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THE HISTOLOGICAL STRUCTURE OF LONG BONES

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Abstract
This study provides a detailed examination of the histological (tissue-level) structure of long bones. It analyzes, at the microscopic level, the main structural components of bone tissue — osteons, Haversian canals, lamellar layers, osteocytes, lacunae, and canaliculi. The differences between compact (dense) and spongy (cancellous) bone tissue, their functional significance, and their role in the bone regeneration process are also highlighted. The study includes information on the vascularization of bone tissue, the intercellular matrix, and mineral components, as well as their impact on bone strength. This topic holds significant scientific and practical value for students studying anatomy, histology, and medicine.

Keywords: Bone tissue, osteon, Haversian canals, osteocyte, compact bone, spongy bone, lamellar layer, lacuna, canaliculus, blood vessels (in bone), bone regeneration, physiological role of bone.

Bones are the main components of the skeleton in humans and vertebrate animals.
Bone tissue is a type of connective tissue. Together with joints, ligaments, muscles, and associated tendons, bones form the **musculoskeletal system**. Bone is composed of **cells** (osteocytes, osteoclasts) and **intercellular substance** rich in mineral components.
Osteocytes are surrounded by intercellular substance and are connected to each other via cellular processes, enabling the exchange of materials (proteins, water, ions) within the bone tissue. **Osteoblasts** are responsible for bone formation, while osteoclasts facilitate the **resorption** of bone. The combined activity of osteoblasts and osteoclasts forms the basis of bone **growth** and adaptation to **functional load**.

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The intercellular matrix consists of **collagen (ossein) fibers** and a **ground substance**, both of which contribute to the **strength and rigidity** of the bone. The collagen in bone tissue differs from cartilage by containing unique polypeptides. The ground substance consists of **glycoproteins** and **proteoglycans**. The mineral component is made up of **crystals of apatite**, **sulfates**, and **calcium carbonate**.

During **embryonic development**, bones originate from **mesenchymal connective tissue**. **Primary bone** forms by ossification of the cartilaginous skeleton (e.g., humerus, femur), while **secondary bone** originates from subdermal dermal plates (e.g., frontal and parietal bones).

Based on their **structure and shape**, bones are classified into **long (e.g., femur, tibia)**, **flat (e.g., sternum)**, and **short (e.g., vertebrae)** bones. **Long bones** consist of a **shaft (diaphysis)** and two **ends (epiphyses)**. The diaphysis is made of **compact bone**, whereas the epiphyses and flat/short bones consist mainly of **spongy bone**. The **medullary cavity** is located in the diaphysis, and **bone marrow** is present between the spongy bone structures in the epiphyses.

The **outer surface** of the bone is covered by the **periosteum**, a connective tissue membrane, while the **inner medullary cavity** is lined with the **endosteum**. The diaphysis consists of **lamellae** (4–15 µm thick), through which **blood vessels and nerves** pass.

Bones serve as a **depot for calcium and phosphorus**. Hormones such as **parathyroid hormone (PTH)** and **calcitonin** regulate blood calcium levels and the activity of osteoclasts. Bone tissue has a high regenerative capacity and is continuously renewed in the body. Therefore, its **mechanical properties adapt** to the **mechanical load** experienced by the organism. The human skeletal composition is continuously renewed throughout life.

Long bones such as the **humerus**, **radius**, **femur**, and **tibia** form the limbs and serve as **support structures**. They act as **levers** for movement, and play a **protective and supportive role**. The **shaft (diaphysis)** of a long bone is typically **cylindrical or triangular** in shape, and contains the **medullary cavity**. The **expanded ends** are called **epiphyses**, which contain the **articular surface (facies articularis)** that articulates with adjacent bones and is covered by **articular**

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cartilage. The epiphyses consist mainly of spongy bone covered by a thin layer of compact bone.

Within the spongy bone of the epiphysis and medullary cavity of the diaphysis lies **bone marrow**, which in children and adults is often **red marrow**. The **metaphysis** is the region where the diaphysis transitions into the epiphysis. It has a thinner compact structure and spongy architecture.

Long bones (compact or lamellar bones) form the **outer dense layer** of bones and play key roles in **mechanical support**, **protection**, and **mineral metabolism**.

Extracellular Matrix:

- **Organic component (~30–35%)**: Primarily **type I collagen fibers**, providing tensile strength and flexibility. Glycoproteins like **osteocalcin** and **osteonectin**, as well as **proteoglycans**, regulate **mineralization**.
- **Inorganic component (~65–70%)**: Dominated by **hydroxyapatite crystals** ($Ca_{10}(PO_4)_6(OH)_2$), giving bone **rigidity and hardness**. Also contains **calcium carbonate** and other **trace elements**.

Cells:

- **Osteoblasts**: Form bone matrix and initiate **mineralization**.
- **Osteocytes**: Mature bone cells located within **lacunae** in mineralized matrix, communicate via **canaliculi**, and regulate bone homeostasis.
- **Osteoclasts**: Multinucleated cells that **resorb bone**, playing a role in **bone remodeling**.

The Osteon (Haversian System):

The **osteon** is the primary functional unit of compact bone:

- **Central (Haversian) canal**: Located at the core, containing **blood vessels**, **lymphatics**, and **nerves**.
- **Lamellae**: Concentric rings of mineralized matrix, each with **collagen fibers** oriented in different directions to withstand multidirectional stress.
- **Lacunae and canaliculi**: Osteocytes reside in lacunae and are connected via **canaliculi**, allowing for nutrient exchange and signal transmission.

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- **Volkmann's canals**: Run **perpendicular** to Haversian canals, linking them and connecting to the **bone surface**. These also carry blood vessels and nerves.

Bone Remodeling:
Bone tissue is **dynamic and continuously renewed**:

- **Osteoclasts** remove old bone through **resorption**.
- **Osteoblasts** produce new bone matrix and **mineralize** it.

This process maintains bone **strength** and enables **adaptation to stress**.

Conclusion:
The **histological structure of long bones**, especially the **Haversian system**, ensures their **strength, durability**, and **biological activity**. This complex system supports both the **mechanical** and **metabolic** functions of bone. The intricate architecture and intercellular interactions are vital for **bone health** and **regeneration**.

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