LOCOMOTION AND MOVEMENT (MUSCLES)

Movement is one of the significant features of living beings. Animals and plants exhibit a wide range of movements. Streaming of protoplasm in the unicellular organisms like Amoeba is a simple form of movement. Movement of cilia, flagella and tentacles are shown by many organisms. Human beings can move limbs, jaws, eyelids, tongue, etc. Some of the movements result in a change of place or location. Such voluntary movements are called locomotion. Walking, running, climbing, flying, swimming are all some forms of locomotory movements. Locomotory structures need not be different from those affecting other types of movements. For example, in Paramoecium, cilia helps in the movement of food through cytopharynx and in locomotion as well. Hydra can use its tentacles for capturing its prey and also use them for locomotion. We use limbs for changes in body postures and locomotion as well. The above observations suggest that movements and locomotion cannot be studied
separately. The two may be linked by stating that all locomotions are movements but all movements are not locomotions. Methods of locomotion performed by animals vary with their habitats and the demand of the situation. However, locomotion is generally for search of food, shelter, mate, suitable breeding grounds, favourable climatic conditions or to escape from enemies/predators.

TYPES OF MOVEMENT

Cells of the human body exhibit three main types of movements, namely, amoeboid, ciliary and muscular.

1. Amoeboid movement

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 involved in amoeboid movement.

2. Ciliary movement

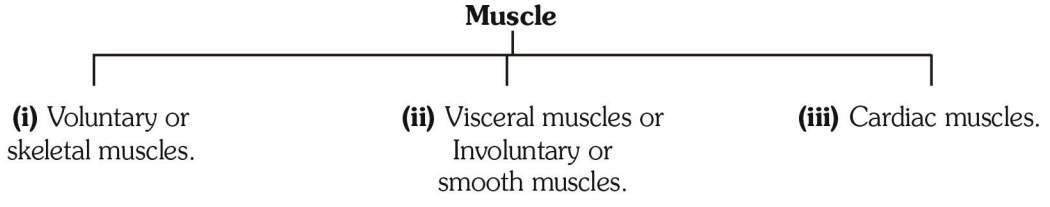
Ciliary movement occurs in most of our internal tubular organs which are lined by ciliated epithelium. The coordinated movements of cilia in the trachea help us in removing dust particles and some of the foreign substances inhaled alongwith the atmospheric air. Passage of ova through the female reproductive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

3. Muscular 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. Locomotion requires a perfect coordinated activity of muscular, skeletal and neural systems. In this chapter, you will learn about the types of muscles, their structure, mechanism of their contraction and important aspects of the skeletal system.

Development of muscle :-

- Origin of muscles is - **mesoderm** except few muscles.
- Muscle of Iris, ciliary body & myoepithelial cell of sweat gland develop from **Ectoderm**. main characterestics of muscle are excitability, contractility and extensibility.
- Muscles constitutes around 40% to 50% of adult body mass in an average healthy person.
- Three types of muscles are found in the body. (on the basis of position/location)



	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

1. VOLUNTARY MUSCLE

- 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**.

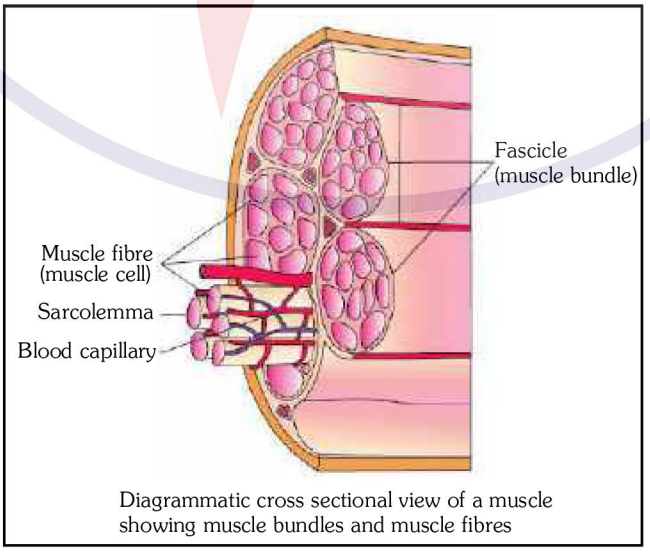
Tendon - The muscle fibres attached to a tough cord of connective tissue called **Tendon** & Tendon is further attached with a bone.

Epimysium - Muscle is also covered by a layer of collagenous connective tissue which is called as **Epimysium**. Many fasciculi combined to form a **muscle**.

Perimysium - Each Fasciculi is covered by a layer of connective tissue which is called **Perimysium**.

Fasciculi - Many muscle fibre are combined to form a group which is called **fasciculi**.

Endomysium - Muscle fibre is covered by a layer of connective tissue which is called **Endomysium**.



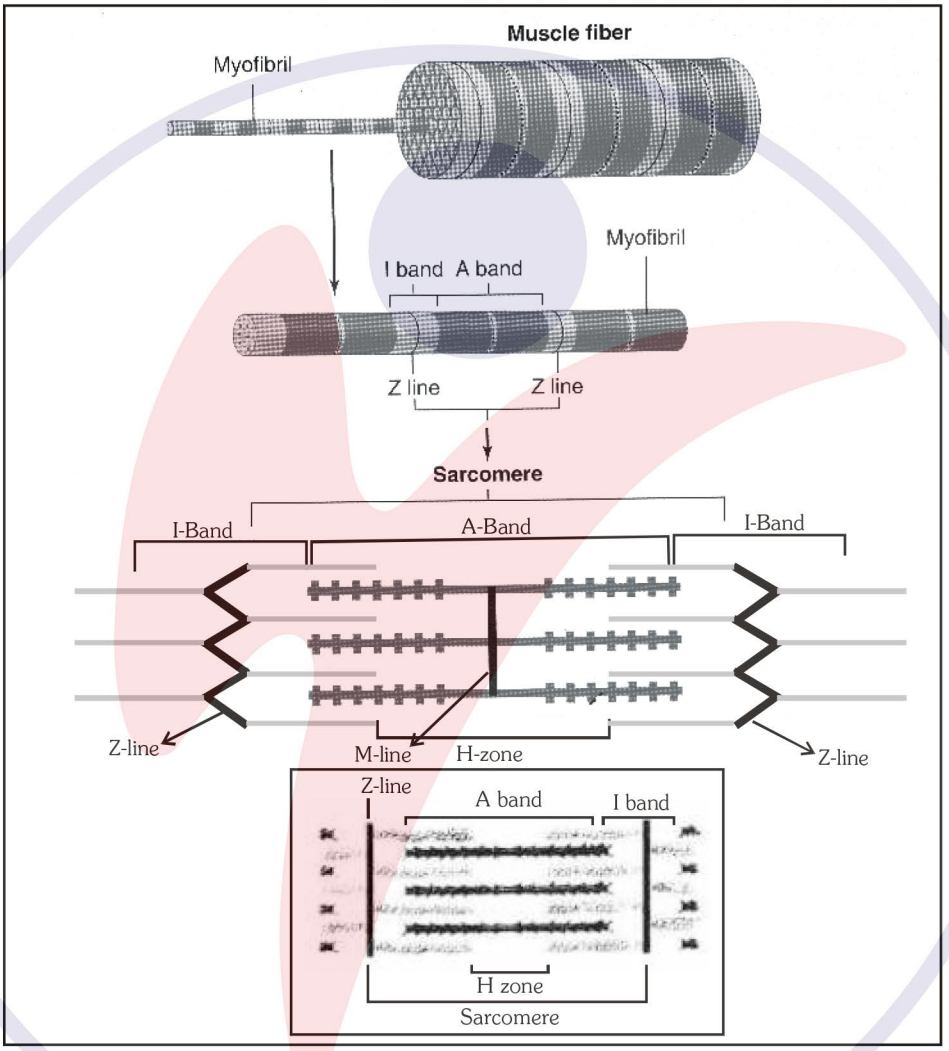
Diagrammatic cross sectional view of a muscle showing muscle bundles and muscle fibres

1.1 STRUCTURE OF MUSCLE FIBRE

Fine structure of muscle fibre.

Muscle fibre is a cylindrical or Tubular shape.

- The outer membrane of muscle fibre is called **sarcolemma**.
- This cell membrane contain collagen fibre.
- Each muscle fibre contain multinucleated sarcoplasm.
- Nucleus & sarcoplasm are found in peripheral part.



- A characteristic feature of the muscle fibre is the presence of a large number of parallelly arranged filaments in the sarcoplasm called myofilaments or **myofibrils**.
- Each myofibril has alternate dark and light bands on it. A detailed study of the myofibril has established that the striated appearance is due to the distribution pattern of two important proteins – **Actin** and **Myosin**.
- The light bands contain actin and is called I-band or Isotropic band, whereas the dark band called 'A' or Anisotropic band contains myosin.
- Both the proteins are arranged as rod-like structures, parallel to each other and also to the longitudinal axis of the myofibrils.
- Actin filaments are thinner as compared to the myosin filaments, hence are commonly called thin and thick filaments respectively. 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.
- Sarcomere is **structural and functional unit** of voluntary muscle fibre.

  Sarcomere = 1A band + two half I band

  The Length of Sarcomere is 2.5 µm. (Actin rod = 1µm, myosin = 1.5 µm)
- 1 Myosin filament is surrounded by 6 Actin filaments & 1 Actin filament is surrounded by 3 Myosin filament.

1.2 STRUCTURE OF CONTRACTILE PROTEINS :

- **Actin protein :**

  Each actin (thin) filament is made of two 'F' (filamentous) actins helically wound to each other. Each 'F' actin is a polymer of monomeric 'G' (Globular) actins.

- **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 and attached at the terminal end of actin.

- **Troponin –**

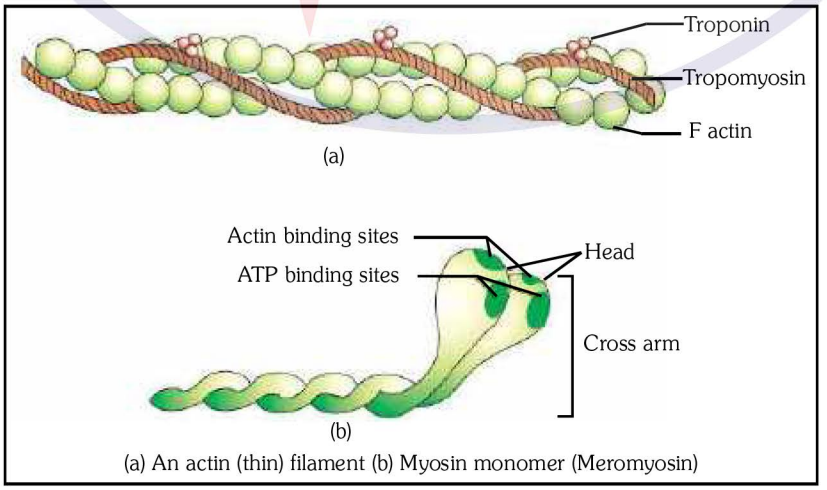
  It is one type of protein which attached with one of ends of the tropomyosin molecules.

  Troponin is made up of three subunit.

  (a) Troponin I (Inhibitory site) (b) Troponin T (Tropomyosin site) (c) Troponin C (Ca^{+2} binding site)

- **Myosin protein :**

  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 distance and angle from each other from the surface of a polymerised myosin 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.



(a) An actin (thin) filament (b) Myosin monomer (Meromyosin)

1.3 Mechanism of Muscle Contraction

SLIDING FILAMENT THEORY :

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

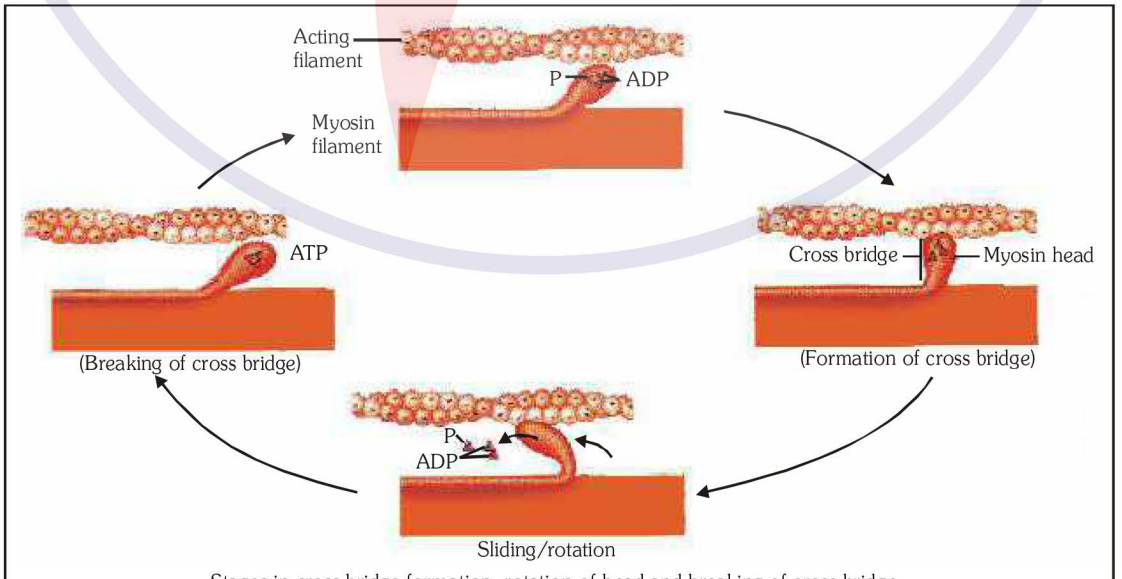
The junction of Nerve & muscle is called as neuromuscular junction.

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

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** where as the cell membrane of muscle fibre which invaginates called **post junctional membrane**.

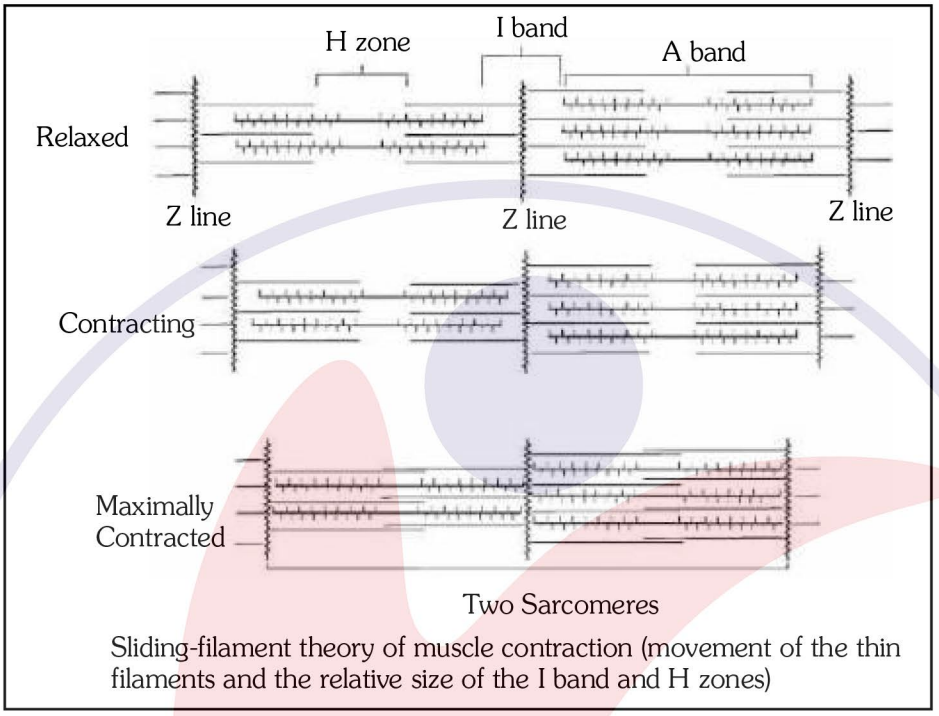
In terminal part of axon large number of vesicles & mitochondria are present. Each vesicle contains Acetylcholine in high concentration. In post junctional membrane, Acetylcholine receptor are present.

- 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 alongwith 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 (Acetyl choline) 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 or Actomyosin 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.
- It is clear from the above steps, that during shortening of the muscle, i.e., 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.



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

- 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.



Sliding-filament theory of muscle contraction (movement of the thin filaments and the relative size of the I band and H zones)

- Contraction is caused by overlaping 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 contration H–zone disappears & length of sarcomere & I-band decreases by 20%.**

  The length of A band remains unchanged.

  All processes are reversible, at the time of relaxation Ca^{++} goes into **L–tubules**.

Role of ATP –

(i) The Rotational movement of myosin head with in the groove.

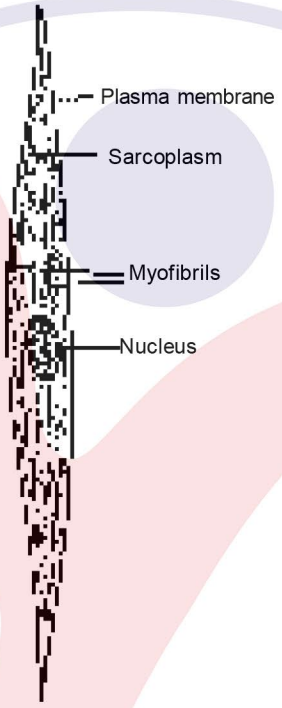
(ii) Deattachment of myosin head from the actin.

- The reaction time of the fibres can vary in different muscles. Repeated activation of the muscles can lead to the accumulation of lactic acid due to anaerobic breakdown of glycogen in them, causing fatigue.
- Muscle contains a red coloured oxygen storing pigment called myoglobin. Myoglobin content is high in some of the muscles which gives a reddish appearance. Such muscles are called the Red fibres. These muscles also contain plenty of mitochondria which can utilise the large amount of oxygen stored in them for ATP production. These muscles, therefore, can also be called aerobic muscles.
- Some of the muscles possess very less quantity of myoglobin and therefore, appear pale or whitish. These are the White fibres. Number of mitochondria are also few in them, but the amount of sarcoplasmic reticulum is high. They depend on anaerobic process for energy.

2. INVOLUNTARY MUSCLE

- 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



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.
- Myofibrils are made up of actin and myosin but remarkably less than skeletal muscle But filaments are not placed in a highly ordered pattern so striations are 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^{++}** .
- Its contraction period is longer.
- It remain in contracted stage for longer period, due to this reason muscle called **Nonfatigue muscle**.

3. CARDIAC MUSCLE

It is special type of muscle found only in heart so it is also called as cardiac muscle. On the basis of structure it is **striated type of muslce**. It is also cylindrical fibre. Fibres 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 and 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 and light line also found in the muscle fibre. Intercalated disc, helps in the propagation of impulse and 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** and control by pacemaker (SA node, AV node and Purkinje fibres). Both central nerve and autonomic nerves are supplied to this type of muscle.