LIMB MUSCLES

Types of movement :

Cells of the human body exhibit three main types of movements, namely, amoeboid, ciliary and muscular. Some specialised cells in our body like macrophages and leucocytes in blood exhibit amoeboid movement. It is effected by pseudopodia formed by the streaming of protoplasm (as in Amoeba). Cytoskeletal elements like microfilaments are also inbvoled in amoeboid movement.

Ciliary movement occurs in most of our internal tubular organs which are lined by ciliated epithelium. The coordinated movements of cilia in the trachea help us in removing dust particles and some of the foreign substances inhaled along with the atmospheric air. Passage of ova through the female reproductive tract is also facilitated by the ciliary movement.

Movement of our limbs, jaws, tongue, etc, require muscular movement. The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms.

MUSCLES

- Study of muscles known as Myology.
- Myology also known as Sarcology.
- All muscles of body develop from mesoderm.
- They have special properties like excitability, contractility, extensibility and elasticity.
- About 40-50 percent of the body weight is contributed by muscles.

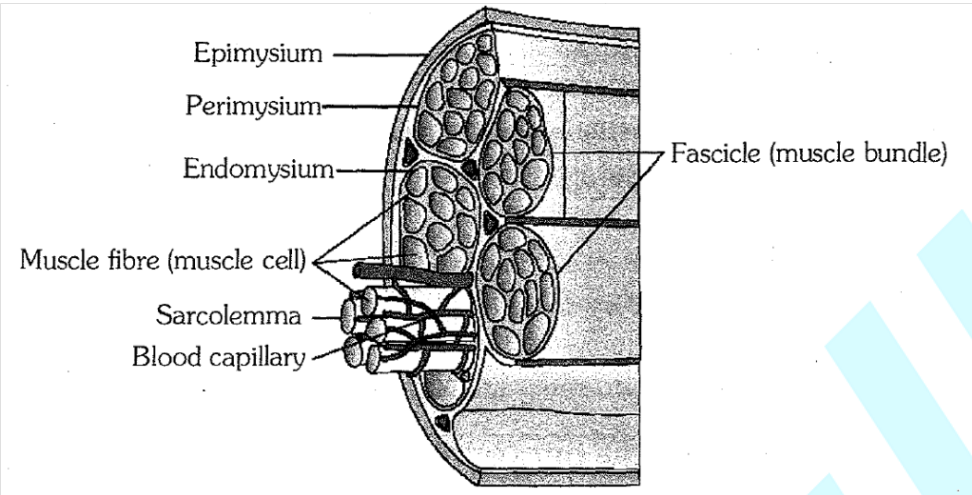
Three types of muscles are found in the body.
(i) Voluntary or skeletal muscles.
(ii) Involuntary or smooth muscles.
(iii) Cardiac muscles.

VOLUNTARY MUSCLES

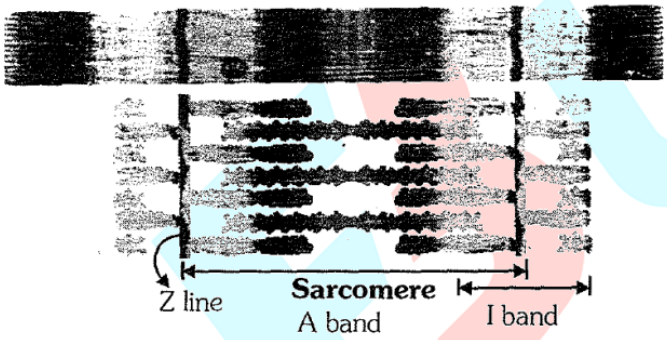
- They are related to the skeletal system. So also called as skeletal muscles.
- Transverse lines are found at regular interval. Hence these muscles are also called as striped or striated muscle.
- They are primarily involved in locomotory actions and changes of body postures.
- Their contractions are-controlled by will power of animal so also called voluntary muscles.

Muscle fibre is covered by a layer of connective tissue which is called endomysium.
Many muscle fibres are combined to form a group which is called fasciculi.
Each fasciculi is covered by a layer of connective tissue which is called perimysium.
Many fasciculi combined to form a muscle . .
Muscle is also covered by a layer of connective tissue which is called as epimysium.
The muscle fibres attached to a tough cord of connective tissue called tendon. Tend on is further attached with a bone.

STRUCTURE OF MUSCLE FIBRE



Diagrammatic cross sectional view of a muscle showing muscle bundles and muscle fibres



Digrammatic representation of anatomy of a muscle fibre showing a sarcomere

Fine structure of muscle fibre :-

- Skeletal muscle fibre is cylindrical or tubular in shape and is long and Unbranched.
- The outer membrane of muscle fibre is called sarcolemma.
- This cell membrane contain collagen fibres.
- Each muscle fibre contain multinucleated sarcoplasm.
- Nucleus & sarcoplasm are found in peripheral part.
- Myofibril are arranged in parallel rows & form the dark & light line.
  These lines are found in alternate order.
  These lines are made up of actin & myosin protein. Both proteins are filamentous proteins.
- Actin filaments are thin while myosin filaments are thick.
- Light line or band is made up of only actin filament, these band are mono-refractive in polarised light so it is called Isotropic band (I band).
- In the centre of each 'I' band is an elastic fibre called 'Z' line which bisects it. The thin filaments are firmly attached to the 'Z' line. The thick filaments in the 'A' band are also held together in the middle of this band by a thin fibrous membrane called 'M' line. The 'A' and 'I' bands are arranged alternately throughout the length of the myofibrils. The portion of the myofibril between two successive 'Z' lines is considered as the functional unit of contraction and is called a Sarcomere. In a resting state. the edges of thin filaments on either side of the thick filaments partially overlap the free ends of the thick filaments leaving the central part of the thick

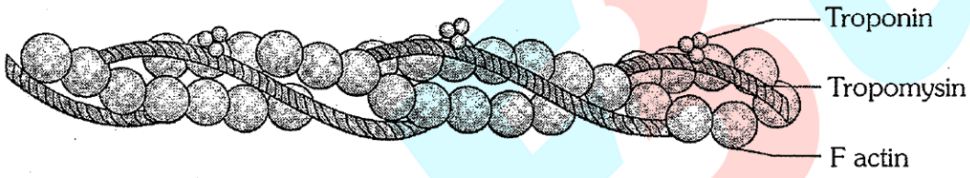
filaments. This central part of thick filament. not overlapped by thin filaments is called the •H' zone.

- ♦ Sarcomere is considered as the functional unit of contraction.
  Sarcomere = 1A band + two half I band
  The Length of Sarocmere is 2.5 μm.
  (I band = 1μm, myosin = 1.5 μm)
- ♦ 1 Myosin filament is surrounded by 6 Actin filaments & 1 Actin filament is surrounded by 3 Myosin filaments .
- ♦ Z-disc is made up of actinin protein.

STRUCTURE OF CONTRACTILE PROTEIN

1. Actin (Thin) filament

Each acitn (thin) filament is made up of two 'F' (filamentours) actins helically wound to each other. Each 'F' actin is a polymer of monomeric 'G' (Globular) actins.
Two filaments of another protein, tropomyosin also run close to the 'F' actins throughout its length.
A complex protein Troponin is distributed at regular intervals on the tropomyosin.
In the resting state a subunit of troponin masks the active binding sites for myosin on the actin filaments.

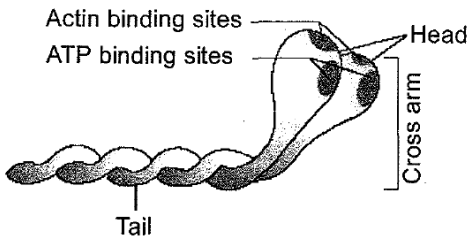


An actin filament

Troponin is made up of three submit.
(1) Troponin I (Inhibitory site)
(b) Troponin T (Tropomyosin site)
(c) Troponin C (Ca^{+2} binding site)

2. Myosin (Thick) Filament

Each myosin (thick) filament is also a polymerised protein. Many monomeric proteins called Meromyosins constitute one thick filament.
Each meromyosin has two important parts, a globular head with a short arm and a tail the former being called the heavy meromyosin (HMM) and the latter, the light meromyosin (LMM).
The HMM component i.e.; the head and short arm projects outwards at regular filament and is known as cross arm.
The globular head is an active ATPase enzyme and has binding sites for ATP and active sites for actin.



Myosin monomer (Meromyosin)

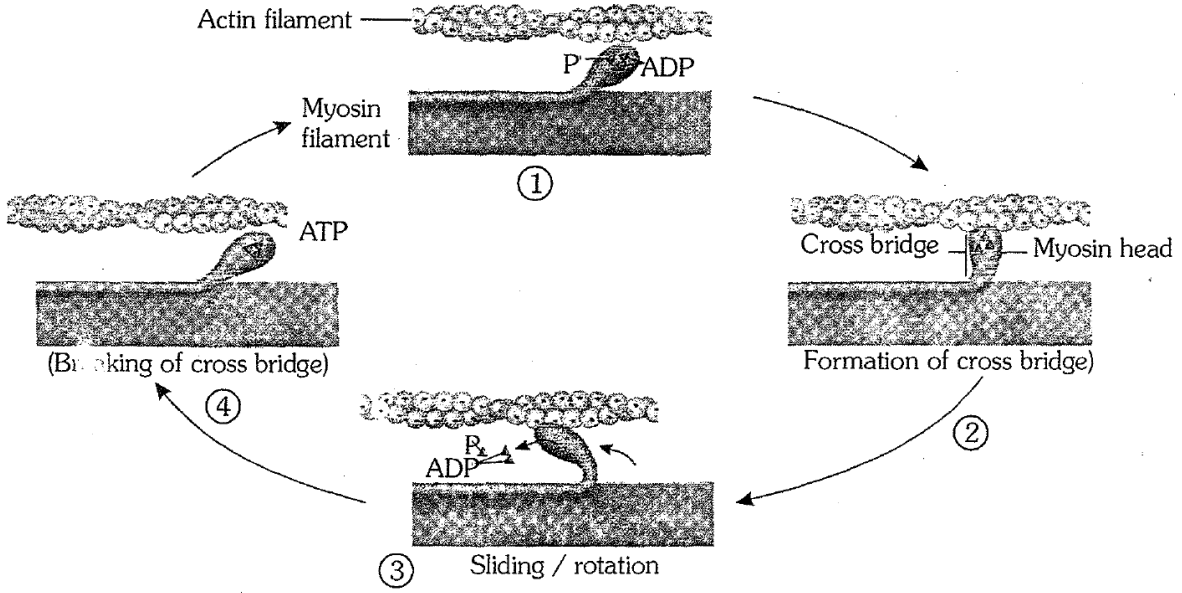
MECHANISM OF MUSCLE CONTRACTION

- Mechanism of muscle contraction is best explained by the sliding filament theory which states that contraction of a muscle fibre takes place by the sliding of the thin filaments over the thick filaments.
- Muscle contraction is initiated by a signal sent by the central nervous system (CNS) via a motor neuron. A motor neuron along with the muscle fibres connected to it constitute a motor unit. The junction between a motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor-end plate. A neural signal reaching this junction releases a neurotransmitter (Acetylcholine) which generates an action potential in the sarcolemma.
- This spreads through the muscle fibre and causes the release of calcium ions into the sarcoplasm.
- Increase in Ca^{++} level leads to the binding of calcium with a subunit of troponin on actin filaments and thereby remove the masking of active sites for myosin.
- Utilising the energy from ATP hydrolysis, the myosin head now binds to the exposed active sites on actin to form a cross bridge.
- This pulls the attached actin filaments towards the centre of 'A' band. The 'Z' line attached to these actins are also pulled inwards thereby causing a shortening of the sarcomere i.e. contraction.
- During shortening of the muscle (contraction}, the 'I' bands get reduced, whereas the 'A' bands retain the length.
- The myosin, releasing the ADP and P_1 goes back to its relaxed state. A new ATP binds and the cross-bridge is broken.
- The ATP is again hydrolysed by the myosin head and the cycle of cross bridge formation and breakage is repeated causing further sliding.
- The process continues till the Ca^{++} ions are pumped back to the sarcoplasmic cisternae resulting in the masking of actin filaments.
- This causes the return of 'Z' lines back to their original position, i.e., relaxation.
- Repeated activation of the muscles can lead to the accumulation of lactic acid due to anaerobic breakdown of glycogen in them, causing fatigue.

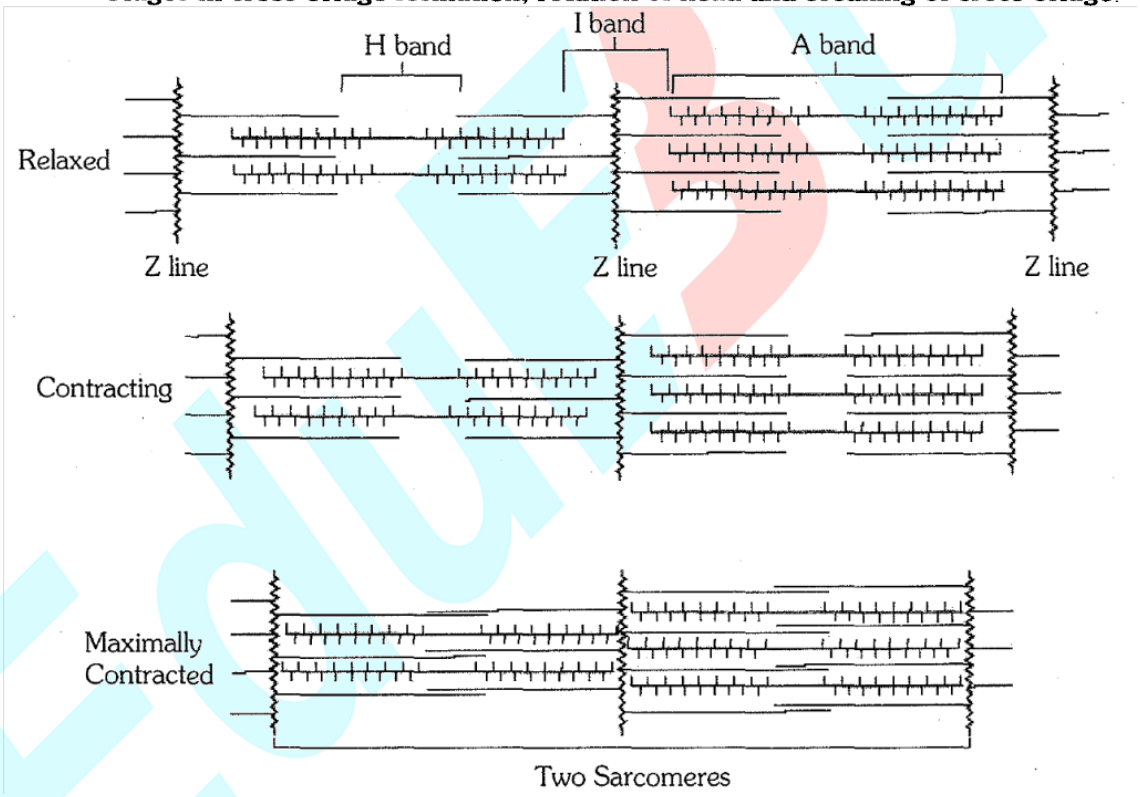
Role of ATP:

(i) The 'back & forth' movement of myosin head with in the groove.

(ii) Deatatachment of myosin head from the actin.



Stages in cross bridge formation, rotation of head and breaking of cross bridge



DEFFERENCE BETWEEN RED MUSCLE AND WHITE MUSCLE

Red (slow) muscle	White (fast) muscle
1. Myoglobin content is high. So, it is red	1. Myoglobin content is less So, it is pale
2. Sarcoplasmic reticulum is less extensive	2. Sarcoplasmic reticulum is more extensive
3. Blood vessels are more extensive	3. Blood vessels are less extensive
4. Mitochondria are more in number	4. Mitochondria are less in number
5. Response is slow with long latent period	5. Response is rapid with short latent period
6. Contraction is less powerful	6. Contraction is more powerful

7. This muscle is involved in prolonged and continued activity as it undergoes sustained contraction	7. This muscle is not involved in prolonged and continued activity as it relaxes immediately.
8. Fatigue occurs slowly	8. Fatigue occur quickly
9. Depends on cellular respiration for ATP production so also called aerobic	9. Depends on anaerobic process for energy.

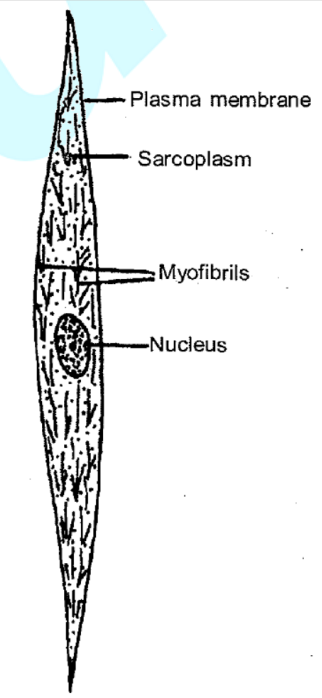
Marathian athelets develops red fibre in thigh muscle due to repeated contraction.

INVOLUNTARY MUSCLE

- It is not related to the skeleton so also called as Non skeletal muscle.
- These muscle are found in the visceral organ so are called as visceral muscles or smooth muscles.
- Transverse lines are absent so also called as unstriated muscle.
- Its contraction is not controlled by will power of animal, so it is called as Involuntary muscle.
- Autonomic nerves are connected to this type of muscle.

STRUCTURE OF SMOOTH MUSCLE FIBRE

- It is short, spindle shaped, unbranched.
- Cells are connected through gap junction.
- It contains uninucleated cytoplasm
- All cell organelles are found in cytoplasm.
- Contractile fibrils are found in the cytoplasm due to this reason this cytoplasm called sarcoplasm.
- This contractile fibre called as myofibril which found in scattered form.
- Myofibril are made up of actin & myosin but remarkably less than skeletal muscle But filaments are not placed in a highly ordered pattern so striation is absent.
- Actin is more than myosin.
- Myofibril is functional unit of involuntary muscle.
- The sarcoplasmic reticulum or L tubular system is not well developed. This makes the contraction of smooth muscles strongly dependent on the ECF Ca^{++} ions.
- Its contraction period is longer.
- It remain in contracted stage for longer period. Due to this reason muscle called non fatigue muscle

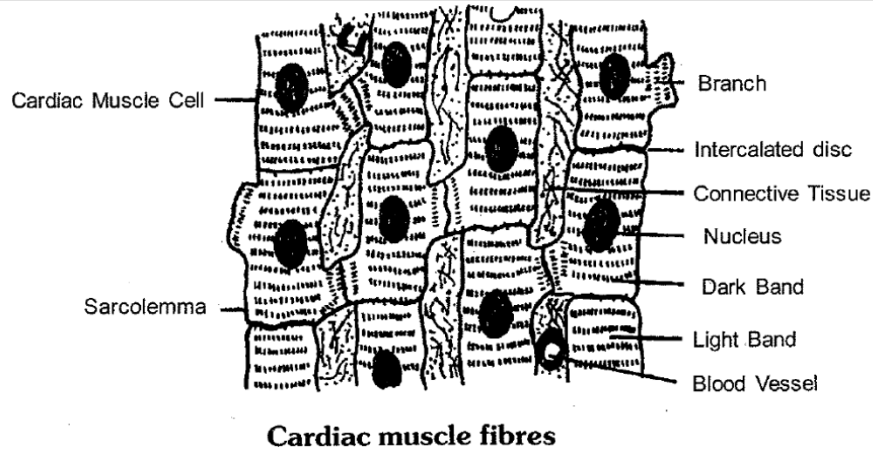


Smooth muscle fibre

CARDIAC MUSCLE

- It is special type of muscle which found only in heart so it is also called as cardiac muscle. On the basis of structure it is striated type of muslce. Intercalated disc, helps in the propagation of impulse & contraction.
- Their muscle fibres are long, cylindrical and branched.
- Many transverse septa are found in the muscle fibre which are called as intercalated disc.
- Due to septa fibres are divided into many segments each segment is uninucleated. Each segment called individuals cells.
- Dark & light line also found in the Muscle fibre. It is also non fatigue type muscle.
- Its contraction is not controlled by will power of animal.

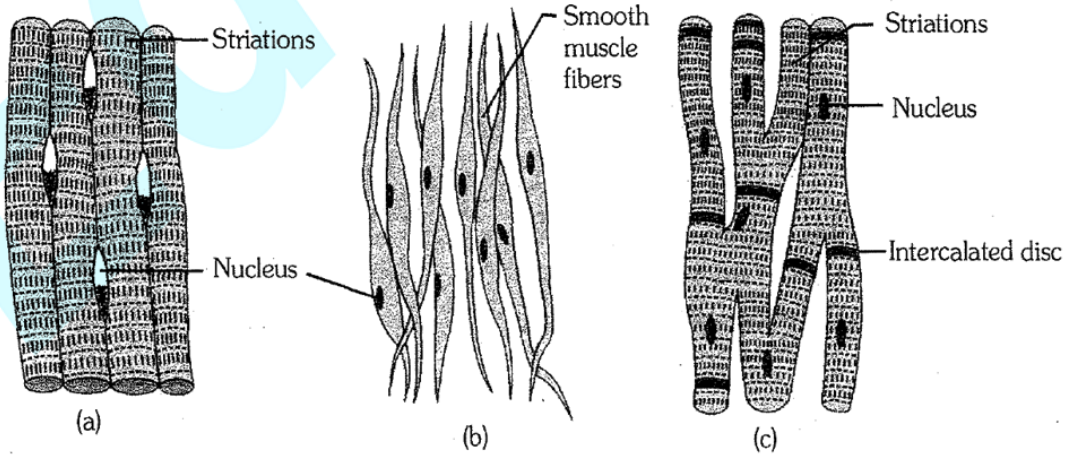
♦ On the basis of function it is smooth muscle type.



Cardiac muscle fibres

DIFFERENCE BETWEEN STRAITED, NON-STRIATED AND CARDIAC MUSCLE

Striated	Non striated	Cardiac
1. They are present in upper limb & lower limb etc.	Iris of eye (Ciliary muscle of eye Urinary bladder, Urinogenital tract, dermis of skin-erector pill muscle of dermis	They are present in walls of Heart
2. Cylindrical	Spindle in shaped	Cylindrical
3. Fibres Unbranched	Unbranched	Fibres are branched
4. Multi Nucleated fibres	Uninucleated	Uninucleated
5. Light and Dark band present	Absent	Present
6. Oblique bridges & Intercalated disc absent	Absent	Present
7. Controlled by CNS.	ANS	Both CNS + ANS
8. Blood supply abundant	Less	Richly Blood supply
9. Soon fatigue	Do not get fatigue	Never fatigued



Muscle tissue : (a) Skeletal (striated) muscle tissue
(b) Smooth muscle tissue, (c) Cardiac muscle tissue

PROPERTIES OFMUSCLES

1. Origin - Origin- fixed end of muscle (Proximal end).
Insertion- Distal end of muscle which is attach to bone (Movable end).

2. Excitability - Muscles r-esponds to stimuli which can be nervous, chemical, electrical & thermal & mechanical.
Conductivity - Stimulus acting in one region of muscle fibres propagated to all parts within no time.
Contractility- on being stimulated the muscle fibres contract& shorten followed by relaxation.

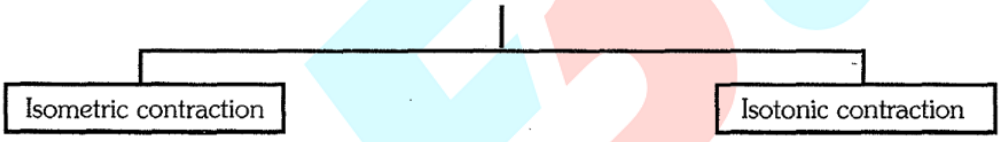
3. Threshold Stimulus-
Intensity of stimulus below the threshold value which does not produces contraction in muscle fibres is called sub threshold stimulus.
Stimulus stronger than threshold one is called supra threshold stimulus.

4. **All or none law :-**
Response of muscle fibre is maximum whether the stimulus has threshold value or supra threshold value.
Response is absent when intensity is sub threshold (Below threshold value).

5. Paralysis- Supply of motor nerve impulse completely cut off. So function of muscle contraction is stopped.

6. Shivering - Involuntary contraction of muscles to make body warm.

7. Muscle tension- force produced during contraction of muscle is known as muscle tension.



Length same but tone changed

(Work done is zero)

Eg. Pushing against an immovable object.

Lenght changed but tone same

Eg. Walking, Load is lifted.

8. Speed of- Skeletal muscle = 0.1 sec. per contraction per cycle
Cardiac muscle= 0.8 sec. per contraction per cycle
Smooth muscle = 46 sec. per contraction per cycle

9. Rigor Mortis -
After death fresh supply of ATP become impossible so once the local store of ATP molecule are exhausted. Due to non availability of ATP/C.P. detachment of myosin from actin cannot take place resulting in permanent state of contraction of muscle. This phenomenon is called rigor mortis. This condition helps fixation of the hour of death.

10. E.D.T.A. (Ethylene Diamine tetra acetic acid) injected inside muscle combined with Ca^{+} and stops contraction.

11. Muscle and nerve exit ability is reduced by K^{+}.

12. During muscle contration chemical energy changed into mechanical energy.

13. Over stretching of ligament is called sprain.

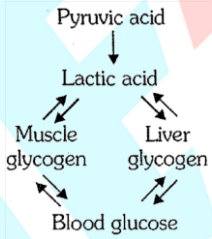
14. Phosphogens: These are highly energy N-based compounds which are found in the muscles. In the invertebrates arginine phosphate and in the vertebrate creatine phosphate act as a phosphogens. These compounds provide energy during contraction.

Creatine phosphate + ADP $\overset{\text{muscle contraction}}{\underset{\text{at rest stage}}{\rightleftharpoons}}$ Creatine + ATP

15. In the muscles, 75% water, 20% protein and in remaining part glycogen, creatine phosphate, inorganic ions (K^+, Na^+, HCO_3^-) are present.

GOLDEN KEY POINTS

1. Muscles make up 40-50% of your total body weight.
2. Smallest muscles is founded in the middle ear.
3. Humans are born with all the muscle fibres they will ever have.
4. When your feeling cold, your voluntary muscles contract involuntarily.
5. Gastrocenemius muscle present in shank.
6. Sartorius Longest muscle of body.
7. Gluteus maximums (Buttock muscles)- Largest muscle of body.
8. Stapedius- Smallest muscle of body.
9. Jaw muscles (massater) - are strongest muscle.
10. In Human beings 639 muscle are found. 400 muscles are striated & most of the muscles are found in back region & number of back muscles are 180. Longest smooth muscle is present in uterus of pregnant lady.
11. Antagonistic muscles - They are pair of muscles which causes opposite movement at the same site when one muscle is contracting, the other is relaxes & viceversa
eg - Biceps (flexor) & Triceps of arms (extensor)
12. Cori cycles- Lactic acid accumulated in muscles during sustained contraction. formed lactic acid transported in blood as blood lactate to liver where it changes into liver glycogen which is changed in to glucose.



Cori cycle