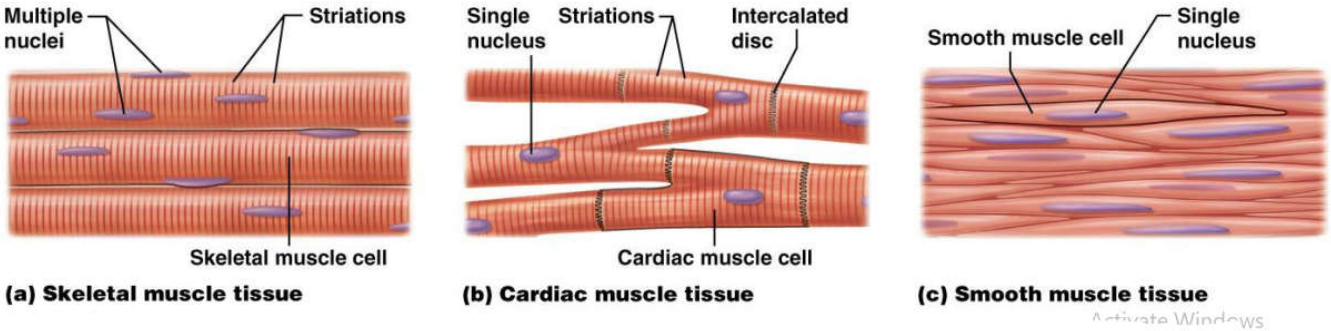
Muscle Physiology

Muscle tissue is made up of a large number of individual **muscle cells** or **myocytes.** The muscle cells are commonly called muscle fibers. Muscle tissue is classified into three types according to structure and function: skeletal, cardiac, and smooth muscle.



Comparison of Structure and Properties of Muscle Tissue Types

Skeletal muscle	Cardiac muscle	Smooth muscle
• association with bones forming the skeletal system. • Long cylindrical cells • Many nuclei per cell • Striated • Voluntary • Rapid contractions	• Found in heart • Branching cells • One or two nuclei per cell • Striated • Involuntary • Medium speed contractions	• Found in viscera • Fusiform cells • One nucleus per cell • Nonstriated • Involuntary • Slow, wave-like contractions

Structure of muscle cell

A single skeletal-muscle cell is known as a **muscle fiber.** The term **muscle** refers to a number of muscle fibers bound together by connective tissue. A skeletal **muscle fiber** is surrounded by a plasma membrane called the sarcolemma, which contains sarcoplasm, the cytoplasm of **muscle** cells (sarcoplasm contains an abundance of: glycogen a form of stored energy and myoglobin – a molecule that can store some O^2). A **muscle fiber** is composed of many fibrils, which give the cell its striated appearance. Along the length of the myofibril a thick and thin

filament arranged in a repeating pattern. One unit of this repeating pattern is known as a Sarcomeres.

Sarcomere surrounded by Sarcoplasmic Reticulum (SR) The main function of the **SR** is to store calcium ions. SR in turn surrounded by T-Tubules the function of **T-tubules** is to conduct impulses from the surface of the cell (sarcolemma) down into the SR.

A sarcomere is the functional unit (contractile unit) of a muscle fiber each sarcomere contains two types of myofilaments: thick filaments, composed primarily of the contractile protein **myosin,** and thin filaments, composed primarily of the contractile protein **actin**. Thin filaments also contain the regulatory proteins, **troponin** and **tropomyosin**. Each sarcomere contains two sets of thin filaments, one at each end. One end of each thin filament is fixed to a network of interconnecting proteins known as the **Z line,** whereas the other end joins a portion of the thick filaments.

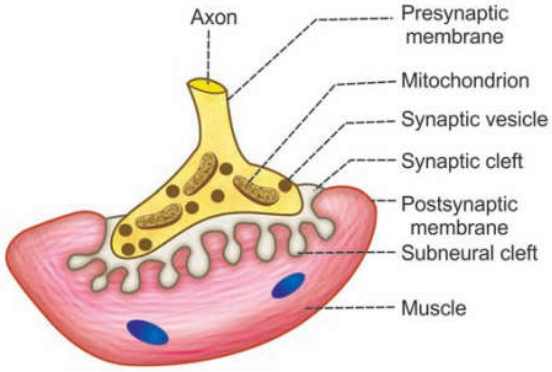
under an electron microscope, myofibril arrangement gives the appearance of alternating bands of light and dark striations. The light bands are called **I bands** and contain only thin filaments. The dark bands are called **A bands** and contain thick and thin filaments, with the thick filaments running the entire length of the A band.

Each myosin molecule has cross bridges in the tow ends . These bridges have enlarged structures called myosin heads at their tips. Myosin heads attach themselves to actin filaments. Each myosin head has two attachment sites. One site is for actin filament and the other one is for one ATP molecule These heads pull the actin filaments during contraction of the muscle, by means of a mechanism called **sliding mechanism.**

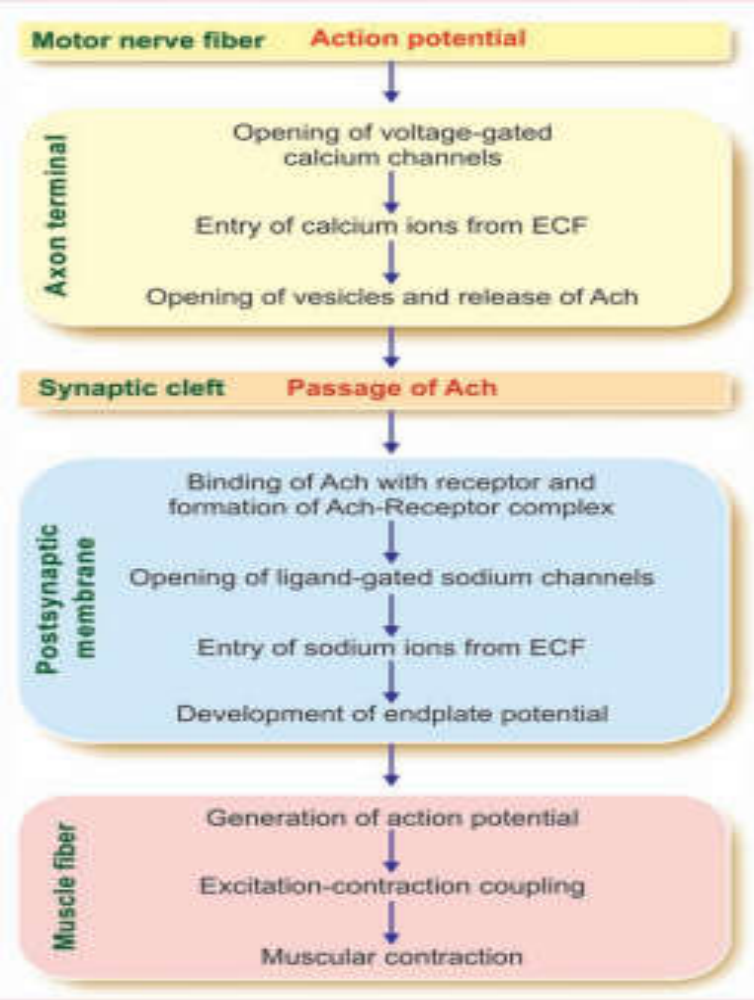
Muscle Property

- Excitability: Response to chemicals released from nerve cells
- Conductivity: Spread electrical signals over membrane
- Contractility: Shorten and generate force
- Extensibility: Stretch without damaging the tissue
- Elasticity: Return to original shape after being stretched

Neuromuscular junction is the junction between axon terminal of the motor nerve fiber and muscle fiber. the neuromuscular junction.



Neuromuscular Transmission

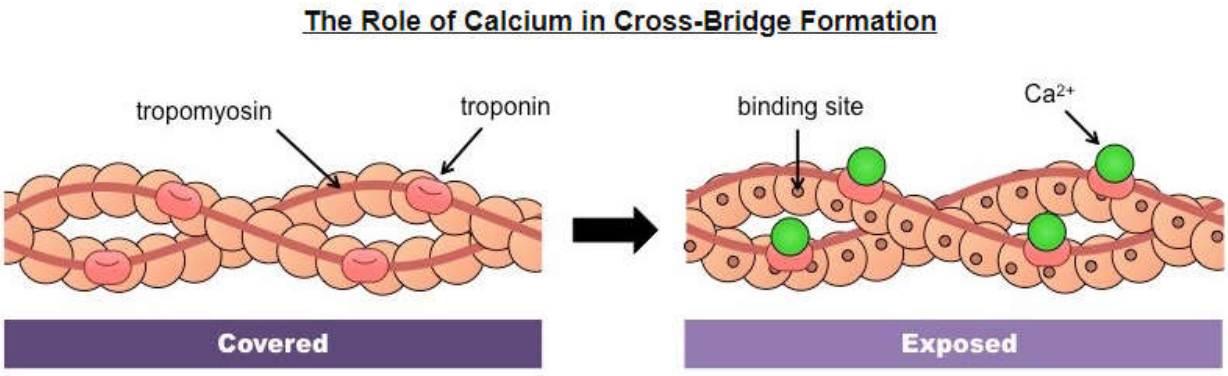


End plate potentials are the voltages which cause depolarization of skeletal muscle fibers caused by neurotransmitters binding to the postsynaptic membrane in the neuromuscular junction. They

are called "end plates" because the postsynaptic terminals of muscle fibers have a large, saucer-like appearance.

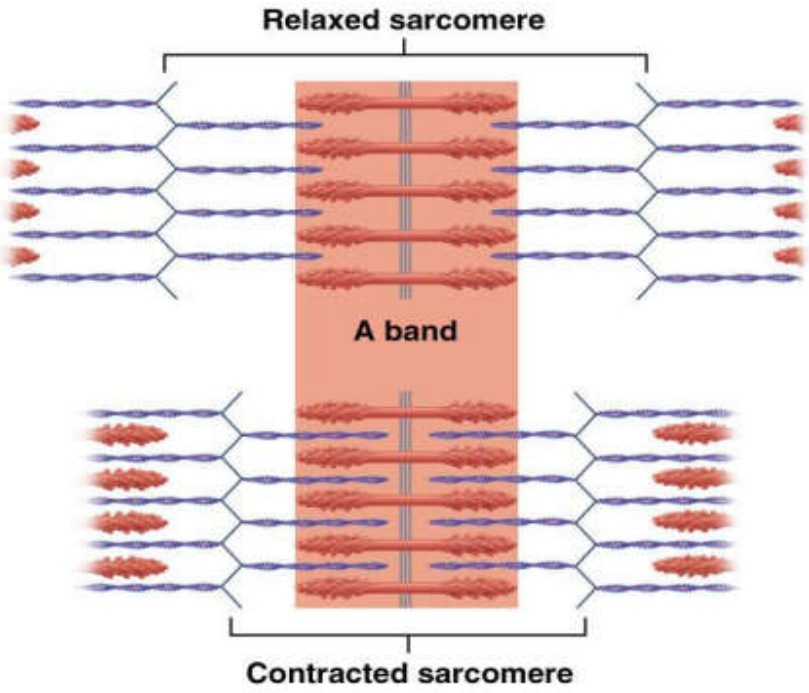
Muscle Cell Contraction:

1. nerve impulse arrives at neuromuscular junction
2. ACh is released and diffuses across synapse
3. binds to receptor on sarcolemma and initiates an impulse
4. impulse travels across sarcolemma via T tubules to the ER
5. impulse triggers release of Ca from SR.
6. Calcium binds to troponin.
7. ATP is hydrolyzed causes a shift in tropomyosin and actin binding site is exposed.
8. Actin-myosin cross bridge forms (actomyosin).
9. ATP bind to Myosin head causes rotates of the head and pulls thin filaments toward thick filaments.
10. The sliding of actin along myosin cause shortens the sarcomere, causing muscle contraction.



Muscle Cell Relaxation

1. When stimulus stops, Ca^{++} ions reenter SR.
2. interaction between actin and myosin is blocked (Actin-myosin cross bridge terminated).
3. Sarcomere returns to resting state muscle cell relaxes.



(b) The A band remains unchanged during a muscle contraction.

Sours of energy of muscle contraction

Muscles need energy to produce contraction. The energy is derived from **adenosine triphosphate** (ATP) present in muscles. Muscles tend to contain only limited quantities of ATP. When depleted, ATP needs to be resynthesized from other sources, namely **creatine phosphate** (CP) and **muscle glycogen**. Other supplies of glycogen are stored in the liver and the body is also able to resynthesize ATP from **lipids**, i.e. free fatty acids. Different modes of energy coverage are used depending on intensity and duration of the workload put on the organism

Note: exercise stimulates increase in myofibrils each muscle cell gets larger. Well exercised muscle cells also develop more mitochondria, more myoglobin and glycogen and a greater density of capillaries when muscle cells are not used, they shrink.

Types of Contraction

1.Isometric Contraction

Produces no movement used in:

-Standing

-Sitting

-Posture

2.Isotonic Contraction

Produces movement used in:

- Walking
- Moving any part of the body

Effects of multiple stimuli:

The multiple stimuli cause two types of effects depending upon the frequency of stimuli:

1. **Fatigue** is defined as the decrease in muscular activity due to repeated stimuli. (the muscle does not show any response to the stimulus).
2. **Tetanus** is defined as the sustained contraction of muscle due to repeated stimuli with high frequency.

Rigor mortis

a condition of the body after death, which is characterized by stiffness of muscles and joints. It occurs due to stoppage of aerobic respiration, which causes changes in the muscles.

Cause of rigor mortis

Soon after death, the cell membrane becomes highly permeable to calcium. So, a large number of calcium ions enters the muscle fibers and promotes the formation of actomyosin complex resulting in contraction of the muscles. Normally for relaxation, the muscle needs to drive out the calcium, which requires ATP. But during continuous muscular contraction and other cellular processes after death, the ATP molecules are completely exhausted. New ATP molecules cannot be produced because of lack of oxygen. So, in the absence of ATP, the muscles remain in contracted state until the onset of decomposition.