

04

Locomotion and Movement (Skeletal System)

01. INTRODUCTION

- **Skeletal system** consists of a **framework of bones** and a **few cartilages**.
- This system has a significant role in movement shown by the body.



SWIMMING



JUMPING



WALKING

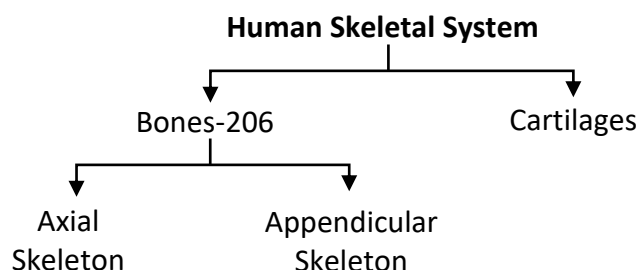


RUNNING

- Imagine **chewing** food **without jaw** bones and **walking** around **without the limb bones**.
- Bone and cartilage are specialised connective tissues.

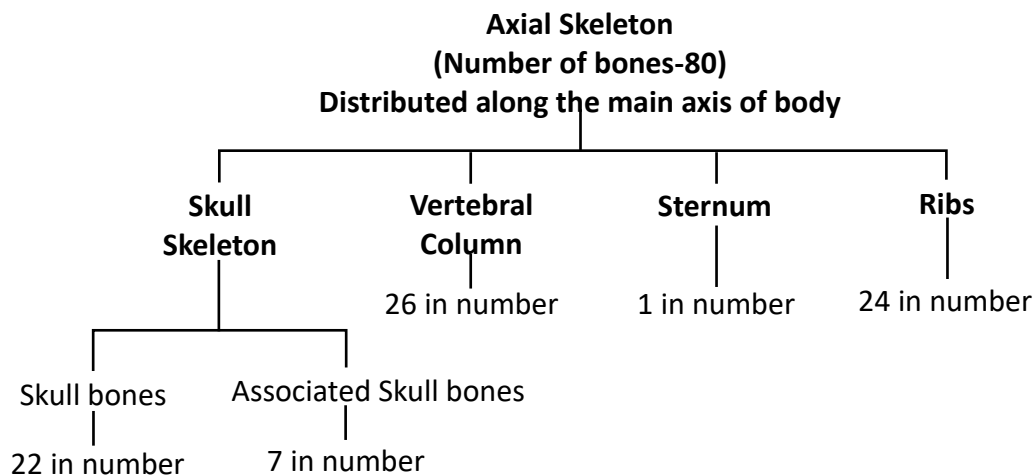
Bone	Cartilage
Very hard matrix.	Slightly pliable matrix
Calcium salts present.	Chondroitin salts present
Bone marrow is present that produces blood corpuscles.	Such structure is absent.
Growth in bone is bi-directional.	Growth in cartilage is unidirectional.

- In human beings, this system is made up of 206 bones and a few cartilages. It is grouped into two principal divisions – the axial and the appendicular skeleton.



02. AXIAL SKELETON

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



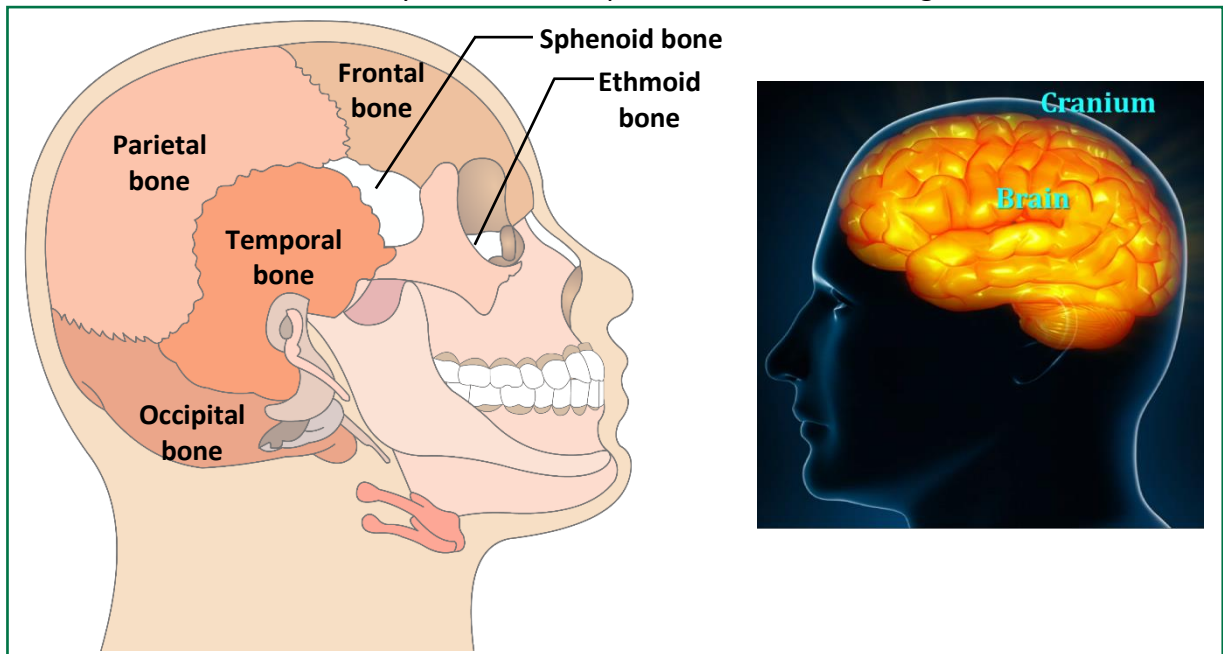
(A) SKULL :

- The Skull is composed of **two sets of bones** – **cranial** and **facial**, that totals to 22 bones.

Cranial Bones :

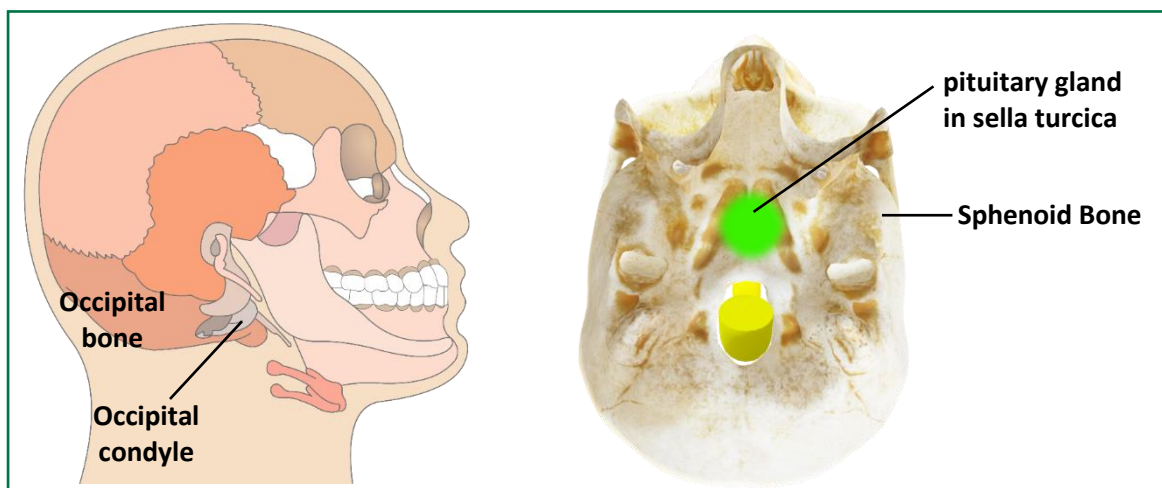
Cranial bones are 8 in number (**frontal-1, parietal-2, temporal-2, occipital-1, ethmoid-1 and sphenoid-1**).

Functions of cranial bones : They form the hard protective outer covering, cranium for the brain.

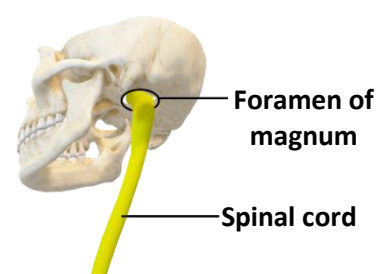


Articulation of Skull With Vertebral Column :

- The skull region articulates with the superior region of the vertebral column with the help of two occipital condyles (dicondylic skull).
- Occipital bone consist of two projections called **Occipital condyles** therefore our skull is called **dicondylic skull**.

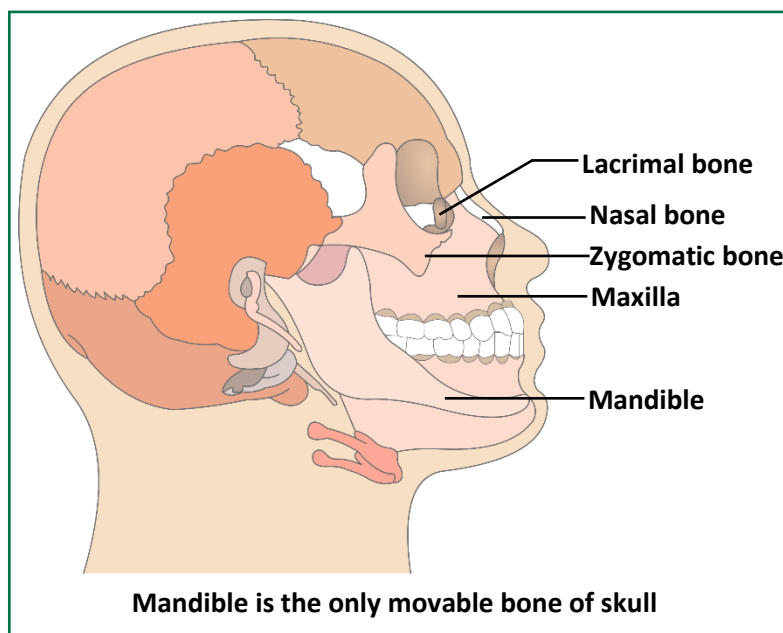


- Cavity of sphenoid bone is called **sella turcica** in which pituitary gland is present.
- At the base of skull an opening is present called **foramen of magnum (Largest Foramen of Skull)** through which **spinal cord** comes out.



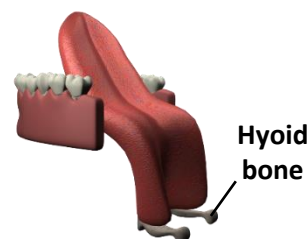
Facial Bones :

- The facial region is made up of 14 skeletal elements (Inferior turbinals-2, Maxilla-2, Malar (Zygomatic)-2, Nasal-2, Palatine-2, Lacrimal-2, Vomer-1, Mandible-1) which form the front part of the skull.



Hyoid Bone :

- A single U-shaped bone called **hyoid** is present at the base of the buccal cavity and it is also included in the skull.
- Hyoid bone is the **only bone** which is **not attached with any other bone of the body**.
- **Tongue is attached with hyoid bone.**



Ear Ossicles :

- Each middle ear contains three tiny bones – **Malleus**, **Incus** and **Stapes**, collectively called **Ear Ossicles**.
- Stapes** is the **smallest bone of our body**.
- The ear ossicles increase the efficiency of transmission of sound waves to the inner ear.



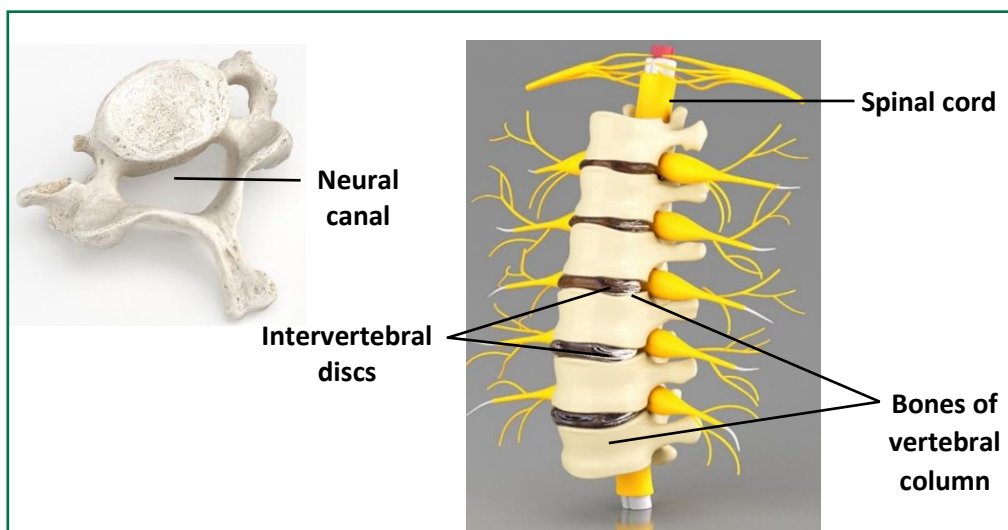
BEGINNER'S BOX-1

SKULL

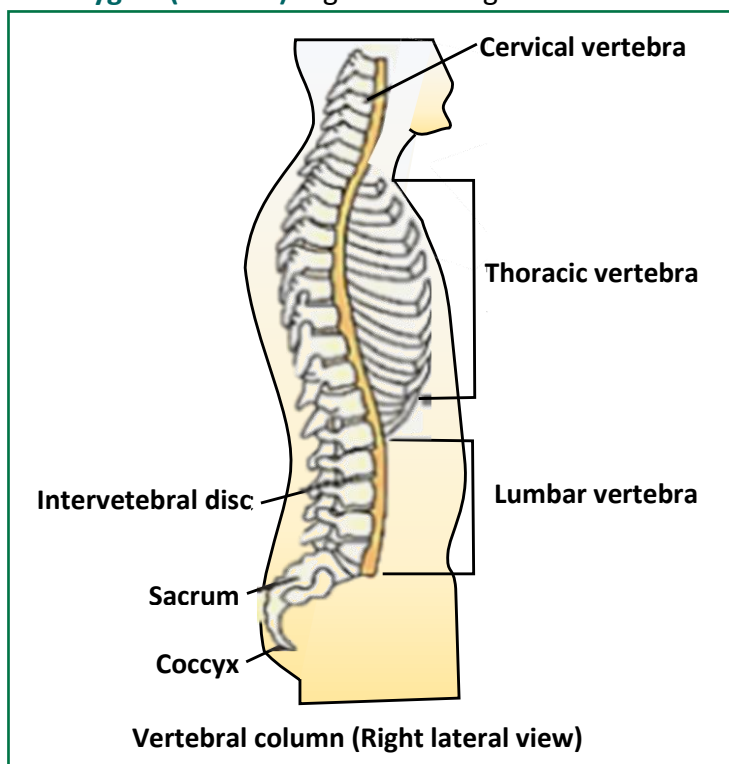
1. Skull of Man is :-	(1) Monocondylic	(2) Dicondylic	(3) Tricondylic	(4) Tetracondylic	BLC084
2. Total number of skull bones in human :-	(1) 22	(2) 49	(3) 39	(4) 19	BLC085
3. Single bone of lower jaw in human is :-	(1) Maxilla	(2) Mandible	(3) Nasal	(4) Lacrimal	BLC086
4. Spinal cord passes to brain through :-	(1) Foramen of Monro	(2) Foramen of Magendie	(3) Foramen ovale	(4) Foramen of magnum	BLC087
5. Total number of bones of human face:-	(1) 10	(2) 12	(3) 14	(4) 16	BLC088
6. Human cranium is made of bones.	(1) 14	(2) 8	(3) 22	(4) 7	BLC089
7. The skull, vertebral column, sternum and ribs constitute :-	(1) Visceral skeleton	(2) Axial skeleton	(3) Appendicular skeleton	(4) Exoskeleton	BLC090
8. Surface for attachment of tongue is :	(1) Palatine	(2) Sphenoid	(3) Ethmoid	(4) Hyoid	BLC091
9. Smallest bone in Human is :-	(1) Nasal	(2) Patella	(3) Stapes	(4) Palatine	BLC092
10. How many occipital condyles do humans possess?	(1) 4	(2) 1	(3) 3	(4) 2	BLC093
11. Skeletal system consist of :-	(1) Framework of bones only	(2) Framework of cartilages only	(3) Framework of bones and a few cartilages	(4) Framework of epithelial and connective tissue	BLC094
12. Matrix of cartilage is :-	(1) Solid, pliable and resist compression	(2) Hard and nonpliable	(3) Fibres free	(4) Rich in collagen fibres	BLC095
13. Which of the following is a function of bone?	(1) Support and protect softer tissues and organs	(2) Production of blood cells	(3) Serve weight bearing functions	(4) All of the above	BLC096

(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.



- The vertebral column is differentiated into **Cervical (7)**, **Thoracic (12)**, **Lumbar (5)**, **Sacral (1-fused)** and **Coccygeal (1-fused)** regions starting from the skull.

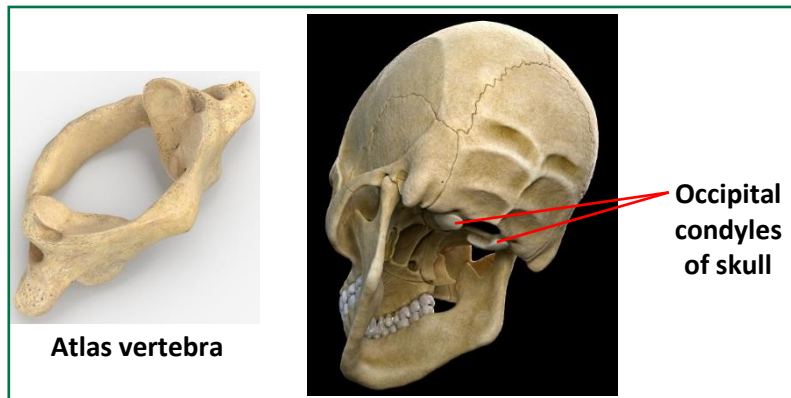


Cervical Vertebrae :

- The number of **cervical vertebrae** are **seven** in almost all mammals including human beings.

Atlas :

- First vertebra is the atlas.
- **Atlas** articulates with the occipital condyles of occipital bone and form condylar joint which is responsible for **downward** and **upward movement**.

**Axis Vertebra :**

- Second vertebra is called axis.
- Axis form **pivot joint with atlas**.
- Pivot joint is responsible for **sideways movement**.

Thoracic Vertebrae :

- Thoracic vertebrae in human beings are 12 in number.
- Play an important role to protect the lungs and heart by attaching to the ribcage

Lumbar Vertebrae :

- Lumbar vertebrae are 5 in number.
- Lumbar vertebrae are the heaviest and largest vertebrae
- The lumbar vertebrae's function is to support the great weight of the body and allow certain movements, such as lifting objects.

Sacrum :-

- (1 fused) (5 in number but fused to form one)
- The sacrum forms the posterior pelvic wall and strengthens and stabilizes the pelvis

Coccyx :-

- (1 fused) (4 in number but fused to form one)
- Coccyx provides weight-bearing support to a person in the seated position.

Functions of Vertebral Column :-

- (1) The vertebral column protects the spinal cord,
- (2) Vertebral column supports the head
- (3) Vertebral column serves as the point of attachment for the ribs and musculature of the back.



BEGINNER'S BOX-2

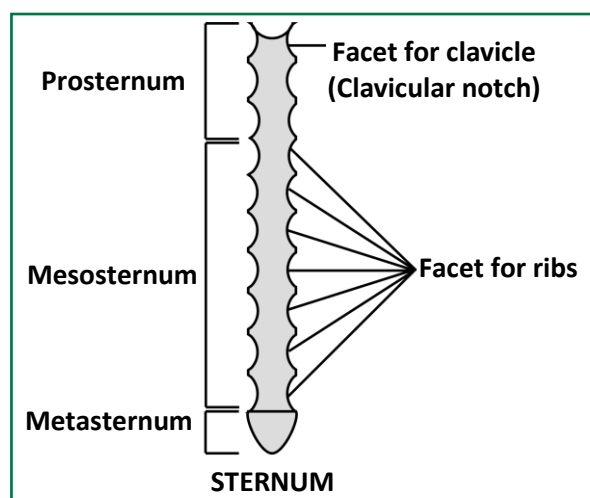
VERTEBRAL COLUMN

1. In camel number of cervical vertebra is :-
 (1) 6 (2) 7 (3) 8 (4) 9 **BLC097**
2. Long neck of Girraffe or camel is due to:-
 (1) More number of cervical vertebra
 (2) More length of cervical vertebra
 (3) Presence of pads between cervical vertebra
 (4) Presence of extra bony plates **BLC098**
3. In humans, coccyx is formed by the fusion of vertebrae :
 (1) 3 (2) 4 (3) 5 (4) 6 **BLC099**
4. Coccygeal bone is a bone of :-
 (1) Skull (2) Pectoral girdle (3) Vertebral column (4) Pelvis **BLC100**
5. The number of cervical vertebrae in mammals including human being are :-
 (1) 7 (2) 8 (3) 9 (4) 10 **BLC101**
6. The major function of intervertebral disc is :-
 (1) absorb shock (2) String vertebrae together
 (3) prevent injuries (4) prevent hyper extension **BLC102**
7. Number of cranial, cervical and thoracic bones in human are ____, ____ and ____ respectively.
 (1) 14,7,14 (2) 8,14,7 (3) 14,7,12 (4) 8,7,12 **BLC103**
8. Which of following helps in rotation of the neck ?
 (1) Atlas (2) Axis
 (3) Cervical (4) Occipital condyle of skull **BLC104**
9. Total number of vertebrae in man are :-
 (1) 30 (2) 26 (3) 40 (4) 35 **BLC105**
10. Sacrum in human is formed by fusion of :-
 (1) 3 vertebrae (2) 5 vertebrae (3) 8 vertebrae (4) 6 vertebrae **BLC106**

(C) STERNUM AND RIBS :

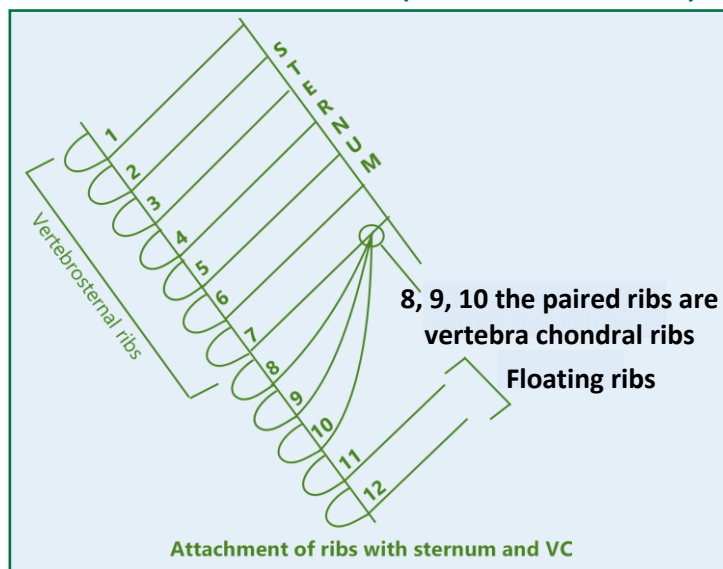
(i) Sternum :

- Sternum is a flat bone on the ventral midline of thorax.
- There are three parts of sternum-
 (i) Superior (anterior) part is the prosternum (**manubrium**)
 (ii) Middle part is the mesosternum (**body**)
 (iii) Inferior (posterior) smallest metasternum (**xiphoid process**)
- The sternum provides spaces for the attachment of the thoracic ribs and abdominal muscles too.



(ii) **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 (**Vertebro-sternal ribs**).



- Dorsally, they (1st to 7th pair of ribs) 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**.
- The thoracic vertebrae, ribs and sternum together form the **rib cage**.

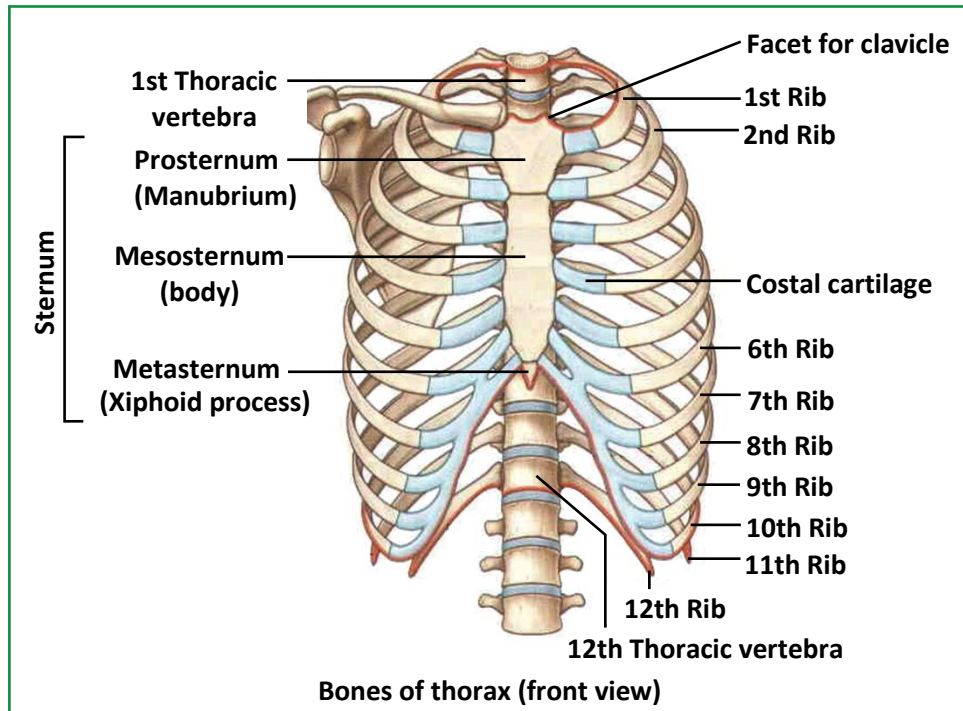
Rib Cage : Thoracic vertebrae, ribs and sternum together form the rib cage .

There are five parts of rib cage :-

- (1) Dorsal consist of vertebral column and ribs
- (2) Ventral consist of sternum and ribs
- (3) Lateral consist of ribs
- (4) Anterior consist of neck and clavicle
- (5) Posterior consist of diaphragm

Significance of Rib Cage :

- The rib cage protects the organs in the thoracic cavity, assists in respiration, and provides support for the upper extremities. During inspiration the ribs are elevated, and during expiration the ribs are depressed.



BEGINNER'S BOX-3

STERNUM AND RIBS

- In man ribs are attached to :-
 (1) Clavicle (2) Sternum (3) Cervical (4) Acromion **BLC107**
- Which connective tissue provides the attachment of the true ribs with sternum?
 (1) Hyaline cartilage (2) Areolar tissue
 (3) Fibrocartilage (4) Elastic cartilage **BLC108**
- Ribs which are dorsally attached with vertebral column and ventrally with sternum are called-
 (1) True ribs (2) False ribs
 (3) Floating ribs (4) Strong ribs **BLC109**
- Number of floating ribs in human :-
 (1) 6 pairs (2) 5 pairs (3) 3 pairs (4) 2 pairs **BLC110**
- Vertebrochondral ribs in human are :-
 (1) 8th, 9th, 10th ribs (2) 7th, 8th, 9th ribs
 (3) 9th, 10th, 11th ribs (4) 6th, 7th, 8th ribs **BLC111**
- The total number of ribs in human body is :
 (1) 10 (2) 12 (3) 24 (4) 36 **BLC112**
- Match the following columns.

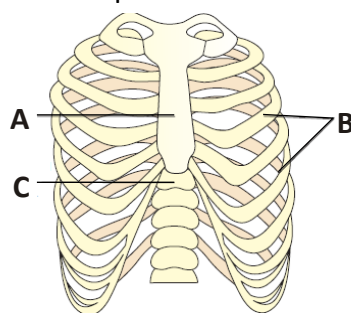
Column-A		Column-B	
A	True ribs	i	06
B	False ribs	ii	04
C	Floating ribs	iii	14

- (1) A-i, B-ii, C-iii (2) A-iii, B-i, C-ii
- (3) A-iii, B-ii, C-i (4) A-ii, B-iii, C-i

BLC113

8. Identify A, B and C in the given diagram and choose the correct option.

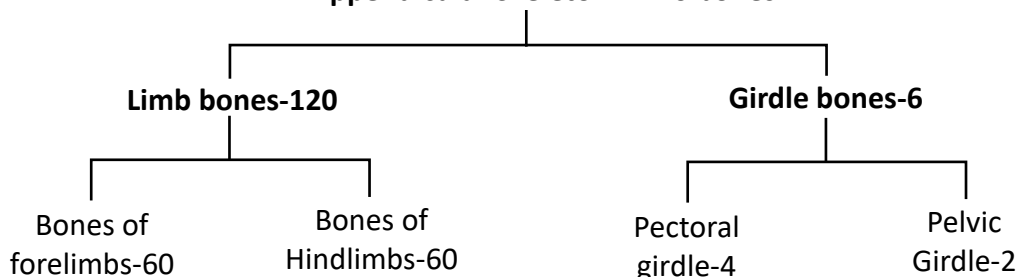
- (1) A–Sternum, B–Vertebral column, C–Ribs
- (2) A–Ribs, B–Vertebral column, C–Sternum
- (3) A– Ribs, B– Sternum, C–Vertebral column
- (4) A–Sternum, B–Ribs, C–Vertebral column



BLC114

03. APPENDICULAR SKELETON

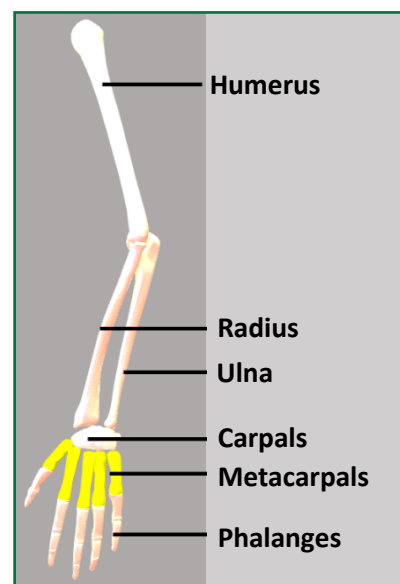
Appendicular Skeleton – 126 bones



- The bones of the limbs along with their girdles constitute the appendicular skeleton.
- Each limb is made of 30 bones.

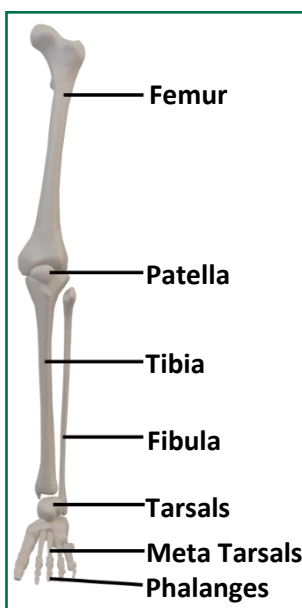
(A) FORE LIMBS BONES :

- The bones of the hand (fore limb) are **humerus**, **radius** and **ulna**, **carpals** (wrist bones – 8 in number), **metacarpals** (palm bones – 5 in number) and **phalanges** (digits – 14 in number).
- Digital formula for phalanges is 2, 3, 3, 3, 3.



(B) HIND LIMBS BONES :

- **Femur** (thigh bone – the longest bone), **tibia** and **fibula**, **tarsals** (ankle bones – 7 in number), **metatarsals** (5 in number) and **phalanges** (digits – 14 in number) are the bones of the legs (hind limb).
- A cup shaped bone called **patella** cover the knee ventrally (**knee cap**).



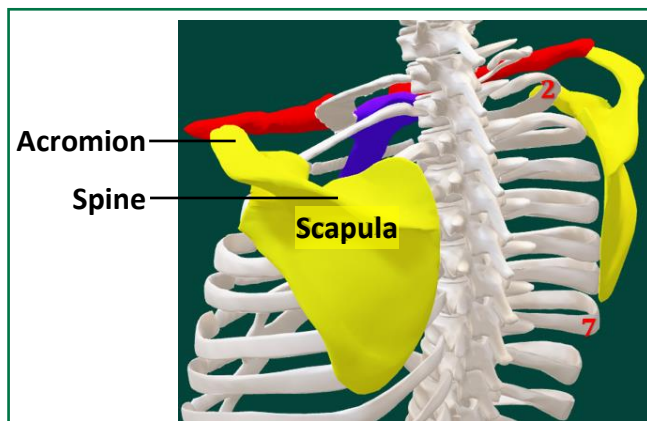
The arrangement and number of bones in the lower limb are similar to those of the upper limb. However, the bones of the lower limb are adapted for weight bearing and locomotion, they may be somewhat different in shape and articulate differently than the comparable bones of the upper limb.

(C) GIRDLE BONES :

- Pectoral and Pelvic girdle bones help in the articulation of the **upper limbs (Fore limb bones)** and the **lower limbs (Hind limb Bones)** respectively with the axial skeleton.

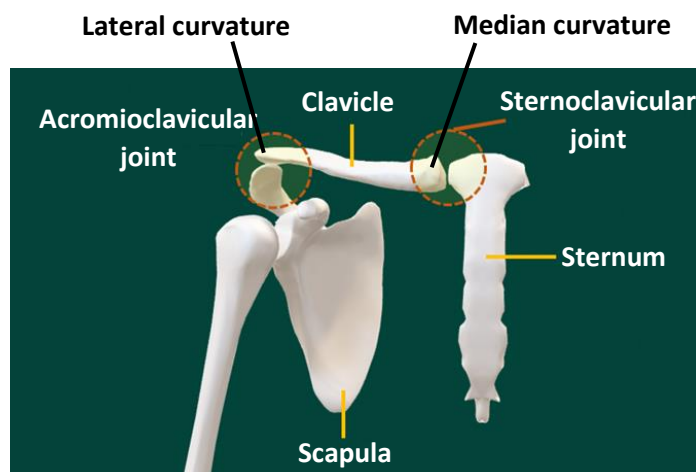
Pectoral Girdle :

- Consists of two halves, helps in the articulation of the upper limbs with the axial skeleton.
- Each half of pectoral girdle consists of a **clavicle** (Collar bone) 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 process**.
- Clavicle articulates with Acromion process of scapula to form acromioclavicular joint.
- Below the acromion process is a depression called the glenoid cavity.
- Head of humerus fits in glenoid cavity of scapula and form shoulder joint.



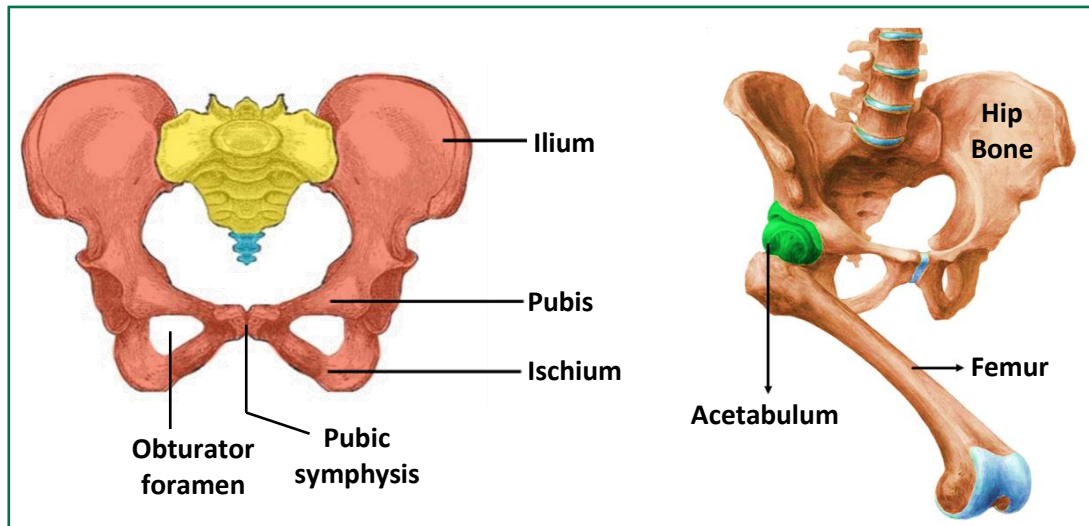
Clavicle :

- Each clavicle is a long slender bone with two curvatures. This bone is commonly called the collar bone.
- Lateral curvature of clavicle form acromioclavicular joint with acromion process of scapula whereas median curvature of clavicle form sternoclavicular joint with sternum.



Pelvic Girdle :

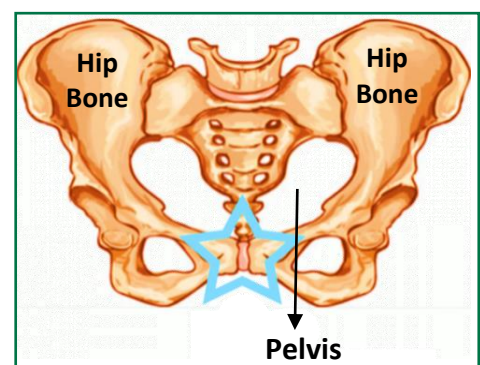
- Pelvic girdle consists of **two coxal bones**.
- Each coxal bone is formed by the fusion of three bones – **ilium**, **ischium** and **pubis**.
- At the point of fusion of ilium, ischium, pubis is a cavity called **acetabulum** to which the thigh bone articulates.



- The two halves of the pelvic girdle meet ventrally to form the **pubic symphysis** containing fibrous cartilage.
- A large opening in the hip bone between the pubis and the ischium called **Obturator foramen**.
- Obturator foramen allows a few vessels and nerves to pass out from the pelvic cavity to communicate with the lower limb.

Pelvis :

- The **pelvis** is the lower part of the trunk, between the abdomen and the thighs (sometimes also called **pelvic region**), together with its embedded skeleton (sometimes also called **bony pelvis** or **pelvic skeleton**).
- Reproductive organs some part of large intestine and urinary bladder are present in this region.



Differences between male and female pelvis

Features	Female Pelvis	Male Pelvis
1. General width	Hips are wider	Hips are narrower
2. Pubis	Longer, More rectangular	Short, Triangular
3. Sacrum	Shorter, wider	Narrower, Longer

NCERT Question :

Write the difference between Pectoral and Pelvic girdle

Ans.

	Pectoral girdle	Pelvic girdle
1.	It is situated in the shoulder region.	It is situated in the hip region.
2.	It is made up of two bones, i.e., Clavicle and Scapula.	It is made up of three bones, i.e., Ilium, Ischium and Pubis.
3.	The glenoid cavity of the scapula forms ball and socket joint with the humerus.	A cup-shaped cavity called acetabulum forms ball and socket joint with the femur.
4.	It gives articulation to forelimb bones.	It gives articulation to hindlimb bones.

**BEGINNER'S BOX-4****APPENDICULAR SKELETON**

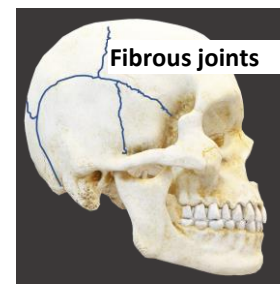
- Total number of bones in appendicular skeleton of human :-
 (1) 126 (2) 80 (3) 44 (4) 33 **BLC115**
- Longest bone of human skeleton :-
 (1) Femur (2) Humerus (3) Tibia (4) Radius **BLC116**
- Digital formula of hand of human is :-
 (1) 23333 (2) 03322 (3) 33332 (4) 02233 **BLC117**
- Number of tarsal bones in human in each hind limb :-
 (1) 2 (2) 7 (3) 6 (4) 5 **BLC118**
- Which of the following is the bone of fore limb?
 (1) Humerus (2) Femur (3) Tibia (4) Fibula **BLC119**
- Os Innominatum consist of :-
 (1) pubis (2) ischium
 (3) ilium (4) all of the above **BLC120**
- A cup shaped cavity for articulation of femur head is :-
 (1) acetabulum (2) glenoid cavity
 (3) sigmoid notch (4) obturator foramen **BLC121**
- Scapula is part of :-
 (1) skull (2) pelvic girdle
 (3) pectoral girdle (4) vertebral column **BLC122**
- Obturator foramen present between:-
 (1) Ilium & Ischium (2) Ischium & Pubis
 (3) Ilium & pubis (4) Scapula & Clavicle **BLC123**
- Number of bones present in a forelimb of human :
 (1) 30 (2) 32 (3) 35 (4) 40 **BLC124**

04. JOINTS

- **Joints** are essential for all types of movements involving the bony parts of the body.
- Locomotory movements are no exception to this. 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**.
- The movability at these joints vary depending on different factors.
- Joints have been classified into three major structural forms, namely, **fibrous**, **cartilaginous** and **synovial**.

(A) FIBROUS JOINTS :

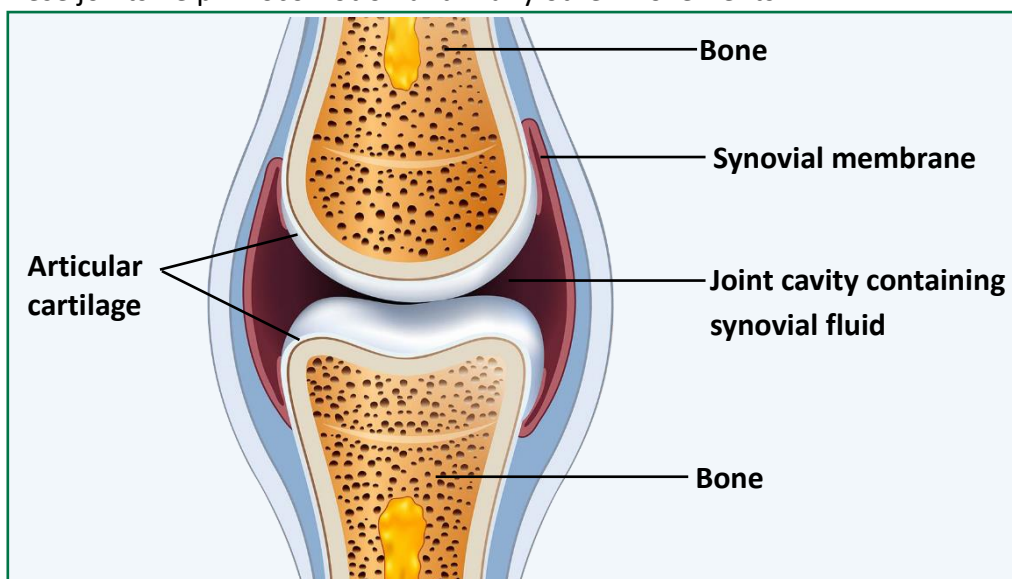
- **Fibrous joints** do not allow any movement.
- This type of joint is shown by the **flat skull bones** which fuse end-to-end with the help of **dense fibrous connective tissues** in the form of **sutures**, to form the **cranium**.

**(B) CARTILAGINOUS JOINTS :**

- In **cartilaginous joints (SYNCHONDROSIS)**, 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.
The two halves of the pelvic girdle meet ventrally to form the pubic symphysis containing fibrous cartilage.

**(C) SYNOVIAL JOINTS :**

- **Synovial joints (DIARTHROSIS)** 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.
- These joints help in locomotion and many other movements.



NCERT Question :

Name the type of joint between the following.

Examples of Synovial joints: -

Joint name	Present in
Ball and socket joint	between humerus and glenoid cavity of pectoral girdle
Ball and socket joint	between femur and acetabulum of pelvic girdle
Hinge joint	knee joint
Pivot joint	between atlas and axis
Gliding joint	between the carpals
Saddle joint	between carpal and metacarpal of thumb
Hinge joint	Between phalanges
Hinge joint	Elbow joint
Condylar joint	Between atlas and occipital condyles of occipital bones

05. DISORDERS OF SKELETAL SYSTEM

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

NCERT Question :

Write true or false. If false change the statement so that it is true.

- (c) Human skeleton has 206 bones.
 (d) There are 11 pairs of ribs in man.
 (e) Sternum is present on the ventral side of the body.

Ans. (c) True

(d) False → There are 12 pairs of ribs in man.

(e) True

NCERT Question :

Fill in the blank spaces:

- (a) All mammals (except a few) have _____ cervical vertebra.
 (b) The number of phalanges in each limb of human is _____
 (e) _____ and _____ pairs of ribs are called floating ribs.
 (f) The human cranium is made of _____ bones.

Ans. (a) 7 (b) 14 (e) 11th and 12th (f) 8



BEGINNER'S BOX-5

JOINTS AND DISORDERS

1. Elbow joint is an example of: -
 (1) Ball & socket joint (2) Pivot joint (3) Gliding joint (4) Hinge joint **BLC125**
2. The shoulder joint is a ball and socket joint between: -
 (1) Glenoid cavity of pectoral girdle & head of humerus
 (2) Coronoid process of pectoral girdle & head of humerus
 (3) Acetabulum cavity of pectoral girdle & head of humerus
 (4) Between radius, ulna and humerus **BLC126**
3. Head of humerus is articulated with pectoral girdle by a joint: -
 (1) Hinge (2) Ball and socket (3) Immovable (4) Pivot joint **BLC127**
4. Which one is a ball and socket joint?
 (1) Knee joint (2) Elbow joint
 (3) Humerus and pectoral girdle (4) Atlas & Axis **BLC128**
5. Which one of the following is correctly matched?
 (1) Hinge joint – between vertebrae
 (2) Pivot joint –between atlas and axis
 (3) Fibrous joint – between phalanges
 (4) Cartilaginous joint – skull bones **BLC129**
6. Bones become fragile in
 (1) Gout (2) Osteoporosis
 (3) Arthritis (4) Myasthenia gravis **BLC130**
7. Symphysis is made of
 (1) Fibrocartilage (2) Synovial fluid
 (3) Elastic cartilage (4) Hyaline cartilage **BLC131**
8. Which one is cartilaginous joint?
 (1) Synchondrosis (2) Symphysis
 (3) Diarthrosis (4) Both (1) and (2) **BLC132**
9. Deposition of uric acid crystals within the synovial joint causes
 (1) Gout (2) Paralysis
 (3) Osteoarthritis (4) Rheumatoid arthritis **BLC133**
10. The example of pivot joint is-
 (1) Hip joint (2) Ankle joint
 (3) Between atlas and axis (4) Metacarpophalangeal joint **BLC134**



BEGINNER'S BOX

ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	1	2	4	3	2	2	4	3	4
	Que.	11	12	13							
	Ans.	3	1	4							

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	2	2	3	1	1	4	2	2	2

BEGINNER'S BOX-3	Que.	1	2	3	4	5	6	7	8		
	Ans.	2	1	1	4	1	3	2	4		

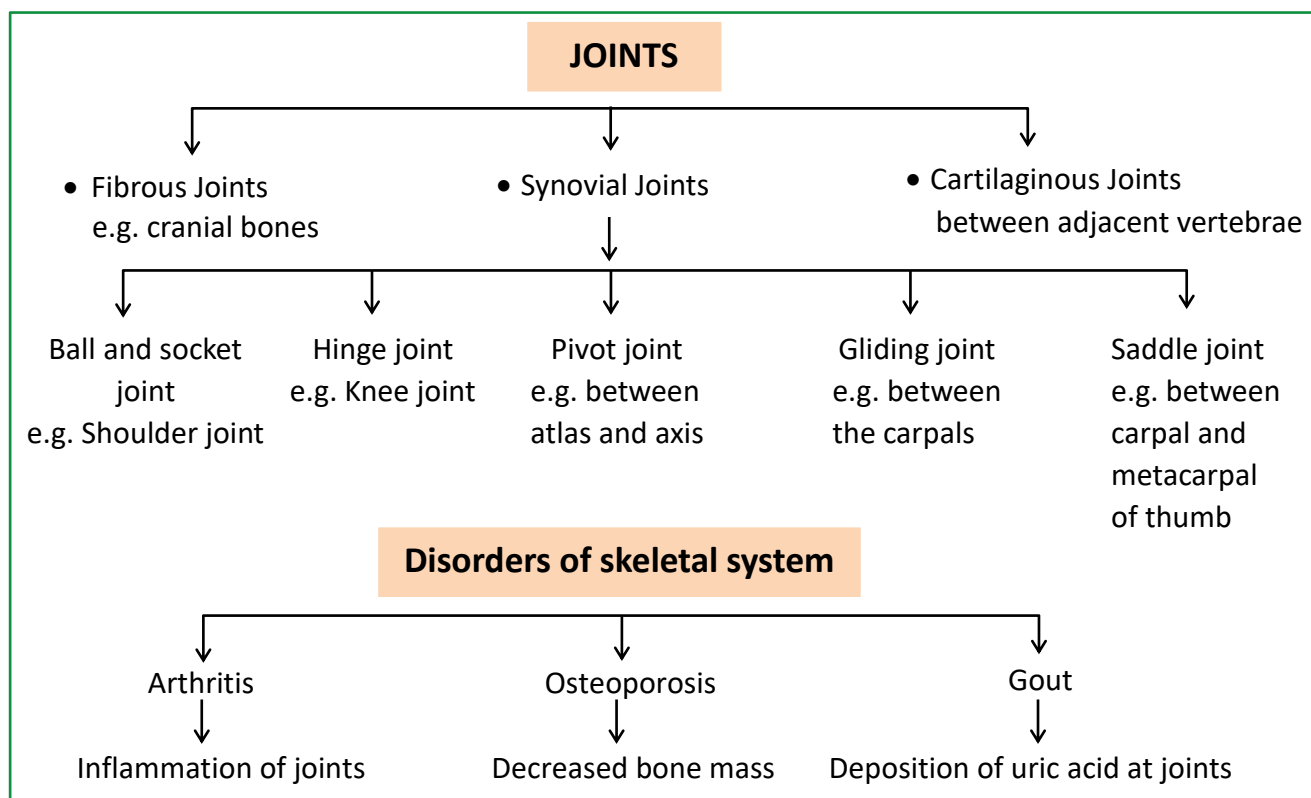
BEGINNER'S BOX-4	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	1	1	1	2	1	4	1	3	2	1

BEGINNER'S BOX-5	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	4	1	2	3	2	2	1	4	1	3



HUMAN SKELETON - 206 bones				
Axial-80			Appendicular-126	
AXIAL SKELETON - 80 BONES				
SKULL SKELETON- 29		STERNUM - 01	RIBS - 24	VERTEBRAL COLUMN - 26
SKULL BONES - 22			True - 14	Cervical - 7
Cranial - 8	Facial - 14		False - 6	Thoracic - 12
Frontal - 1	Maxilla - 2		Floating-4	Lumbar - 5
Parietal - 2	Palatine -2			Sacral - 5
Temporal - 2	Zygomatic - 2			Coccygeal - 4
Occipital - 1	Nasal - 2			
Ethmoid - 1	Lacrimal - 2			
Sphenoid -1	Inferior Turbinals - 2			
	Mandible - 1			
	Vomer - 1			
ASSOCIATED SKULL BONES - 07				
Hyoid Bone - 1		Ear ossicles - 2x3 (Malleus, Incus, Stapes)		

APPENDICULAR SKELETON - 126 BONES			
LIMB BONES - 120		GIRDLE BONES - 06	
Fore limb Bones - 60	Hind limb Bones - 60	Pectoral Girdle - 4	Pelvic Girdle - 2
Humerus – 1×2	Femur – 1×2	Scapula - 1×2	(is formed by 2 hip bones and each hip bone is formed by fusion of 3 bones ilium, ischium and pubis)
Radius – 1×2	Patella - 1×2	Clavicle - 1×2	
Ulna - 1×2	Tibia - 1×2		
Carpals - 8×2	Fibula - 1×2		
Metacarpals - 5×2	Tarsals - 7×2		
Phalanges - 14×2	Metatarsals - 5×2		
	Phalanges - 14×2		



NCERT SUMMARY

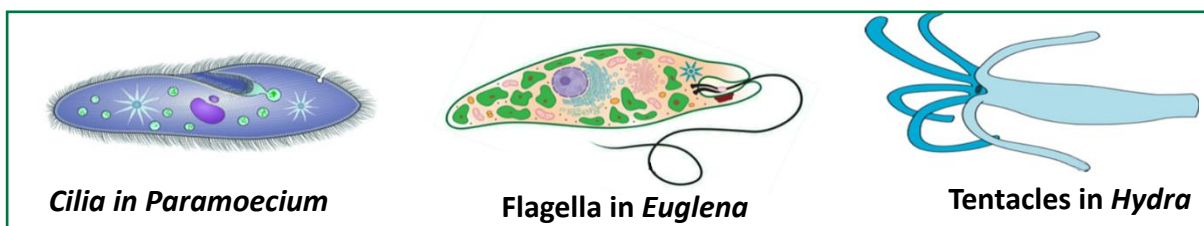
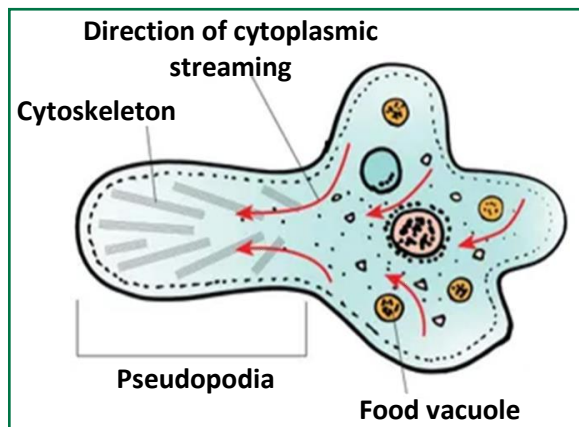
Bones and cartilages constitute our skeletal system. The skeletal system is divisible into axial and appendicular. Skull, vertebral column, ribs and sternum constitute the axial skeleton. Limb bones and girdles form the appendicular skeleton. Three types of joints are formed between bones or between bone and cartilage – fibrous, cartilaginous and synovial. Synovial joints allow considerable movements and therefore, play a significant role in locomotion.

05

Locomotion and Movement (Muscles)

01. INTRODUCTION

- 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 *Paramecium*, cilia helps in the movement of food through cytopharynx and in locomotion as well.
Ciliary movements in our respiratory tract.
- *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.
- Locomotion is generally for search of food, shelter, mate, suitable breeding grounds, favourable climatic conditions or to escape from enemies/predators.

02. TYPES OF MOVEMENTS

NCERT Question :

What are the different types of movements exhibited by the cells of human body?

Cells of human body exhibit mainly three types of movements

(1) Ciliary (2) Amoeboid (3) Muscular

(A) CILIARY MOVEMENT :

- It occurs in most of our internal organs which are lined by ciliated epithelium.
e.g. 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.

(B) AMOEBOID MOVEMENT :

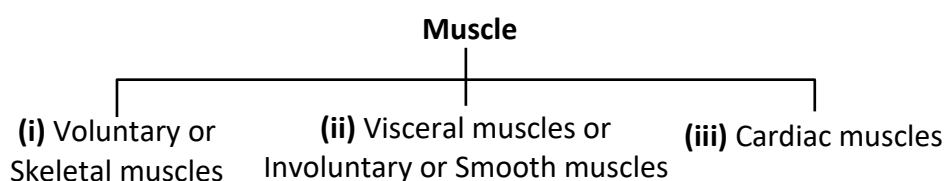
- Some specialised cells in our body like macrophages and leucocytes in blood exhibit amoeboid movement.
- It is effected by pseudopodia formed by the streaming of protoplasm (as in *Amoeba*).
- Cytoskeletal elements like microfilaments are also involved in amoeboid movement.

(C) MUSCULAR MOVEMENT :

- Locomotion requires a perfect coordinated activity of muscular, skeletal and neural systems.
- The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms.
- Movement of our limbs, jaws, tongue etc. require muscular movement.
- Multicellular animals movements are the result of a special kind of tissue called **muscular tissue (muscle)**.
- Study of muscles known as **Myology/Sarcology**.

03. ORIGIN OF MUSCLES

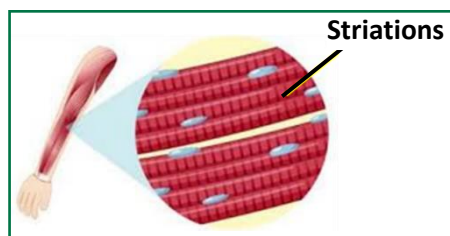
- Origin of muscles is - **mesoderm** except few muscles.
- Muscle of Iris, ciliary body & myoepithelial cell of sweat gland develop from **Ectoderm**.
- Main characteristics of muscle are **excitability, contractility, extensibility** and **elasticity**.
- Muscles constitutes around **40% to 50%** of adult body mass in an average healthy person.
- Three types of muscles are found in the body. (On the basis of position/location)



04. MUSCLES

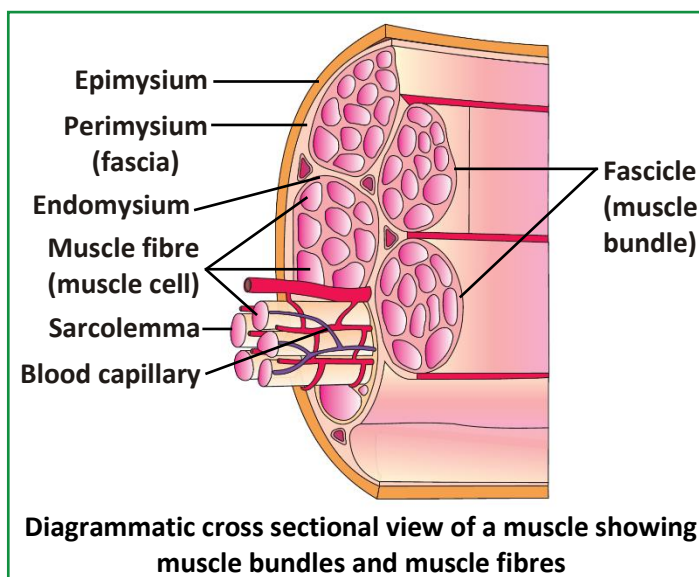
(A) SKELETAL MUSCLES :

- Skeletal muscles 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.



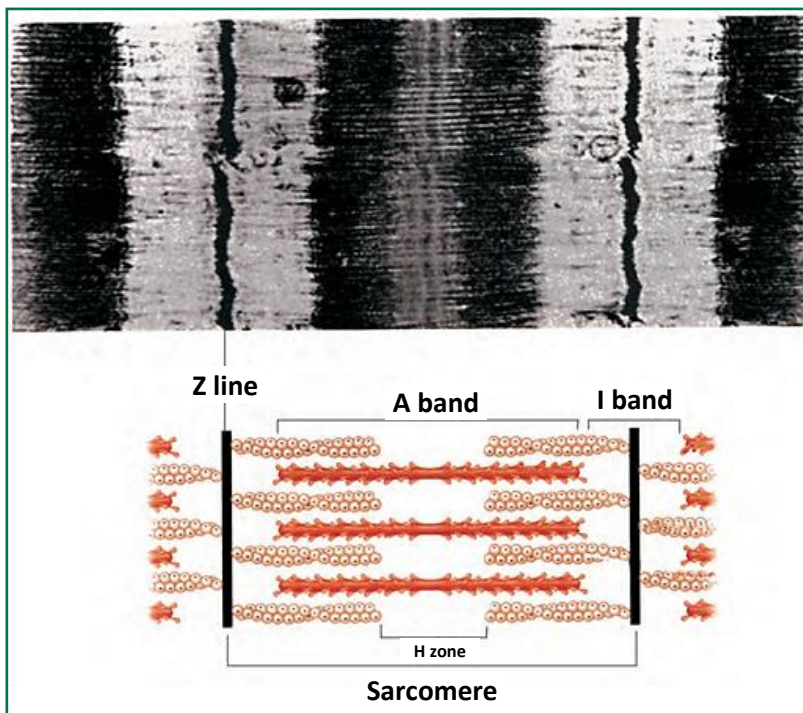
(i) Structure of Skeletal Muscles and Muscle fibre :

- Each organised skeletal muscle in our body is made of a number of muscle bundles or fascicles.
- They are held together by a common collagenous connective tissue layer called fascia.
- Each muscle bundle contains a number of muscle fibres.
- Skeletal muscle fibre is cylindrical or tubular in shape and is long and Unbranched.
- The outer plasma membrane of muscle fibre is called **sarcolemma**, which contains collagen fibres.



- Each muscle fibre contain multinucleated sarcoplasm (Syncitium).
- Nucleus & sarcoplasm are found in peripheral part.
- Myofibril are arranged in parallel rows & form the dark & light line 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).
- Dark band is made up of myosin filaments called as Anisotropic bond (A band).
- Both the proteins are arranged as rod-like structures, parallel to each other and also to the longitudinal axis of the myofibrils.
- 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.

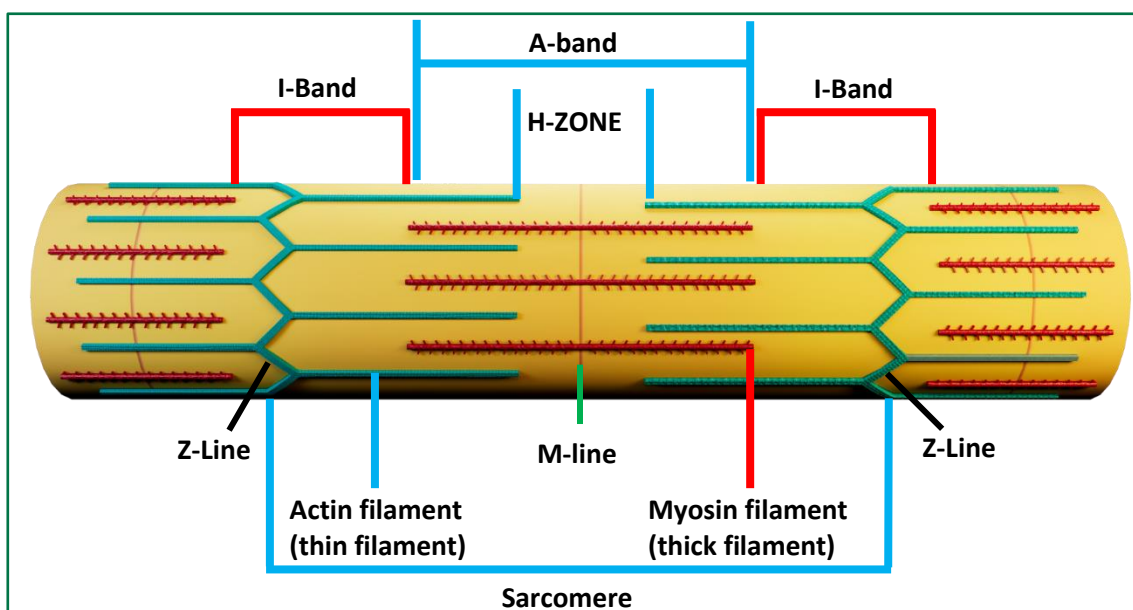
- The 'A' and 'I' bands are arranged alternately throughout the length of the myofibrils.
- In a resting state, the edges of thin filaments on either side of the thick filaments partially overlap the free ends of the thick filaments leaving the central part of the thick filaments.
- This central part of thick filament, not overlapped by thin filaments is called the '**H' zone**'.
- The portion of the myofibril between two successive 'Z' lines is called sarcomere which is considered as the **functional unit** of contraction.



Diagrammatic representation of anatomy of a muscle fibre showing a sarcomere

NCERT Question :

Draw the diagram of a sarcomere of skeletal muscle showing different regions.

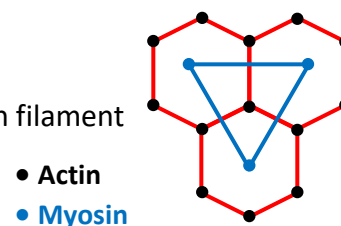


Sarcomere = 1A band + two half I band

The Length of Sarcomere is $2.5\ \mu\text{m}$.

(I band = $1\ \mu\text{m}$, myosin = $1.5\ \mu\text{m}$)

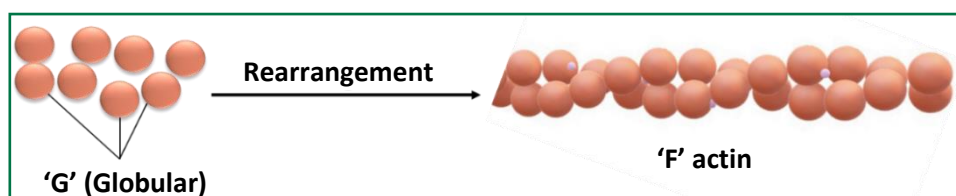
- 1 Myosin filament is surrounded by 6 Actin filaments & 1 Actin filament is surrounded by 3 Myosin filaments.
- Z-disc is made up of actinin protein.



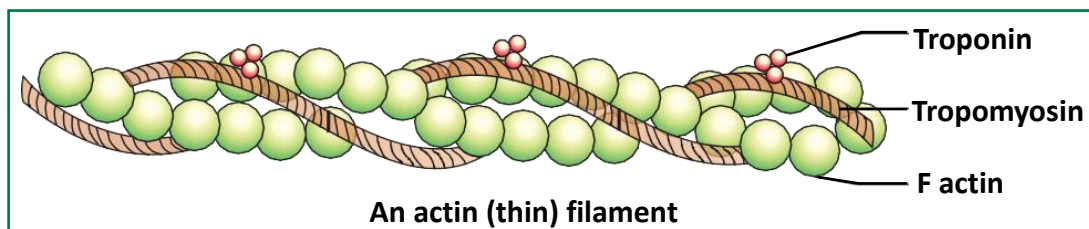
(ii) Structure of Contractile Protein :

(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.



Troponin is made up of three subunit.

(a) Troponin I (Inhibitory site)

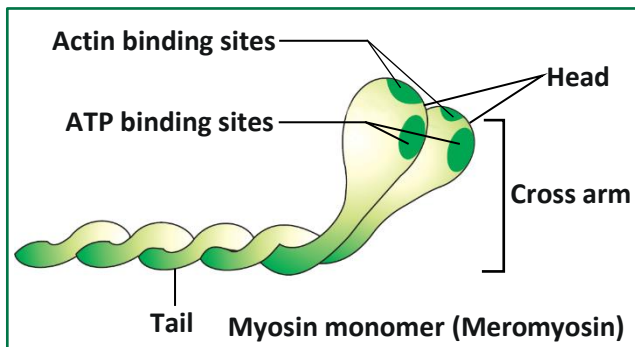
(b) Troponin T (Tropomyosin binding site)

(c) Troponin C (Ca^{+2} binding site)

(b) Myosin (Thick) Filament :

- 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.



NCERT Question :

Write the difference between Actin and Myosin

Actin	Myosin
The filament is composed of monomers called G-actins which forms filamentous F-actins.	The filament is composed of monomers called meromyosin.
This is known as the thin filament and short in length.	This is known as the thick filament and longer in length.
One end is free and the other end is attached to the Z-line.	Both the ends are free.
This allows sliding into the H-zone during muscle contraction.	This does not slide during muscle contraction.
Thin filaments are firmly attached to the elastic fibre called Z-line.	Thick filaments are held together by thin fibrous membrane called M-line.

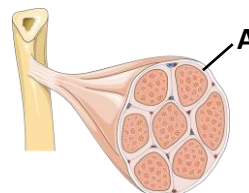


BEGINNER'S BOX-1

INTRODUCTION, STRUCTURE OF SKELETAL MUSCLE

- Cells of human body does not exhibit which of the following type of movement?
 (1) Flagellated (2) Ciliary (3) Muscular (4) Amoeboid **BLC207**
- In the trachea _____ help us in removing dust particles and some of the foreign substances inhaled along with the atmospheric air.
 (1) Villi (2) Microvilli
 (3) Cilia (4) Brush border epithelium **BLC208**
- Movement of our limbs, jaws, tongue etc. require -
 (1) Joints (2) Muscles (3) Tendons (4) Ligaments **BLC209**
- Origin of Muscles is-
 (1) Ectodermal (2) Endodermal
 (3) Mesodermal (4) Ecto-Endodermal **BLC210**
- Activities of Smooth muscles are classified as-
 (1) Voluntary (2) Involuntary (3) Both (4) None of the above **BLC211**

6. The store house of calcium ions in the muscle fibres is :
 (1) Epimysium (2) Fascicle
 (3) Collagen fibres (4) Sarcoplasmic reticulum **BLC212**
7. Identify the correct labelling in the following diagram :
 (1) Fascicle
 (2) Epimysium
 (3) Perimysium
 (4) Syncytium **BLC213**
8. This central part of thick filament, not overlapped by thin filaments is called-
 (1) 'H' zone (2) 'I' zone (3) 'M' Line (4) 'A' Band **BLC214**
9. Type of movement shown by macrophages is :
 (1) Amoeboid (2) Ciliary (3) Muscular (4) Flagellar **BLC215**
10. 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 **BLC216**
11. Monomeric form of actin is called –
 (1) F-actin (2) G-actin (3) M-actin (4) A-actin **BLC217**
12. The binding of calcium with a subunit of (___A___) on actin filaments removes the masking of active sites for (___B___).
 (1) A = Troponin, B = Myosin (2) A = Myosin, B = Tropomyosin
 (3) A = Actin, B = Tropomyosin (4) A = Troponin, B = Actin **BLC218**
13. Components of heavy meromyosin are –
 (1) Head & cross arm (2) Head & short arm
 (3) Head & tail (4) Cross arm & tail **BLC219**

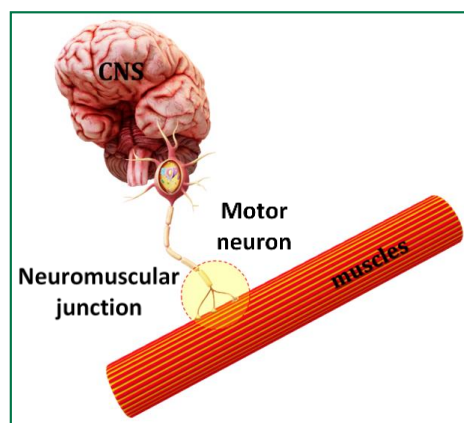


(iii) Mechanism of Muscle Contraction :

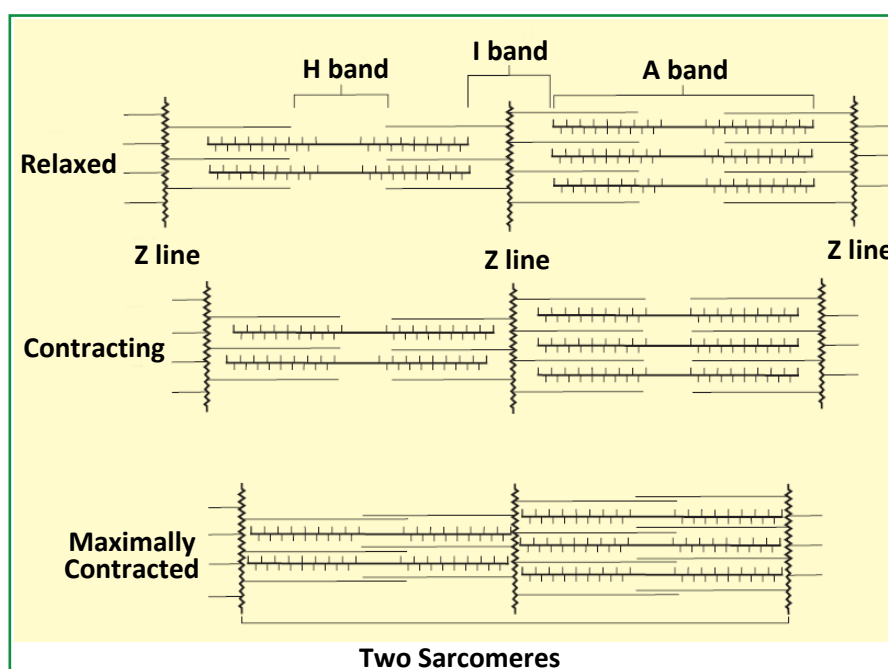
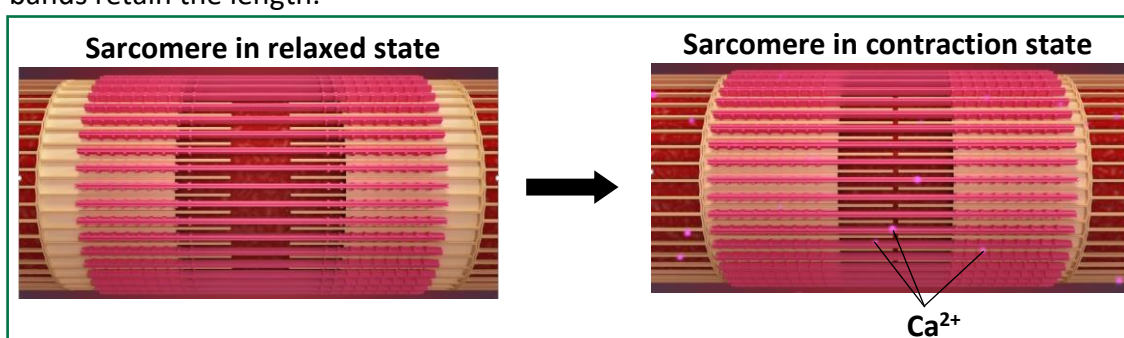
NCERT Question :

Define sliding filament theory of muscle contraction.

- **Sliding filament theory** - 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**.



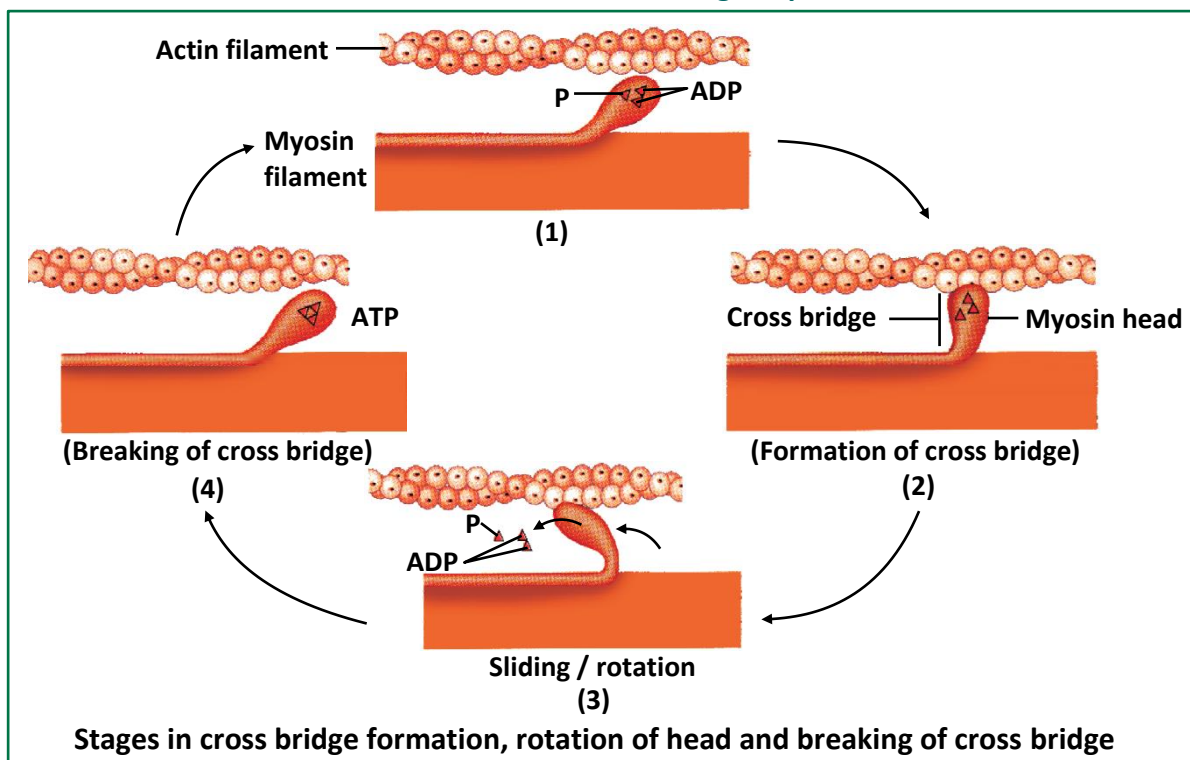
- A neural signal reaching this junction releases a **neurotransmitter (Acetylcholine)** which generates an action potential in the sarcolemma.
- This spreads through the muscle fibre and causes the release of **calcium ions** into the sarcoplasm.
- Increase in Ca^{++} level leads to the binding of calcium 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.



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

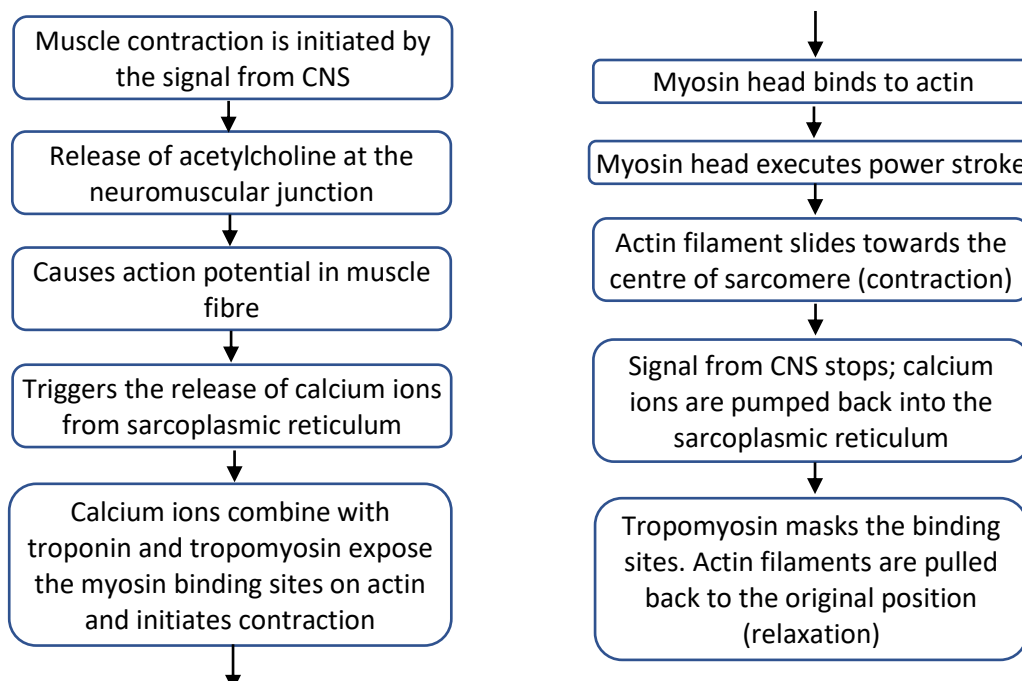
- The myosin, releasing the ADP and P_1 goes back to its relaxed state. A new ATP binds and the cross-bridge is broken.
- The ATP is again hydrolysed by the myosin head and the cycle of cross bridge formation and breakage is repeated causing further sliding.

- 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**.



NCERT Question :

Describe the important steps in muscle contraction.



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

(iv) Role of ATP :

- (i) The '**back & forth**' movement of myosin head with in the groove.
- (ii) **Detachment** of myosin head from the actin.

(v) Difference Between Red Muscle and White Muscle :

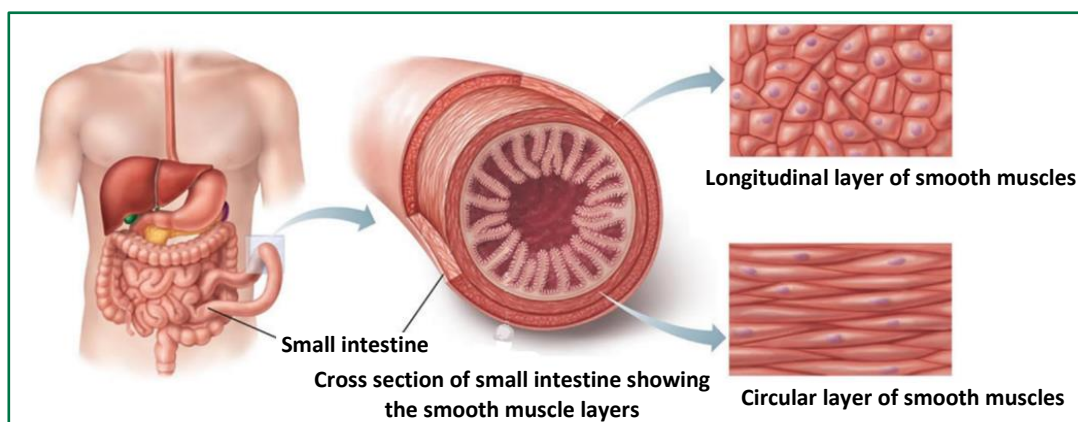
NCERT Question :

Write the difference between Red and White muscles.

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.

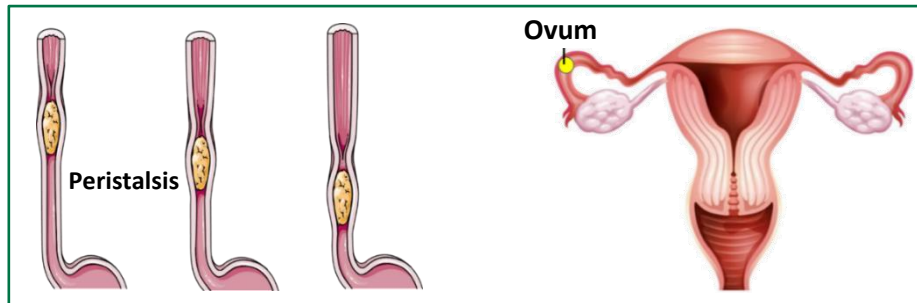
(B) VISCERAL MUSCLES :

- Visceral muscles are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc.



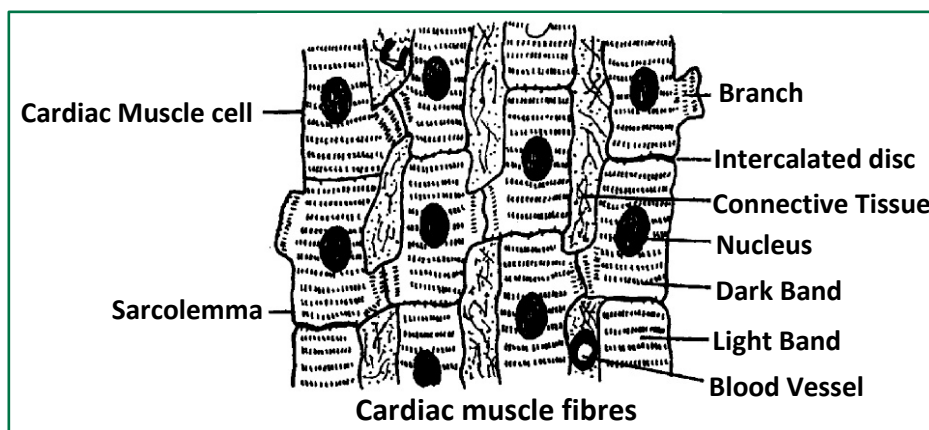
- They do not exhibit any striation and are smooth in appearance. Hence, they are called smooth muscles (nonstriated muscle).

- 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.



(C) CARDIAC MUSCLES :

- 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. Their muscle fibres are long, cylindrical and branched.
- They are involuntary in nature as the nervous system does not control their activities directly.
- 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 muscle**.
- Many transverse septa are found in the muscle fibre which are called as **intercalated disc**. Intercalated disc helps in the propagation of impulse & contraction.
- Due to septa, fibres are divided into many segments and each segment is **uninucleated**. Each segment is called individuals cell.
- Dark & light bands are also found in this muscle fibre. It is also **non-fatigue type muscle**.
- Its contraction is not controlled by will power of animal, hence involuntary.
- On the basis of function, it is **smooth muscle type**.



NCERT Question :

How do you distinguish between a skeletal muscle and a cardiac muscle?

DIFFERENCE BETWEEN STRIATED AND CARDIAC MUSCLE

Skeletal Muscle	Cardiac
1. They are present in skeletal components of the body.	They are present in walls of Heart
2. Fibres are Unbranched	Fibres are branched
3. Multi Nucleated fibres	Uninucleated
4. Controlled by CNS.	Both CNS + ANS
5. Gets fatigue soon.	Non-fatigue type

05. 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.

NCERT Question :

Write true or false. If false change the statement so that it is true.

(a) Actin is present in thin filament

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

Ans. (a) True

(b) False → H-zone of striated muscle fibre represents only thick filament not overlapped by thin filaments.

NCERT Question :

Fill in the blank spaces:

(c) Thin filament of myofibril contains 2 'F' actins and two other proteins namely _____ and _____.

(d) In a muscle fibre, Ca^{++} is stored in _____.

Ans. (c) Tropomyosin and troponin

(d) Sarcoplasmic reticulum



BEGINNER'S BOX-2

MUSCLE CONTRACTION & DISORDERS

1. Length of following does not decrease during muscle contraction –
 (1) Sarcomere (2) A-band (3) I band (4) H-zone **BLC220**
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 **BLC221**
3. Multinucleated muscle is –
 (1) Skeletal (2) Cardiac (3) Smooth (4) Both (2) & (3) **BLC222**
4. Autoimmune disorder affecting muscle is :
 (1) Myasthenia gravis (2) Tetany
 (3) Muscular dystrophy (4) Rheumatoid arthritis **BLC223**
5. Which one is incorrect for Red-muscle?
 (1) Myoglobin content is high. (2) Sarcoplasmic reticulum is less extensive.
 (3) Blood vessels are more extensive. (4) Mitochondria are less in number. **BLC224**
6. Which one is correct for White-muscle?
 (1) Fatigue occur quickly.
 (2) Response is slow with long latent period.
 (3) Contraction is less powerful.
 (4) This muscle is involved in prolonged and continued activity as it undergoes sustained contraction. **BLC225**
7. Increase in Ca^{++} level leads to the binding of calcium with a subunit of troponin on-
 (1) Actin filaments (2) Myosin filaments
 (3) Both (1) and (2) (4) Tropomyosin filaments **BLC226**
8. Cross bridge forms between-
 (1) one actin and two myosin filaments.
 (2) one actin and one myosin filaments.
 (3) muscle and nerve cells.
 (4) two actin and one myosin filaments. **BLC227**
9. Motor-end plate is the junction between-
 (1) actin and myosin filaments.
 (2) two actin filaments.
 (3) sensory neuron and the sarcolemma of the muscle fibre.
 (4) motor neuron and the sarcolemma of the muscle fibre. **BLC228**
10. The neuromuscular junction or motor-end plate comprises of :-
 (1) The junction between a sensory neuron and the sarcolemma of the muscle fibre.
 (2) The junction between a motor neuron and the sarcolemma of the muscle fibre.
 (3) The junction between a motor neuron and sensory neuron.
 (4) The junction between two muscle fibres. **BLC229**
11. A neural signal reaching this junction releases a neurotransmitter (_____) which generates an action potential in the sarcolemma. Identify the neurotransmitter :-
 (1) Adrenaline (2) Serotonin (2) Glutamate (4) Acetylcholine **BLC230**

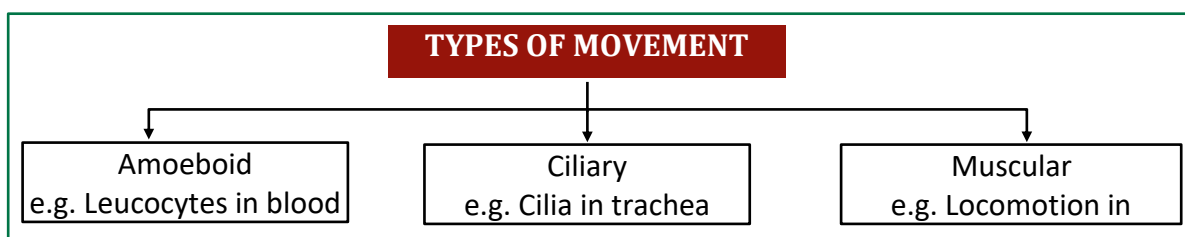


BEGINNER'S BOX

ANSWERS KEY

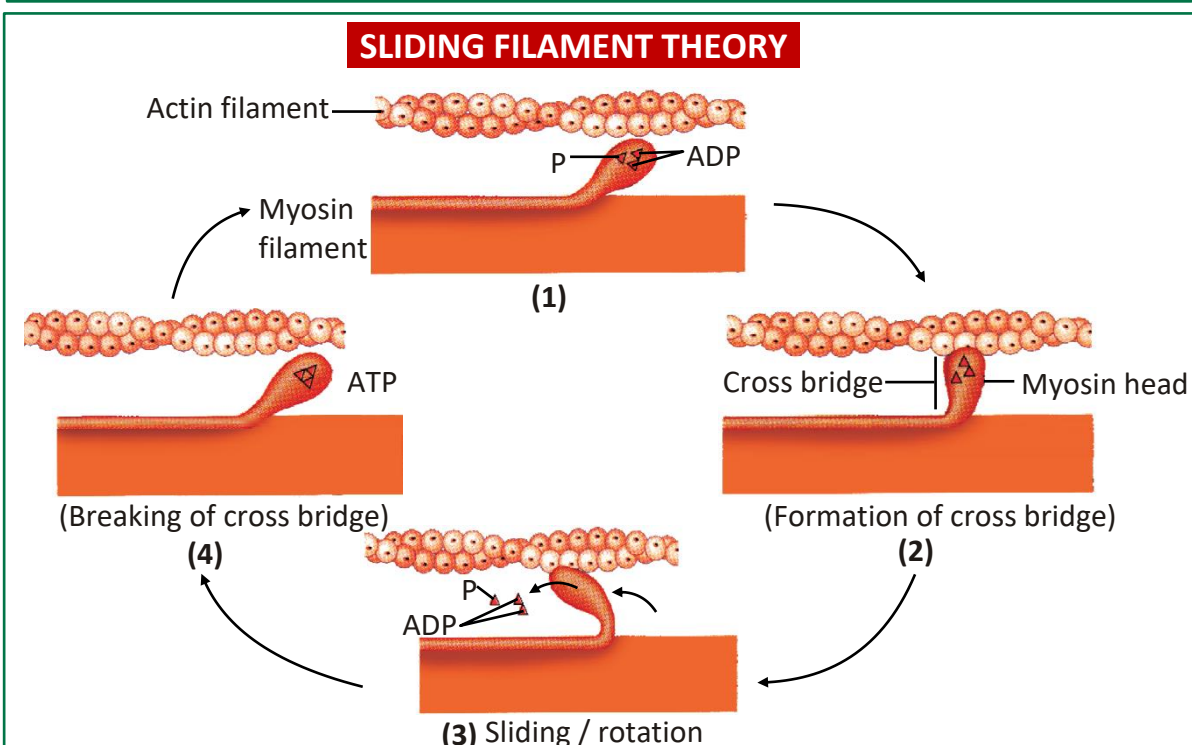
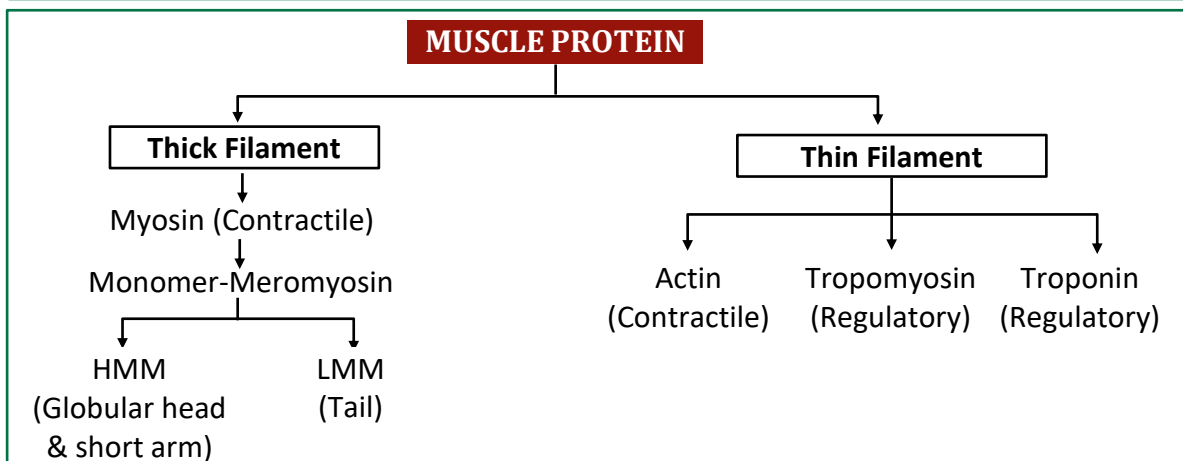
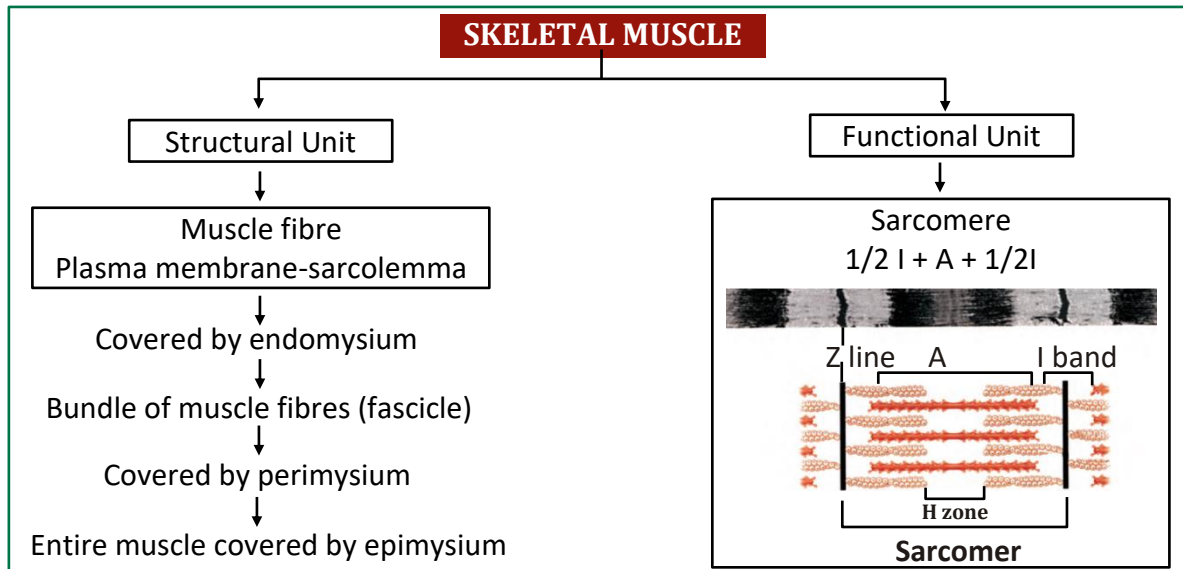
BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	1	3	2	3	2	4	1	1	1	1
	Que.	11	12	13							
	Ans.	2	1	2							

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	1	1	1	4	1	1	2	4	2
	Que.	11									
	Ans.	4									



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. Controlled by CNS.	ANS	Both CNS + ANS
7. Fatigue soon	Do not get fatigued	Never get fatigued



NCERT SUMMARY

Movement is an essential feature of all living beings. Protoplasmic streaming, ciliary movements, movements of fins, limbs, wings, etc., are some forms exhibited by animals. A voluntary movement which causes the animal to change its place, is called locomotion. Animals move generally in search of food, shelter, mate, breeding ground, better climate or to protect themselves.

The cells of the human body exhibit amoeboid, ciliary and muscular movements. Locomotion and many other movements require coordinated muscular activities. Three types of muscles are present in our body. Skeletal muscles are attached to skeletal elements. They appear striated and are voluntary in nature.

Visceral muscles, present in the inner walls of visceral organs are nonstriated and involuntary. Cardiac muscles are the muscles of the heart. They are striated, branched and involuntary. Muscles possess excitability, contractility, extensibility and elasticity.

Muscle fibre is the anatomical unit of muscle. Each muscle fibre has many parallelly arranged myofibrils. Each myofibril contains many serially arranged units called sarcomere which are the functional units. Each sarcomere has a central 'A' band made of thick myosin filaments, and two half 'I' bands made of thin actin filaments on either side of it marked by 'Z' lines. Actin and myosin are polymerised proteins with contractility. The active sites for myosin on resting actin filament are masked by a protein-troponin. Myosin head contains ATPase and has ATP binding sites and active sites for actin. A motor neuron carries signal to the muscle fibre which generates an action potential in it. This causes the release of Ca^{++} from sarcoplasmic reticulum. Ca^{++} activates actin which binds to the myosin head to form a cross bridge. These cross bridges pull the actin filaments causing them to slide over the myosin filaments and thereby causing contraction. Ca^{++} are then returned to sarcoplasmic reticulum which inactivate the actin. Cross bridges are broken and the muscles relax.

Repeated stimulation of muscles leads to fatigue. Muscles are classified as Red and White fibres based primarily on the amount of red coloured myoglobin pigment in them.