MUSCULO SKELETAL SYSTEM

MUSCLE CONTRACTION :

- Muscular tissue is useful for animals to move the whole or part of their bodies and to maintain particular posture.
- Functionally, muscle cells are specially organised to convert chemical energy into mechanical work. In a vertebrate body three types of muscles are identified. They are **striated, unstriated and cardiac** muscles.

Structure of a striated muscle

- Striated muscles, as mentioned earlier, are composed of many striated muscle fibres. Each fibre is cylindrical and is enclosed in a sheath called **sarcolemma.** Its cytoplasm is called sarcoplasm.
- Sarcoplasm contains many peripherally arranged nuclei and many parallelly arranged fibres called **myofibrils.**
- Sarcoplasm also contains well formed sarcoplasmic reticulum (endoplasmic reticulum) and many mitochondria or the sarcosomes.

Structure of myofibril

- Myofibril contains alternate dark and light bands. The dark band is known as anisotrophic band or A- band and the light band is known as isotropic band or I-band.
- In the middle of A-band, there is a paler zone called Hensen's disc or H-zone. H-zone has an M-line in the centre.
- I-band is bisected at its mid point by a dense and narrow Z - line or **Krause's membrance.** The part of myofibril between two Z-lines is known as **sarcomere.**
- A-band is formed by thick filaments of myosin and thin filaments of actin filaments.
- Each thick myosin filament is made up of 200 myosin molecules
- A myosin molecule is with **6 polypeptide chains** (2 heavy and 4 light chains)
- Myosin filaments have cross bridges. I-band is formed by thin filaments composed of proteins, *viz.,* **actin, tropomyosin** and **troponin.**
- **Troponin has 3 sub units – T_nC, T_nT, T_nI**
- They extend into the A-band among myosin filaments. The thick and thin filaments, therefore, overlap in certain regions of A- band giving a darker appearance.

Triad system :

- Plasma membrane invaginates into the muscle fibre forming the T-tubule (transverse tubule) in the A-I junctions.
- Sarcoplasmic reticulum surrounds the myofibrils. It organises into longitudinal tubules and terminal cisternae.
- Terminal cisternae are close to the T-tubule. T-tubule along with the terminal cisternae on either side together forms the **triad system** of the muscle.
- In vertebrates these are present at the Z-membrane

MECHANISM OF MUSCLE CONTRACTION

- Muscle contraction is a **physicochemical mechanism**. Physical changes are explained as sliding filament hypothesis.

1. Sliding filament hypothesis :

- The sliding filament hypothesis of muscle contraction was put forth by Hugh Huxley and Hanson (1965).
- According to their hypothesis, the contraction of sarcomere depends on the presence of two sets of filaments.
- During muscle contraction, thin filaments slide over the myosin filaments resulting in shortening of sarcomere. A series of events takes place during this process.

Stimulation of muscle

- When a nerve impulse reaches the neuromuscular junction, the sarcolemma of that muscle cell gets depolarised.
- The depolarisation extends into the T-tubule and cisternae of sarcoplasmic reticulum.
- Hence, Ca^{++} ions release into the sarcoplasm from cisternae of sarcoplamic reticulum. These calcium ions diffuse into the thin filaments.

Contraction of muscle

- 1. The Ca^{++} ions bind to the T_PC of troponin protein in the thin filament.
- 2. Binding of Ca^{++} to T_PC shifts the troponin-tropomyosin complex so that active sites are exposed in thin filaments. The increase in the concentration of Ca^{++} ions also causes the conformational changes in the myosin that permit the binding of myosin to the thin filament at active site.
- 3. In the absence of ATP, myosin head binds to the thin filament at the active site tightly, forming the actomyosin complex.
- When ATP binds to the pocket of the myosin head, this bond weakens.
- ATPase present in the head of myosin filament hydrolysis the ATP.
- Hydrolysed ATP causes conformational changes in the head of myosin, so that head of myosin moves to a new position and recombines with the another active site of actin filament.

- 4. Actin-myosin complex at the active site releases inorganic phosphorus. It swings the cross bridge towards the H-zne. It is called **power stroke.** Thin filament slides over the myosin filament. This power stroke is followed by the release of ADP.

- The conformation of myosin, which is with a pocket for ATP and tightly bound to the active site, is restored.

Relaxation of muscle

- 1. Ca^{++} ions detach from the thin filaments and diffuse toward the sarcoplasmic reticulum.
- 2. Troponin permits the tropomyosin to cover the active site of thin filament.
- 3. Myosin-actin cross bridges break.
- The swinging movements and the attachment and detachment of the heads of cross bridges from action filaments is termed as **ratchet mechanism**, which forms the basis of sliding filament hypothesis.
- It is also called **walk along mechanism.**
- In the process of muscle contraction there is no change in the length of A band, but I and and H zone decrease in size, or disappear.

Bio chemical changes during muscle contraction

- For the contraction of muscle, continuous supply of energy is needed. ATP is the immediate source of energy for muscle contraction. As the **ATP** content is very low, it is actively replenished continuously by an energy rich phosphogen compound.

  $ATP \longrightarrow ADP + Pi$

- Creatine phosphate is the immediate additional source of energy in the muscles.
- In vertebrate muscles creatine phosphate is the phosphogen, a back up source. (In invertebrate muscles, it is in the form of argenine phosphate.
- The high energy phosphates of muscles that donate high energy phosphate group to ADP are known as phosphogens. This reaction is catalysed by creatine kinase.

  $Creatine\ phosphate + ADP \longrightarrow ATP + Creatine$

- When creatine phosphate gets exhausted, the next source of energy is utilised, which includes oxidation of glucose and fatty acids. The energy liberated in this process is transferred to ADP and creatine.
- Thus ATP and creatine phosphate are formed and which inturn supply energy for muscle contraction.
- During rapid activity of a muscle, the respiratory system is unable to supply sufficient oxygen needed by it.
- Thus the pyruvic acid produced by glycolysis is transformed into lactic acid in the absence of oxygen.(Accumulation of lactic acid in the muscle leads to **muscle fatigue**).
- Lactic acid formed in the muscle reaches the liver through blood circulation. In liver, during rest, 80% of lactic acid is utilised in the resynthesis of glycogen which is transported back to muscle. This is known as Cori and Cori cycle. 20% of lactic acid is oxidised as CO_2 and H_2O.