**SKELETAL SYSTEM**

**FUNCTIONS**
1. Support – Bones form the internal framework that supports and anchors all soft organs.
2. Protection – Bones protect soft body organs.
3. Movement – Skeletal muscles, attached to bones by tendons, use the bones as levers to move the body and its parts.
4. Storage – Bones serve as storehouses for minerals such as Calcium and Phosphorus. Fat is stored in the internal cavities of bones.
5. Blood Cell Formation – Hematopoiesis occurs within the red marrow cavities of certain bones.

**CLASSIFICATION** – The 206 bones are divided into two groups.

- Axial – skull, vertebral column, thoracic cage, sternum
- Appendicular – limbs and bones connecting the limbs to the pectoral girdle (scapula, clavicle) and the pelvic girdle

**Bone Shapes**

<table>
<thead>
<tr>
<th>Long – longer than they are wide; have a shaft plus two ends</th>
<th>Short – roughly cubed shape</th>
<th>Flat – thin, flattened &amp; usually curved</th>
<th>Irregular – shape that doesn’t fit into other groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex. bones of limbs</td>
<td>Ex. wrist, ankle</td>
<td>Ex. scapula, ribs, sternum, skull</td>
<td>Ex. vertebrae, hip</td>
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**Bone Markings** – *projections or depressions*

**Projections for muscle & ligament attachment:**
- Tuberosity – large rounded projection
- Crest – narrow ridge of bone
- Trochanter – large, irregularly shaped process
- Line – narrow ridge of bone; less prominent
- Tubercle – small rounded projection
- Epicondyle – raised area on or above a condyle
- Spine – sharp, slender, pointed projection
- Process – any bony prominence

**Projections that help form joints:**
- Head – bony expansion on a narrow neck

**Depressions and openings allow blood vessels and nerves to pass:**
- Meatus – canal-like passageway
- Sinus – cavity filled with air & mucous membrane
- Fossa – shallow depression or articular surface
- Groove – slight indentation
- Fissure – narrow, slit-like opening
- Foramen – round opening through bone

**Types of Osseous Tissue:**
- **Compact Bone** – dense outer layer
- **Spongy Bone** – honeycomb of flat pieces called trabeculae; open spaces between trabeculae are filled with red or yellow bone marrow.
GROSS ANATOMY – Structure of a Long Bone

**Diaphysis** – shaft of bone constructed of compact bone that surrounds a central medullary cavity.
- The medullary cavity contains yellow marrow (fat) in adults and red marrow in infants.

**Epiphyses** – Ends of bone with exterior compact bone and interior spongy bone.
- The joint surface of each epiphysis is covered with a thin layer of articular (hyaline) cartilage which cushions the opposing bone ends during movement and absorbs stress.
- Red marrow is found within trabecular cavities of spongy bone. In adults, red marrow is only found in head of femur and humerus, trabeculae of flat bones and some irregular bones.
- Between the diaphysis and each epiphysis of adult long bones is an epiphyseal line, a remnant of the epiphyseal plate. The epiphyseal plate is a disc of hyaline cartilage that grows during childhood to lengthen bone.

**Periosteum** – double-layered membrane covering entire bone except articular cartilage.
- Outer fibrous layer is dense irregular connective tissue.
- Inner osteogenic layer composed of osteoclast (bone destroying cells) and osteoblast (bone forming cells).
- The periosteum is richly supplied with nerve fibers, blood, and lymphatic vessels, which enter the diaphysis via nutrient foramina.
- Membrane is secured to underlying bone by perforating (Sharpey) fibers, collagen fibers that extend into fibrous layer.
- Membrane provides anchoring points for tendons and ligaments. At these points, the fibers are exceptionally dense.

**Endosteum** – membrane covering the internal bone surface.
- Membrane covers the trabeculae of spongy bone and lines the canals that pass through compact bone.
- Inner osteogenic layer is composed of osteoclast and osteoblast

Structure of Short, Irregular and Flat Bones
Consist of thin plates of periosteum-covered compact bone on the outside and endosteum covered spongy bone within. They contain bone marrow between their trabeculae.
MICROSCOPIC ANATOMY – Structure of bone

Cells found in bone – osteogenic cells, osteoblasts, osteocytes and osteoclast. These cells are surrounded by extracellular matrix. The matrix is composed of mineral salts (calcium & phosphorus) and collagenous fibers.

1) Osteogenic cells (osteoprogenitor cells) – are actively mitotic stem cells found in the membranous periosteum and endosteum. Some of their daughter cells differentiate into osteoblast or osteoclast.

2) Osteoblasts – bone cells that secrete the extracellular substances of bone tissue.

3) Osteoclasts – bone cells that break down bone and phagocytize bone fragments.

4) Osteocytes – mature bone cells. Osteoblasts become osteocytes once they are enclosed by extracellular substances.

Compact bone

Haversian system or Osteon – the structural unit of compact bone
- Osteocytes – mature bone cells
- Lacunae – small cavities in bone that contain osteocytes
- Lamellae – ring of column-like matrix tubes composed mainly of collagen formed by lacunae arranged in concentric rings
- Haversian or central canal – central channel containing vessels and nerves
- Canaliculi – canals that connect lacunae to each other and the central canal
- Volkmann’s canals – connecting blood and nerves of the periosteum to the Haversian canal

Spongy bone

The trabeculae align precisely along lines of stress and help the bone resist stress. Trabeculae contain irregularly arranged lamellae and osteocytes interconnected by canaliculi. No osteons are present. Nutrients reach the osteocytes by diffusing through canaliculi from capillaries in the endosteum surrounding the trabeculae.
**BONE DEVELOPMENT AND GROWTH**

**Osteogenesis & Ossification** – the process of bone tissue formation, which leads to the formation of bony skeleton, bone growth, bone thickness, remodeling and repair. The formation of the bony skeleton begins at week 8 of embryo development.

**INTRAMEMBRANOUS OSSIFICATION** –
Osteoblast develops bone from a fibrous membrane and occurs in flat bones of skull and clavicle.
1. Mesenchymal cells (stem cells) cluster and differentiate into osteoblast at an ossification center.
2. Osteoblast secrete bone matrix and trapped osteoblasts become osteocytes.
3. Accumulating matrix forms around blood vessels forming trabeculae and periosteum forms.
4. Trabeculae thicken forming bone and vascular tissue becomes red marrow.

**ENDOCHONRAL OSSIFICATION: Bone Growth**
Hyaline cartilage gradually changes into bone tissue – a process called OSSIFICATION, which begins near the middle of the diaphysis and later the bone begins to ossify in the epiphysis. Growth and sex hormones control ossification.

Growth in Length –
1. Chondrocytes become surrounded by matrix and calcify.
2. Mesenchymal cells specialize into OSTEOBLASTS to produce bone matrix. Once the cell is enclosed in matrix, it is a mature bone cell called an OSTEOCYTE.
3. Bones increase in length as these cartilage cells continue to reproduce and ossify. As long as growth is occurring, a “band” of cartilage (epiphyseal disc) remains between the diaphysis and epiphysis.

Growth in Width –
1. Osteoblast beneath the periosteum secrete bone matrix as osteoclasts under the endosteum remove bone. There is normally less breaking down than building up.

**REMODELING** – Adjacent osteoblast and osteoclast deposit and resorb bone at the periosteal and endosteal surface.

Bone DEPOSITION –
- Osteoblast secrete new matrix and become trapped within to become osteocytes. Phosphorus, matrix proteins that bind, concentrate calcium salts and the enzyme alkaline phosphatase is essential for mineralization. Deposition occurs where bone is injured or added strength is needed.

Bone RESORPTION –
- Osteoclasts secrete lysosomal enzymes that digest organic matrix and acids that convert calcium salts into soluble forms. These digested materials are secreted into the interstitial fluid and then into the blood.
FACTORS that influence growth, remodeling and health –

Minerals
- Magnesium deficiency slows osteoclasts and osteoblast activity.
- Insufficient Ca and P causes weak bones when mineral matrix components can’t be maintained.
- Insufficient Boron – B normally aids in Ca absorption in digestive tract, promotes better Ca resorption and promotes reabsorption of Ca by the kidneys to prevent Ca lose in urine.
- Vitamin C deficiency results in decreased production of collagen thus slows down bone growth and fracture healing.
- Vitamin A deficiency results in slower growth because it coordinates osteoblast and osteoclast activity.
- Vitamin B_{12} plays a role in osteoblast activity.

Hormones
- Human growth hormone produced by the pituitary gland promotes general bone growth.
- Rising blood Ca levels trigger the thyroid gland to release the hormone, calcitonin. Calcitonin accelerates Ca absorption and inhibits osteoclast.
- Falling blood Ca levels signal the parathyroid glands to release the hormone, parathyroid hormone (PTH). PTH signals osteoclasts to break down bone and release Ca into bloodstream.
- Sex hormones, estrogen and testosterone, promote osteoblast activity by stimulating bone growth. These hormones contribute to a spurt of growth during puberty.
- Additional thyroid hormones and insulin influence bone growth, maintenance and general skeletal health.

Exercise – mechanical and gravitational forces
- Exercise stimulates the piezoelectric effect – a physical connection between exercise and bone maintenance that stimulates the formation of osteoblasts. Exercise provided a healthy stress on bones and stimulates the production of calcitonin by the thyroid gland. Bone growth and remodeling responds to the forces or demands placed upon it through gravity or pull of muscle.

Aging
- Loss of Ca and decrease in protein formation is correlated with aging. Some loss is due to natural aging process and/or disease, some is the result of lifestyle behaviors.
- Females – Ca loss begins after age 30 and accelerates at age 40-45 as estrogen decreases.
- Males – Ca loss begins around age 60.
- Premature abandonment of exercise results in decreased ability to make bone matrix and contributes to bone brittleness.
Excessive vitamin A and elevated blood levels of protein homocysteine increase fracture risk. In old age, factors occur as bones thin & weaken.

**Bone FRACTURES – classified by:**
- The position of the bone ends after fracture – nondisplaced or displaced (bone ends out of alignment)
- Completeness of the break – complete (broken through) or incomplete
- The orientation of the bone to the long axis – linear or transverse
- Whether or not the bones ends penetrate the skin – simple (closed) or compound (open)

<table>
<thead>
<tr>
<th>Fracture type</th>
<th>Illustration</th>
<th>Description</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comminuted</td>
<td><img src="image" alt="Comminuted Fracture" /></td>
<td>Bone breaks into many fragments.</td>
<td>Particularly common in the aged, whose bones are more brittle.</td>
</tr>
<tr>
<td>Compression</td>
<td><img src="image" alt="Compression Fracture" /></td>
<td>Bone is crushed. (i.e., osteoporotic bones).</td>
<td>Common in porous bones</td>
</tr>
<tr>
<td>Depressed</td>
<td><img src="image" alt="Depressed Fracture" /></td>
<td>Broken bone portion is pressed inward.</td>
<td>Typical of skull fracture.</td>
</tr>
<tr>
<td>Impacted</td>
<td><img src="image" alt="Impacted Fracture" /></td>
<td>Broken bone ends are forced into each other.</td>
<td>Commonly occurs when one attempts to break a fall with outstretched arms</td>
</tr>
<tr>
<td>Spiral</td>
<td><img src="image" alt="Spiral Fracture" /></td>
<td>Ragged break occurs when excessive twisting forces are applied to a bone.</td>
<td>Common sports fracture.</td>
</tr>
<tr>
<td>Greenstick</td>
<td><img src="image" alt="Greenstick Fracture" /></td>
<td>Bone breaks incompletely, much in the way a green adult.</td>
<td>Common in children, whose bones are more flexible than those of adults.</td>
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**Stages in the Healing of a Bone Fracture**
1. Hematoma formation – a mass of clotted blood forms at fracture site and tissue becomes swollen, painful and inflamed.
2. Fibrocartilaginous callus formation – Capillaries regrow, phagocytic cells clean debris, fibroblast and osteoblasts invade site and begin reconstructing bone. The callus splints the broken bone.
3. Bone callus formation – Within a week, new bone appears and is converted into bony callus.
4. Bone remodeling – Compact bone is laid down to replace callus.

**TYPES OF JOINTS (articulations)**
- Synarthrotic (fibrous) joints – immovable joint such as skull; junctions are called sutures
- Amphiarthrotic (cartilaginous) joint – slightly moveable joint such as vertebrae
- Diarthrotic (synovial) joint – freely moveable joint such as shoulders, hips, knees, elbows, wrist, etc. (plane, hinge, pivot, condyloid, saddle, ball-and-socket joints)