PRE-MEDICAL

ZOOLOGY

ENTHUSIAST | LEADER | ACHIEVER

STUDY MATERIAL

Locomotion and movement (Limb muscles)

ENGLISH MEDIUM

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LOCOMOTION AND MOVEMENT-II (LIMB MUSCLES)

01. INTRODUCTION

- Introduction
- Types of movements
- Muscles
- Disorders of muscular system
- Properties of 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.

02. 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 along with 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.

03. MUSCLES

- Study of muscles known as Myology.
- Myology also known as Sarcology.
- All muscles of body develop from **mesoderm.**
- They have special properties like excitability, contractility, extensibility and elasticity.
- About 40-50 percent of the body weight is contributed by muscles.

Three types of muscles are found in the body.

(i) Voluntary or skeletal muscles.

(ii) Involuntary or smooth muscles.

(iii) Cardiac muscles.

(1) SKELETAL MUSCLES

- 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.**
- They are primarily involved in locomotory actions and changes of body postures.
- Their contractions are controlled by will power of animal so also called **voluntary muscles**.

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**.

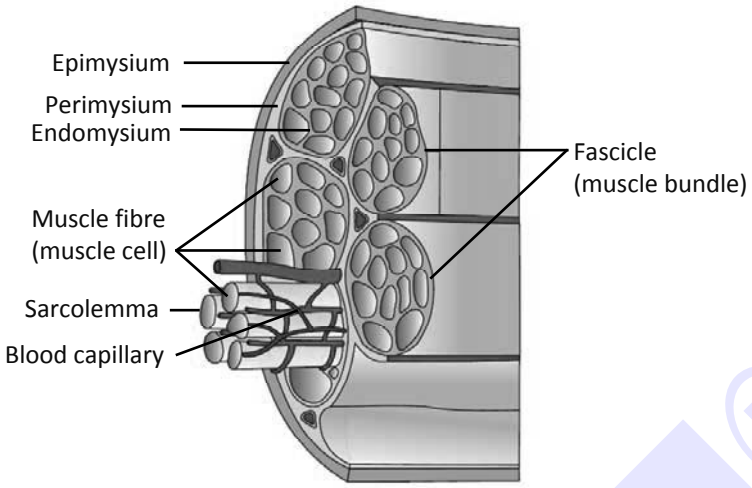
Each fasciculi is covered by a layer of connective tissue which is called **perimysium**.

Many fasciculi combined to form a **muscle**.

Muscle is also covered by a layer of connective tissue which is called as **epimysium**.

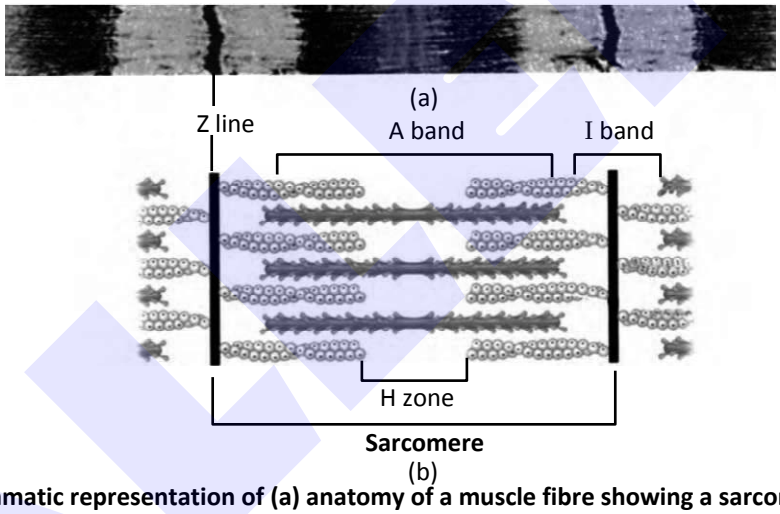
The muscle fibres attached to a tough cord of connective tissue called **tendon.** Tendon is further attached with a bone.

(A) Structure of muscle fibre :



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

NCERT XI Page No. 304, Figure No. 20.1



Diagrammatic representation of (a) anatomy of a muscle fibre showing a sarcomere (b) a sarcomere

NCERT XI Page No. 305, Figure No. 20.2

Fine structure of muscle fibre :-

- Skeletal muscle fibre is cylindrical or tubular in shape and is long and Unbranched.
- The outer membrane of muscle fibre is called **sarcolemma**.
- This cell membrane contain collagen fibres.
- Each muscle fibre contain multinucleated sarcoplasm.
- Nucleus & sarcoplasm are found in peripheral part.
- Myofibril are arranged in parallel rows & form the dark & light line.

  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 band are mono-refractive in polarised light so it is called **Isotropic band** (I band).
- 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.** In a resting state, the edges of thin filaments on either side of the thick filaments partially overlap the free ends of the thick filaments leaving the central part of the thick filaments. This central part of thick filament, not overlapped by thin filaments is called the **'H' zone.**
- **Sarcomere** is considered as the **functional unit** of contraction.

Sarcomere = 1A band + two half I band

The Length of Sarcomere is 2.5 µm.

(I band = 1µm, myosin = 1.5 µm)

- 1 Myosin filament is surrounded by 6 Actin filaments & 1 Actin filament is surrounded by 3 Myosin filaments.
- Z-disc is made up of **actinin protein.**

(B) Structure of contractile protein :

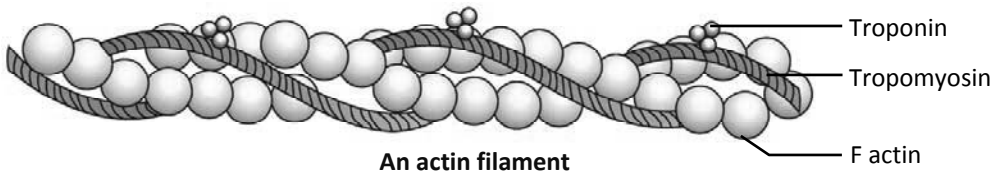
(a) Actin (Thin) filament

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

Two filaments of another protein, tropomyosin also run close to the 'F' actins throughout its length.

A complex protein Troponin is distributed at regular intervals on the tropomyosin.

In the resting state a subunit of troponin masks the active binding sites for myosin on the actin filaments.



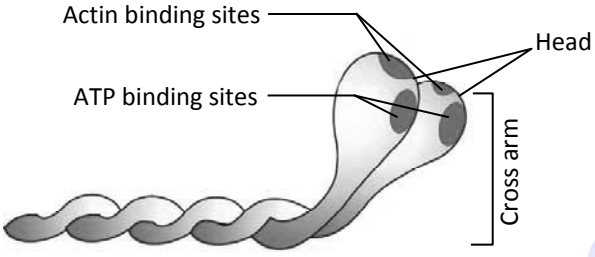
An actin filament

NCERT XI Page No. 306, Figure No. 20.3 (a)

Troponin is made up of three subunit.

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

(b) Myosin (Thick) Filament



Myosin monomer (Meromyosin)

NCERT XI Page No. 306, Figure No. 20.3 (b)

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 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.

BEGINNER'S BOX — INTRODUCTION, STRUCTURE OF SKELETAL MUSCLE

1. Type of movement shown by macrophages is :
   (1) Amoeboid (2) Ciliary (3) Muscular (4) Flagellar

2. From outer to inner correct sequence of connective tissue layers covering a muscle fibre is :
   (1) Epimysium → Perimysium → Endomysium
   (2) Perimysium → Epimysium → Endomysium
   (3) Epimysium → Endomysium → Perimysium
   (4) Perimysium → Endomysium → Epimysium

3. Monomeric form of actin is called –
   (1) F-actin (2) G-actin (3) M-actin (4) A-actin

4. Components of heavy meromyosin are –
   (1) Head & cross arm (2) Head & short arm (3) Head & tail (4) Cross arm & tail

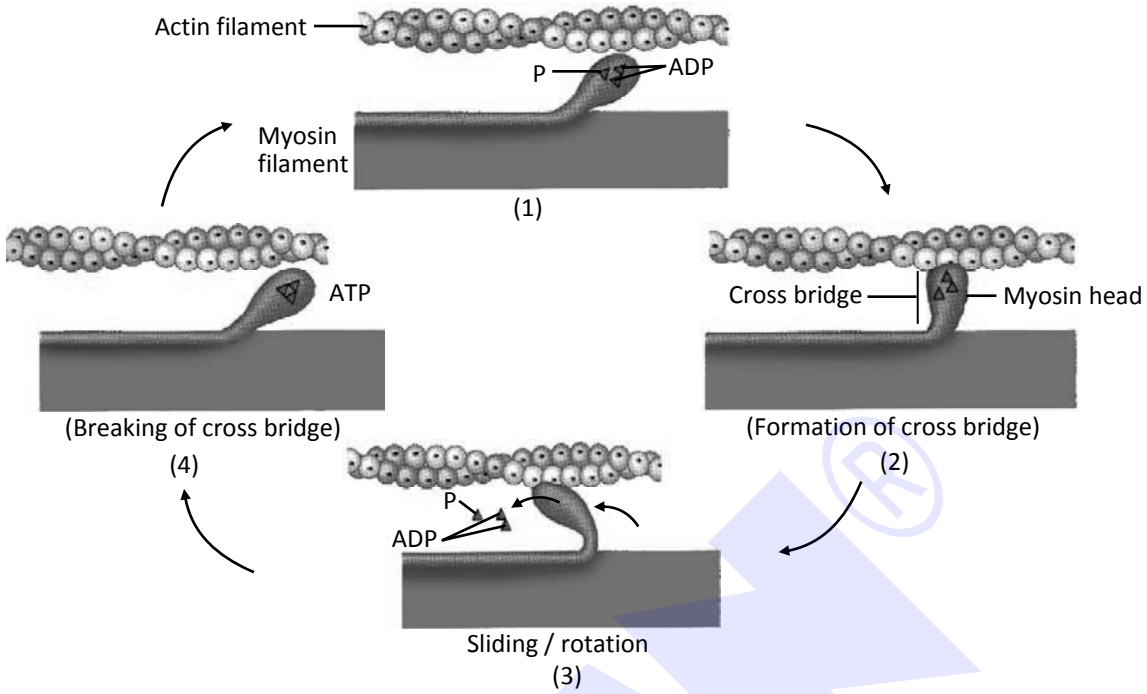
(C) Mechanism of muscle contraction :

- 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 along with 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 (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^{++} 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.**
- 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.
- During shortening of the muscle (contraction), the 'I' bands get reduced, whereas the 'A' bands retain the length.
- The myosin, releasing the ADP and P_i 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.
- 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.
- Repeated activation of the muscles can lead to the accumulation of lactic acid due to anaerobic breakdown of glycogen in them, causing fatigue.

Role of ATP :

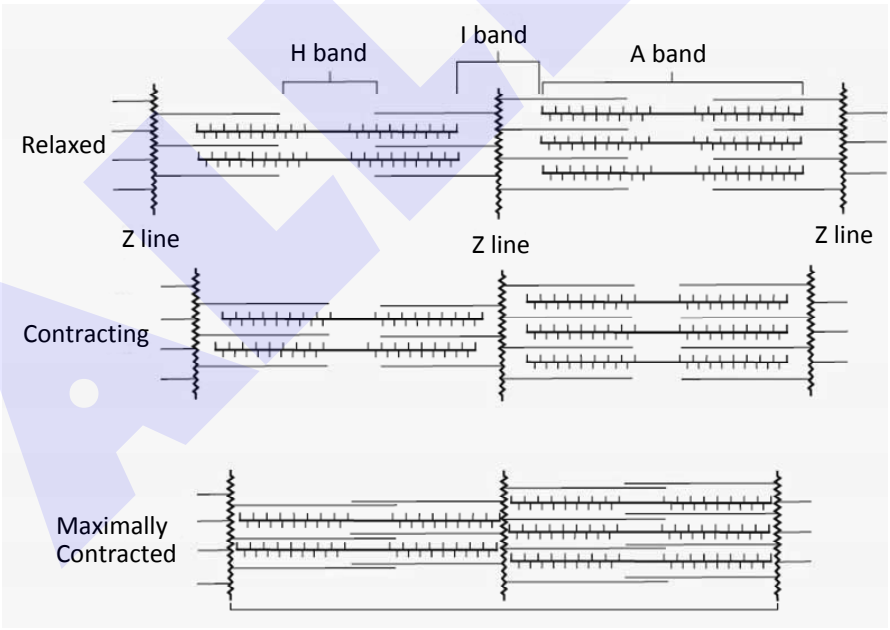
(a) The 'back & forth' movement of myosin head with in the groove.

(b) Detachment of myosin head from the actin.



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

NCERT XI Page No. 307, Figure No. 20.4



Two Sarcomeres

NCERT XI Page No. 308, Figure No. 20.5

DIFFERENCE BETWEEN RED MUSCLE AND WHITE MUSCLE

Red (slow) muscle	White (fast) muscle
1. Myoglobin content is high so, it is red	1. Myoglobin content is less so, it is pale
2. Sarcoplasmic reticulum is less extensive	2. Sarcoplasmic reticulum is more extensive
3. Blood vessels are more extensive	3. Blood vessels are less extensive
4. Mitochondria are more in number	4. Mitochondria are less in number
5. Response is slow with long latent period	5. Response is rapid with short latent period
6. Contraction is less powerful	6. Contraction is more powerful
7. This muscle is involved in prolonged and continued activity as it undergoes sustained contraction	7. This muscle is not involved in prolonged and continued activity as it relaxes immediately
8. Fatigue occurs slowly	8. Fatigue occur quickly
9. Depends on cellular respiration for ATP production so also called aerobic	9. Depends on anaerobic process for energy.

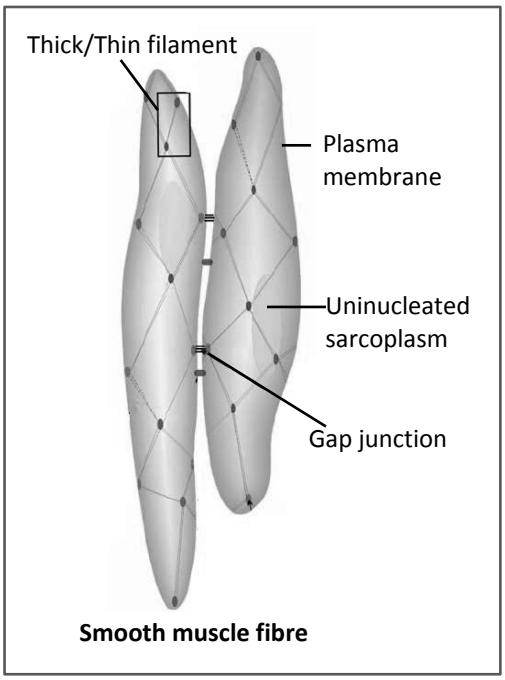
Marathon athletes develops red fibre in thigh muscle due to repeated contraction.

(2) SMOOTH MUSCLE

- It is not related to the skeleton so also called as **Non skeletal muscle**.
- These muscle 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 short, spindle shaped, unbranched.
- 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.

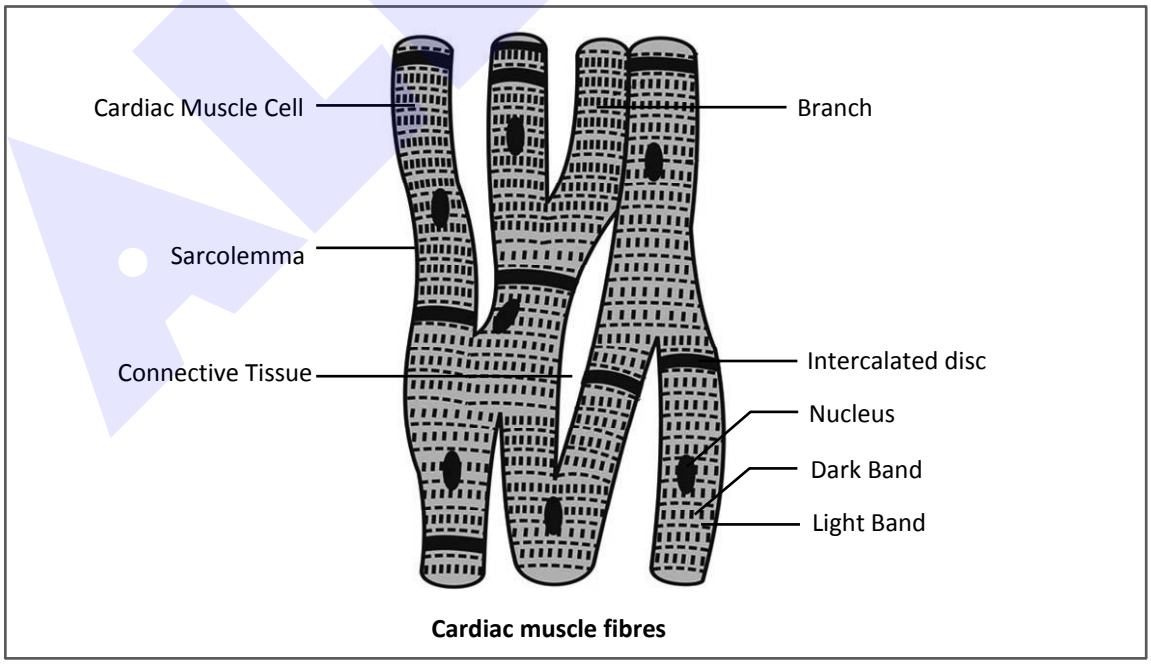


Smooth muscle fibre

- **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^{++} ions**.
- Its contraction period is longer.
- It remain in contracted stage for longer period. Due to this reason muscle called **non fatigue muscle**.

(3) CARDIAC MUSCLE

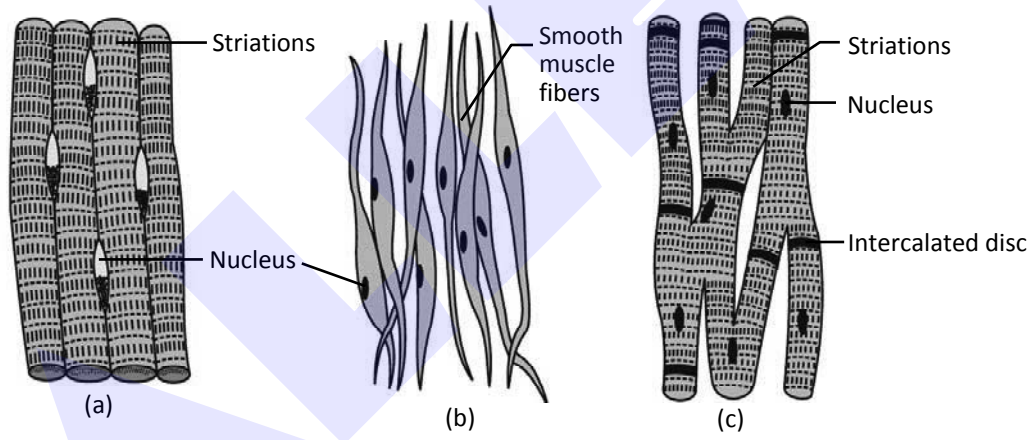
- It is special type of muscle which found only in heart so it is also called as cardiac muscle. On the basis of structure it is **striated type of muscles**. Intercalated disc, helps in the propagation of impulse & contraction.
- Their muscle fibres are long, cylindrical and branched.
- Many transverse septa are found in the muscle fibre which are called as **intercalated disc**.
- 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. It is also **non fatigue type muscle**.
- Its contraction is not controlled by will power of animal.
- On the basis of function it is **smooth muscle type.**



Cardiac muscle fibres

DIFFERENCE BETWEEN STRIATED, NON-STRIATED AND CARDIAC 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.	Do not get fatigue	Never fatigued



Muscle tissue : (a) Skeletal (striated) muscle tissue
(b) Smooth muscle tissue, (c) Cardiac muscle tissue

NCERT XI Page No. 105, Figure No. 7.7

04. DISORDERS OF MUSCULAR SYSTEM

Myasthenia gravis: Auto immune disorder affecting neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscle.

Muscular dystrophy: Progressive degeneration of skeletal muscle mostly due to genetic disorder.

Tetany: Rapid spasms (wild contractions) in muscle due to low Ca^{++} in body fluid.

05. PROPERTIES OF MUSCLES

(a) **Origin** - fixed end of muscle (Proximal end).

Insertion - Distal end of muscle which is attach to bone (Movable end).

(b) **Excitability** - Muscles responds to stimuli which can be nervous, chemical, electrical & thermal & mechanical.

Conductivity - Stimulus acting in one region of muscle fibres propagated to all parts within no time.

Contractility - on being stimulated the muscle fibres contract & shorten followed by relaxation.

(c) **Threshold Stimulus -**

Intensity of stimulus below the threshold value which does not produces contraction in muscle fibres is called **sub threshold stimulus.**

Stimulus stronger than threshold one is called **supra threshold stimulus.**

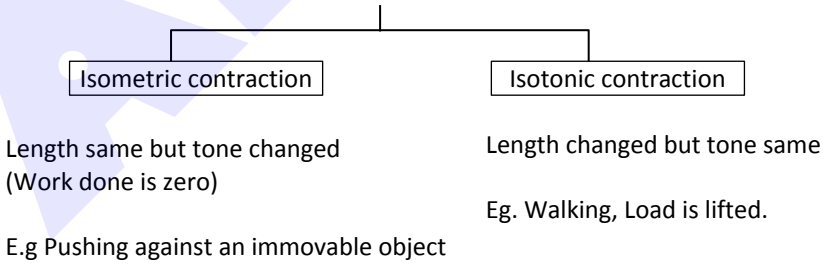
(d) **All or none law -** Response of muscle fibre is maximum whether the stimulus has threshold value or supra threshold value.

Response is absent when intensity is sub threshold (Below threshold value).

(e) **Paralysis -** Supply of motor nerve impulse completely cut off. So function of muscle contraction is stopped.

(f) **Shivering -** Involuntary contraction of muscles to make body warm.

(g) **Muscle tension -** force produced during contraction of muscle is known as muscle tension.



(h) **Rigor Mortis –** 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. detachment 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.

(i) During muscle contraction chemical energy changed into mechanical energy.

(j) Over stretching of ligament is called Sprain.

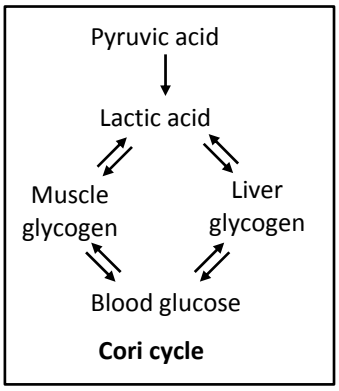
(k) **Phosphogens -** These are highly energy N-based compounds which are found in the muscles. In the invertebrates **arginine phosphate** and in the vertebrate **creatine phosphate** act as a phosphogens. These compounds provide energy during contraction.

Creatine phosphate + ADP $\underset{\text{at rest stage}}{\overset{\text{muscle conraction}}{\rightleftharpoons}}$ Creatine + ATP

(l) In the muscles, 75% water, 20% protein and in remaining part glycogen, creatine phosphate, inorganic ions (K^+, Na^+, HCO_3^-) are present.

Golden Key Points

1. Muscles make up 40-50% of your total body weight.
2. Humans are born with all the muscle fibres they will ever have.
3. Gastrocenemius muscle present in shank.
4. Sartorius **Longest** muscle of body.
5. Gluteus maximus (Buttock muscles) – **Largest** muscle of body.
6. Stapedius – **Smallest** muscle of body.
7. Jaw muscles (masseter) – are strongest muscle.
8. In Human beings 639 muscle are found. 400 muscles are striated & most of the muscles are found in back region & number of back muscles are 180. Longest smooth muscle is present in uterus of pregnant lady.
9. **Cori cycles –** Lactic acid accumulated in muscles 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.



Cori cycle

BEGINNER'S BOX — MUSCLE CONTRACTION & DISORDERS

1. Length of following does not decrease during muscle contraction –
   (1) Sarcomere (2) A-band (3) I band (4) H-zone
2. Cross bridge is broken due to –
   (1) Binding of ATP at myosin head (2) Hydrolysis of ATP at myosin head
   (3) Binding of ATP at troponin (4) Hydrolysis of ATP at troponin
3. Multinucleated muscle is –
   (1) Skeletal (2) Cardiac (3) Smooth (4) Both (2) & (3)
4. Autoimmune disorder affecting muscle is :
   (1) Myasthenia gravis (2) Tetany
   (3) Muscular dystrophy (4) Rheumatoid arthritis
5. Organ involved in cori cycle is –
   (1) Kidney (2) Spleen (3) Lungs (4) Liver

BEGINNER'S BOX — ANSWER KEY

INTRODUCTION, STRUCTURE OF SKELETAL MUSCLE

Que.	1	2	3	4
Ans.	**1**	**1**	**2**	**2**

MUSCLE CONTRACTION & DISORDERS

Que.	1	2	3	4	5
Ans.	**2**	**1**	**1**	**1**	**4**

TYPES OF MOVEMENT

- Amoeboid — e.g. Leucocytes in blood
- Ciliary — e.g. Cilia in trachea
- Muscular — e.g. Locomotion in Human

DIFFERENCE BETWEEN STRIATED, NON-STRIATED AND CARDIAC 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
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5.	Light and Dark band present	Absent	Present
6.	Controlled by CNS.	ANS	Both CNS + ANS
7.	Soon fatigue.	Do not get fatigue	Never fatigued

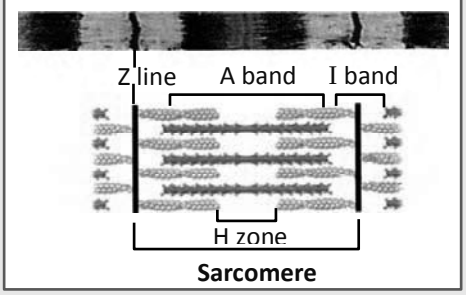
SKELETAL MUSCLE

Structural Unit

Muscle fibre
Plasma membrane-sarcolemma
↓
Covered by endomysium
↓
Bundle of muscle fibres (fascicle)
↓
Covered by perimysium
↓
Entire muscle covered by epimysium

Functional Unit

Sarcomere
1/2 I + A + 1/2I



Sarcomere

MUSCLE PROTEIN

- Thick Filament
  - Myosin (Contractile)
    - Monomer-Meromyosin
      - HMM
      - LMM
- Thin Filament
  - Actin (Contractile)
  - Tropomyosin (Regulatory)
  - Troponin (Regulatory)

SLIDING FILAMENT THEORY