LOCOMOTION AND MOVEMENT

Locomotion is the voluntary movements resulting in a in location. All locomotion are movements but all movements are not locomotion. Both are interlinked. E.g.

- In *Paramoecium*, cilia help in the movement of food through cytopharynx and in locomotion.
- *Hydra* use tentacles to capture prey and for locomotion.
- Limbs help to change body postures and for locomotion.

Types of movement in human being

- **Amoeboid movement:** By **pseudopodia** formed by streaming of protoplasm as in *Amoeba.* Cytoskeletal elements like microfilaments also help for this. E.g. change Macrophages & leucocytes.
- **Ciliary movement:** By **cilia.** E.g. ciliary movements in trachea (to remove dust particles and foreign substances), and oviducts (for the passage of ova).
- **Muscular movement:** By muscles. E.g. movement of limbs.

Flagellar movement helps in the swimming of spermatozoa, maintenance of water current in the canal system of sponges and in locomotion of Protozoans like *Euglena.*

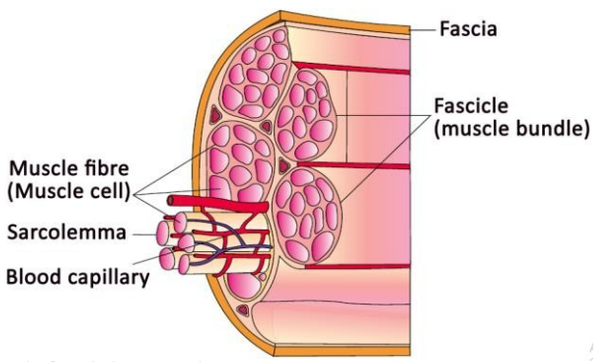
HUMAN MUSCULAR SYSTEM

- It includes muscles which are mesodermal in origin.
- Muscles constitute 40-50% of the body weight.
- Muscles have excitability, contractility, extensibility & elasticity.
- Based on location, muscles are 3 types:

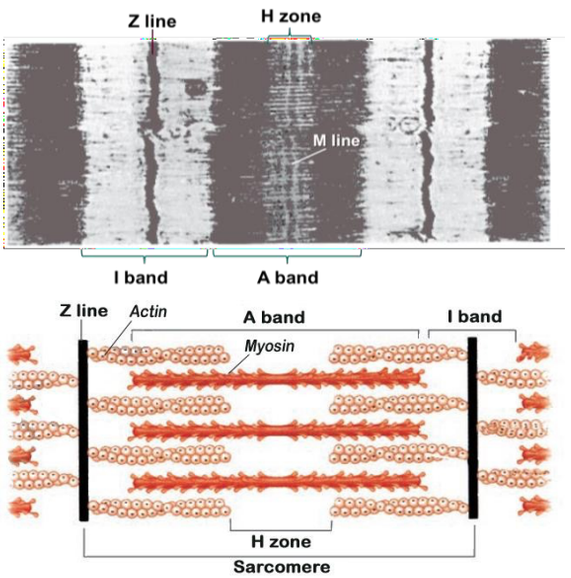
Skeletal (striated) muscles	Visceral (Non-striated) muscles	Cardiac muscles
Attached to skeleton	In visceral organs	In heart wall
Striations present	Absent	Present
Voluntary	Involuntary	Involuntary
Rich blood supply	Poor blood supply	Rich blood supply
Fatigue muscle	Non-fatigue	Non-fatigue
Multinucleate	Uninucleate	Uninucleate
More mitochondria	Less mitochondria	More mitochondria

STRUCTURE OF STRIATED MUSCLE

- Skeletal muscle is made of **muscle bundles (fascicles)** held together by collagenous connective tissue layer **(fascia).**

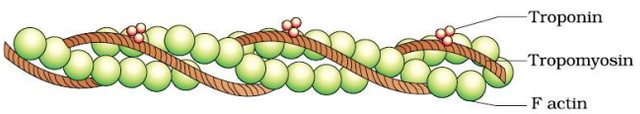


- Each fascicle contains many **muscle fibres (muscle cells).**
- Muscle fibres are lined by **plasma membrane (sarcolemma)** enclosing the **sarcoplasm.**
- Each muscle fibre contains **myofilaments (myofibrils).**
- Each myofibril has alternate **dark (Anisotropic or A-band)** and **light striations (Isotropic or I-band)**. This is due to the presence of 2 fibrous contractile proteins- thin **Actin filament** and thick **Myosin filament**.
- I-bands contain actin. A-bands contain actin and myosin. They are arranged parallel to each other.
- A-band bears a lighter middle region **(H band)** formed of only myosin. A thin dark line (**M-line**) runs through the centre of **H-zone**.
- I-band is bisected by a dense dark band called **Z-line**. Region between two Z-lines is called **sarcomere.** They are the *functional units of muscle contraction.*

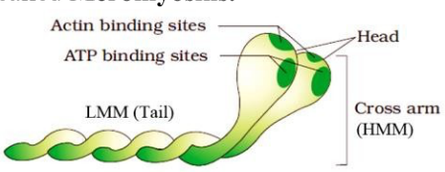


Structure of contractile proteins

- An **actin filament** is made of **2 filamentous (F) actins** which form double helix.
- F-actin is a polymer of monomeric **Globular (G) actins.**



- Actin contains 2 other proteins **(tropomyosin & troponin).**
- Two filaments of **tropomyosin** run along the grooves of the F-actin double helix.
- **Troponin** has 3 subunits. It is seen at regular intervals on tropomyosin. In the resting state, **a subunit of troponin** masks the binding sites for myosin on the actin filaments.
- Each myosin filament is a polymer of many **monomeric proteins** called **Meromyosins.**



- A meromyosin has 2 parts:
  - **Heavy meromyosin or HMM or cross arm (globular head + short arm)**: It projects outwards.
  - **Light meromyosin or LMM (tail).**
- The globular head is an active ***ATPase*** **enzyme** and has **binding sites for ATP** and **active sites for actin.**

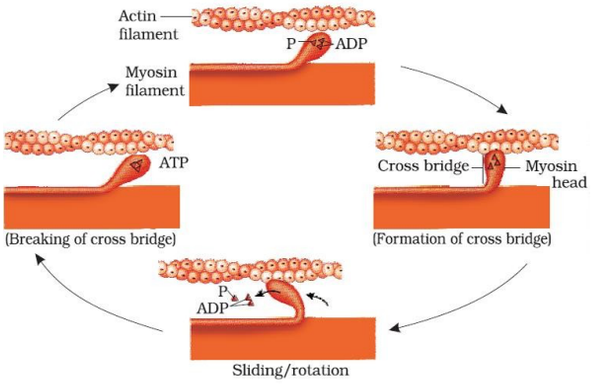
MECHANISM OF MUSCLE CONTRACTION

According to **sliding filament theory,** *contraction of a muscle fibre occurs by the sliding of thin filaments over thick filaments.* The steps are given below:

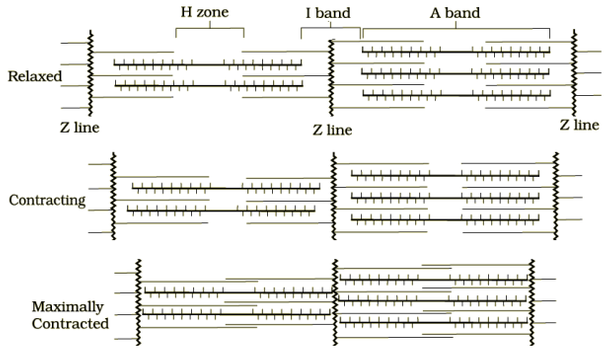
- An **impulse** from the **CNS** reaches the **neuromuscular junction (Motor-end plate)** via **motor neuron**.

> **Neuromuscular junction** is the synapse between a motor neuron and the sarcolemma of the muscle fibre.
> **A motor neuron + muscle fibres = a motor unit.**

- Synaptic vesicles release a neurotransmitter **Acetylcholine.** It generates an **action potential** in the sarcolemma that spreads through the muscle fibre. It causes the release of **Ca^{2+} ions** from sarcoplasmic cisternae into **sarcoplasm.**
- **Ca** binds with a subunit of **troponin** on actin filaments and unmask the active sites for myosin.



- Using energy from **ATP hydrolysis, myosin head** binds to **active sites** on the actin to form **cross bridge.** This pulls actin filaments on both sides towards the centre of **A-band.** Actin filaments partially overlap so that H-zone disappears.
- The **Z- line** attached to actins is also pulled inwards. It causes a shortening **(contraction)** of **sarcomere.**
- I-bands get shortened, whereas A-bands retain the length.
- Myosin releases **ADP** and **Pi** and goes back to its relaxed state. A new ATP binds and the cross-bridge is broken.
- The ATP is again hydrolyzed by the myosin head and the above processes are repeated causing further sliding.
- When Ca^{2+} ions are pumped back to sarcoplasmic cisternae, actin filaments are again masked. As a result, Z-lines return to their original position. It results in **relaxation.**



- The reaction time of the fibres varies in different muscles.
- Repeated activation of muscles leads to the accumulation of the **lactic acid** causing **muscle fatigue**. This is due to **anaerobic breakdown** of **glycogen** in muscles.

Red muscle fibres and white muscle fibres

Red (Aerobic) muscles	White muscle
Red coloured due to myoglobin	White coloured due to lesser myoglobin
More mitochondria	Less mitochondria
Aerobic metabolism	Anaerobic metabolism
Slow & sustained contraction	Fast contraction for short period

HUMAN SKELETAL SYSTEM

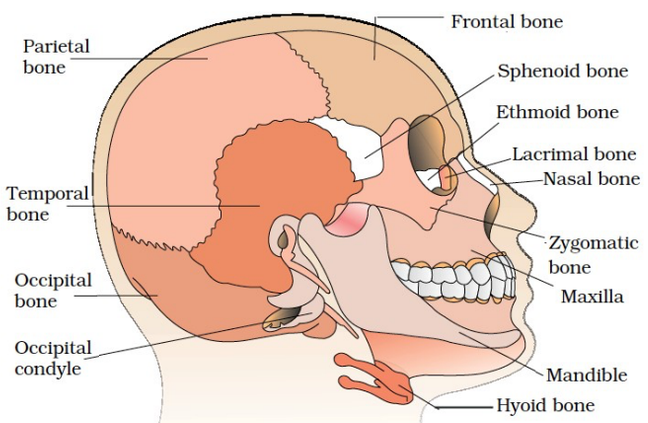
It consists of a framework of **bones (206)** & **few cartilages**. Human skeletal system has 2 parts: **axial & appendicular.**

1. Axial skeletal system (80 bones)

Includes **bones of head, vertebral column, sternum & ribs.**

a. Bones of Head (29 bones)

It includes skull, Hyoid and Ear ossicles.

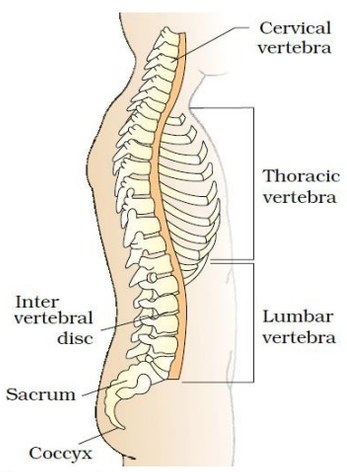


- **Skull (22):** Include cranial bones and facial bones.
  Cranial bones (8): Include *Frontal (1), Parietals (2), Temporals (2), Occipital (1), Sphenoid (1) &Ethmoid (1).*
  Facial bones (14): Include *Nasals (2), Maxillae (2), Zygomatics (2), Lacrimals (2), Palatines (2), Inferior nasals (2), Mandible (1) and Vomer (1).*

  Skull articulates with ***First vertebra (atlas)*** with the help of 2 ***occipital condyles (dicondylic skull).***
- **Hyoid bone (1):** U-shaped bone seen below buccal cavity.
- **Ear ossicles (3 x 2 = 6):** *Malleus (2), Incus (2) & stapes (2).*

b. Vertebral column

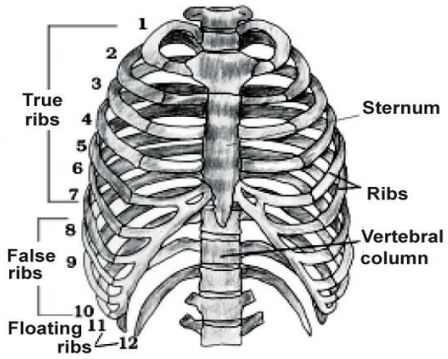
- Formed of **26 vertebrae.** Includes *Cervical vertebrae (7), Thoracic vertebrae (12), Lumbar vertebrae (5), Sacral vertebrae (1-fused) and Coccygeal vertebrae (1-fused).*
- Vertebra has a central hollow portion ***(neural canal)*** through which the ***spinal cord*** passes.
- Number of cervical vertebrae are 7 in almost all mammals.
- The ***vertebral column*** protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back.



c. Sternum or Breast bone (1)

- Flat bone on the ventral midline of thorax.

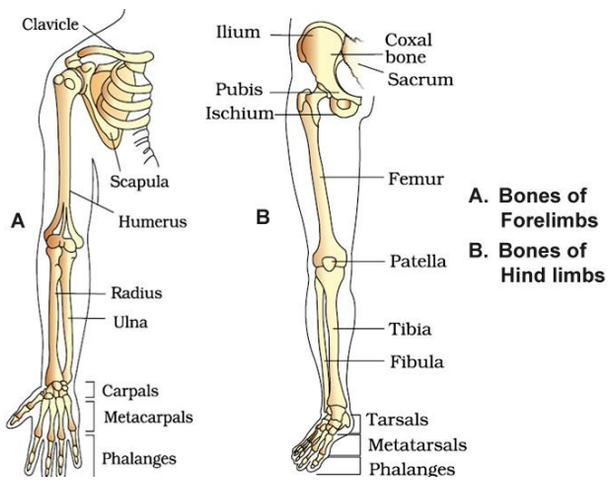
d. Ribs (12 pairs)



- **True ribs** (first 7 pairs): They are attached to ***thoracic vertebrae*** and ventrally connected to sternum with the help of ***Hyaline cartilage.***
- **Vertebrochondral (false) ribs** (8^{th}, 9^{th} & 10^{th} pairs): They do not articulate directly with the sternum but join the ***7^{th} rib*** with the help of ***Hyaline cartilage.***
- **Floating ribs** (11^{th} & 12^{th} pairs): They are not connected ventrally (no connection with sternum or other ribs).

- Each rib has 2 articulation surfaces on its dorsal end and is hence called **bicephalic.**

2. Appendicular skeletal system (126 bones)



a. Bones of fore-limbs (30 x 2 = 60)

Include *Humerus (1), Radius (1), Ulna (1), Carpals (wrist bones-8), Metacarpals (palm bones-5) & Phalanges (digits-14).*

b. Bones of hind-limbs (30 x 2 = 60)

Include *Femur (thigh bone- 1), Patella (knee cap- 1), Tibia (1) & fibula (1), Tarsals (ankle bones-7), Metatarsals (5) & Phalanges (digits-14).*

c. Pectoral girdles (2x2=4)

- Include **clavicle (2) & scapula (2).**
- Scapula is a large *triangular* flat bone situated in the dorsal part of the thorax between ***the second and 7^{th} ribs.***
- **Scapula (shoulder blade)** has a slightly elevated ridge ***(spine)*** which projects as a flat, expanded process ***(acromion).*** The ***clavicle*** **(collarbone)** articulates with this.
- Below the acromion is ***glenoid cavity*** which articulates with the head of ***humerus*** to form the ***shoulder joint.***

d. Pelvic girdles (2)

- Formed of 2 coxal bones. Each coxal bone is formed by the fusion of 3 bones- *Ilium, Ischium & pubis.*
- At the point of fusion of ***Ilium, Ischium*** and ***Pubis*** is a cavity ***(Acetabulum)*** to which the ***thigh bone*** articulates.
- The 2 halves of the ***pelvic girdle*** meet ventrally to form ***pubic symphisis*** containing ***fibrous cartilage.***

JOINTS

Joints are points of contact between bones, or between bones and cartilages. 3 types:

1. **Fibrous (immovable) joints:** E.g. sutures b/w skull bones.
2. **Cartilaginous joints (Slightly movable joints):** Bones are joined together with the help of cartilages. E.g. Joints between the adjacent vertebrae.
3. **Synovial (movable) joints:** They have a fluid filled synovial cavity between articulating surfaces of 2 bones.

Types of synovial joint

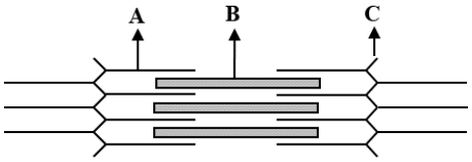
Joint	Examples
Ball & socket	Shoulder joint & hip joints.
Hinge joint	Knee joint, elbow joint, phalanges joints
Pivot joint	Joints b/w atlas & axis.
Gliding joint	Joints b/w carpals
Saddle joint	Joints b/w carpal & metacarpal of thumb

DISORDERS OF MUSCULAR & SKELETAL SYSTEMS

- **Myasthenia gravis:** An auto immune disorder that affects neuromuscular junction. It leads to fatigue, weakening and paralysis of skeletal muscles.
- **Muscular dystrophy:** Progressive degeneration of skeletal muscles. Mostly due to genetic disorder.
- **Tetany:** Rapid muscle spasm due to low Ca^{2+} in body fluid.
- **Arthritis:** Inflammation of joints.
- **Osteoporosis:** Age-related disorder characterized by decreased bone mass and increased chances of fractures. Decreased level of estrogen is a common cause.
- **Gout:** Inflammation of joints due to accumulation of uric acid crystals.

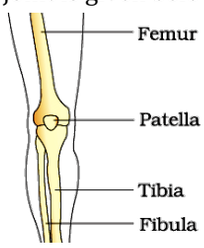
MODEL QUESTIONS

1. When a muscle cell is viewed under a microscope, it has the following characters
   Striations present, Multi nucleate, Sarcolemma present
   a) Identify the tissue b) Mention the function of the tissue
2. Observe the relaxed unit of a muscle given below.

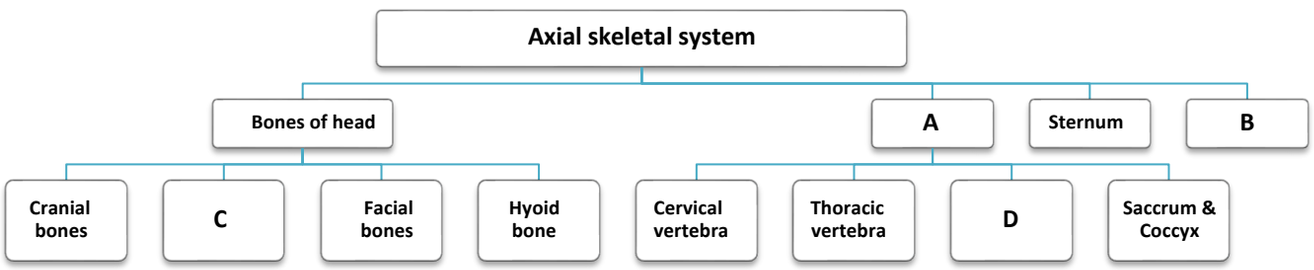


   a) Label A, B & C.
   b) Redraw the diagram when the muscle unit is maximally contracted.
   c) Repeated activation of the muscle can lead to fatigue. Justify.
3. Arrange the following flow chart in the correct sequence of events:

   Generation of action potential in the sarcolemma → Release of Ca^{2+} ions from sarcoplasmic cisternae into sarcoplasm → Active sites of actin are exposed → Impulse from the CNS → Neuromuscular junction → Shortening (contraction) of sarcomere → Synaptic vesicles release Acetylcholine → Actin filaments are pulled towards H-zone → Ca binds with troponin on actin filaments → Myosin head binds to active sites to form cross bridge → H-zone disappears.
4. Suppose a person is suffering from calcium deficiency for a prolonged time. How does it affect muscular contraction?
5. Diagram of a joint is given below:



   a) Identify the joint.
   b) Name three major structural forms of joints.
6. Complete the following chart



7. Match the following

Type of joints	Examples
i. Ball and socket	a) Joints of skull bone
ii. Pivot joint	b) Between carpals and metacarpals of the thumb
iii. Saddle joint	c) Between humerus and pectoral girdle
iv. Gliding joint	d) Between atlas and axis
	e) Between the carpals