**Lecture 13**

**Bone tissues. Osteohistogenesis. Histological structure of tubular bone**

Introduction

Bone tissue, also known as osseous tissue, is a specialized form of connective tissue that provides structural support, protection for internal organs, and plays a vital role in mineral storage and hematopoiesis. Bone is a dynamic tissue that undergoes continuous remodeling throughout life. In this lecture, we will explore the composition of bone tissue, the process of osteohistogenesis (bone formation), and the detailed histological structure of tubular bones.

1. Bone Tissue: Composition and Types

Bone tissue consists of two main components:

* Cells: The primary cells in bone tissue include:
  + Osteoblasts: Cells responsible for bone formation. They secrete the bone matrix and promote the mineralization of the tissue.
  + Osteocytes: Mature bone cells derived from osteoblasts. They maintain the bone matrix and reside in small cavities called lacunae.
  + Osteoclasts: Large, multinucleated cells that break down bone tissue during bone remodeling. Osteoclasts play a crucial role in bone resorption and the regulation of calcium and phosphate levels.
* Extracellular Matrix (ECM): The bone matrix consists of:
  + Organic Component: Primarily composed of collagen fibers (type I) and other proteins that provide flexibility and tensile strength.
  + Inorganic Component: Composed mainly of hydroxyapatite crystals (calcium phosphate), which give bone its hardness and strength.

Bone tissue is classified into two types based on the density and arrangement of its matrix:

* Compact Bone (Cortical Bone): Dense and solid, compact bone forms the outer layer of bones and provides strength for weight-bearing.
* Spongy Bone (Cancellous or Trabecular Bone): Found inside bones, spongy bone consists of a network of trabeculae, which provide structural support while reducing bone weight.

2. Osteohistogenesis: Bone Development

Osteohistogenesis refers to the process of bone formation, which occurs through two primary mechanisms: intramembranous ossification and endochondral ossification.

A. Intramembranous Ossification

This type of bone formation occurs directly from mesenchymal tissue (undifferentiated connective tissue) and is responsible for forming flat bones such as the skull, clavicles, and parts of the mandible.

* Process:
  1. Mesenchymal cells differentiate into osteoblasts within a fibrous membrane.
  2. Osteoblasts begin to secrete osteoid (unmineralized bone matrix), which then calcifies.
  3. Osteoblasts become trapped in the matrix and differentiate into osteocytes.
  4. As more osteoid is secreted and mineralized, bone tissue expands, forming trabeculae (small, supporting struts of spongy bone).
  5. Trabeculae thicken and combine to form spongy bone, which may later be remodeled into compact bone.

B. Endochondral Ossification

Endochondral ossification involves the formation of bone from a cartilage model. This process is responsible for the development of long bones such as the femur, humerus, and tibia.

* Process:
  1. A hyaline cartilage model is formed during fetal development.
  2. Cartilage cells, or chondrocytes, begin to enlarge and calcify, leading to the formation of a bone collar around the diaphysis (shaft of the bone).
  3. Blood vessels invade the cartilage, bringing osteoblasts that replace the calcified cartilage with bone.
  4. Osteoblasts begin producing bone matrix in the primary ossification center within the diaphysis.
  5. Secondary ossification centers form in the epiphyses (ends of the bone) after birth.
  6. Epiphyseal plates (growth plates) remain between the diaphysis and epiphyses, allowing for continued growth during childhood. Once the growth plates close, bone growth stops.

Endochondral ossification allows for the elongation of bones during growth, and this process is vital for the development of most of the bones in the body.

3. Histological Structure of Tubular Bone

Tubular bones (also known as long bones) are characterized by their elongated shape and consist of several structural regions that provide strength, flexibility, and functionality.

A. Gross Anatomy of Tubular Bone

1. Diaphysis: The long, central shaft of the bone, primarily composed of compact bone. The hollow interior of the diaphysis contains the medullary cavity, which is filled with bone marrow.
2. Epiphysis: The rounded ends of the bone, composed of spongy bone surrounded by a thin layer of compact bone. The spongy bone within the epiphysis houses red bone marrow, which is involved in hematopoiesis (blood cell formation).
3. Metaphysis: The region between the diaphysis and epiphysis, which contains the epiphyseal (growth) plate in growing bones. After growth stops, the epiphyseal plate is replaced by an epiphyseal line.
4. Periosteum: A dense, fibrous membrane that covers the outer surface of the bone. It contains osteoblasts for bone growth and repair and provides an attachment site for tendons and ligaments.
5. Endosteum: A thin layer of connective tissue lining the inner surface of the medullary cavity. It contains osteoclasts and osteoblasts, which are involved in bone remodeling.

B. Histological Structure of Compact Bone

Compact bone is highly organized and consists of structural units called osteons (or Haversian systems). Each osteon has a central canal surrounded by concentric layers of bone matrix, known as lamellae.

* Osteon Structure:
  + Haversian Canal: The central canal in each osteon that contains blood vessels and nerves, providing nourishment and communication within the bone.
  + Lamellae: Concentric rings of calcified matrix surrounding the Haversian canal. Collagen fibers in each lamella run in opposite directions to provide strength.
  + Lacunae: Small cavities between lamellae that contain osteocytes. The osteocytes maintain the bone matrix and communicate with one another via canaliculi (tiny channels).
  + Volkmann's Canals: Horizontal channels that connect adjacent Haversian canals, allowing blood vessels and nerves to penetrate the bone tissue.

C. Histological Structure of Spongy Bone

Spongy bone, also known as cancellous bone, has a porous, lattice-like structure composed of trabeculae. Unlike compact bone, spongy bone does not have osteons. Instead, trabeculae are arranged along lines of stress to help the bone resist mechanical forces.

* Structure of Trabeculae:
  + Trabeculae are made up of layers of lamellae, but they are thinner and more irregular than those found in compact bone.
  + Within the trabeculae, osteocytes are found in lacunae, and they communicate via canaliculi.
  + Spaces between trabeculae are filled with red bone marrow, where hematopoiesis occurs.

Spongy bone is found predominantly in the epiphyses of long bones and the interior of other bones, such as the vertebrae and pelvis.

4. Bone Remodeling

Bone is a dynamic tissue that undergoes continuous remodeling throughout life. This process involves the coordinated activity of osteoclasts (bone resorption) and osteoblasts (bone formation). Bone remodeling is essential for maintaining bone strength, repairing microdamage, and regulating calcium and phosphate levels in the body.

* Bone resorption: Osteoclasts break down old or damaged bone, releasing minerals like calcium into the bloodstream.
* Bone formation: Osteoblasts lay down new bone matrix, which later becomes mineralized.

The balance between bone resorption and formation is influenced by several factors, including hormones (e.g., parathyroid hormone, calcitonin, and estrogen), mechanical stress, and nutritional status (e.g., calcium and vitamin D levels).

Conclusion

Bone tissue is a highly specialized form of connective tissue that provides structural support, protects vital organs, and plays a key role in mineral storage and blood cell formation. Osteohistogenesis involves two distinct processes—intramembranous ossification and endochondral ossification—each essential for the development and growth of bones. The histological structure of tubular bones, with its organized arrangement of compact and spongy bone, allows for strength, flexibility, and efficient metabolic functions. Understanding the composition and function of bone tissue is crucial for insights into skeletal development, growth, and repair.