Chapter - 30
Movements and Locomotion in Man

Skeleton System in Man

Skeleton forms a supporting frame work in the body. Skeleton originates from ectoderm and mesoderm.

There are two types of skeleton in vertebrates-

(i) Exoskeleton (ii) Endoskeleton

(i) Exoskeleton - This skeleton is completely or partially present outside the body. It is derived from epidermis or dermis or both layers. Generally exoskeleton is dead but the roots of some structures are embedded in skin are alive by this they grow continuously.

In human hairs and nails are in the form of exoskeleton. Both of these are formed from ectoderm. Exoskeleton is found in other animals also i.e. scales in fishes, scales and scutes in reptiles, feathers and claws in birds and hairs, nails and horns in mammals.

(ii) Endoskeleton – Endoskeleton is located inside the body. It is made up of bones and cartilage. It originates from mesoderm. At initial stage endoskeleton is made of cartilage but with development of body it change into bones. Some bones are developed directly as bone. Endoskeleton is living.

Cartilages and Bones –

Cartilage – Cartilage is a soft and flexible structure. Most of the bones of skeleton are cartilages initially. Matrix of cartilage is made of chondrin protein. Chondrocyte are found solitary or in groups in matrix. Covering of periochondrium is found around them (Fig. 30.1).

On the basis of origin cartilages are of three types-

(i) Hyaline cartilage– Matrix of this cartilage is transparent and light blue in colour.

(ii) Elastic Cartilage– The matrix has flexible yellow fibres. It is found in ear pinna and epiglottis.

(iii) Fibro cartilage– The matrix of this cartilage has more fibres. Due to compact arrangement of fibres it is rigid. This cartilage is found in inter-vertebral disc.

Bone– Bones are rigid and strong. A covering of thin but rigid membrane periostium is present on it. A layer of osteoblast is present below this layer. Matrix is in the form of concentric rings. Osteocytes are arranged in these rings. Matrix is made of Ossein protein. The salts of calcium and phosphate are also present in them which provide rigidity to bone. Endosteum layer is present on inner surface (Fig. 30.1).

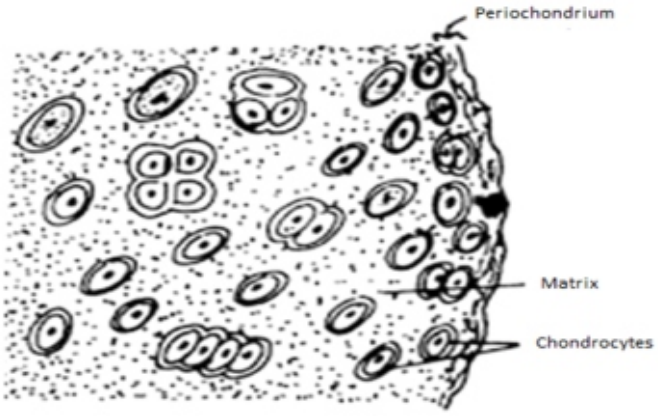

Fig. 30.1Transverse section of Cartilage

On the basis of origin bones are of two types-

(i) Cartilaginous or replacing bones

(ii) Membranous or investing bones

(I) Cartilaginous or replacing bones - Cartilaginous bones are developed in the form of cartilage in initial stage of its formation. These are soft in this stage. The matrix is made up of chondrin protein and chondrocytes are present in it and has a covering of perichondrium but their structure changes along with the growth of animal. Calcium ions deposit in it then it becomes rigid and hard. Its chondrocytes destroy and in place of them osteocytes are formed. Osteocyte secretes ossien protein in matrix. Perichondrium converts into periosteum. Thus cartilage is modified into bone (Fig. 30.2)

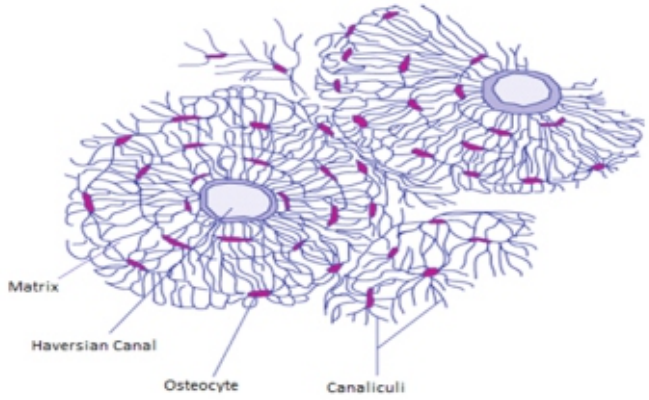

Fig. 30.2 Transverse section of Bone

(ii) Membranous or investing bones – Membranous bones are also called investing bones. These bones are formed from connective tissue. Some mesenchymal cells are arranged below the skin in small groups. These groups modify into fibres and form a network. Osteoblasts get attached with this network secrete ossein protein, this protein forms matrix, other mesenchyme cells secrete calcium salt by which this structure become hard. Mesenchymal cells form periosteum around it therefore bones are formed. Their formation takes place by membrane hence these are called membranous bones.

Functions of skeleton

1. The skeleton forms supporting frame work of body and maintains definite shape of body.
2. It protects the vital organs of body like brain, lungs, heart, spinal cord etc.
3. It provides surface for attachment of muscles.
4. Skeleton helps in locomotion
5. Bone marrow of bones forms blood corpuscles.

Endoskeleton

Endoskeleton is well developed in human. It can be differentiate into two parts(Fig. 30.3).

(1) Axial skeleton – This skeleton lies along the longitudinal axis of the body. Skull, vertebral column, sternum and ribs combine together and form axial skeleton. Axial skeleton of human has total 80 bones.

(2) Appendicular skeleton – This skeleton is situated laterally along with body axis. Bones of fore and hind limbs and girdles etc are included in it. Appendicular skeleton of human has about 126 bones. Therefore complete human skeleton has 206 bones.

1. Axial Skeleton –

(I) Skull- Skeleton of head is called skull.29 bones are present in human skull. These are fused with each other by sutures and can be divided in four parts. Skull is mainly differentiated into two parts (Fig. 30.4)

(a) Cranial region – These are eight flat bones which combine with each other tightly to form bony chamber which is called **cranium**. Cranium is dome shaped. Its main function is to protect brain and sensory organs i.e. nose, eye, ear and to support jaws. It is made up of two paired bones – parietal and temporal and four unpaired bones frontal, ethmoid, occipital and sphenoid.

Frontal part of cranium is made of frontal bones, lateral by parietal and temporal bone and basal part by ethmoid, occipital and frontal bones. Bones of upper jaw are also fused with cranium. At posterior basal part of skull foramen magnum is present. Rounded protuberance occipital condyles are presentat both side of foramen magnum. They articulate skull from first vertebra Atlas. Nodding movement is possible by this joint while rotational movement of head is due to joint between atlas and

axis. Due to presence of two occipital condyles skull is called dicondylic.

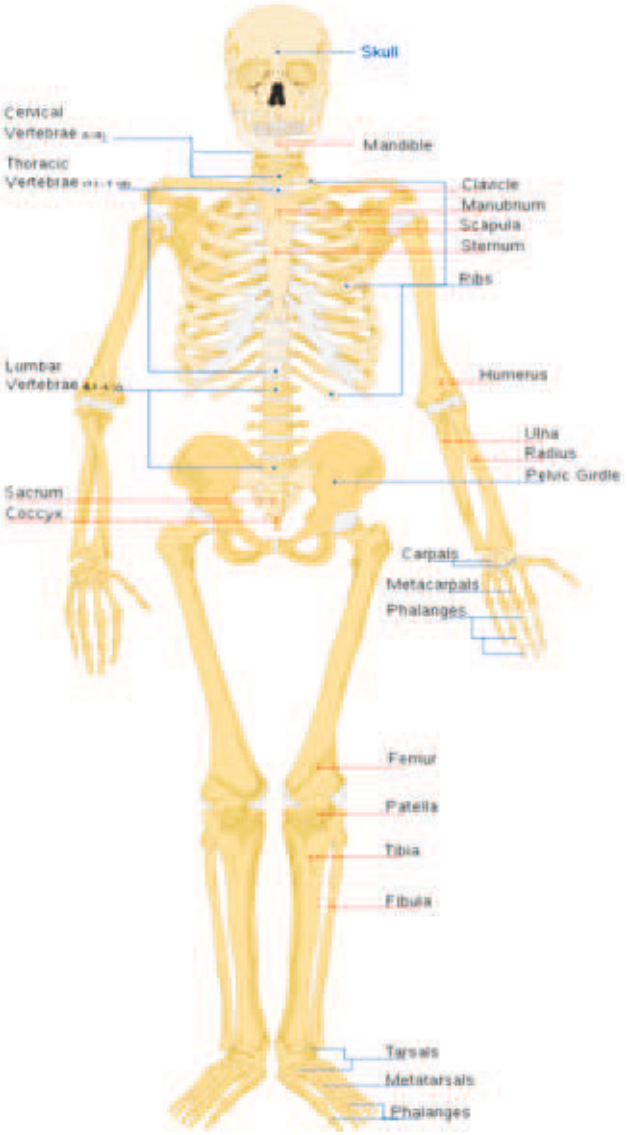

Fig. 30.3 Human Skelenton

(b) Facial bones - These are 14 in number. Paired nasal, palatine, maxilla, zygomatic, lacrymal, lower temporal and unpaired vomer and dentary bones are included in it. They form nose, hard palate, upper jaw and lower jaw skeleton along with anterior part of skull. Mandibles are formed by dentary which are attached with skull by muscles. Eye socket is situated is in front whose outer corner is made of zygomaticarc etc.

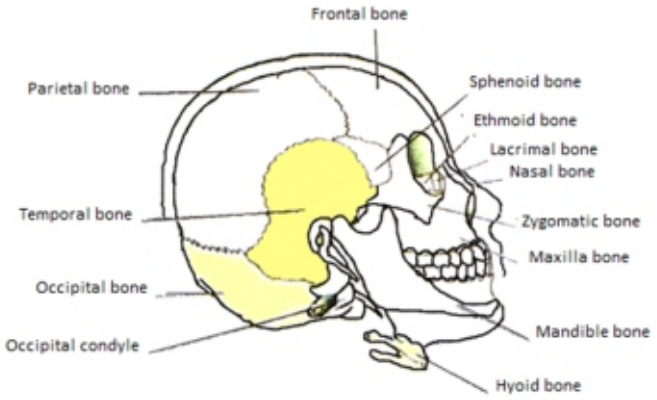

Fig. 30.4 Human Skull

(c) Hyoid bone – It is single bone lies at the base of buccal cavity.

(d) Ear ossicles –These are total six (three in each ear) bones – Malleus, Incus and stapes.

(ii) Vertebral column – Vertebral column of human consists of 26 separate bones which includes 24 free vertebrae, a compound bone triad (sacrum) and one compound bone coccyx. Actually in sacrum 5 and in coccyx 4 vertebrae are fused. Therefore there are total 33 vertebra are present. Vertebral column forms main axis of body and provides support to trunk (Fig. 30.5 (a)). Vertebras are joined together with ligaments. Pads made from fibro cartilage are present between vertebrae, which are called **intervertebral discs**. Vertebral column becomes flexible by the presence of intervertebral disc and ligaments. Structure of a typical vertebra is shown in figure (Fig. 30.5 (b)). Anterior part is centrum and posterior part is neural arch in each vertebra. In all mammals including human the shape of centrum is **amphiplatyan or acoelous** type. To fuse with neighbouring vertebra pre zygapophysis and post zygapophysis are present in them. By joining vertebra in order in vertebral column their neural canal forms a hollow tube. Spinal cord remains safe in it. Vertebrae are named according to the position of vertebra in body.

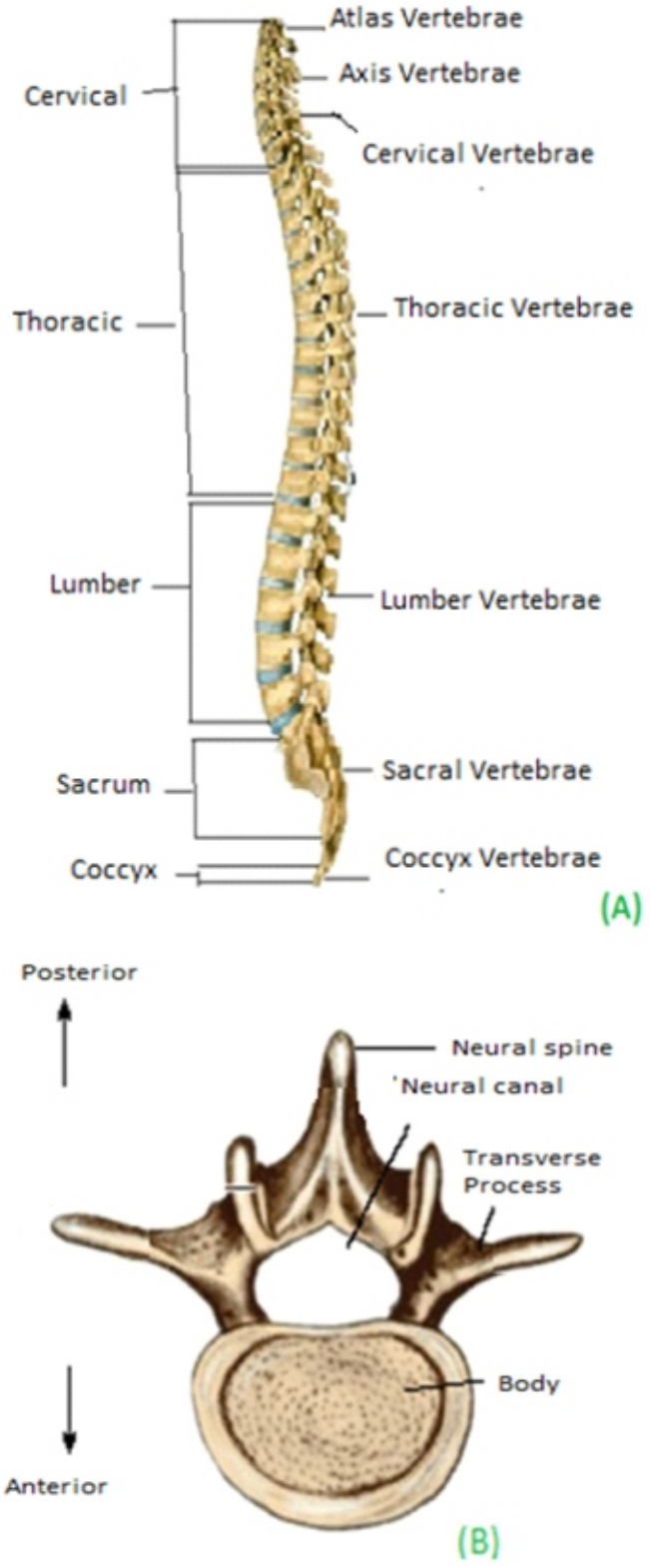

Fig. 30.5 (A) Human Vertebral columan
(B) Typical Vertebra

7 cervical vertebrae in cervical region,12 thoracic vertebraein thoracic region, 5 lumber vertebraein lumber region, in sacral region a large triangular bone sacrum is made up of 5 fused vertebras and in tail region one coccyx is made up of 4 fused vertebrae are present in human. First cervical vertebra is called atlas. Second is axis and remaining five cervical vertebrae are called typical cervical vertebrae. Presence of apertures in transverse processes of cervical vertebrae and presence of joining site for ribs in lateral side of centrum of thoracic vertebrae are their specific characteristic features. The centrum of lumber vertebra is thick.

(iii) Sternum or Breast bone – sternum is a flat and narrow bone. It has three parts – manubrium, middle body and xiphoid process. It is present on mid ventral side of thoracic region of body. Ribs are joined with its lateral sides.

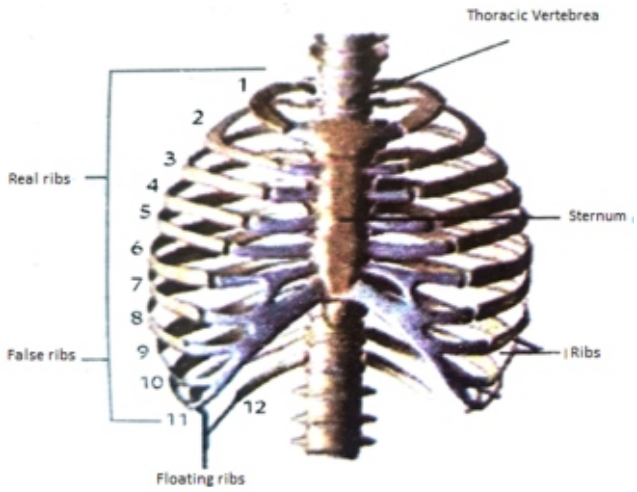

Fig. 30.6 Ribs and sternum of Human

(iv) Ribs– There is twelve pairs of ribs in human that areattached with thoracic vertebrae. Each rib is a thin, flat and curved structure. Dorsal side of each rib has two facets one **capitulum** and second one is **Tuberculum**. Each rib articulates by related thoracic vertebra with their facets of dorsal side end. With the help of costal cartilage sternal parts of first seven pairs of ribs are directly articulated to sternum. These seven pairs of ribs are

called **True ribs.** Sternal part of eighth, ninth and tenth pair of ribs are attached on that of seventh pair of rib through cartilage. These ribs are called **False ribs**. First ten pair of ribs also called vertebro-chondrial ribs because their ventral parts are cartilaginous. The sternal parts of last two pairs (11th and 12th) of ribs do not join with sternum. These ribs are called **Floating ribs**. Thoracic ribs provide protection and support to lateral part of thoracic cavity (Fig. 30.6)

Thoracic vertebras, Ribs and sternum together form rib cage or thoracic basket. Heart, large blood vessels, lungs and trachea remain safe in it means rib cage enclose these four.

2. Appendicular skeleton –

Girdles and bones of fore and hind limbs are included in this part of skeleton.

Pectoral girdle – Human pectoral girdle has two halves. Each half is called Osinnominate. Both halves are separate from each other. Each half has a **clavicle** and a **scapula.**

Scapula is a flat and triangular bone. It is found up to upper dorsal part of thorax by covering second to seventh ribs. It forms shoulder part. Scapular spine (ridge) is present on upper surface of pectoral girdle. One process of this spine is known as **acromian.** Near to it second process coracoid is present. At the junction of these processes a smooth cavity is present which is called glenoid cavity. Head of humerus fits in it and forms shoulder joint which is ball and socket joint (Fig. 30.7 a)

Clavicle or collar bone is a well-developed bone. It is long, thin and curved rod shaped. It's one end joints with acromian and another end joins with scapula.

Pelvic girdle – Like pectoral girdle, pelvic girdle also has two halves but both halves are attached together at middle line by pubic symphysis. Pelvic girdle is located in the lower part of body between two legs in abdominal cavity.

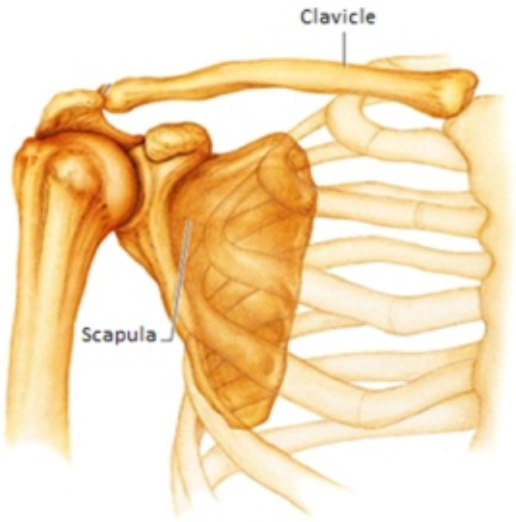

Fig. 30.7 (a) Pectoral Girdle

Each half is made of three bones – Ilium, Ischium and Pubis.

Ilium is large and located at anterior dorsal part. Pubis and Ischium are located on ventral part along with anterior and posterior direction respectively. Between ischium and pubis of each side obtutator foramen is found.

A cavity acetabulum is present at outer edge of each halve in which head of femur articulates and forms pelvic joint. Pelvic bones, sacral vertebra and coccygeal vertebra together forms pelvis (Fig. 30.7 (b))

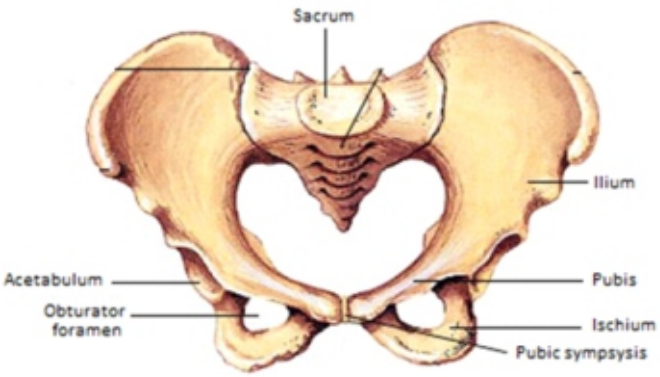

Fig. 30.7 (b) Pelvis Girdle

Arm Bones

Each arm or hand of human has humerus, radius-ulna, carpals, metacarpals and phalanges bones.

Humerus - This bone is found in upper arm of hand. It contains a knob at proximal end which is called head. Laterally at one side of head greater tuberosity and at another side lesser tuberosity is found. Behind head a triangular ridge or deltoid ridge is found at which muscles are attached. At distal end of bone pully shaped trochlea is found. Trochlea contains a deep olecranon fossa and supra trochlear foramen is present anteriously the trochlea (Fig 30.8).

Fig. 30.8 Bones of Hand in Human

Anterior end of humerus forms a joint with glenoid cavity of pectoral girdle. Its posterior end forms a joint with sigmoid notch of radius and ulna.

Radius and Ulna– This bone is located in the fore arm of hand. It contains two bones, radius is small and towards inner side and ulna large and towards outside. Both bones are attached along with total length.

Anterior end of radius has sigmoid notch in which trochlea of humerus makes a joint. Next to sigmoid notch ulna forms an olecranon process. Posterior end of radius and ulna forms a joint with carpals (Fig.30.8).

Carpals - Carpals are located in wrist of hand. These bones are 8 in number. These are arranged in two rows. In first row three bones – radiale, intermedium and ulnare are present and in second row five bones trapezium trapezoid, centralae, magnum and unciform are present (Fig. 30.8).

Metacarpals and Phalanges– Metacarpals are five long bones located in palm. There are 14 phalanges in fingers in which two are in thumb and three are in each fingers. The formula of phalanges in human's hand is 2, 3, 3, 3, 3 (Fig. 30.8).

Hind Limb or Leg bones

Hind limb or human leg consists of femur, tibiofibula, tarsals, metatarsals and phalanges bones.

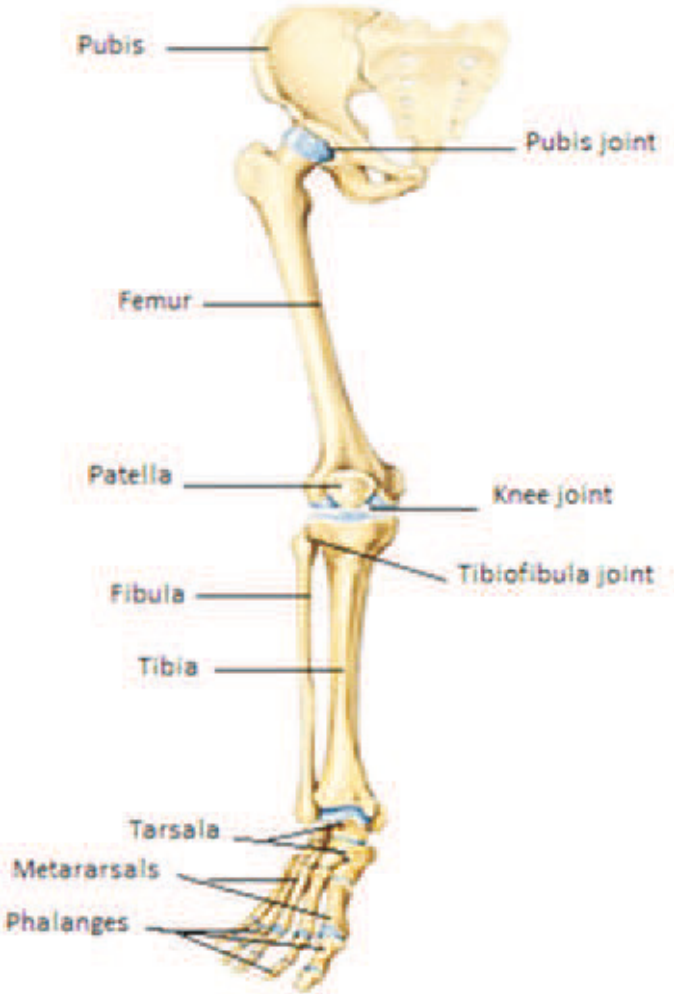

Fig. 30.9 Bones of leg of human

Femur– This bone is situated in thigh. It possesses a knob like head at proximal end. Head forms a joint with acetabulum of pelvic girdle. At the anterior end there are three trochanter arise which are called greater, lesser and third trochanter respectively. Femur has two condyles at distal or posterior end. In between these two condyles a groove is found which is known as inter condylar groove. Posterior end of femur makes a joint with tibiofibula. This joint possesses a flat bony patella. Femur is the longest bone of human (Fig. 30.9).

Tibiofibula –This leg bone is located in shank. It is made of tibia and fibula. Tibia is long and erect bone. A cnemial crest is found at its anterior part. Muscles of shank are attached to their crest. Fibula is small and situated externally. Its anterior part is free while posterior part is connected with tibia. Anterior part of tibia joins with femur and posterior end joints with tarsals (Fig. 30.9).

Tarsals and Phalanges – Seven tarsals are found in ankle of hind limb which is arranged in three rows. Five metatarsals are found in the sole of human and phalanges formula of foot is 2,3,3,3,3; Triangular and flat sesamoid bone of knee is called patella. Its formation takes place in tendon of greater extensor muscle of leg (Fig. 30.10).

Joints

Joint is that place in vertebrates where two or more bones or bone and cartilage are connected with each other. In other words the place of contact site between two or more bones or bone and cartilage is called joint. The movement of different parts of skeleton is possible due to presence of different type of joints. Joints have different types and functions. On the basis of movement joints can be divided into three groups.

1. Synarthrosis–The joint in which movement is not possible, is called immovable joint. In such joints bones are joined tightly by fibrous connective tissue. There is no space between the bones, for example the sutures between the bones of skull (Fig. 30.10 (a)).

2. Amphiarthrosis – It is a rigid joint but due to tension and spasms limited movement is possible in it. In such type of joints the edges of bones are joined by fibrous cartilage. Such type of joints between bones is also called symphysis. Pubic symphysis, joints of vertebrae, mandibular symphysis etc are the examples of such types of joints (Fig. 30.10 (b)). It has following sub types –

(I) Pivot joint – For example a joint between atlas and axis vertebra. Lateral movement is possible in them.

(ii) Gliding joint – for example joints of vertebra, joints of wrists and joints of ankle. It has flat joint surfaces. Bones are glided over to each other.

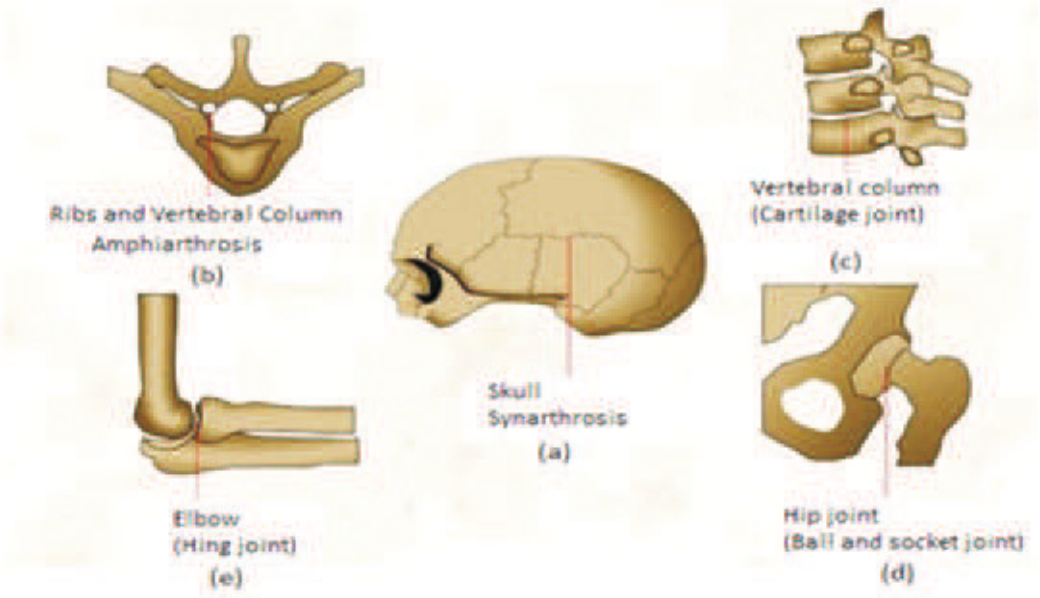

Fig. 30.10 Type of Joints

3. Synovial joints or Diarthrosis – The bones which are joined by this joint move freely in one or more directions. The articular surface of bone is covered by highly smooth thin layer of hyaline cartilage. Cartilage reduces the friction between bones during movement. A space is found between the bones of such type of joints which is called synovial cavity. Bones are jointed together by many ligaments. Ligaments join together and form a hard fibrous capsule. Capsule is covered by cellular synovial membrance. This membrane secretes synovial fluidcontainingmucin. This fluid provides nutrition to hyaline cartilage and lubrication to joints. Some sub types of these joints are as follows (Fig. 30.10 (c)).

(i) Ball and socket joint – For example shoulder joints and hip joints. Movement in various directions is possible in it(Fig. 30.10(d)).

(ii) Hinge joint – For example elbow joint, Knee joint, fingers joint, occipital condyle and atlas joint. Movement is possible in one plane only (Fig. 30.10(e)).

(iii) Ellipsoidal joint - For example joint between radius and carpus of human. Movement is possible in two planes in it.

Muscles

Movement by muscles is the main character of animals. Beside locomotion muscles are helpful in various types of activities in digestion, respiration, excretion, circulation and reproductive activities. Hence muscle contraction is main function of animal life.

To understand physiology of muscle contraction, knowledge of structure of muscle is necessary. The cells of muscle tissue are long which are called muscle fibers. These muscle fibres are located near each other and amount of matrix is less between them. On the basis of histological and physiological variations muscles are of three types.

(i) Skeletal or voluntary muscles –

These muscles are attached with bones by tendons. Therefore these are called skeletal muscles. Their muscle cell is long cylindrical and multi nucleated. Myofibrils of skeletal muscle have light and dark bands in alternate manner therefore these appear striated in normal light microscope. So as a result these are also called striated muscles. Skeletal muscles work under voluntary control, thus these muscles are called voluntary muscles (Fig.30.11 (a)).

(ii) Smooth or Involuntary muscle-

These muscles are found in the wall of different visceral organs. Their muscle cells are spindle shaped. The middle part of the cell is broad which contains large nucleus. The end of myofibril or cell is pointed. Myofibrils are located around nucleus in sarcoplasm. Like striated muscle transverse striations are not found in these fibrils. Hence these are called unstriated muscles. Regulation of contraction these muscles is not under the control of animal's will; so these are called involuntary muscles. Contraction in unstriated muscles takes place slowly but long lasting (Fig. 30.11 (b)).

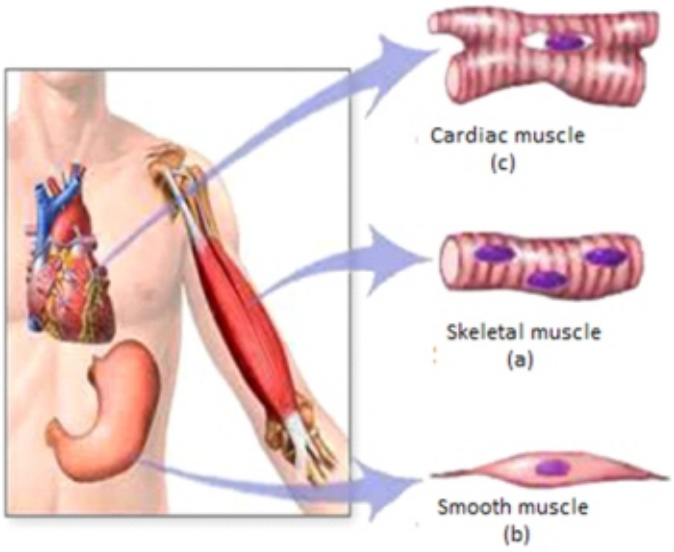

Fig. 30.11 Different type of muscle fibre (a) Striated (b) Smooth © Cardiac muscle fibre

(iii) Cardiac muscles-

These muscles are found in the wall of heart. These muscles possess some characters of striated and some of unstriated muscles. Cardiac muscles are striated and branched. Intercalated discs are present at some distances in each muscle fiber. Therefore each fiber is divided into small segments. Single nucleus is present in each segment. Like unstriated muscles these are involuntary (Fig. 30.11 (c)).

Functional architecture of skeletal or voluntary muscle-

Each striated muscle is made of innumerable long and cylindrical muscle fibers. A muscle fiber of the muscle represents a muscle cell, which is structural unit of each muscle.

Each muscle fiber is covered by a thin layer of connective tissue which is called endomysium. Many muscle fibers are arranged together in bundles. Each bundle is known as fascicle. Fascicle is surrounded by a membrane of connective tissue which is called perimysium. Many such fascicles in skeletal muscles are combined together surrounded by a normal covering of connective tissue this external covering is called epimysium.

Structure of muscle fiber – Muscle fiber is a long muscle cell. It is about 1 to 40mm long and about 0.01 mm to 0.1 mm in diameter. It is multinucleated cell, which is covered by sarcolemma. Semiliquid cytoplasm of muscle cell is called sarcoplasm. Innumerable myofibrils, mitochondria (sarcosomes) and sarcoplasmic reticulum are found in sarcoplasm.

The diameter of each myofibril is about 1-2 micron. Light and dark transverse bands are present in alternate order. Dark bands are called anisotropic or A-bands and light bands are called isotropic or I-bands. A thin dark Z-line is found in each I-band. Middle part of A-band is relatively less dark. This part is known as H-Zone. Much thin M-line is situated in middle of H-Zone. Each part between Z-line is called sarcomere. Actually sarcomere is the smallest physiological unit of myofibril or unit of contractibility.

By study of electron microscope it has been known that two types of myofilaments are found in each myofibril. These myofilaments are arranged longitudinally.

1. Primary or thick myofilament -These are formed of myosin protein. Their diameter is about $100A^0$. These myofilaments are situated on A-band.

2. Secondary or Thin myofilament- These are formed of actin. Their diameter is about $50A^0$. These filaments are extended from Z-line up to the edge of H-band.

2. Molecular Organization of contractile System - Three types of proteins are found in the molecular structure of myofibril for contraction process -

1. Force generating Protein –
   (a) Myosin
   (b) Actin
2. Regulatory Protein –
   (a) Tropomyosin
   (b) Troponin.
3. Structural Protein –
   (a) α-Actinin
   (b) M – Disc protein
   (c) C– Protein

(i) **Myosin** – Myosin forms primary and thick myofilament. About half part of protein of complete filament is made of myosin. Its molecular weight is 500,000. It is a α- helix protein.

(ii) **Actin** – Its molecular weight is 42000. Actin is found in two states. Several units of globular actin (G-actin) combine to form a chain such as structure of f-actin filament. Actin is always found in the form of F-actin which forms due to polymerization of G- actin. It is found in double coiled stranded form which is coiled with each other.

(iii) **Tropomyosin** – Its molecular weight is 64000. It is long (about $400A^0$) and formed of two alpha – helix (α - helix) units. Each tropomyocin molecule is extended up to seven G- actin monomers.

(iv) **Troponin** – The second protein which is associated with tropomyosin is troponin. It is made of three types of components.

(a) Troponin – C - Its molecular weight is 17000. Calcium ions forms bond with this protein.

(b) Troponin – I - Its molecular weight is 22000 – 24000. It acts as inhibitor for the bonding between myosin and F-actin.

(c) Troponin – T - Its molecular weight is 370000 – 400000. It is bounded with tropomyosin.

(v) C- protein – This protein is found in middle of A- band of myosin filament.

(vi) M- line protein – M- line is situated in middle part of H – zone is formed from this protein. Its main role is to maintain myosin myofilament at their position.

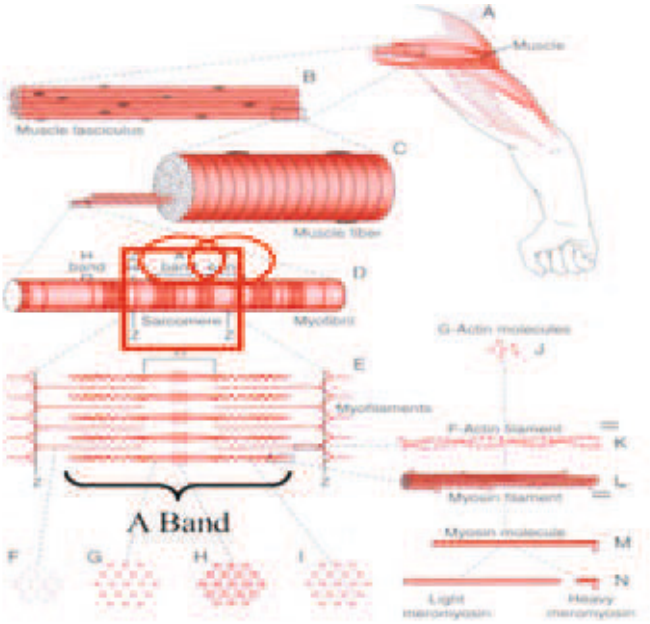

Fig. 30.12 Structure of skeletal muscle upto the moleculer level

3. Sarcotubular system– It is made from following structures which are present in sarcoplasm.

(i) T – System

(ii) Sarcoplasmic reticulum.

(i) **T – System** – Transverse tubules are present in this system. These tubules are directly related with sarcolemma.

(ii) **Sarcoplasmic reticulum** – Around each myofilament smooth endoplasmic reticulum modified into sarcoplasmic reticulum. It is mainly made from thin tubules and cisternae.

4. **Sarcosome** – The mitochondria of muscle cell are called sarcosomes. Their size is bigger than to mitochondria present in other cells

5. **Neuromuscular junction** – This joint is a physiological communication between muscle and nerve fiber. The axons of neuron which innervate in skeletal muscle are called motor neurons. These axons are myelinated. These are divided into thin branches near to myofibril. Myelin sheath is absent around these branches. These branches are invaginated into sarcolemma but are completely separated from sarcolemma. The ends of terminal branches of axon form a knob like structure which is known as synaptic knobs. A neurotransmitter actyl choline, ACh is filled in synaptic vesicles of these knobs. After modification the muscle cell forms a motor end plate below terminal axon. Here the receptors of ACh are situated at sarcolemma.

Mechanism of Muscle Contraction

Sliding Filament Theory – According to this theory of mechanism of muscle contraction at the time of contraction thin filaments (actin filaments) slide on thick filaments (myosin filaments) therefore the length of sarcomere decreases. Through transverse bridge myosin filaments attach as hook with actin filament situated in front of it. The changes in configuration (like bending of right finger) occur which pull the action filaments towards the central part of sarcomere. Due to this Z-lines come closer to each other. The length of A-band remains same but the length of I – band and H-zone is decreased. Hence the contraction occurs. In next step myosin head is detached from actin filament and is rejoined with next point of actin filament and pulls filament. This sequence is repeated many times. At the end of contraction actin filament slip out from A band and returns to their original position. During contraction there is no change in length of filaments, only filaments slides over each other.

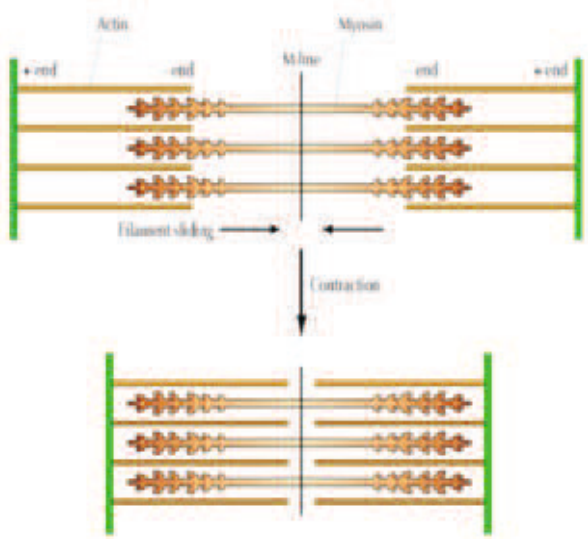

Fig. 30.13 Fibre sliding process

Physiology of Muscle contraction – The process of muscle contraction and relaxation is completed into following four steps-

1. **Excitation** – Due to nerve impulse a neurotransmitter acetylcholine is released from the ends of axon at neuro muscular junction. This chemical increases the permeability of plasma membrane towards Na^+. Therefore Na^+ enters in muscle cell by which a positive potential is created on inner side of plasma membrane (There is a negative potential on inner side of muscle plasma membrane in normal condition). The positive potential is transmitted on whole plasma membrane and creates active potential which is called excitation state of muscle cell.

2. Excitation - contraction coupling – It is the process by which action potential induces muscle contraction. Active potential from muscle plasma membrane is rapidly transmitted by T – tubules system in sarcoplasm. Due to this potential Ca^{++} ions are released from sarcoplasmic reticulum and get attached with troponin – C (Fig. 30.14(a)). As a result such type of configurational changes occur in troponin molecule by which tropomyosin and troponin present on active site of actin both are removed from there. As the active site becomes free, transverse bridges of myosin filament get attached with them and contraction process starts.

3. Contraction – Contraction takes place by sliding filament process which starts along with the attachment transverse bridges of myosin and actin filament. Just before binding the active site of actin filament the head of transverse bridge joins with a molecule of ATP. ATP breakdown into ADP^+ Pi by ATPase of myosin head (Fig. 30.14 (b)). ADP^+ Pi remains attached to head. After this myosin head gets attached to active site of actin filament. The configurations are changed due to bonding between head and active site. As a result a turn in head develops (like bend in right finger) and actin filament pulls toward sarcomere centre (in H-zone). For this energy obtained from cleavage of ATP is used. Due to turn in head ADP^+ Pi attached from it is also freed. By getting free a new ATP molecule is attached with head. Due to attachment of ATP head becomes separate from actin. Again cleavage of ATP takes place. Myosin head gets attached with a new active site and above processes is repeated again. Actin filament slides due to repeated activity of head of transverse bridge and contraction takes place. Many filaments and transverse bridges are involved in contraction. While Ca^{++} attached with troponin, contraction continues in muscle fiber.

4. Relaxation – When excitation of muscles by nerve impulse completes then Ca^{++} is transferred to sarcoplasmic reticulum. Consequently troponin-c becomes free from Ca^{++} and active sites of actin filament are blocked. Attachment of actin and myosin filament is stopped. Filament comes to its normal state and muscle is relaxed.

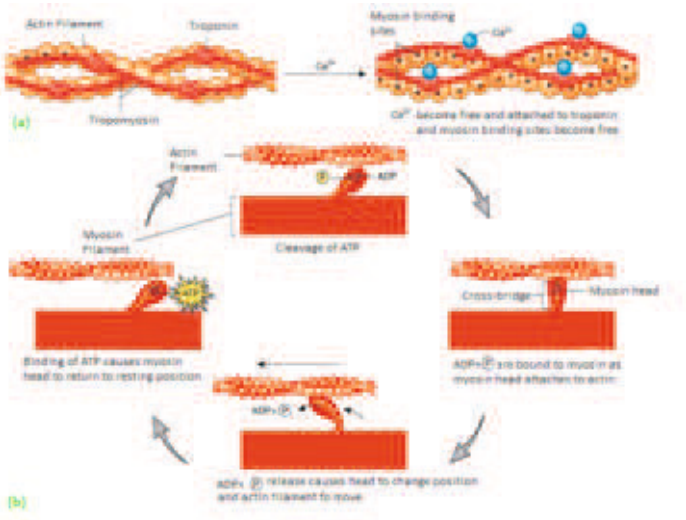

Fig. 30.14 Contraction Process

Energy source for contraction – Energy is derived from ATP for muscle contraction. ADP released during contraction quickly changes again into ATP by creatinine phosphate. Formation of ATP in muscles takes place by oxidation of glycogen, glucose and fatty acids. Myoglobin in red muscles can stores oxygen which is used in ATP formation. Lactic acid gets deposited in muscles in anaerobic condition by which muscles feel pain.

Role of Muscles and Bones in Movement – Primary importance of skeleton muscular system is in locomotion. Movement in vertebrates is not possible without muscle. Muscles are attached with bones act as machine and convert chemical energy into mechanical energy. Muscles do not perform

pushing activity. Only pulling force is generated by contracting muscles. This force is used in pushing bones. As a result of pulling of bones movements and locomotion's are possible. Muscles, bones and joints all together work as system of lever. Relative motion takes place in joints which acts as fulcrum of lever. In muscular skeleton system of human functioning similar to all three types of lever can be observed. Movement can possible due to coordinating process of lever. For example during the movement of elbow, joints of elbow act as fulcrum. Biceps muscle near elbow joint contract and apply a force in between fulcrum and weight. The distal end of arm helps in controlling weight balance.

Generally at least two groups of muscles take part in the movement of bones. One group takes a bone in one position and another return back to it. These types of muscles are known as antagonistic muscles. They work in opposition to each other but in co-ordination. For example flexor muscle is opposite to extensor muscle. When flexor contracts then extensor muscle is in resting state. Biceps muscle of arm is flexor which turn arm at elbow joint and triceps muscle is extensor which expands arm at elbow joint. Many muscles are co-ordinated with each other.

Body balance of animal is also maintained by muscular skeletal system. It is directly controlled by nervous system. Involuntary muscles do not take part in locomotion of animal. These are used in transportation of different substances inside of systems from one place to another place, i.e. translocation of food materials in alimentary canal by peristalsis.

Disorders of Bones –

1. Arthritis - Generally it is called joint pain or Arthritis. Due to stiffness and pain in joints mobility, spontaneous sitting becomes difficult in it. There are three important types of it –

(i) Rheumatoid Arthritis – Inflammation in synovial membrance and membrane becomes thick in this disorder secretion of synovial fluid is increased. Due to this pressure increases and pain starts. Temperature also increases at joints. Synovial membrane secretes abnormal granules i.e. pannus. Due to deposition of these pannus joint becomes immovable. It is a kind of autoimmune disease in which immune system of body attacks on tissues of body itself. The diagnosis of this disease is possible by the presence of rheumatoid factor (immunoglobulin, Igm) and by increased erythrocyte sedimentation rate (ESR). This disease is generally at old age person and affects joints of hands and legs. Pain killer medicines, which reduces pain and physiotherapy and hot compress which reduces inflammation are beneficial for its treatment.

(ii) Osteo – arthritis – Joint is damaged in this disease. There is no inflammation in joints and result of blood test is normal in this disease. It is common disease in old age. Pelvic joints, knee joints and ankle joints are more affected by this. Joint cartilages become thin and weak, gap between joints is reduced, bone becomes damaged and new bone formations are main symptoms of this disease. Due to narrowing of joint movement is reduced and joint becomes painful. For treatment pain killers are given. Joints are replaced by metallic and plastic components in serious condition.

(iii) Gouty Arthritis – Due to deposition of uric acid on joints swelling, pain and stiffness occors in bones. Steroids and pain killer medicines are given for its treatment.

(iv) Osteoporosis - Main characteristics of this disease is loss of bone mass means deficiency of matrix (organic part) and minerals (calcium) in bones. Bone becomes thin, weak and less elastic so it lost strength. Bone breaking tendency increases. By fall down marginally the bone may be broken. Osteoporosis affects whole skeleton but pelvis, wrist and vertebrae are more affected this disease increases with age but deficiency of estrogen hormone is more frequent in old women. Hormones like calcitonin, parathyroid and glucocorticoids are causes of this disease.

Important Points

1. The skeleton provides support to the body. It is of two types – exoskeleton and endoskeleton.
2. On the basis of origin cartilages are hyaline, elastic and fibrous.

3. On the basis of origin bones are of two types' cartilaginous bones and membranous bones.
4. Endoskeleton has two main parts- axial skeleton and appendicular skeleton.
5. Human skeleton is formed by total 206 bones and some cartilages. Along with providing protection and support, skeleton is essential for locomotion.
6. Axial skeleton in human consists of skull, vertebral column, sternum and ribs.
7. Girdles and limb bones make appendicular skeleton.
8. Appendicular skeleton includes girdles and bones of fore and hind limbs.
9. Pectoral girdle is made up of clavicle, scapula, and coracoid acromian.
10. Each half of pelvic girdle comprises by joining three bones – ilium, ischium and pubis.
11. Main bones of hands are humerus, Radius – ulna, carpals, metacarpals, and phalanges.
12. Main bones of legs are femur, tibiofibula, larsals, metatarsals and phalanges.
13. Muscular movement is important in human. Three types of muscles are present in human skeletal, cardiac and smooth muscles.
14. Skeletal muscles are made of muscle fibres and its functional unit is called sarcomere.
15. Sarcomere is made of thick myosin fibres and thin actin fibers.
16. Muscle contraction happens on gliding theory where actin fibres slide over myosin fibres.
17. Joints are of three types – synarthrosis, amphi-arthrosis and synovial.
18. Muscles, bones and joints work together like lever by which movement is possible.
19. Arthritis (joints pain) and osteoporosis (weakness of bones) are common disease of bones which occur in old age person.

Practice Questions

Multiple choice questions-

1. Exoskeleton of animal is –
   (a) Skull (b) Ribs
   (c) Nails (d) Sternum
2. Matrix of bone is made of which protein –
   (a) Chondrin (b) Ossein
   (c) Fibrin (d) Retinin
3. Function of skeleton is –
   (a) Protection of soft organs
   (b) Provide surface for muscle attachment
   (c) Formation of erythrocyte
   (d) All of above
4. The reason of pendular movement of cilia is –
   (a) Gliding of microtubules
   (b) Contraction of micro fibrils
   (c) Elongation of cell wall
   (d) Change in turgidity
5. According to sliding filament theory, the molecule decreases length of muscle during muscle contraction is-
   (a) Collagen (b) Actin
   (c) Myosin (d) Titin
6. Type of elbow joint is-
   (a) Synarthrosis joint (b) Hinge Joint
   (c) Amphiarthrosis joint (d) Pivot joint
7. Contractile protein is –
   (a) Troponin (b) Myosin
   (c) Tropomyosin (d) All of above
8. The number of bones in hind limb of human is –
   (a) 14 (b) 24
   (c) 26 (d) 30
9. Storage of which substance in anaerobic contraction of muscles become painful-
   (a) Calcium ion (b) Myosin
   (c) Lactic acid
   (d) Creatine phosphate

10. Presence of which ion is essential for binding of transvers bridges-

(a) Calcium (b) Sodium

(c) Iron (d) Potassium

Very Short Answer Questions-

1. Mention structural and functional unit of muscle.
2. By which structure muscle is jointed with bone?
3. By which structure bone is jointed with bone?
4. How many vertebra form sacrum bone in human?
5. How many bones form skull in human?
6. Give the name of main substances stored in bones.
7. Which type of energy changes in muscular function?

Short Answer Questions –

1. What are cartilaginous bones? Explain.
2. Write main functions of skeleton.
3. Write notes on sternum.
4. Draw labelled diagram of pelvic girdle.
5. Write difference between ligament and tendon.
6. How does a muscle stimulated for contraction?
7. What effects will be on human if all joints of arm become inactivated?
8. What is Osteoporosis?
9. What is source of energy for muscle contraction?
10. If the nerve of skeletal muscle is cut then what effect will be on contraction.

Essay Type Questions-

1. Write the detailed structure of skeletal muscle.
2. What is joint? Describe different types of joints present in human.
3. Describe the mechanism of muscle contraction with diagram.
4. Explain the structure and importance of girdles in human.

Answer Key

1. (c) 2. (b) 3. (d) 4. (b) 5. (b)
6. (b) 7. (b) 8. (d) 9. (c) 10. (a)