

Muscle

Introduction

All animal movement depends on the use of muscles. Whether the movement is as simple as opening the eyes or as complex as running the high hurdles at a track event, each is the result of a complex series of electric, chemical, and physical interactions involving the brain, the central nervous system, and the muscles themselves. However, movement is just one of the functions of muscle. Muscle plays a key role in metabolism and thermoregulation. Muscles help move food through the intestine and urine out of the bladder. Without muscle, the heart could not pump blood through the body.

Muscle Tissue

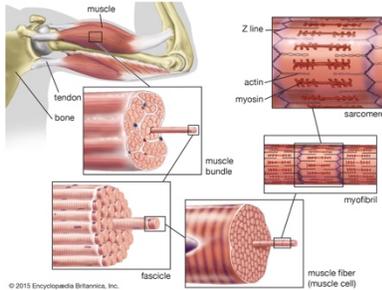


Figure 1: The skeletal, or striated, muscles of the human muscular system are under the voluntary control of the brain. They govern movement, posture, and balance.

Muscle is one of the four major tissue types in animals—the other three types are epithelial, connective, and nervous tissue. Vertebrates have three types of muscle tissue: skeletal, smooth, and cardiac. Skeletal muscle is the most prevalent muscle type and makes up a large portion of body weight. Smooth muscle is found in the walls of hollow organs, such as the stomach, intestines, and bladder; most blood vessels; the airways; and the diaphragm. Cardiac muscle is found only in the heart.

Muscle is composed of bundles of long, cylindrical cells, called fibers. The fibers are bound together by connective tissue into bundles called fascicles. The fascicles, in turn, are bundled together to form a muscle.

Each muscle fiber consists of a bundle of myofibrils. Myofibrils contain two types of filaments: thick filaments and thin filaments. Thick filaments are composed of the protein myosin. Thin filaments are made up of the proteins actin, tropomyosin, and troponin.

The distinct appearances and qualities of the three muscle types result from the arrangement of their fibers. The myofibrils of skeletal and cardiac muscle have a parallel, alternating arrangement. The ends of the thick filaments overlap with the ends of the thin filaments in the next row. This area of overlap forms a dark region called the Z line. The region between two adjacent Z lines is called a sarcomere.

The arrangement of sarcomeres in skeletal and cardiac muscle is what gives these muscles their striated, or banded, appearance under the microscope. A muscle cell contains thousands of sarcomeres—a human biceps may have as many as 100,000 of these units. Smooth muscle is not striated. Its cells do not have sarcomeres because the myofibrils are not arranged in parallel rows.

Skeletal Muscle

Skeletal muscle is so named because it is attached to the bones of the skeleton. The muscle is covered with a tough, elastic connective tissue that is condensed into tendons at each end of the muscle that attach to bone. The muscles contain blood vessels that bring oxygen and nutrients, nerve endings that carry electric impulses from the central nervous system, and nerve sensors that relay messages back to the brain.

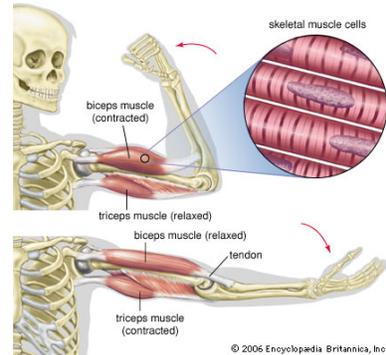


Figure 2: Skeletal muscle makes bones move parts of the body.

Skeletal muscle has several important functions.

Its primary function is to operate the skeleton as a system of levers. However, skeletal muscle also plays an important role in metabolism and in thermoregulation and serves as a storage site for glycogen.

Skeletal muscle cells are cylindrical and contain many nuclei. Contraction of skeletal muscle causes the fibers to shorten along their long axes. Skeletal muscles around joints usually work in antagonistic pairs. In the mammalian forelimb, contraction of the biceps causes the elbow joint to flex. Contraction of the triceps causes the joint to extend. As this occurs, the biceps simultaneously relaxes.

Smooth Muscle

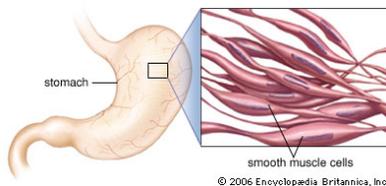


Figure 3: Smooth muscle is located in the intestines and the stomach.

Smooth muscle is found in the hollow organs, such as the stomach, the urinary bladder, and the uterus; the airways; and in the walls of most blood vessels. Smooth muscle fibers have only one nucleus and are smaller than those in skeletal and cardiac muscle. The fibers in smooth muscle are arranged in bundles interwoven with intermediate filaments that act like a drawstring during contraction. The netlike arrangement of the intermediate filaments causes smooth muscle to shorten in all directions when the muscle contracts.

Smooth muscle is controlled by the autonomic nervous system. This means it cannot be controlled consciously. For this reason, smooth muscle contraction is sometimes called involuntary. Contraction of the smooth muscle in the bladder causes the organ to empty. The symptoms of an asthma attack result from constriction of the smooth muscle lining the bronchioles. Smooth muscle in the walls of arteries and veins provides support against the force produced when the heart contracts. Peristalsis, the wavelike passage of digested food through the intestine, results from synchronized contractions of the smooth muscle in the intestinal wall.

Cardiac Muscle

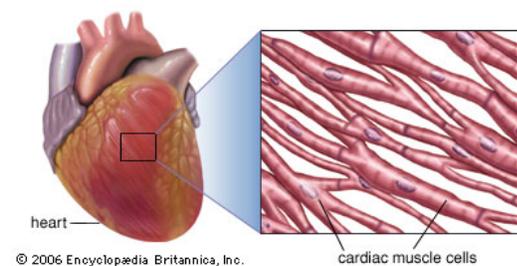


Figure 4: Cardiac muscle is located in the heart.

Cardiac muscle forms the myocardium, the middle tissue layer of the heart. Like skeletal muscle, cardiac muscle fibers have sarcomeres, giving the muscle a striated appearance. However, unlike skeletal muscle fibers, cardiac muscle fibers are connected by intercalated discs, a specialized double membrane that enables rapid transmission of

electric impulses from one fiber to the next. This allows the muscle fibers to contract synchronously—at the same time. This characteristic is essential for the heart to function—synchronous contraction is necessary to pump blood effectively through the heart. It also prevents the muscle fibers from tearing from the force of the contraction.

Contraction of the heart muscle is an involuntary movement. As in skeletal muscle, contraction of cardiac muscle causes the fibers to shorten along their long axes. Contraction originates with an electric impulse in a natural pacemaker called the sinoatrial node, located within the heart itself. Thus the heart contains its own electric conducting system capable of controlling both the rate and the order of contractions.

Muscle Contraction

Muscle contraction causes the muscle fibers to shorten. This occurs by a process called the sliding-filament mechanism. During a muscle contraction, the thin and thick filaments in a sarcomere slide past each other. This action causes the myofibrils to shorten. Myosin molecules have little pegs, called cross bridges, that protrude from the thick filament. During contraction, actin molecules seem to climb across these cross bridges.

Skeletal muscle contraction begins with impulses from the central nervous system. The motor nerves release chemicals called neurotransmitters at the cell membrane of the muscle fibers. This initiates a wave of electric and chemical activity involving the filament proteins, calcium ions, and adenosine triphosphate (ATP), an energy source. Calcium, ATP, and other chemicals play similar roles in smooth muscle and cardiac muscle contraction.

Muscles and Metabolism

Muscle contraction is work and therefore produces heat. This helps maintain body temperature. In cold weather the muscles react by shivering, a rapid alternating of contraction and relaxation. Shivering is an involuntary response. The rapid repeated contractions and relaxation produce heat, warming the body and helping it maintain a constant temperature.

Injuries and Disease

Like all tissues, muscle is prone to injury and disease. Common injuries to skeletal muscle include tears and spasms. Skeletal muscle can become infected by parasites such as the roundworm *Trichinella spiralis*. A virulent strain of the bacterium *Streptococcus pyogenes*, known as the flesh-eating bacterium, spreads rapidly through muscle, causing massive and irreversible damage.

Diseases of muscle are called myopathies. Skeletal muscle is vulnerable to several autoimmune disorders, including dermatomyositis, polymyositis, and myasthenia gravis. Infection with the polio virus causes the disease poliomyelitis, which is marked by paralysis and muscle wasting. Bell's palsy affects the facial nerve, resulting in weakness or paralysis of all the muscles on one side of the face. The muscular dystrophies are genetic diseases characterized by progressive muscular weakness and wasting. Both smooth and skeletal muscle can form tumors, which may be malignant or benign. Deterioration of the heart muscle, or cardiomyopathy, has several causes, ranging from genetic factors to coronary artery disease.

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