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BONE

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1/1/1900

BONE: INTRODUCTION

Bone is a specialized connective tissue composed of calcified intercellular material, the bone matrix, and three cell types:

- **Osteoblasts:-** which synthesize the organic components of the matrix.
- **Osteocytes :-** which are found in cavities (lacunae) between layers (lamellae) of bone matrix
- **Osteoclasts:-** which are multi-nucleated giant cells involved in the resorption and remodeling of bone tissue.

As the main constituent of the adult skeleton,

1- Bone tissue supports fleshy structures,
2- Protects vital organs such as those in the cranial and thoracic cavities,
3- Harbors the bone marrow, where blood cells are formed.
4- Bone also serves as a reservoir of calcium, phosphate, and other ions that can be released or stored in a controlled fashion to maintain constant concentrations of these important ions in body fluids
5- Bones form a system of levers that multiply the forces generated during skeletal muscle contraction and transform them into bodily movements. This mineralized tissue therefore confers mechanical and metabolic functions to the skeleton.

Components of Bone

The overview of the basic features of bone.

1- **The periosteum** :- consists of dense connective tissue, with a primarily fibrous layer covering a more cellular layer. Bone is vascularized by small vessels that penetrate the matrix from the periosteum.

Because metabolites are unable to diffuse through the calcified matrix of bone, the exchanges between osteocytes and blood capillaries depend on communication through the canaliculi , which are very thin, cylindrical spaces that perforate the matrix .

All bones are lined on both internal and external surfaces by layers of connective tissue containing osteogenic cells—endosteum on the internal surface and periosteum on the external surface.

2- BONE CELLS

- Osteoblasts : are responsible for the synthesis of the organic components of bone matrix, consisting of type I collagen fibers, proteoglycans, and several glycoproteins including osteonectin. Deposition of the inorganic components of bone also depends on viable osteoblasts. Osteoblasts are located exclusively at the surfaces of bone matrix, usually side by side in a layer somewhat resembling a simple epithelium. When they are actively engaged in matrix synthesis, osteoblasts have a cuboidal to columnar shape and basophilic cytoplasm.

When their synthesizing activity declines, they flatten and cytoplasmic basophilia is reduced. Osteoblast activity is stimulated by parathyroid hormone (PTH).

During matrix synthesis, osteoblasts have the ultrastructure of cells actively synthesizing proteins for secretion. Osteoblasts are polarized cells: matrix components are secreted at the cell surface in contact with older bone matrix, producing a layer of new (but not yet calcified) material called osteoid between the osteoblast layer and the bone formed earlier . This process of bone appositional growth is completed by subsequent deposition of calcium salts into the newly formed matrix.

- **Osteocytes** Individual osteoblasts are gradually surrounded by their own secretion and become osteocytes enclosed singly within spaces called lacunae. In the transition from osteoblasts to osteocytes the cells extend many long cytoplasmic processes, which also become surrounded by calcifying matrix. An osteocyte and its processes occupy each lacuna and the canaliculi radiating from it.

Processes of adjacent cells make contact via gap junctions, and molecules are passed via these structures from cell to cell. The exchange via gap junctions can provide nourishment for a chain of about ten cells. Some molecular exchange between osteocytes and blood vessels also takes place through the small amount of extracellular fluid located between osteocytes and the bone matrix.

When compared with osteoblasts, the flat, almond-shaped osteocytes exhibit a significantly reduced RER and Golgi apparatus and more condensed nuclear chromatin . These cells are involved in maintaining the bony matrix and their death is followed by resorption of this matrix.

- **Osteoclasts** are very large, motile cells with multiple nuclei. The large size and multinucleated condition of osteoclasts is due to their origin from the fusion of bone marrow-derived cells. In areas of bone undergoing resorption, osteoclasts lie within enzymatically etched depressions or crypts in the matrix known as resorption bays (formerly called Howship lacunae).

In active osteoclasts, the surface against the bone matrix is folded into irregular projections, which form a ruffled border. Formation of the ruffled borders is related to the activity of osteoclasts. Surrounding the ruffled border is a clear cytoplasmic zone rich in actin filaments which is the site of adhesion to the bone matrix. This circumferential adhesion zone creates a microenvironment between the osteoclast and the matrix in which bone resorption occurs.

Into this subcellular pocket the osteoclast secretes collagenase and other enzymes and pumps protons, forming an acidic environment locally for dissolving hydroxyapatite and promoting the localized digestion of collagen. Osteoclast activity is controlled by local signaling factors and hormones. Osteoclasts have receptors for calcitonin, a thyroid hormone, but not for parathyroid hormone. Osteoblasts activated by PTH produce a cytokine called osteoclast

stimulating factor. Thus, activity of these two cells is coordinated and both are essential in bone remodeling. BONE MATRIX

Inorganic material represents about 50% of the dry weight of bone matrix. Hydroxyapatite is most abundant, but bicarbonate, citrate, magnesium, potassium, and sodium are also found. Significant quantities of amorphous (noncrystalline) $CaPO_4$ are also present. The surface ions of hydroxyapatite are hydrated and a layer of water and ions forms around this crystal. This layer, the hydration shell, facilitates the exchange of ions between the crystal and the body fluids.

TYPES OF BONE

Gross observation of bone in cross section shows dense areas generally without cavities—corresponding to compact bone—and areas with numerous interconnecting cavities—corresponding to cancellous (spongy) bone. Under the microscope, however, both compact bone and the trabeculae separating the cavities of cancellous bone have the same basic histologic structure.

Compact and Cancellous (spongy or trabecular) Bone.

Close gross examination of a thick section of dried bone illustrating the cortical compact bone and the lattice of trabeculae in cancellous bone at the bone's interior. In living tissue the compact bone is covered externally with periosteum and all surfaces of cancellous bone are covered with endosteum.

In long bones, the bulbous ends—called epiphyses—are composed of spongy bone covered by a thin layer of compact bone. The cylindrical part—the diaphysis is almost totally composed of compact bone, with a thin component of spongy bone on its inner surface around the bone marrow cavity. Short bones usually have a core of spongy bone surrounded completely by compact bone. The flat bones that form the calvaria (skullcap) have two layers of compact bone called plates (tables), separated by a thicker layer of spongy bone called the diploë.

OSTEOGENESIS

Bone can be formed initially by either of two ways:

- Intramembranous ossification, in which osteoblasts differentiate directly from mesenchyme and begin secreting osteoid
- Endochondral ossification, in which the matrix of preexisting hyaline cartilage is eroded and replaced by osteoblasts producing osteoid.

In both processes, the bone tissue that appears first is primary or woven. Primary bone is a temporary and is soon replaced by the definitive secondary lamellar bone. During bone growth, areas of primary bone, areas of resorption, and areas of secondary bone all appear side by side.

JOINTS

Joints are regions where bones are capped and surrounded by connective tissues that firmly hold the bones together and determine the type and degree of movement between them. Joints may be classified as diarthroses, which permit free bone movement, and synarthroses, in which very limited or no movement occurs. There are three types of synarthroses, based on the type of tissue uniting the bone surfaces:

- Synostoses, in which bones are united by bone tissue and no movement takes place. In older adults, synostoses unite the skull bones, which, in children and young adults, are united only by dense connective tissue
- Synchondroses, in which the bones are joined by hyaline cartilage. The epiphyseal plates of growing bones are one example and in adults a synchondrosis unites the first rib to the sternum, with little movement
- Syndesmoses, in which bones are joined by an interosseous ligament of dense connective tissue or fibrocartilage (eg, the pubic symphysis), again with very limited movement.

Diarthroses are joints that generally unite long bones and have great mobility, such as the elbow and knee joints. In a diarthrosis, ligaments and a capsule of dense connective tissue maintain proper alignment of the bones. The capsule encloses a sealed joint cavity that contains synovial fluid, a colorless, transparent, viscous fluid. The joint cavity is not lined by epithelium, but by a specialized connective tissue called the synovial membrane which extends folds and villi into the cavity and secretes the lubricant synovial fluid. Synovial fluid is derived from blood plasma, but with a high concentration of hyaluronic acid produced by cells of the synovial membrane.