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FUNDAMENTALS OF ORTHOPEDICS & TRAUMA

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Bone

"It is life near the bone where it is sweetest."

—Henry David Thoreau

BONE

Adult human skeleton consists of 206 bones, 80 of which are in the axial skeleton. Vertebra is the first bone to appear in the seventh intraembryonic week. The clavicle is the first bone to ossify.

Bone is a dynamic specialized connective tissue in which calcium and phosphorus are stored with constant turnover. The microscopic structure of spongy and compact bones is the same except that the spaces in the spongy bone are large, while in compact bones, the bony tissue is dense and contains narrow channels.

The unit of bone is lamellus—a thin plate of bone consisting of groundwork of collagen fibers, gelatinous matrix and calcium phosphate salts.

The lamellae are stacked one over another to form trabeculae. The spaces between the lamellae are called lacunae, which contains basic bone cells—the osteocytes. The osteocytes in different layers and spaces are connected by their radiating processes, which pass through numerous minute canals piercing the lamellae, which are called canaliculi. The above whole arrangement is of spongy bone.

According to need the spongy bone gets converted into compact bone. The spaces between the trabeculae of spongy

bone are filled with vascular tissue lined by osteogenic cells—osteoblasts. These cells lay down rings of bony lamellae reducing the space to a small canal carrying a few blood vessel, lymphatics, nerve fibres—the Haversian canal. Thus, the Haversian system (primary osteons) is formed. These primary osteons get destroyed to form a new series of spaces, which in turn again get filled by bony lamellae forming the typical Harversian systems or secondary osteons.

The bone contains three types of cell:
1. Osteoblasts
2. Osteocytes
3. Osteoclasts.

Osteoblast

- They are derived from primitive mesenchymal cells
- They are directly involved in bone laying
- They get matured into osteocytes.

Osteoclast

- They originate from bone marrow
- They are involved in bone absorption.

The bone is formed either by intramembranous ossification from mesenchymal osteoblasts, e.g. skull bone or endochondral ossification from pre-existing cartilaginous models, e.g. long bones. The bone is constituted of organic and inorganic components.

Organic Components

The bone consists of matrix—98% (type 1 collagen 95% + non-collagenous proteins—5%) + Cells—2% (osteoblasts—involved in bone formation and osteoclasts—involved in bone

absorption). Organic connective tissue makes the bone tough and resilient, which can put resistance against tensile forces.

Inorganic Component

Inorganic components form 7% of bone—hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] and small amount of carbonate, magnesium, sodium, calcium, fluoride and potassium. These make the bone rigid and hard, which can withstand the impact of weight bearing, jumping, etc.

Strength of bone depends on *bone mineral density* (mass per volume, which determines 70% of bone strength), mineral contents and the quality of collagen. Bone mass is the amount of trabecular and cortical bone contained in the skeleton.

Types of Bone Tissue

Macroscopically the bone tissues are of two types:

Compact Bone (Cortical Bone)

It forms the ivory-like homogeneous dense textured surface layers of the matured bone.

Spongy Bone (Cancellous Bone or Trabecular Bone)

It consists of a network of trabeculae in which inter-communicating spaces (canaliculi) can be seen.

Diploic bone: Diploic bone has inner and outer tables of compact bone and in between there is spongy substance containing bone marrow and diploic veins, e.g. several cranial bones.

According to shape, the bones are of following types:

Long bones: Of the long bones some are long long bones such as femur, tibia, humerus, radius and ulna, whereas some are short-long bones such as metacarpals, metatarsals, phalanges and clavicle.

Flat bones: Such as pelvic bone, scapula, sternum, etc.

Irregular bones: Such as vertebrae, carpals, tarsals, some skull bones.

Sesamoid bones: Sesamoid means 'seed like'. They are small nodules of bones, which develop in relation to certain tendons. They help tendon in diminishing their friction and sometimes changing the direction of muscular pull. Patella is the biggest sesamoid bone.

Pneumatic bones: Certain flat and irregular bones have hollow spaces containing air by virtue of which they become light in weight and have more expanded shape such as maxilla, ethmoid, mastoid portion of temporal bones.

Blood Supply of Bone

Long bones have three main sources of blood supply (**Fig. 3.1**):

1. Nutrient artery enters usually in the middle third and divides into ascending and descending branches, which run along the medullary cavity and end in metaphyseal region forming anastomoses with metaphyseal, epiphyseal and periosteal arteries.
2. Periosteal arteries, receive blood from adjoining soft tissue, and enter the Volkmann's canals to supply the outer one-third of cortex.
3. Metaphyseal arteries emerge from articular (arteries) blood vessels or adjoining muscular arteries and enter into metaphyses to reinforce the metaphyseal branches of the nutrient artery.

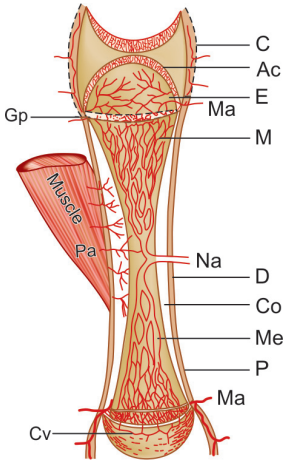


Fig. 3.1: Different parts of long bone and its blood supply (C = capsule; AC = articular cartilage; GP = growth plate; Ma = metaphysical artery; M = metaphysis; Na = nutrient artery; D = diaphysis; Co = cortex; Me = medulla; P = periosteum; Pa = periosteal artery; Cv = circulus vasculosus)

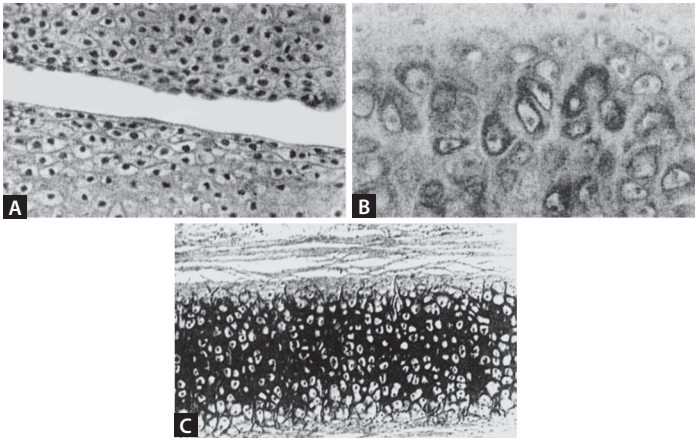
Other bones are supplied by numerous preiosteal blood vessels.

Nerve Supply of Bone

Nerves enter the bone along with the blood vessels. Most of them are sympathetic and vasomotor in function. Articular ends of bones are rich in nerve supply.

Cartilage

Cartilage (**Figs 3.2A to C**) originates from closely packed condensation of mesenchymal cells. Chondroblasts emerge from it and leads to the formation of chondrocytes and intercellular substance.



Figs 3.2A to C: Histological pattern: (A) Hyaline cartilage; (B) Articular cartilage; (C) Elastic cartilage (*Courtesy*: Gray's Anatomy, 37th edition. Edinburgh: Churchill Livingstone)

Depending upon various fibers in the substance of cartilage it is divided as:

- Fibrocartilage (obvious numerous collagen fibers are seen)
- Hyaline cartilage (there are less visible collagen fibers): Hyaline cartilage takes the shape of 'would-be-bone', cartilaginous model, which is precursor of bone formation
- Elastic cartilage (elastic fibers are present in intracellular substance)
- Articular cartilage—a thin, smooth, low friction gliding surface is present over the articulating bone end, which has a remarkable resiliency to compressive force.

Joints

The junction between the skeletal components where slight to free movements occur, is defined as joint.

Joints can be placed in two broad groups:

Synovial Joint (Diarthroses)

- The articulating bones of the joints are linked together by the fibrous capsule
- The capsule is lined by synovial membrane
- The articular surface of bone is covered by a thin layer of hyaline cartilage—the articular cartilage
- The synovial membrane secretes the synovial fluid, which is clear or pale yellow highly viscous glairy fluid of alkaline pH
- The synovial fluid contains:
  - cells < 200 mm^3—neutrophil (25%), monocytes, lymphocytes, macrophages
  - protein—1.3 to 1.7 g/dL—20% of normal plasma protein
  - glucose content—within 20 mg/dL of the fasting serum glucose level.
- The synovial fluid acts as a lubricant, provides nutrients to articular cartilage and makes the joints freely movable.

Non-synovial Joints

Non-synovial Joints are either *fibrous or fixed joints (*synarthrodial*)*. The joint is held together by only the ligament, e.g. skull sutures in sagittal and parietal bones or *cartilaginous*, *or slightly movable joint* (*synchondrosis* and *symphysis*), e.g. sacroiliac joint.

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- Prepared in simple straightforward language
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- Gives the condensed description on clinical methods with illustrations, line drawings of basic implants, amputation, orthotics, physiotherapy and accident management
- Includes an appendix in the end containing the name, photograph and main utility of the basic instruments used for an average orthopedic operation.

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