

Functions of the muscular system

1. **Locomotion**
2. **Vasoconstriction** and **vasodilatation**- constriction and dilation of blood vessel Walls are the results of smooth muscle contraction.
3. **Peristalsis** – wavelike motion along the digestive tract is produced by the Smooth muscle.
4. **Cardiac motion**
5. **Posture maintenance**- contraction of skeletal muscles maintains body posture and muscle tone.
6. **Heat generation** – about 75% of **ATP** energy used in muscle contraction is released as heat.

Muscle characteristics:

Striation: only present in skeletal and cardiac muscles. Absent in smooth muscle.

Nucleus: smooth and cardiac muscles are uninucleated (one nucleus per cell), skeletal muscle is multinucleated (several nuclei per cell).

Transverse tubule (T tubule): well developed in skeletal and cardiac muscles to transport calcium. Absent in smooth muscle.

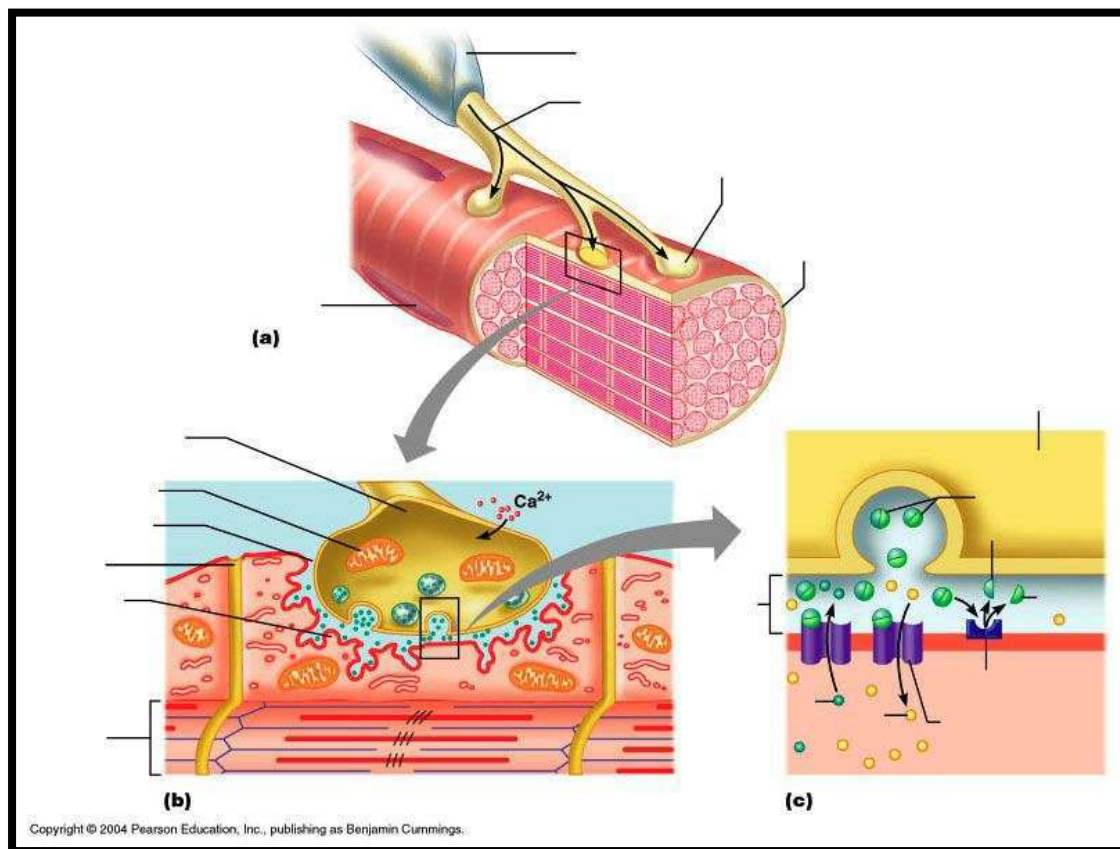
Intercalated disk: specialized intercellular junction that only occurs in cardiac muscle.

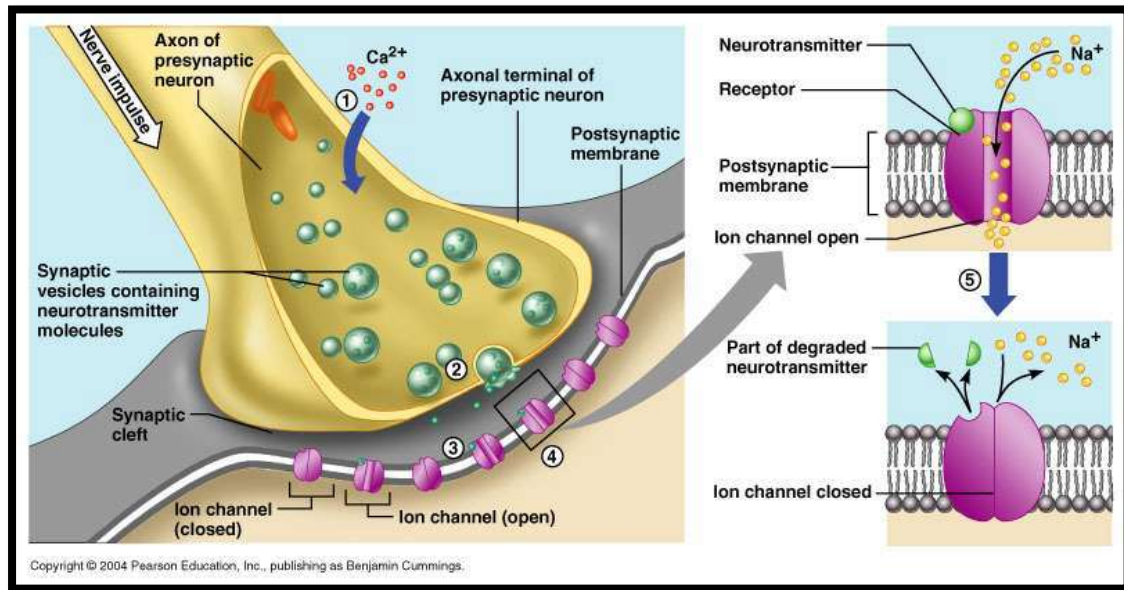
Control: skeletal muscle is always under voluntary control, with some exceptions (the tongue and pili arrector muscles in the dermis). smooth and cardiac muscles are under involuntary control.

Innervation: motor unit

- a) a **motor nerve** and a **myofibril** from a **neuromuscular junction** where gap (called **synapse**) occurs between the two structures. at the end of motor nerve, neurotransmitter (i.e. acetylcholine) is stored in **synaptic vesicles** which will release the neurotransmitter using exocytosis upon the stimulation of a nerve impulse. Across

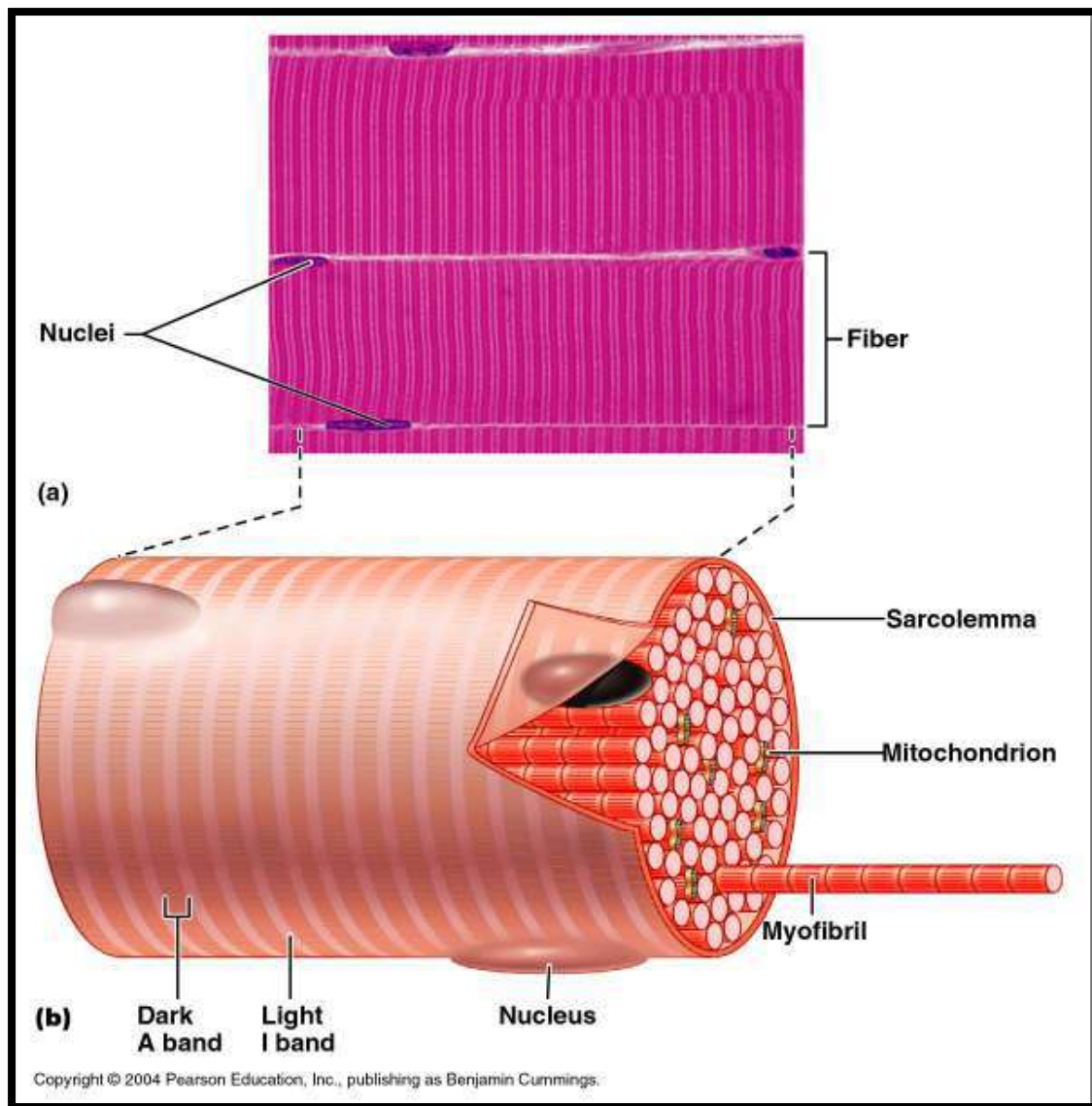
the synapse the surface the of myofibril contains **receptors** that can bind with the neurotransmitter

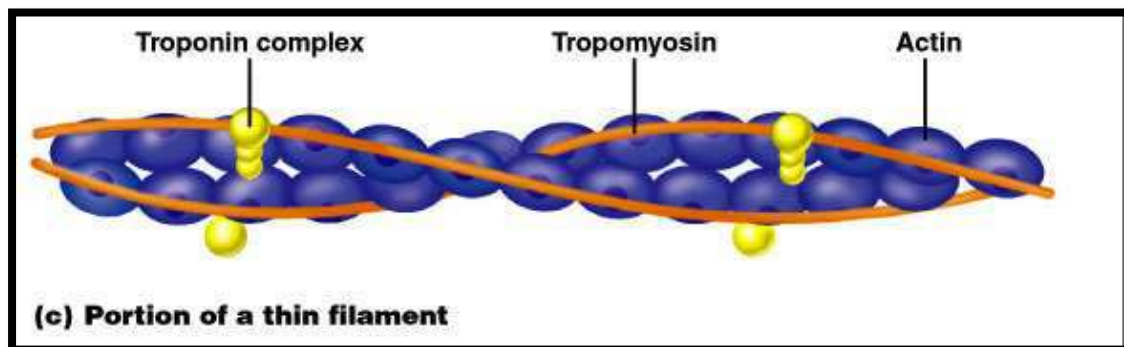
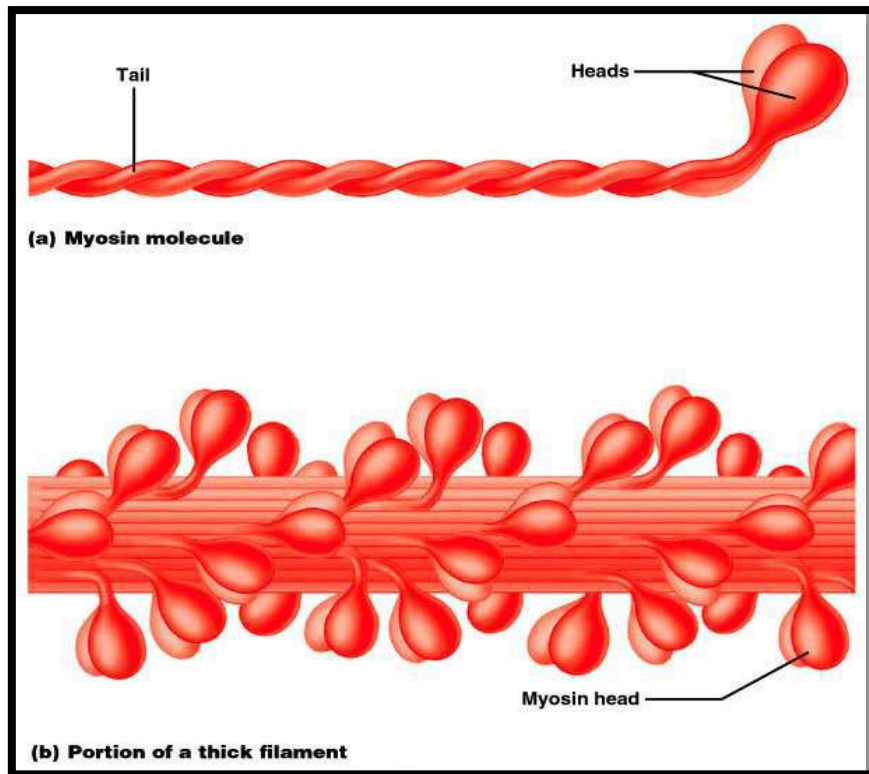




Skeletal muscle fiber

1. Each skeletal muscle fiber is a single muscle cell , which is the unit of contraction .
2. Muscle fibers are cylindrical cells with many nuclei .
3. The cell membrane is called . Sarcolemma, the cytoplasm is called sarcoplasm .
4. The sarcoplasm contains abundant , parallel thread like myofibrils , that run in parallel fashion .
5. The myofibrils contain 2 kinds of protein filaments .
 - a. Thick filaments –composed of myosin .
 - b. Thin filaments – composed of Actin , troponin and tropomyosin .
 - c. striations are produced by alternating light and dark filaments .





Striation pattern of skeletal muscles: 2 parts

1. The I bands (The light bands) - Extends from the edge of one stack of thick filaments to the edge of next stack of thick filaments .

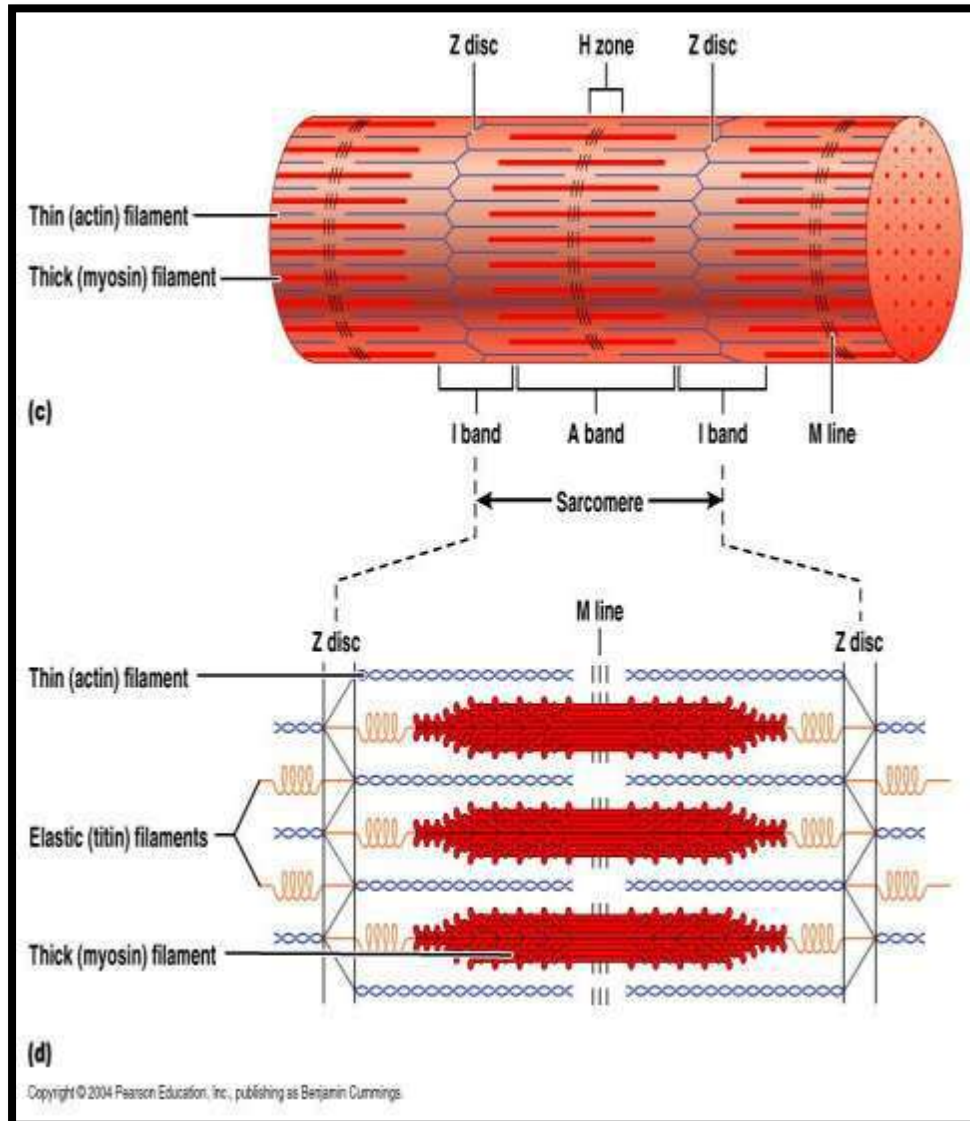
- The I band is composed of thin actin filaments .

2. The A bands (The dark bands) – composed of thick myosin filaments , overlapping thin filaments (actin) .

- myosin filaments are held together by Z lines (not attached) .

- A band consist of a region Where the thick and thin filaments overlap , and a region called central region (H zone) , consisting of only thick filaments . In the center of A band is a dark band called the M line .

Sarcomere : The segment of myofibrils that extends from one Z line to the next Z line.





Cross bridge Attachment:

The activated myosin heads are attracted to the exposed binding sites on actin and cross bridge attachment occurs .

Power stroke : The sliding action , which occurs at the same time for thousands of actin and myosin molecules is referred to as the power stroke.

Role of Ca⁺ in muscle contraction:

1. Promotes neurotransmitter release .
2. Triggers Ca⁺ release from SR .
3. Triggers sliding of my filaments and ATPase activity .
4. promotes glycogen breakdown & ATP synthesis .

Sliding Filament Theory

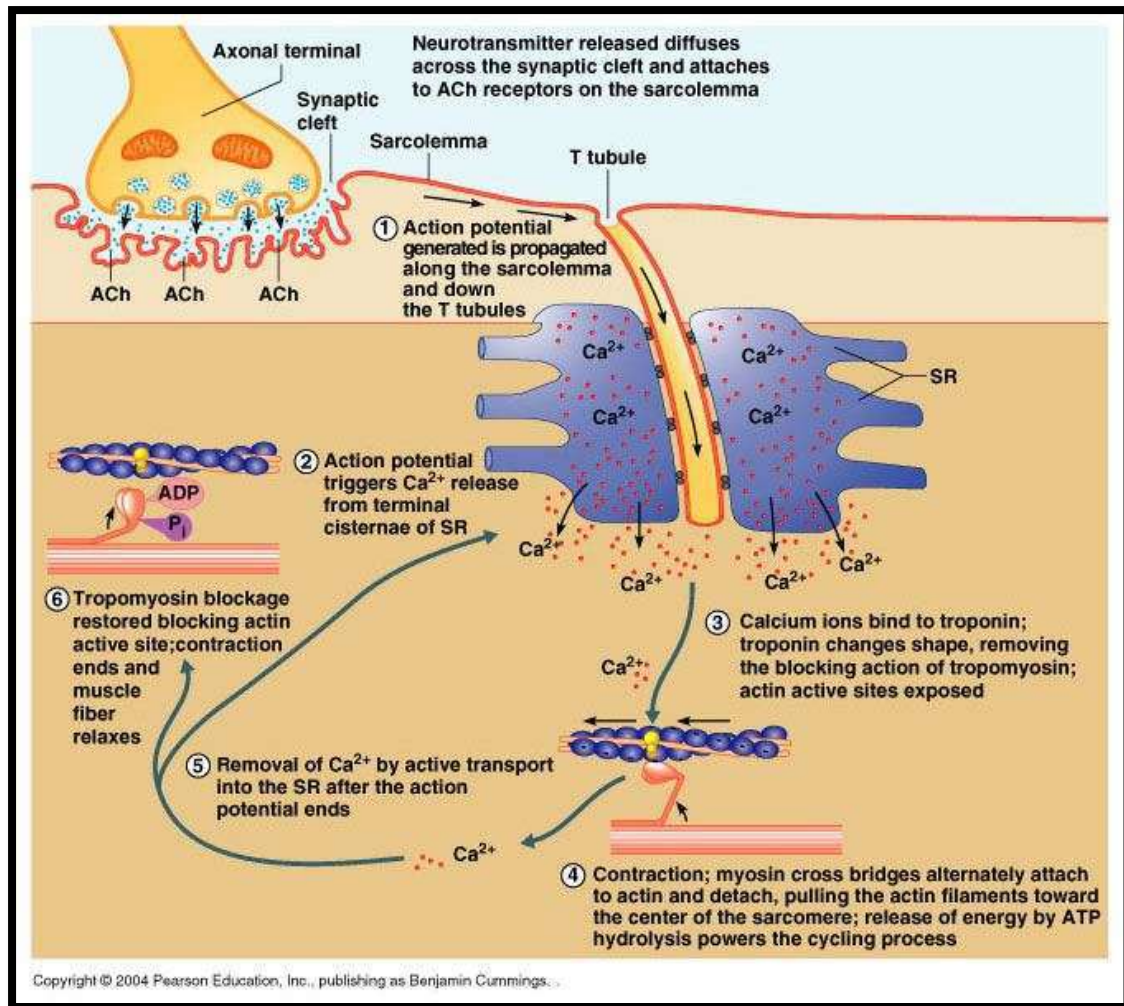
1. A myofiber , together with all of its myofibrils , shortens by movement of the insertion towards the origin of the muscle .
2. Shortening of the myofibrils is caused by shortening of the sarcomere (The distance between Z lines is reduced) .
3. shortening of the sarcomere is accomplished by each filament remains the same during contraction .
4. sliding is produced by power strokes of myosin cross bridges , which pull the thin actin over the thick myosin .
5. The A band remains the same length during contraction , but are pulled toward the origin of the muscle .
6. Adjacent A bands are pulled closer together as the I bands between them shorten .
7. The H band shorten during contraction as the thin filaments on the sides of the sarcomeres are pulled towards the middle.

Major Events of muscle contraction :

1. The distal end of a motor neuron releases Acetylcholine .
2. Acetylcholine diffuse across the gap at the neuromuscular junction .
3. The sarcolemma is stimulated , and a muscle impulse travels over the surface of the muscle fiber and deep into the fiber through the transverse tubules and reaches the sarcoplasmic reticulum .
4. Ca²⁺ ions diffuse from the sarcoplasmic reticulum into the sarcoplasm bind to troponin molecules .
5. Tropomyosin molecules move and expose specific sites on actin filament .
6. Actin and myosin filaments form linkages .
7. Actin filaments are pulled inward by myosin cross – bridges .
8. muscle fiber shortens as a contraction occurs .


Smooth Muscle Contraction

1. Smooth muscles contain filaments of actin and myosin .
2. Lack transverse tubules and S.R. is not well developed .
3. Display rhythmicity (spontaneous repeated contractions) , responsible for peristalsis (alternate contraction and relaxation) .
4. Lack troponin (protein that binds to Ca²⁺) , instead calmodulin binds to Ca²⁺ .
5. Both Acetylcholine & norepinephrine are neurotransmitters for smooth muscles .
6. Hormones and stretching affect smooth muscle contractions .
7. Can contract for a long period of time.



Cardiac muscle

- unique arrangement of actin and myosin filaments produces the cross-striations (an optical illusion the microscope), and rapid contraction with powerful forces involved.
- muscle cells are joined by **intercalated disks**, and allow muscle groups to form branching networks - both features are necessary for cardiac muscle to function as a unit ("sancytium").
- SR** and **T** tubules are well developed, so a large amount of calcium can be released rapidly through the T tubules.
- contains more mitochondria in each muscle cell than skeletal and smooth muscles, providing more ATP energy for continuous contraction.



e) self- exciting muscle fibers form "pacemakers" which initiate spontaneous nerve impulses for autorhythmic contraction . These pacemakers can be influenced by the autonomic nervous system and hormones.

Cardiac Muscle:

1. Contracts for a longer time than skeletal muscle

because transverse tubules supply extra Ca^{+2} ions .

2. intercalated disc connects the ends of adjacent muscles and hold cells together as a unit (syncytium) .

3. Fibers contracts as a unit .

4. Muscle fibers are self – exiting , rhythmic , and remain refractory until a contraction is completed.

5. No Tetanic contractions.