CHATPTER-20 HSSLIVE.IN

LOCOMOTION AND MOVEMENT

Introduction

- 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.
- all locomotions are movements but all movements are not locomotions.

TYPES OF MOVEMENT

Cells of the human body exhibit **three** main types of movements, namely, **amoeboid, ciliary and muscular**

a. 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.

b. Ciliary movement

- ✓ This type of 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.

c. 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.

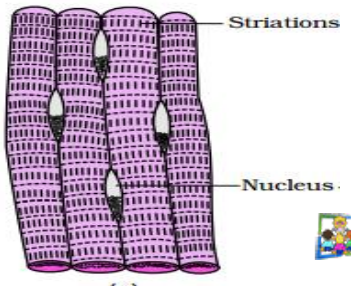
MUSCLES

Muscle is a specialised tissue of **mesodermal origin**. About **40-50 per cent** of the body weight of a human adult is contributed by muscles. They have special properties like **excitability, contractility, extensibility and elasticity**. Muscles have been classified using different criteria, namely location, appearance and nature of regulation of their activities. Based on their location, three types of muscles are identified :

(i) Skeletal (ii) Visceral (iii) Cardiac.

i) Skeletal muscles

They are closely associated with the skeletal components of the body. They have a striped appearance under the microscope and hence are called **striated muscles**. As their activities are under the **voluntary control** of the nervous system, they are known as **voluntary muscles** too. They are primarily involved in locomotory actions and changes of body postures.



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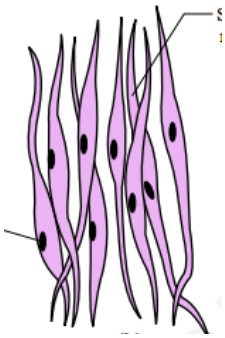
ii) Visceral muscles

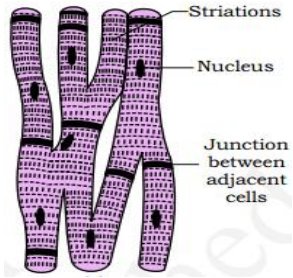
They are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc. They do not exhibit any striation and are smooth in appearance. Hence, they are called **smooth muscles (nonstriated**

muscle). Their activities are not under the voluntary control of the nervous system and are therefore known as **involuntary muscles**. They assist, for example, in the transportation of food through the digestive tract and gametes through the genital tract.



iii)Cardiac muscles

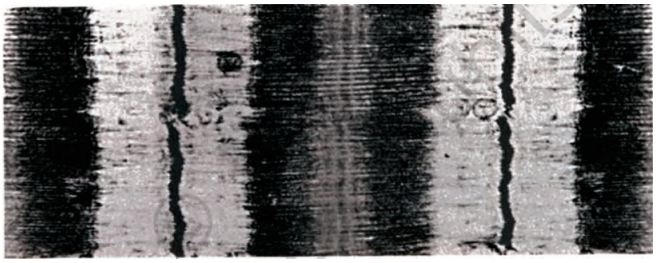
As the name suggests, **Cardiac muscles** are the muscles of heart. Many cardiac muscle cells assemble in a branching pattern to form a cardiac muscle. Based on appearance, cardiac muscles are striated. They are **involuntary** in nature as the nervous system does not control their activities directly.

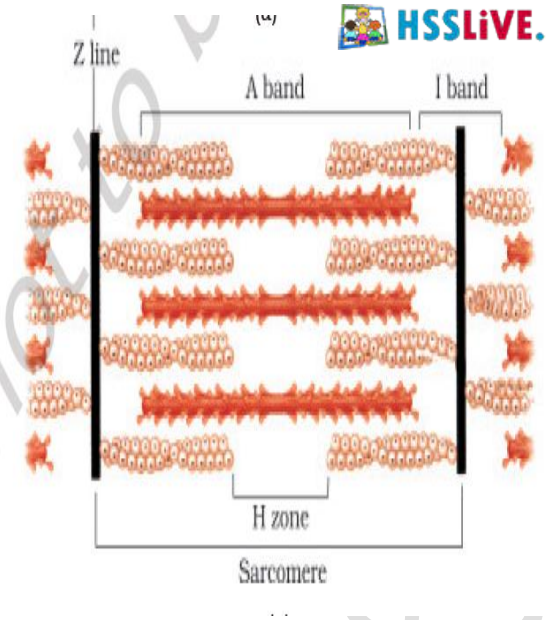


ULTRA STRUCTURE OF SKELETAL MUSCLE

- Each organised skeletal muscle in our body is made of a number of **muscle bundles** or **fascicles** held together by a common collagenous connective tissue layer called **fascia**.
- Each muscle bundle contains a number of **muscle fibres / Muscle cell**
- Each muscle fibre/muscle cell is lined by the plasma membrane called **Sarcolemma** enclosing the **sarcoplasm.**
- Muscle fibre is a **syncitium** as the sarcoplasm contains many nuclei.
- The endoplasmic reticulum, i.e., **sarcoplasmic reticulum** of the muscle fibres is the store house of **calcium ions.**
- A characteristic feature of the muscle fibre is the presence of a large number of parallelly arranged filaments in the sarcoplasm called **myofilaments** or **myofibrils**.
- Each myofibril has **alternate dark and light bands on it**. A detailed study of the myofibril has established that the striated appearance is due to the distribution pattern of two important proteins – **Actin** and **Myosin**.
- **The light bands** contain **actin** and is called **I-band or Isotropic band,** whereas the **dark band called 'A' or Anisotropic band contains myosin**. Both the proteins are arranged as rod-like structures, parallel to each other and also to the longitudinal axis of the myofibrils.
- Actin filaments are thinner as compared to the myosin filaments, hence are commonly called thin and thick filaments respectively.
- 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**.

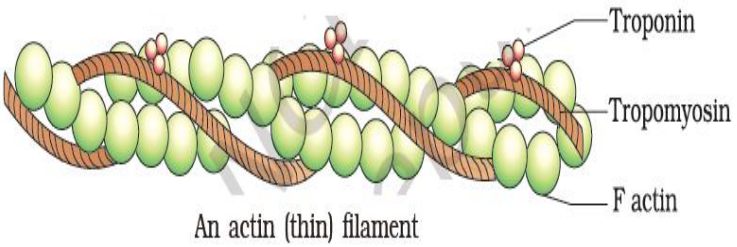




Structure of Contractile Proteins

Actin

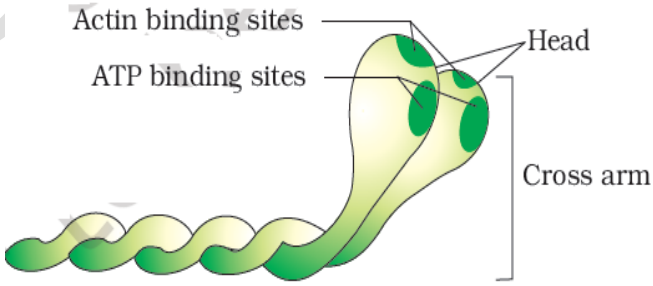
- Each actin (thin) filament is made of **two 'F' (filamentous) actins** helically wound to each other. Each 'F' actin is a polymer of monomeric 'G' (Globular) actins.
- Two filaments of another protein, **tropomyosin** also run close to the 'F' actins throughout its length.
- A complex protein **Troponin** 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 (thin) filament

Myosin

- Each myosin (thick) filament is also a polymerised protein.
- Many monomeric proteins called **Meromyosins** constitute one thick filament nt.
- 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 distance and angle from each other from the surface of a polymerised myosin 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**



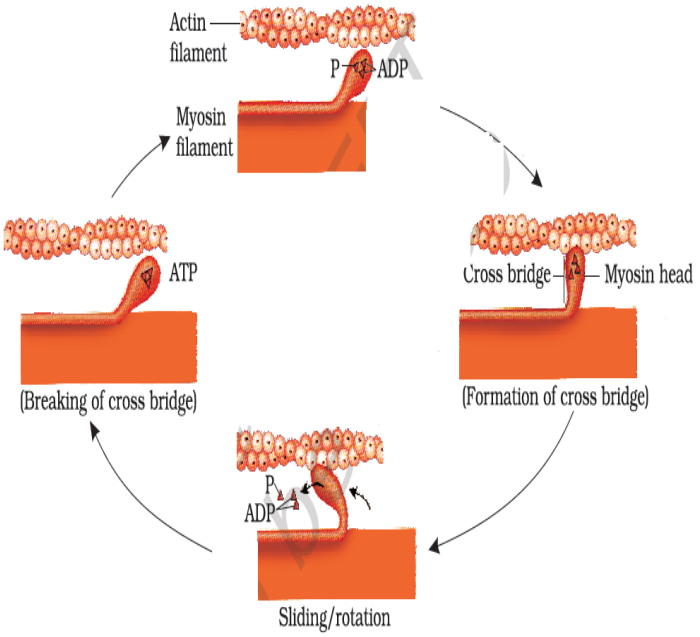
Myosin monomer (Meromyosin)

Mechanism of Muscle Contraction

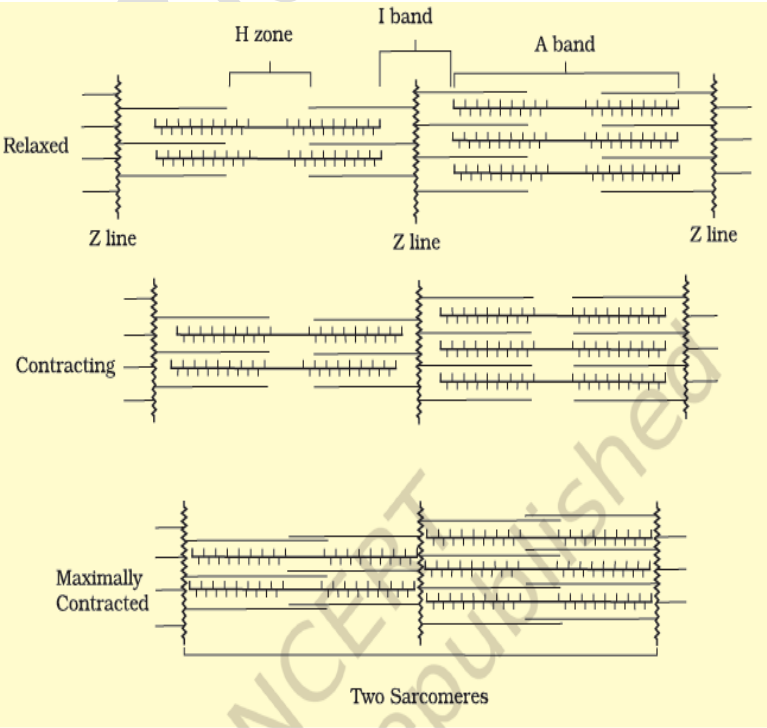
- Mechanism of muscle contraction is best explained by **the sliding filament theory** (Proposed by Huxley and Huxley) which states that contraction of a muscle fibre takes place by the sliding of the thin filaments over the thick filaments
- Muscle contraction is initiated by a signal sent by the central 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** (Acetyl choline) which generates an action potential in the sarcolemma.
- This Action potential or impulse spreads through the muscle fibre and causes the release of **calcium ions** from sarcoplasmic reticulum 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,**
  - **i) shortening of the sarcomere i.e. the adjacent Z line come closer,**
  - **ii) Width of the 'I ' band reduced**
  - **iii) 'H' zone shortens and finally disappear**
  - **iv) The width of the A band remains the same**
- The myosin, releasing the ADP and P1 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.



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



Sliding-filament theory of muscle contraction (movement of the thin filaments and the relative size of the I band and H zones)

Muscle fatigue

Repeated activation of the muscles can lead to the accumulation of **lactic acid** due to anaerobic breakdown of glycogen in them, causing fatigue

Difference between red msucle fire and white muscle fibre

Red muscle	White muscle
1.Red in color	1.pale or White in color

2.Myoglobin content is high	2. less quantity of myoglobin
3.Plenty of mitochondria present	3. Number of mitochondria are also few
4.this muscles uses large amount of oxygen for ATP production and hence called aerobic muscles	4. They depend on anaerobic process for energy
5.Sarcoplasmic reticulam is low in number	5.It contain high number of sarcoplasmic reticulam

Disorders of muscular system

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

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

3. **Tetany:**
   Rapid spasms (wild contractions) in muscle **due to low Ca++** in body fluid.

HUMAN SKELETAL SYSTEM

- Skeletal system consists of a framework of bones and a few cartilages.
- Bone and cartilage are specialised connective tissues.
- The bone has a very hard matrix due to calcium salts in it and the cartilage has slightly pliable matrix due to chondroitin salts
- In human beings, skeletal system is made up of 206 bones and a few cartilages.
- human skeletal system grouped into two principal divisions –

A. the axial skeleton
B. appendicular skeleton.

A. Axial skeleton (80 Bones)

Axial skeleton comprises 80 bones distributed along the main axis of the body. The skull, vertebral column, sternum and ribs constitute axial skeleton.

a.Skull

- The **skull** is composed of two sets of bones cranial and facial, that totals to 22 bones.
- Cranial bones are 8 in number. They form the hard protective outer covering, cranium for the **brain.**
- The facial region is made up of **14 skeletal elements** which form the front part of the skull.
- A single **U-shaped bone** called **hyoid** is present at the base of the buccal cavity and it is also included in the skull.
- Each middle ear contains three tiny bones – **Malleus, Incus and Stapes**, collectively called **Ear Ossicles**.
- The skull region articulates with the superior region of the vertebral column with the help of **two occipital condyles** (**dicondylic skull).**

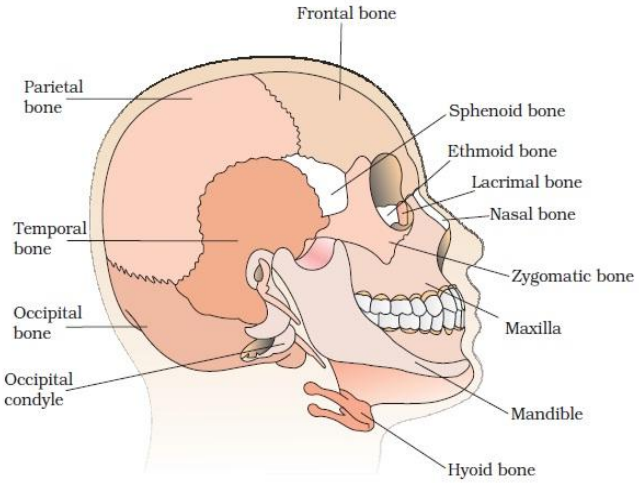
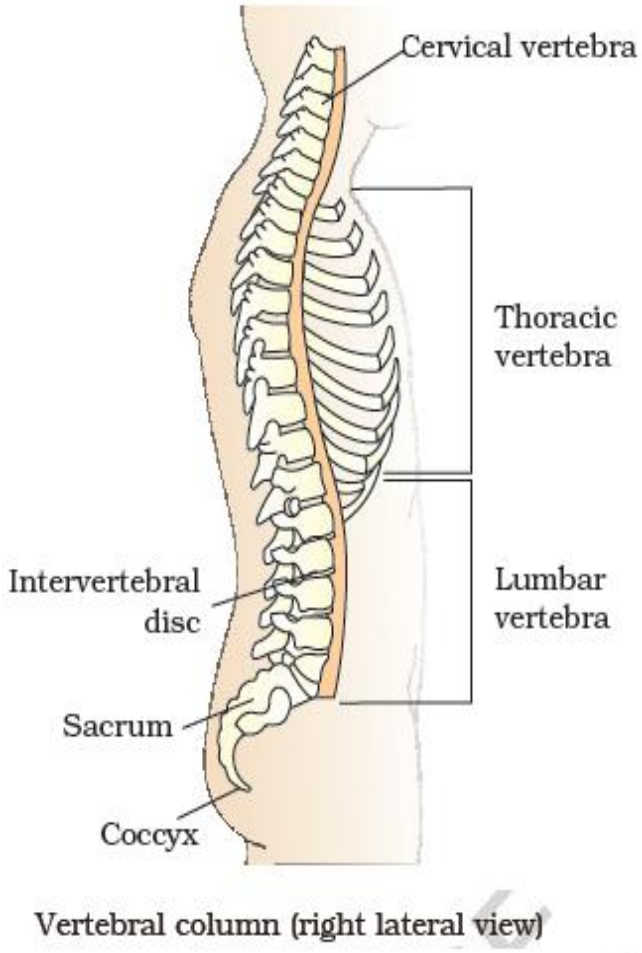


Figure 20.6 Diagrammatic view of human skull

b. vertebral column

- Our **vertebral column** is formed by **26** serially arranged units called vertebrae and is dorsally placed.
- It extends from the base of the skull and constitutes the main framework of the trunk.
- Each vertebra has a central hollow portion (**neural canal**) through which the **spinal cord passes.**
- First vertebra is the **atlas** and it articulates with the **occipital condyles.**
- The vertebral column is differentiated into **cervical (7), thoracic (12), lumbar (5), sacral (1-fused) and coccygeal (1-fused)** regions starting from the skull.
- **The number of cervical vertebrae are seven in almost all mammals including humanbeings**.
- Functions of vertebral column :
  I. The vertebral column protects the spinal cord,
  II. It supports the head and
  III. it serves as the point of attachment
  IV. for the ribs and musculature of the back



Vertebral column (right lateral view)

c.Sternum

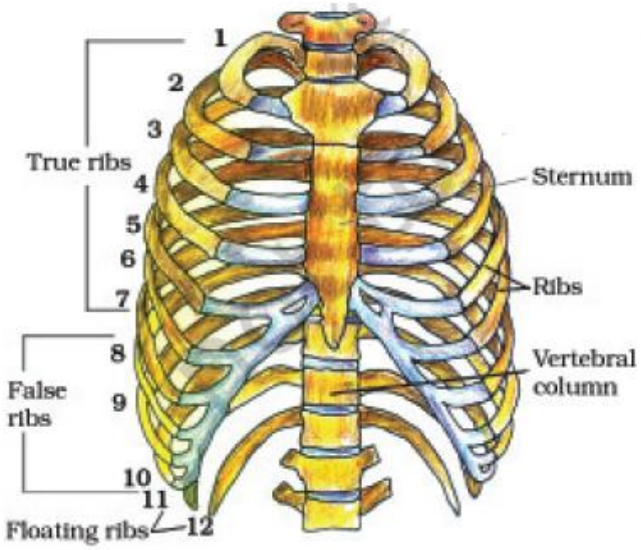
Sternum is a flat bone **on the ventral midline of thorax**

d.Ribs

- There are **12 pairs** of **ribs.**
- Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum.
- It has two articulation surfaces on its dorsal end and is hence called **bicephalic.**
- **First seven pairs of ribs** are called **true ribs.** Dorsally, they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilage.
- **The 8th, 9th and 10th pairs** of ribs do not articulate directly with the sternum but join the seventh rib with the help of hyaline cartilage. These are called **vertebrochondral (false) ribs.**
- **Last 2 pairs (11th and 12th) of ribs** are not connected ventrally and are therefore, called **floating ribs.**

RIB CAGE

- Thoracic vertebrae, ribs and sternum together form the rib cage



Ribs and rib cage

B. Appendicular skeleton (126 bones)

- The bones of the limbs alongwith their girdles constitute the **appendicular skeleton.**

1.Limb Bones

Human being has a pair of fore limb and hind limb and each limb contains **30** bones

a.Fore limb (30×2=60)

The Bones in the hand (fore limb) are

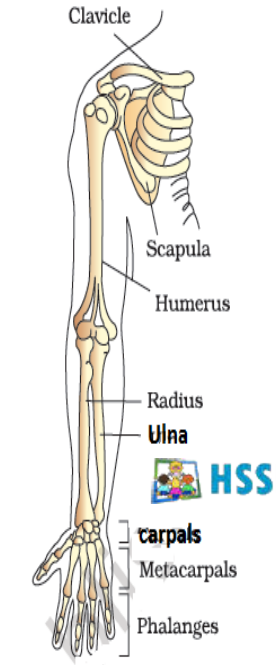
- ✓ humerus (1),
- ✓ radius(1)
- ✓ ulna(1)
- ✓ carpals (wrist bones – 8),
- ✓ metacarpals (palm bones –5)
- ✓ phalanges (digits – 14)

b.Hind limb(30×2=60)

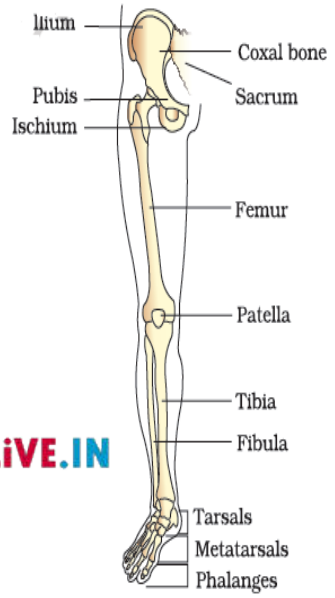
the Bones in the hind limbs are

- ✓ Femur (thigh bone – the longest bone),
- ✓ tibia (1)
- ✓ fibula (1)
- ✓ tarsals (ankle bones – 7)
- ✓ metatarsals (5)
- ✓ phalanges (digits – 14)

- A cup shaped bone called **patella** cover the knee ventrally (knee cap).



Right pectoral girdle and upper arm. (frontal view)



Right pelvic girdle and lower limb bones (frontal view)

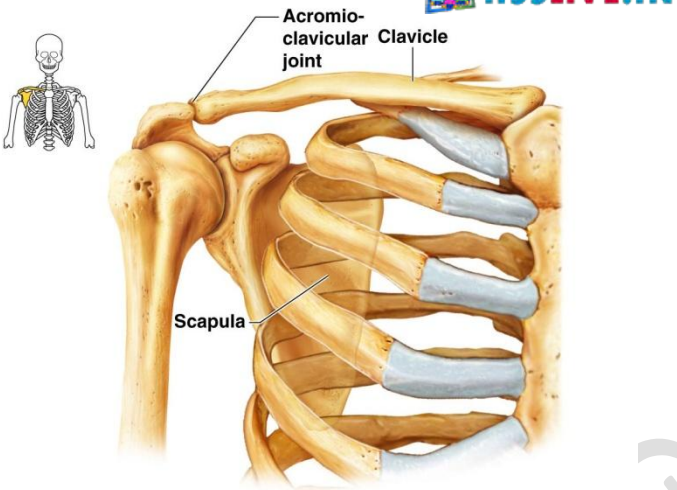
2. Girdle bones

Girdle bones are bones which connect the limb bones with axial skeleton. There are **two girdle bones** namely pectoral girdle and pelvic girdle

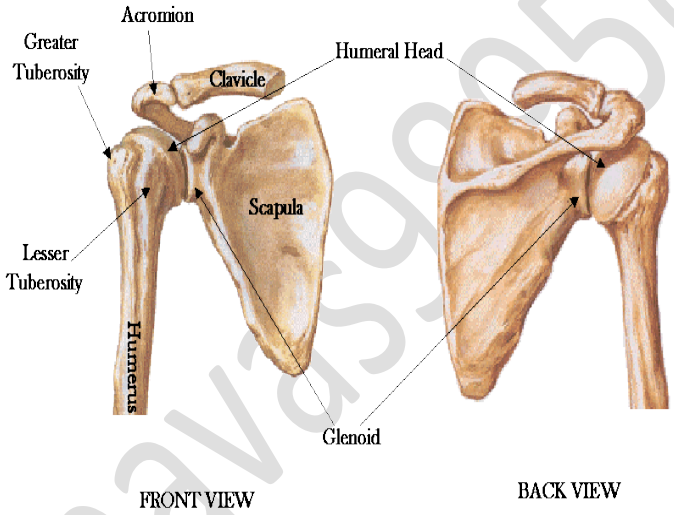
a.Pectroal gridle

- **Pectoral** bones help in the articulation of the upper limbs with the axial skeleton.
- Each girdle is formed of two halves. Each half of pectoral girdle consists of **a clavicle and a scapula**
- Scapula is a large triangular flat bone situated in the dorsal part of the thorax between the second and the seventh ribs.

- The dorsal, flat, triangular body of scapula has a slightly elevated ridge called the spine which projects as a flat, expanded process called the **acromion**. The clavicle articulates with this.
- Below the acromion is a depression called the **glenoid cavity** which articulates with the head of the humerus to form the shoulder joint.
- Each clavicle is a long slender bone with two curvatures. This bone is commonly called the **collar bone**.

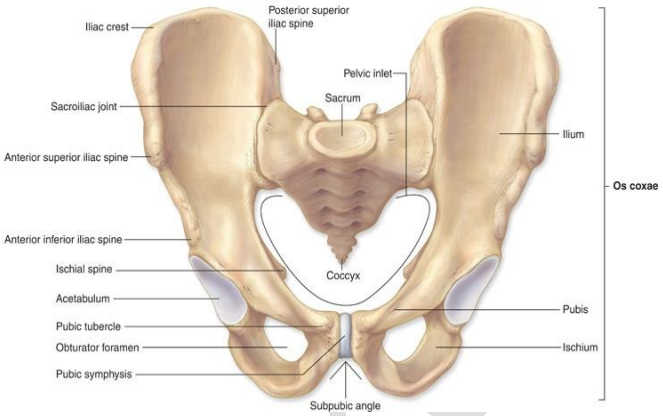


(a) Articulated right shoulder (pectoral) girdle showing the relationship to bones of the thorax and sternum



b)Pelvic girdle

- **Pelvic** bones help in the articulation of the **lower limbs with the axial skeleton**
- **Pelvic girdle** consists of **two coxal bones**
- Each coxal bone is formed by the fusion of three bones – **ilium, ischium and pubis**.
- At the point of fusion of the above bones is a cavity called **acetabulum** to which the thigh bone articulates.
- The two halves of the pelvic girdle meet ventrally to form the **pubic symphysis containing fibrous cartilage**



JOINTS

- Joints are essential for all types of movements involving the bony parts of the body.
- Joints are points of contact between bones, or between bones and cartilages.
- Force generated by the muscles is used to carry out movement through joints, where the joint acts as a fulcrum.
- Joints have been classified into three major structural forms, namely, fibrous, cartilaginous and synovial.

a.Fibrous joints/Immovable joints

- Fibrous joints do not allow any movement.
- This type of joint is shown by the **flat skull bones** which fuse end-to-end with the help of dense fibrous connective tissues in the form of sutures, to form the cranium.

b.Cartilaginous joints/slightly movable joints

- **cartilaginous joints,** the bones involved are joined together with the help of **cartilages.**
- The joint between the **adjacent vertebrae in the vertebral column** is of this pattern and it permits limited movements.

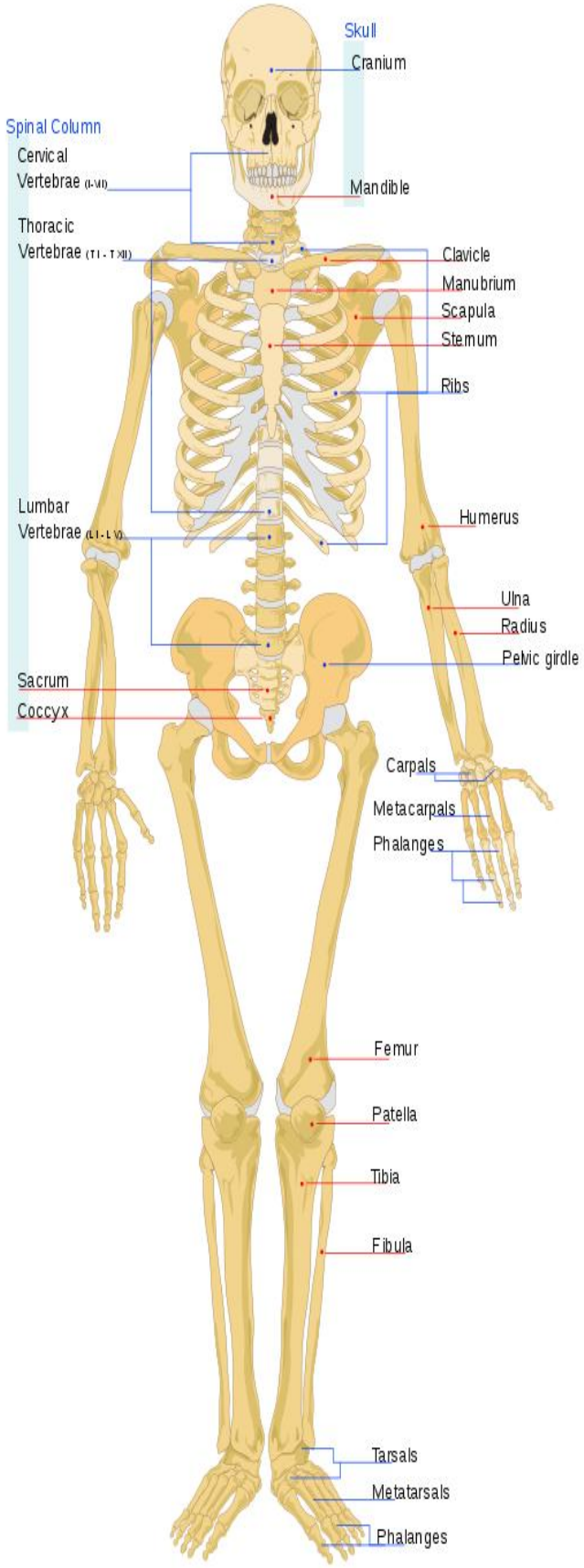
c.Synovial joints/movable joints

- **Synovial joints** are characterised by the presence of a fluid filled **synovial cavity** between the articulating surfaces of the two bones. Such an arrangement allows considerable movement.
  Some synovial joints are given below
- Ball and socket joint (between humerus and pectoral girdle),

- hinge joint (knee joint),
- pivot joint (between atlas and axis),
- Gliding joint (between the carpals)
- saddle joint (between carpal and metacarpal of thumb)

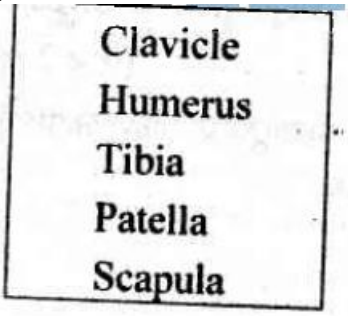
Disorders of SKELETAL SYSTEM

1. **Osteoporosis:**
   Age-related disorder characterised by decreased bone mass and increased chances of fractures. **Decreased levels of estrogen is a common cause**.
2. **Gout:**
   Inflammation of joints due to accumulation of **uric acid crystals.**
3. **Arthritis:**
   It is the Inflammation of joints.



Previous years question Paper

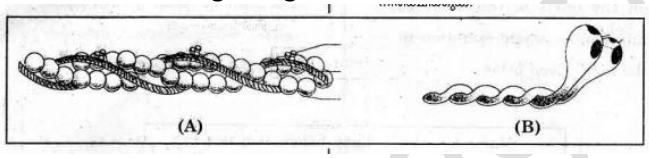
1. Name-of the bones of appendicular skeleton are given below (HSE-July-2019)(2)



(a) Select the bones of pectoral girdle.
(b) Name the articulating cavity between femur and pelvic girdle

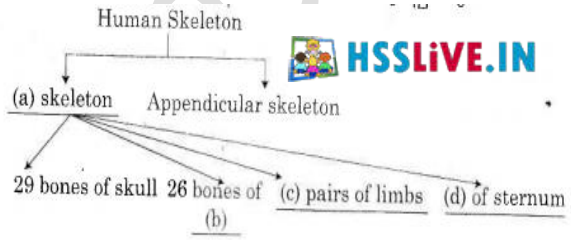
2. Major steps involved in muscle contraction are given below, which are not in the correct order. Arrange them in the correct order.
(a)Remove the mask of active sites for binding myosin
(b) A signal sent out by CNS
(c) Binding of Ca+ with troponin
(d) Release of a neuro-transmitter substance
(e) Release of Ca+ into the sarcoplasm
(HSE-July-2019)(2)

3. Observe the figures given below



a) Identify figure 'A' and 'B'.
b) Name the subunits of 'A' and 'B'.
(HSE-March-2019)(2)

4. Complete the division of human skeletal system by- filling the blanks (HSE-Model-2019)(2)

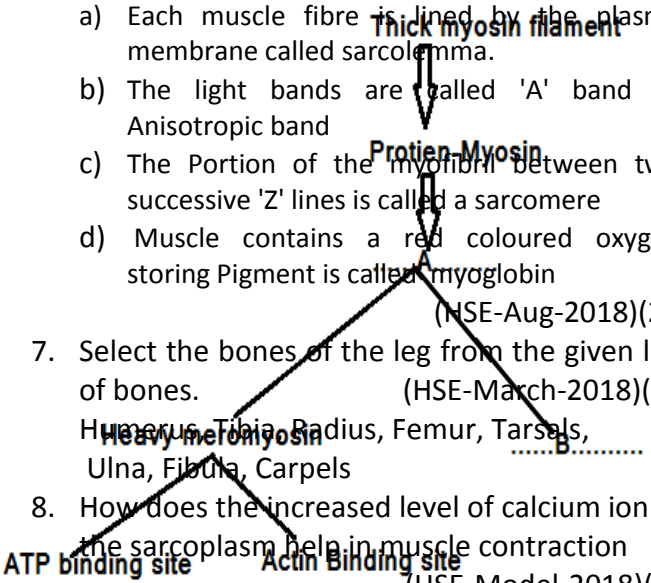


5. Identify the disorders based on the symptoms given below. (HSE-Aug-2018)(2)
a) Inflammation of joints.
b) Decreased bone mass and increased chance of fracture.
c) Inflammation of joints due to the accumulation of uric acid crystals
d) Rapid spasms in muscles due to low Ca++ in body fluids.

6. Select the WRONG statement regarding muscles from those given below and correct it.
a) Each muscle fibre is lined by the plasma membrane called sarcolemma.
b) The light bands are called 'A' band or Anisotropic band
c) The Portion of the myofibril between two successive 'Z' lines is called a sarcomere
d) Muscle contains a red coloured oxygen storing Pigment is called myoglobin
(HSE-Aug-2018)(2)

7. Select the bones of the leg from the given list of bones. (HSE-March-2018)(2)
Humerus, Tibia, Radius, Femur, Tarsals, Ulna, Fibula, Carpels

8. How does the increased level of calcium ion in the sarcoplasm help in muscle contraction (HSE-Model-2018)(2)



9. Certain disorders and their causes are given. Match them suitably (HSE-Model-2018)(2)

• Myasthenia gravis	• Inflammation of Joints
• Tetany	• Auto Immune disorder
• Muscular dystrophy	• Low Calcium ions in body fluid
	• Genetic disorder

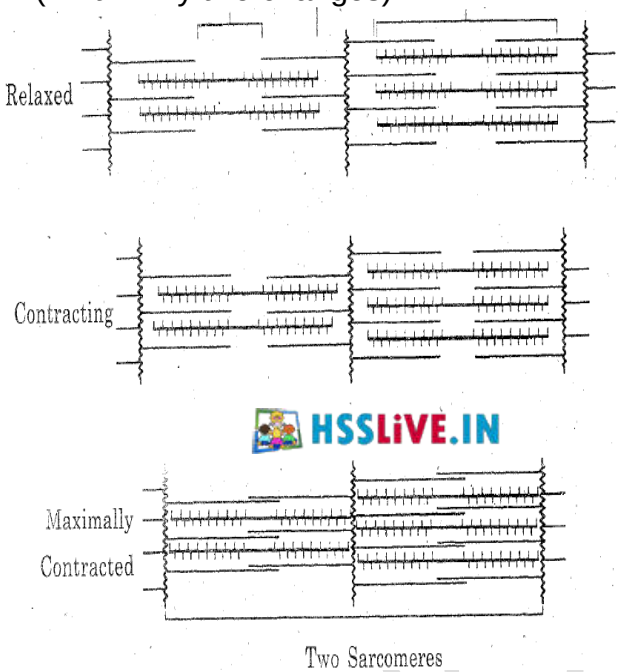
10. An athlet met an accident on the ground. His thigh bone slipped off from the girdle.
a) Write the name of the above mentioned girdle ?
b) Identify the type of joint that slipped off?
c) Name the disorder caused due to the accumulation of uric acid crystals in such a joint? (HSE-July-2017)(2)

11. Complete the following chart showing structure of myosin filament and its protein based on the hints given in the brackets. (HSE-March-2017)(2)

12. Name of few bones of appendicular skeleton is given below
Clavicle
Humerus
Tibia
Patella
Scapula
a)select the bone of pectoral girdle?

b)Name the articulating cavity between femur (Thigh bone) and pelvic girdle? (HSE-sept-2016)(2)

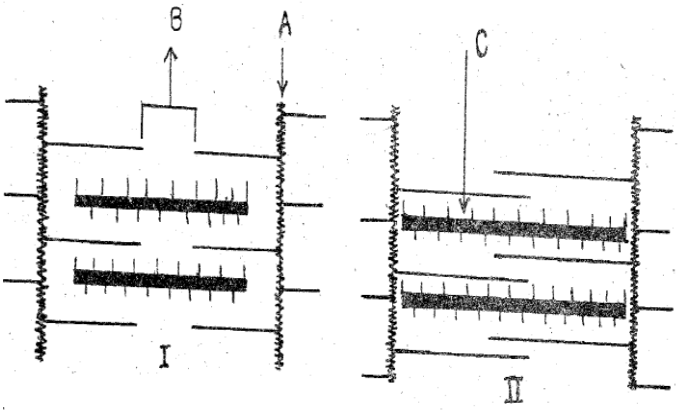
13. "A contracted muscle become shorter and thicker but its volume remains the same"
    a)Which theory explains the process of muscle contraction?
    b)Identify two contractile protein present in the muscle ? (HSE-march-2016)(2)
14. Based on the diagram given below, can you write down the structural changes occurring in sarcomere during muscular contraction
    (Hint : Any two changes)



(HSE-Sept-2015)(2)

15. Red muscle fibre has greater capacity to do work for a prolonged period, where as white muscle fibre suffers from fatigue after a short work. Evaluate this statement? (HSE-March-2015)(2)

16. The important finding in the case sheet of Two patients A and B show that both are suffering from the disorder of the skeletal system
    a) Patient A is suffering from inflammation of the joint due to accumulation of uric acid crystal
    b)Patient B shows decreased bone mass and decreased level of oestrogen
    Identify the disorder Or Diseases of A and B? (HSE-August -2014)(2)
17. Give two examples for each of the following
    a)synovial joints
    b)muscular proteins (HSE-march-2014)(2)
18. In your zoology practical class, teacher brought a tray containing the following human bones
    Humerus, patella, carpals, ulna, radius, tibia, tarsal, femur
    a) Categorize them into two?
    b) Give the criteria for your categorization (HSE-September-2013)(2)
19. Observe the structural representation of the muscles given below :



a) Which among these represent contracted state?
b) Name the part labeled as A, B, and C (HSE-March-2013)(2)

20. Draw a flow chart showing physiological processes involved in the formation of cross bridge during muscle contraction ? (HSE-Sept-2012)(2)