

MUSCULATURE OF LIMBS

Study of muscles known as Myology.

Myology also known as Sarcoloby.

Development of muscle:-

Accept Iris & ciliary body all muscles of body develop from mesoderm.

- Muscle of Iris, ciliary body & myoepithelial cell of sweat gland develop from Ectoderm.

Conductivity & contractility are the two main characteristics of muscle.

Three types of muscles are found in the body.

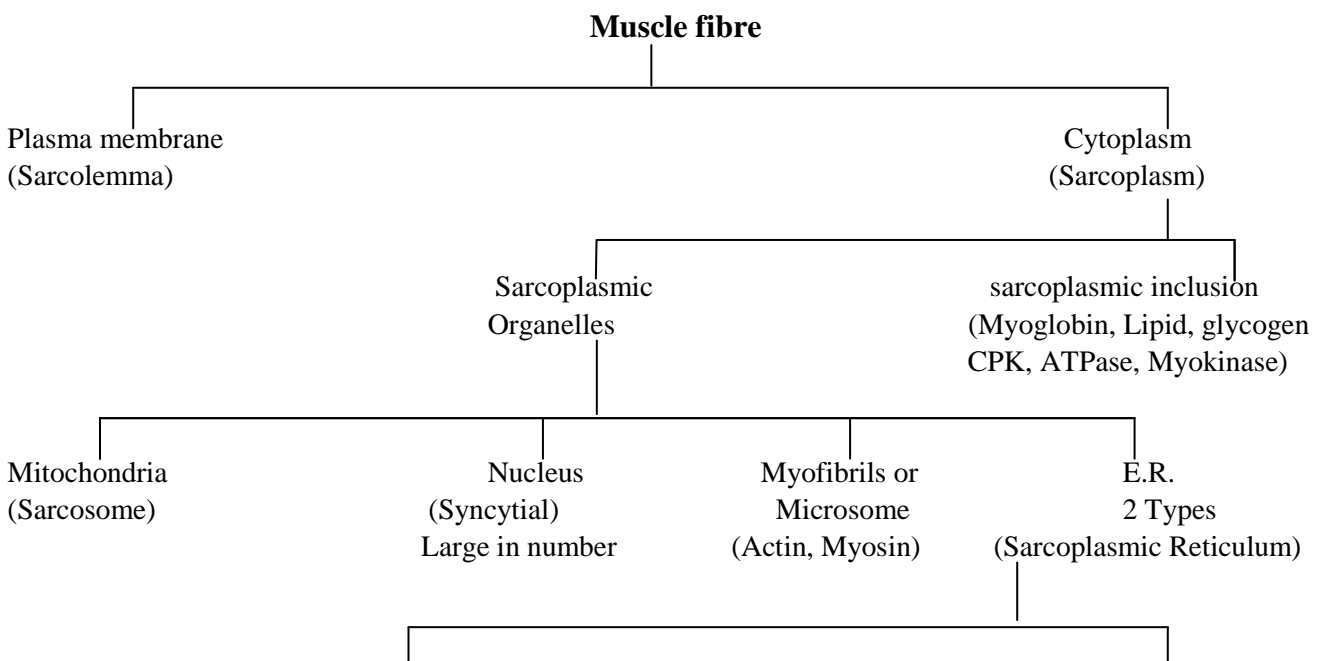
- Voluntary or skeletal muscles.
- Involuntary or smooth muscles.
- Cardiac muscles.

Voluntary Muscle-

It develops from the epimeric layer of myotome

Skeletal muscles constitutes around 40% of adult body mass in an average healthy person.

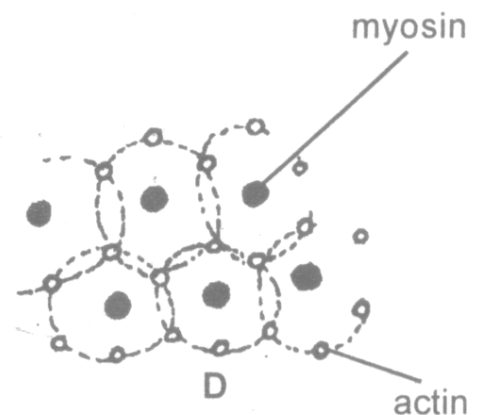
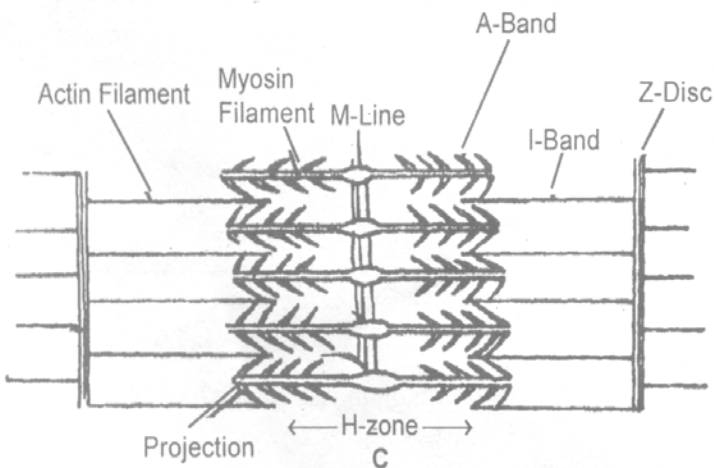
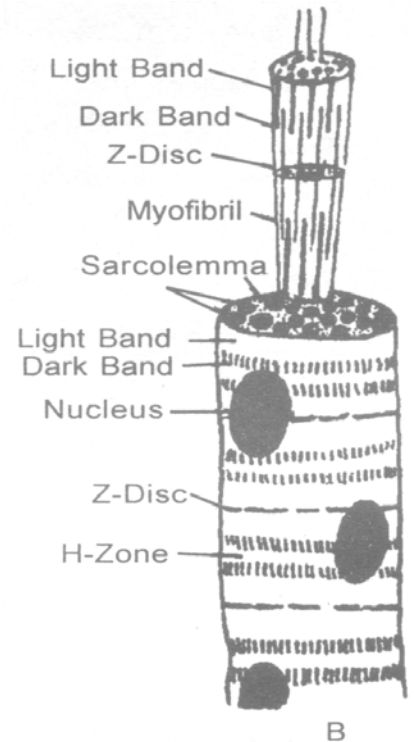
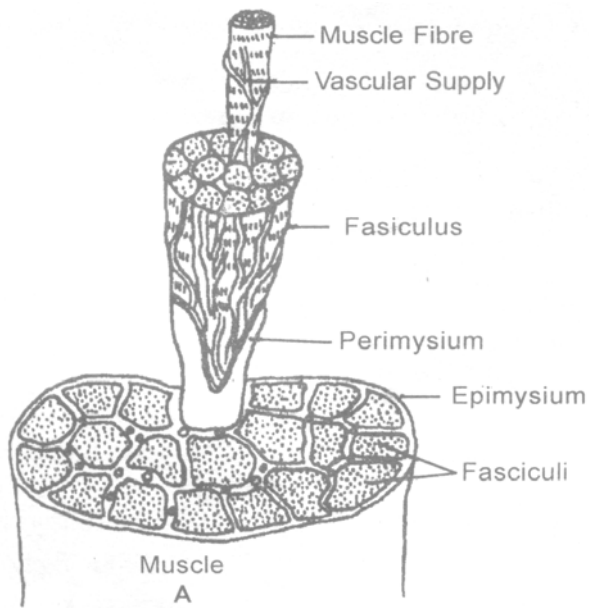
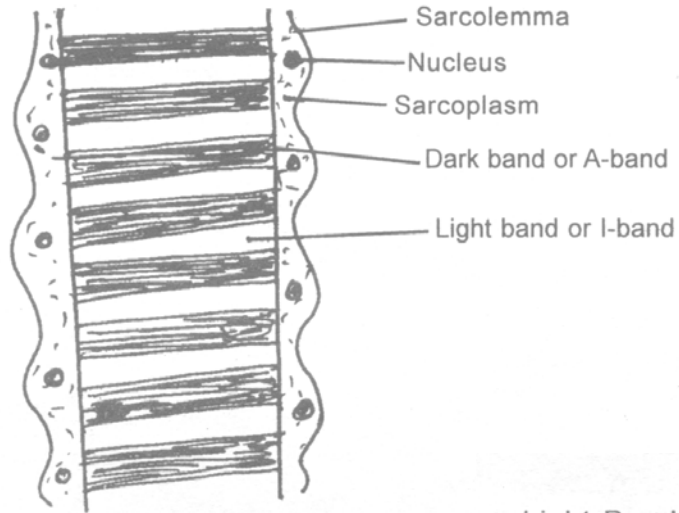
- They are related to the skeletal system. So also called as skeletal muscles.
- Transverse lines are found at regular interval. Hence these muscles are also called as striped or striated muscle
- Their contractions are controlled by will power of animal so also called voluntary muscles.



T. tubules
(lying Transverse to Myofibril)

L- Tubules
(lying parallel or longitudinal to myofibrils)

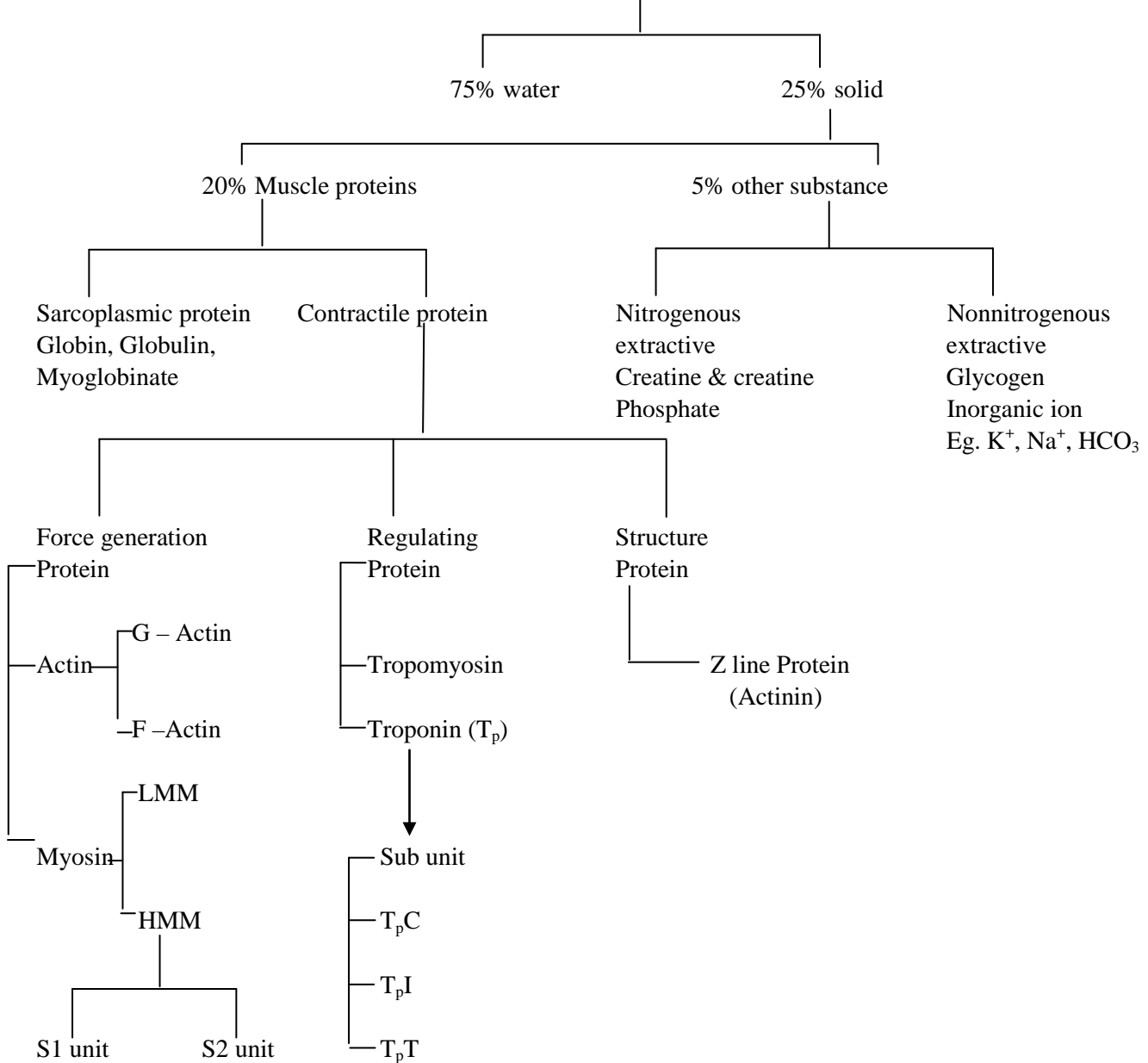
STRUCTURE OF MUSCLE FIBRE



Fine structure of muscle fibre

- ☛ The outer membrane of muscle fibre is called sarcolemma.
 - ☛ This cell membrane contains collagen fibre.
 - ☛ Each muscle fibre contains multinucleated sarcoplasm.
 - ☛ Nucleus & sarcoplasm are found in peripheral part.
 - ☛ Myofibrils are arranged in parallel rows & form the dark & light lines.
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 bands are monorefractive in polarized light so it is called Isotropic band (I band).
 - ☛ Actin filaments are connected with a disc of Z – line protein (Actinin) which is called as Z line (Zweichenschiebe) or (Doble's membrane) or (Krause's membrane).
 - ☛ Dark line is made up of actin & myosin filament so it is double monorefractive in polarised light due to overlapping so it is called Anisotropic band.
 - ☛ The terminal end of actin filament is embedded among the myosin filament so peripheral part of A band is darker as compared to the middle part of a band which is called as H-Zone or Hensen zone.
 - ☛ A dark line is also found in the central part of H-zone which is called as M line or mesogramme line.
The distance between two Z-lines is called as Sarcomere.
It is structural unit or functional unit of voluntary muscle fibre.
Sarcomere = 1A band + two half I band
The length of Sarcomere is 2.5 μ m.
- (I band = 1 μ m, myosin = 1.5 μ m)
- ☛ 1 Myosin filament is surrounded by 6 Actin filaments & 1 Actin filament is surrounded by 3 Myosin filaments.
Number of molecules per myosin filament is 294 and actin filament is 342.
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.
Muscle fibre is a cylindrical or Tubular shape.
The muscle fibres attached to a tough cord of connective tissue called Tendon & Tendon is further attached with a bone.

CHEMICAL COMPOSITION OF SKELETAL MUSCLES



FORCE GENERATION PROTEIN:

Actin -

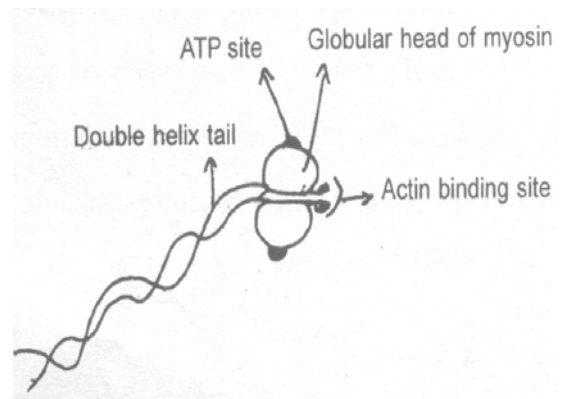
The Actin or thin filament is a double helix made up of protein molecule called as. G-Actin. (Globular actin) Many G-actin combined to form a filament like structure, which is called as filamentous-actin. G-actin contain a active site where myosin head is attached.

Myosin -

Each myosin molecule consist of a tail & a head. Tail is made up two chains intertwined with each other like double helix.

The myosin filament (ii) ATP molecules.

Each myosin (thick) filament is also a polymerized 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 ATP ase enzyme and has binding sites for ATP and active sites for actin.



REGULATING PROTEIN:

Tropomyosin -

It is one type of contractile protein. In the relaxed state of the muscle situated in such a way, that the active sites remain covered by the Tropomyosin & attached at the terminal end of actin.

Troponin-

It is one type of protein which attached with one of ends of the tropomyosin molecules. Troponin is made up of three subunit.

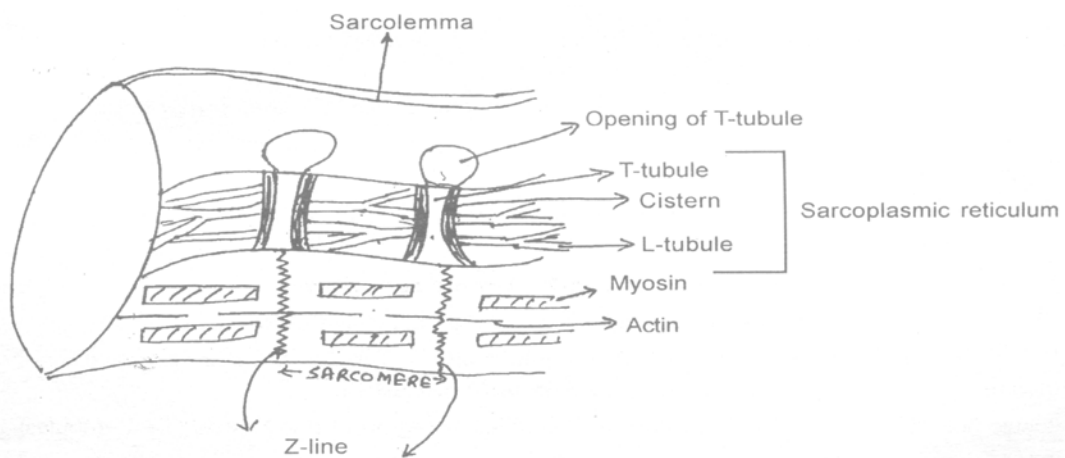
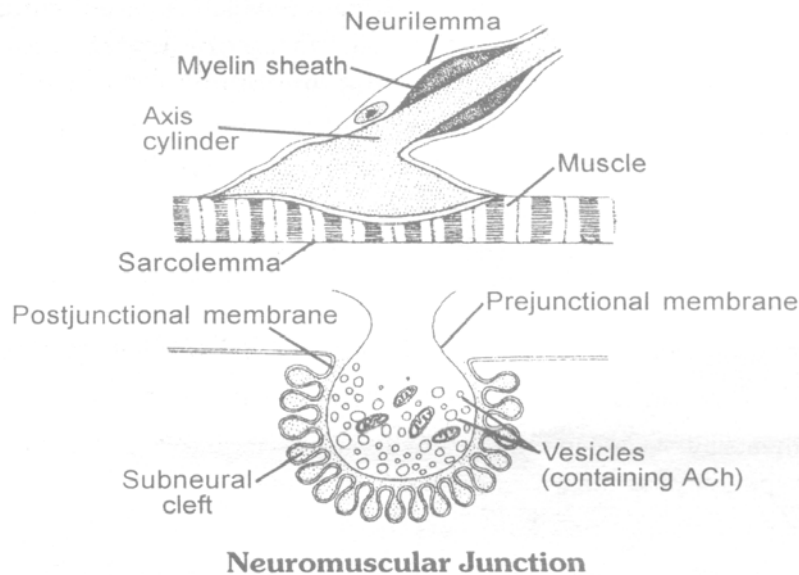
- (a) Troponin I (Inhibitory site)
- (b) Troponin T (Tropomyosin site)
- (c) Troponin c (Ca⁺² binding site)

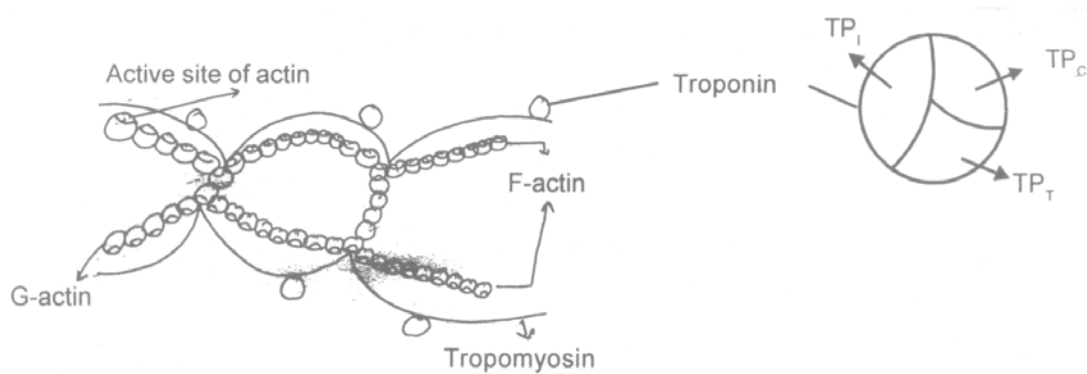
STRUCTURAL PROTIN:

Actinin-

It is one type of protein which found in Z- line.

PHYSIOLOGY OF MUSCLE CONTRACTION





SLIDING FILAMENT THEORY:

This theory is given by A.F. HUXLEY, H.E. HUXLEY & J. HANSEN

The junction of Nerve & muscle is called as neuromuscular junction.

Terminal branches of Axon of motor nerve is embedded into sarcolemma.

Its bulb like structure is called as motor end plate.

Sarcolemma invaginate inside & form a fimbriated structure which is called synaptic gutter or subneural cleft. The cell membrane of the bulbous terminal is called as the pre junctional membrane whereas the cell membrane of muscle fibre with invaginates called post junctional membrane.

In motor end plate large number of vesicles & mitochondria are present. Each vesicle contains Ach in high concentration. In post junctional membrane, Ach receptor are presented.

(Ach = Acetylcholine, it is a neurotransmitter chemical)

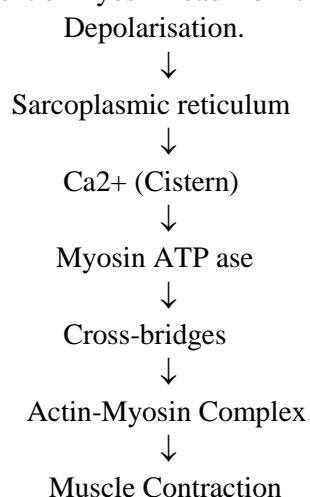
Neuromuscular Transmission-

- ☛ When motor nerve fibre stimulated it develops an Action potential (Resting potential 50 to 100 mV)
- ☛ AP reaches in the neuromuscular junction & goes to bulbous expansion of the nerve terminal.
- ☛ Then it increases permeability of Ca^{++} in the pre junctional membrane & Ca^{++} enter from E.C.F. in to the cytosol of motor end plate by penetrating the prejunctional membrane.
- ☛ Ca^{++} ions causes bursting of the vesicles & releases the Ach.
- ☛ These Ach now cross the prejunctional membrane. Via subneural cleft reach the post junctional membrane & attach the Ach receptor also called as End plate receptor.
- ☛ End plate receptor stimulate & develop end plate potential by opening of Na^+K^+ channels in post synaptic membrane.
- ☛ When end plate potential sufficiently higher than A.P. develop on sarcolemma & this ATP propagates over muscle fibre & initiate the muscle contraction.
- ☛ A dense network of sarcoplasmic reticulum is found between sarcolemma & myofibril.
- ☛ Sarcolemma invaginates inside & form transverse & longitudinal tubules which are also called as T-tubule and L-tubule
- ☛ T-Tubules are parallel to Z-line whereas L-tubule is perpendicular to the Z-line.
- ☛ T-Tubules communicates with ECF.
- ☛ T & L system of tubules together called as endoplasmic reticulum.
- ☛ L-Tubules dilated on both side of T-Tubules this dilated part called cisterns.
- ☛ A.P. proceeds along the sarcolemma & A.P. contact with T-Tubules & further proceeds via T-tubules & enter with in muscle fibre & now this. AP called as T-tubule potential.
- ☛ T-tubule potential come in close contact of l-tubules at region of the Triads (T+L- tubules).
- ☛ L-tubules is very rich source & store house of Ca^{++} ion in higher concentration than release of Ca^{++} ion in large amount.

- ☛ Released Ca^{++} ion combine with troponin C.
 - ☛ In Relaxed state tropomyosin covers the active site of actin.
 - ☛ But troponin-C combines with Ca^{++} ion some physiochemical changes occur in tropomyosin & Tropomyosin move away of active site of actin.
 - ☛ Myosin have a strong tendency to bind the actin molecule & form Actomyosin complex
 - ☛ Myosin head attach on active site of actin with the help of cross bridges.
 - ☛ Now the myosin head twists in the groove of the active site of actin –F. This causes movement of actin towards H zone.
 - ☛ Contraction is caused by overlapping of actin filament over myosin filament – Sliding filament hypothesis
 - ☛ All the cross bridges move simultaneously in one direction so the actin filaments move vigorously towards H- zone.
 - ☛ When cross bridge disrupted than myosin molecule detached & reattach the new active site of actin.
 - ☛ **After muscle contraction H-zone disappears & length of sarcomere & I-band decreases by 20%. The length of A band remains unchanged.**
- All process are reversible, at the time of relaxation Ca^{++} are goes into L-tubules.

Role of ATP -

- (i) The Rotational movement of myosin head with in the groove.
- (ii) Deattachment of myosin head from the actin.



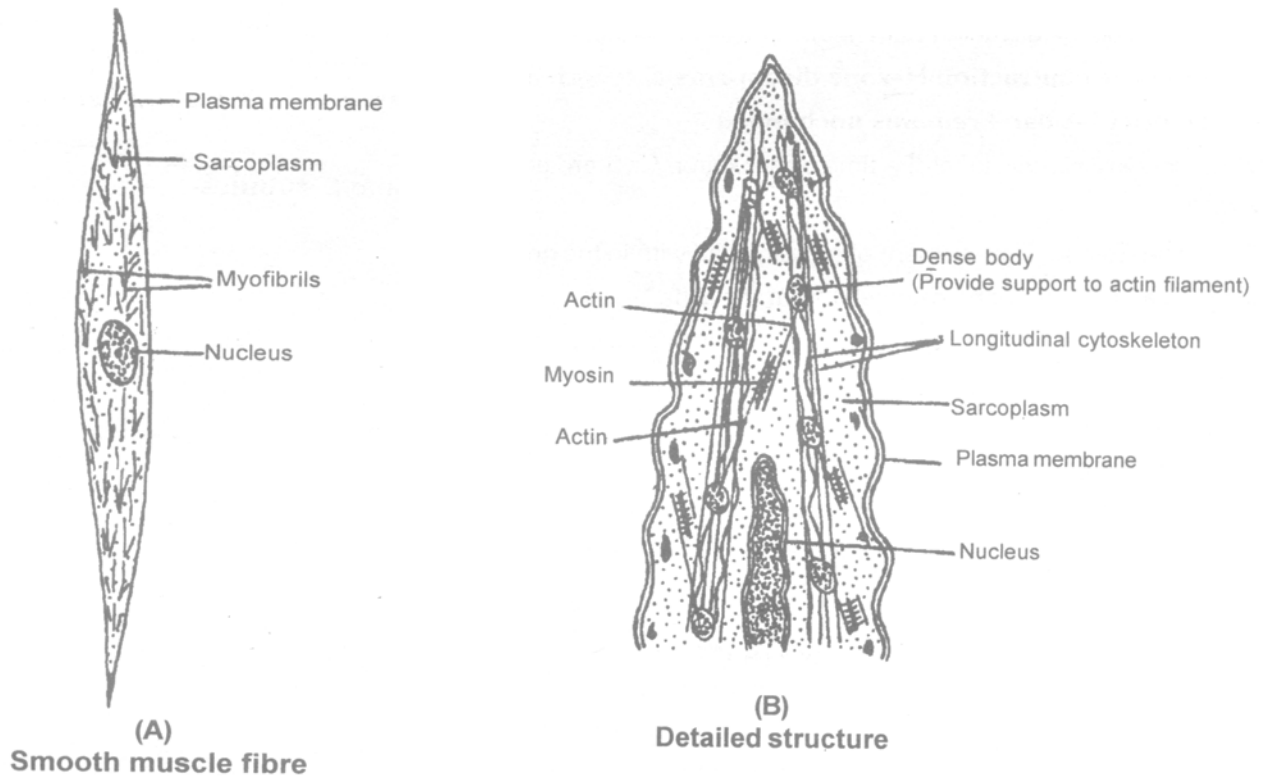
Chemical reaction in Muscles:

1. $\text{ATP} + \text{H}_2\text{O} \xrightarrow{\text{Creatine kinase}} \text{ADP} + \text{P}_i + \text{Energy (For contractile muscle)}$
2. $\text{Creatine phosphate} + \text{ADP} \longrightarrow \text{Creatine} + \text{ATP (Muscle contraction)}$
3. $\text{Glycogen} \xrightarrow{\text{Glycolysis}} \text{Lactic acid} + \text{Energy}$
4. $80\% \text{ Lactic acid} + \text{Water} \xrightarrow{\text{ATP}} \text{Glycogen (Liver cell)}$
5. $205 \text{ Lactic Acid} + \text{Oxygen} \longrightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{ATP (Liver cell)}$
6. $\text{Creatine} + \text{ATP} \longrightarrow \text{Creatine phosphate} + \text{ADP (Resting Muscle)}$

INVOLUNTARY MUSCLE

- It develops from the hypomeric layer of Myotome.
- It is not related to the skeleton so also called as Non skeletal muscle.
- These muscles 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 spindle shaped.
- 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 function 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 remains in contracted stage for longer period due to this reason muscle called **Nonfatigue muscle**.

On the basis of structure this muscle is two types:-

(1) Single Unit:-

They are compact muscles where the individual cells joined together by gap junctions. is diffused or weak. Muscular activity is initiated spontaneously due to hormonal action, stretching and other stimulations . The excitation spreads by myogenic activity. Single unit smooth muscles occur in the wall of gastrointestinal tract, fallopian tube, uterus, ureter, bladder. When completely denervated these smooth muscle continue contracted rhythmically.

(2) Multi Unit:-

Muscle fibres occur in small groups which are innervated separately and contract independently. A muscle has, therefore, a number of small units, Multi-unit smooth muscles are found in

- (i) Nictitating membrane (iris)
- (ii) Pilomotor muscle in the hair follicle. (Skin)

Arteriolar Smooth Muscle – Both type of properties found

CARDIAC MUSCLE

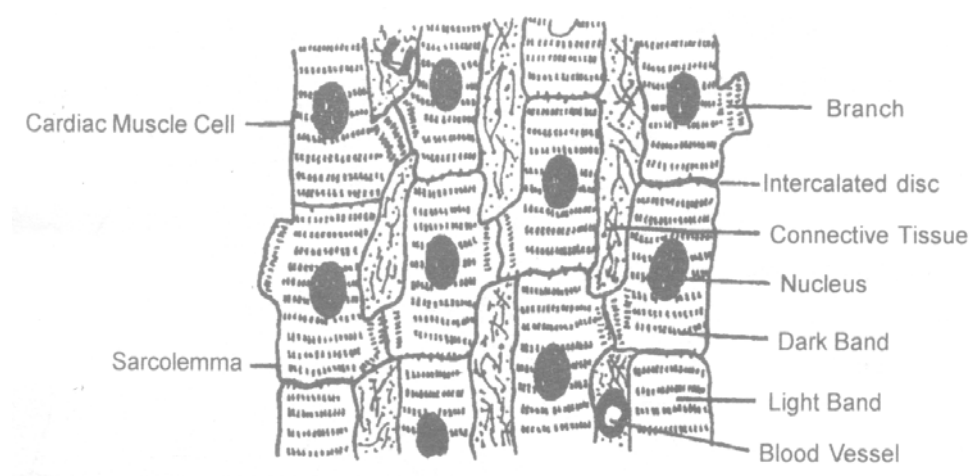
It is special type of muscle which found only in heart so it is also called as cardiac muscle. On the basis of structure it is striated type of muscle. It is also cylindrical fibre. Fibre are branched. Many transverse septa are found in the muscle fibre which are called as intercalated disc. Junctional region b/w the cell membrane called intercalated discs & these are made up of sarcolemma.

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. Intercalated disc, helps in the propagation of impulse & contraction. It is also Nonfatigue type muscle.

Its contraction is not controlled by will power of animal.

On the basis of function it is involuntary type & control by pacemaker (SA,AV & Purkinje fibres). Both central nerve & autonomic nerves are supplied to this type of muscle.

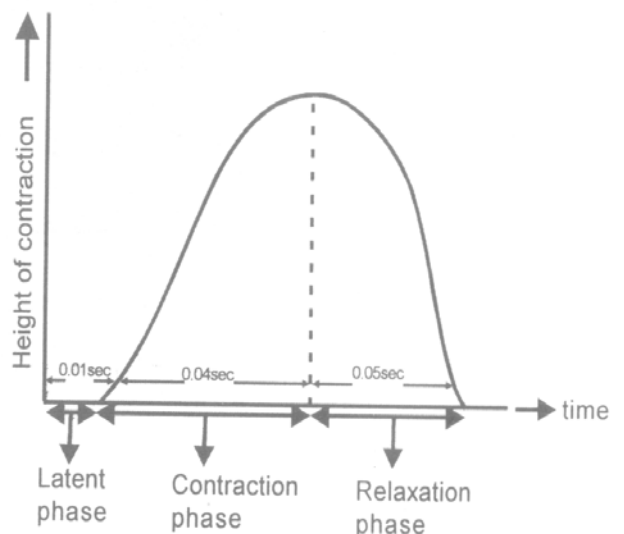


Striated	Non striated	Cardiac
1. They are present in upper limb & lower limb etc.	Iris of eye (Ciliary muscle of eye) Urinary bladder, Urinogenital tract, Dermis of skin - Erector pill muscle of dermis	They are present in walls of Heart
2. Cylindrical	Spindle in shaped	Cylindrical
3. Fibres Unbranched	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.	Donot get fatigue	Never fatigued

PROPERTIES OF MUSCLES

Terminology

1. **Origin** – fixed end of muscle (Proximal end)
- Insertion** – Distal end of muscle which is attach to bone (Movable end)
2. **Excitability** – Muscles responds to stimuli which can be nervous, chemical electrical & thermal & mechanical.
3. **Conductivity** - Stimulus acting in one region of muscle fibres propagated to all parts within no time.
Contractility- On being stimulated the muscle fibers contract & shorten followed by Relaxation.
4. **Threshold Stimulus** -
Intensity of stimulus below the threshold value which does not produces contraction in muscle fibres is called subthreshold stimulus.
Stimulus stronger than threshold one is called suprathreshold stimulus.
4. **All or none law :-**
Response of muscle fibre is maximum whether the stimulus ahs threshold value or suprathreshold value.
Response is absent when intensity is subthreshold. (Below threshold value)
5. **Muscle twith** - It is single isolated contraction of Muscle fibres due to single stimulus.
Muscle curve or kymograph indicates three phases:
 - (a) Period of latent excitation (Latent period)
Interval between the application of appropriate stimulus & initiation of contraction
It is 0.01 sec. in skeletal muscle. 3sec. in smooth muscle.
 - (b) Contraction phase – Duration for which muscle remain contracted state. It is 0.04 sec. in skeletal muscle. 20 sec. in smooth muscle.
 - (c) Relaxation phase- Interval for contracted Muscle to regain its original/Relaxed state
0.05 sec. in skeletal muscle. 23 sec. in smooth muscle.



6. **Refractory period** - It is period between two twitches during this muscle does not respond to second stimulus after single twitch

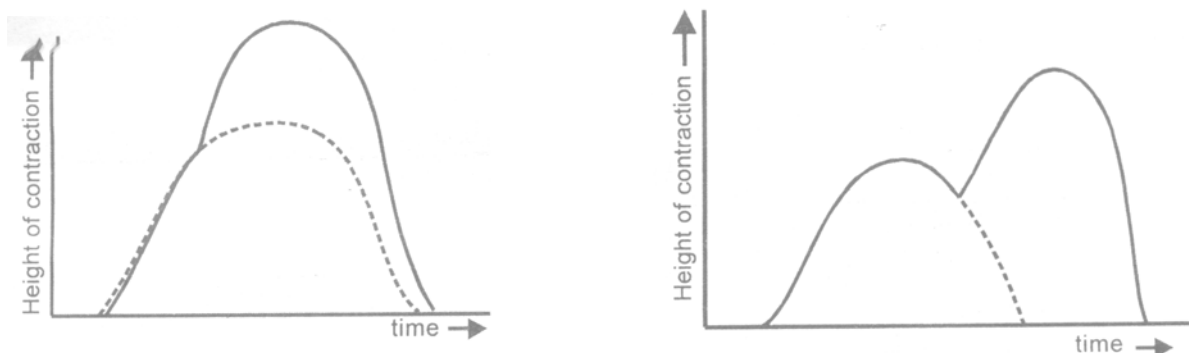
It is 0.002-0.005 second in skeletal muscles and 0.1-0.2 second in visceral muscles.

7. **Summation of stimuli** – two subliminal stimuli Applied simultaneously get added up & Evoke the response Muscle response = (1st stimulus + 2nd stimulus – threshold value)

Subliminal Subliminal

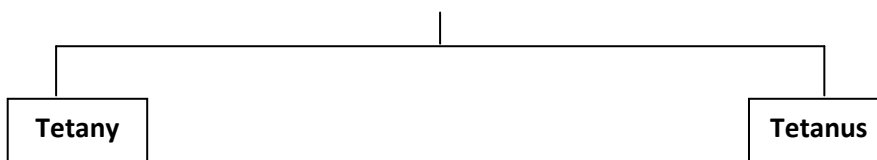
However a muscles consist of large no. of muscle fibres with different threshold value so in intensity of stimulus increases contraction of muscle although individual fibres obey all/ none law.

Summation of Ind stimulus during contraction phase



8. **Muscle tone** – In relaxed muscles , a few fibres always undergoing contraction alternately so maintain the health of muscles It is known as Muscle tone.

9. **Tetanic condition** – It is sustained muscles contraction due to rapid series of Impulse, During this relaxation of muscle does not take place.



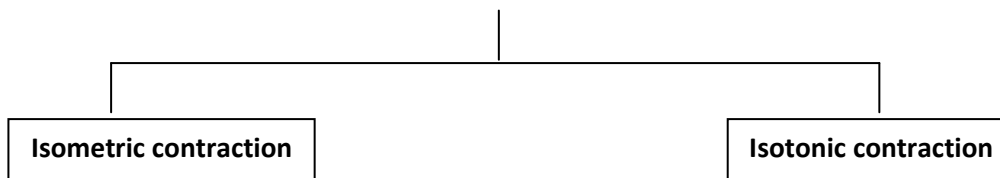
It is due to hypocalcaemia
It is hormonal deficiency disease

It is bacterial disease
(Clostridium tetani) lock jaw disease during this
Abnormal muscles contraction of jaw muscle take place.

10. **Paralysis** - Supply of motor nerve impulse completely cut off. So function of muscle contraction is stoped.

11. **Shivering** - Involuntary contraction of muscles of make body warm.

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



Length same but tone changed
Eg. Pushing against an immovable object.
Isometric –

Length changed but tone same

Contraction occur when a muscle is stimulated adequately but is prevented to shorten.

e.g. By applying too heavy load against the muscle so that the muscle contract but cannot lift the load at all ext. work done is zero.

Isotonic-

When muscle is stimulated adequately & is allowed to shorten, Then the contraction is called Isotonic some external work is done. Technically called a load is lifted.

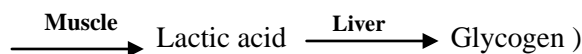
13. Antagonistic muscles -

They are pair of muscles which which causes opposite movement at the same sit when one muscle is contracting, the other is 7 viceversa

eg- Biceps (flexor) & Triceps of arms (extensor)

14. Motor unit – Groups of muscle s fibres supplied by single motor neuron. It is a functional unit of muscles because all the muscles fibres of motor unit contract & relax simultaneously.

15. Cori cycles – Lactic acid accumulated in muscles during 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. (Glycogen



16. 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

17.

Red muscle fibres	White muscle fibres
- Slow & Tonic muscle fibres	Fast & twith muscle fibres
- Dard red b/o myoglobin +	Pale
- Mitochondria +++	Mitochondria +
- Slow sustained work long period without getting fatigue	Perform fast, strenous work for short duration & get fatigued quickly accumulation of lactic acids.
Sarcoplasmic reticulum – Less	More
Eg Extensor muscles of back flight muscles	Eg eyeball muscles

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

18. Fatigue –

Due to sustained contraction initially muscle give beneficial effects of contraction (warm ups) but after it ATP is exhausted & muscle is a state of permanent contraction & no relaxation because no fresh ATP available for deathmet of actomysoin complex.

- B/o 1. Accumulation of lactic acids

2. Consumption of stored glycogen, ATP, CTP

Infatigue-

(i) Increase latent period and phase of relaxation.

(ii) Decrease height of contraction

19. Rigor Motis -

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. deattachment 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.

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

21. Muscle and nerve exitability is reduced by K⁺.

22. During muscle contraction chemical energy changed into mechanical energy.

23. Over stretching of tendon is called sprain.

MUSCLE TYPES ON BASIS OF MOVEMENTS

1. Flexor= Fore arm move in upward direction. (Bend)
Bending of part over one another Eg. Biceps brachii
Extensor – Fore arm move in downward direction. Straightening of bending part
Eg. Triceps
2. Adductor – Toward body axis. Towards the body.
Lattissimus dorsi brings the arms towards body
Abductor- Upper & lower limb move away from body axis. Away from the body (midline) deltoids
3. Pronator- Palm state in down. Rotate downward eg pronator teres
Supinator- Palm state in upward rotate upward eg Brachioradialis
4. Dilation- diameter increases, widening of Iris (radial muscle of iris)
Constrictor- Diameter decreases, Closing an aperture- sphincter ani closes anus
5. Depressor- Lower Jaw move in downward direction. Lowering part depressor mandibularis Elevator-
Lower Jaw move upward direction. Raising the part eg. Masseter.
6. Median Rotation:- Out ward direction rotation.
7. Inversion:- When sole of foot turn toward body axis.
Eversion:- Away from body axis
Aryepiglotticus muscle is called Hilton muscle.
Gastrocnemius muscle present in shank.
Sartorius the longest muscle of body
Gluteus maximus (Buttock muscles)- Largest muscle of body.
Stapedius – Smallest muscle of body.
In human being 639 muscle are found. 634 muscle are paired and 5 muscle are unpaired. 400 muscle are striated & most of the muscles are found in back region & number of back muscles are 180. Jaw muscles are strongest. Longest smooth muscle is present in uterus of pregnant lady.