■ MOLECULAR BASIS OF MUSCULAR CONTRACTION

Molecular mechanism is responsible for formation of actomyosin complex that results in muscular contraction. It includes three stages:

1. Excitation-contraction coupling.
2. Role of troponin and tropomyosin.
3. Sliding mechanism.

1. *Excitation-contraction Coupling*

Excitation-contraction coupling is the process that occurs in between the excitation and contraction of the muscle. This process involves series of activities, which are responsible for the contraction of excited muscle.

Stages of excitation-contraction coupling

When a muscle is excited (stimulated) by the impulses passing through motor nerve and neuromuscular junction, action potential is generated in the muscle fiber.

Action potential spreads over sarcolemma and also into the muscle fiber through the 'T' tubules. The 'T' tubules are responsible for the rapid spread of action potential into the muscle fiber. When the action potential reaches the cisternae of 'L' tubules, these cisternae are excited. Now, the calcium ions stored in the cisternae are released into the sarcoplasm (Fig. 31.6). The calcium ions from the sarcoplasm move towards the actin filaments to produce the contraction.

Thus, the calcium ion forms the link or coupling material between the excitation and the contraction of muscle. Hence, the calcium ions are said to form the basis of excitation-contraction coupling.

2. *Role of Troponin and Tropomyosin*

Normally, the head of myosin molecules has a strong tendency to get attached with active site of F actin. However, in relaxed condition, the active site of F actin is covered by the tropomyosin. Therefore, the myosin head cannot combine with actin molecule.

Large number of calcium ions, which are released from 'L' tubules during the excitation of the muscle, bind with troponin C. The loading of troponin C with calcium ions produces some change in the position of troponin molecule. It in turn, pulls tropomyosin molecule away from F actin. Due to the movement of tropomyosin, the active site of F actin is uncovered and exposed. Immediately the head of myosin gets attached to the actin.

3. *Sliding Mechanism and Formation of Actomyosin Complex – Sliding Theory*

Sliding theory explains how the actin filaments slide over myosin filaments and form the actomyosin complex during muscular contraction. It is also called ratchet theory or walk along theory.

Each cross bridge from the myosin filaments has got three components namely, a hinge, an arm and a head.

After binding with active site of F actin, the myosin head is tilted towards the arm so that the actin filament is dragged along with it (Fig. 31.7). This tilting of head is called power stroke. After tilting, the head immediately breaks away from the active site and returns to the original position. Now, it combines with a new active site on the actin molecule. And, tilting movement occurs again. Thus, the head of cross bridge bends back and forth and pulls the actin filament towards the center of sarcomere. In this way, all the actin filaments of both the ends of sarcomere are pulled. So, the actin filaments of

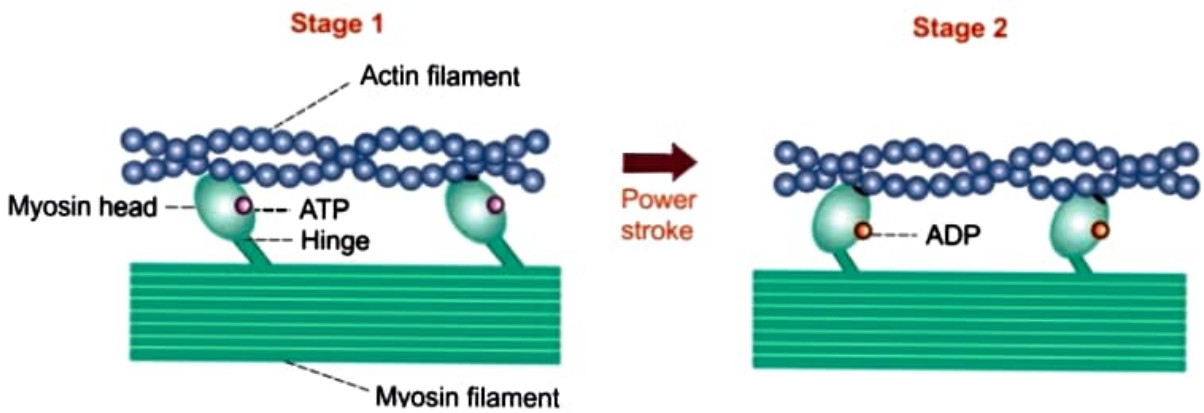

FIGURE 31.7: Diagram showing power stroke by myosin head.
Stage 1: Myosin head binds with actin; Stage 2: Tilting of myosin head (power stroke) drags the actin filament.

opposite sides overlap and form actomyosin complex. Formation of actomyosin complex results in contraction of the muscle.

When the muscle shortens further, the actin filaments from opposite ends of the sarcomere approach each other. So, the 'H' zone becomes narrow. And, the two 'Z' lines come closer with reduction in length of the sarcomere. However, the length of 'A' band is not altered. But, the length of 'I' band decreases.

When the muscular contraction becomes severe, the actin filaments from opposite ends overlap and the 'H' zone disappears.

Changes in sarcomere during muscular contraction

Thus, changes that take place in sarcomere during muscular contraction are:

1. Length of all the sarcomeres decreases as the 'Z' lines come close to each other
2. Length of the 'I' band decreases since the actin filaments from opposite side overlap
3. 'H' zone either decreases or disappears
4. Length of 'A' band remains the same.

Summary of sequence of events during muscular contraction is given in Figure 31.8.

Energy for Muscular Contraction

Energy for movement of myosin head (power stroke) is obtained by breakdown of adenosine triphosphate (ATP) into adenosine diphosphate (ADP) and inorganic phosphate (Pi).

Head of myosin has a site for ATP. Actually the head itself can act as the enzyme ATPase and catalyze the breakdown of ATP. Even before the onset of contraction, an ATP molecule binds with myosin head.

When tropomyosin moves to expose the active sites, the head is attached to the active site. Now ATPase cleaves ATP into ADP and Pi, which remains in head itself. The energy released during this process is utilized for contraction.

When head is tilted, the ADP and Pi are released and a new ATP molecule binds with head. This process is repeated until the muscular contraction is completed.

Relaxation of the Muscle

Relaxation of the muscle occurs when the calcium ions are pumped back into the L tubules. When calcium ions enter the L tubules, calcium content in sarcoplasm decreases leading to the release of calcium ions from the troponin. It causes detachment of myosin from actin followed by relaxation of the muscle (Fig. 31.9). The detachment of myosin from actin obtains energy from breakdown of ATP. Thus, the chemical process of

muscular relaxation is an active process although the physical process is said to be passive.