16. Skeleton and Movements

Can you recall?

1. Which are different types of muscular tissues ?
2. Name the type of muscles which bring about running and speaking.
3. Name the muscles which do not contract as per of our will.
4. Which types of muscles show rhythmic contractions?
5. Which type of muscle is present in the diaphragm of the respiratory system ?
6. Name the part of human skeleton situated along the vertical axis.

Organism exhibit varieties of the movements. Movements vary from streaming of protoplasm to peristalsis to walking or running etc. A movement may or may not end up into locomotion or displacement of organism.

16.1 Movements and locomotion :

Movements : Movements may be internal or external. Which of the above mentioned the movements are internal? Which are external? Can you add few more examples! Movements may be voluntary or involuntary. Three type of muscles bring about these movements in human beings.

a. Smooth muscles bring about involuntary movements like peristaltic movements in the alimentary canal, constriction and dilation of blood vessels, etc.
b. Contraction and relaxation of the heart is controlled by cardiac muscles.
c. Voluntary movements of limbs, head, trunk, eyes, etc. are controlled by striated muscles.

Locomotion : The change in locus of whole body of living organism from one place to another place is called locomotion. Locomotion is for search of food, shelter, mate, breeding ground and escape from enemy. There are four basic types of locomotory movements found throughout the animal kingdom.

1. **Amoeboid movement :** performed by pseudopodia e.g. leucocytes.
2. **Ciliary movement :** performed by cilia e.g. ciliated epithelium. In *Paramecium*, cilia help in passage of food through cytopharynx.
3. **Whorling movement :** performed by flagella e.g. Sperms.

Always Remember

There are about 640 muscles in human body. Out of these 634 are paired and 6 muscles are unpaired.

Think about it

1. Why do we shiver during winter ?
2. Why do muscles show spasm after rigourous contraction?
3. Did you ever feel tickling in muscles?

4. **Muscular movement :** Performed by muscles, with the help of bones and joints.

Remember : All locomotions are movements but all movements are not locomotion.

Skeletal muscles are attached to the bones by tendons and help in the movement of the parts of skeleton. Tendons are inelastic thick band of collagen fibers. Movement and locomotion is the combined action of bones, joints and skeletal muscles.

16.2 Location and structure of skeletal muscles :

Major part of the muscle which moves a bone usually do not lie on the same bone but is located on the bone atop. e.g. Biceps and triceps that move forearm are located in the upper arm. At any joint, two types of bones are present i.e. stationary and movable.

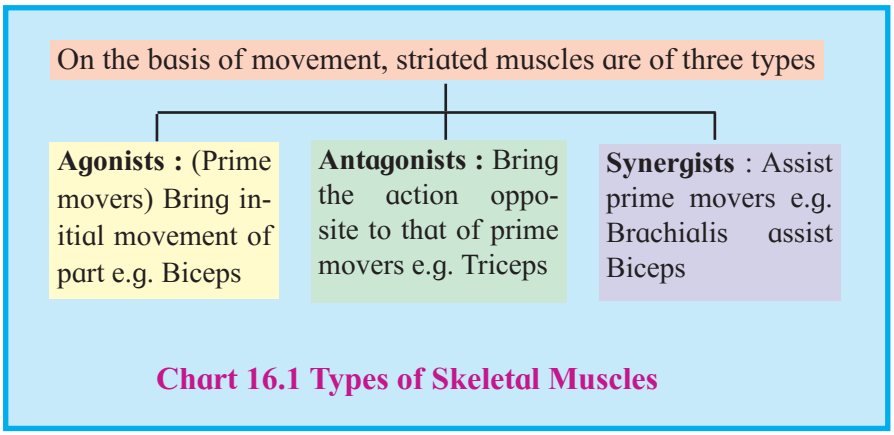


Chart 16.1 Types of Skeletal Muscles

The end of muscle attached to stationary bone is called origin while the opposite end attached to movable bone is called insertion. The middle thick part of muscle is called belly. All the fibres in a muscle do not extend from end to end and there is a maximum number in the middle. Thus, large muscles are most often fusiform in shape.

16.3 Working of Skeletal Muscles :

Generally muscles work in pairs and produce opposite action e.g. Biceps (flexors) bring flexion (folding) and triceps (extensors) bring extension of elbow joint. The muscles which bring opposite action are called antagonistic. If one member of a pair is capable of bending the joint by pulling of bones, the other member is capable of straightening the same joint also by pulling. e.g. Triceps and Biceps of upper arm are antagonistic to each other.

In antagonistic pair of muscles, one member is much stronger than the other. e.g. The biceps is stronger than the triceps.

The fundamental characteristic of muscle is contraction. Therefore, muscle can only pull and not push the bone.

Can you recall?

Comment on contraction of skeletal muscles (Hint : Refer chapter on Animal Tissues)

Some important antagonistic muscles

1. **Flexor and Extensor:** Flexor muscle on contraction results in bending or flexion of a joint e.g. Biceps. Extensor on contraction results in straightening or extension of a joint e.g. Triceps.
2. **Abductor and Adductor :** Abductor muscle moves body part away from the body axis e.g. Deltoid muscle of shoulder moves the arm away from the body. Adductor moves body part towards the body axis e.g. Latissimus dorsi of shoulder moves the arm near to the body.
3. **Pronator and Supinator :** Pronator turns the palm downward. Supinator to turns the palm upward.
4. **Levator and Depressor :** Levator raises a body part. Depressor lowers the body part
5. **Protractor and Retractor :** Protractor move forward. Retractor move backward.
6. **Sphincters :** Circular muscles present in inner wall of anus, stomach, etc. for closure and opening.

Can you tell?

1. Why are movement and locomotion necessary among animals?
2. Differentiate between :
   a. Flexor and extensor muscles
   b. Pronator and Supinator.
3. What are antagonistic muscles? Explain with example.

You are aware that both flexion and extension take place by contraction of skeletal muscles. Do you know, how do these muscles contract and bring about movement and locomotion? Striated muscles are specifically designed to bring about vigorous contractions.

Refer to ultra-microscopic structure of skeletal muscle you have studied in animal tissues. The contractile unit of muscles is called sarcomere which contains contractile proteins actin and myosin.

Structure of myosin and actin filaments :

Myosin filament :

Each myosin filament is a polymerized protein. Many monomeric proteins called meromyosins constitute one thick filament. Myosin molecule consists of two heavy chains (heavy meromyosin/HMM) coiled around each other forming double helix. One end of each of these chains is projected outwardly. It is known as cross bridge. This end is folded into a globular protein mass called myosin head.

Two light chains are associated with each head (Total 4 light chains/light meromyosin/LMM). Myosin head has a special ATPase activity. It can split ATP to produce energy. Myosin contributes 55% of muscle proteins.

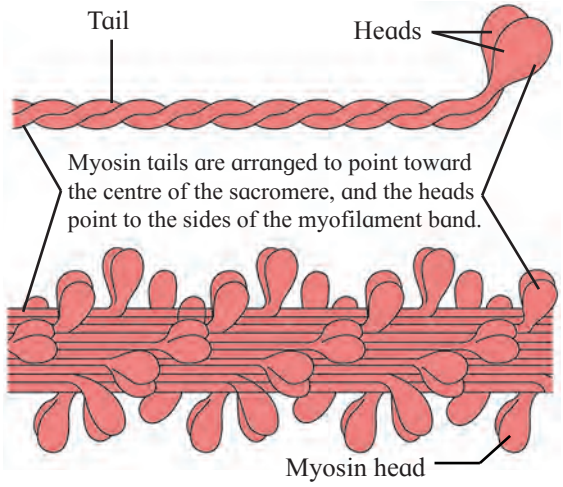


Fig. 16.2 Myosin filament

Actin filament :

It is also a complex type of contractile protein. It consists of three different components.

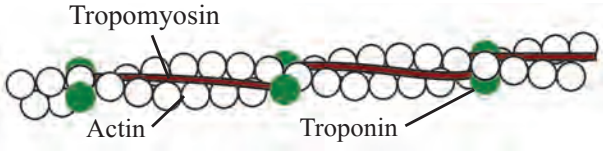


Fig. 16.3 Actin filament

i. **F actin :** It forms the backbone of actin filament. It is double stranded protein. Each strand is composed of polymerized G actin molecules. One ADP molecule is attached to each G actin molecule.

ii. **Tropomyosin :** The actin filament contains two additional protein strands that are polymers of tropomyosin molecules. Each strand is loosely attached to an F actin. In the resting stage, tropomyosin physically covers the active binding sites for myosin of the actin strand.

iii. **Troponin :** It is a complex of three globular proteins, which are attached approximately 2/3 rd distance along each tropomyosin molecule. It has affinity for actin, tropomyosin and calcium ions. The troponin complex is believed to attach the tropomyosin to the actin. The strong affinity of troponin for calcium ions is believed to initiate the contraction process.

16.4 Mechanism of muscle contraction :

Sliding filament theory was putforth by H.E. Huxley and A.F. Huxley. It is also called walk along theory or Ratchet theory.

According to this theory, interaction between actin and myosin is the basic cause of muscular contraction. Actin filaments are interdigitated with myosin filaments. (like the crossing of fingers of two hands)

The head of the myosin is joined to the actin backbone by a cross bridge forming a hinge joint. From this joint, head can not tilt in forward and backward directions. This movement is an active process which requires use of ATP.

Myosin head contains ATPase activity. It can derive energy by the breakdown of ATP molecule. This energy can be used for the movement of myosin heads.

During contraction process, the myosin heads gets attached to the active site of actin filaments and pull them inwardly, so that actin filaments slide over the myosin filaments. This results in the contraction of muscle fibre.

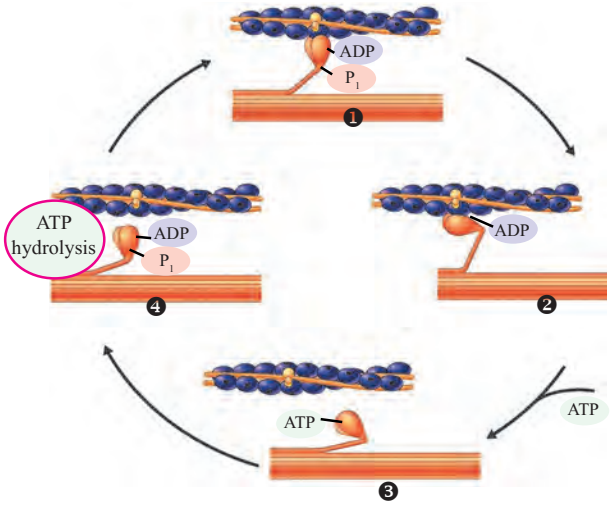


Fig. 16.4 Cyclic events in muscle Contraction

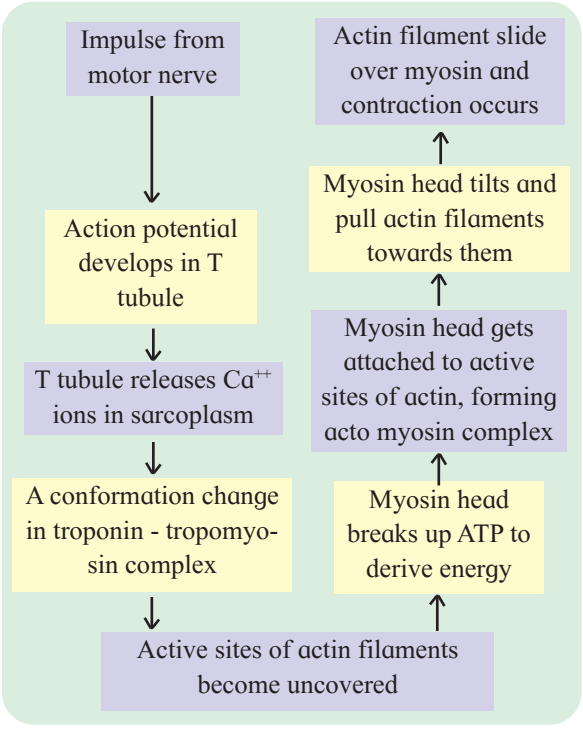


Chart 16.5 Mechanism of Muscle Contraction

16.5 Physiology of muscle relaxation :

When the muscle is relaxed, the active sites remain covered with tropomyosin and troponin complex. Due to this, myosin cannot interact with active site of actin and therefore contraction cannot occur. When an action potential (impulse) comes to muscle through motor end plate, it spreads throughout the sarcolemma of the myofibril. The transverse tubules of sarcoplasmic reticulum releases large number of calcium ions into sarcoplasm.

These calcium ions interact with troponin molecules. This interaction inactivates troponin-tropomyosin complex. This leads to change in the structure of tropomyosin.

As a result, it gets detached from the active site of actin (F actin) filament. Thus active site becomes uncovered. Now head of the myosin cleaves the ATP and derives energy.

Using this energy, myosin gets attached to the uncovered active site of actin and results in the formation of actomyosin complex.

The myosin heads are now tilted backwards and pull the attached actin filament inwardly. This results in contraction of the muscle fibres.

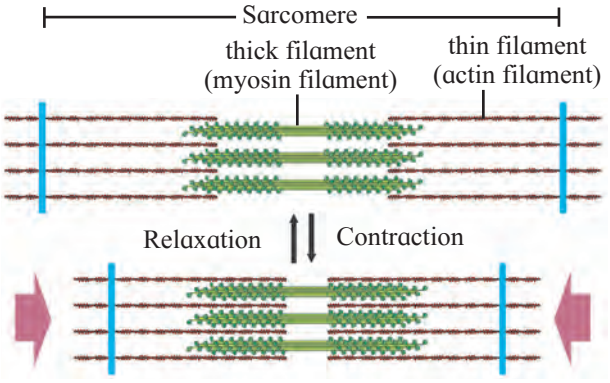


Fig. 16.6 Relaxation and contraction of muscle

Internet my friend

Collect information about 'T' tubules of sarcoplasmic recticulum.

16.6 Relaxation of muscle fibres :

During relaxation all the events occur in reverse direction. When stimulation is terminated, actomyosin complex is broken down and myosin head gets detached from actin filaments. This process involves use of ATP. At the same time calcium ions return back. This is also an active process that uses energy. Due to disappearance of calcium ions, troponin – tropomyosin complex is restored again. This complex covers the active sites of actin filament. Due to this the interaction between actin and myosin ceases to occur and the actin filaments return back to their original position. This results in muscular relaxation. Like contraction, relaxation is also an active process.

Always Remember

Oxygen debt is used in oxidizing the accumulated lactic acid aerobically and in restoring the depleted creatine phosphate and ATP.

Rigor Mortis : Usually, some hours after the death of an individual, its muscles are stiffened. This muscular stiffening, after death is rigor mortis. It helps in fixation of hours of death after a murder. After death, the fresh supply of ATP to muscles becomes impossible. Therefore once the local store of ATP is finished, the detachment of myosin from actin cannot take place. This results in permanent state of contraction of the muscle.

Can you tell?

1. Why are muscle rich in creatine phosphate?
2. What do you understand by muscle twitch?
3. Explain mechanism of muscle contraction and relaxation.
4. Explain the chemical changes taking place in muscle contraction.

16.7 Properties of Muscles on Electrical Stimulation:

A. Single muscle twitch : A muscle contraction initiated by a single brief-stimulation is called a single muscle twitch. It occurs in 3 stages : a latent period of no contraction, a contraction period and a relaxation period.

B. Summation : If the muscle is stimulated before the end of the twitch, it generates greater tension i.e., summation or addition of effect takes place. Repeated stimuli will produce increasing strength of contraction (stair case phenomenon).

C. Tetanus : If stimulation is very rapid and frequent the muscle does not have time to relax. It remains in a state of contraction called tetanus.

D. Refractory period : Immediately after one stimulus, the muscle fibre cannot respond to another stimulus. This resting or refractory period is about 0.02 seconds.

E. Threshold stimulus : For a muscle fibre to contract, a certain minimum strength or intensity of stimulus is required. This is called threshold stimulus.

F. All or none principle : A stimulus below threshold will not result in contraction. A threshold stimulus will result in contraction. This contraction leads to maximum force. Higher stimulus will not increase force of contraction i.e. a muscle fibre contracts either fully or not at all. This is 'all or none' principle. All types of muscle fibres and nerve fibres obey this law.

G. Oxygen debt : During strenuous exercise, muscle's oxygen supply rapidly becomes insufficient to maintain oxidative phosphorylation of respiratory substrate. At this stage, muscles contract anaerobically and accumulate lactic acid produced by anaerobic glycolysis. Lactic acid produces less ATP and is toxic. It causes tiredness, pain and muscle cramps. During recovery, oxygen consumption of the muscle far exceeds than that in the resting state. This extra oxygen consumed during recovery is called oxygen debt of the muscle.

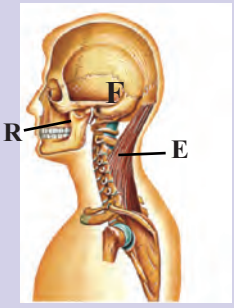
Do you remember?

1. What are the components of our skeletal system ?
2. What type of bones are present in our body?
3. How do bones help us in various ways ?

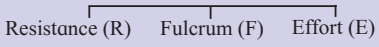
Use your brain power

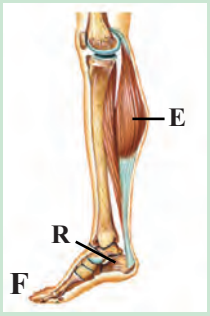
Can you compare bone, muscle and joint which help in locomotion with any of simple machines you have studied earlier ?

We can compare this unit with lever. Where joint acts as fulcrum, respective muscle generates the force required to move the bone associated with joint.

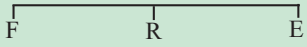


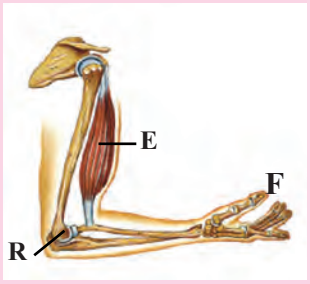
Class I lever : The joint between the first vertebra and occipital condyle of skull is an example of first class lever. The force is directed towards the joints (fulcrum); contraction of back muscle provides force while the part of head that is raised acts as resistance.



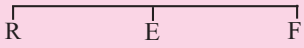


Class II lever : Human body raised on toes is an example of second class lever. Toe acts as fulcrum, contracting calf muscles provides the force while raised body acts as resistance.





Class III lever : Flexion of forearm at elbow exhibit lever of class III. Elbow joint acts as fulcrum and Radius and ulna provides resistance. Contracting biceps muscle provides force for the movement.



16.8 Skeletal System :

Multicellular animals need support to maintain body structure. Various groups of organisms show various supportive structures; either inside or outside the body or both inside as well as outside. You have studied that these skeletal structures are called exoskeleton. When present on outer surface of the body and endoskeleton when they are present inside the body.

Bones and cartilage form major endoskeletal components. Exoskeletal components change from lower to higher groups of animals. These include chitinous structures, nails, horns, hooves, scales, hair, etc; you may add to the list.

Do any of these exoskeletal structures help in movement and locomotion? How do scales and plates of a snake help in movement and locomotion? Are scales of a fish and that of a snake similar? Find out more information about exoskeletal structures and their role in movement and locomotion.

Can you imagine life without skeletal system? Our skeletal system is made up of cartilage and bone; which together form the framework of the body. Cartilage is slightly pliable while bones have hard matrix.

Bones form the framework of our body and thus provide shape which give us our identity. They protect delicate organs thus help in smooth functioning of body. Joints between bones help in movement and locomotion. Bones provide firm surface for attachment of muscles. They are reservoirs of calcium and one important site for haemopoiesis.

Endoskeleton of an adult human consists of 206 bones which can be grouped into two principle divisions; axial and appendicular skeleton.

Bones of axial skeleton lie along the longitudinal axis of human body. Bones of appendicular skeleton include bones of fore limb, hind limb and girdles. Girdles are the bones that connect the limbs to the axial skeleton.

Identify and label

Identify the different bones.

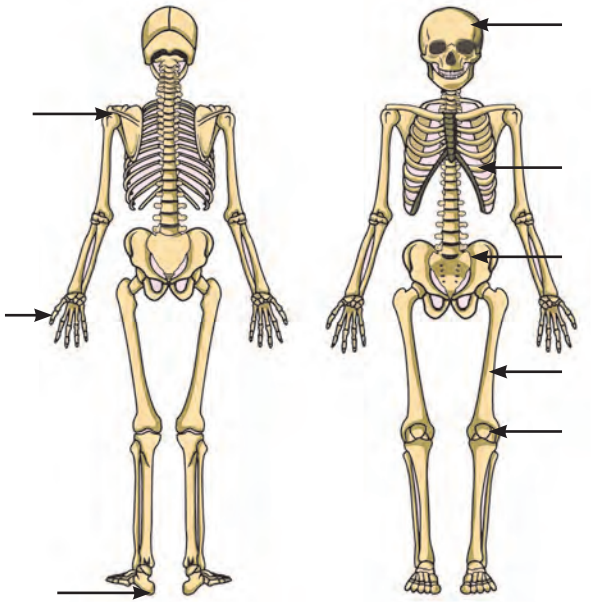


Fig. 16.7 Human Skeleton

Use your brain power Why are long bones slightly bent and not straight ?

16.9 Group of skeleton :

A. Axial Skeleton :

Skull :

Made up of 22 bones, skull is located at superior end of vertebral column. It consists of two main sets of bones, cranium or brain box and facial bones. Bones are joined by fixed or immovable joints except for lower jaw.

Cranium :

It is made up of four median and two paired bones.

Frontal bone : Median bone (Unpaired) forms forehead, roof of orbit (eye socket) and most of the anterior part of cranium. It is connected to two parietals, sphenoid and ethmoid bone.

Parietal bones : Paired bones, form roof of the cranium and greater portion of sides of the cranium.

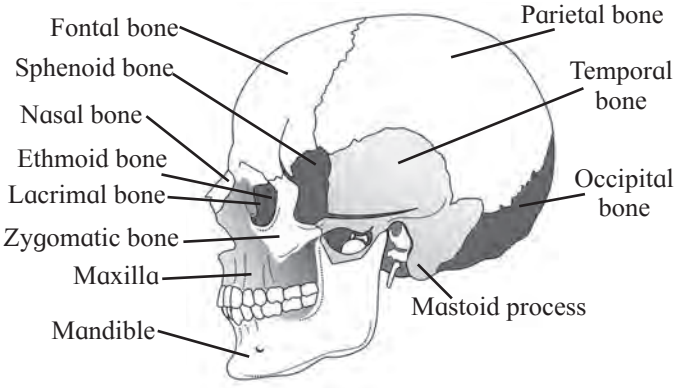


Fig. 16.8 Lateral view of skull

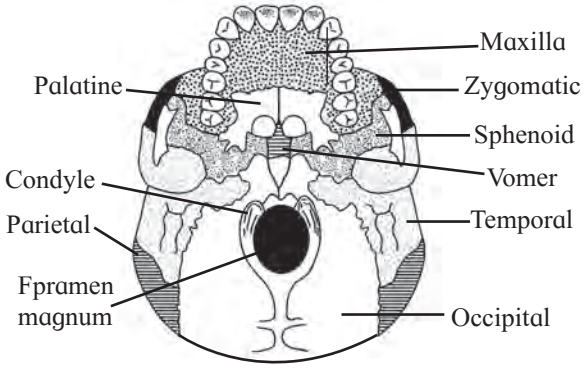


Fig. 16.9 Ventral view of skull

Temporal bones : Paired bones situated laterally just above the ear on either side. Each temporal bone gives out zygomatic process that joins zygomatic bone to form zygomatic arch. Just at the base of zygomatic process is mandibular fossa, a depression for madibles (lower jaw bone) that forms only movable joint of skull. This bone harbours ear canal that directs sound waves into the ear.

Processes of temporal bones provide points for attachment for various muscles of neck and tongue.

Occipital bone : Present at the back of the head, this single bone forms posterior part and most of the base of cranium. Inferior part of this bone shows 'Foramen magnum' the opening through which medulla oblongata connects with spinal cord. On either side of foramen magnum are two prominent protuberances called 'Occipital condyles'. These fit into the corresponding depressions present in 1st vertebra.

Sphenoid bone : Median bone present at the base of the skull that articulates with all other cranial bones and holds them together. This butterfly shaped bone has a saddle shaped region called sella turcica. In this hypophyseal fossa, the pituitary gland is lodged.

Refer : Read about sella turcica in chapter hormonal co-ordination.

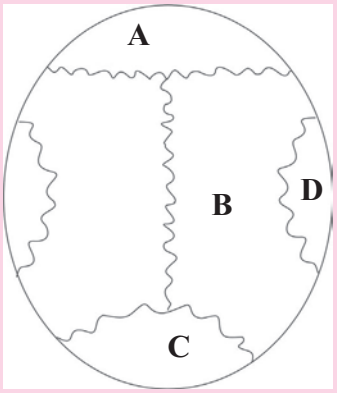
Ethmoid bone : This median bone is spongy in appearance. It is located anterior to sphenoid and posterior to nasal bones. It contributes to formation of nasal septum and is major supporting structure of nasal cavity.

In this chapter you are going to learn about sutures, a type of immovable joints. In skull there are many sutures present; four prominent ones are;

1. Coronal suture : Joins frontal bone with parietals.
2. Sagittal suture : Joins two parietal bones.
3. Lambdiodal suture : Joins two parietal bones with occipital bone.
4. Lateral/squamous sutures : Joins parietal and temporal bones on lateral side.

Identify and label

Name A, B, C and D from the given figure and discuss in group.



Axial skeleton :

Skull	
Cranium	8
Face	14
Hyoid	1
Ear ossicles	6
Vertebral column	26
Thorax	
Sternum	1
Ribs	24
Subtotal : 80	
Appendicular skeleton	
Pectoral Girdle	
Clavicle	2
Scapula	2
Upper Limbs	
Humerus	2
Radius	2
Ulna	2
Carpals	16
Metacarpals	10
Phalanges	28
Pelvic Girdle	
Hip bone	2
Lower Limbs	
Femur	2
Patella	2
Tibia	2
Fibula	2
Tarsals	14
Metatarsals	10
Phalanges	28
Subtotal : 126	
Total : 206	

Table 16.10 Details of Human Skeleton

Do you know ?

If there is a newborn in the family, you are told not to touch the head as it is still soft. Have you seen it? Why is it so? There are six soft spots called fontanelles in cranial bones. Eventually they get ossified at the age of two. Fontanelles provide some flexibility to skull during birth and also for rapid growth of brain during infancy.

Facial Bones : Fourteen facial bones give characteristic shape to face. Growth of face stops of the age of 16. Facial bones are as under :

Nasals : Paired bones form bridge of nose.

Maxillae : Upper jaw bones, paired bones that join with all facial bones except mandible. Upper row of teeth are lodged in these.

Palatines : Paired bones, form roof of buccal cavity or floor of nasal cavity.

Zygomatic bones : Commonly called cheek bones. You have read about zygomatic arch earlier in this chapter.

Lacrimal bones : Smallest of the facial bones. These bones form medial wall of each orbit. They have lacrimal fossa that houses lacrimal sacs. These sacs gather tears and send them to nasal cavity.

Inferior nasal conchae : They form part of lateral wall of nasal cavity. These help swirl and filter air before it passes to lungs.

Vomer : Median, roughly triangular bone that forms inferior portion of nasal septum.

Mandible : Median bone that forms lower jaw. Largest and strongest facial bone. Only movable bone of skull. It has curved horizontal body and two perpendicular branches i.e. rami. These help in attachment of muscles. It has lower row of teeth lodged in it.

Hyoid bone : It is a 'U' shaped bone that does not articulate with any other bone. It is suspended from temporal bone by lingaments and muscles. It is located between mandible and larynx. It has horizontal body and paired projections called horns. It provides site for attachment of some tongue muscles and muscles of neck and pharynx.

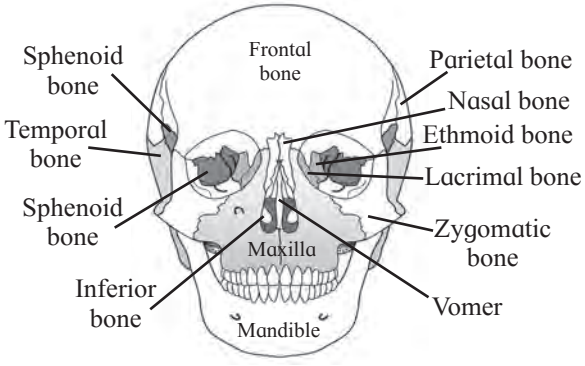


Fig. 16.11 Anterior view of skull

Internet my friend

Cleft palate and cleft lip.

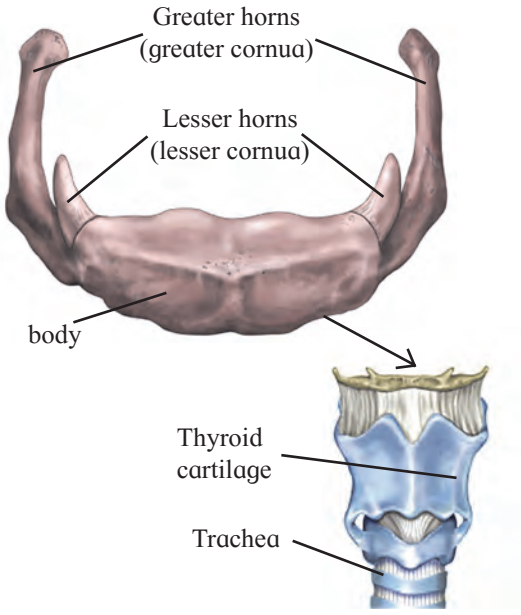


Fig. 16.12 Hyoid bone

Can you tell?

1. Give schematic plan of human skeleton.
2. Enlist the bones of cranium.
3. Write a note on structure and function of skull.

Something interesting : If Police suspect strangulation, they carefully inspect hyoid bone and cartilage of larynx. These get fractured during strangulation. Various such investigations are done in case of suspicious death of an individual where ossification of sutures in skull, width of pelvic girdle, etc. are examined to find out approximate age of victim or gender of victim, etc. You may find out information about forensic science.

Internet my friend

Find out information about sinuses present in skull, functions of skull and disorder 'sinusitis'.

Can you Tell?

Why skull is important for us? Enlist few reasons.

Ear ossicles : Three tiny bones namely malleus, incus and stapes, together called 'ear ossicles' are present in each middle ear.

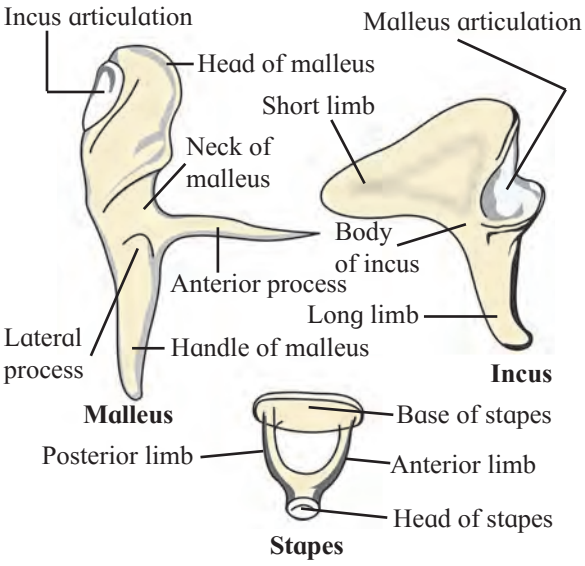


Fig. 16.13 Ear ossicles

Vertebral Column :

Human backbone or vertebral column is made up of a chain of irregular bones called vertebrae. It consists of 33 vertebrae during childhood. In adults, five sacral vertebrae fuse to form one sacrum and four coccygeal vertebrae fuse to form single coccyx, thus total number of bones are 26.

Try this

Feel your spine (vertebral column). Is it straight or curved?

There are four curvatures in human spine, cervical and lumbar curves are secondary and convex whereas thoracic and sacral curvatures are primary and concave. Curvatures help in balancing in upright position, absorb shocks while walking and also protect vertebrae from fracture.

You will study about intervertebral discs in this chapter. Find information about slipped disc.

There are five types of vertebrae in human spine namely, 7 cervical (neck), 12 Thoracic (chest), 5 lumbar (abdominal), 5 sacral (hip region, fused in adults forming 1 sacrum) and 4 coccygeal (fused to form vestigial tail bone called coccyx).

Though vertebrae vary in size, shape or processes, they exhibit similar basic plan.

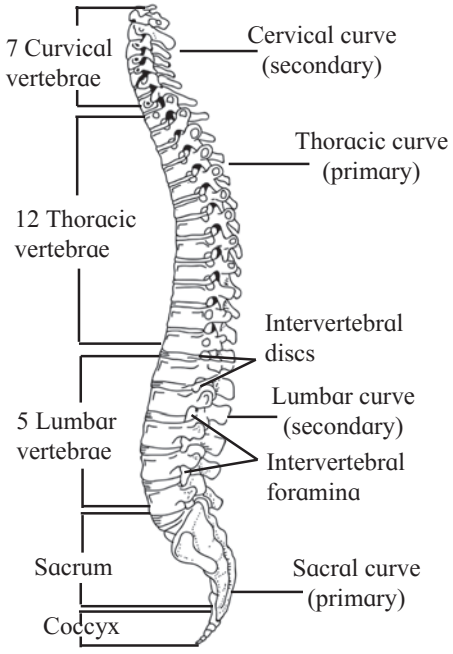


Fig. 16.14 Vertebral column lateral view

Typical Vertebra :

Each vertebra has prominent central body called centrum. Centra of human vertebrae are flat in anterio-posterior aspect. Hence human vertebrae are amphiplatyan. From either side of centrum are given out two short, thick processes which unite to form an arch like structure called neural arch, posterior to centrum. Neural arch forms vertebral foramen which surrounds the spinal cord. Vertebral foramina of all vertebrae form a continuous 'neural canal'. Spinal cord along with blood vessels and protective fatty covering passes through neural canal.

Point where two processes of centrum meet, neural arch is drawn into a spinous process called neural spine. From the base of neural arch, two articulating processes called zygapophyses are given out on either side. The anterior are called superior and posterior called inferior zygapophyses. In a stack of vertebrae, inferior zygaphyses of one vertebra articulates with superior zygapophyses of next vertebra. This allows slight movement of vertebrae without allowing them to slip off. At the junction of zygapophyses, a small opening is formed on either side of vertebra called intervertebral foramen that allows passage of spinal nerve. From the base of neural arch, lateral processes are given out called transverse processes. Neural arch, neural spine and transverse processes are meant for attachment of muscles.

Let us now study modifications seen in vertebrae in different regions of vertebral column.

Atlas vertebra : This is a ring like 1st cervical vertebra. It consists of anterior and posterior arches. It does not have centrum and spinous process. Transverse processes and transverse foramina are large. Vertebral foramen is large and divided into two parts by transverse ligament. Spinal cord passes through anterior compartment. Anterior zygapophyses, are replaced by facets for attachment with occipital condyle of skull that forms 'Yes Joint'.

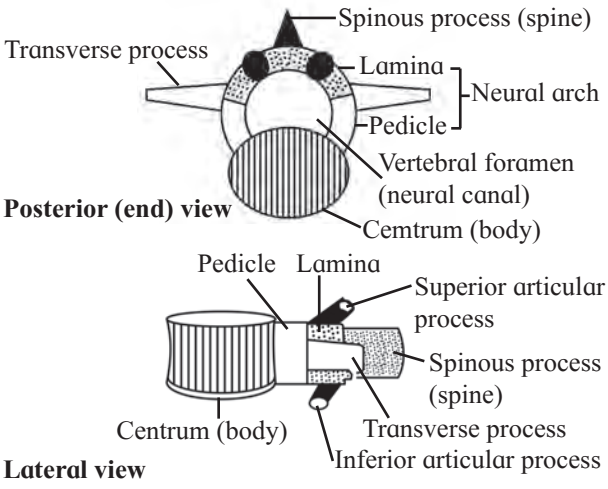


Fig. 16.15 Basic plan of vertebra

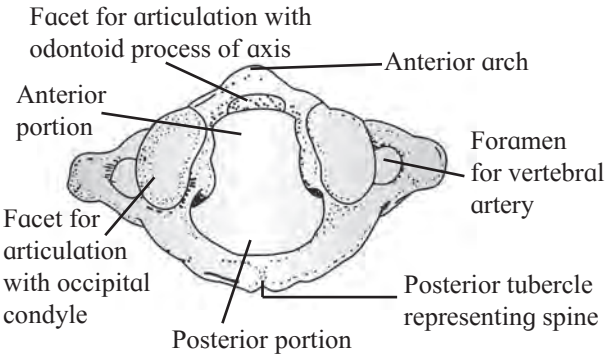


Fig. 16.16 Atlas vertebra

Axis vertebra : This is the second cervical vertebra. Centrum of this vertebra gives out tooth-like 'Odontoid Process'. This process fits into the anterior portion of vertebral foramen of Atlas vertebra forming pivot joint, also called 'No joint'.

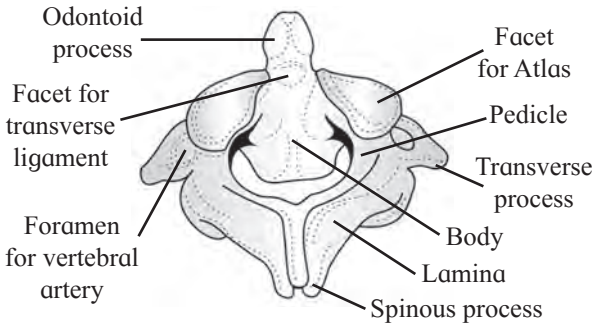


Fig. 16.17 Axis vertebra

Typical cervical vertebrae : Vertebrae number 3 to 6 are called typical cervical vertebrae. They show short centrum and bifid spinous process. Transverse processes of these vertebrae are reduced; each having large vertebrarterial canal at it's base for passage of vertebral artery.

7th cervical vertebra (Vertebra prominens) : It is the largest cervical vertebra where neural spine straight.

Thoracic vertebra : These are twelve in number and found in chest region. Centrum of thoracic vertebrae is heart shaped and all processes are well developed. Except for vertebrae number 11, 12; transeverse process of other thoracic vertebrae show facets for attachment with ribs.

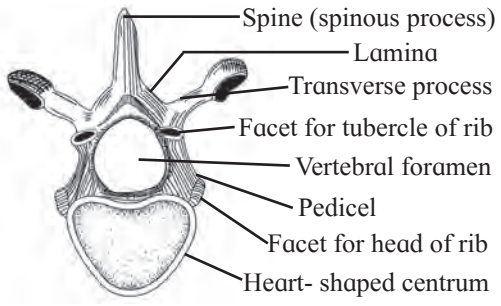


Fig. 16.18 Thoracic vertebra

Lumbar vertebra : There are five lumbar vertebrae. These are well developed vertebrae that exhibit all characters of a typical vertebra. Centrum is kidney shaped.

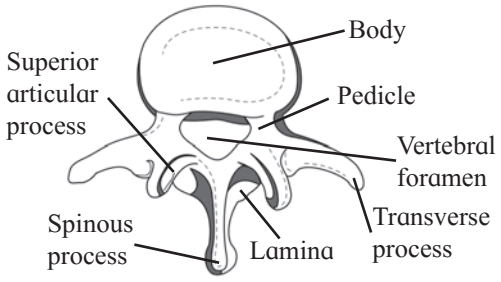


Fig. 16.19 Lumbar vertebra

Sacrum : Sacrum is a triangular bone formed by fusion of five sacral vertebrae. It is located in pelvic cavity between two hip bones. Anterior end of sacrum is broad and posterior end is narrow. Vertebral foramina that are formed by fusion of vertebrae can be seen. Reduced neural spines can be observed projecting from dorsal aspect of sacrum. It gives strength to pelvic girdle.

Coccyx : Coccyx is formed by fusion of four coccygeal vertebrae. It is reduced and does not show vertebral foramina and spinous processes. Transverse processes of coccygeal vertebrae are reduced. It is a triangular bone.

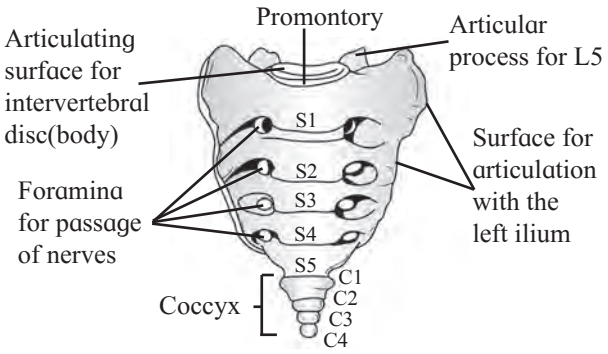


Fig. 16.20 Sacrum and Coccyx

Thoracic cage : It consists of twelve thoracic vertebrae; which are already discussed; twelve pairs of ribs and breast bone, the sternum.

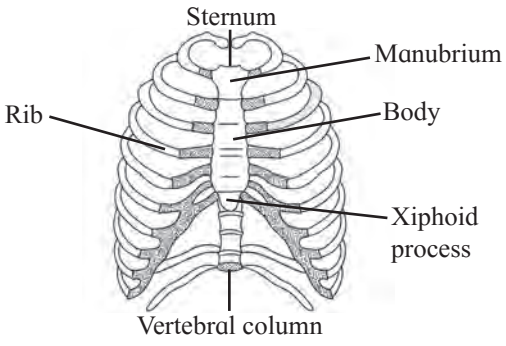


Fig. 16.21 Thoracic cage

Can you tell?

1. Explain the structure of a typical vertebra.
2. How will you identify a thoracic vertebra?
3. Write a note on curvatures of vertebral column and mention their importance.

Sternum : It is a flat, narrow bone, around 15 cms in length. It is placed medially in anterior thoracic wall (chest region). It consists of three distinct parts-manubrium, body and xiphoid processes.

Manubrium shows two notches on anterio-lateral side for attachment with clavicle of each side. It also shows two notches on each of the lateral side for attachment of first two pairs of ribs.

Body of sternum is a flat bone that shows five notches on lateral aspect which are meant for direct or indirect attachment of ribs. Ribs are attached to sternum by means of cartilaginous extensions called coastal cartilages.

Xiphoid process is lowermost part of sternum which is cartilaginous initially and gets ossified in adults. It provides space for attachment of diaphragm and abdominal muscles.

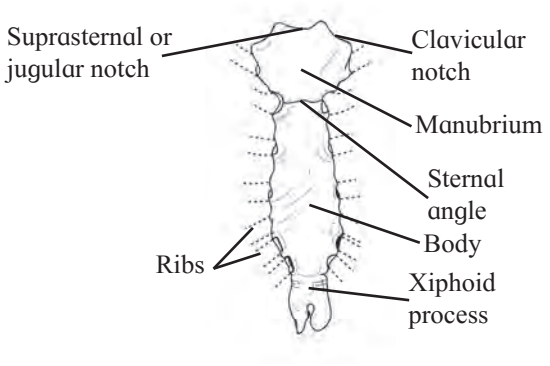


Fig. 16.22 Sternum

Rib : A rib is a 'C' shaped bone that is attached to respective thoracic vertebrae on dorsal side. Twelve pairs of ribs are attached to twelve thoracic vertebrae. For this attachment, posterior ends of ribs have two protuberances namely the head and tubercle. The head of rib attaches to facet formed by demifacets of adjacent thoracic vertebrae at the base of transverse processes. Tip of transverse processes of these vertebrae also have facets for attachment of ribs where tubercles of ribs are attached.

On the ventral side, the ribs may or may not attach to the sternum. Depending on their attachment, ribs are classified into three types.

i. ***True ribs :*** First seven pairs of ribs are attached directly to the sternum by means of their coastal cartilages.

ii. ***False ribs :*** Coastal cartilages of ribs no. 8, 9 and 10 are attached to rib number 7 on either side and not directly to the sternum. Hence these are called false ribs.

iii. ***Floating ribs :*** Last two pairs of ribs have no ventral connection. Hence are called floating ribs.

Space between ribs is called intercoastal space. Ribs provide space for attachment of intercoastal muscles.

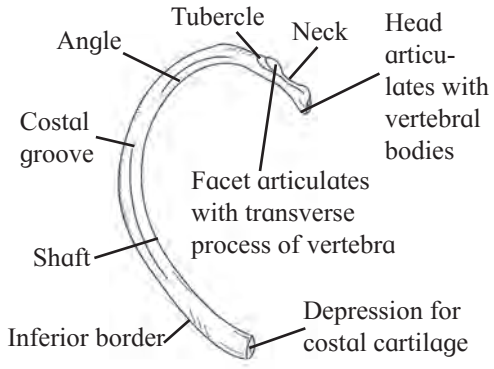


Fig. 16.23 Rib

Something interesting :

Approximately 8 % of humans have an extra pair of ribs attached to the lumbar vertebra. Such a rib is found in some types of gorillas. Hence 13th pair of ribs is called gorilla rib.

B. Appendicular skeleton : As mentioned earlier in this chapter, appendicular skeleton consists of bones of limbs and girdles.

Pectoral girdle : Also called shoulder girdle, it attaches forelimb skeleton with axial skeleton. There are two pectoral girdles, each consists of a shoulder blade or scapula and collar bone or clavicle.

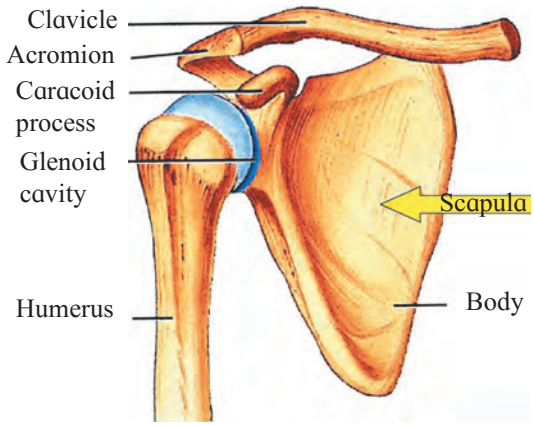


Fig. 16.24 Pectoral girdle

Clavicle : It is 's' shaped slender bone. One end of clavicle is attached to acromion process of scapula. The other rounded end called sternal end attaches to manubrium of sternum. This connects upper arm skeleton to axial skeleton.

Scapula : It is a large, flat, triangular bone that occupies posterior chest wall extending from second to seventh ribs. It is attached to axial skeleton by muscles and tendons.

At it's lateral angle, scapula bears a concave socket called glenoid cavity. Head of humerus (the upper arm bone) fits into the glenoid cavity. Two processes arise from scapula, a beak like coracoid process that projects from lateral angle of scapula and acromion process, easily felt as high point of shoulder. Both are meant for attachment of muscles.

Bones of forelimb : It consists of humerus, radius and ulna (together forming forearm bones), Bones of wrist-the carpals, bones of palm-the metacarpals and bones of digits-phalanges together making to 30 bones.

Can you recall?

How does humerus form ball and socket joint? Where is it located ?

Humerus : This is the bone of upper arm. It has hemispherical head at it's proximal end.

On either side of head of humerus are present a pair of projections termed greater and lesser tubercles. There is a deep groove between the tubercles called bicipital groove where a tendon of biceps muscle is attached.

Shaft of humerus shows deltoid tuberosity. Distal end of humerus shows pulley like part called trochlea that articulates with ulna.

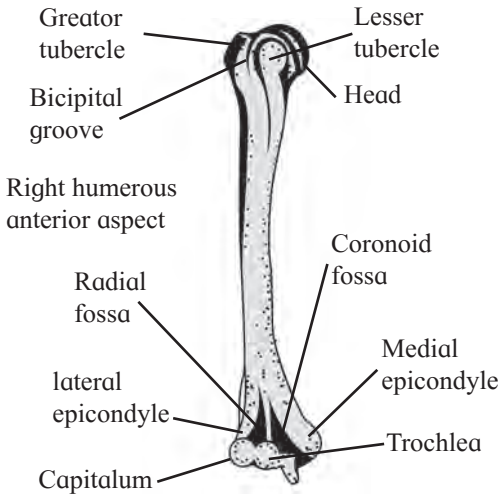


Fig. 16.25 Humerus

Radius and Ulna : Radius is located laterally on thumb side of the forearm. Proximal end of radius has disc like head that articulates with humerus bone. The shaft of radius widens distally to form styloid process.

Ulna is located medially on little finger side of forearm. At the proximal end of ulna there is a prominent process called 'Olecranon process' that forms elbow joint with humerus bone. On the lateral side, near the upper end of ulna is present the radial notch into which the side of head of radius is fixed.

Radius and ulna articulate with each other at upper and lower extremities by superior and inferior radio-ulnar joints. In between the shaft of two bones, interosseous membrane is present.

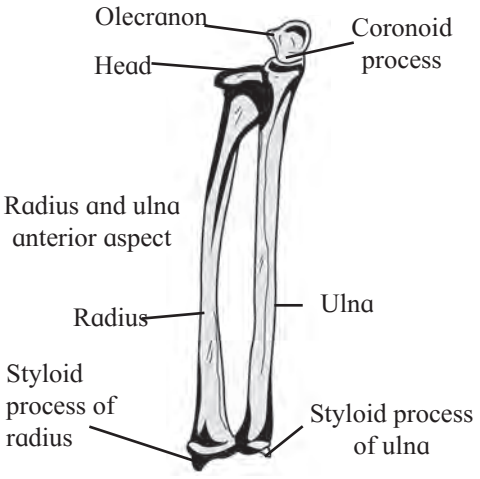


Fig. 16.26 Radius and Ulna

Carpals : These are bones of wrist, arranged in two rows of four each.

Metacarpals : Five elongated metacarpals form bones of palm. Their proximal ends join with carpals and distal ends form knuckles.

Phalanges : These are bones of fingers and thumb. Four fingers have three phalanges each and thumb has two; thus making it fourteen phalanges in each hand.

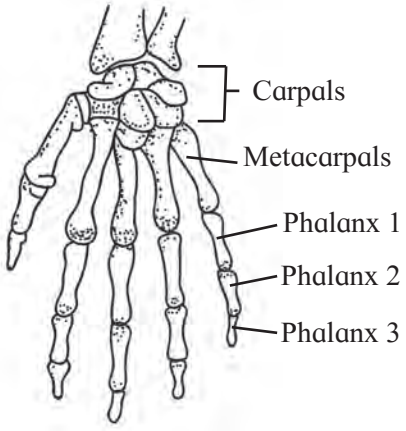


Fig. 16.27 Carpals, Metacarpals and Phalanges

Pelvic girdle : Pelvic or hip girdle connects hind limb skeleton with axial skeleton. It is made up of two hip bones called coxal bones. They unite posteriorly with sacrum. Each large irregularly shaped bone, the coxal bone is made up of three parts, ilium, ischium and pubis. At the point of fusion of three bones, a cavity called acetabulum is present that forms ball and socket joint with thigh bone.

The two pubis bones are joined medially by cartilaginous joint called pubic symphysis. Pubis and ischium together form a ring of bone that encloses a space called obturator foramen.

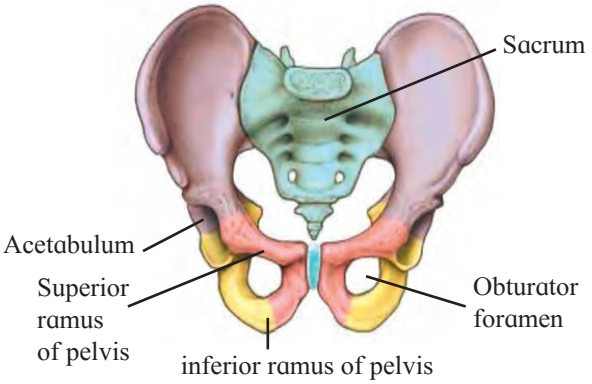


Fig. 16.28 Pelvic girdle

Bones of lower limb :

Femur : The thigh bone is the longest a bone in the body. The head is joined to shaft at an angle by a short neck. It forms ball and socket joint with acetabulum cavity of coxal bone.

The lower one third region of shaft is triangular flattened area called popliteal surface. Distal end has two condyles that articulate with tibia and fibula.

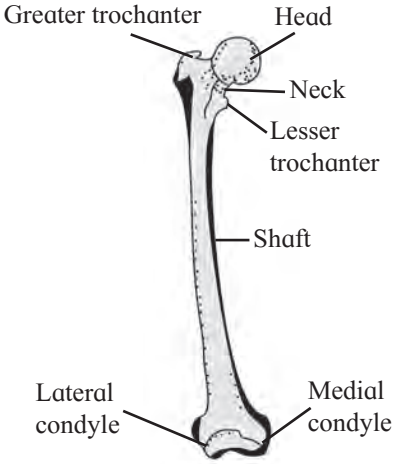


Fig. 16.29 Femur

Patella : Also called knee cap is a sesamoid bone. It is a flat rounded bone with a pointed lower end.

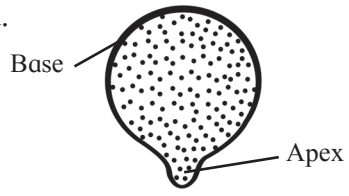


Fig. 16.30 Patella

Tibia and fibula : These are the two long bones of shank or lower le.g. The two are connected to each other at the extremities. In between the two bones interosseous membrane is present.

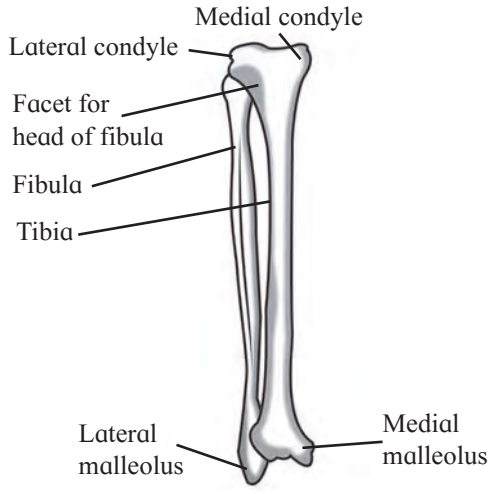


Fig. 16.31 Tibia and Fibula

Tibia : It is much thicker and stronger than fibula. It's broad and expanded upper end articulates with femur. Lower end articulates with talus, a tarsal bone.

Fibula : It is a long slender bone on lateral side of tibia.

Tarsals : These are the bones of ankle. Seven tarsals are arranged in three row, two proximal, one intermediate and four distal.

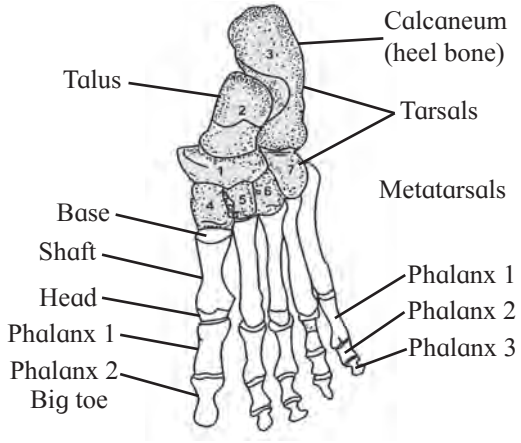


Fig. 16.32 Tarsals, Metatarsals and phalanges

Metatarsals : Five metatarsal bones support the sole region of the foot. Proximally they attach with distal row of tarsals. Distally metatarsals articulate with phalanges.

Phalanges : These are the bones of the toes. Except the big toe which has two phalanges, rest four toes have three phalanges each.

Can you tell?

1. Differentiate between skeleton of palm and foot.
2. Explain the longest bone in human body.

Do you remember?

1. What are joints? What are their types?
2. What types of joint is present at knee?

Imagine

If your elbow joint would be a fixed type of joint and joint between teeth and gum would be freely movable.

16.10 Types of joints :

You have studied about joints in previous standard. Without joints, various movements of the body wouldn't be possible.

A point where two or more bones get articulated is called joint or articulation or arthrosis. Study of joints is called arthrology.

Though bones are rigid, the ligaments that cover the bones, forming a joint render slight flexibility to the bones.

Joints are classified based on degree of flexibility or movement they permit into three types namely, fibrous joints, which are also known as synarthroses or immovable joints, cartilagenous or slightly movable joints also called amphiarthroses and lastly synovial or freely movable or diarthroses type of joints.

Degree of movement of joints in various parts of your body is so apt! We must always appreciate the design of our body.

Synarthroses : In this joint, the articulating bones are held together by means of fibrous connective tissue. Bones do not exhibit movement. Hence it is immovable or fixed type of joint.

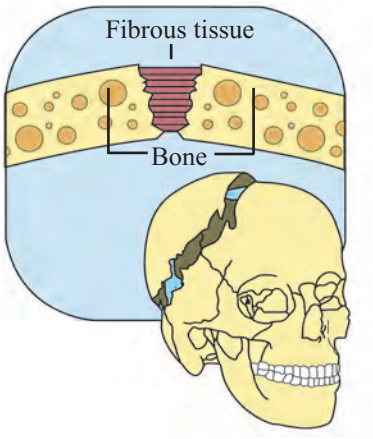


Fig. 16.33 Structure of Sutures

Type of suture	Character	Diagram	Example
Butt joint	Square edged		Two nasal bones
Scarf joint	Tapering		Various skull bones
Lap joint	Over lapping		Temporal and parietal bone
Serrate joint	Irregular/Inter locking		Various skull bones

Table 16.34 Types of Sutures

Fibrous joints are further classified into sutures, syndesmoses and gomphoses.

Sutures : It is composed of thin layer of a dense fibrous connective tissue. Sutures are places of growth. They remain open till growth is complete. On completion of growth they tend to ossify. Sutures may permit some moulding during childhood. Sutures are further classified into different types as shown in Table 16.34.

Syndesmoses : It is present where there is greater distance between articulating bones. At such locations, fibrous connective tissue is arranged as a sheet or bundle. e.g. Distal tibiofibular ligament, inter osseous membrane between tibia and fibula and that between radius and ulna.

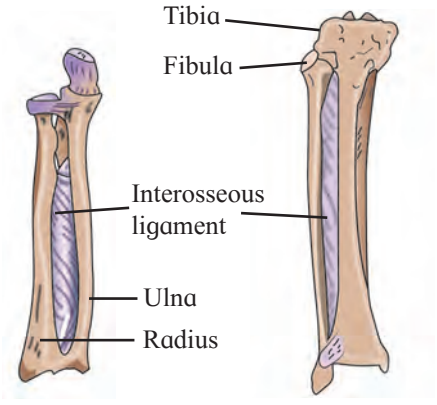


Fig. 16.35 Syndesmoses

Gomphoses : In this type of joint a cone shaped bone fits into a socket provided by other bone. e.g. Tooth and jow bones.

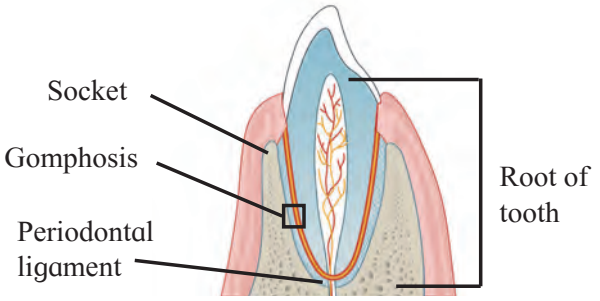


Fig. 16.36 Gomphoses

A. Cartilagenous or slightly movable joints : These are also called as **amphiarthroses**. These joints are neither fixed nor freely movable. Articulating bones are held together by hyaline or fibrocartilages. They are further classified as

a. Synchondroses : The two bones are held together by hyaline cartilage. They are meant for growth. On completion of growth, the joint gets ossified. Example: Epiphyseal plate found between epiphysis and diaphysis of a long bone, Rib – Sternum junction.

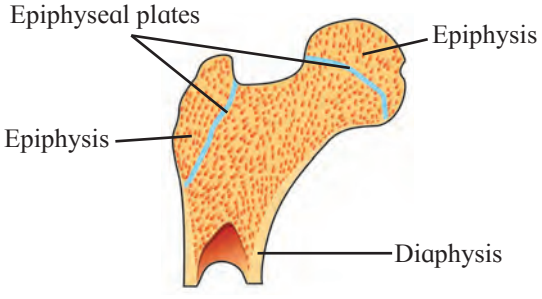


Fig. 16.37 Synchondroses

b. Symphysis : In this type of joint, broad flat disc of fibrocartilage connects two bones. These occur in midline of the body. One example of this type of joint is intervertebral discs. Can you write another example?

B. Synovial joints or freely movable joints :

They are also called as **diarthroses**.

It is characterized by presence of a space called synovial cavity between articulating bones that renders free movement at the joint. Articulating surfaces of bones at a synovial joint are covered by a layer of hyaline cartilage. (Bones do not touch to each other). It reduces friction during movement and helps to absorb shock. Synovial cavity is lined by synovial membrane that forms synovial capsule. Synovial membrane secretes synovial fluid.

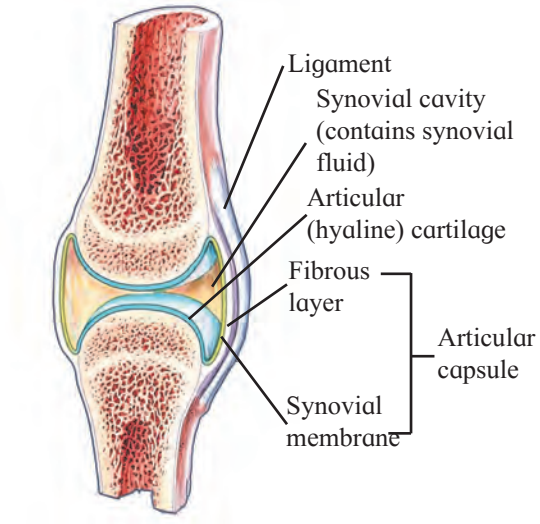


Fig. 16.38 Synovial joint

Synovial fluid is a clear, viscous, straw coloured fluid similar to lymph. It is viscous due to hyaluronic acid. Fluid also contains nutrients, mucous and phagocytic cells to remove microbes. Synovial fluid lubricates the joint, absorbs shocks, nourishes the hyaline cartilage and removes waste materials from hyaline cartilage cells (as cartilage is avascular) phagocytic cell destroy microbes and cellular debris formed by wear and tear of the joint.

If the joint is immobile for a while, the synovial fluid becomes viscous and as joint movement starts, it becomes less viscous. The joint is provided with capsular ligament and numerous accessory ligaments. The fibrous capsule is attached to periosteum of articulating bones. The ligament helps in avoiding dislocation of joint. Let us study types of synovial joints. Note that any type of synovial joint will show above mentioned components.

Pivot joint : Here, the rounded or pointed surface of one bone articulates with a ring formed partly by another bone and partly by ligament. Rotation only around it's own longitudinal axis is possible. Example : In joint between atlas and axis vertebrae, head turns side ways to form 'NO' joint.

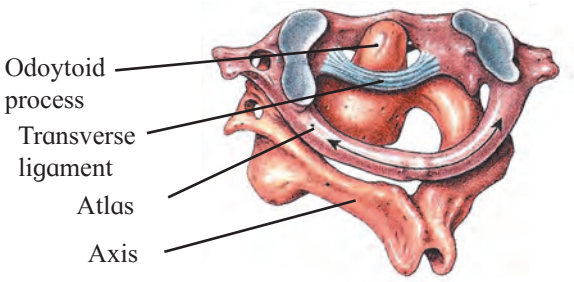


Fig. 16.39 Pivot joint

Ball and socket joint : Ball like surface of one bone fits into cup like depression of another bone forming a moveble joint. Multiaxial movements are possible. This type of joint allows movements along all three axes and in all directions. Example : Shoulder and hip joint

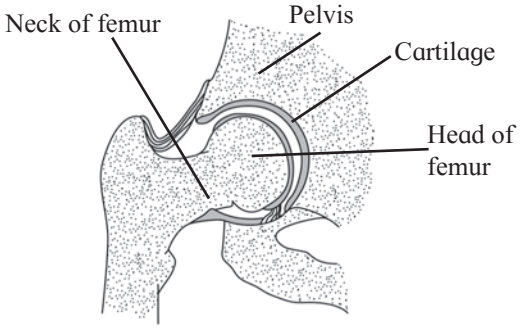


Fig. 16.40 Ball and socket joint

Use your brain power Why are warming up rounds essential before regular exercise?

Hinge joint : In a hinge joint, convex surface of one bone fits into concave surface of another bone. In most hinge joints one bone remains stationery and other moves. Angular, opening and closing motion like that of a hinge is possible. In this joint only monoaxial movement takes place like flexion and extension. Example : Elbow and knee joint.

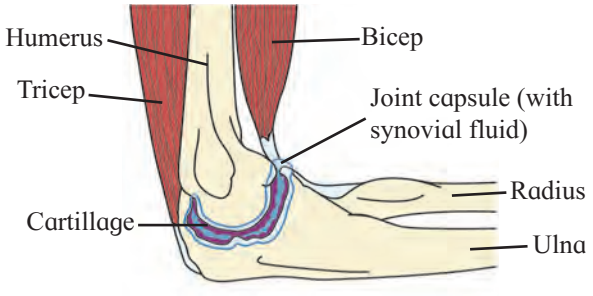


Fig. 16.41 Hinge joint

Condyloid joint : It is an ellipsoid joint. The convex oval shaped projection of one bone fits into oval shaped depression in another bone. It is a biaxial joint because it permits movement along two axes viz. flexion, extension, abduction, adduction and circumduction is possible. Example : Metacarpophalyngeal joint

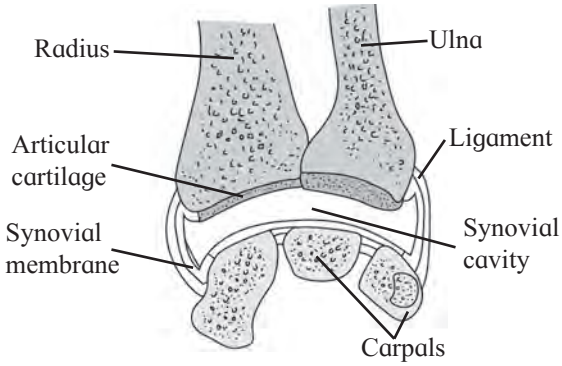


Fig. 16.42 Condyloid joint between radius and carpals

Gliding joint : A planar joint, where articulating surfaces of bones are flat or slightly curved. These joints are non-axial because motion they allow does not occur along an axis or a plane. Example : Intercarpal and intertarsal joints.

Saddle joint : This joint is a characteristic of *Homo sapiens*. Here, articular surface of one bone is saddle-shaped and that of other bone fits into such saddle as a sitting rider would sit. i.e. each bone has both concave and convex areas. It is a modified condyloid joint in which movement is somewhat more free. It is a biaxial joint that allows flexion, extension, abduction, adduction and circumduction. Example : Carpometacarpellar jont between trapezium carpal and metacarpal of thumb.

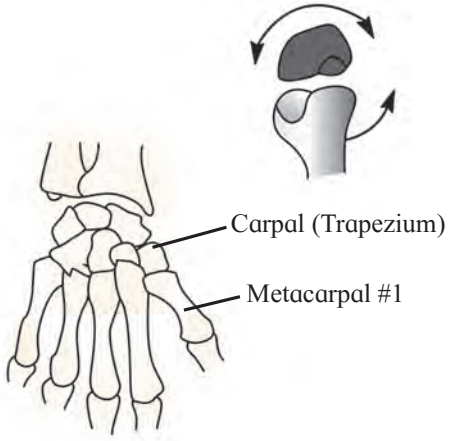


Fig. 16.43 Saddle joint

Can you tell?

1. Classify various type of joints found in human body. Present the information in the form of chart. Give examples of each type.
2. Human beings can hold an object in a better manner than monkeys. Why?
3. What makes the synovial joint freely moveable?

Internet my friend

Now a days we hear from many elderly people that they are undergoing knee replacement surgery. Find out why one has to undergo knee replacement; how it is carried out and how it can be prevented.

16.11 Disorders related to muscles :

Muscular dystrophy : It is a gradual wasting disease affecting various groups of muscles. These are genetically inherited in families. Usually voluntary skeletal muscles are weakened whereas internal muscles such as diaphragm are not affected. Duchenne type usually occurs in boys affecting lower limbs. Limb girdle muscular dystrophy affects the muscles of shoulders or hips and it usually starts in adults of 20-35 years. No treatment appears to cure the disease.

Myasthenia gravis : It is a weakness of skeletal muscles. It is caused by an abnormality at the neuromuscular junction that partially blocks contraction. It is an autoimmune disorder caused by an excess of certain antibodies in the blood stream. Antibodies bind to accetylecholine receptors of neuromuscular junction. Thus transmission of nerve impulses to the muscle fibres is blocked. This causes progressive and extensive muscle weakness. It may affect the eye and eyelid movements, facial expression and swallowing. The degree of muscle weakness varies form local to general. Example of symptoms are – Ptosis, (diplopia or double vision) difficulty in swallowing, chewing and speech.

16.12 Disorders related to bones :

Arthritis : It is an inflammation of joints. It is a painful disorder of bones, ligaments tendons etc. In this disorder, joints become swollen, stiff and painful. It can lead to disability. Arthritis is of three types.

i. **Osteoarthritis :** In this, joint cartilage is degenerated. It is caused by various factors like aging, obesity, muscle weakness, etc. This is most common type of arthritis that affects hands, knees and spine.

ii. **Gouty arthritis (Gout) :** In this disorder joint pain occurs due to deposition of uric acid in joints. If uric acid is produced in excess or is not excreted, it accumulates in joints as sodium urate and degenerates cartilage, causing inflammation and pain. It generally affects joints of feet.

iii. **Rheumotoid arthritis :** It is an autoimmune disorder where body's immune system attacks it's own tissues. In rheumatoid arthritis, synovial membrane swells up and starts secreting extra synovial fluid. This fluid exerts pressure on joint and makes it painful. Membrane may develop abnormal granulation tissue called pannus. Pannus may erode cartilage. Fibrous tissue gets ossified and may lead to stiffness in joints.

Find out

You must have heard of Sachin Tendulkar suffering from 'tennis elbow', a cricketer suffering from a disorder named after another game. Can common people too suffer from this disorder?

Find out more information about this disorder.

Internet my friend

Find out information about types of fractures and how they heal.

Osteoporosis : In this disorder, bones become porous and hence brittle. It is primarily age related disease more common in women than men. As age advances, bone resorption outpaces bone formation hence bones loose mass and become brittle. More calcium is lost in urine, sweat etc. than it is gained through diet. Hence prevention of disease is better than treatment by consuming adequate amount of calcium and exercise at young age. Osteoporosis may be caused due to decreasing estrogen secretion after menopause, deficiency of vitamin D, low calcium diet, decreased secretion of sex hormones and thyrocalcitonin.

Apart from fractures, osteoporosis may lead to shrinkage of vertebrae, height loss, hunched back and bone pain.

Exercise

1. Choose the correct option

A. The functional unit of striated muscle is .....
   a. cross bridges b. myofibril
   c. sarcomere d. z-band

B. A person slips from the staircase and breaks his ankle bone. Which bones are involved?
   a. Carpals b. Tarsal
   c. Metacarpals d. Metatarsals

C. Muscle fatigue is due to accumulation of .....
   a. pyruvic acid b. lactic acid
   c. malic acid d. succinic acid

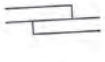
D. Which one of the following is NOT antagonistic muscle pair?
   a. Flexo-extensor
   b. Adductor-abductor
   c. Levator-depressor
   d. Sphinetro-suprinater

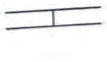
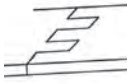
E. Swelling of sprained foot is reduced by soaking in hot water containing a large amount of common salt,
   a. due to osmosis
   b. due to plasmolysis
   c. due to electrolysis
   d. due to photolysis

F. Role of calcium in muscle contraction is .....
   a. to break the cross bridges as a cofactor in the hydrolysis of ATP
   b. to bind with troponin, changing its shape so that the actin filament is exposed
   c. to transmit the action potential across the neuromuscular junction.
   d. to re-establish the polarisation of the plasma membrane following an action potential

G. Hyper-secretion of parathormone can cause which of the following disorders?
   a. Gout b. Rheumatoid arthritis
   c. Osteoporosis d. Gull's disease

H. Select correct option between two nasal bones

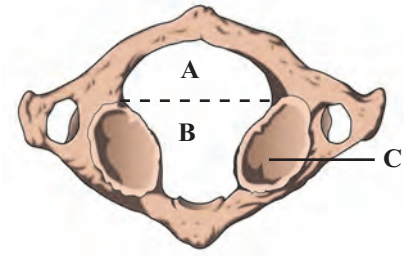
a.  b. 

c.  d. 

2. Answer the following questions

A. What kind of contraction occurs in your neck muscles while you are reading your class assignment?

B. Observe the diagram and enlist importance of 'A', 'B' and 'C'.



C. Raju intends to train biceps; while exercising using dumbbells, which joints should remain stationary and which should move?

D. In a road accident, Moses fractured his leg. One of the passers by, tied a wodden plank to the fractured leg while Moses was rushed to the hospital Was this essential? Why?

E. Sprain is more painful than fracture. Why?

F. Why a red muscle can work for a prolonged period whereas white muscle fibre suffers from fatigue after a shorter work? (Refer to chapter animal tissues.)

3. Answer the following questions in detail

A. How is the structure of sarcomere suitable for the contractility of the muscle? Explain its function according to sliding filament theory. (Refer to chapter animal tissues.)

B. Ragini, a 50 year old office goer, suffered hair-line cracks in her right and left foot in short intervals of time. She was worried about minor jerks leading to hair line cracks in bones. Doctor explained to her why it must be happening and prescribed medicines.

What must be the cause of Ragini's problem? Why has it occurred? What precautions she should have taken earlier? What care she should take in future?

C. How does structure of actin and myosin help muscle contraction?

D. Justify the structure of atlas and axis vertebrae with respect to their position and function.

E. Observe the blood report given below and diagnose the possible disorder.

Report D

PERFECT PATHOLOGY **Reg. No. :_____**

Dr._____ **Date:_____**

Patient Name :_____ **Age:_____** **M/F**

Reference:

Examination of Blood

Test	Result	Normal value
Uric Acid	9.2	2.5 - 7.0 mg/l
Blood Urea Nitrogen (Bun)	24	10 - 20 mg/dl

4. Write short notes on following points

A. Actin filament

B. Myosin filament

C. Role of calcium ions in contraction and relaxation of muscles.

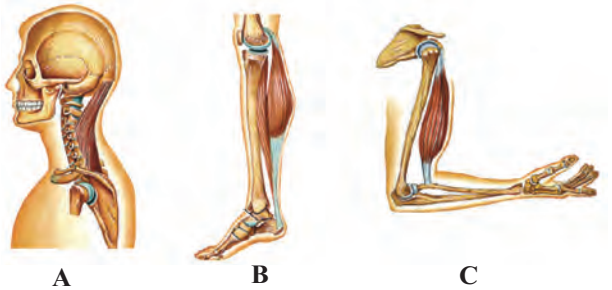
5. Draw labelled diagrams

A. Synovial joint.

B. Different cartilagenous joints.

Practical / Project :

Identify the following diagrams and demonstrate the concepts in classroom.



A B C