

## The Muscular System

There are three types of muscle tissue:

Skeletal – (Voluntary). Long, straight, multinucleated, striated fibers with the nucleus just under the cell membrane called the sarcolemma.

Cardiac – (Involuntary). Striated, long, branching fibers. Nucleus is more centrally located. Cells are connected by gap junctions called intercalated discs.

Smooth – (Involuntary). Nonstriated sheets of cells often in hollow organs.

The functions of the muscular system are to produce movement, maintain posture, stabilize joints and generate heat

### Skeletal Muscle Organization

Each muscle cell or fiber is covered with a connective tissue sheath called the endomysium. Muscle fibers are bundled together as a fascicle and covered with a sheath called the perimysium. Fascicles are bundled together and covered with the epimysium. All of these sheaths are continuous with one another and with the tendon connecting the muscle to the bone. Sheet-like tendons are referred to as aponeuroses. The more moveable bone attached to the muscle is called its insertion, and moves the less moveable bone, the origin.

Muscles are well supplied with nerve endings and a rich supply of blood vessels because of high demands for oxygen and nutrients and the large amount of metabolic wastes that must be removed. Muscle fibers contain large amounts of the oxygen-binding protein called myoglobin.

Each striated muscle fiber is packed with hundreds of long cylinders called myofibrils which contain the contractile myofilaments. Thin filaments are mostly composed of the protein actin. Thick filaments are mostly composed of the protein myosin. The regular arrangement of the thick and thin filaments make up the striations. The A Band is where the thick filaments occur and overlap with the thin filaments. The I Band is where only thin filaments occur. Running perpendicular to the filaments, down the middle of the I Band is the Z Disc to which both kinds of filaments are connected. From Z Disc to Z Disc is considered the sarcomere, the functional unit of the muscle. A modified endoplasmic reticulum called the sarcoplasmic reticulum fits over each myofibril like an interlacing sleeve and is enlarged at each end as the terminal cisternae. The terminal cisternae overlie the I Band-A Band junctions and are storage areas for calcium. Between the two terminal cisternae runs an invagination of the sarcolemma called the T tube.

### Muscle Contraction Physiology

When an action potential of a nerve cell reaches the axonal terminal, acetylcholine is released into the synaptic cleft and binds to receptors on the motor end plate of the sarcolemma opening sodium channels. Depolarization is continued along the sarcolemma and down the T tubes which results in the release of calcium from the terminal cisternae.

This released calcium attaches to certain proteins which causes them to change shape. This exposes a site on the actin to which the myosin binds. A myosin filament consists of a head and a tail. When the myosin head binds to the actin, a cross bridge is formed. Myosin then releases ADP and Pi causing the head to bend toward the midline of the sarcomere pulling the actin filament along with it. ATP then binds to the myosin causing the head to release from the actin. ATP is hydrolyzed to ADP and Pi which causes the myosin head to become repositioned so that it can again bind to the actin. This process repeats many times, “ratcheting” the actin filaments toward each other. As calcium is pumped back to the cisternae, myosin binding sites are no longer exposed and the muscle relaxes.

Rigor mortis, which peaks about 12 hours after death, is the result of the cross bridges unable to separate from the actin (because no more ATP is available). Rigor passes when muscle proteins break down.

Naming Muscles: muscles are sometimes named according to:

- Location. Example: the frontalis overlies the frontal bone
- Shape. Example: deltoid (delta shaped)
- Relative size. Example: gluteus maximus
- Direction of muscle fibers. Example: rectus abdominis
- Number of origins. Example: triceps brachii
- Location of attachment. Example: sternocleidomastoid
- Action. Example: adductor longus

Attachments:

- Origin – attachment to the bone that moves less (usually the more proximal attachment)
- Insertion – attachment to the more moveable bone

Types of Motion:

- flexion
- extension
- abduction
- adduction
- rotation
- circumduction
- dorsiflexion
- plantar flexion
- inversion
- eversion
- pronation
- supination

Muscle Metabolism

ATP is the only source of energy used directly for muscle contraction. A high-energy molecule stored in muscle tissue is used to regenerate ATP:



Aerobic respiration yields relatively large amounts of ATP from the breakdown of glucose and the electron transport system. However, working muscles restrict blood supply and therefore oxygen. An anaerobic pathway allows for the breakdown of glucose to **lactic acid** (rather than CO<sub>2</sub> and H<sub>2</sub>O). Relatively small amounts of ATP are generated during glycolysis but ATP is produced much faster. Lactic acid diffuses into the blood where it can be used by a few other organs as a source of energy or reconverted back into glucose by the liver in a process called the **Cori cycle**.

When oxygen is limited and ATP production can't keep up with use, muscles contract less and less effectively until muscle fatigue sets in. **Muscle fatigue** is the physiological inability to contract even though the muscle may still be receiving stimuli. A **contracture** is a state of continuous contraction resulting from undetached myosin cross bridges which persist due to the lack of ATP. Reconversion of lactic acid to glucose and the restoration of ATP and creatine phosphate requires oxygen. The **oxygen debt** is the extra amount of oxygen that the body must take in for the restorative processes.

Most of the energy released in muscle contraction is given off as heat that is dissipated by radiation and sweating.

## Muscle List

<b>NAME</b>	<b>REGION</b>	<b>ORIGIN</b>	<b>INSERTION</b>	<b>ACTION</b>
1.Frontalis	Forehead	Cranial aponeurosis	skin of eyebrows, root of nose	raises eyebrows
2.Obicularis Oris	Encircles mouth	Maxillae & Mandible	muscles and skin at angles of mouth	closes mouth, purses lips
3.Buccinator	Cheek	Maxillae & Mandible near molars	Obicularis Oris	compress cheek
4.Masseter	Jaw	Zygomatic arch and Maxillae	Mandible	elevates mandible
5.Sternocleidomastoid	Neck	Sternum & Clavicle	Mastoid process of temporal bone	head flexion & forward rotation
6.Deltoid	Over Shoulders	Clavicle & Scapula	Deltoid tuberosity of humerus	abduction, flexion, extension of humerus
7.Biceps Brachii	Superior Anterior Arm	Scapula (2) locations	Radial tuberosity	flexes elbow
8.Triceps Brachii	Superior Posterior Arm	Scapula and (2) locations on humerus	Ulna	extends forearm
9.Pectoralis Major	Chest	Clavicle, Sternum, Cartilage of ribs 1 – 6	Humerus	flexion, adduction, rotation of arm
10.External Intercostals	Lateral Trunk	rib above	rib below	elevates ribs
11.Rectus Abdominis	Abdomen	Pubis	Sternum, cartilage of ribs 5 – 7	compresses abdomen. flexes vertebral column
12.External Obliques	Lateral Trunk	Lower 8 ribs	Ilium, linea alba	compresses abdomen flexes vertebral column
13.Trapezius	Posterior Trunk and Neck	Occipital, C7 thoracic vertebrae	Clavicle & Scapula	elevates, rotates retracts scapula
14.Latissimus Dorsi	Lower Posterior Trunk	Iliac crest, T7 to sacrum, ribs 8 – 12	Humerus	extends, adducts rotates arm
15.Gluteus Maximus	Buttocks	Ilium, sacrum, coccyx	Femur	extends thigh
16.Quadriceps Femoris	Anterior Thigh	Ilium, femur	Tibial tuberosity via patellar ligament	extends knee flexes thigh
17.Biceps Femoris	Posterior Thigh	Iscial tuberosity, femur	head of Fibula, Tibia	extends thigh flexes knee
18.Gastrocnemius	Posterior Calf	Femur	Calcaneous	plantar flexes foot flexes knee

A motor neuron (including all its axonal terminals) and all the muscle fibers it supplies are called a motor unit. The response of a motor unit to a single action potential of its motor neuron is called a muscle twitch. If two identical stimuli are delivered to a muscle in rapid succession, the second twitch will be stronger than the first. This occurs because the second contraction takes place before the muscle has completely relaxed. If the stimulus strength is held constant and the muscle is stimulated at an increasingly faster rate, the relaxation time between twitches becomes shorter and the concentration of  $\text{Ca}^{++}$  in the muscle increases until the contractions fuse into a smooth, sustained contraction called complete tetanus. (Not to be confused with the bacterial disease.) There are two main categories of contractions: isotonic, in which the muscle length changes and moves the load, and isometric in which the muscle attempts to move a load which is greater than the force. In isometric contractions the muscle neither shortens nor lengthens. Even relaxed muscles are almost always slightly contracted. This is called muscle tone. Muscle tone does not produce active movements but keeps the muscles firm and ready to respond to stimulation.

#### Effects of Exercise

Aerobic exercise results in a number of changes in the skeletal muscles. Capillaries surrounding the muscle fibers increase as does the number of mitochondria within them. More myoglobin is synthesized. This leads to more efficient muscle metabolism and greater endurance and resistance to muscle fatigue. (Not to mention effects on heart and lung capacity.)

#### Smooth Muscle Contraction

Usually smooth muscle fibers exhibit slow synchronized contractions. The whole sheet responds to a stimulus in unison. This is possible because smooth muscle cells are electrically coupled by gap junctions which allow the transmission of action potentials from fiber to fiber. Some smooth muscles move in progressive, wavelike contractions (such as in swallowing), a phenomenon known as peristalsis.

#### Conditions, Diseases and Injuries

Atrophy – Disuse (from immobilization or loss of stimulation) may lead to loss of strength and muscle tissue may be lost. If this occurs for long periods, muscle tissue may be replaced by fibrous connective tissue.

Tetanus – A disease caused by *Clostridium tetani*. This anaerobic bacteria releases a very potent neurotoxin called tetanospasmin which blocks the relaxation pathway so that both opposing sets of muscles contract. Early symptoms may affect muscles of the jaw which give the disease the name lockjaw.

Charley horse – A muscle contusion where there is a tearing of the muscle followed by bleeding into the tissues accompanied by severe and prolonged pain.

Hernia – This is a protrusion of an organ through its muscular wall and may be caused by heavy lifting. An inguinal hernia (males) occurs where the spermatic cord goes through the inguinal canal through the abdomen. Weakness of the inguinal canal occurs with increased abdominal pressure and intestines can protrude out. The hernia may become strangulated if the blood supply is cut off. A hiatal hernia occurs when the stomach protrudes through a weakness in the diaphragm into the thoracic cavity. An umbilical hernia occurs in newborns when the intestinal muscles fail to close around the umbilicus allowing the intestine to protrude. An incisional hernia may occur after surgery when there is a weakness of the muscle around a surgical wound.

Myalgia – muscle pain

Muscle Strain – excessive stretching and/or tearing of a muscle which then becomes inflamed.