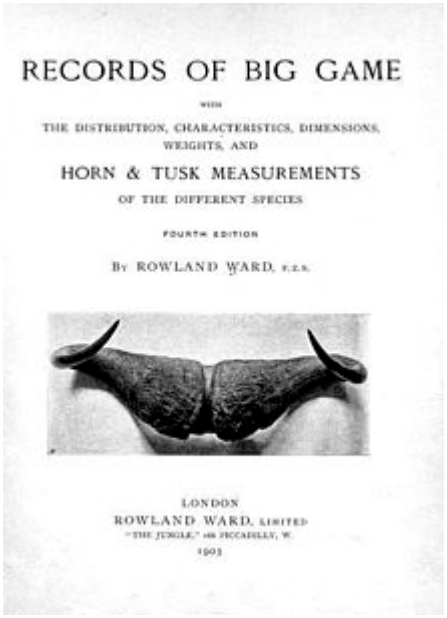
History

Tanning and early stuffing techniques

Preserving animal skins has been practiced for a long time. Embalmed animals have been found with Egyptian mummies.

Although embalming incorporates the use of lifelike poses, it is not considered taxidermy. In the Middle Ages, crude examples of taxidermy were displayed by astrologers and apothecaries. The earliest methods of preservation of birds for natural history cabinets were published in 1748 by Reaumur in France. Techniques for mounting were described in 1752 by M. B. Stollas. There were several pioneers of taxidermy in France, Germany, Denmark and England around this time. For a while, clay was used to shape some of the soft parts, but this made specimens heavy.

By the 18th century, almost every town had a tannery business. In the 19th century, hunters began bringing their trophies to upholstery shops, where the upholsterers would actually sew up the animal skins and stuff them with rags and cotton. The term "stuffing" or a "stuffed animal" evolved from this crude form of taxidermy. Professional taxidermists prefer the term "mounting" to "stuffing". More sophisticated cotton-wrapped wire bodies supporting sewn-on cured skins soon followed. In France, Louis Dufresne, taxidermist at the Muséum national d'Histoire naturelle from 1793, popularized arsenical soap in an article in "Nouveau dictionnaire d'histoire naturelle'" (1803–1804). This technique enabled the museum to build the greatest collection of birds in the world.


RECORDS OF BIG GAME

WITH

THE DISTRIBUTION, CHARACTERISTICS, DIMENSIONS, WEIGHTS, AND

HORN & TUSK MEASUREMENTS

OF THE DIFFERENT SPECIES

FOURTH EDITION

BY ROWLAND WARD, F.Z.S.

LONDON

ROWLAND WARD, LIMITED

1903

The naturalist Rowland Ward developed methods of taxidermy.

Dufresne's methods spread to England in the early 19th century, where updated and non-toxic methods of preservation were developed by some of the leading naturalists of the day, including Rowland Ward and Montague Brown. Ward established one of the earliest taxidermy firms, Rowland Ward Ltd. of Picadilly. However, the art of taxidermy remained relatively undeveloped, and the specimens that were created, remained stiff and unconvincing.

Taxidermy as art

The golden age of taxidermy was during the Victorian era, when mounted animals became a popular part of interior design and decor.[2] The father of modern taxidermy is considered to be John Hancock, an English ornithologist. An avid collector of birds, which he would shoot himself, he began modelling them with clay and casting in plaster.

For the Great Exhibition of 1851 in London, he mounted a series of stuffed birds as an exhibit. They generated much interest among the public and scientists alike who considered them as superior to earlier models and were regarded as the first lifelike and artistic specimens on display.[3] A judge remarked that Hancock's exhibit "...will go far towards raising the art of taxidermy to a level with other arts which have hitherto held higher pretensions".[4]

Hancock's display sparked great national interest in taxidermy, and amateur and professional collections for public view proliferated rapidly. Displays of birds were particularly common in middle-class Victorian homes - even Queen Victoria amassed an impressive bird collection. Taxidermists were also increasingly used by the bereaved owners of dead pets to 'resurrect' them.[5]

Anthropomorphic taxidermy

Walter Potter's *Rabbit School*, 1930s

In the late 19th century a style known as Anthropomorphic taxidermy became popular. A 'Victorian whimsy', mounted animals were dressed as people or displayed as if engaged in human activities. An early example of this genre was displayed by Herman Ploucquet, from Stuttgart, Germany, at the Great Exhibition in London.[6]

The best-known practitioner in this genre was the English taxidermist Walter Potter, whose most famous work was *The Death and Burial of Cock Robin*. Among his other scenes were "a rat's den being raided by the local police rats ... [a] village school ... featuring 48 little rabbits busy writing on tiny slates, while the Kittens' Tea Party displayed feline etiquette and a game of croquet."[7] Apart from the simulations of human situations, he had also added examples of bizarrely deformed animals such as two-headed lambs and four-legged chickens. Potter's museum was so popular that an extension was built to the platform at Bramber railway station.[8]

20th century

A striated thornbill on display in a 'realistic' setting

Gorilla diorama in the American Museum of Natural History is one of Carl Akeley's dioramas that did use **taxidermy**

In the early 20th century, taxidermy was taken forward under the leadership of artists such as Carl Akeley, James L. Clark, William T. Hornaday, Coleman Jonas, Fredrick and William Kaempfer, and Leon Pray. These and other taxidermists developed anatomically accurate figures which incorporated every detail in artistically interesting poses, with mounts in realistic settings and poses that were considered more appropriate for the species. This was quite a change from the caricatures popularly offered as hunting trophies.

- **Preserving a Record of extinct and threatened species**. Museums use taxidermy as a method to preserve a record of specimens of extinct and threatened species.[9]

Methods

The methods taxidermists practise have been improved over the last century, heightening taxidermic quality and lowering toxicity. The animal is first skinned in a process similar to removing the skin from a chicken prior to cooking. This can be accomplished without opening the body cavity, so the taxidermist usually does not see internal organs or blood. Depending on the type of skin, preserving chemicals are applied or the skin is tanned. It is then either mounted on a mannequin made from wood, wool and wire, or a polyurethane form. Clay is used to install glass eyes. Forms and eyes are commercially available from a number of suppliers. If not, taxidermists carve or cast their own forms.

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  Preparation: Scientific measurement

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  1. Skinning

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  2. Stuffing of the skin

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  3. Labeling

A mounted fish - as the skin of fish is thin and not leathery, they are more difficult to mount than other vertebrates. Scientific collections of fish therefore mostly consist of specimens preserved in alcohol.

Taxidermists seek to continually maintain their skills to ensure attractive, lifelike results. Many taxidermists in the US use bears, though some use creatures such as snakes, birds and fish. Although mounting an animal has long been considered an art form, often involving months of work, not all modern taxidermists trap or hunt for prize specimens.[10]

Taxidermy specimens can be saved for later use by freezing. The taxidermist then removes the skin, to be tanned and treated at a later date. Numerous measurements are then taken of the remaining body. A traditional method that remains popular today involves retaining the original skull and leg bones of a specimen and using these as the basis to create a mannequin made primarily from wood wool (previously tow or hemp wool was used) and galvanised wire. Another method is to mould the carcass in plaster, and then make a copy of the animal using one of several methods. A final mould is then made of polyester resin and glass cloth; from which a polyurethane form is made for final production. The carcass is then removed and the mould is used to produce a cast of the animal called a 'form'. Forms can also be made by sculpting the animal first in clay. Many companies produce stock forms in various sizes. Glass eyes are then usually added to the display, and in some cases, artificial teeth, jaws, tongue, or for some birds, artificial beaks and legs can be used.

An increasingly popular trend is to freeze dry the animal. This can be done with reptiles, birds, and small mammals such as cats, large mice and some types of dogs. Freeze drying is expensive and time consuming. The equipment is costly and requires much upkeep. Large specimens can be required to spend as long as six months in the freeze dryer, although it is the preferred technique for pets. Freeze dried animals, though, may later be susceptible to being eaten by carpet beetles.

Some taxidermy specimens do not involve a carcass at all, particularly in the case of sporting fish, such as trout and bass, for which the practice of catch and release is becoming increasingly prevalent. Instead, detailed photos and measurements are taken of the animal, and then a taxidermist creates a resin or fibreglass sculpture of the animal that can be mounted and displayed as a specimen. The actual animal is released.

A vegan form of taxidermy is seen in the works of the artist Charlie Tuesday Gates.[11]

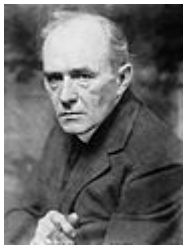
Rogue taxidermy

Stuffed griffin, Zoological Museum, Copenhagen

Rogue taxidermy is a multimedia art form that references traditional trophy or natural history taxidermy. It often, but does not necessarily, include traditional taxidermy. Rogue taxidermy is characterized by its intentional modification of traditional taxidermy forms and genres, which art historian Steve Baker has described as "botched taxidermy."[12] Examples include imaginative works combining the bodies of different animals (such as the jackalope), anthropomorphized animals (such as British artist and taxidermist Adele Morse's piece "Stoned Fox"), and other creations using recognizable animal parts (horns, beaks, claws) and other materials.

Many taxidermists[*who?*] do not consider rogue taxidermy "true" taxidermy. The term "rogue taxidermy" was introduced by the Minneapolis, Minnesota-based group, The Minnesota Association of Rogue Taxidermists (MART) in October 2004. It was first coined by MART founders Sarina Brewer, Scott Bibus, and Robert Marbury. The term first appeared in print in a *New York Times* article about the group's debut exhibition on January 3, 2005.[13]

Taxidermists

- 

  Carl Akeley

See also

- Freeze-drying
- Plastination
- Taxidermy art and science

Plastination

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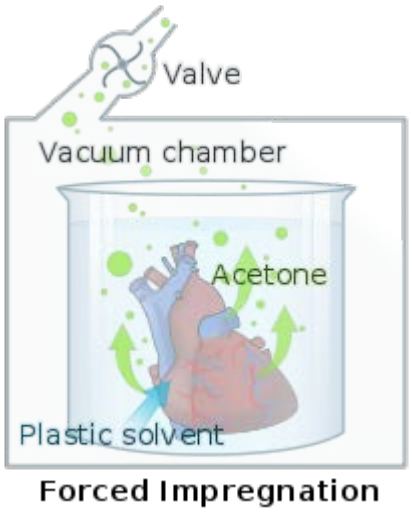
A plastinated and sectioned example of a diseased horse's hoof, mounted for teaching purposes.

Plastination is a technique or process used in anatomy to preserve bodies or body parts, first developed by Gunther von Hagens in 1977.[1] The water and fat are replaced by certain plastics, yielding specimens that can be touched, do not smell or decay, and even retain most properties of the original sample.[2]

Contents

Process



Forced Impregnation

The centerpiece of plastination: "forced impregnation"

There were four steps in the standard process of plastination: fixation, dehydration, forced impregnation in a vacuum, and hardening.[3] Water and lipid tissues are replaced by curable polymers. Curable polymers used by plastination include silicone, epoxy and polyester-copolymer.[3]

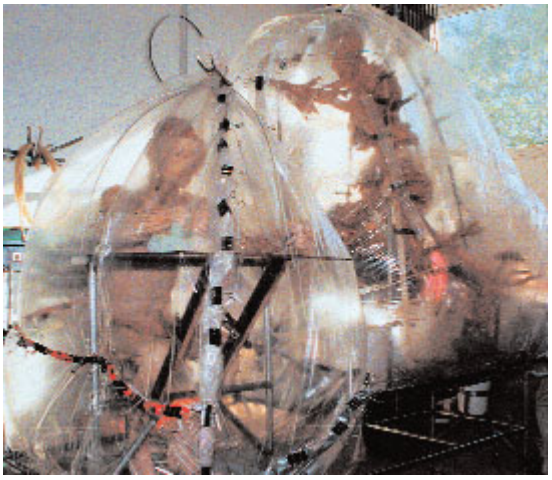
The first step of plastination is fixation.[4] Fixation, frequently utilizing a formaldehyde based solution, serves two functions. Dissecting the specimen to show specific anatomical elements can be time consuming. Formaldehyde or other preserving solutions help prevent decomposition of the tissues. They may also confer a degree of rigidity. This can be beneficial in maintaining the shape or arrangement of a specimen. A stomach might be inflated or a leg bent at the knee for example.

After any necessary dissections take place, the specimen is then placed in a bath of acetone. Under freezing conditions, the acetone draws out all the water and replaces it inside the cells.[5]

In the third step, the specimen is then placed in a bath of liquid polymer, such as silicone rubber, polyester or epoxy resin. By creating a vacuum, the acetone is made to boil at a low temperature. As the acetone vaporizes and leaves the cells, it draws the liquid polymer in behind it, leaving a cell filled with liquid plastic.[5]

The plastic must then be cured with gas, heat, or ultraviolet light, in order to harden it.[4]

A specimen can be anything from a full human body to a small piece of an animal organ, and they are known as 'plastinates'.[*citation needed*] Once plastinated, the specimens and bodies are further manipulated and positioned prior to curing (hardening) of the polymer chains.[*citation needed*]



Hardening and posing of Plastinates

History

In November 1979, Gunther von Hagens applied for a German patent, proposing the idea of preserving animal and vegetable tissues permanently by synthetic resin impregnation.[6] Since then, von Hagens has applied for further US patents regarding work on preserving biological tissues with polymers.[7][8]

With the success of his patents, von Hagens went on to form the Institute for Plastination in Heidelberg, Germany in 1993. The Institute of Plastination, along with von Hagens made their first showing of plastinated bodies in Japan in 1995, which drew more than three million visitors. The Institute maintains three international centres of plastination: in Germany, Kyrgyzstan and China.[9]

Gunther von Hagens

Other plastination methods

Other methods have been in place for thousands of years to halt the decomposition of the body. Mummification used by the Egyptians is a widely known method which involves the removal of body fluid and wrapping the body in linens. Prior to mummification, Egyptians would lay the body in a shallow pit in the desert and allow the sun to dehydrate the body.[10]

Formalin, an important solution to body preservation, was introduced in 1896 to help with body preservation. Soon to follow formalin, color preserving embalming solutions were developed to preserve lifelike color and flexibility to aid in the study of the body.[11]

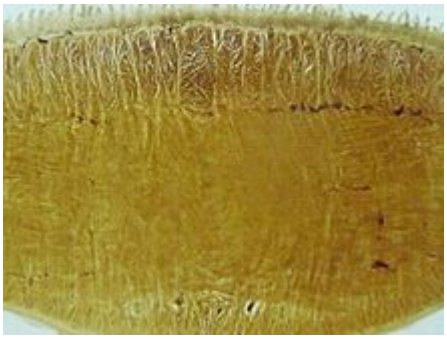
Paraffin impregnation was introduced in 1925 and the embedding of organs in plastic was developed in the 1960s.[*citation needed*]

Body preservation methods current to the twenty-first century are cryopreservation, which involves the cooling of the body to very low temperatures to preserve the body tissues, plastination and embalming.[12]

Other methods used in modern times include the Silicone S 10 Standard Procedure, the Cor-Tech Room temperature procedure, the Epoxy E 12 procedure, and the Polyester P 35 (P 40) procedure.[13] The Silicone S 10 is the procedure most often used in plastination and creates opaque, natural-looking specimen.[14] Dow Corning Corporation's Cor-Tech Room Temperature Procedure is designed to allow plastination of specimen at room temperature to various degrees of flexibility using three combinations of polymer, crosslinker and catalyst.[15] According to the International Society for Plastination, the Epoxy E 12 procedure is utilized "for thin, transparent, and firm body and organ slices", while the Polyster P 35 (P 40) preserves "semitransparent and firm brain slices".[13] Samples are prepared for fixation through the first method by deep freezing,[16] while the second method works best following 4–6 weeks of preparation in a formaldehyde mixture.[17]

Uses of plastinated specimens

Plastination is useful in anatomy as well as serving as models and teaching tools.[18] Plastination is used at more than 40 medical and dental schools throughout the world as an adjunct to anatomical dissection.



Histological section of bovine tongue, epoxy technique

Students enrolled in introductory animal science courses at many universities learn animal science through collections of multi-species large-animal specimens. Plastination allows students to have hands on experience in this field, without exposure to chemicals such as formalin. For example, plastinated canine gastrointestinal tracts are used to help in the teaching of endoscopic technique and anatomy.[19] The plastinated specimens retain their dilated conformation by a positive pressure air flow, which allows them to be used to teach both endoscopic technique and gastrointestinal anatomy.

With the use of plastination as a teaching method of animal science, fewer animals have to be killed for research, as the plastination process allows specimens to be studied for a long time.[20]

TTT sheet plastinates for school teaching and lay instruction provide a thorough impression of the complexity of an animal body in just one specimen.

TTT sheet plastinate of a fish

The North Carolina State University's College of Veterinary Medicine in Raleigh, North Carolina uses both PC (plastic coating) and PN (plastination) to investigate and compare the difference in the two methods. The PC method was simple and inexpensive, but the plastinated specimens (PN method) were more flexible, durable, and lifelike than those preserved by the PC method. The use of plastination allowed the use of many body parts such as muscle, nerves, bones, ligaments, and central nervous system to be preserved.[21]

The University of Texas Health Science Center at San Antonio was the first school in the United States to use this technique to prepare gross organ specimens for use in teaching.[22] The New York University College of Dentistry.,[18] Philadelphia College of Osteopathic Medicine, [23] University of Warwick, and University of Northumbria [24] use collections of plastinates as teaching aids. The University of Vienna has its own plastination laboratory.[25]

Ethical concerns

Concern over consent of bodies being used in the plastination process has arisen. Over 20 years ago, von Hagens set up a body donation program in Germany and has signed over 9,000 donors into the plastinate program: 531 have already died. The program has reported an average of one body a day being released to the plastination process. Ninety percent of the donors registered are German. Although von Hagens says he follows strict consent procedures for whole-body specimens, he maintains that "consent is not important for body parts."[*citation needed*][*clarification needed*] Von Hagens' body donations are now being managed by the Institute for Plastination (IfP)[26] established in 1993.[27]

Plastination exhibitions

For the first 20 years, plastination was used to preserve small specimens for medical study. It was not until the early 1990s that the equipment was developed to make it possible to plastinate whole body specimens, each specimen taking up to 1,500 man hours to prepare.[28] The first exhibition of whole bodies was displayed by von Hagens in Japan in 1995.

Over the next two years, Von Hagens developed the Körperwelten (BODY WORLDS) public exhibitions, showing whole bodies plastinated in lifelike poses and dissected to show various structures and systems of human anatomy. The earliest exhibitions were presented in the Far East and in Germany, and Gunther von Hagens' BODY WORLDS exhibitions have subsequently been hosted by museums and venues in more than 50 cities worldwide, attracting more than 29 million visitors.[*citation needed*].

Gunther von Hagens' BODY WORLDS exhibitions are the original, precedent-setting public anatomical exhibitions of real human bodies, and the only anatomical exhibits that use donated bodies, willed by donors to the Institute for Plastination for the express purpose of serving the BODY WORLDS mission to educate the public about health and anatomy. To date, more than 10,000 people have agreed to donate their bodies to Institute for Plastination.[26]

In 2004, Premier Exhibitions began their "Bodies Revealed" exhibition in Blackpool, England which ran from August through October 2004.[*citation needed*] In 2005 and 2006 the company opened their Bodies Revealed and Bodies The Exhibition exhibitions in Seoul (South Korea), Tampa (Florida, USA) and New York City, (USA).[*citation needed*] The West Coast exhibition site opened on 22 June 2006 at the Tropicana Resort & Casino Las Vegas, USA .[*citation needed*] As of June 2009, BODIES... The Exhibition is showing at the Ambassador Theatre (Dublin) in Dublin, Ireland.[29] The exhibition is in Istanbul, Turkey until the end of March 2011.

Plastination galleries are offered in a few college medical schools including University of Michigan (said to be the nation's largest such lab)[30] and the Vienna University[31] Gunther von Hagens maintains a permanent exhibition of plastinates and plastination at the Plastinarium in Guben, Germany.[*citation needed*]

Freeze-drying

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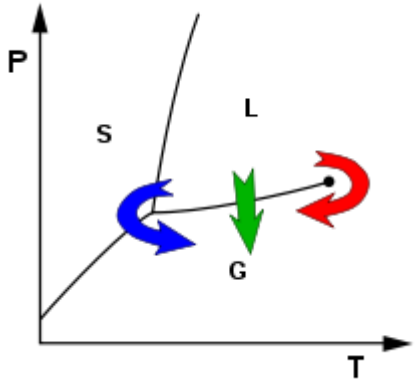

In a typical phase diagram, the boundary between gas and liquid runs from the triple point to the critical point. Freeze-drying (blue arrow) brings the system around the triple point, avoiding the direct liquid-gas transition seen in ordinary drying time (green arrow).

A benchtop manifold freeze-drier

Freeze-drying, also known as **lyophilisation, lyophilization,** or **cryodesiccation,** is a dehydration process typically used to preserve a perishable material or make the material more convenient for transport. Freeze-drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublimate directly from the solid phase to the gas phase.

Contents

The origins of freeze drying

Modern freeze-drying was developed during WWII. Blood serum being sent to Europe from the US for medical treatment of the wounded required refrigeration, but because of the lack of simultaneous refrigeration and transport, many serum supplies were spoiling before reaching their intended recipients. The freeze-drying process was developed as a commercial technique that enabled serum to be rendered chemically stable and viable without having to be

refrigerated. Shortly thereafter, the freeze-dry process was applied to penicillin and bone, and lyophilization became recognized as an important technique for preservation of biologicals. Since that time, freeze-drying has been used as a preservation or processing technique for a wide variety of products. These applications include the following but are not limited to: the processing of food,[1] pharmaceuticals,[2] and diagnostic kits; the restoration of water damaged documents;[3] the preparation of river-bottom sludge for hydrocarbon analysis; the manufacturing of ceramics used in the semiconductor industry; the production of synthetic skin; the manufacture of sulfur-coated vials; and the restoration of historic/reclaimed boat hulls.

The freeze-drying stages

There are four stages in the complete drying process: pretreatment, freezing, primary drying, and secondary drying.

Pretreatment

Pretreatment includes any method of treating the product prior to freezing. This may include concentrating the product, formulation revision (i.e., addition of components to increase stability, preserve appearance, and/or improve processing), decreasing a high-vapor-pressure solvent, or increasing the surface area. In many instances the decision to pretreat a product is based on theoretical knowledge of freeze-drying and its requirements, or is demanded by cycle time or product quality considerations.[4]

Freezing

In a lab, this is often done by placing the material in a freeze-drying flask and rotating the flask in a bath, called a shell freezer, which is cooled by mechanical refrigeration, dry ice and methanol, or liquid nitrogen. On a larger scale, freezing is usually done using a freeze-drying machine. In this step, it is important to cool the material below its triple point, the lowest temperature at which the solid and liquid phases of the material can coexist. This ensures that sublimation rather than melting will occur in the following steps. Larger crystals are easier to freeze-dry. To produce larger crystals, the product should be frozen slowly or can be cycled up and down in temperature. This cycling process is called annealing. However, in the case of food, or objects with formerly-living cells, large ice crystals will break the cell walls (a problem discovered, and solved, by Clarence Birdseye), resulting in the destruction of more cells, which can result in increasingly poor texture and nutritive content. In this case, the freezing is done rapidly, in order to lower the material to below its eutectic point quickly, thus avoiding the formation of ice crystals. Usually, the freezing temperatures are between −50 °C and −80 °C. The freezing phase is the most critical in the whole freeze-drying process, because the product can be spoiled if improperly done.

Amorphous materials do not have a eutectic point, but they do have a critical point, below which the product must be maintained to prevent melt-back or collapse during primary and secondary drying.

Primary drying

During the primary drying phase, the pressure is lowered (to the range of a few millibars), and enough heat is supplied to the material for the ice to sublime. The amount of heat necessary

can be calculated using the sublimating molecules' latent heat of sublimation. In this initial drying phase, about 95% of the water in the material is sublimated. This phase may be slow (can be several days in the industry), because, if too much heat is added, the material's structure could be altered.

In this phase, pressure is controlled through the application of partial vacuum. The vacuum speeds up the sublimation, making it useful as a deliberate drying process. Furthermore, a cold condenser chamber and/or condenser plates provide a surface(s) for the water vapour to re-solidify on. This condenser plays no role in keeping the material frozen; rather, it prevents water vapor from reaching the vacuum pump, which could degrade the pump's performance. Condenser temperatures are typically below −50 °C (−60 °F).

It is important to note that, in this range of pressure, the heat is brought mainly by conduction or radiation; the convection effect is negligible, due to the low air density.

Secondary drying

The secondary drying phase aims to remove unfrozen water molecules, since the ice was removed in the primary drying phase. This part of the freeze-drying process is governed by the material's adsorption isotherms. In this phase, the temperature is raised higher than in the primary drying phase, and can even be above 0 °C, to break any physico-chemical interactions that have formed between the water molecules and the frozen material. Usually the pressure is also lowered in this stage to encourage desorption (typically in the range of microbars, or fractions of a pascal). However, there are products that benefit from increased pressure as well.

After the freeze-drying process is complete, the vacuum is usually broken with an inert gas, such as nitrogen, before the material is sealed.

At the end of the operation, the final residual water content in the product is extremely low, around 1% to 4%.

Properties of freeze-dried products

Freeze dried ice cream

If a freeze-dried substance is sealed to prevent the reabsorption of moisture, the substance may be stored at room temperature without refrigeration, and be protected against spoilage for many years. Preservation is possible because the greatly reduced water content inhibits the action of microorganisms and enzymes that would normally spoil or degrade the substance.

Freeze-drying also causes less damage to the substance than other dehydration methods using higher temperatures. Freeze-drying does not usually cause shrinkage or toughening of the material being dried. In addition, flavours, smells and nutritional content generally remain unchanged, making the process popular for preserving food. However, water is not the only chemical capable of sublimation, and the loss of other volatile compounds such as acetic acid (vinegar) and alcohols can yield undesirable results.

Freeze-dried products can be rehydrated (reconstituted) much more quickly and easily because the process leaves microscopic pores. The pores are created by the ice crystals that sublimate, leaving gaps or pores in their place. This is especially important when it comes to pharmaceutical uses. Freeze-drying can also be used to increase the shelf life of some pharmaceuticals for many years.

Freeze-drying protectants

Similar to cryoprotectants, some molecules protect freeze-dried material. Known as lyoprotectants, these molecules are typically polyhydroxy compounds such as sugars (mono-, di-, and polysaccharides), polyalcohols, and their derivatives. Trehalose and sucrose are natural lyoprotectants. Trehalose is produced by a variety of plant (for example selaginella and arabidopsis thaliana), fungi, and invertebrate animals that remain in a state of suspended animation during periods of drought (also known as anhydrobiosis).

Applications of freeze-drying

Pharmaceutical and biotechnology

Pharmaceutical companies often use freeze-drying to increase the shelf life of the products, such as vaccines and other injectables. By removing the water from the material and sealing the material in a vial, the material can be easily stored, shipped, and later reconstituted to its original form for injection. Another example from the pharmaceutical industry is the use of freeze drying to produce tablets or wafers, the advantage of which is less excipient as well as a rapidly absorbed and easily administered dosage form.

Food and agriculture-based industries

Freeze dried bacon bars


Freeze-dried coffee, a form of instant coffee

Although freeze-drying is used to preserve food, its earliest use in agriculturally based industries was in processing of crops such as peanuts/groundnuts and tobacco in the early 1970s (Tob. Sci. 16: 1-5, Tob. Sci. 17: 33-36, Physiol. Plantarum. 28(2):320-326). Because heat, commonly used in crop and food processing, invariably alters the structure and chemistry of the product, the main objective of freeze-drying is to avoid heat and thus preserve the structural and chemical integrity/composition with little or no alteration (Physiol. Plantarum. 28(2):320-326, Tob. Sci. 16: 1-5). Therefore, freeze-dried crops and foods are closest to the natural composition with respect to structure and chemistry. The process came to wide public attention when it was used to create freeze-dried ice cream, an example of astronaut food. It is also widely used to produce essences or flavourings to add to food.

Because of its light weight per volume of reconstituted food, freeze-dried products are popular and convenient for hikers. More dried food can be carried per the same weight of wet food, and remains in good condition for longer than wet food, which tends to spoil quickly. Hikers reconstitute the food with water available at point of use.

Instant coffee is sometimes freeze-dried, despite the high costs of the freeze-driers used. The coffee is often dried by vaporization in a hot air flow, or by projection onto hot metallic plates. Freeze-dried fruits are used in some breakfast cereal or sold as a snack, and are an especially popular snack choice among toddlers, preschoolers and dieters, as well as being used by some pet owners as a treat for pet birds. Most commercial freezing is done either in cold air kept in motion by fans (blast freezing) or by placing the foodstuffs in packages or metal trays on refrigerated surfaces (contact freezing).

Culinary herbs are also freeze-dried, although air-dried herbs are far more common and less expensive. Freeze dried tofu is a popular foodstuff in Japan ("Koya-dofu" or "shimi-dofu" in Japanese).

Technological industry

In chemical synthesis, products are often freeze-dried to make them more stable, or easier to dissolve in water for subsequent use.

In bioseparations, freeze-drying can be used also as a late-stage purification procedure, because it can effectively remove solvents. Furthermore, it is capable of concentrating substances with low molecular weights that are too small to be removed by a filtration membrane.

Freeze-drying is a relatively expensive process. The equipment is about three times as expensive as the equipment used for other separation processes, and the high energy demands lead to high energy costs. Furthermore, freeze-drying also has a long process time, because

the addition of too much heat to the material can cause melting or structural deformations. Therefore, freeze-drying is often reserved for materials that are heat-sensitive, such as proteins, enzymes, microorganisms, and blood plasma. The low operating temperature of the process leads to minimal damage of these heat-sensitive products

Other uses

Organizations such as the Document Conservation Laboratory at the United States National Archives and Records Administration (NARA) have done studies on freeze-drying as a recovery method of water-damaged books and documents. While recovery is possible, restoration quality depends on the material of the documents. If a document is made of a variety of materials, which have different absorption properties, expansion will occur at a non-uniform rate, which could lead to deformations. Water can also cause mold to grow or make inks bleed. In these cases, freeze-drying may not be an effective restoration method.

In bacteriology freeze-drying is used to conserve special strains.

In high-altitude environments, the low temperatures and pressures can sometimes produce natural mummies by a process of freeze-drying.

Advanced ceramics processes sometimes use freeze-drying to create a formable powder from a sprayed slurry mist. Freeze-drying creates softer particles with a more homogeneous chemical composition than traditional hot spray drying, but it is also more expensive.

Freeze drying is also used for floral preservation. Wedding bouquet preservation has become very popular with brides who want to preserve their wedding day flowers[5]

A new form of burial which previously freeze-dries the body with liquid nitrogen has been developed by the Swedish company Promessa Organic AB, which puts it forward as an environmentally friendly alternative to traditional casket and cremation burials.

Freeze-drying equipment

Unloading trays of freeze-dried material from a small cabinet-type freeze-dryer

There are essentially three categories of freeze-dryers: the manifold freeze-dryer, the rotary freeze-dryer and the tray style freeze-dryer. Two components are common to all types of freeze-dryers: a vacuum pump to reduce the ambient gas pressure in a vessel containing the substance to be dried and a condenser to remove the moisture by condensation on a surface cooled to −40 to −80 °C (−40 to −112 °F). The manifold, rotary and tray type freeze-dryers differ in the method by which the dried substance is interfaced with a condenser. In manifold freeze-dryers a short usually circular tube is used to connect multiple containers with the dried

product to a condenser. The rotary and tray freeze-dryers have a single large reservoir for the dried substance.

Rotary freeze-dryers are usually used for drying pellets, cubes and other pourable substances. The rotary dryers have a cylindrical reservoir that is rotated during drying to achieve a more uniform drying throughout the substance. Tray style freeze-dryers usually have rectangular reservoir with shelves on which products, such as pharmaceutical solutions and tissue extracts, can be placed in trays, vials and other containers.

Manifold freeze-dryers are usually used in a laboratory setting when drying liquid substances in small containers and when the product will be used in a short period of time. A manifold dryer will dry the product to less than 5% moisture content. Without heat, only primary drying (removal of the unbound water) can be achieved. A heater must be added for secondary drying, which will remove the bound water and will produce a lower moisture content.

Tray style freeze-dryers are typically larger than the manifold dryers and are more sophisticated. Tray style freeze-dryers are used to dry a variety of materials. A tray freeze-dryer is used to produce the driest product for long-term storage. A tray freeze-dryer allows the product to be frozen in place and performs both primary (unbound water removal) and secondary (bound water removal) freeze-drying, thus producing the driest possible end-product. Tray freeze-dryers can dry products in bulk or in vials or other containers. When drying in vials, the freeze-dryer is supplied with a stoppering mechanism that allows a stopper to be pressed into place, sealing the vial before it is exposed to the atmosphere. This is used for long-term storage, such as vaccines.

Improved freeze drying techniques are being developed to extend the range of products that can be freeze dried, to improve the quality of the product, and to produce the product faster with less lab