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Locomotion and Movement

Movement is one of the significant features of all living organisms. Animals and plants exhibit a wide range of movements. At the cellular level the cytoplasm shows streaming of protoplasm in the unicellular organisms like Amoeba. It is a simple form of movement. Movement of flagella, cilia and tentacles are shown by many living animals. Human beings can move jaws, eyelids, tongue, limbs etc. Some of the movements bring in a change of place or position, such voluntary movements are called locomotion. Plants move their parts by phototropism and geotropism.

Running, walking, flying, swimming, climbing are all some sort of locomotory movements. Locomotory structures are different from those affecting other types of movements. For example, in Paramoecium cilia help in locomotion and in the movement of food through cytopharynx as well Hydra can use their tentacles for capturing its prey and also use them for locomotion. The human use their limbs for changes in body postures and locomotion also as such. It is very difficult to separate movement from locomotion. The above remark gives a hint that movement and locomotion cannot be studied separately. These two may be linked by stating that all locomotion are movements but all movements are not locomotion. In animals locomotion is closely related to movement. Animals are different with their habitats and according to demand of the situation. Thus, locomotion is commonly for shelter, search of food, escape from enemies or predators, mate, suitable breeding grounds or favourable climate conditions.

Type of movement :

The act of changing place or position by the entire body or by one part or more of its part is called movement. Cells exhibit three main basic type of movements, namely amoeboid, ciliary and muscular.

Amoeboid type's movement is found in Amoeba as well as in some specialized cells in our body like macrophages and leucocytes in blood. In Amoeba this movement helps in food collection and change of place also. Movement is effected by pseudopodia formed by the streaming movement of protoplasm. Cytoskeleton elements like microfilaments also exhibit amoeboid movement. Ciliary movement occurs in trachea, oviducts and vasa efferentia, propelled by their lashing movements. The

coordinated movements of cilia of the upper respiratory track of human help in removing dust particles, some foreign substance involved and microbes invading out. The cilia of the oviduct and vasa efferentia of human transport eggs and sperms respectively in specific direction in these organs. Paramoecium as a animal shows ciliary movement for different functions.

Movement of our limbs, jaws, tongue etc. require muscular movement. The contractive property of muscle is used for locomotion. It also takes place in lower animals having no skeleton. Muscular locomotion required a perfect arrangement, interaction and coordination of the nervous, muscular and skeletal system of body in higher animals like vertebrates. In this chapter, you will study about types of muscle, their structure, and mechanism of their contraction and important aspects of the skeletal system.

Muscle :

Muscle is a specialized tissue of mesoderm origin. In adult humans, it constitutes about 40 – 50 percent of the total body weight. Muscle has some distinguishing properties like ability to conduct (impules), excitability, contractibility, extensibility and elasticity. The electrical excitability is due to the energy stored in an electrical potential difference across the plasma membrane. Muscles have been classified using different criteria, namely location, appearance and nature of their activities. Based on their location three types of muscle are classified.

(1) Skeletal or striated or voluntary muscles.

(2) Smooth or non-striated or involuntary or visceral muscle

(3) Cardiac muscle

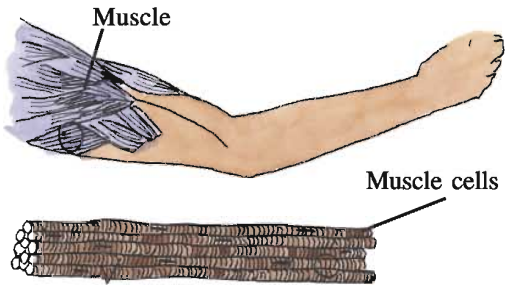
Skeletal muscle :

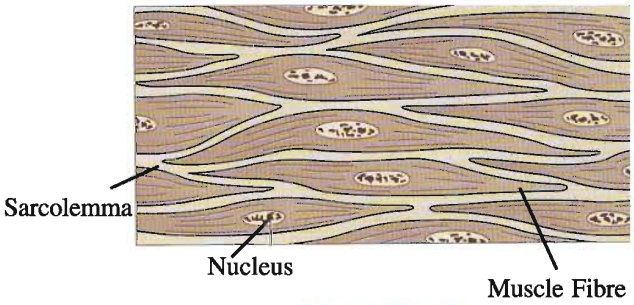
The skeletal muscles are generally closely attached to skeletal components like head, trunk and limb region, hence they are called skeletal muscles. Under the light microscope, these skeletal muscles exhibit transverse stripes appearance, therefore, they are also called striated muscles. As their activities are under the voluntary control of the nervous system, they are also known as voluntary muscle. Skeletal muscles are responsible for locomotory actions and change in body postures.

Visceral muscles are located in the inner walls of hollow visceral organs of the body such as alimentary canal, reproductive track, and respiratory organs. They do not show any striation and are smooth in appearance. Hence they are known as smooth or non-striated muscle. Smooth muscle fibre are of spindle shaped. These are involuntary and are innervated by autonomous nervous system. These muscles help in the movement of the substances through the canals of organs.

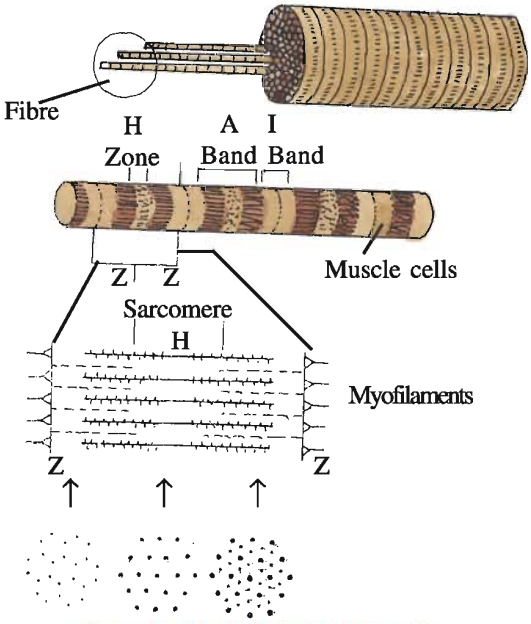
Cardiac muscle :

Cardiac muscles are exclusively found in the wall of the heart and maintain rhythmicity of heart beat. A cardiac muscle cell is short cylindrical, uninucleated, branched and striated. Every cardiac muscle cells are connected to each other known as intercalated disc by a special zigzag junctions. They are involuntary in nature as the nervous system does not control their activities directly. The cardiac muscles are innervated by autonomous nervous system. The cardiac muscles contract quickly, rhythmically, powerfully. The indefatigable fibers join by short oblique bridge and their blood supply is abundant.

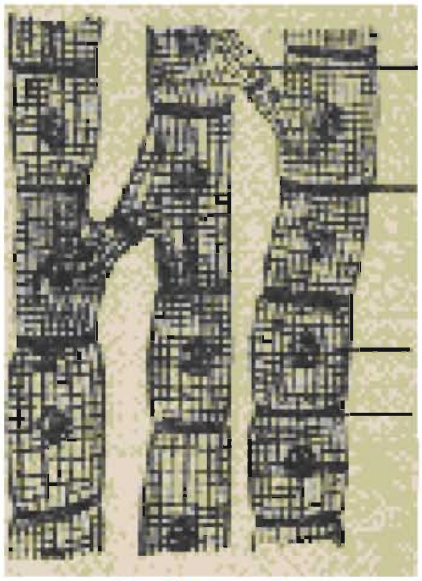




Visceral musle



Organisation of skeletal muscles



Cardiac muscle

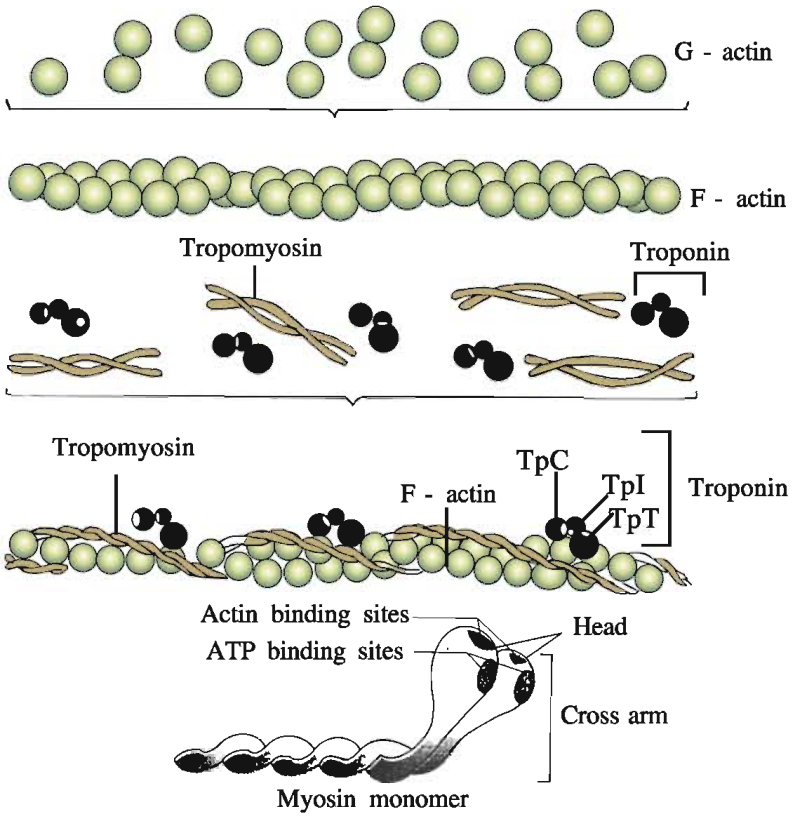
Ultra structure of skeletal muscle

Let us study a skeletal muscle in detail to understand the structure and mechanism of contraction. It consists of numerous fibres. Each muscle fibre is an elongated, narrow, cylindrical and un-branched and contains many flattened, elongated nucleus located near the sarcolemma. Multinucleate condition results from cell fusion. Thus a skeletal muscle fibre is syncytium. Sarcoplasm contains mitochondria known as sarcosome. The sarcoplasma contains endoplasmic reticulum known as sarcoplasm reticulum. It contains a large number of fine and rod-like myofibrils. A myofibril has light and dark bands. The light bands are isotropic (having same refractive index in all planes) and are known as isotropic or I-band.

The dark bands are anisotropic (refract light differently in different plane) and are known as anisotropic or A bands. Each A band possesses a light zone in its centre which is known as Hensen's line or H-Zone. In the centre of the H-zone is the M-line. In the centre each I band has a dark membrane known as Z-line. The Z-line is also known as Z-disc or membrane of Krause. The part of the myofibril between two successive Z-lines is known as sarcomere. Thus sarcomere consists of the A-band in the centre and half I-band on both the sides. It is contractile and a functional unit of myofibril. In each sarcomere thin filaments (actins) are located at the two ends, while the thick filaments (myosins) are present in the centre. Thus each sarcomere is a bundle of thick and thin myofilaments. The thick and thin filaments are alternately arranged. The I band contains only thin filament while H-zone contains only thick filaments. While A-band has both thick and thin filaments at both the ends.

Structure of contractile proteins

Actin filaments occur in two forms, the monomer G-actin and the polymeric 'F' actin. G-actin polymerizes in presence of Mg^{2+} to the fibrous form F-actin. Two filaments of another protein, tropomyosin also run close to 'F-actin' throughout its length. Tropomyosin is a rod-shaped fibrous protein. Tropomyosin forms two helical strands, which are wrapped around the F-actin. Troponin is a complex small globular protein which is distributed at regular intervals on the tropomyosin. In the resting state a subunit of troponin makes the active binding sites for myosin on the actin filaments.



(TpC : Troponin C, TpI : Troponin I, TpT : Troponin T)

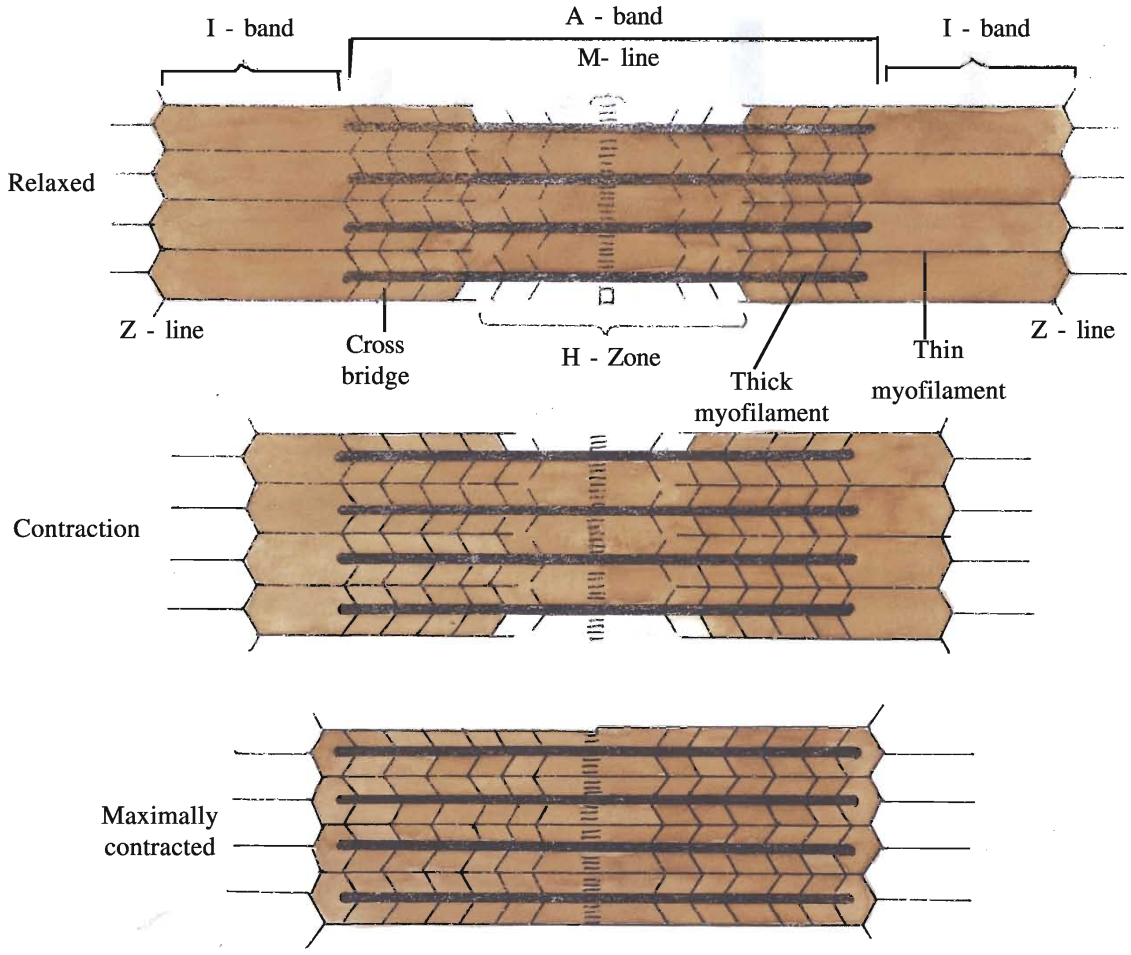
Figure showing contractile protein

Each myosin filament is also a polymerized myosin protein contend to A band only. Many monomeric proteins known as meromyosin form one thick filament. Each myosin molecule has two important components, a globular head with a short arm, and a tail. The tail is formed of a light meromyosin (LMM) while the head is form of heavy meromyosin (HMM). The HMM component projects outward at an angle from a polymerized myosin filament at regular distance which is known as cross arm. The globular head has ATPase action and binding sites which has site for attachment with ATP and actin.

Mechanism of muscle contraction

Mechanism of muscle contraction is explained by the sliding filament theory. According to this theory the contractile units of muscle composed of thick and thin filaments which overlap somewhat in relaxed muscle. On stimulation when muscle contract. The length of filament does not change but merely slide over one another. Thus actin filaments slide in the space between the myosin filaments. Due to I-band or light band shorten, while there is no change in the A or dark band. But disappearance of H-Zone in dark band may be seen. This is because two Z-line come close to each other. It is thought that the cross bridges on the myosin filaments might pull the actin filaments, during muscle is contracted

and during relaxation of muscle these cross bridge disappear. Thus contraction and relaxation of muscles are brought about by the repeating formation and disappearance of cross-bridges between myosin filaments of A band and actin filaments of I-band.



Sliding filament theory of muscle contraction Events during muscle contraction.

Muscle contraction is initiated by a signal sent by the central nervous via motor neuron. The junction between a motor neuron and the sarcolemma of the muscle fibre is known as neuromuscular junction or motor-end plate. A neural signal reaching this junction releases a neuro transmitter, the acetylcholine, which potential spreads deep into muscle fibre and causes the release of calcium ions into the sarcoplasm. Calcium activates the interaction of myosin and actin, but only through the intervention of tropomyosin and troponin utilizing the energy produced by ATP hydrolysis. The myosin head now binds to the exposed active site of actin to form a cross bridge. It pulls the attached actin filaments towards the centre of 'A' band, the Z line attached to their actins are also pulled in wards thus causing a shortening of sarcomere. i.e. contraction. The myosin, releasing the ADP and P_i goes back to relaxed state. A new ATP binds and the cross-bridges is broken. The most significant molecular basis of muscle contraction is formation and breakage of cross-bridge which is repetitive. These cross bridge are formed in between the myosin filament of A-band and Actin filament of I band. These two sets of filaments start movement passing on one another and causing in the shorting

of sarcomere. It is fact that cross bridge is formed only in absence of ATP. While breaking of cross bridge is in presence of ATP.

The duration of process is till the Ca^{2+} are pumped back to the sarcoplasm resulting in the masking of actin filaments. Thus the return of 'Z' line back to original position. i.e. relaxation. Thus relaxation is brought about when the Ca^{2+} ions concentration is reduced. In different types of muscles the reaction time of the fibres can vary. Prolong time activation of the muscles can lead to the accumulation of lactic acid because of anaerobic breakdown of glycogen in them causes fatigue. The muscle which does not respond to stimuli, is said to be a state of fatigue.

Skeletal muscle

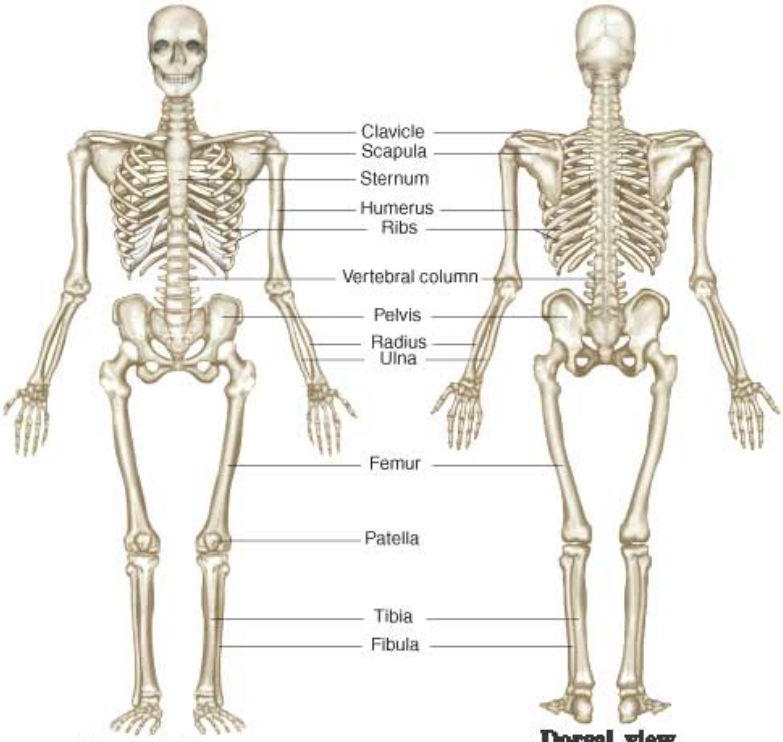
The skeletal muscle are of two types, red and white muscle. In red muscle there is the presence of very high amount of myoglobin, which gives a reddish appearance. Such muscles are also known as red fibres. The red fibres also contain large amount of mitochondria, which can utilize the large amount of oxygen stored in them for ATP production. These muscles thus also known as aerobic muscle eg. Red muscle, flight muscle of birds. The white muscles contain low amount of myoglobin, hence they appear pale or whitish. The white fibres contain small amount of mitochondria, but the quantity of sarcoplasmic reticulum is high eg. Muscles of eye ball of human.

Skeleton System :

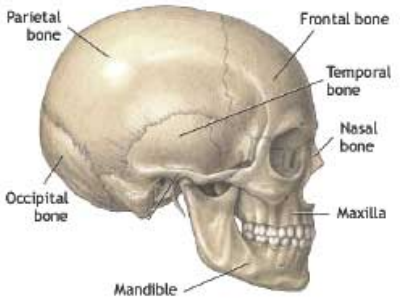
The hard, supportive or protective elements of the animal body form the skeleton or skeletal system. The study of skeleton is called osteology. (osteon = bone, logs = discourse). The greater number of animals have some skeleton. Skeleton may vary from simple spicules of sponges to complex frame work of vertebrate. Design of the skeleton depends on the animal's mode of life. Different design of skeleton is necessary for the terrestrial or aquatic animals, bipedal or quadrapedals and for flying. Skeletal system consists of bones and a few cartilages. This system has an important role in movement shown by the body. Bone and cartilage are specialized connective tissues. The bones have a very hard matrix due to calcium salts while cartilage has a slightly pliable matrix due to chondroitin salts. In human beings this system is made up of **206** bones and a few cartilages. It is grouped into the principal division – the axial and appendicular skeleton.

Axial skeleton :

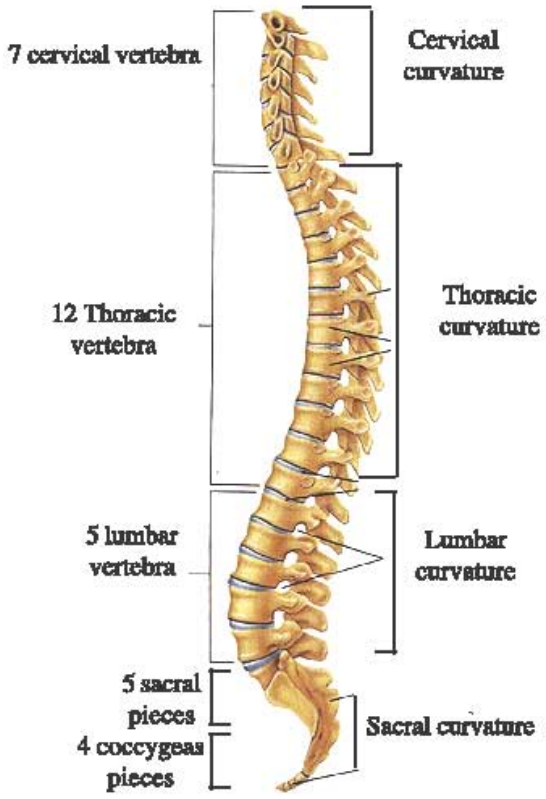
It is made up of **80** bones distributed along the main axis of the body. Axial skeleton constitutes the skull, vertebral column, sternum and ribs. The skull consists main regions cranium and face, composed of two sets of bones, cranial and facial bones, the total bones are **22**. Cranium possesses **8** flattened bones, which are tightly interlocked, forming a box called cranium. The bones which forms cranium are: 1 frontal bones, 2 parital bones, 2 temporal bones, 1 occipital bone, 1 sphenoid and 1 ethmoid bone. The cranial bones fit together by wavy, immovable boundaries called sutures. Facial bones include 2 nasal bones, 2 maxillae, 2 palatine, 2 zygomatic, 2 lacrymal bones, 2 interior nasal conchae, 1 vomer and 1 mandible. The palatine, inferior nasal conchae and vomer are not visible from the outer surface. A single U-shaped bone called hyoids is present at the base of the buccal cavity. Each middle ear contains three tiny bones, malleus, incus and stapes, collectively known as ear ossicles. The skull region articulates with the superior region of vertebral column with the help of occipital condyles.



Human Skeleton System



Human Skull



Vertebral column

Vertebral Column

Vertebral Column is formed by **26** serially arranged bones called vertebrae and is dorsally place. The vertebral column is the main axis of the body, which articulates with skull, pectoral girdle, pelvic girdle and ribs. Each vertebrum has centrally hollow portion through which the spinalcord passes. The vertebrae are named on the basis of region of the body where they are located. In neck region, they are known as cervical vertebrae. Cervical (7), thoracic (12), lumber (5). In the lower most region of the vertebral column the sacral vertebrae are 5 in number and they are fused. Coccygeal vertebrae are 4 in number and found in the vestigial tail, and are very small and fused to form a curved, triangular bone, the coccyx.

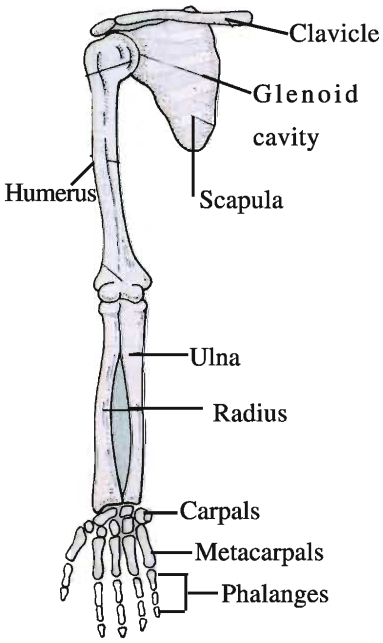
Thus vertebral formula of human is C_7, T_{12}, L_5, S_5, and C_4. The vertebral column encloses and protects the spinal cord and supports the head above. It strengthens the neck and the trunk for upright posture in standing and walking. It serves as the point of attachment for the ribs and musculature of the back. Sternum is a flat bone on the ventral midline of thorax.

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. The ribs have two articulation surface on its dorsal end and is hence called bicephalic. The upper 7 pairs of rib are attached in front directly to the sternum. These are called true ribs. The 8^{th}, 9^{th}, 10^{th} pairs of ribs do not articulate directly with the sternum but join the seventh rib with The help of cartilage. They are known as false ribs. Last 2 pairs (11^{th} and 12^{th}) of ribs are not connected ventrally and they are termed as floating ribs. The thoracic vertebrae, ribs and sternum together form the rib cage. They protect the heart, large blood vessels and lungs. They provide the surface for attachment of respiratory muscle.

Appendicular skeleton

(1) Bones of Limbs : The bones of the limbs along with their girdles constitute the appendicular skeleton. Each limb is made of **30** bones. The bones of the fore limb are humerus, radius and ulna. **8** carpals in the wrist, **5** metacarpals in the palm and **14** phalanges in the fingers. Each leg has **30** bones: **1** femur in the thigh bone – the largest and heaviest bone. **1** patella in the knee, **1** tibia and 1 fibula, **7** tarsals in the ankle, **5** metatarsal in the sole and **14** phalanges in the toes.



Human pectoral girdle and arm bones (Anterior view)

Phalangeal formula for human arms and legs is 2, 3, 3, 3, 3. Function of bones of the arms is to provide strength to make the arms effective in working with them. While the leg bones strengthen the legs to bear the body weight, to balance the body while standing and help in locomotion.

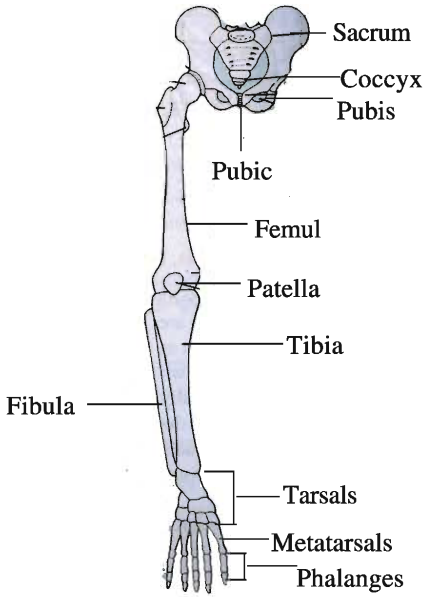
(2) Girdles : The girdles give articulation to the limbs. There are 2 girdles on each side. Pectoral girdle and pelvic girdle. Each girdle formed of two halves.

Pectoral girdle

Each half of the pectoral girdle consists of a clavicle and a scapula. The scapula is large, flat, triangular bone place on the dorsal side of the thorax above second to seven rib. There is a ridge, called spine which projects as a flat, expanded process termed as acromion process. The clavicle articulates with this. Below this process a cavity is present, called glenoid cavity which articulates with the head of the humerus to form the shoulder joint. The each clavicle is a long, slender rod-like bone with two curves. This bone is commonly known as collar bone.

Pelvic girdle

Pelvic girdle consists of two coxal bones. Each coxal bone is formed by the fusion of **3** bones; upper illum, lower ischium and inner pubis, faced to form a stout hip bone. At the point of



Human pelvic girdle, sacrum and coccyx

fusion of the above bones. There is a cavity termed as acetabulum to which the head of the thigh bone femur articulates. The two halves of the pelvic girdle meet ventrally to form the pubic symphysis containing fibrous cartilage.

Joints

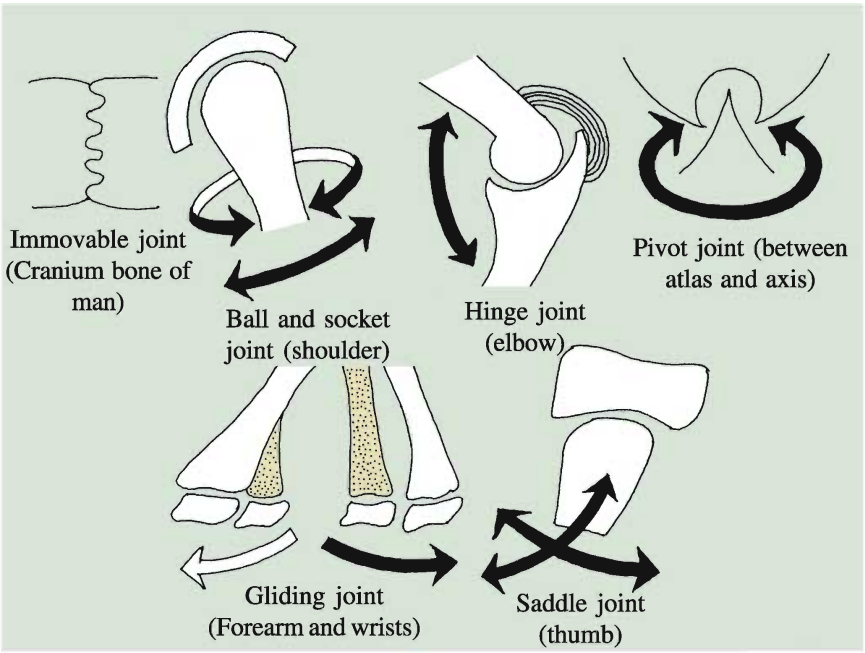
The structural arrangement of tissues which connects two or more bones together at their place of meeting is termed as joint. Joint are essential for all types of movements involving the bony part of body. Joints are points of contact between bones, or between cartilage and bones. Force is generally by muscle which is used to carry out movement of joints, here the joints acts as fulcrum.

Types of Joints :

There are three main types of joints. Joints have classified into three major structural forms, namely fibrous, or immovable. Cartilaginous and synovial and movable.

Fibrous, fixed or immovable joints occur between the bones of the cranium. They do not allow movement because the bones are held firmly together by bundle of strong white collagen fibres. The immovable joints are known as the sutures.

Cartilaginous or slightly movable joints are found between the centra of vertebrate, at the pubic symphysis. The articulating ends of bones are provided with elastic dense disc of fibro cartilage which separates the bone that are held together. The disc allows a limited little movement like bending and slight rotation at the joints.



Joints

Synovial or freely movable joints : The end of articulating bones are capped with a layer of hyaline cartilage. The articular surface between the articulating bones enclose a space between them known as synovial cavity. This cavity is filled with viscous synovial fluid, which lubricates the joint for easy considerable movement of bone. These joints help in locomotion and many other movements. These joints are ball and socket joint (between humerus and pectoral girdle), hinge joint (knee joint) pivot joint (between atlas and axis), gliding joint (between the carpals) and saddle joint (between carpel and metacarpal of thumb)

Disorders of skeletal system

Myasthenia gravis : It is an auto immune disorder that affects neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscle.

Tetany : It is a muscular disorder in which rapid spasms in muscle occur due to lesser Ca^{2+} in the body fluid.

Summary

Movement is an essential feature of all living organisms. Animals generally show two types of movement i.e. locomotion and movement of the body parts. Streaming of protoplasm, ciliary, movement, movements of fins, limbs, wings, etc. are some forms shown by animals. Locomotion takes animal to favourable environment. Animals move generally in search of food, shelter, mate, breeding ground, better climate, and protect themselves. The three basic types of movements exhibited by human cells. are amoeboid, ciliary and muscular movement. Skeletal muscle are attached to skeletal element. They show striation and are voluntary in nature. Visceral muscle are involuntary and non-striated. Cardiac muscles are found in heart. They are involuntary, branched and striated.

Muscle fibre is the anatomical unit of muscle. Each muscle fibre has many myofibrils arranged parallely. Each myofibril consists of many serially arranged units known as sarcomere. Each sacromere has a central 'A' band made of myosin (thick) filaments and two half 'I' band made of actin (thin) filament on either side of it marked by 'Z' lines. Actin and myosin are polymerise protein with contractibility nature. The active side for myosin on resting actin filament is masked by a troponin. Myosin head contains ATP ase and has ATP binding sites and active site for actin. A motor neuron carries signals which generate an action potential in muscle fibre. Because of this the release of Ca^{++} from sarcoplasmic reticular occurs. Ca^{2+} activates actin which binds to the myosin head to form a cross bridge. This cross bridge pulls the actin filament causing them to slide over myosin filament and causing contraction. Calciumions are then returned to sarcoplasmic reticulum which activates actin. These cross bridges are broken and muscles relax.

Muscles are of two kinds: the red fibres are thin, dark red and contain a high content of myoglobin, while white fibre are thick, white and contain a less content of myoglobin.

Bones and cartilage forms the skeletal system. This system is divisible into axial and appendicular. Axial skeleton constitutes skull, vertebral column, ribs and sternum. Limb bones and girdles form the appendicular skeleton. Joins are of two types, formed between bones or between bones and cartilage.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Number of floating ribs in human body is ..... .

(a) 6 pairs ○ (b) 5 pairs ○ (c) 3 pairs ○ (d) 2 pairs ○

(2) Number of vertebrae in human skeleton is ..... .

(a) 30 ○ (b) 32 ○ (c) 33 ○ (d) 26 ○

(3) Total numbers of bones in the hind limb is ..... .

(a) 21 ○ (b) 14 ○ (c) 30 ○ (d) 24 ○

(4) Functional unit of striated muscle is ..... .

(a) I Band ○ (b) Z line ○

(c) Myofilament ○ (d) Sarcomere ○

(5) Total number of bones in human skull is ..... .

(a) 26 ○ (b) 22 ○ (c) 30 ○ (d) 107 ○

(6) The joint between atlas and axis is ..... .

(a) Ball and socket ○ (b) Pivot ○

(c) Saddle ○ (d) Collagen ○

(7) ATPase enzyme needed for muscle contraction is ..... .

(a) Myosin ○ (b) Actin ○

(c) Tropomyasin ○ (d) Troponin ○

(8) The contractile protein of skeletal muscle involving ATPase activity is ..... .

(a) Troponin ○ (b) Tropomyosin ○

(c) Myosin ○ (d) Actin ○

(9) The region between two successive Z line in a myofibril is ..... .

(a) Sarcomere ○ (b) Sarcosome ○

(c) Fascia ○ (d) Anisotropic band ○

2. Answer the following questions in very short :

(1) How do ilium differ from ischium ?

(2) What causes muscle fatigue? How is it removed ?

(3) Human has 3 kinds of ribs. Name these with examples.

(4) What is acetabulum ?

(5) What is muscle ? Write the name of different types of muscles.

(6) How do the joints help in movement ? Explain.

(7) Name the major parts of human skeleton. Give the number of bone in its each part.

(8) Explain the sliding filament theory of muscle contraction.

(9) What makes the synovial joint freely movable ? List the various types of synovial joints

4. Answer the following questions in detail :

(1) Explain : The types of movements found among the animals.

(2) Write the difference between :

(a) Bones of Fore Limb - Bone of Hind Limbs

(b) Red muscles and white muscles

(c) Pectoral girdle - Pelvic girdle