CHAPTER 08

Locomotion and Movement

In this Chapter...

- Muscles
- Detailed Structure of a Skeletal Muscle
- Mechanism of Muscle Contraction
- Red and White Muscle Fibre

Muscles

These are made up of highly specialised thin and elongated cells called **muscle fibres**. Muscles arise from the **embryonic mesoderm**. It makes about 40-50% of a human body weight.

Special Properties

Muscles exhibit various special properties, some of them are given below

(i) **Contractibility** The cells of muscle can be shorten considerably and return to the original relaxed state.

(ii) **Excitability** It is due to the energy stored in the electrical potential difference across the plasma membrane.

(iii) Muscles also possess properties of extensibility and elasticity (because of proteins actin and myosin).

Types of Muscles

Muscles have been classified using different criteria, i.e. **location**, **appearance** and **nature of regulation** of their activities.

Based on their location, the muscles are of three types, i.e. skeletal, visceral and cardiac.

(i) Skeletal or Striated Muscles

These muscles function in association with the skeleton of organism. Under the microscope, they show a striped appearance and hence are called **striated muscles.**

They are also known as **voluntary muscles** as their activities are under the voluntary control of the central nervous system. They are primarily involved in locomotory actions and change of body postures.

(ii) Visceral or Smooth Muscles

They are found in the inner walls of hollow visceral (internal) organs of body like alimentary canal, reproductive tract, etc.

They do not exhibit any striation and are smooth in appearance and hence, are called **smooth muscles** (non-striated muscle). They are also known as **involuntary muscles** as they are not under the voluntary or direct control of the nervous system. They assist in the transportation of materials, e.g. movement of food through the digestive tract and gametes through the genital tract.

(iii) Cardiac Muscles

They occur in the wall of the heart and in walls of big veins (e.g. pulmonary veins and superior vena cava), where these veins enter the heart. These are **striated** and **involuntary** in nature. Presence of **oblique bands** and **intercalated** discs are their characteristic feature.

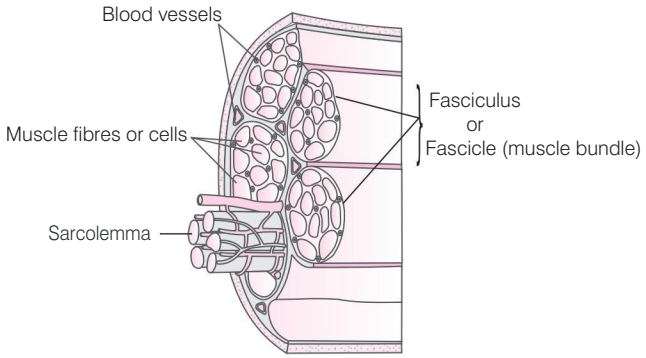
These assemble in a branching pattern to form a cardiac muscle. They never get fatigue.

Detailed Structure of a Skeletal Muscle

Skeletal muscle is made up of a number of **muscle bundles** or **fascicles** held together by **fascia** (collagenous connective tissue layer).

Composition of Muscle Bundle

Each muscle bundle contains a number of **muscle fibres** (muscle cells), bounded by **sarcolemma** (plasma membrane) and contains well-developed **endoplasmic reticulum** (sarcoplasmic reticulum), specialised for calcium storage in its sarcoplasm (cytoplasm).

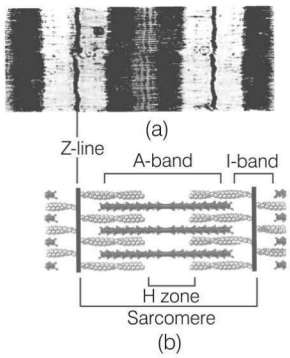


Diagrammatic cross-sectional view of a muscle showing muscle bundles and muscle fibres

Muscle fibre is a **syncytium** as its sarcoplasm contains many nuclei. There are large number of parallel arrangement of filaments called **myofilaments** or **myofibrils** (characteristic feature of muscle fibre).

Detailed Study of a Myofibril

- A myofibril has alternate **dark** and **light bands**. The dark bands are also called **Anisotropic band** or **A-band** which contains protein **myosin**. The light bands are called **Isotropic band or I-band** which contain protein **actin**.
- The striated appearance of myofibril is due to the distribution pattern of the proteins, **actin** and **myosin** in the muscle tissue. Both these proteins are arranged as rod-like structures, parallel to each other and also to the longitudinal axis of myofibrils. Actin filaments are thinner than myosin filaments.



Diagrammatic representation of
(a) Anatomy of a muscle fibre showing a sarcomere,
(b) A sarcomere

- Each I-band has its centre, a dark membrane called **Z-line** (an elastic fibre). It is also called **Z-disc** or **Krause's membrane** or **Dobie's line**. The part of the myofibril between two successive Z-lines is called a **sarcomere** (functional unit of muscle contraction).
- A sarcomere consists of the A-band and half of each adjacent I-band. A thin fibrous membrane called **M-line** present in the middle of A-band holds the thick filaments together.
- The A and I-bands are arranged alternately throughout the length of myofibril. At the centre of A-band, a portion is present that is not overlapped by thin filaments. It is called the **H-zone** (Hensen zone).
- In resting state, the edges of thin filaments on either side of thick filaments partially overlap each other leaving H-zone in the centre of thick filaments.

Structure of Contractile Proteins

The thick myofilaments are formed by **myosin protein**. The thin myofilaments are formed by three types of proteins called **actin**, **tropomyosin** and **troponin**. These four proteins are collectively known as **contractile proteins.**

Thick Myofilament or Primary Myofilament

It consists mainly of myosin protein. Each myosin filament is a polymerised protein made up of many monomeric proteins called **meromyosins**.

Each meromyosin has two important parts which are as follows

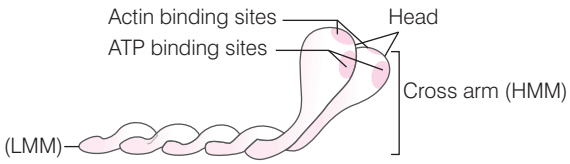
(i) Globular Head

It has a short arm, called **Heavy Meromyosin** (HMM). The HMM components project outwards at regular distance and angle from each other, from surface of a polymerised myosin filament and known as **cross arm**.

The globular head is an **active ATPase enzyme,** which has binding sites for ATP and active sites for actin.

(ii) Tail

It is called the **Light Meromyosin** (LMM). The myosin molecule has two identical heavy chains and four light chains. The two heavy chains wrap spirally around each other to form a double helix. The light chains are the parts of the myosin heads and help to control the function of head during the contraction of muscle.



Myosin monomer (meromyosin)

Thin Myofilament or Secondary Myofilament

It is composed of following proteins

(i) Actin

It is a globular protein with low molecular weight. It is made up of two 'F' (filamentous) actin helically wound to each other. Each **F actin** is a polymer of monomeric '**G**' (globular) **actins**.

(ii) Troponin

It is a complex protein of three globular peptides (Troponin-T, Troponin-I and Troponin-C) distributed at regular intervals on tropomyosin.

An actin (thin) filament

In the resting stage of muscle fibre, a subunit of troponin masks the active sites for myosin on the actin filaments.

(iii) Tropomyosin

Two filaments of this protein run close to the '**F**' **actins** throughout its length.

Mechanism of Muscle Contraction

- The contraction of muscle is best explained by the **sliding filament theory**. It states that contraction of muscles takes place by the sliding of thin and thick filaments (that are placed over each other) with the help of **cross-bridge.** It reduces the length of the sarcomere.
- This theory was proposed independently by **AF Huxley** and **R Niedergerke** and by **HE Huxley** and **Jean Manson** in England in 1954.
- The sequence of events leading to contraction is initiated by a signal in the Central Nervous System (CNS), either from the **brain** (voluntary activity) or from **spinal cord** (reflex activity) *via* a motor neuron.
- A **motor neuron** along with the muscle fibres connected to it, forms a motor unit and the action potential is conveyed to a **motor end plate** at neuromuscular junction, i.e. it is the junction between a motor neuron and sarcolemma of muscle fibre.
- A **neurotransmitter** (acetylcholine) is released at the junction by the neural signal which generates an action potential in the sarcolemma. This spreads and causes the release of calcium ions into sarcoplasm.
- Calcium plays a key regulatory role in muscle contraction. Increase in calcium ions level leads to binding of $\mathbf{Ca^+}$ ions the troponin subunit on actin filament. This removes the masking of active sites for myosin.

Formation of Cross-Bridge

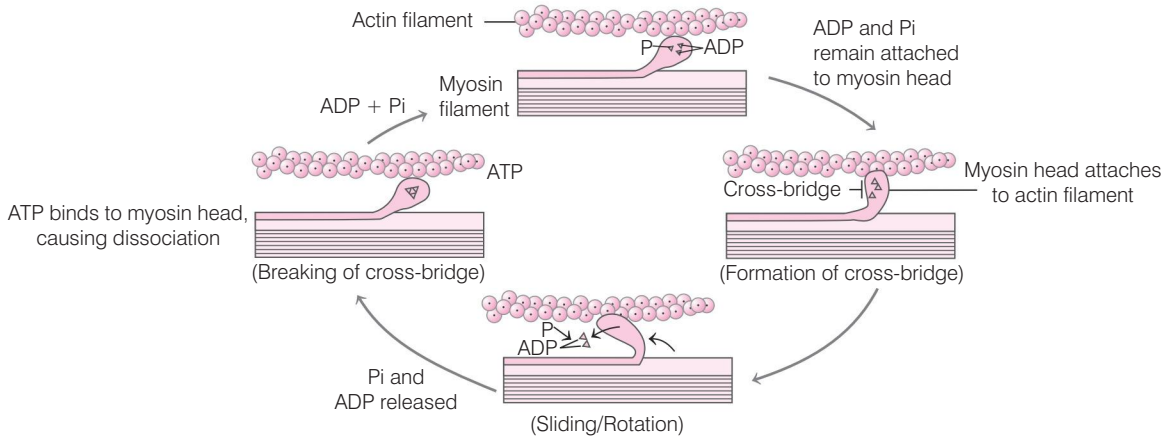
An ATP molecule joins the active site on myosin head of myosin myofilament. These heads contain an enzyme, **myosin ATPase** that along with Ca^{2+} and Mg^{2+} ions catalyse the breakdown of ATP.

$$ATP \xrightarrow[Ca^{2+},\, Mg^{2+}]{\text{Myosin ATPase}} ADP + Pi + Energy$$

The energy is transferred to myosin head, which energises and straightens to join an active site on actin myofilament, forming a cross-bridge.

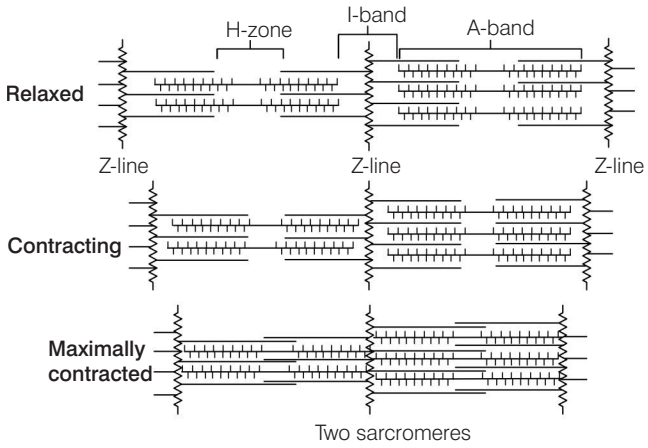
The energised cross-bridges move, causing the attached actin filaments to move towards the centre of A-band. The Z-line is also pulled inwards causing shortening of sarcomere, i.e. contraction. It is clear from the above explanation that during contraction, A-bands retain the length, while I-bands get reduced.

The myosin head releases ADP and Pi, relaxes to its low energy state. The head detaches from actin myofilaments when new ATP joins it (cross-bridge broken).



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

- In repeating cycle, the free head cleaves the new ATP. The cycles of cross-bridge formation and breakage is repeated causing further sliding.



Sliding filament theory of muscle contraction

Muscle Relaxation

After contraction, the calcium ions are pumped back to the sarcoplasmic cisternae, blocking the active sites on actin myofilaments. The Z-line returns to original position, i.e. relaxation of muscle fibre takes place.

Red and White Muscle Fibres

Birds and mammals have two kinds of striated muscle fibres, in their skeletal muscles, i.e. red (slow) and white (fast) muscle fibres.

Differences between Red and White Muscle Fibres

Red Muscle Fibres	White Muscle Fibres
They are dark red muscle fibres due to the presence of abundant myoglobin in them.	They are pale or whitish as they have less myoglobin.
Mitochondria are more in number, but they have less sarcoplasmic reticulum.	Mitochondria are few in number, but amount of sarcoplasmic reticulum is high.
They depend on aerobic process for energy.	They depend on anaerobic process for energy.
They have slow rate of contraction for long periods.	They have fast rate of contraction for short periods.
e.g. extensor muscle of the human back.	e.g. eyeball muscles.

Chapter Practice

PART 1
Objective Questions

• Multiple Choice Questions

1. Locomotory actions within human body are carried out using
(a) unstriped muscles (b) striated muscles
(c) involuntary muscles (d) visceral muscles

Ans. (*b*) Locomotory actions within human body are carried out using striated muscles or skeletal muscles. These muscles are closely associated with the skeletal components of the body and are primarily involved in locomotory actions and changes of body postures.

2. The storehouse of calcium ions in the muscle fibre is
(a) smooth endoplasmic reticulum
(b) Golgi body
(c) sarcoplasmic reticulum
(d) lysosomes

Ans. (*c*) The storehouse of calcium ions in the muscle fibre is sarcoplasmic reticulum.

3. The muscle bundles, fascicles are held together by the collagenous connective tissue called
(a) intercalated disc (b) myofibril
(c) fascia (d) All of these

Ans. (*c*)

4. Choose the incorrect pair.
(a) Globular head of meromyosin – Active ATPase enzyme
(b) Thin fibrous membrane holding – M-line thick filaments in A-band
(c) Dark bands – Isotropic band
(d) None of the above

Ans. (*c*) The pair in option (c) is incorrect and can be corrected as
Dark bands are called A-bands or Anisotropic bands whereas light bands are Isotropic or I-bands.
Rest of the pairs are correctly matched.

5. In the centre of each I-band, there is an elastic fibre called
(a) I-line (b) Z-line
(c) A-line (d) H-zone

Ans. (*b*) In the centre of each I-band, there is an elastic fibre called Z-line, which bisects it. The thin filaments are firmly attached to the Z-line.

6. The H-zone in the skeletal muscle fibre is due to
(a) the absence of myofibrils in the central portion of A-band
(b) the central gap between myosin filaments in the A-band
(c) the central gap between actin filaments extending through myosin filaments in the A-band
(d) extension of myosin filaments in the central portion of the A-band

Ans. (*c*) The H-zone in the skeletal muscle fibres is the central gap between actin filaments extending through myosin filaments in the A-band. Alternate arrangement of dark and light bands gives the striated appearance to a skeletal muscle. At the centre of A-band, a comparatively less dark zone called H-zone is present.

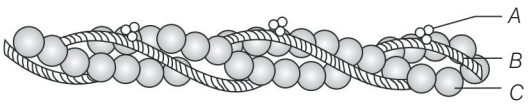
7. Cross arms of the myosin monomer consist of
(a) outward projection of G-actin filament
(b) outward projection of the head region of meromyosin
(c) outward projection of the tail region of meromyosin
(d) Both (b) and (c)

Ans. (*b*) The cross arms of myosin monomer consist of a head and short arm which projects outwards at regular distance and angle from each other, from the surface of polymerised myosin filament. The globular head is an active ATPase enzyme and has binding sites for ATP and active sites for actin.

8. Active binding sites for actin are located on
(a) troponin (b) tropomyosin
(c) meromyosin (d) Both (a) and (c)

Ans. (*c*) Active (binding) sites for actin are located on the globular head of a meromyosin. The globular head is an active ATPase enzyme which contains binding sites for both ATP and actin.

9. Identify *A*, *B* and *C* in the given diagram.



(a) *A*–Troponin, *B*–Tropomyosin, *C*– F-actin
(b) *A*–Thick filament, *B*–Troponin, *C*–Tropomyosin
(c) *A*–Myosin filament, *B*–Troponin, *C*–Tropomyosin
(d) *A*–Meromyosin, *B*–Troponin, *C*–Tropomyosin

Ans. (*a*) The given diagram is of an actin filament in which *A* is troponin *B* is tropomyosin and *C* is F-actin.

10. Action potential in the sarcolemma of muscles is generated by
(a) neuroinhibitors (b) acetylcholine
(c) methylcholine (d) ethylcholine

Ans. (*b*) A neural signal reaching neuromuscular junction releases a neurotransmitter, i.e. acetylcholine. It generates an action potential in the sarcolemma. This spreads through the muscle fibre and causes the release of calcium ions into the sarcoplasm.

11. Which muscle band remains unchanged during the contraction and relaxation of the skeletal muscle?
(a) I (b) H
(c) A (d) E

Ans. (*c*) A-band or Anisotropic band remains unchanged during the contraction and relaxation of the skeletal muscles. The H-zone narrows and even disappears when the thin myofilaments meet at the centre of the sarcomere. The size of I-band also decreases.

12. For how long, contraction of the muscles continues in sliding filament theory?
(a) Till ATP binds to myosin head
(b) Till ADP binds to myosin head
(c) Till Ca^{2+} present in sarcoplasm
(d) Till polymerisation of myosin head is going on

Ans. (*c*) Sliding of actin and myosin filaments continues till the Ca^{2+} 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 of muscle fibre.

13. Match the following columns.

	Column I		Column II
A.	Fast muscle fibres	1.	Myoglobin
B.	Slow muscle fibres	2.	Lactic acid
C.	Actin filament	3.	Contractile unit
D.	Sarcomere	4.	I-band

Codes

	A	B	C	D
(a)	1	2	4	3
(b)	2	1	3	4
(c)	2	1	4	3
(d)	3	2	4	1

Ans. (*c*) A–2, B–1, C–4, D–3

14. Muscle contains a red coloured oxygen containing pigment called
(a) rhodopsin
(b) myoglobin
(c) haemocyanin
(d) Both (a) and (b)

Ans. (*b*) Muscles contain a red coloured oxygen containing pigment called the myoglobin. It is abundantly found in the red muscle fibres than white muscle fibres.

15. Aerobic muscles and anaerobic muscles are called
(a) red fibres; white fibres, respectively
(b) white fibres; red fibres, respectively
(c) white fibres; yellow fibres, respectively
(d) red fibres; yellow fibres, respectively

Ans. (*a*) Aerobic muscles and anaerobic muscles are called red and white fibres, respectively.

• Assertion-Reasoning MCQs

Direction (Q. Nos. 1-5) *Each of these questions contains two statements, Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) A is false, but R is true

1. **Assertion** (A) Muscle fibre is a syncytium.
Reason (R) The sarcoplasm of muscle fibre contains numerous nuclei.

Ans. (*a*) Both A and R are true and R is the correct explanation of A.
Muscle fibre is a syncytium as its sarcoplasm contains many nuclei.

2. **Assertion** (A) The myosin rich zone called A-band maintains its length during sarcomere contraction.
Reason (R) The length of I-band remains the same during muscle contraction.

Ans. (*c*) A is true, but R is false. R can be corrected as
The length of the I-band shortens during muscle contraction.

The formation of cross-bridges causes the pulling of 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 the shortening of the muscle, the I-bands get reduced, whereas the A-bands retain its length.

3. **Assertion** (A) On stimulation, a muscle cell releases calcium ions ($\mathbf{Ca^{2+}}$) from sarcoplasmic reticulum.

Reason (R) By reacting with a protein complex, $\mathbf{Ca^{2+}}$ uncover active sites on the actin filaments.

Ans. (***b***) Both A and R are true, but R is not the correct explanation of A.

A neural signal reaching the neuromuscular 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^+ levels leads to the binding of calcium to the subunit of troponin on actin filaments and thereby removes the masking of active sites for myosin.

4. **Assertion** (A) Calcium is required for skeletal muscle contraction.

Reason (R) Calcium influx releases acetylcholine at neuromuscular junction.

Ans. (***c***) A is true, but R is false. R can be corrected as

Calcium ions are required for skeletal contraction. Sarcoplasmic reticulum releases Ca^+ on receiving stimulus at the neuromuscular junction or motor end plate. When a neural signal reaches the neuromuscular junction, a neurotransmitter called acetylcholine is released at this junction and generates an action potential in the sarcolemma. This spreads throughout the muscle fibre and causes the release of the calcium ions into the sarcoplasm.

5. **Assertion** (A) Red muscle fibres depend on anaerobic process for energy.

Reason (R) Red muscle fibres have more number of mitochondria in them.

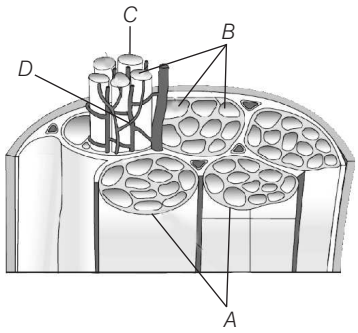
Ans. (***d***) A is false, but R is true. A can be corrected as

Red muscle fibres have more number of mitochondria but less sarcoplasmic reticulum. These fibres are dark red in colour due to the presence of myoglobin. These carry out aerobic respiration.

White muscle fibres depend on anaerobic process for energy as, number of mitochondria are also few in them, but the amount of sarcoplasmic reticulum is huge.

• Case Based MCQ

1. Observe the diagram given below and answer the questions that follows.



(i) Identify *A* and *B*.

(a) Fascicle, Muscle fibre
(b) Muscle cell, Muscle bundle
(c) Sarcolemma, Muscle bundle
(d) Muscle cell, Muscle fibre

Ans. (***a***) *A*–Fascicle and *B*–Muscle fibre

(ii) *A* is held together by

(a) myofibrils (b) fascia
(c) fasicle (d) sarcomere

Ans. (***b***) Muscle bundle or fascicle (*A*) is held by fascia.

(iii) *B* contain well-developed sarcoplasmic reticulum also known as

(a) ectoplasmic reticulum
(b) sacrolemma
(c) endoplasmic reticulum
(d) Both (a) and (c)

Ans. (***c***) Muscle fibre contain well-developed sacroplasmic reticulum also known as endoplasmic reticulum.

(iv) Identify *C*.

(a) Sarcolemma (b) Sarcomere
(c) Sarcoplasm (d) Myofibrils

Ans. (***a***) *C* represents sarcolemma.

(v) Thin filament of myofibril contains two F-actins and two other proteins namely …*P*… and …*Q*… .

P	*Q*
(a) Actin	Myosin
(b) Troponin	Actin
(c) Troponin	Tropomyosin
(d) Meromyosin	Meromyosin

Ans. (***c***) Thin filament of myofibril contains two F-actins and two other proteins namely troponin and tropomyosin.

PART 2

Subjective Questions

• Short Answer (SA) Type Questions

1. Mention and explain the special properties of muscle.

Ans. The special properties exhibited by muscles are

(i) **Contractibility** The cells of muscle can be shorten considerably and return to the original relaxed state.

(ii) **Excitability** It is due to the energy stored in the electrical potential difference across the plasma membrane.

(iii) Muscles also possess properties of extensibility and elasticity (because of proteins, actin and myosin).

2. How do you distinguish between a skeletal muscle and a cardiac muscle. **(NCERT)**

Ans. Differences between skeletal muscle and cardiac muscle are as follows

Skeletal Muscle	Cardiac Muscle
It is found in limbs, tongue, all parts in association with the skeleton of organism.	It is found in the walls of heart and large veins.
Fibres are unbranched.	Fibres are branched.
It is multinucleate.	It is uninucleate.
No oblique bridge and intercalated discs.	Oblique bridges and intercalated discs are present.
It gets fatigued soon.	It never gets fatigued.
It is voluntary in nature.	It is involuntary.

3. Give a brief account of visceral muscles. Mention their function.

Ans. Visceral or smooth muscles are found in the inner walls of hollow visceral (internal) organs of body like alimentary canal, reproductive tract, etc. They do not exhibit any striation and are smooth in appearance and hence, are called **smooth muscles** (non-striated muscle). They are also known as **involuntary muscles** as they are not under the voluntary or direct control of the nervous system.

They assist in the transportation of materials, e.g. movement of food through the digestive tract and gametes through the genital tract.

4. Sarcolemma, sarcoplasm and sarcoplasmic reticulum refer to a particular type of cell in our body. Which is this cell and to what parts of that cell do these names refer to? **(NCERT Exemplar)**

Ans. The cell is muscle.

These names refer to the following parts

Sarcolemma–Plasma membrane

Sarcoplasm–Cytoplasm

Sarcoplasmic reticulum–Endoplasmic reticulum

5. Write true or false. Correct each false statement to make it true.

(i) Actin is present in thin filament.

(ii) H-zone of striated muscle fibre represents both thick and thin filaments.

(iii) In a muscle fibre, Ca^{2+} is stored in nucleus.

(iv) Thin filaments of myofibrils contain 2 F-actins. **(NCERT)**

Ans. (i) True

(ii) False, H-zone of striated muscle fibre represents only thick filaments.

(iii) False, in a muscle fibre, Ca^{2+} is stored in sarcoplasmic reticulum.

(iv) True

6. Name the two important parts of meromyosin.

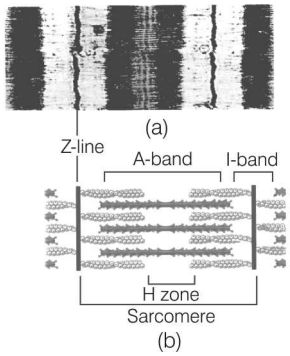
Ans. Two important parts of meromyosin are

(i) Globular head with short arm, called Heavy Meromyosin (HMM).

(ii) Tail, called the Light Meromyosin (LMM).

7. Draw the diagram of a sarcomere of skeletal muscle showing different regions. **(NCERT)**

Ans.



Diagrammatic representation of (a) Anatomy of a muscle fibre showing a sarcomere, (b) A sarcomere

8. Describe the important steps in muscle contraction. **(NCERT)**

Ans. Following are the steps involved in skeletal muscle contraction

(i) **Stimulation**

(a) Nerve impulse arrives at neuromuscular junction and release of acetylcholine takes place.

(b) Spreading of action potential through muscle fibre.

(c) The release of Ca^{2+} from sarcoplasmic reticulum to cytoplasm of muscle fibre.

(ii) **Contraction**

(a) ATP joins to meromyosin head that hydrolyses into ADP and Pi releasing energy, which in turn raises the head to high energy state (the head joins active site on actin, forming cross-bridge).

(b) ADP and Pi are released and head returns to low energy state.

(c) Actin filament is thus, pulled towards centre of sarcomere. And a new ATP joins head, detaching it from actin filament.

(d) Above mentioned steps are thus, repeated many times during one contraction to draw the thin myofilaments further inward.

9. What is the role of calcium in muscle contraction?

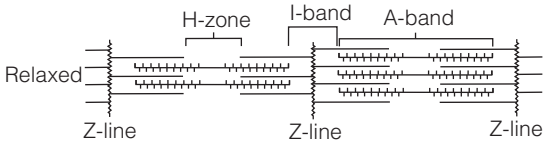
Ans. Calcium is important in skeletal muscle contraction because it binds to troponin to unmask/expose the active sites on actin for myosin binding. By utilising the energy from ATP hydrolysis, the myosin head now binds to the exposed active sites on actin to form a cross-bridge.

This pulls the attached actin filaments towards the centre of A-band and the Z-line attached to these actins are also pulled inwards thereby, causing contraction of muscle.

10. (i) How does a muscle return to its original form during relaxation? Also draw a diagram showing relaxation of muscle.

(ii) What causes muscle fatigue?

Ans. (i) The calcium ions after contraction are quickly pumped back to the sarcoplasmic cisternae. This leads to blocking of active sites on actin myofilaments.
The Z-line returns to the original position. Causing muscles to return to its original position, i.e. relaxation form.



(ii) Repeated activation of the muscles leads to accumulation of lactic acid due to anaerobic breakdown of glycogen in them which causes fatigue.

11. Radha was running on a treadmill at a great speed for 15 minutes continuously. She stopped the treadmill and abruptly came out. For the next few minutes, she was breathing heavily/fast. Answer the following questions.

(i) What happened to her muscles when she strenuously exercised?

(ii) How did her breathing rate change?

(NCERT Exemplar)

Ans. (i) By strenuous exercise, the metabolism of the muscle increases, which leads to increased consumption of oxygen and ATP. To meet this demand, blood supply of muscle is also enhanced.

(ii) Increased consumption of oxygen and increased production of $\mathbf{CO_2}$ stimulates the respiratory centres, which causes the change of breathing rate.

12. What kind of muscle fibres are richly found in the extensor muscles of the back?
What characteristics enable these fibres to serve their purpose?

Ans. Red striated muscle fibres are richly found in the extensor muscles of the back.

Their abundant myoglobin and mitochondria enable them to serve their purpose.

13. Why is muscle fibre a syncytium? How are myofilaments arranged in it?

Ans. Muscle fibre is a syncytium as the sarcoplasm contains many nuclei. Myofilaments are parallelly arranged and are present in large number in muscle fibre.

14. Why are muscles rigidly locked in whatever position they are after death? What is the phenomenon known as?

Ans. Muscles require ATP to relax as well as to contract. On animal's death, its muscles soon exhaust ATP and lose the ability to contract or relax. They become rigidly locked in whatever position they were when ATP gets completely used up. This phenomenon is known as Rigor Mortis. It is used in determining the time of death.

• Long Answer (LA) Type Questions

1. Differentiate between

(i) Actin and myosin filaments,

(ii) A-band and I-band,

(iii) Non-muscular and muscular movements

Ans. (i) Differences between actin and myosin filaments are as follows

Actin Filaments	Myosin Filaments
These are found in I-band.	These are found in A-band.
These are thin.	These are thick.
Cross-bridges (heads) are absent.	Cross-bridges (heads) are present.
It is a globular protein with low molecular weight.	It is a heavy molecular weight polymerised protein.

(ii) Differences between A-band and I-band are as follows

A-Band	I-Band
It is formed of myosin filaments.	It is formed of only actin filaments.
It gives dark appearance.	It gives light appearance.

It has a light H-zone in the centre.	It has dark Krause's membrane in the centre.
It is anisotropic band which possesses two types of proteins.	It is isotropic band which possesses only one type of proteins.

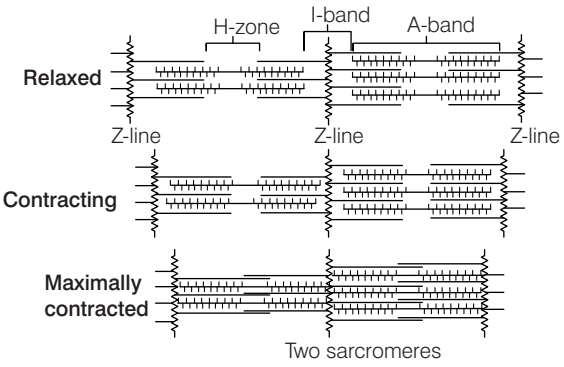
(iii) Differences between non-muscular and muscular movements are as follows

Non-muscular Movements	Muscular Movements
These movements include pseudopodial and ciliary movements.	These movements are brought about by movement of myofilaments within muscle firbres.
They persist in the animals in some of their cells.	These are found in majority of animals.

2. Explain sliding filament theory of muscle contraction with neat sketches. **(NCERT Exemplar)**

Ans. The sliding filament theory of muscle contraction was given by two individual groups of scientists AF Huxley and R. Niedergerke and by HE Huxley and Jean Manson. The muscle contraction begins when the neural signal reaches the neuromuscular junction from CNS *via* motor neurons which release acetylcholine. The acetylcholine present in the synaptic cleft binds to the receptor sites of motor end plate and cause its depolarisation which creates an action potential.

The induced action potential reaches sarcoplasmic reticulum of muscle fibre and cause the relase of Ca^{2+}ions. These Ca^{2+} ions bind to troponin and change their shape which in turn change the shape of tropomyosin and expose the active sites on the F-actin. Then the myosin cross-bridge is able to bind with the active sites in the presence of myosin, ATPase, Ca^{2+} ions and Mg^{2+} ion, ATP breaks down into ADP and phosphate and energy is released in the head.



Energised myosin head binds to actin filament. The cross-bridge moves and causes this filament to slide along the thick myofilament. Loss of energy causes the myosins to move back to its original position. ATP binds to myosin head, causing dissociation from actin and muscle relaxes. This process continues till Ca^{2+} are pumped back to the sarcoplasmic cisternae, masking the actin filaments. This causes relaxation of the muscles.

• Case Based Questions

1. **Direction** *Read the following passage and answer the questions that follows.*

In a biology class, Amit read that human body contain different muscles, depending upon the functions of associated organs. He also learnt about the structure of these muscles and found that skeletal muscles anatomy is of great significance.

(i) Which type of muscles are found in visceral organs of body?

Ans. Visceral organs are lined by smooth muscles. These are non-striated in appearance.

(ii) Name the muscles which are controlled voluntarily and non-voluntarily, respectively.

Ans. Skeletal or striated muscles are controlled voluntarily whereas cardiac and smooth muscles are controlled involuntarily.

(iii) Mention two structural characteristics of cardiac muscles.

Ans. Cardiac muscles are branched, striated in appearance and possess intercalated discs.

(iv) Name two important proteins which form light and dark bands in skeletal muscles.

Ans. Light bands in skeletal muscles are formed by actin protein whereas the dark bands are composed of myosin protein.

2. **Direction** *Read the following passage and answer the questions that follows.*

Akhil, a class XI student is very casual regarding his studies. One day, his classes were suppose to commence from 8 : 00 AM. But he left his home at 7 : 45 AM. He started running on his way, but after 400-500 m, he felt a severe cramp in his leg. Due to this cramp, he had to stop and he missed his morning class.

(i) What is the reason of the muscle cramp?

Ans. Due to lack of oxygen, anaerobic respiration start in the muscle. This leads to accumulation of lactic acid in the muscle which results in muscle cramp.

(ii) How could one get rid off the cramp?

Ans. One can get rid off it by resting for some time, so that normal breathing rate resumes.

(iii) Name the oxygen carrying pigment in muscles?

Ans. Myoglobin or muscle haemoglobin is the oxygen carrying pigment of muscles.

(iv) What does the sliding filament theory states?

Ans. The sliding filament theory states that contraction of muscle takes place by the sliding of thin and thick filament with the help of cross-bridge.

(v) What changes in I and A-bands occur during muscle contraction?

Ans. During muscle contraction the I-band get reduced while the A-band retain its length.

Chapter Test

Multiple Choice Questions

1. Visceral muscles are likely to be found in
(a) brain and spinal cord
(b) digestive tract
(c) biceps and triceps
(d) All of the above

2. Myofilaments or Myofibrils are
(a) obliquely arranged filaments of muscle fibre
(b) parallelly arranged filaments of muscle fibre
(c) horizontally arranged filaments of muscle fibre
(d) radially arranged filaments of muscle fibre

3. Which one is incorrectly matched?
(a) Heavy meromyosin — Globular head
(b) Smooth muscle — Involuntary muscle
(c) Red muscle — Myoglobin
(d) Troponin — Fibrous protein

4. Actin and myosin filaments of muscles are also called
(a) thick and thin filaments, respectively
(b) thin and thick filaments, respectively
(c) black and white filaments, respectively
(d) white and black filaments, respectively

5. Consider the following statements.
I. In resting state, edges of thin filament partially overlap the ends of thick filament.
II. H-zone is the overlapped area of thick and thin filaments.

Select the correct option.
(a) I is true, II is false
(b) Both I and II are true
(c) I is false, II is true
(d) Both I and II are false

Assertion-Reasoning MCQs

Direction (Q. Nos. 1-3) *Each of these questions contains two statements, Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) A is false, but R is true

1. **Assertion** (A) Visceral muscles are smooth in appearance.
Reason (R) Many muscles assemble in a branching pattern to form a visceral muscle.

2. **Assertion** (A) Biceps and triceps are antagonastic muscles.
Reason (R) The biceps flexes the arm and the triceps straighten the arm.

3. **Assertion** (A) There are similarities between the locomotion of unicellular organism and multicellular animal.
Reason (R) Ciliary, fragellar and amoeboid movements occur in unicellular organisms.

Short Answer Type Questions

1. Define myoglobin. What is its importance in muscles?

2. Define the given terms
(i) Tropomyosin
(ii) Meromyosin

3. Write a short note on skeletal muscle.

Long Answer Type Questions

1. How does a muscle shorten during its contraction and return to its original form during relaxation?

2. (i) Exchange of calcium between bone and extracellular fluid take place under the influence of certain hormones. What will happen if more of Ca^{2+} is in extracellular fluid?
(ii) What will happen if very less amount of Ca^{2+} is in the extracellular fluid?

Answers

Multiple Choice Questions

1. *(b)* ***2.*** *(b)* ***3.*** *(d)* ***4.*** *(b)* ***5.*** *(a)*

Assertion-Reasoning MCQs

1. *(c)* ***2.*** *(a)* ***3.*** *(b)*