Anatomy

Specialties and related fields: All
Definition: the structure of the human body—its parts, systems, and organs

KEY TERMS

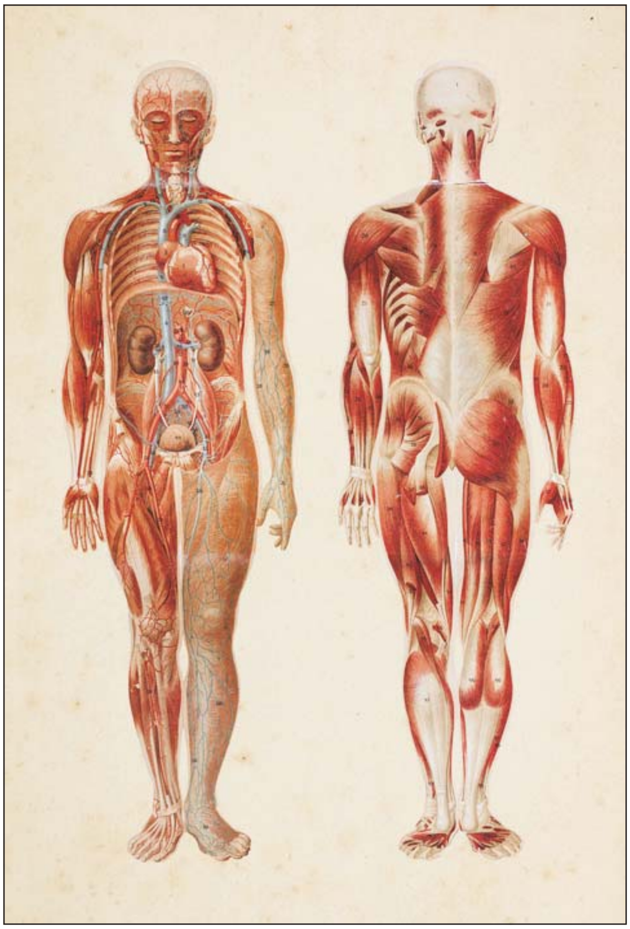
abdomen: the rib-free part of the trunk, below the diaphragm
head: the part of the body containing the major sense organs (such as the eyes and ears) and the brain
lower extremities: the thigh, lower leg, and foot
thorax: the part of the trunk above the diaphragm, containing the ribs; the chest
trunk: the central part of the body to which the extremities are attached
upper extremities: the arm, forearm, and hand

STRUCTURE AND FUNCTIONS

The body's parts can be categorized either regionally or functionally. Regionally, the body consists of a trunk attached to two upper extremities, two lower extremities, and a head attached through a neck. Functionally, the body consists of a digestive system, a circulatory system, an excretory system, a respiratory system, a reproductive system, a nervous system, an endocrine system, an integument (skin), a skeleton, and a series of muscles.

The trunk can be divided into an upper portion called the "chest" (or thorax), containing ribs, and a lower, rib-free portion called the "abdomen." Internally, the thorax and abdomen are separated by a muscular sheet called the "diaphragm." The upper extremities of the trunk include the arms, forearms, and hands; the lower extremities include the thighs, lower legs, and feet. The head includes the brain and the major sense organs such as the eyes and ears; the neck is the narrower, flexible part that connects the head to the trunk. The abdomen's ventral (front) surface is often divided around the umbilicus into upper-left, upper-right, lower-left, and lower-right quadrants.

Functionally, the body consists of several organ systems. The digestive system breaks down foods into simpler substances and absorbs them. The circulatory system transports oxygen and other materials around the body. The excretory system rids the body of many waste products. In contrast, the respiratory system rids the body of carbon dioxide and adds oxygen to the blood. The reproductive system produces sex cells and, in females, provides an environment for the development of an embryo. The nervous system sends signals in the form of nerve



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KEY TERMS

distal: farther away from the base or attached end

femur: the long bone extending from the hip joint to the knee

fibula: the smaller of the two bones in the lower leg, on the lateral side

knee: the complex articulated joint between the thigh and the lower leg

lateral: on the outer side; toward the little toe when in reference to the leg

leg: the lower extremity, excluding the foot; the lower leg runs from the knee to the ankle

medial: on the side toward the midline of the body; toward the big toe when in reference to the leg

proximal: closer to the base or attached end

tarsus: the ankle

thigh: the upper segment of the leg, from the hip joint to the knee

tibia: the larger of the two bones in the lower leg, on the medial side

STRUCTURE AND FUNCTIONS

The lower extremities consist of the thighs, lower legs, and feet. Each extremity attaches to the pelvis (innominate bone) at the hip joint. The lower extremity is made mostly of bones and muscles. Still, it also contains blood vessels, lymphatics, nerves, skin, toenails, and other structures. Important directional terms for the lower extremity include proximal (closer to the base or attached end), distal (further from the base or attached end), medial (on the same side as the tibia and big toe), and lateral (on the same side as the fibula and little toe). Along the foot, the lower surface is called "plantar"; the upper surface is called "dorsal." The lower extremity is clothed in the skin (or integument). The sole or plantar surface of the foot is unusual, along with the palm, in being completely hairless; it also contains the thickest outer skin layer (the stratum corneum) of any part of the body. Each toe has a hardened toenail on its dorsal surface.

The pelvic girdle that supports the lower extremity develops as three separate bones: the ilium, ischium, and pubis. All three help form the acetabulum, a socket into which the femur fits. Below the acetabulum, the ischium and pubis surround a large opening called the "obturator foramen." The right and left pubis meet to form a pubic symphysis. The lower extremity bones include the femur, tibia, fibula, tarsals, metatarsals, and phalanges. The femur (thigh bone) is the largest bone in the body. Its rounded upper end, or head, fits into the acetabulum and is attached by a short neck. A rough-surfaced greater trochanter lies just beyond this neck and serves for the attachment of many muscles. The lesser trochanter, also for muscle attachments, lies below the neck. The knee joint is covered and protected by the kneecap, or patella, the largest of the sesamoid bones formed within tendons at stress points. The lower leg, from the knee to the ankle, contains two bones: the tibia on the medial side and the slenderer fibula on the lateral side. The tarsus, or ankle, includes the talus, calcaneus, and five smaller bones. The talus (or astragalus) has a pulley-like facet for the tibia and other curved surfaces for articulation with the calcaneus and navicular. The calcaneus, or heel bone, is vertically enlarged in humans; the Achilles tendon attaches to its roughened lower tuberosity. Smaller tarsal bones include the navicular, the medial (or inner) cuneiform, the intermediate cuneiform, the lateral (or outer) cuneiform, and the cuboid. Beyond the tarsal bones, the foot is supported by five metatarsal bones. The big toe, or hallux, contains two phalanges; each of the remaining toes contains three phalanges.

The lower extremity muscles include extensors, which straighten joints, and flexors, which bend joints. Abductor muscles move the limbs sideways, away from the midline, while adductors pull the limbs back toward the midline. The muscles of the iliac region attach the lower extremity to the body.

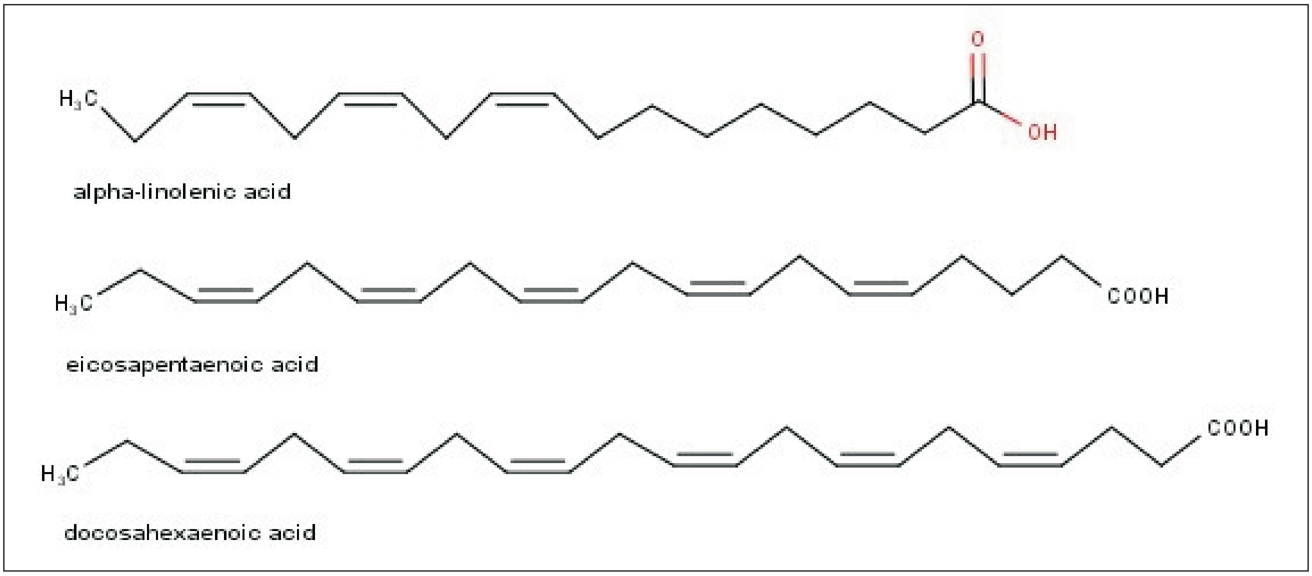

Figure 2. The structure of essential fatty acids. Image by M. Buratovich.

the organism. The excess is stored in the form of lipids. In humans, such excesses are stored around the abdomen and buttocks, where they can accumulate in considerable quantity.

Suppose a human's food supply is severely reduced or completely cut off. In that case, the body draws on these reserves, using the stored fat until it is completely depleted. Afterward, nutrients, mostly proteins, are drawn from muscle mass, the sudden reduction of which can quickly eventuate in death.

The survival of organisms is usually dependent upon the work that they perform. Energy to carry out work is derived through splitting the chemical bonds of adenosine triphosphate (ATP). A highly sophisticated biochemical process called "cellular respiration" transfers energy from the chemical bonds of nutrient molecules to those of ATP.

Almost every cell in the body has the enzymes and cellular equipment to carry out aerobic catabolism and manufacture its ATP. There are two ways to synthesize ATP in cells, substrate-level phosphorylation and oxidative phosphorylation (also known as cellular respiration). Substrate-level phosphorylation (SLP) transfers the energy of a high-energy phosphate group to adenosine diphosphate to make ATP. Oxidative phosphorylation in the human body requires molecular oxygen (O_2) as a terminal electron acceptor. It also requires reduced niacin or riboflavin-based electron carriers, an intact biological membrane, and several membrane-embedded electron carriers. Oxygen, carried through the blood, is the essential ingredient in aerobic catabolism, which results in the oxidization and degradation of nutrient molecules into small molecules composed largely of carbon dioxide and water. In this process, energy is released, some of it lost as heat, and some of it conserved in the bonds of ATP.

The main biochemical pathway that degrades food-based molecules is glycolysis. Glycolysis is a stepwise, consecutive set of enzyme-catalyzed reactions that begin with the six-carbon compound glucose and degrade it to two three-carbon molecules, pyruvate. Glycolysis produces two net ATP molecules per glucose and two reduced electron carriers (Fig. 3).

Pyruvate, the end-product of glycolysis, is transported from the cell cytoplasm into an organelle called the "mitochondrion." The pyruvate the termination of the Olympic Games and other sporting competitions in about 400 CE.

HOW IT WORKS

Competitive sports did not gain great popularity again until the time of the second phase of the Industrial Revolution, around 1850. With competition, the use of performance-enhancing drugs also returned. In particular, competitive swimmers, runners, and cyclists used caffeine, strychnine, codeine, cocaine, heroin, and nitroglycerin to stimulate their bodies to perform. Numerous athletes died from taking these drugs, but their deaths did deter many others from using such drugs. After World War II and throughout the Cold War period, the use of performance-enhancing drugs escalated, particularly the use of anabolic steroids.

Bodybuilding supplements. The most widely known class of performance-enhancing drugs used since the 1930s is anabolic steroids (also known as "anabolic-androgenic steroids"). These are testosterone-like substances that augment male sex characteristics and muscle building. Anabolic steroids were first developed in Nazi Germany and were used to increase the aggressiveness of troops in battle.

Many studies have shown that anabolic steroids increase muscle mass and strength, which has made them popular among many different kinds of athletes, from football players to track-and-field athletes who participate in throwing events. Athletes use two strategies to maximize strength and muscle mass with anabolic steroids: stacking and pyramiding. Stacking is blending different types of drugs in oral and injectable forms to maximize their effects. Pyramiding is the continual increase in dosage over time to maximize its benefit. However, taking large doses of anabolic steroids have many dangerous side effects. Because the liver is responsible for breaking down and removing excess chemicals from the body, anabolic steroids can cause severe liver damage. These substances have also been linked to high blood pressure, adult-onset diabetes mellitus, increased blood clotting factors, and decreased high-density lipoproteins (good cholesterol) in the blood, all of which increase the risk of cardiovascular disease.

Human growth hormone (HGH) is another substance that has been reported to increase muscle mass and strength is human growth hormone (HGH). With the advances made in genetic engineering during the 1980s, HGH became increasingly widely available and hit the black market, where athletes could access it. However, research on the effects of HGH has been very limited, and any actual benefits of the substance for athletes have not been identified conclusively. Athletes at the 2012 Summer Olympics were tested for HGH. Still, the unreliability of one of the test's constituent assays was taken off the market, rendering the tests invalid.

Two other substances that have been promoted as useful in increasing muscle mass and strength are dehydroepiandrosterone (DHEA) and androstenedione. Both are precursors to testosterone that are converted to testosterone by the body. Research has not found either substance to be effective for enhancing athletic abilities, and both decrease the high-density lipoproteins in the blood, increasing the risk of cardiovascular disease.

One supplement that is effective in improving performance in high-intensity exercise is creatine. Research indicates that ingesting creatine in high doses helps the muscles work harder and increases the body's ability to gain muscle and strength. Although creatine is not regulated by the US Food and Drug Administration (FDA), it is banned by most sports federations. The long-term side effects of this substance have not been identified.

Stimulants. The primary stimulant substances used by athletes for much of recent history are amphetamines. Athletes take these drugs to decrease fatigue, increase alertness, and decrease reaction time. Most research has found, however, that these a potentially fatal medical emergency was prevented.

Mary is a fifteen-year-old high school all-state cross-country runner. She is now entering her junior year and is expected to compete nationally. Six weeks into the fall season, Mary's times begin to decrease slightly. When asked about her performance, she states that she has been experiencing pain in both her shins, particularly the one on the right, for two weeks. Her coach asks Mary to see her family doctor since the school does not have an athletic trainer or team physician. Mary's doctor tells her that she has shin splints and should rest. Mary does not accept this and continues to run against her doctor's advice. In the next race, Mary finishes last. The pain has become unbearable. Mary is referred to a sports medicine physician, who discovers several relevant facts. Mary is underweight and has not been eating well. She has been forcing herself to vomit for several days before each race. She has also not experienced her first menses. X-rays of Mary's right leg reveal severe stress fractures. Mary is referred to several specialists, including an orthopedic surgeon who places her in a cast, a nutritionist, a psychologist who evaluates and treats her eating disorder, and a gynecologist who proceeds with a workup for her late development. Mary is diagnosed with functional hypothalamic amenorrhea, which is a menstrual dysfunction in the setting of restrictive eating and excessive exercise. This condition is referred to as the female athlete triad of functional hypothalamic amenorrhea. It is characterized by strenuous physical activity or low intake of calories, low bone mineral density, and amenorrhea, a lack of menses. The pathophysiology of functional hypothalamic amenorrhea involves low energy availability (due to caloric restriction or excessive exercise) and elevated cortisol levels (secondary to stress or excessive exercise), which results in decreased hypothalamic gonadotropin-releasing hormone (GnRH) pulsatile secretion. Normally, GnRH from the hypothalamus stimulates the release of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) from the anterior pituitary. In functional hypothalamic amenorrhea, the decreased GnRH pulsatile secretion results in decreased secretion of both LH and FSH, which consequently decreases estrogen levels. The reduced estrogen levels in individuals with functional hypothalamic amenorrhea lead to anovulation and amenorrhea. After several months of collaborative treatment by several health-care professionals, Mary begins retraining on a bicycle under the direction of an athletic trainer and a physical therapist. She moves on to compete in the spring track and field season and becomes a national champion. Without the collaborative care of the sports medicine team, Mary's condition could have progressed to serious complications or even death. This is a common scenario among adolescent athletes. The pressures placed upon them by friends, coaches, and parents can damage their emotional and physical well-being.

Henry is a fifty-five-year-old businessman who spends five days a week playing tennis at the local health club to stay in shape. After buying a new racket, he begins to experience pain in his right elbow. An orthopedic surgeon who specializes in sports medicine evaluates him. After speaking with Henry and examining his elbow, the doctor recommends anti-inflammatory medication, a special forearm strap, and the use of the old racket. Henry's condition, called "tennis elbow" or lateral epicondylitis, is quite common. Lateral epicondylitis is caused by excessive pronation, supination, and extension motions of the wrist, resulting in inflammation of the wrist extensor muscles. After several weeks of the initial treatment, Henry does not feel any better. His doctor, therefore, injects him with medication to ease the pain and calm the inflammation. Henry is instructed to rest his arm for a week before starting tennis again.