Biology

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BONE TISSUE

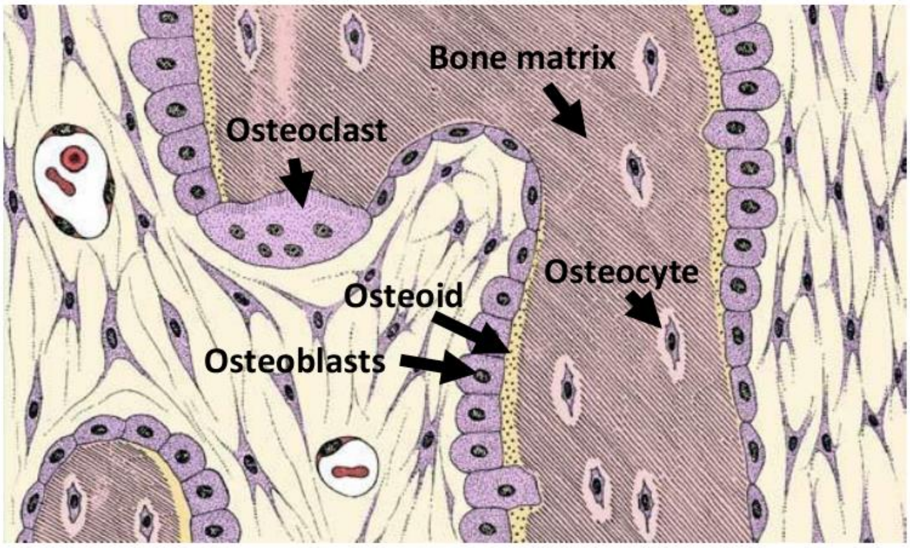
Bone tissue is a specialized form of connective tissue and is the main element of the skeletal tissues. It is composed of cells and an extracellular matrix in which fibers are embedded. Bone tissue is unlike other connective tissues in that the extracellular matrix becomes calcified.

FUNCTIONS OF BONE TISSUE

1. The skeleton is built of bone tissue. Bone provides the internal support of the body and provides sites of attachment of tendons and muscles, essential for locomotion.
2. Bone provides protection for the vital organs of the body: the skull protects the brain; the ribs protect the heart and lungs. The hematopoietic bone marrow is protected by the surrounding bony tissue.
3. The main store of calcium and phosphate is in bone. Bone has several metabolic functions especially in calcium homeostasis.

Bone is a hard, but brittle tissue. Bone is a dynamic tissue, which throughout life bone tissue is continually being formed and resorbed.

BONE CELLS



4 different cell types are found in developing bone:
1. Osteoprogenitor cells
2. Osteoblasts
3. Osteocytes
4. Osteoclasts

Osteoprogenitor cells

Bone, like other connective tissue in the embryo, is derived from mesenchyme cells. After birth, flattened, poorly-differentiated, mesenchyme-like cells, are found in the periosteum and endosteum. These cells can divide (mitosis) and differentiate into bone cells (osteogenic potential) and as a result are known as osteoprogenitor cells.

Osteoblasts

The first cells to develop from the osteoprogenitor cells are the osteoblasts. Osteoblasts are involved in the formation of bone and are found on the boundaries of developing and growing bone. The cells are typically oval, with a large eccentric nucleus, and the cytoplasm is fairly basophilic. These cells are very active in synthesizing and secreting the components of the bone matrix and have well-developed rough endoplasmic reticulum (RER), Golgi bodies and granules. Osteoblasts are rich in the enzyme alkaline phosphatase, which plays a major role in the formation of the mineral deposits in the matrix. The collagen fibers are synthesized and secreted by the osteoblasts.

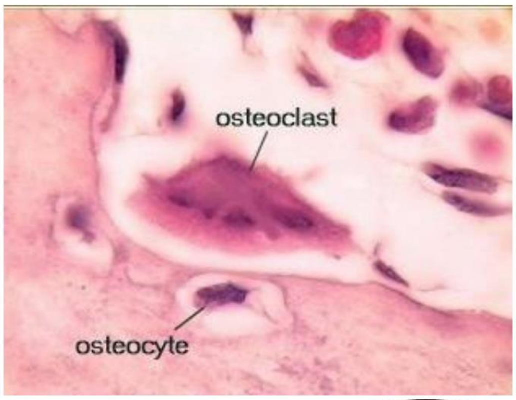
The matrix closest to the osteoblasts is not yet calcified and is known as osteoid or prebone. This osteoid is rich in collagen fibers. Small membrane-bound matrix vesicles (not visible by light microscopy) are budded off processes of the osteoblast cell membrane and secreted to the matrix. These play an important role in the calcification process of the matrix.

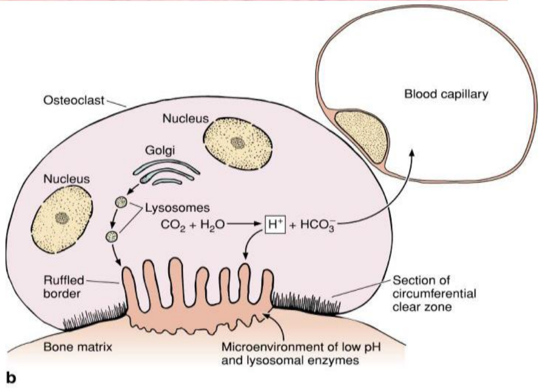
Osteocytes

Osteocytes are mature bone cells that develop from osteoblasts and are located in lacunae within the bony matrix. Osteocytes have cytoplasmic processes located in canaliculi, which penetrate the bony matrix. Cytoplasmic processes from one osteocyte make contact with the processes from neighboring osteocytes and can communicate via gap junctions. Because the bony matrix is calcified there is no possibility of diffusion except via the network of canaliculi.

Osteoclasts

Osteoclasts are the largest of the bone cells and are multinuclear (with up to 50 nuclei). Osteoclasts are involved in bone resorption and can be found on the eroding surfaces of bone, often in cavities known as Howship's lacunae. The osteocytic cell membrane closest to the bone undergoing resorption has multiple invaginations and is known as the "ruffled border". These cells are metabolically very active, possess large numbers of mitochondria (resulting in the acidophilia of regular staining) and have well developed Golgi bodies.
Osteoclasts originate from monocytes and are included in the **mononuclear phagocyte system.**



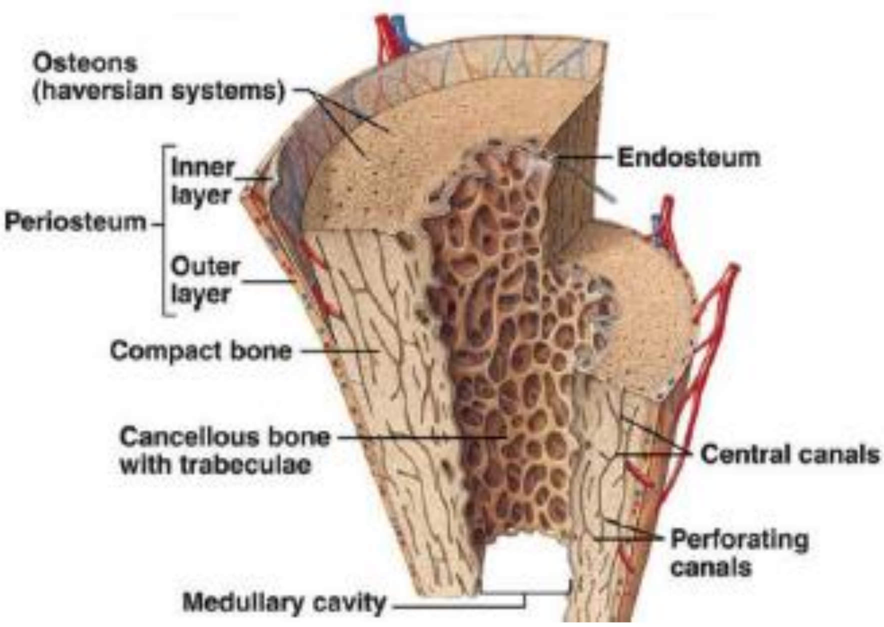


Bone Matrix

Bone matrix is made by organic (30%) & non-organic (70%) components.
The organic component is type I collagen and ground substance, which contains proteoglycan aggregates and structural glycoproteins. Other tissues containing type I collagen are not normally calcified and do not contain these glycoproteins.
Non-organic components are minerals, mainly calcium & phosphorus, but bicarbonate, citrate, magnesium, potassium, and sodium are also found. Calcium and phosphorus form crystals with the composition Ca10 (PO4)6(OH)2. However, noncrystalline calcium phosphate is also present. In electron micrographs, crystals of bone appear as plates parallel to the collagen fibrils & surrounded by ground substance.
The association of minerals with collagen fibers is responsible for the hardness and resistance of bones. If a bone is decalcified, its shape is preserved, but it becomes flexible. If a bone is devoid of collagen, its shape is also preserved, but it becomes fragile.

Periosteum & Endosteum

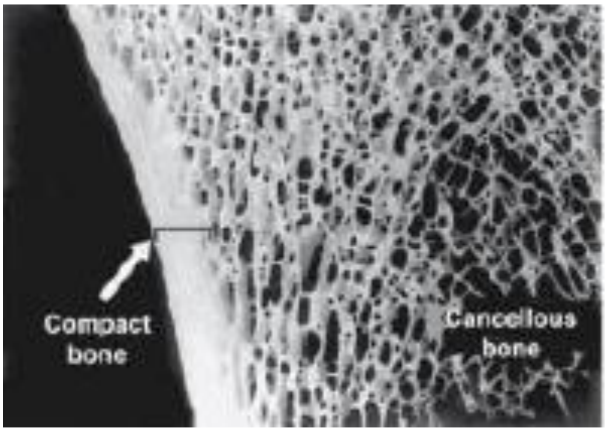
External and internal surfaces of bone are covered by connective tissue called periosteum and endosteum.



The ***periosteum*** consists of an outer layer of collagen fibers and fibroblasts. Bundles of periosteal collagen fibers, called Sharpey's fibers, penetrate the bone matrix, binding the periosteum to bone. The inner, more cellular layer of the periosteum is composed of fibroblast-like cells called osteoprogenitor cells, with the potential to divide by mitosis and differentiate into osteoblasts. Osteoprogenitor cells play a prominent role in bone growth and repair.

The ***endosteum*** lines all internal cavities within the bone and is composed of a single layer of flattened osteoprogenitor cells and a very small amount of connective tissue. The endosteum is therefore considerably thinner than the periosteum.

The principal functions of periosteum and endosteum are nutrition of osseous tissue and provision of a continuous supply of new osteoblasts for repair or growth of bone.



Types of Bone

Anatomical classification of **bones**: long, short, flat, & irregular bones.

Macroscopic classification of **bone tissue**: compact bone, cancellous bone (microscopically they are almost identical).

Developmental classification of bone tissue: primary & secondary.

Macroscopic classification of bone tissue:

Compact bone:

Here, bone tissue forms a solid mass of bone with no cavities. In a long bone, compact bone tissue forms the bone shaft (diaphysis) around the bone marrow cavity, & the outer layer of the metaphysis & epiphysis.

Under microscope, compact bone matrix is made of bone layers (lamellae) having small cavities (lacunae) between them that contain osteocytes. Osteocytes are oval cells with many slender cytoplasmic processes that occupy small tunnels (canaliculi) connecting adjacent lacunae. As mentioned above, inside each canaliculus, cytoplasmic processes of adjacent osteocytes contact each other by gap junctions.

In compact bone, lamellae are arranged as follows:

- Outer circumferential lamellae: large in number, occupy the outer zone, beneath & parallel to the periosteum

- Inner circumferential lamellae: less in number, occupy the inner zone parallel to the endosteum .

- Osteons (Haversian systems): longitudinal cylinders of bone made of concentric lamellae with a central narrow canal "***the central (Haversian) canal***" filled with loose connective tissue. Osteons fill the zone between the outer & inner circumferential lamellae & are parallel to the long axis of the bone. Central canals are connected to each other by several transverse or oblique canals "***perforating (Volkmann's) canals***", that also connect central canals to the outer & inner surfaces of the bone.

- Interstitial lamellae: short parallel lamellae that fill the small triangular spaces between osteons.

Notes:

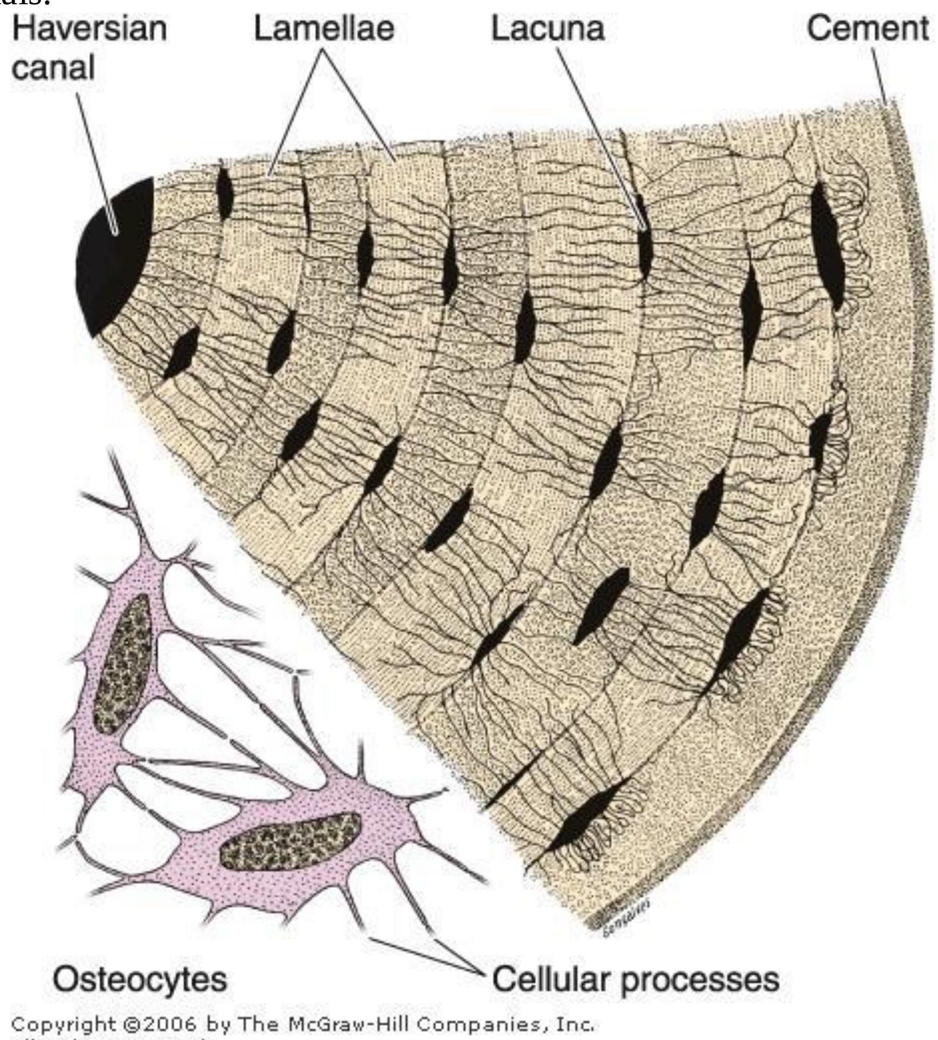
 In each lamella, collagen fibers are arranged spirally, in a direction opposite to that of the collagen fibers of the adjacent lamella.

 Osteons are in a continuous renewal process, therefore, they differ in diameter & number of lamellae.

 Surrounding each osteon is a layer of amorphous material called the **cementing substance** that consists of mineralized matrix with few collagen fibers.

 Perforating canals are not surrounded by concentric lamellae, they perforate the lamellae of haversian systems. Perforating canals are lined with endosteum & filled with loose connective tissue.

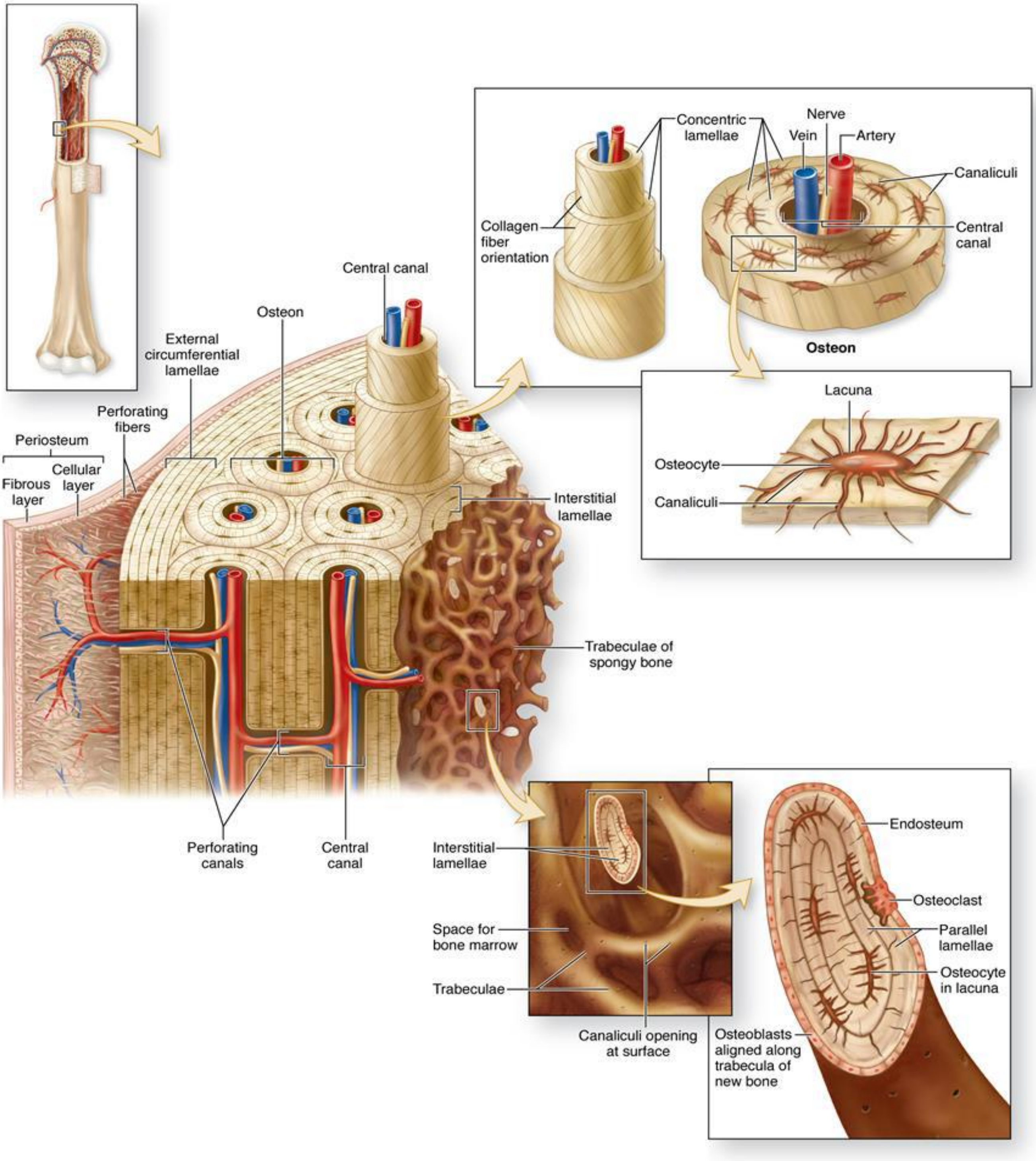
 Blood vessels & nerves enter the bone via foramina & are distributed through all central & perforating canals.



Cancellous bone:

Cancellous (spongy, trabecular) bone fills the epiphysis & metaphysis of long bones & form a thin zone on the inner surface of diaphysis around the marrow cavity. In short & irregular bones, cancellous bone forms the core & compact bone makes the outer layer of the bone. In flat bones, 2 plates of compact bone sandwich a thin zone of cancellous bone called the diploe.

Cancellous bone is made of bony trabeculae separated by extensively interconnected cavities, just like a sponge. Histologically, it is similar to compact bone in being made by concentric lamellae with lacunae containing osteocytes, but the lamellae are not perforated by central or perforating canals. On the surface of the bony trabeculae, osteoblasts are present, together with fewer osteoclasts, all surrounded by thin endosteum.



Developmental classification of bone tissue:

Primary bone tissue:

Primary (immature, woven) bone is the first bone tissue to appear in embryonic development and in fracture repair and other repair processes. It is characterized by random disposition of fine collagen fibers, a lower mineral content and a higher proportion of osteocytes than in secondary bone tissue. Primary bone tissue is usually temporary, it is replaced in adults by secondary bone tissue except in few places (near the sutures of the flat bones of the skull, in tooth sockets, and in the insertions of some tendons).

Secondary bone tissue:

Secondary (mature, lamellar) bone tissue is usually found in adults. It shows collagen fibers arranged in lamellae forming compact or cancellous bone tissue (discussed above).

Clinical notes:

Green stick fracture:

A greenstick fracture occurs when a bone bends and cracks, instead of breaking completely into separate pieces. The fracture looks similar to what happens when you try to break a small, "green" branch on a tree.

Most greenstick fractures occur in children younger than 10 years of age. This type of broken bone most commonly occurs in children because their bones are softer and more flexible than are the bones of adults.

Even mild greenstick fractures are usually immobilized in a cast. In addition to holding the cracked pieces of the bone together so they can heal, a cast can help prevent the bone from breaking all the way through if the child falls on it again.