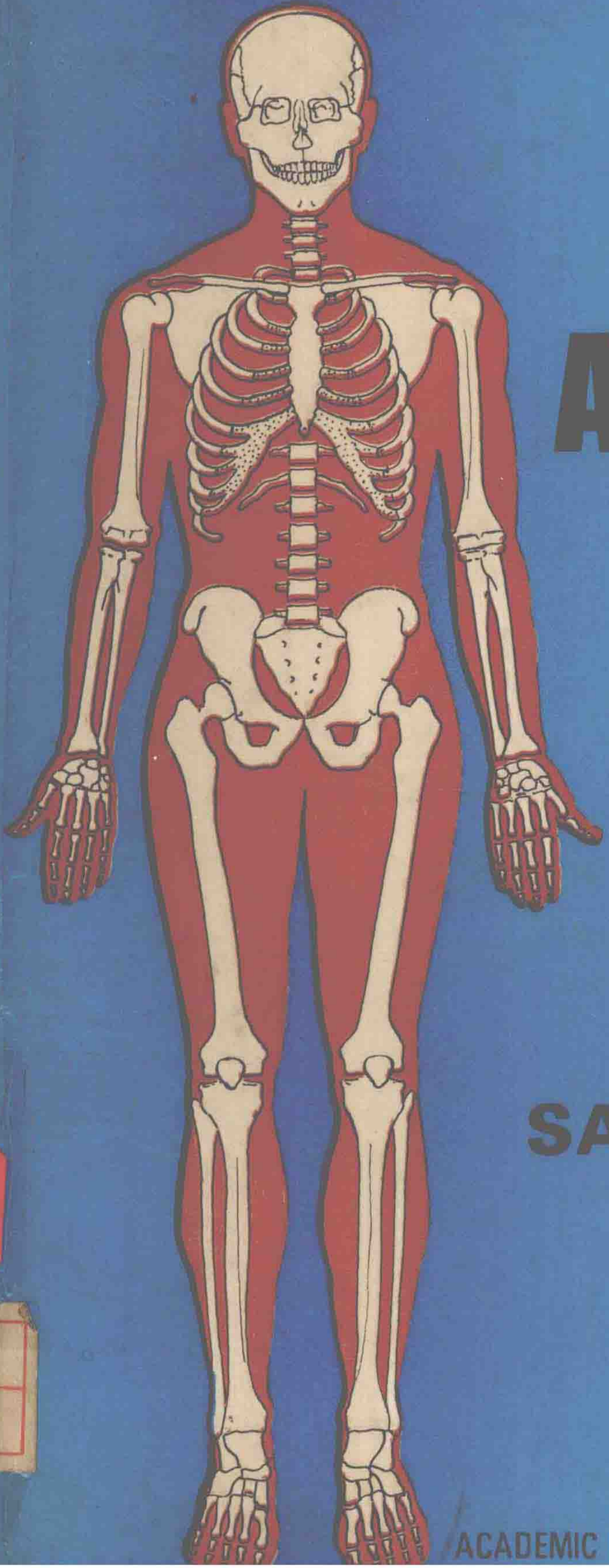

ANATOMY

SAMAR MITRA

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ANATOMY

[OSTEOLOGY, IMPORTANT LANDMARKS & SURFACE MARKINGS, NERVOUS SYSTEM & EYEBALL]

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AWARD' as an eminent medical teacher.

Illustrated throughout with innumerable
black & white and coloured diagrams

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PREFACE

It was my idea, when I first started writing this book on Anatomy, that I should complete it in three volumes. Actually, I followed the plan, but while bringing out Volume Three there appeared many unforeseen difficulties. As a result Volume Three was brought out in two parts. Now that both the parts of Volume Three are complete, I have decided to combine the parts into one. So, the Volume Three of my book on Anatomy now contains the Osteology, Important Landmarks and Surface Markings, the Nervous System and the Eyeball.

I am indebted to Sri Mahesh Goenka, a prosector and student of Medical College and Dr. N. G. Das, Head of the Department of Anatomy, N. R. S. Medical College, Calcutta for helping me in writing the Surface Anatomy.

Once more I beg to acknowledge my gratefulness to my colleagues, friends and students who have helped me to complete this work successfully. I still eagerly crave for their suggestions towards improvement.

Lastly, I tender my gratitude to my wife, Mrs. Basanti Mitra for her encouragement.

S. Mitra

Department of Anatomy,
Medical College
Calcutta
June, 1982

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OSTEOLOGY

HUMAN SKELETON

I. Skeleton (Fig. 1)—The bony and cartilaginous framework that forms the framework of the body is called the *skeleton.* The morphological study of the skeletal system in accordance with other systems of the body is called *osteology.*

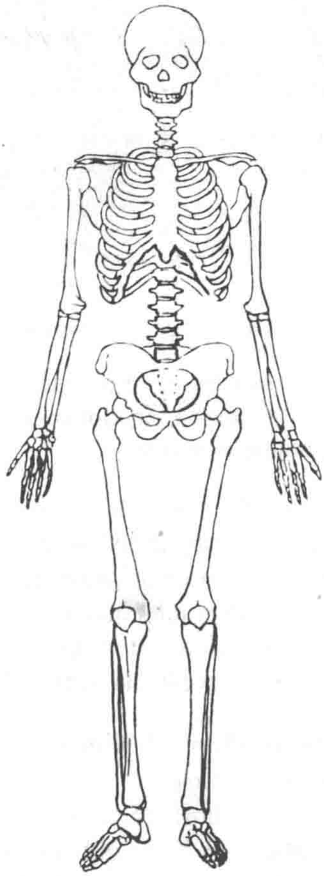


Fig. 1. Skeleton.

The skeleton consists of

(1) An *axis* formed by the vertebrae separated by intervertebral discs to allow flexibility for movement.

(2) *Bones* forming two paired limbs for superior and inferior extremity. These bones are divided into joints for locomotion, grasping etc.

(3) The cranial end of the axis is expanded to form the *skull.*

(4) There are also some osseocartilaginous nodules, the *sesamoid bones,* developed in tendons.

All these elements are collectively called the skeleton. Skeleton is primarily classified as *exoskeleton* whose only remnants in human beings are the nails, and enamel of teeth, and *endoskeleton* which is formed by all bones of the body.

Functions of the Skeleton

(1) It acts as a framework to give form of the body.

(2) It provides attachment to muscles.

(3) It gives protection to viscera.

(4) It transmits weight.

(5) It forms a depot for calcium and its marrow has haemopoietic function.

II. Cartilage—It is a translucent bluish white tissue and is present where firmness is needed with elasticity. Here ground substance is solidified. Cartilages may be temporary when they are later converted into bone or permanent which remain as such throughout life.

Structurally the cartilages have cells or *chondrocytes* in spaces called *lacunae.* The lacunae are scattered in an intercellular substance of chondroitin sulphate and scattered collagen fibres. The cartilages have no vascular or nerve supply.

Morphologically cartilages are of 3 types : (1) Hyaline cartilage (2) White fibrocartilage, (3) Yellow elastic cartilage.

(1) **Hyaline cartilages** (Fig. 2)—They may show calcification with age. The perichondrium covers the outer surfaces of all the cartilages except the articular hyaline cartilages. Structurally the outer layer of cells are flattened and parallel to the surface and the inner layer of cells are oval and arranged vertically. The ground substance is granular, *e.g.*, cartilages in synovial joints, epiphyseal cartilage, costal cartilage etc.

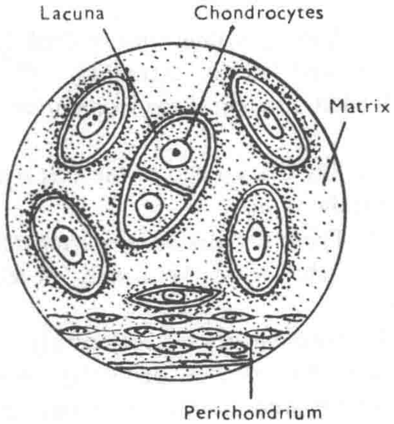


Fig. 2 Hyaline cartilage.

(2) **White fibrocartilages** (Fig. 3)—White fibrous tissue or collagen fibres are present in between the cartilage cells. When present in bulk as in an intervertebral disc, they provide strength and rigidity combined with an appreciable degree of elasticity. When present in lesser amounts as in an articular disc, acetabular or glenoidal labrum, they provide toughness to enable it to resist the effect of pressure and friction.

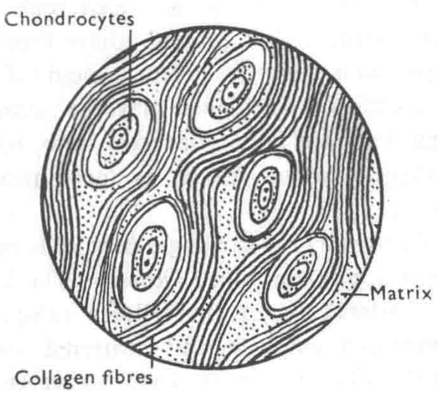


Fig. 3. White fibrocartilage.

(3) **Yellow elastic cartilages** (Fig. 4)—The matrix has an abundance of anastomosing yellow elastic fibres in between the cartilage cells, *e.g.*, auricle of the ear, corniculate cartilage of the larynx, epiglottis, apical portion of the arytenoid cartilage.

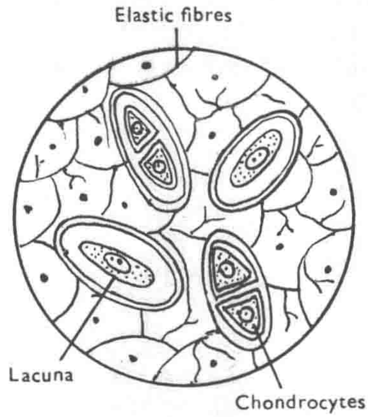


Fig. 4. Yellow elastic cartilage.

III. Bones—The bone is a highly vascular living mineralized connective tissue. It contains cells and a dense ground substance where the organic and inorganic materials come into intimate combination. It is the hardest structure of the body except the teeth.

(A) Classification of Bones

1. *According to shape*

(*a*) Long. (*b*) Short. (*c*) Flat. (*d*) Irregular. (*e*) Pneumatic. (*f*) Sesamoid. (g) Accessory.

(*a*) *Long bones* are those which are found in the limbs, possess tubular shaft and two ends. They act as lever for muscular action. Long bones are of two types—(*i*) Long long bones, *e.g.*, femur, humerus etc. These have one diaphysis and two epiphyses. (*ii*) Short long bones, *e.g.*, phalanges, metacarpals, metatarsals. These have one diaphysis and one epiphysis.

(*b*) *Short bones* are present where there is necessity of strength and compactness combined with limited range of movement, *e.g.*, carpus, tarsus. These contain a core of spongy substance with a coating of compact bone outside.

(*c*) *Flat bones* are those which have spongy layer between the outer and inner layers of compact bone. Its main function is protection, *e.g.*, parietal, frontal etc.

(*d*) *Irregular bones* are those which are separately classified for their irregular form. They have spongy layer within a thin layer of compact bone, *e.g.*, vertebrae.

(*e*) *Pneumatic bones* are those which contain air-filled spaces lined by the mucous membrane, *e.g.*, maxilla, sphenoid etc.

(*f*) *Sesamoid bones* are those which are found in the tendons.

(1) *Differences of sesamoid bones from other bones are as follows*

(*i*) No periosteum.

(*ii*) No haversian system.

(*iii*) No primary centre of ossification.

(*iv*) No separate arterial supply but supplied by the arteries of the muscle in which they are present.

(2) *Enumeration*

(*i*) Patella—in the quadriceps femoris. It is the largest.

(*ii*) Pisiform in the flexor carpi ulnaris.

(*iii*) Two sesamoid bones in front of the head of 1st metacarpal in the flexor pollicis brevis.

(*iv*) Two sesamoid bones in the plantar aspect of the head of 1st metatarsal in the flexor hallucis brevis.

(*v*) One on the lateral surface of the cuboid in the peroneus longus.

(*vi*) One on the medial surface of the medial cuneiform in the tibialis anterior.

(*vii*) One called fabella in the lateral head of the gastrocnemius.

(*viii*) One called Rider's bone in the tendinous origin of the adductor longus.

(*g*) *Accessory bone*—These bones are not naturally present. They develop from separate centres of ossification and fail to unite with the main mass, *e.g.*, wormian bones, interparietal bones.

2. *According to development*

They are classified as : (*a*) *Membranous*, *e.g.*, parietal, frontal etc. (*b*) *Cartilaginous*, *e.g.*, humerus, femur etc. (*c*) *Membranocartilaginous*, *e.g.*, sphenoid, clavicle etc.

3. *According to position*

(*a*) Axial. (*b*) Appendicular.

(*a*) *Axial*—These form the axis of the body, *e.g.*, vertebrae 33, of which 5 sacral fuse to form sacrum, 4 coccygeal vertebrae fuse to form coccyx ; skull 29, ribs 24, sternum 1.

(*b*) *Appendicular*—They form the skeleton of limbs ; upper limb 64, lower limb 62.

(B) Structure of the Bone

1. *Gross Structure*—Typically a long bone has an outer thin coating of compact bone around inner spongy bone and a medullary cavity in the middle. The spongy bone is present mostly at the ends with red marrow in the trabeculae. The bone is lined on the outside by the periosteum. The lining of the medullary cavity is formed by the endosteum. The flat bones of the skull have excess of spongy bone in between two layers of compact bone. This is termed the *diploic bone*.

2. *Periosteum*—It is the outer covering of the bone except articular surfaces where they join the articular margins. They have an outer fibrous layer consisting of white fibrous tissue and an inner osteogenic layer consisting of loose connective tissue which is very vascular.

In the young bones the periosteum is very vascular and has a layer of osteogenetic tissue; even the periosteum in adults may transform into osteoblasts when required. The periosteum is bound to the bone by the *perforating fibres of Sharpey.*

Functions—

(*i*) It gives nutrition to bone.

(*ii*) From its osteogenic layer bones are formed by membranous ossification. *These increase the breadth of the bone.*

(*iii*) It helps in repairing a bone after fracture.

(*iv*) It affords attachments of muscles, tendons and ligaments.

3. *Microscopic anatomy* (Fig. 5)—The structure of a compact long bone consists of typical haversian systems or secondary osteons. Haversian system has a *haversian canal* in the

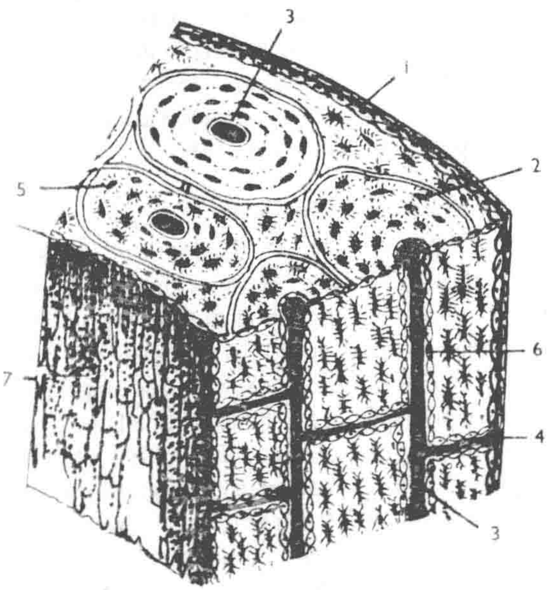


Fig. 5. Structre of a long bone.
1. Periosteum ; 2. Osteocytes ; 3. Haversian canal ; 4. Volkmann's canal ; 5. Canaliculi ; 6. Endosteal layer of haversian canal ; 7. Bone marrow.

centre, with blood vessels, nerves, and lymphatics. Around the canal are lamellated patterns of collagen fibres in which bone salts are deposited. Between the lamellae small spaces called *lacunae* are present, containing bone cells like osteoblasts, osteocytes and osteoclasts. The lacunae are connected with each other and with haversian canal via the canaliculi. The canaliculi anastomose with each other. The different haversian systems are separated from each other by interstitial lamellae.

The interstitial lamellae also separate the canaliculi of different haversian systems. The haversian systems are enclosed in the circumferential or secondary lamellae. The *Volkmann's canals* communicate between the medullary cavity and the outer surface of bones. Their branches communicate with the haversian canals. Through these Volkmann's canals the blood vessels, nerves and lymphatics pass. The spongy bones contain trabeculae surrounded by lamellae. In the trabeculae, calcified cartilages are present but haversian systems are not. The medullary cavity present in the centre of long bones contain the bone marrow. The bone marrow is red in colour in childhood and contains haemopoietic tissue. Later it is invaded by fat and is converted into yellow bone marrow. The 3 types of cells found in a bone are *osteocytes, osteoblasts* and *osteoclasts*. Osteocytes are the dormant cells which transform into osteoblasts when bone formation is necessary. The osteoblasts lay down collagen and intercellular ground substance like hyaluronic acid and protein polysaccharides. Later they produce alkaline phosphatase which increases the phosphate concentration in the area and helps in deposition of calcium phosphate. Other salts like calcium carbonate, calcium fluoride and magnesium chloride are also deposited. When bone resorption is to take place, the giant multinucleated osteoclasts take over. They produce acid phosphatase which dissolves the bone salts. The remaining collagen is dissolved by the lysosome of the cells.

(C) Chemical Composition of Bone

(*a*) *Organic matter*—33.3 per cent. It gives elasticity to bone. If a bone is kept in acid, the inorganic matter is dissolved. So the bone becomes elastic and can be bent and even a knot can be prepared.

(*b*) *Inorganic matter*—66.7 per cent. It consists of calcium and magnesium phosphate, calcium carbonate and fluoride etc. So if bone is burnt the organic matter is lost and the bone becomes brittle.

(D) Functions of Bone

(1) It forms the framework of the body and maintains the shape of the part.

(2) It acts as a lever for the muscles acting on the joints.

(3) Some bones are meant for protection.

(4) It has a haemopoietic function.

(5) It is a store house of the calcium.

(6) It affords attachment to muscles.

(E) Blood Supply of Bone

The bones are usually supplied by four types of arteries—(1) Nutrient, (2) Epiphyseal, (3) Metaphyseal or Juxta-epiphyseal and (4) Periosteal vessels. The articulating surface of a bone is avascular and gets nutrition from the synovial fluid and capillary network in the synovial membrane.

(*a*) *Supply of a long bone* (Fig. 6)—The nutrient artery via its many ramifications supplies the bone marrow and the inner 2/3 of the compact bone. Its terminal branches make hairpin loops at the epiphysiodiaphyseal junction and anastomose with the epiphyseal and metaphyseal arteries. In a growing bone metaphysis is supplied by nutrient and metaphyseal arteries and epiphysis is supplied by epiphyseal arteries only. A few branches of the artery form sinusoids in the marrow, others supply the bone cells by passing through the haversian and Volkmann's canals.

The epiphyseal arteries reach the bones via the capsular ligament, supply the articular cartilage, then turn back to form loops and end in intertrabecular sinuses.

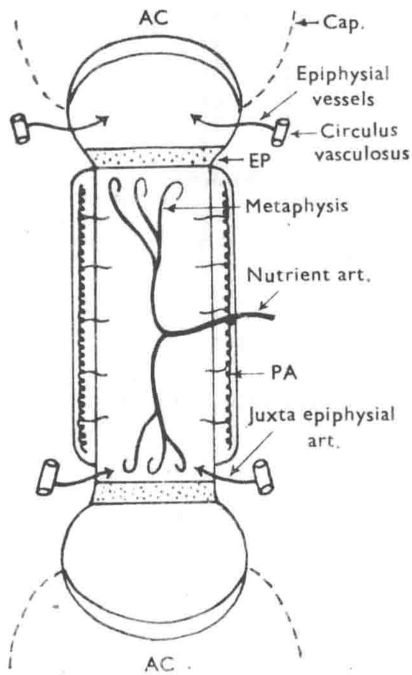


Fig. 6. Blood supply of a long bone.
AC—Articular cartilage ; Cap—Capsule ;
EP—Epiphysis ; PA—Periosteal arteries.

The metaphyseal arteries are branches of the neighbouring systemic arteries. They enter the bone beyond the articular cartilage. They supply the epiphysis and adjoining part of diaphysis. The periosteal arteries are branches of the muscular arteries ; they supply the outer third of the compact bone passing through the Volkmann's canals. They also supply the traction epiphysis.

(*b*) The *short long bones* (Fig. 7) are supplied mainly by periosteal vessels along with the epiphyseal and metaphyseal arteries at the only epiphyseal end. In the growing bone nutrient arteries also provide nutrition.

(*c*) The *flat bones* (Fig. 8), as for examples, hip bone and scapula are supplied by freely anastomising periosteal and nutrient arteries.

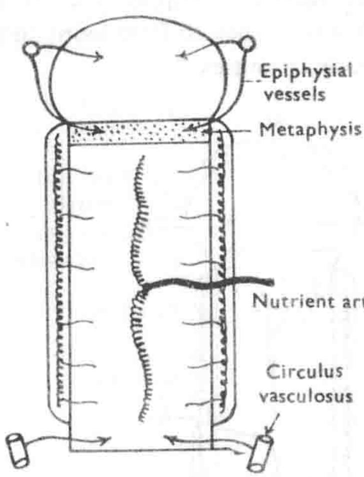


Fig. 7. Arterial supply of a short long bone.

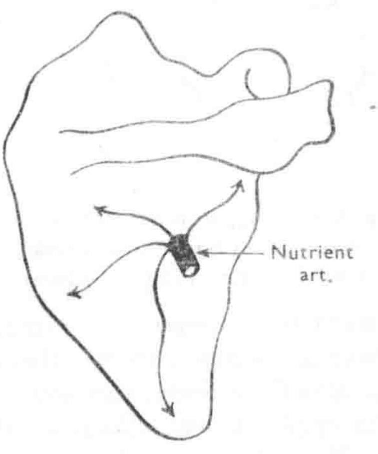


Fig. 8. Arterial supply of a flat bone.

(*d*) *Irregular bones* (Fig. 9) are supplied by periosteal vessels entering through non-articular surfaces. In the vertebrae the arteries enter through the circumference but mainly close to the base of the transverse processes.

The venous drainage occurs by veins running through red marrow and Volkmann's canals. Lymphatics follow the same route.

The nerves are mostly present at the articular ends of long bones and vertebrae. They are present freely in layers of periosteum. The branches enter through the nutrient foramen and supply the blood vessels.

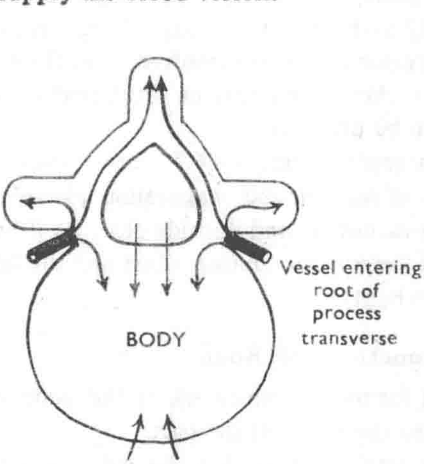


Fig. 9. Arterial supply of a vertebra.

Ossification of Bones

There are two types of ossification :

(A) Some bones, *e.g.*, those of roof and side of skull, are formed in fibrocellular membranes called *intramembranous* (*mesenchymal*) *ossification.*

(B) Majority are preceded by cartilaginous masses called *intracartilaginous* (*endochondral*) *ossification.*

A. *Intramembranous ossification* (Fig. 10)

Here direct mineralization of a highly vascular connective tissue occurs. The process starts in some constant centres of ossification where proliferation and condensation of mesenchymal cells around a capillary network take place. In between the cells and around the vessels, a fine network of collagen fibres and amorphous ground substance is formed which gradually changes into eosinophilic interweaving labyrinth. The cells, now polygonal, retain intercellular contact via short branches. They become eosinophilic with eccentric nucleus and are called osteoblasts. The collagen and protein polysaccharides synthesized by them form osteoid matrix which is studded with calcium phosphate deposits and which later forms typical hydroxyapatite crystals. As further layers of calcifying matrix are added to this primary spongiosa, some osteoblasts a e enclosed in

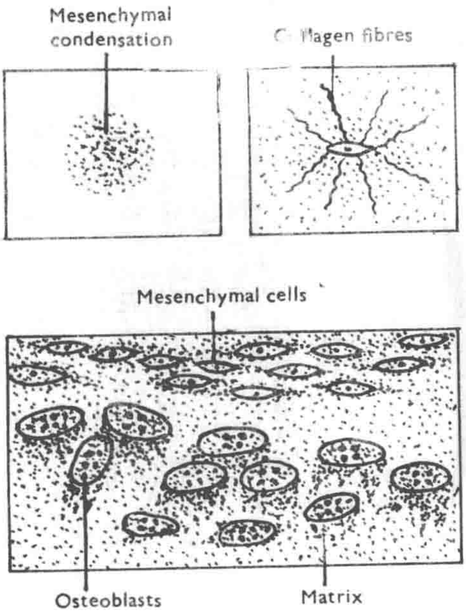


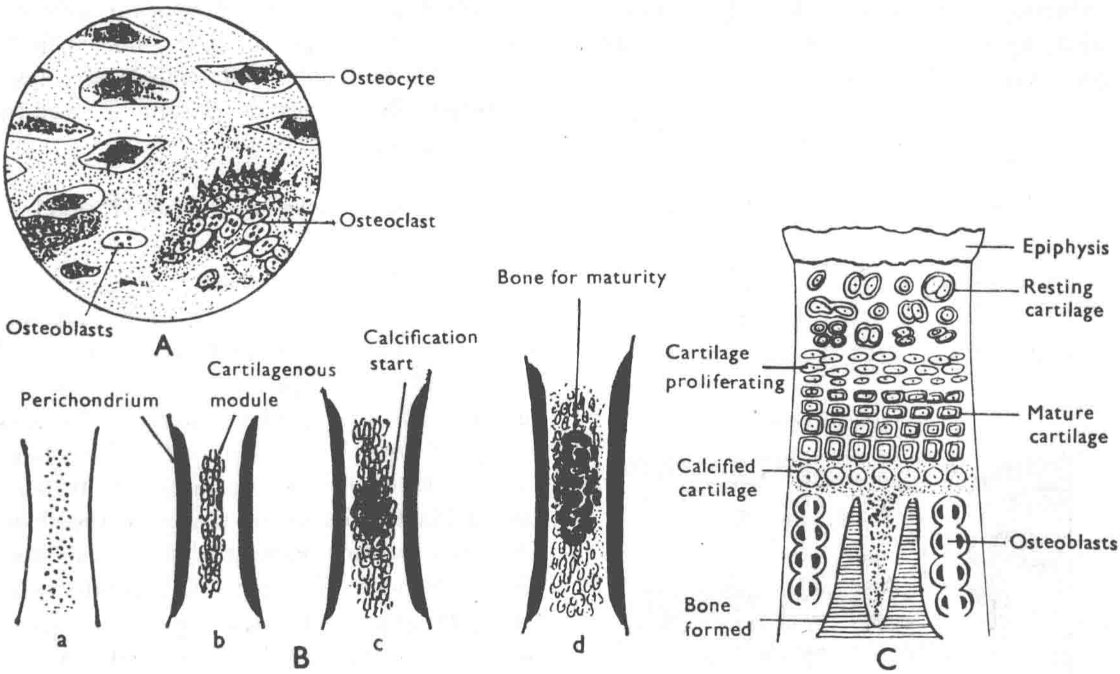
Fig. 10. Intramembranous ossification.

primitive lacunae and canaliculi are formed by condensation of matrix around intercellular contact processes. Where cancellous bone is formed, this process gradually stops and haemopoietic tissue invades the spaces. For compact bones, the process continues in a more regular manner and masses of compact parallel-fibred bone containing central vascular canal, termed *primary osteons* or atypical *haversian systems*, are formed. These and the intermediate areas of labyrinthine bones are later eroded and generations of lamellar secondary osteons are formed. While these changes are taking place in the centres of ossification, the surrounding mesenchyme condenses as fibrovascular periosteum around its end and extension of ossification occurs through osteogenic cells of inner layers of periosteum. When active bone growth is in progress, much remodelling occurs involving deposition and removal of bone at different places. For resorption, large multinucleate and lightly basophilic cells called *osteoclasts* are responsible. They are probably formed by fusion of modified osteoblasts.

B. *Intracartilaginous ossification* (Figs. 11 A, B, C)

Each long bone is represented in early foetal life by a strip of hyaline cartilage which replaces a strip of condensed mesenchyme. This model is surrounded by a highly vascular mesenchymal condensation or perichondrium, the deeper layers of which contain osteogenic cells. Primary centre of ossification appears, involving the cartilage cells in the centre of the shaft. The cells become enlarged and vacuolated. They accumulate glycogen and ultimately die, leaving the enlarged lacunae as primary areolae, the walls of which are now calcified. At the same time subperichondrial cells transform into osteoblasts and lay down a periosteal collar of fenestrated young bone, which progressively increases in girth and extends to both ends of the shaft. Near the shaft centre, sprouts from deeper layers of periosteum of vascular channels with accompanying cells, transforming into osteoblasts and osteoclasts, excavate passages through newly formed bone to pass into underlying calcified cartilage. They erode some walls of primary areolae forming larger secondary areolae or medullary spaces. These are filled with vascular mesenchyme, osteoblasts and osteoclasts and their walls are lined with osteoblasts which lay down bony lining with formation of bony lacunae containing osteocytes. With more deposition of subperiosteal bone the process stops and absorption of those early spicules of bone with coalescence and enlargement of marrow spaces occur.

While these changes are taking place in the centre of shaft, similar changes occur in



Figs. 11A,B,C.
Fig. 11A. Formations of osteoblast ; Fig. 11B. Cartilaginous ossification at different stages ; Fig. 11C. Ossification at epiphyseal cartilage and metaphyses.

adjoining layers of cartilages. The cartilaginous extremity grows in pace with the rest, by appositional and interstitial mechanisms. As division of cells in zone of growth continues, the bone grows in length. Continued internal erosion and remodelling together with further subperiosteal bone formation go on towards the bone ends. Thus the bone increases also in girth and the medullary cavity enlarges both longitudinally and transversely.

Eventually one or more secondary centres of ossification appear in cartilaginous ends. At first scattered isogenous groups of cells hypertophy and die and the same sequence of events occurs. It is surrounded by a spherical growth cartilage. Soon the growth plate becomes localized to metaphysis.

As bone matures, epiphyseal and metaphyseal ossification encroaches upon the growth plate and final bony union occurs with stoppage of growth. Final bony fusion occurs on walls of communicating epiphyseal and metaphyseal vessels which then involves the intervening bones. The junction is recognized as epiphyseal line in radiographs. In articulating ends of bones, the cartilaginous surface of epiphysis remains unossified. These woven-fibred bones are first replaced by roughly concentric tracts of non-lamellated parallel-fibred bone, and atypical haversian systems are deposited on the walls of the vascular spaces, which are replaced by typical haversian systems as the bone matures.

Growth of Bone

Increase in size of bone occurs exclusively by appositional mechanisms, in which new layers of bony tissue are simply added sequentially to pre-existing surfaces. A long bone increases in length by bone formation at epiphyseal plate and in diameter by subperiosteal bone deposition.

Flat and irregular bones grow by subperiosteal bone deposition and through metaphyseal growth where there are separate epiphyses.

Bones of vault of skull grow by subperiosteal bone formation at outer surface, with resorption of bone by the osteoclasts at inner surface.

Parts of a Young Bone

Primary centre of ossification is that from which main part of the bone ossifies. The shaft of a long bone ossifies from the primary centre. Usually the primary centre appears before birth with the *exception* of carpal bones.

Secondary centre of ossification is that from which an accessory part is ossified. They usually appear after birth with the *exception* of lower end of femur.

A young bone presents—

1. *Diaphysis* : Central region or shaft ossified from primary centre.
2. *Metaphysis* : The portion of the diaphysis adjacent to the epiphyseal cartilage is called metaphysis, *i.e.*, it is the epiphyseal end of the diaphysis. It is highly vascular and here growth activities are high.
3. *Epiphysis* : The bone ends which develop from secondary centre of ossification later fuse with the diaphysis. Epiphyses are of the following types :

(*a*) *Pressure epiphysis*—It helps in transmission of body weight and protection of epiphyseal cartilage, *e.g.*, head of femur, head of humerus etc.

(*b*) *Traction epiphysis*—It is caused by pull of muscles, *e.g.*, trochanters of femur, tuberosities of the humerus etc.

(*c*) *Atavistic epiphyses*—These aref ormed by centres of ossification, which are considered to represent the skeletal elements which were separate in some earlier evolutionary phases but later found to remain fused with adjacent bones, *e.g.*, coracoid process of the scapula.

(*d*) *Aberrant epiphysis*—When a bone has one epiphysis, an occasional separate epiphysis may be present, *e.g.*, in 1st metacarpal epiphysis is at base, but may have another at head which is then called aberrant epiphysis.

Laws of Ossification

1. Ossification may begin either from a membrane or from a cartilage, *i.e.*, intramembranous and endochondral respectively.
2. Ossification starts from a particular point called *centre of ossification* and spreads out on a radiating manner.
3. Centres of ossification may be primary (early appearing) or secondary (late appearing). Primary centre usually appears before birth (*exceptions*—os cuneiformis and os navicularis), while secondary centre appears after birth (*exception*—lower end of femur)
4. (*a*) Primary centre is usually one, if multiple, all appear simultaneously.

   (*b*) Secondary centres are usually multiple and usually do not appear simultaneously.
5. *Law of union of epiphysis*—The epiphysis which begins to ossify first, unites with the shaft (diaphysis) last and vice versa (*exception*—fibula). The end where ossification first begins is the *growing end of the bone.*
6. In the milking-cow position, the direction of the nutrient artery is always downwards, (*i.e.*, to the elbow I go, from the knee I flee) and the growing end of the bone is opposite to the direction of the nutrient artery.
7. The different secondary centres of ossification of an epiphysis first unite together between themselves and then join with the shaft (diaphysis) (*exception*—upper end of femur).