4 The Muscular System

- What is muscular system?
- How you can understands about muscles?
- What is the function of muscle in life of animals, human?
- What is the component of muscle; from what the composed?
- How we can classify muscle, based on what criteria?

Introduction

Muscle is originated from Latin word “**Mus**” which means “**Little mouse**”. The science that study about muscle is called **Myology**. Muscle is a flesh that attached to the bone under skin. They are how to move and live; all the movement in the body can takes place and controlled by muscle contraction that full function of the body. Due to that muscle is viewed as the machines of the body. There are more than 600 muscles which found in our body to make muscular system. They make up averagely 30-40% of body mass.

The muscular system is composed of specialized **cells called muscle fibers**. When these muscle fibers are stimulated by nerve they became contract or became short and thick. That means muscle fibers get a signal from a nerve proteins and chemicals to releases energy to either contract the muscle or relax it. Their predominant function is contractibility. Muscles, attached to bones or internal organs and blood vessels, are responsible for movement. Nearly all movement in the body is the result of muscle contraction. Exceptions to this are the action of cilia, the flagellum on sperm cells and amoeboid movement of some white blood cells. The integrated action of joints, bones and skeletal muscles produces obvious movements such as walking and running. Skeletal muscles also produce more subtle movements that result in various facial expressions, eye movements, and respiration.

Many of our muscles come in pairs. An example of this is the biceps and triceps in our arms. When the biceps contract the triceps will relax, this allows our arm to bend. When we want to straighten our arm back out, the biceps will relax and the triceps will contract. Muscle pairs allow us to move back and forth.

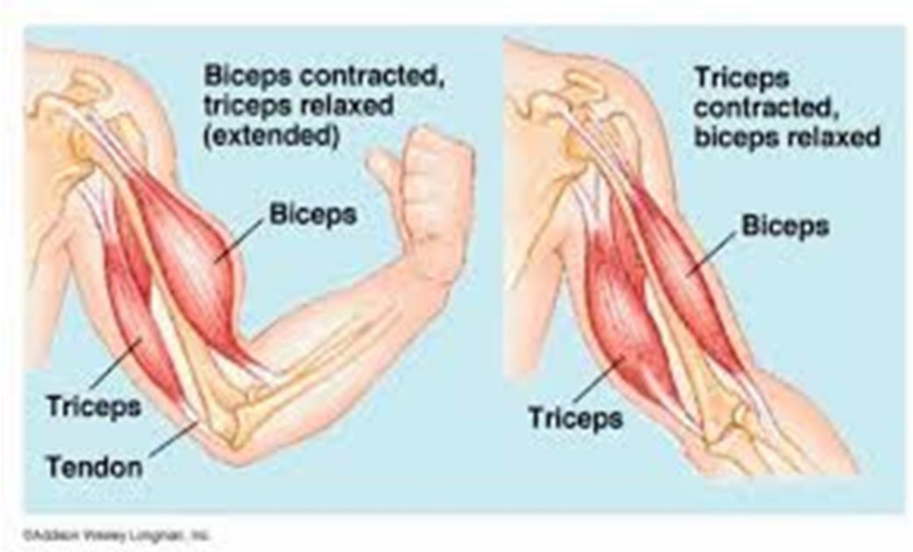


Figure1. Contraction and relaxation of muscle

Note that: From 600 muscle in our body

- The longest muscle is called **Sartorius**:- which run from the outside of hip down and across to the knee. It twists and pull the thigh outwards.
- The smallest muscle is called **Stapedius**:- which is located deep in the ear. It is only 5mm long and thinner than cotton thread. It is involved in hearing.
- The biggest muscle is called **Gluteus Maximus**:- which is located in the buttock. It pulls the leg backwards powerfully for walking and running.
- The strongest muscles is called the **Masseters**:- which is Pound for pound, it's the muscles that you chew with. They found on our face.
- If all of the muscles in the body could all pull in one direction, it would create a force of 25 tons.

3.2 Types of muscles

A muscle enables complex movement that are either under conscious control (voluntary) and unconscious (involuntary). They are different in structure, location function and means of all activation. Based on this they are **3** types of muscles in the body:

A. Skeletal muscle

Skeletal muscles are the only muscles that can be consciously controlled. They are attached to bones, and contracting the muscles causes movement of those bones. Any action that a person consciously undertakes involves the use of skeletal muscles.

B. Smooth muscle

Smooth muscle lines the inside of blood vessels and organs, such as the stomach, and is also known as visceral muscle. It is the weakest type of muscle but has an essential role in moving food along the digestive tract and maintaining blood circulation through the blood vessels. Smooth muscle acts involuntarily and cannot be consciously controlled.

C. Cardiac muscle

Located only in the heart, cardiac muscle pumps blood around the body. Cardiac muscle stimulates its own contractions that form our heartbeat. Signals from the nervous system control the rate of contraction. This type of muscle is strong and acts involuntarily.

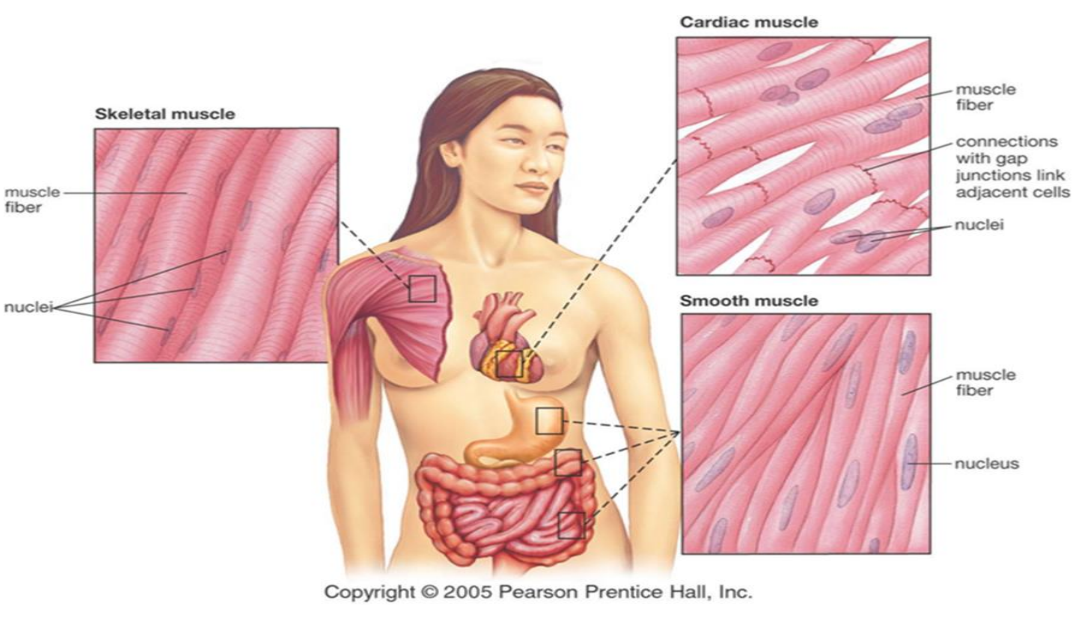


Figure 2. Types of muscles

3.3 Functions of the muscular system

The main functions of the muscular system are as follows:

1. Mobility:- The muscular system's main function is to allow movement. When muscles contract, they contribute to gross and fine movement. Most muscle movement of the body is under conscious control. However, some movements are reflexive, such as withdrawing a hand from a source of heat.

2. Stability:- Muscle tendons stretch over joints and contribute to joint stability. Muscle tendons in the knee joint and the shoulder joint are crucial in stabilization. The core muscles are those in the abdomen, back and pelvis and they also stabilize the body and assist in tasks, such as lifting weights.

3. Posture:- Skeletal muscles help keep the body in the correct position when someone is sitting or standing. This is known as posture. Good posture relies on strong, flexible muscles. Stiff, weak, or tight muscles contribute to poor posture and misalignment of the body.

4. Circulation:- The heart is a muscle that pumps blood throughout the body. The movement of the heart is outside of conscious control, and it contracts automatically when stimulated by electrical signals. Smooth muscle in the arteries and veins plays a further role in the circulation of blood around the body. These muscles maintain blood pressure and circulation in the event of blood loss or dehydration. They expand to increase blood flow during times of intense exercise when the body requires more oxygen.

5. Respiration:- Breathing involves the use of the diaphragm muscle. The diaphragm is a dome-shaped muscle located below the lungs. When the diaphragm contracts, it pushes downward, causing the chest cavity to get bigger. The lungs then fill with air. When the diaphragm muscle relaxes, it pushes air out of the lungs. When someone wants to breathe more deeply, it requires help from other muscles, including those in the abdomen, back, and neck.

6. Digestion:- The muscular system allows for movement within the body, for example, during digestion or urination. Smooth muscles in the gastrointestinal or GI tract control digestion. The GI tract stretches from the mouth to the anus. Food moves through the digestive system with a wave-like motion called peristalsis. Muscles in the walls of the hollow organs contract and relax to cause this movement, which pushes food through the esophagus into the stomach. The upper muscle in the stomach relaxes to allow food to enter, while the lower muscles mix food particles with stomach acid and enzymes.

7. Urination:-The urinary system comprises both smooth and skeletal muscles. The muscles and nerves must work together to hold and release urine from the bladder. Urinary problems, such as poor bladder control or retention of urine, are caused by damage to the nerves that carry signals to the muscles.

8. Childbirth:- Smooth muscles in the uterus expand and contract during childbirth. The pelvic floor muscles help to guide the baby's head down the birth canal.

9. Vision:- Six skeletal muscles around the eye control its movements. These muscles work quickly and precisely, and allow the eye to: maintain a stable image, scan the surrounding area and track moving objects.

10. Organ protection:- Muscles in the torso protect the internal organs at the front, sides and back of the body. The bones of the spine and the ribs provide further protection. Muscles also protect the bones and organs by absorbing shock and reducing friction in the joints.

11. Temperature regulation:- Maintaining normal body temperature is an important function of the muscular system. Almost 85 percent of the heat a person generates in their body comes from contracting muscles. Skeletal muscles contribute to the maintenance of homeostasis in the body by generating heat. Muscle contraction requires energy and when ATP is broken down, heat is produced. This heat is very noticeable during exercise, when sustained muscle movement causes body temperature to rise, and in cases of extreme cold, when shivering produces random skeletal muscle contractions to generate heat.

3.4 Physiological characteristic of muscle tissue

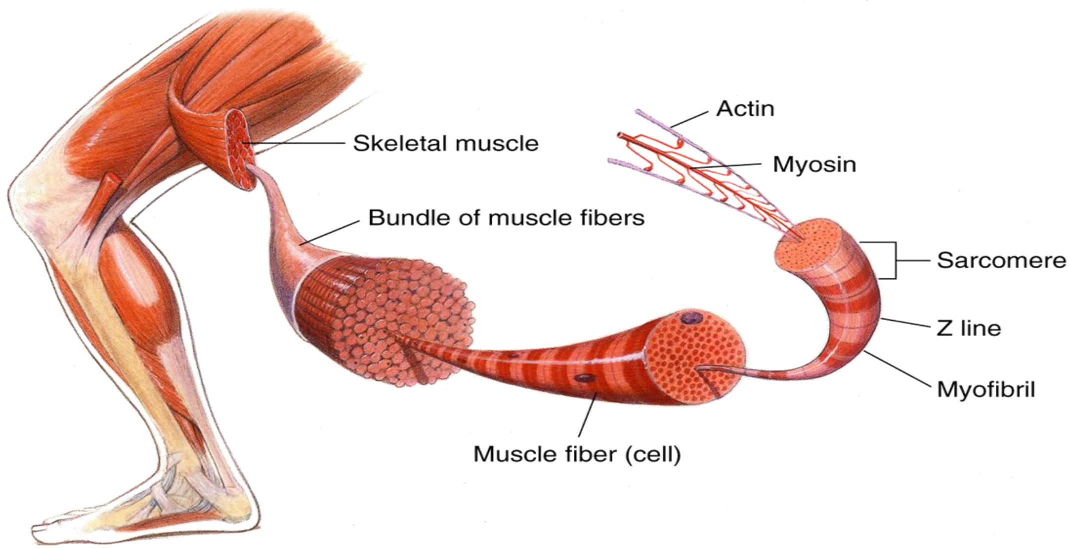
Humans are born with all of the muscle fibers they will ever have. They don't grow new fibers, they just grow thicker. Muscle tissue has four principal characteristics that enable it to carry out its function and contribute to homeostasis.

1. **Excitability (irritability):-** formation of electrical signal. It is a property of both muscle and nerve cells (neurons) ability to respond to certain stimuli by producing electrical signal.
2. **Contractility:-** is the ability of muscle tissue to shorten and thicker to be contract to generating force to do work. Muscle contraction is in response to one or more muscle action potential.
3. **Extensibility:-** means that the muscle can be extended (stretched) without damaging the tissue. Most of skeletal muscle is arranged in opposing pairs.
4. **Elasticity:-** is the process of returning to its original place and original shape after contraction or extension.

3.5 Skeletal Muscle Structure

The best-known feature of skeletal muscle is its ability to contract and cause movement. Skeletal muscles act not only to produce movement but also to stop movement, such as resisting gravity to maintain posture. Small, constant adjustments of the skeletal muscles are needed to hold a body upright or balanced in any position. Skeletal muscle is composed from striated muscle cell called muscle fibers and connective tissue. They have two parts; connective tissue sheath (tendon and aponeurosis) and flesh part (belly or gaster).

Each skeletal muscle is an organ that consists of various integrated tissues. These tissues include the skeletal muscle fibers, blood vessels, nerve fibers, and connective tissue. Each skeletal muscle has three layers of connective tissue (called “mysia”) that enclose it and provide structure to the muscle as a whole and also maintaining its structural integrity. Inside each skeletal muscle, muscle fibers are organized into individual bundles, called fascicles, are covered by the **perimysium**. This fascicular organization is common in muscles of the limbs; it allows the nervous system to trigger a specific movement of a muscle by activating a subset of muscle fibers within a bundle, or fascicle of the muscle. Inside each fascicle, each muscle fiber is encased in a thin connective tissue layer of collagen and reticular fibers called the **endomysium**. The **endomysium** contains the extracellular fluid and nutrients to support the muscle fiber. These nutrients are supplied via blood to the muscle tissue. The **epimysium** also separates muscle from other tissues and organs in the area, allowing the muscle to move independently.



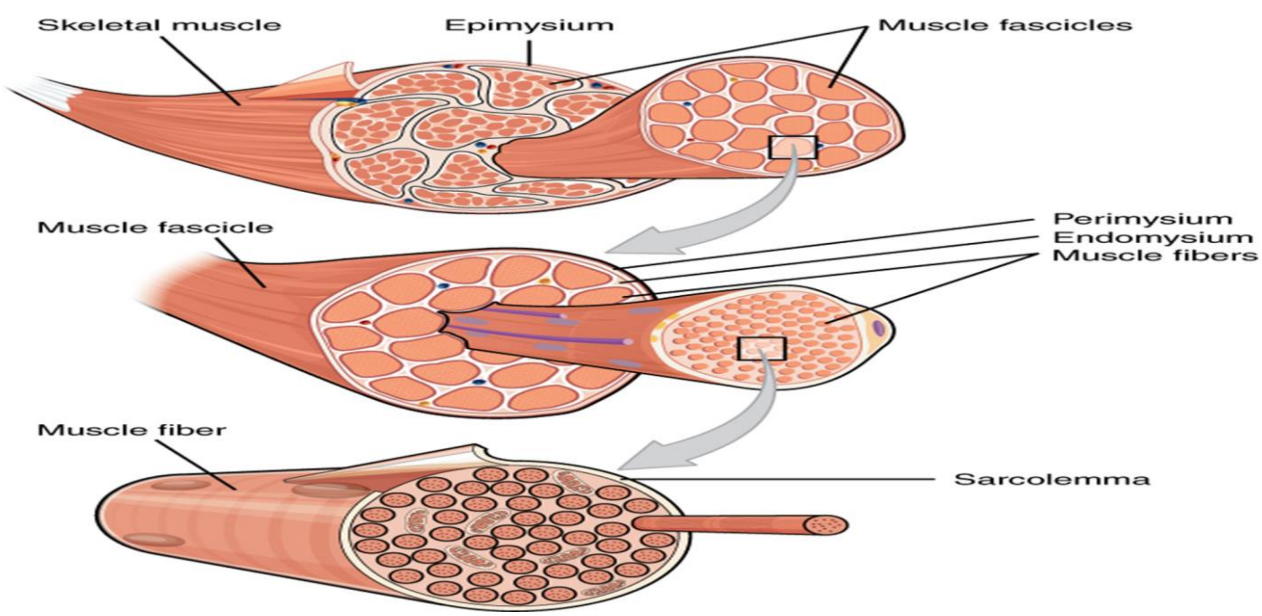


Figure 3. The Three Connective Tissue Layers.

In skeletal muscles that work with tendons to pull on bones, the collagen in the three tissue layers (the mysia) intertwines with the collagen of a tendon. At the other end of the tendon, it fuses with the periosteum coating the bone. The tension created by contraction of the muscle fibers is then transferred though the mysia, to the tendon, and then to the periosteum to pull on the bone for movement of the skeleton. In other places, the mysia may fuse with a broad, tendon-like sheet called an **aponeurosis**, or to **fascia**, the connective tissue between skin and bones. The broad sheet of connective tissue in the lower back that the latissimus dorsi muscles (the "lats") fuse into is an example of an aponeurosis.

Every skeletal muscle is also richly supplied by blood vessels for nourishment, oxygen delivery, and waste removal and by axon branch of a somatic motor neuron, which signals the fiber to contract. Unlike cardiac and smooth muscle, the only way to functionally contract a skeletal muscle is through signaling from the nervous system.

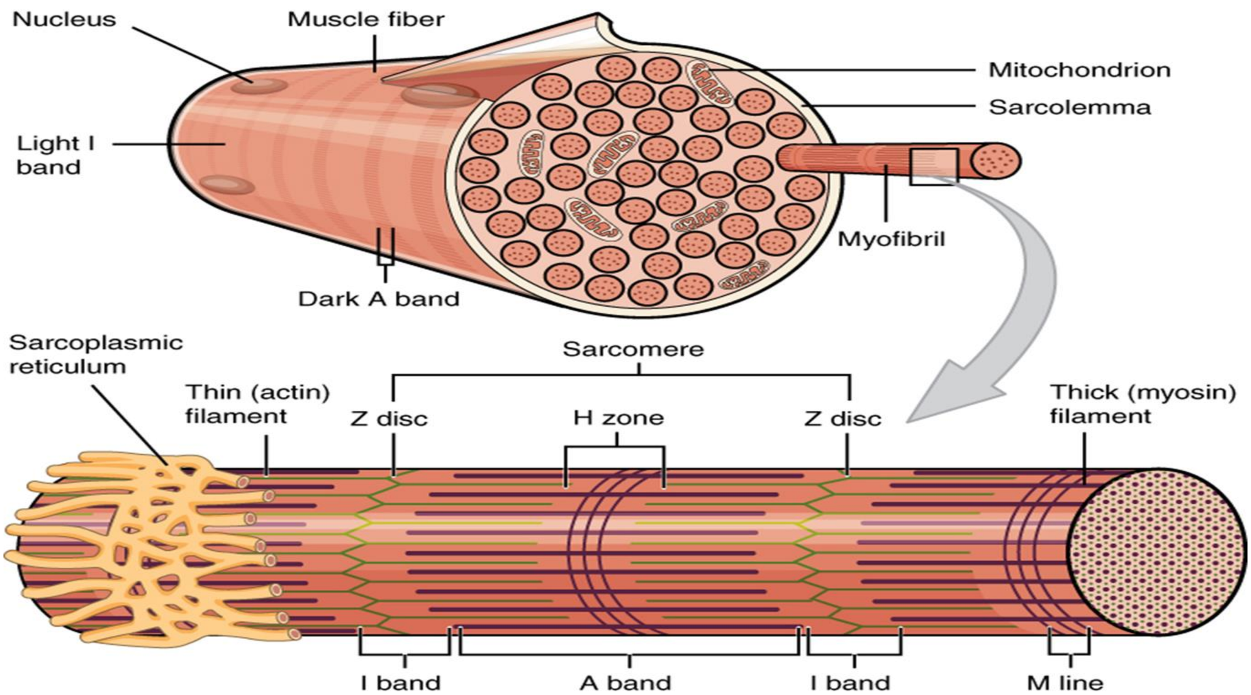


Figure 4. Muscle Fiber.

A skeletal muscle fiber is surrounded by a plasma membrane called the **sarcolemma**, which contains **sarcoplasm**, the cytoplasm of muscle cells. A muscle fiber is composed of many fibrils, which give the cell its striated appearance.

The Sarcomere

The striated appearance of skeletal muscle fibers is due to the arrangement of the myofilaments of actin and myosin in sequential order from one end of the muscle fiber to the other. Each packet of these microfilaments and their regulatory proteins, troponin and tropomyosin (along with other proteins) is called a **sarcomere**.

The **sarcomere** is the functional unit of the muscle fiber. The sarcomere itself is bundled within the myofibril that runs the entire length of the muscle fiber and attaches to the sarcolemma at its end. As myofibrils contract, the entire muscle cell contracts. Because myofibrils are only approximately 1.2 µm in diameter, hundreds to thousands (each with thousands of sarcomeres) can be found inside one muscle fiber. Each sarcomere is approximately 2 µm in length with a three-dimensional cylinder-like arrangement and is bordered by structures called **Z-discs** (also called **Z-lines**, because pictures are two-dimensional), to which the actin myofilaments are anchored. Because the **actin** and its **troponin-tropomyosin** complex (projecting from the Z-discs toward the center of the sarcomere) form strands that are thinner than the myosin, it is called the **thin filament** of the sarcomere. The **myosin** strands have multiple heads (projecting from the center of the sarcomere, toward but not all to way to, the Z-discs) and are thicker. hey are called the **thick filament** of the sarcomere.

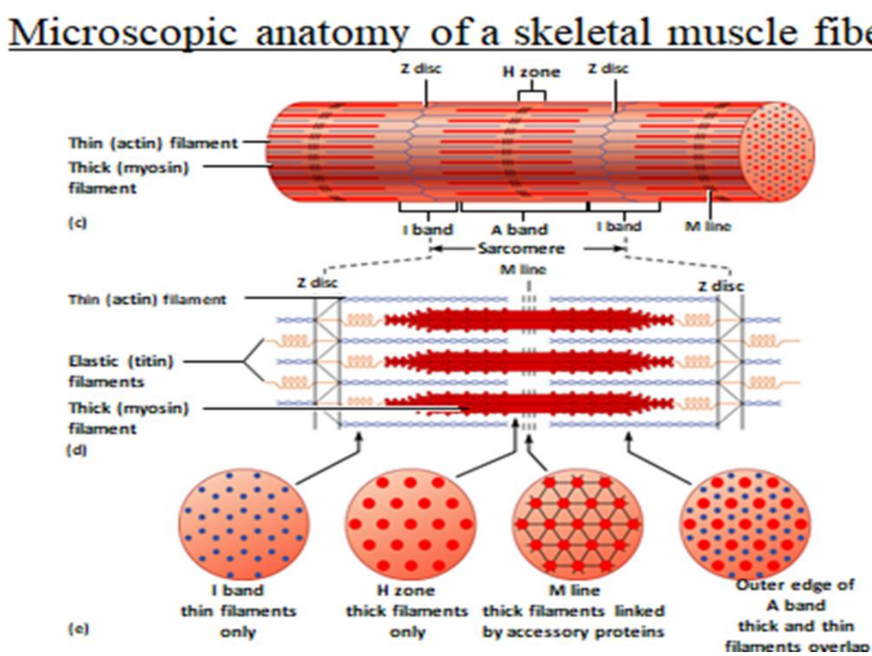


Figure 5. The Sarcomere.

The Neuromuscular Junction

Another specialization of the skeletal muscle is the site where a motor neuron's terminal meets the muscle fiber—called the **neuromuscular junction** (NMJ). This is where the muscle fiber first responds to signaling by the motor neuron. Every skeletal muscle fiber in every skeletal muscle is innervated by a motor neuron at the NMJ. Excitation signals from the neuron are the only way to functionally activate the fiber to contract. Every skeletal muscle fiber is supplied by a motor neuron at the NMJ.

Figure 6. Neuromuscular Junction

Excitation-Contraction Coupling

All living cells have membrane potentials, or electrical gradients across their membranes. The inside of the membrane is usually around -60 to -90 mV, relative to the outside. This is referred to as a cell's membrane potential. Neurons and muscle cells can use their membrane potentials to generate electrical signals. They do this by controlling the movement of charged particles, called **ions**, across their membranes to create electrical currents. This is achieved by opening and closing specialized proteins in the membrane called **ion channels**. Although the currents generated by ions moving through these channel proteins are very small, they form the basis of both neural signaling and muscle contraction.

Both neurons and skeletal muscle cells are electrically excitable, meaning that they are able to generate **action potentials**. An action potential **is a special type of electrical signal** that can travel along a cell membrane as a wave. This allows a signal to be transmitted quickly and faithfully over long distances.

Excitation-contraction coupling means for a skeletal muscle fiber to contract, its membrane must first be "excited"; it must be stimulated to fire an action potential. The muscle fiber action potential, which sweeps along the sarcolemma as a wave, is "coupled" to the actual contraction through the release of calcium ions (Ca++) from the SR. Once released, the Ca++ interacts with the shielding proteins, forcing them to move aside so that the actin-binding sites are available for attachment by myosin heads. The myosin then pulls the actin filaments toward the center, shortening the muscle fiber.

The motor neurons that tell the skeletal muscle fibers to contract originate in the spinal cord, with a smaller number located in the brainstem for activation of skeletal muscles of the face, head, and neck. These neurons have long processes, called **axons**, which are specialized **to transmit action potentials long distances**. The distance of all the way from the spinal cord to the muscle; it makes up to three feet away. The axons of multiple neurons bundle together to form nerves, like wires bundled together in a cable.

Signaling begins when a neuronal action potential travels along the axon of a motor neuron, and then along the individual branches to terminate at the NMJ. At the NMJ, the axon terminal releases a chemical messenger or **neurotransmitter**, called **acetylcholine** (ACh). The ACh molecules diffuse across a minute space called the **synaptic cleft** and bind to ACh receptors located within the motor end-plate of the sarcolemma on the other side of the **synapse**. Once ACh binds, a channel in the ACh receptor opens and positively charged ions can pass through into the muscle fiber, causing it to **depolarize**, meaning that the membrane potential of the muscle fiber becomes **less negative** (closer to zero). As the membrane depolarizes, another set of ion channels called voltage-gated sodium channels are triggered to open. Sodium ions enter the muscle fiber and an action potential rapidly spreads (or “fires”) along the entire membrane to initiate excitation-contraction coupling.

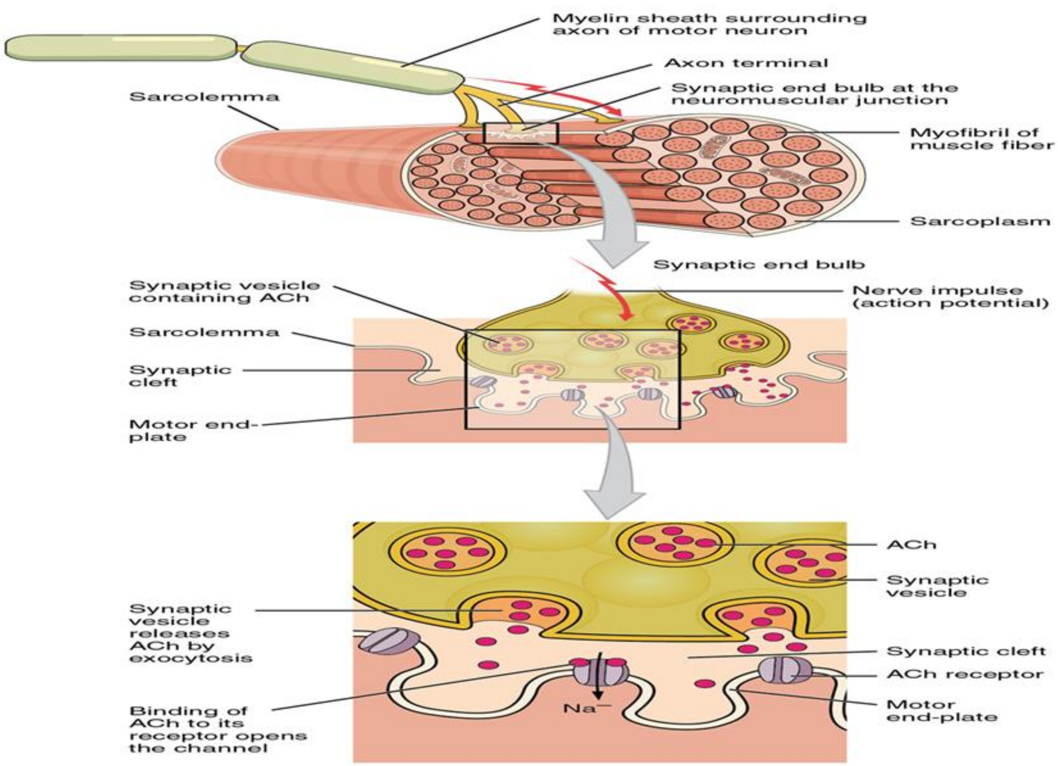


Figure 7. Motor End-Plate and Innervation.

Things happen very quickly in the world of excitable membranes (just think about how quickly you can snap your fingers as soon as you decide to do it). Immediately following depolarization of the membrane, it repolarizes, re-establishing the negative membrane potential. Meanwhile, the ACh in the synaptic cleft is degraded by the enzyme acetylcholinesterase (AChE) so that the ACh cannot rebind to a receptor and reopen its channel, which would cause unwanted extended muscle excitation and contraction.

Propagation of an action potential along the sarcolemma is the excitation portion of excitation-contraction coupling. Recall that this excitation actually triggers the release of calcium ions (Ca++) from its storage in the cell's SR. For the action potential to reach the membrane of the SR, there are periodic invaginations in the sarcolemma, called **T-tubules** ("T" stands for "transverse"). The diameter of a muscle fiber can be up to 100 μm, so these T-tubules ensure that the membrane can get close to the SR (sarcoplasmic reticulum) in the sarcoplasm. The arrangement of a T-tubule with the membranes of SR on either side is called a triad. The triad surrounds the cylindrical structure called a myofibril, which contains actin and myosin.

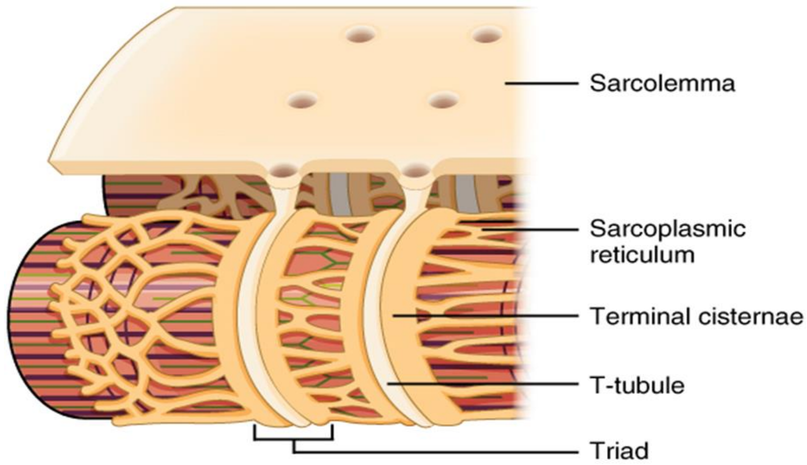


Figure 8. The T-tubule of muscle.

Narrow T-tubules permit the conduction of electrical impulses. The SR (sarcoplasmic reticulum) functions to regulate intracellular levels of calcium. Two **terminal cisternae** (where enlarged SR connects to the T-tubule) and one T-tubule comprise a triad a "threesome" of membranes, with those of SR on two sides and the T-tubule sandwiched between them. The **T-tubules carry** the **action potential into the interior of the cell**, which triggers the opening of calcium channels in the membrane of the adjacent SR, causing Ca^{++} to diffuse out of the SR and into the sarcoplasm. It is the arrival of Ca^{++} in the sarcoplasm that initiates contraction of the muscle fiber by its contractile units, or sarcomeres.

Attachment of muscle (Origin and Insertion Points)

Each muscle has two main points of attachment, the **origin** point and the **insertion** point. The origin of a muscle is the fixed end, the end that doesn't move. This end is usually a bone, cartilage or connective tissue. The opposite end of the muscle is the insertion point. This is the movable end of the muscle which is attached to the structure that is being moved.

If we take a look at the upper arm bone, called the humerus, we can see a large muscle on top of it. This muscle, called the **biceps brachii** has a point of origin at the **scapula** and its insertion point on the radius of the lower arm. When the muscle contracts, it moves the radius upwards towards the scapula, but the scapula and upper arm do not move. That is why the radius is termed the insertion point, while the scapula is the origin point.