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ENERGY

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ENERGY

Energy may be defined as “the capacity to do work”

Energy must be supplied regularly to meet needs for the body's survival (i.e. chemical reactions that maintain body tissues, electrical conduction of the nerves, mechanical work of the muscles, and heat production to maintain body temperature)

The body makes use of the energy from dietary carbohydrates, proteins, fats, and alcohol; this energy is locked in chemical bonds within food and is released through metabolism.

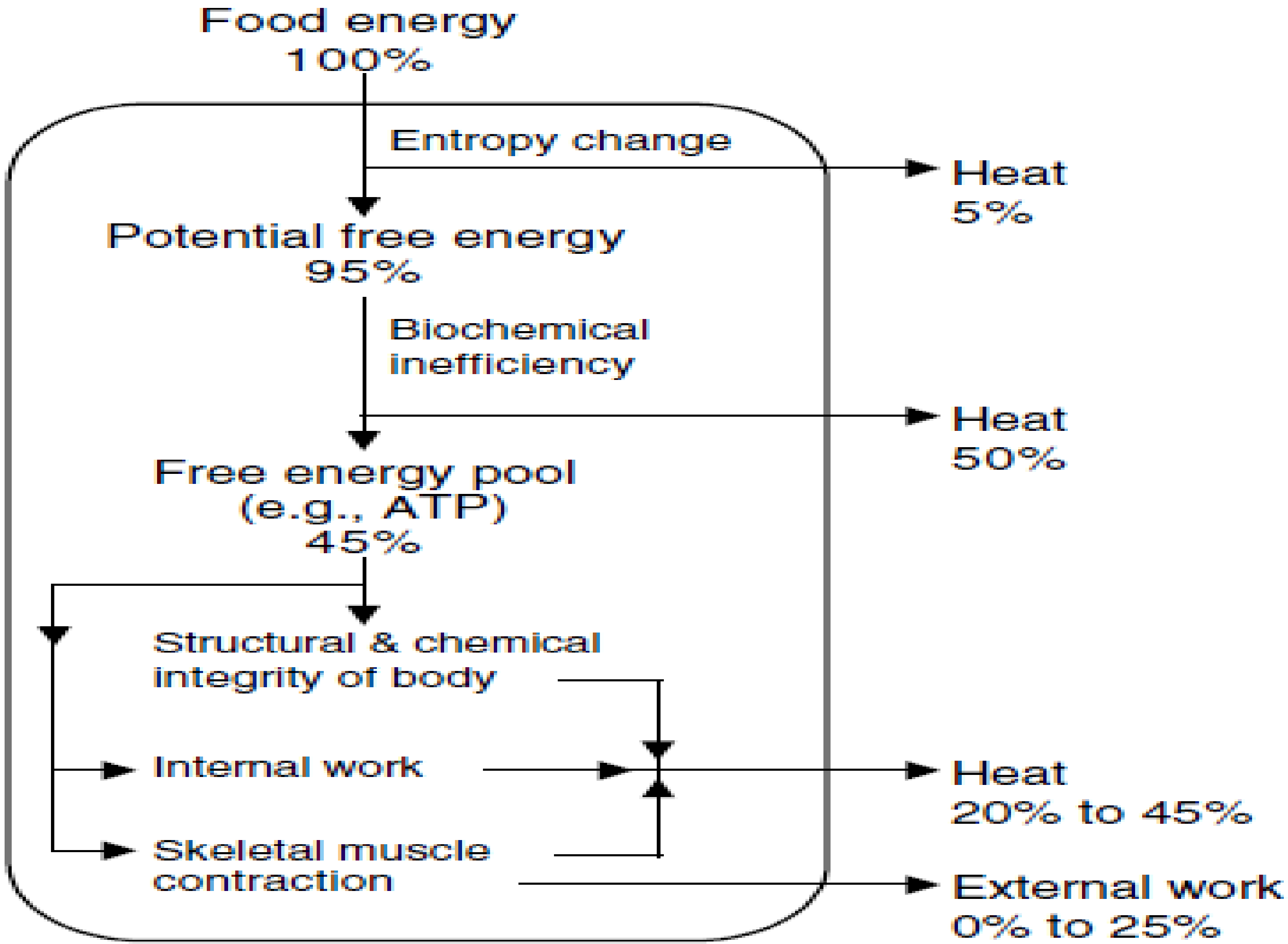


Fig. 5.1. Energy utilization within the body. The distribution of food energy within the body and its transfer to the environment as heat or external work is illustrated (see text for further details). *ATP*, adenosine triphosphate.

Energy requirements are defined as the dietary energy intake required for growth or maintenance in a person of a defined age, gender, weight, height, and level of physical activity.

In children and pregnant or lactating women, energy requirements include the needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health.

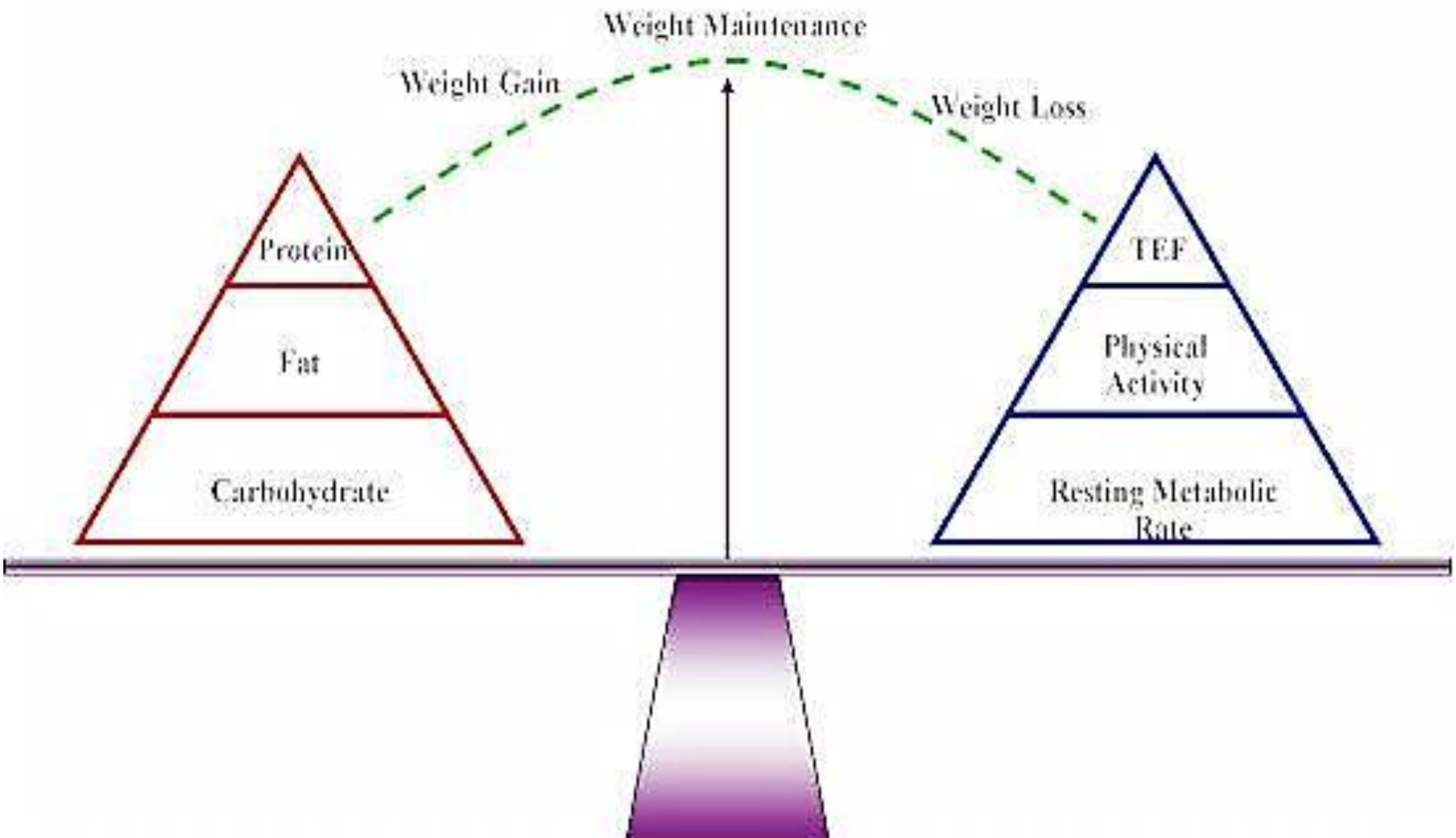
In ill or injured people, the stressors have an effect by increasing or decreasing energy expenditure.

Consuming too much or too little energy over time results in body weight changes; thus, **body weight is one indicator of energy adequacy or inadequacy**.

Although body weight reflects adequacy of energy intake, it is not a reliable indicator of nutrient adequacy.

Since body weight is affected by body composition, a person with a higher lean mass to body fat mass or vice versa may require differing energy intakes compared with the norm or "average" person.

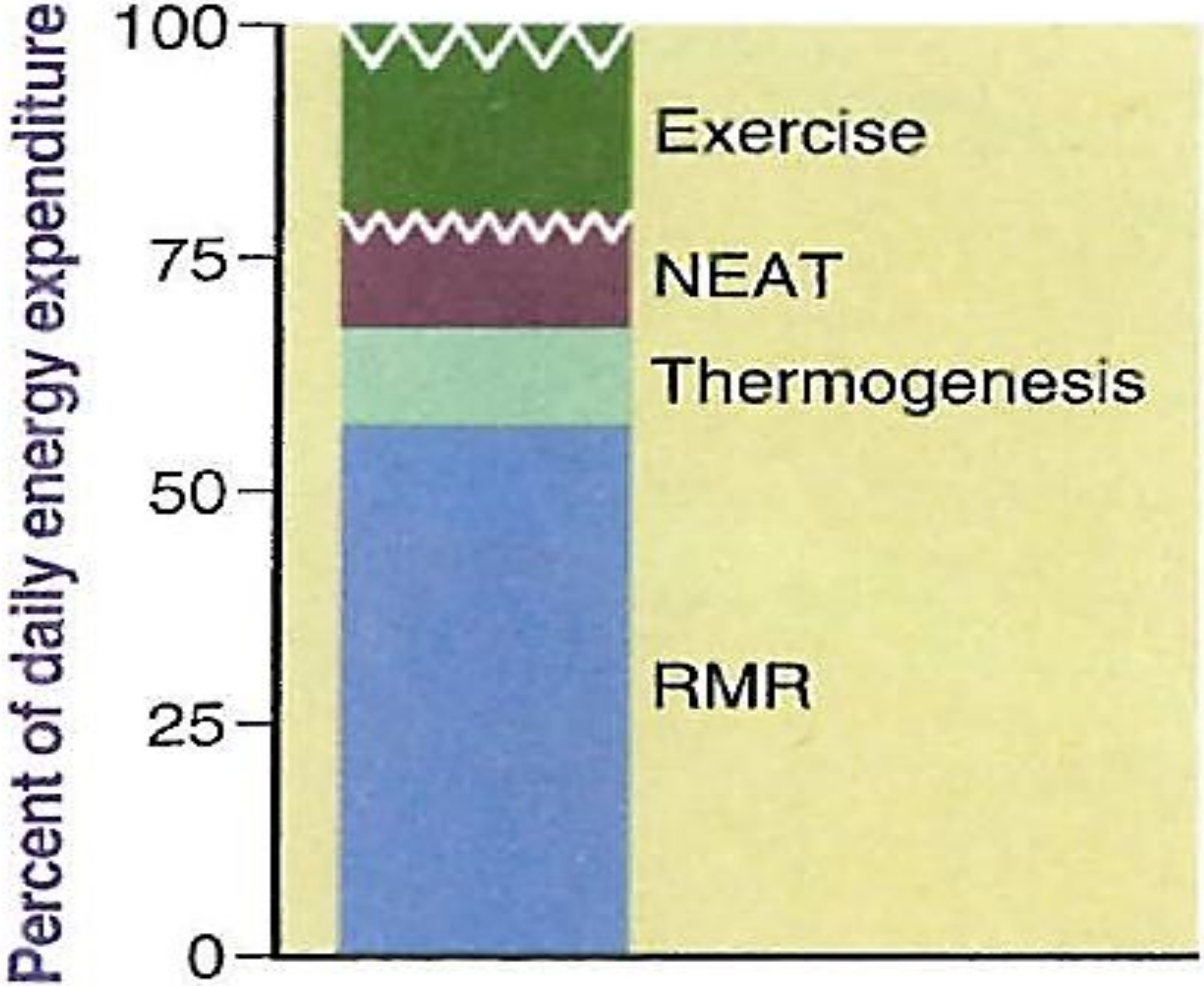
Energy Balance Equation



Components of Energy Expenditure

Energy is expended by the human body in the form of basal energy expenditure (BEE), thermic effect of food (TEF), and activity thermogenesis (AT).

These three components make up a person's daily total energy expenditure (TEE).



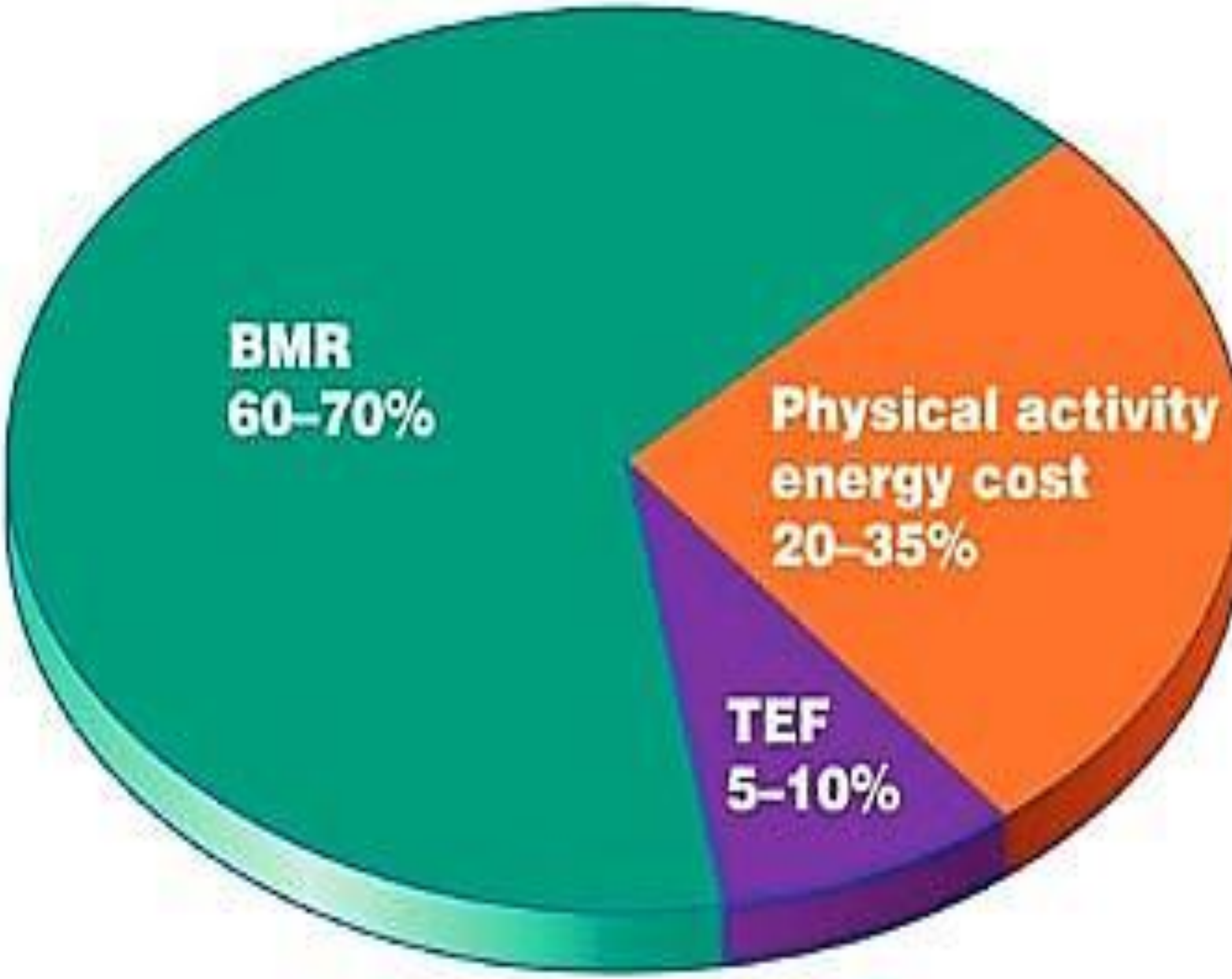
The components of total energy expenditure: activity, diet-induced thermogenesis, and basal or resting metabolic rate.

Basal and Resting Energy Expenditure

BEE, or basal metabolic rate (BMR), is the minimum amount of energy expended that is compatible with life.

An individual's BEE reflects the amount of energy used during 24 hours while physically and mentally at rest in a thermo-neutral environment that prevents the activation of heat-generating processes, such as shivering.

The BEE remains remarkably constant on a daily basis, typically representing 60% to 70% of TEE.



Components of energy expenditure

Measurements of BEE should be done before an individual has engaged in any physical activity (preferably on awakening from sleep) and 10 to 12 hours after the ingestion of any food, drink, or nicotine.

TABLE 5.3 SCHOFIELD EQUATIONS FOR ESTIMATING BASAL METABOLIC RATE (kcal/d) FROM WEIGHT (kg)

		n	MULTIPLE CORRELATION	STANDARD ERROR
	Children: <3 y			
Males	BMR = 59.5 wt − 30.4	162	0.95	69.9
Females	BMR = 58.3 wt − 31.1	137	0.96	58.7
	3–10 y			
Males	BMR = 22.7 wt + 504.3	338	0.83	67.0
Females	BMR = 20.3 wt + 485.9	413	0.81	69.9
	10–18 y			
Males	BMR = 17.7 wt + 658.2	734	0.93	105.2
Females	BMR = 13.4 wt + 692.6	575	0.80	111.4
	Adults: 18–30 y			
Males	BMR = 15.0 wt + 692.1	2879	0.65	153.8
Females	BMR = 14.8 wt + 486.6	829	0.73	119.2
	30–60 y			
Males	BMR = 11.5 wt + 873.0	646	0.60	167.9
Females	BMR = 8.1 wt + 845.6	372	0.68	111.7
	>60 y			
Males	BMR = 11.7 wt + 587.7	50	0.71	164.8
Females	BMR = 9.1 wt + 658.4	38	0.68	108.3

BMR, basal metabolic rate; wt, weight.

TABLE 5.4	SCHOFIELD EQUATIONS FOR ESTIMATING BASAL METABOLIC RATE (kcal/d) FROM WEIGHT (kg) AND HEIGHT (m)			
		n	MULTIPLE CORRELATION	STANDARD ERROR
	Children: <3 y			
Males	BMR = 1.67 wt + 1517 ht − 618	162	0.97	58.0
Females	BMR = 16.2 wt + 1023 ht − 413	137	0.97	51.6
	3–10 y			
Males	BMR = 19.6 wt + 130 ht + 415	338	0.83	66.8
Females	BMR = 17.0 wt + 162 ht + 371	413	0.81	69.4
	10–18 y			
Males	BMR = 16.2 wt + 137 ht + 516	734	0.93	105.0
Females	BMR = 8.4 wt + 466 ht + 200	575	0.82	108.1
	Adults: 18–30 y			
Males	BMR = 15.0 wt − 10.0 ht + 706	2879	0.65	153.2
Females	BMR = 13.6 wt + 283 ht + 98	829	0.73	117.7
	30–60 y			
Males	BMR = 11.5 wt − 2.6 ht + 877	646	0.60	167.3
Females	BMR = 8.1 wt + 1.4 ht + 844	372	0.68	111.4
	>60 y			
Males	BMR = 9.1 wt + 972 ht − 834	50	0.74	157.7
Females	BMR = 7.9 wt + 458 ht + 17.7	38	0.73	102.5

BMR, basal metabolic rate; ht, height; wt, weight.

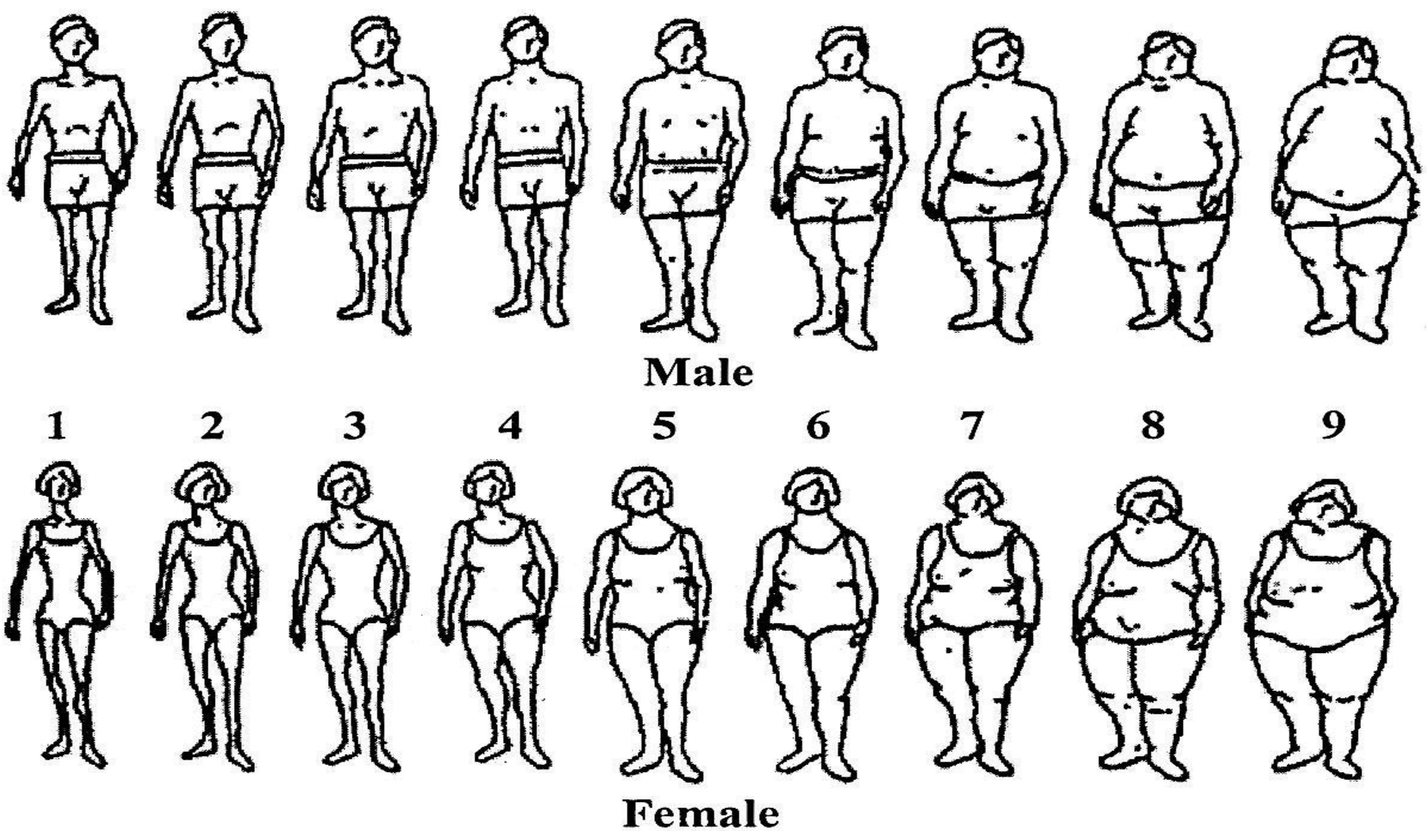
Resting energy expenditure (REE), or resting metabolic rate (RMR), is the energy expended in the activities necessary to sustain normal body functions and homeostasis.

These activities include respiration and circulation, synthesis of organic compounds, pumping of ions across membranes, normal functioning of the central nervous system, and maintenance of body temperature.

For practical reasons the BEE is now rarely measured; thus, REE measurements are used in its place, which in most cases are higher than the BEE by 10% to 20%.

Factors Affecting Resting Energy Expenditure

Numerous factors cause the REE to vary among individuals, but body size and composition have the greatest effect.



Age

Because REE is highly affected by the proportion of lean body mass (LBM), it is highest during periods of rapid growth, especially the first and second years of life.

The additional energy required for synthesizing and depositing body tissue (e.g. in children) is nearly 5 kcal/g of tissue gained.

Thus, growing infants may store as much as 12% to 15% of the energy value of their food in the form of new tissue.

As a child becomes older, the energy requirement for growth is reduced to approximately 1% of TEE.

After early adulthood there is a decline in REE of 1% to 2% per kilogram of fat free mass (FFM) per decade.

Exercise can help maintain a higher LBM and a higher REE.

Decreases in REE with increasing age may be partly related to age-associated changes in the relative size of LBM components.

Body Composition

Fat-free mass (FFM), or LBM, comprises the majority of metabolically active tissue in the body and is **the primary predictor of REE**.

FFM contributes to approximately 80% of the variations in REE.

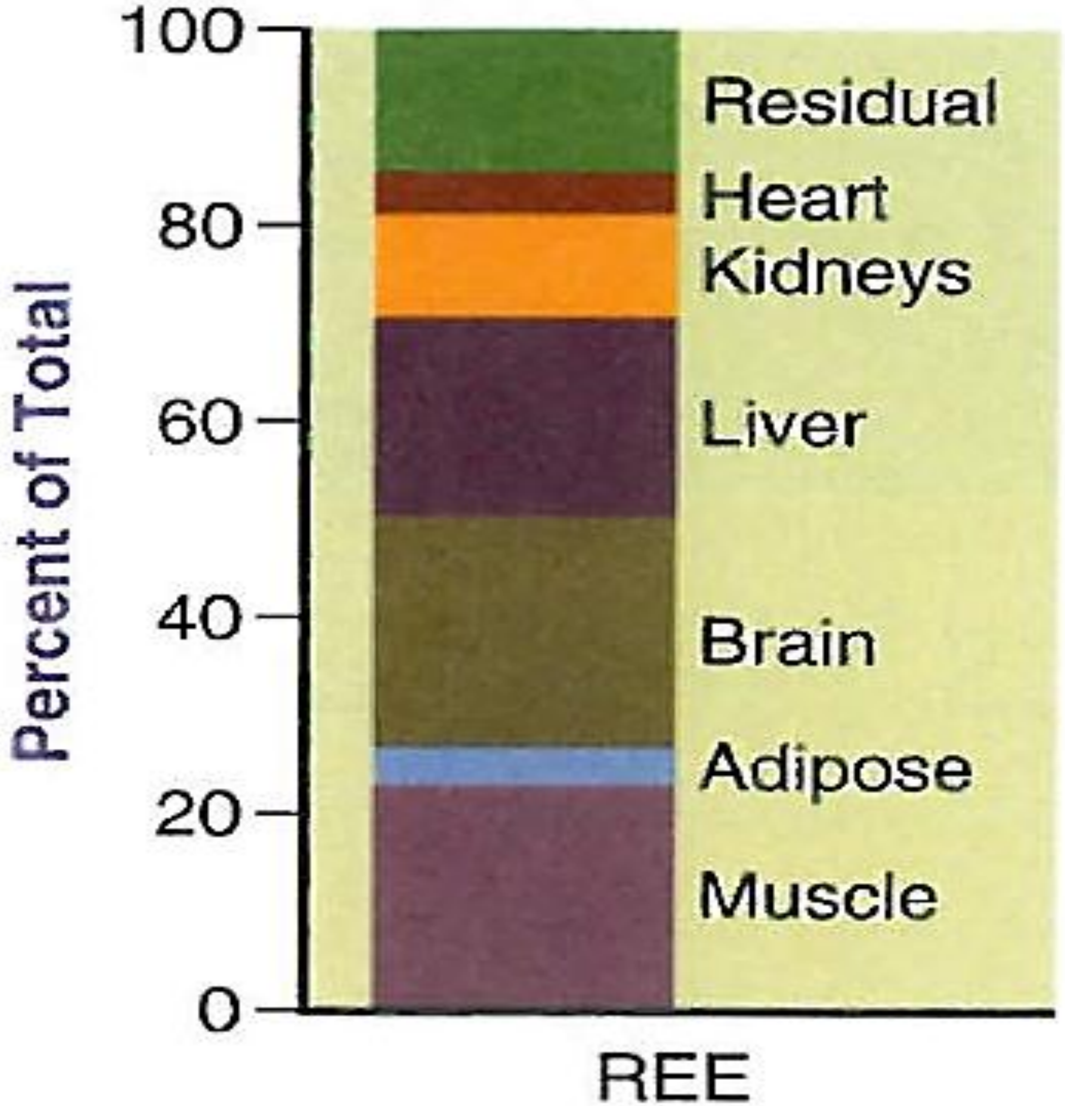
Because of their greater FFM, athletes with greater muscular development have approximately a 5% higher resting metabolism than nonathletic individuals.

Organs in the body contribute to heat production.

Approximately 60% of REE can be accounted for by the heat produced by high-metabolic-rate organs (HMROs), that is, the liver, brain, heart, spleen, and kidneys.

Indeed, differences in FFM between ethnic groups may be related to the total mass of these HRMOs.

Relatively small individual variation in HMRO mass significantly affects REE.



Proportional contribution of organs and tissues to calculated resting energy expenditure.

TABLE 1.10 CONTRIBUTION OF DIFFERENT ORGANS AND TISSUES TO ENERGY EXPENDITURE

	WEIGHT		METABOLIC RATE	
ORGAN OR TISSUE	kg	(% OF TOTAL)	kcal/kg TISSUE/d	(% OF TOTAL)
Kidneys	0.3	(0.5)	440	(8)
Brain	1.4	(2.0)	240	(20)
Liver	1.8	(2.6)	200	(21)
Heart	0.3	(0.5)	440	(9)
Muscle	28.0	(40.0)	14	(22)
Adipose tissue	15.0	(40.0)	4	(4)
Other (e.g., skin, gut, bone)	23.2	(33.0)	12	(16)
Total	70.0	(100.0)		(100)

Data for a 70-kg man from Elia M. Organ and tissue contribution to metabolic rate. In: Kinney JM, Tucker HN, eds. Energy Metabolism: Determinants and Cellular Corollaries. New York: Raven Press, 1992:61–79, with permission.

Body Size

Larger people have higher metabolic rates than smaller people, but tall, thin people have higher metabolic rates than short, wide people.

For example, if two people weigh the same, the taller person has a larger body surface area and a higher metabolic rate.

The amount of LBM is highly correlated with total body size.

For example, obese children have higher REEs than non-obese children, but, when REE is adjusted for body composition, no REE differences are found.

Climate

The REE is affected by extremes in environmental temperature.

People living in tropical climates usually have REEs that are 5% to 20% higher than those living in temperate areas.

Exercise in temperatures > 86° F imposes an additional metabolic load of 5% from increased sweat gland activity.

The extent to which energy metabolism increases in extremely cold environments depends on the insulation available from body fat and protective clothing.

Gender

Gender differences in metabolic rates are attributable primarily to differences in body size and composition.

Women, who generally have more fat in proportion to muscle than men, have metabolic rates that are approximately 5% to 10% lower than men of the same weight and height.

However, with aging, this difference becomes less pronounced.

Hormonal Status

Endocrine disorders, such as hyperthyroidism and hypothyroidism, increase or decrease energy expenditure, respectively.

Stimulation of the sympathetic nervous system during emotional excitement or stress causes the release of epinephrine, which promotes glycogenolysis and increases cellular activity; thus, increasing energy expenditure.

The metabolic rate of women fluctuates with the menstrual cycle, so that during the luteal phase (i.e. the time between ovulation and the onset of menstruation), metabolic rate increases slightly.

During pregnancy, growth in uterine, placental, and fetal tissues, along with the mother's increased cardiac workload, contributes to gradual increases in BEE.

Temperature

Fevers increase REE by approximately 7% for each degree of increase in body temperature more than 98.6° F or 13% for each degree more than 37° C.

Studies in hospitalized patients have demonstrated increases in energy expenditure during fever as well as during cooling, varying according to the patient's condition.

Other Factors

Caffeine, nicotine, and alcohol use stimulate metabolic rate.

Under conditions of stress and disease, energy expenditure may increase or decrease, based on the clinical situation.

Energy expenditure may be higher in people who are obese, but depressed during starvation or chronic dieting and in people with anorexia nervosa.

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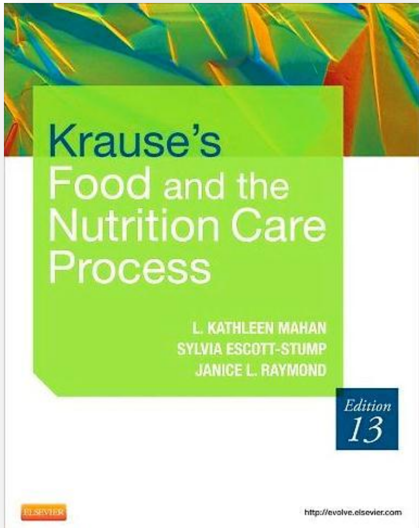

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