

Biology

MUSCULAR SYSTEM

Chapter

The muscular system is responsible for the movement of the human body. Attached to the bones of the skeletal system are about 700 named muscles that make up roughly half of a person's body weight. Each of these muscles is a discrete organ constructed of skeletal muscle tissue, blood vessels, tendons, and nerves. Muscle tissue is also found inside of the heart, digestive organs, and blood vessels. In these organs, muscles serve to move substances throughout the body.

ANATOMY

Muscle Types

There are three types of muscle tissue:

Visceral Muscle

Visceral muscle is found inside of organs like the stomach, intestines, and blood vessels. The weakest of all muscle tissues, visceral muscle makes organs contract to move substances through the organ. Because visceral muscle is controlled by the unconscious part of the brain, it is known as involuntary muscle—it cannot be directly controlled by the conscious mind. The term “smooth muscle” is often used to describe visceral muscle because it has a very smooth, uniform appearance when viewed under a microscope. This smooth appearance starkly contrasts with the banded appearance of cardiac and skeletal muscles.

Cardiac Muscle

Found only in the heart, cardiac muscle is responsible for pumping blood throughout the body. Cardiac muscle tissue cannot be controlled consciously, so it is an involuntary muscle. While hormones and signals from the brain adjust the rate of contraction, cardiac

muscle stimulates itself to contract. The natural pacemaker of the heart is made of cardiac muscle tissue that stimulates other cardiac muscle cells to contract. Because of its self-stimulation, cardiac muscle is considered to be autorhythmic or intrinsically controlled.

The cells of cardiac muscle tissue are striated—that is, they appear to have light and dark stripes when viewed under a light microscope. The arrangement of protein fibers inside of the cells causes these light and dark bands. Striations indicate that a muscle cell is very strong, unlike visceral muscles. The cells of cardiac muscle are branched X or Y shaped cells tightly connected together by special junctions called intercalated disks. Intercalated disks are made up of fingerlike projections from two neighboring cells that interlock and provide a strong bond between the cells. The branched structure and intercalated disks allow the muscle cells to resist high blood pressures and the strain of pumping blood throughout a lifetime. These features also help to spread electrochemical signals quickly from cell to cell so that the heart can beat as a unit.

Skeletal Muscle

Skeletal muscle is the only voluntary muscle tissue in the human body—it is controlled consciously. Every physical action that a person consciously performs (e.g. speaking, walking, or writing) requires skeletal muscle. The function of skeletal muscle is to contract to move parts of the body closer to the bone that the muscle is attached to. Most skeletal muscles are attached to two bones across a joint, so the muscle serves to move parts of those bones closer to each other. Skeletal



muscle cells form when many smaller progenitor cells lump themselves together to form long, straight, multinucleated fibers. Striated just like cardiac muscle, these skeletal muscle fibers are very strong. Skeletal muscle derives its name from the fact that these muscles always connect to the skeleton in at least one place.

ANATOMY OF A SKELETAL MUSCLE

Most skeletal muscles are attached to two bones through tendons. Tendons are tough bands of dense regular connective tissue whose strong collagen fibers firmly attach muscles to bones. Tendons are under extreme stress when muscles pull on them, so they are very strong and are woven into the coverings of both muscles and bones. Muscles move by shortening their length, pulling on tendons, and moving bones closer to each other. One of the bones is pulled towards the other bone, which remains stationary. The place on the stationary bone that is connected via tendons to the muscle is called the origin. The place on the moving bone that is connected to the muscle via tendons is called the insertion. The belly of the muscle is the fleshy part of the muscle in between the tendons that does the actual contraction.

Number of Origins

Some muscles connect to more than one bone or to more than one place on a bone, and therefore have more than one origin. A muscle with two origins is called a biceps. A muscle with three origins is a triceps muscle. Finally, a muscle with four origins is a quadriceps muscle.

PHYSIOLOGY

Function of Muscle Tissue

The main function of the muscular system is

movement. Muscles are the only tissue in the body that has the ability to contract and therefore move the other parts of the body. Related to the function of movement is the muscular system's second function: the maintenance of posture and body position. Muscles often contract to hold the body still or in a particular position rather than to cause movement. The muscles responsible for the body's posture have the greatest endurance of all muscles in the body—they hold up the body throughout the day without becoming tired. Another function related to movement is the movement of substances inside the body. The cardiac and visceral muscles are primarily responsible for transporting substances like blood or food from one part of the body to another. The final function of muscle tissue is the generation of body heat. As a result of the high metabolic rate of contracting muscle, our muscular system produces a great deal of waste heat. Many small muscle contractions within the body produce our natural body heat. When we exert ourselves more than normal, the extra muscle contractions lead to a rise in body temperature and eventually to sweating.

Contraction Cycle

Muscles contract when stimulated by signals from their motor neurons. Motor neurons contact muscle cells at a point called the Neuromuscular Junction (NMJ). Motor neurons release neurotransmitter chemicals at the NMJ that bond to a special part of the sarcolemma known as the motor end plate. The motor end plate contains many ion channels that open in response to neurotransmitters and allow positive ions to enter the muscle fiber. The positive ions form an electrochemical gradient to form inside of the cell, which spreads throughout the sarcolemma and the T-tubules by opening even more ion channels. When the positive ions reach the sarcoplasmic reticulum, Ca^{2+} ions are released and allowed to flow into the myofibrils.



Ca^{2+} ions bind to troponin, which causes the troponin molecule to change shape and move nearby molecules of tropomyosin. Tropomyosin is moved away from myosin binding sites on actin molecules, allowing actin and myosin to bind together. ATP molecules power myosin proteins in the thick filaments to bend and pull on actin molecules in the thin filaments. Myosin proteins act like oars on a boat, pulling the thin filaments closer to the center of a sarcomere. As the thin filaments are pulled together, the sarcomere shortens and contracts. Myofibrils of muscle fibers are made of many sarcomeres in a row, so that when all of the sarcomeres contract, the muscle cells shorten with a great force relative to its size. Muscles continue contraction as long as they are stimulated by a neurotransmitter. When a motor neuron stops the release of the neurotransmitter, the process of contraction reverses itself. Calcium returns to the sarcoplasmic reticulum; troponin and tropomyosin return to their resting positions; and actin and myosin are prevented from binding. Sarcomeres return to their elongated resting state once the force of myosin pulling on actin has stopped.

Types of Muscle Contraction

The strength of a muscle's contraction can be controlled by two factors: the number of motor units involved in contraction and the amount of stimulus from the nervous system. A single nerve impulse of a motor neuron will cause a motor unit to contract briefly before relaxing. This small contraction is known as a twitch contraction. If the motor neuron provides several signals within a short period of time, the strength and duration of the muscle contraction increases. This phenomenon is known as temporal summation. If the motor neuron provides many nerve impulses in rapid succession, the muscle may enter the state of tetanus, or complete and lasting contraction. A muscle

will remain in tetanus until the nerve signal rate slows or until the muscle becomes too fatigued to maintain the tetanus. Not all muscle contractions produce movement. Isometric contractions are light contractions that increase the tension in the muscle without exerting enough force to move a body part. When people tense their bodies due to stress, they are performing an isometric contraction. Holding an object still and maintaining posture are also the result of isometric contractions. A contraction that does produce movement is an isotonic contraction. Isotonic contractions are required to develop muscle mass through weight lifting.

Muscle Metabolism and Fatigue

Muscles get their energy from different sources depending on the situation that the muscle is working in. Muscles use aerobic respiration when we call on them to produce a low to moderate level of force. Aerobic respiration requires oxygen to produce about 36-38 ATP molecules from a molecule of glucose. Aerobic respiration is very efficient, and can continue as long as a muscle receives adequate amounts of oxygen and glucose to keep contracting. When we use muscles to produce a high level of force, they become so tightly contracted that oxygen carrying blood cannot enter the muscle. This condition causes the muscle to create energy using lactic acid fermentation, a form of anaerobic respiration. Anaerobic respiration is much less efficient than aerobic respiration—only 2 ATP are produced for each molecule of glucose. Muscles quickly tire as they burn through their energy reserves under anaerobic respiration. When muscles run out of energy during either aerobic or anaerobic respiration, the muscle quickly tires and loses its ability to contract. This condition is known as muscle fatigue.

