Skeletal Tissues

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Functions of Bones

1. **Support and protection:**
   - Bones give shape to body structure.
   - Bones provide support to body weight.
   - Certain bones protect vital internal organs (i.e. the skull protects the brain, the vertebral column protects the spinal cord, the thoracic cage protects the heart and lungs, and the pelvic girdle protects the reproductive organs).

2. **Lever actions:**
   - Bones, along with skeletal muscles, perform body movements.

3. **Blood cell formation (hematopoieses)**
   - Red bone marrow in bones contains "stem cells" that give rise to red blood cells, white blood cells, and the platelets.
4. Storage of inorganic salts

• 70% of all inorganic salts is in the matrix of bone tissue.

• Most abundant salts are calcium carbonate and calcium phosphate.

• Calcium is also important in blood clot formation, nerve impulse transmission, and muscle contraction.

• Because of this calcium deposition in bone matrix, bones are extremely strong (the most rigid connective tissue) and are very durable.
Classification of bones based on their shapes

- **Long bones** have a longitudinal axis and two expanded ends (e.g. femur, humerus, tibia, fibula, ulna, radius, phalanges, and clavicles).

- **Short bones** have equal lengths and widths (e.g. carpals and tarsals).

- **Flat bones** are plate-like with broad surfaces (e.g. ribs, scapula, cranial bones).

- **Irregular bones** are bones that do not fit into above categories (e.g. vertebrae, facial bones, coxal bone).
Gross Anatomy of Long Bone

- **Epiphysis** – the expanded end of a long bone that articulates with another bone at a joint; composed of **spongy bone** which stores **red bone marrow**.

- **Diaphysis** – the longitudinal axis of a long bone; composed of **compact bone** which stores **yellow bone marrow** in its medullary cavity.
• **Articular cartilage** – a layer of hyaline cartilage covering the epiphyses for protection purposes.

• **Periosteum** – a layer of fibrous connective tissue covering the diaphysis; also involved in the formation and repair of a bone.

• **Medullary cavity** – a hollow channel in the diaphysis to contain the yellow bone marrow; it is continuous with the pores in the spongy bone (at the epiphyses).
• **Endosteum** – a layer of epithelial tissue lining the inside wall of the medullary cavity.

• **Epiphysis disk** – a band of active osteoblasts involved in bone growth; located at the junctions between the diaphysis and epiphysis.
Microscopic Anatomy of Bone Tissues

- **Compact bone** is composed of individual functional units called **osteons** (Haversian systems).
- Each Osteon consists of an **osteonic canal** (Haversian canal) surrounded by concentric circles of **Osteocytes** inside **lacunae**.
- Nutrients that diffuse out of the blood vessels in the osteonic canals flow into small canals called **canaliculi** which transport the nourishment to the Osteocytes.

- Osteons are held by calcified loose connective tissue.

- **Spongy bone** is made of branching bony plates called **trabeculae** that contain spaces (pores) to provide strength and to handle compression forces.

- The pores in spongy bone also provide a means to contain the red bone marrow.
Osteogenesis

• Bones begin to develop on the 4th week of fetal development.
• Mesoderm tissue in the embryo gives rise to mesenchyme, which in turn gives rise to bone tissues.
• The skull, mandible, and clavicles always develop first.
• Bone growth is extremely active before adult height is reached, after that bone development continues through adulthood.
• Bones are formed by replacing existing connective tissue (either fibrous connective tissue or hyaline cartilage) with bone tissues, in two mechanisms: intramembranous and endochondral ossification.
Intramembraneous Ossification

- Forms clavicles and cranial bones.
- Bone matrix is deposited between collagen fibers in fibrous connective tissue to form spongy bone.
- Fibroblasts differentiate into Osteoblasts in spongy bone, Osteoblasts later become Osteocytes surrounded by lacunae and bone matrix.
- Some spongy bone will develop into compact bone, mainly on the outer regions.
- Fibroblasts on the outside develop the periosteum layers.
- In cross section, bones developed by this method have a "sandwich" configuration where the periosteum is the outermost layer, then the compact bone, and the spongy bone at the center.
Ossification centers appear in the fibrous connective tissue membrane.
- Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center that produces the first trabeculae of spongy bone.

Osteoid is secreted within the fibrous membrane and calcifies.
- Osteoblasts continue to secrete osteoid, which calcifies in a few days.
- Trapped osteoblasts become osteocytes.

Woven bone and periosteum form.
- Accumulating osteoid is laid down between embryonic blood vessels in a manner that results in a network (instead of concentric lamellae) of trabeculae called woven bone.
- Vascularized mesenchyme condenses on the external face of the woven bone and becomes the periosteum.

Lamellar bone replaces woven bone, just deep to the periosteum. Red marrow appears.
- Trabeculae just deep to the periosteum thicken. Mature lamellar bone replaces them, forming compact bone plates.
- Spongy bone (diploë), consisting of distinct trabeculae, persists internally and its vascular tissue becomes red marrow.
Endochondral Ossification

• Forms most of the bones (except clavicles and cranial bones).
• Bones are formed from a *hyaline cartilage* model.
• Cartilage tissue degenerates as ossification begins.
• Fibrous connective tissue forms periosteum on the outside.
• Blood vessels and Osteoblasts start to develop into spongy bone.
• Some spongy bone becomes compact bone, especially in the diaphysis region.
• In sagittal section, a typical long bone developed by this method would have spongy bone at the two ends (epiphysis) and compact bone at the longitudinal axis (diaphysis) covered by periosteum.
1. Bone collar forms around the diaphysis of the hyaline cartilage model.
2. Cartilage in the center of the diaphysis calcifies and then develops cavities.
3. The periosteal bud invades the internal cavities and spongy bone forms.
4. The diaphysis elongates and a medullary cavity forms. Secondary ossification centers appear in the epiphyses.
5. The epiphyses ossify. When completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.

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Bone Growth

- Bones begin to grow in its length (bone elongation) at the "primary ossification center" in the center of diaphysis and grows toward the epiphysis.

- "secondary ossification centers" appear later in the two epiphysis to form spongy bone; and they grow toward the diaphysis.

- As these ossification centers meet one another, they form the epiphyseal disks where active osotoblasts continue to be developed.

- Bones continue to elongate as cells in epiphyseal disks remain active.

- Bone grows in thickness by the deposition of compact bone by intra-membranous ossification beneath the periosteum.
**Bone growth**

1. **Proliferation zone**
   Cartilage cells undergo mitosis.

2. **Hypertrophic zone**
   Older cartilage cells enlarge.

3. **Calcification zone**
   Matrix calcifies; cartilage cells die; matrix begins deteriorating; blood vessels invade cavity.

4. **Ossification zone**
   New bone forms.

**Bone remodeling**

- Cartilage grows here.
- Bone replaces cartilage here.
- Bone that was here has been resorbed.
- Epiphyseal plate
- Appositional growth adds bone here.
- Bone that was here has been resorbed.

- Articular cartilage
- Bone replaces cartilage here.
Organization of Bones

• The skeleton is divided into two portions: axial and appendicular skeletons.

• **Axial skeleton** includes the skull (about 22 bones), middle ear (6 bones), hyoid (1 bone), vertebral column (26 bones), and the thoracic cage (25 bones).

• **Appendicular skeleton** includes the pectoral girdle (4 bones), upper limb (60 bones), pelvic girdle (2 bones), and the lower limb (60 bones).

• The total number of bones in the entire skeleton is about 206 bones.

• Most bones in the skeleton are articulated with one another, with the exceptions of the middle ear bones (malleus, incus, and stapes are articulated to each other, but not to the temporal bone), the hyoid (attached to the underlying surface of the tongue with connective tissues), and the patella (attached to the knee joint with ligaments and connective tissues).
Terminology

- **Condyle** = a rounded process that articulates with another bone.
- **Foramen** = an opening through a bone.
- **Fossa** = a deep depression.
- **Meatus** = a tube like passageway within a bone.
- **Process** = a prominent projection on a bone.
- **Ramus** = a structure given off from another larger structure.
- **Suture** = an interlocking line of union between bones.
- **Trochanter** = a large process.
- **Tubercle** = a small, knoblike process.
Clinical Terms

– Osteoporosis: Decreased bone mineral content, mostly in postmenopausal ♀.

– Osteomyelitis: Bone inflammation caused by bacterial or fungal infection.

– Osteosarcoma: Bone cancer typically arising in long bones, deadly.

– Laminectomy: Surgical removal of the posterior arch of vertebra, to relieve herniated disc problems.

– Osteomalacia: Bone is inadequately mineralized (due to lack of Ca⁺ and vitamin D) [in children called rickets].
Fracture

1. A fracture is a break in the bone.

2. Pathologic fractures are caused by disease, while traumatic fractures are caused by injuries.

3. Simple fractures have broken bones remained under the skin, while compound fractures have their broken bones protruded through the skin.

4. Repair of a fractures involves 7 major steps:
   a) A blood clot (hematoma) is formed at the damaged site.
   b) Blood vessels and osteoblasts invade into the hematoma.
   c) Osteoblasts begin to build spongy bone.
   d) Macrophages remove hematoma and dead cells.
   e) Osteoclasts reabsorb bone fragments.
   f) Spongy bone develops into fibrocartilage which forms a cartilage callus at damaged site.
g) callus is replaced by bone tissue and bone remodeling continues for several months.
### Table 6.2 Common Types of Fractures

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<th>FRACTURE TYPE</th>
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<td>Comminuted</td>
<td>Bone fragments into three or more pieces. Particularly common in the aged, whose bones are more brittle</td>
<td>Compression</td>
<td>Bone is crushed. Common in porous bones (i.e., osteoporotic bones) subjected to extreme trauma, as in a fall</td>
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1. A group of diseases where bone resumption occurs faster than bone formation, as a result bones become light and porous.
2. Loss of bone mass is not dangerous, but it can lead to fracture easily.
3. Mostly occur after 50 years of age, particularly in postmenopausal women.
4. After menopause (ovaries stop functioning), estrogen secretion decreases and as a result inhibits the homeostasis of bone tissue.
5. Diets poor in vitamin D, protein, or calcium contribute to the problem.
6. Treatments include supplemental calcium and vitamin low-heeled shoes, estrogen replacement, fluoridated water, and exercise.
(a) Normal bone

(b) Osteoporotic bone