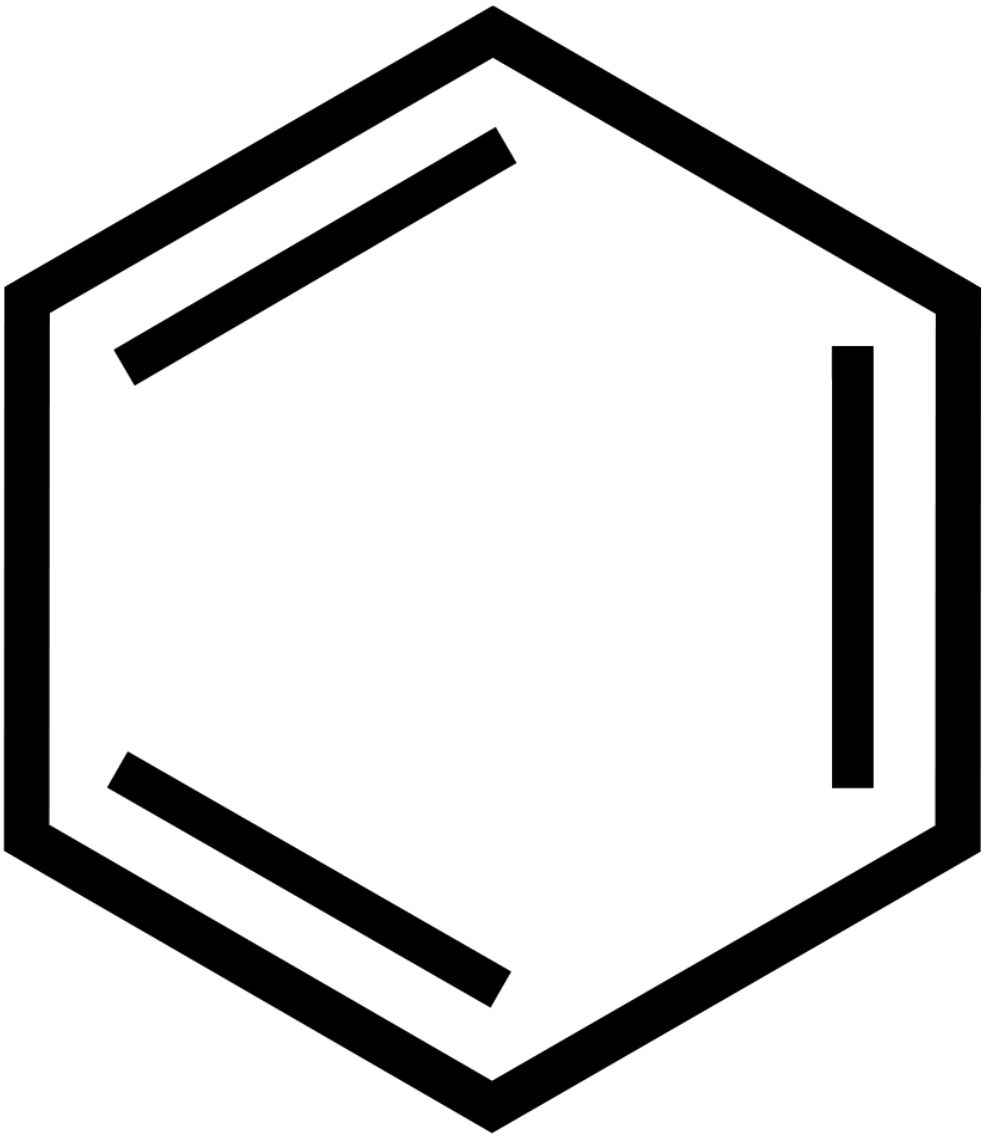

CLUTCH

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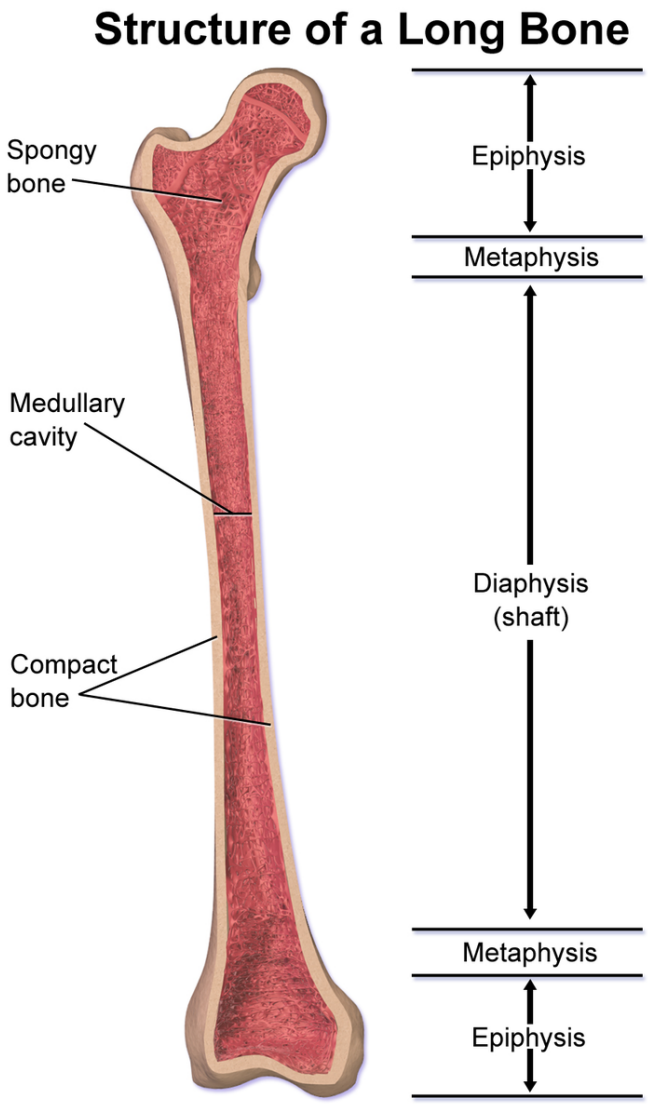
CONCEPT: BONE CLASSIFICATIONS

- There are four classifications of bones based on their _____

1. **Long bones** are greater in length than in width

- Found in the upper and lower limbs (ex: arm, forearm, palm, fingers, thigh, leg, sole, toes)

EXAMPLE:



2. **Short bones** are nearly equal in length and width

- Found in the wrist (carpals), foot (tarsals), and kneecap (patella)

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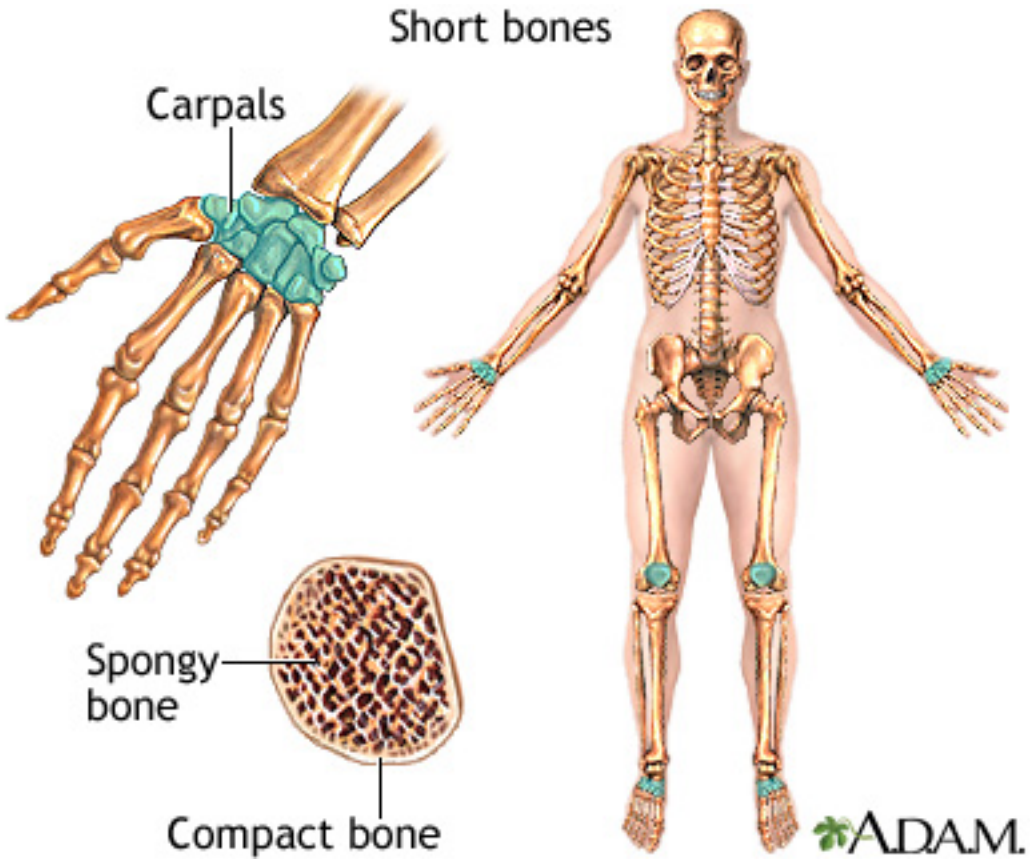
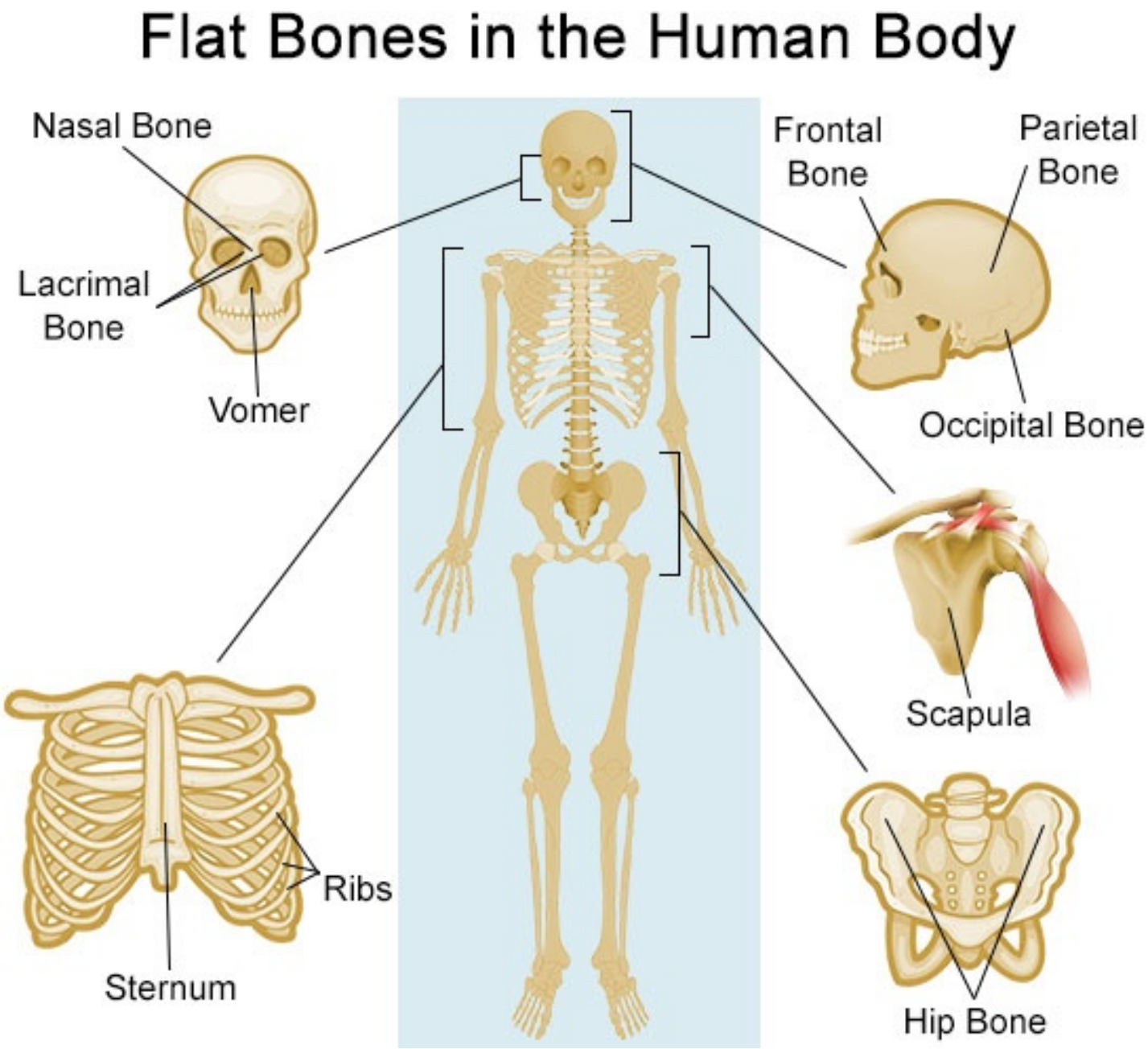


3. **Flat bones** have flat, thin surfaces that may be curved, which allow muscle attachment

- Found in the skull, shoulder blades (scapulae), ribs, and breast-bone (sternum)

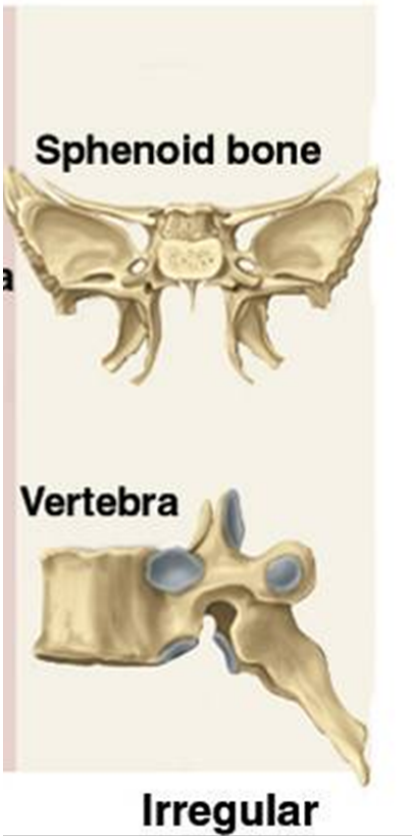
EXAMPLE:



4. **Irregular bones** are bones that do not fit into any other category

- Found in the skull, vertebrae, hip bones (ossa coxae)

EXAMPLE:

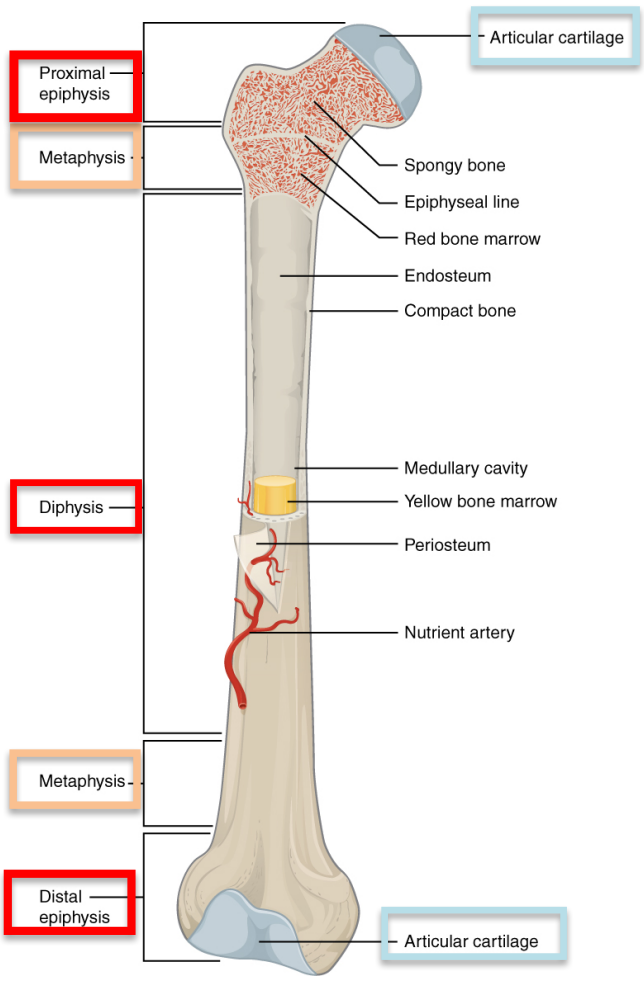


CONCEPT: ANATOMY OF BONES

Anatomy of a Long Bone

- Long bones are most common in the body and therefore can act as a model of bone anatomy
  - □ Regions of a long bone include:
    - **Diaphysis** Is the elongated, cylindrical shaft of the bone
      - Provides leverage and weight support to the bone
    - **Epiphysis** is the knobby region on either end of the bone
      - **Proximal epiphysis** faces the trunk of the body
      - **Distal epiphysis** faces away from the trunk of the body
      - **Articular cartilage** covers the epiphysis with hyaline cartilage
        - Purpose is to reduce friction and act as shock absorbers in the joint
    - **Metaphysis** is the region in between the diaphysis and epiphysis

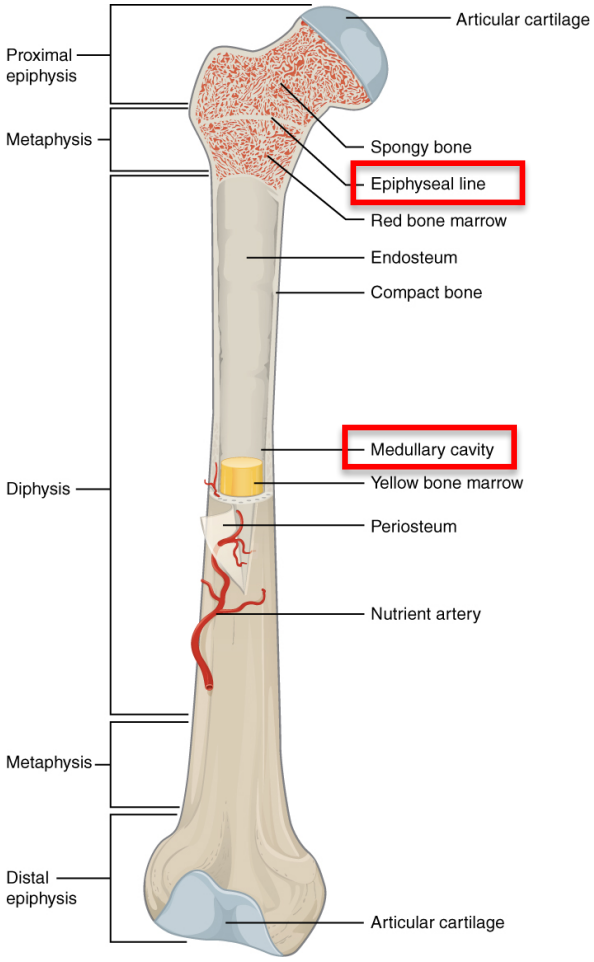
EXAMPLE:



□ Regions inside the long bone include:

- **Medullary cavity** is a hollow space in the diaphysis
- Spongy bone exists inside the epiphysis
- **Epiphyseal plate** is a thin layer of hyaline cartilage of a growing bone in infants and children
  - Becomes the **epiphyseal line**, a thin area of compact bone, in adults
  - Both are in the metaphysis

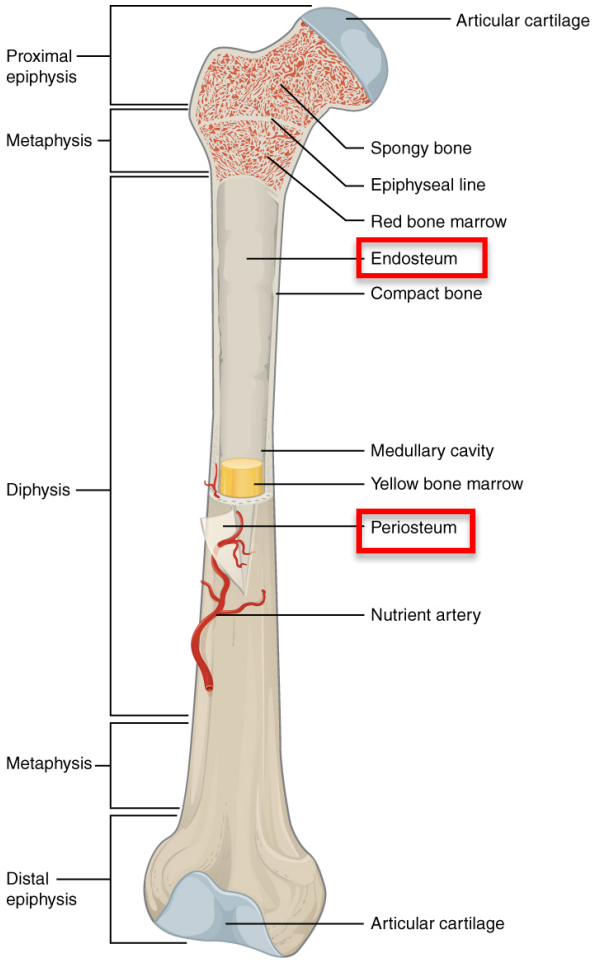
EXAMPLE:



□ Regions covering and lining the bone include:

- **Periosteum** covers the outer surface of the bone and allows attachment of blood vessels, nerves, tendon
  - *Outer layer* consists of dense irregular connective tissue
  - *Inner layer* consists of bone cells (osteoprogenitor cells, osteoblasts, and osteoclasts)
  - **Perforating fibers** attaches the periosteum to the bone through collagen
- Blood vessels enter through the periosteum and fill the spongy bone regions of a bone
- **Endosteum** lines the medullary cavity with bone cells (osteoprogenitor, osteoblasts, and osteoclasts)

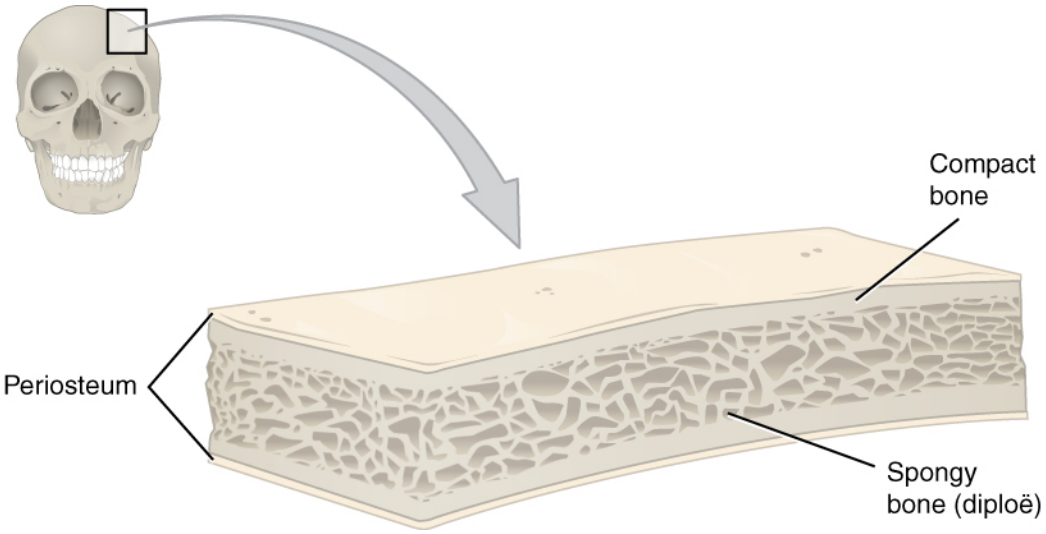
EXAMPLE:



Anatomy of Other Bone Types

- Other bone types differ in their anatomy from long bones
    - □ They lack a medullary cavity and instead spongy bone completely fills the space between the compact bone
        - **Diploë** is a term used to describe the spongy bone in the flat bones of the skull

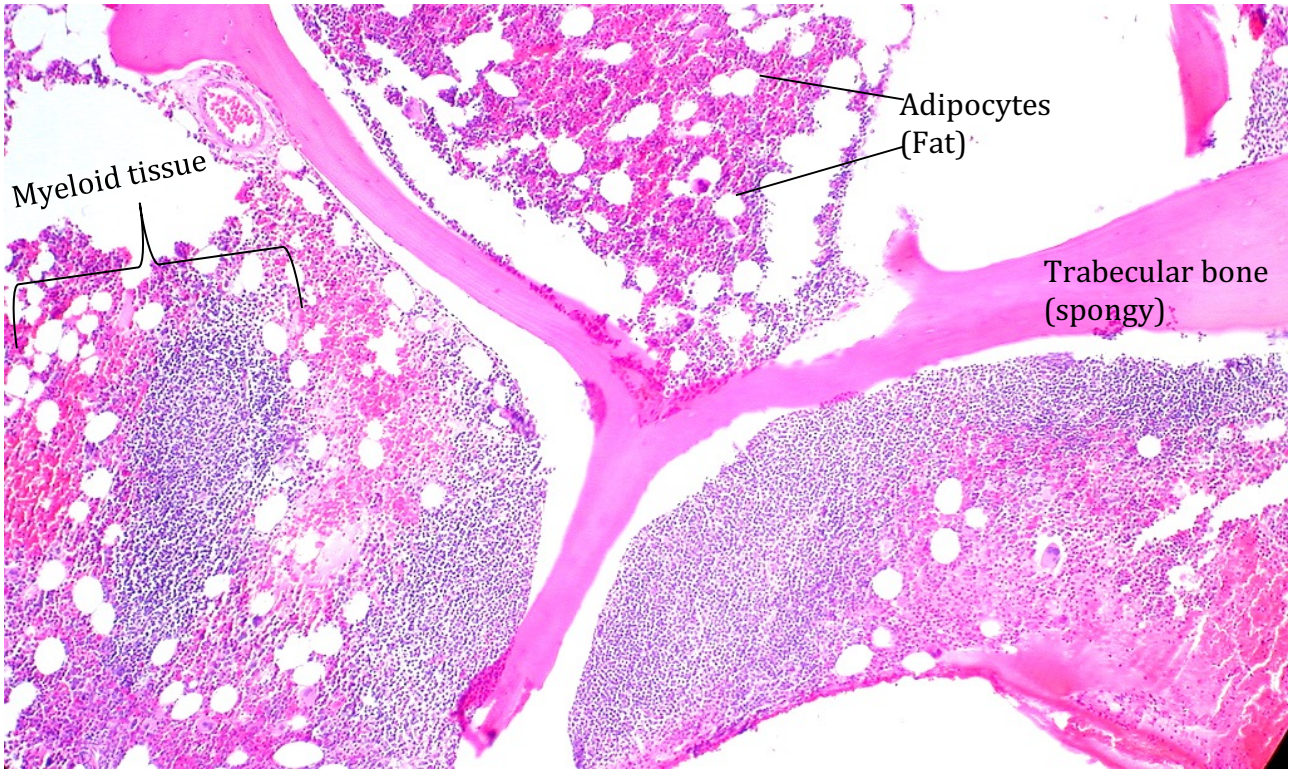
EXAMPLE:



CONCEPT: BONE MARROW

- Bone marrow is a _____ tissue in the bone
  - □ **Red bone marrow** (myeloid tissue) is involved in blood cell formation (hematopoiesis)
    - Composed of reticular connective tissue, adipocytes (fat), and immature blood cells
  - □ **Yellow bone marrow** is a matured form of red bone marrow and is more fatty than red bone marrow
    - Found mainly in medullary cavities of long bones
  - □ As people age the location and type of bone marrow _____
    - As children, red bone marrow is found in spongy bone and in medullary cavities
    - As we age, the red bone marrow degrades and turns into yellow bone marrow in medullary cavities
    - As adults, red bone marrow exists only in certain areas
      - Ex: flat bones of skull and proximal epiphyses of humerus and femur
      - In anemic patients, yellow bone marrow can convert back to red bone marrow

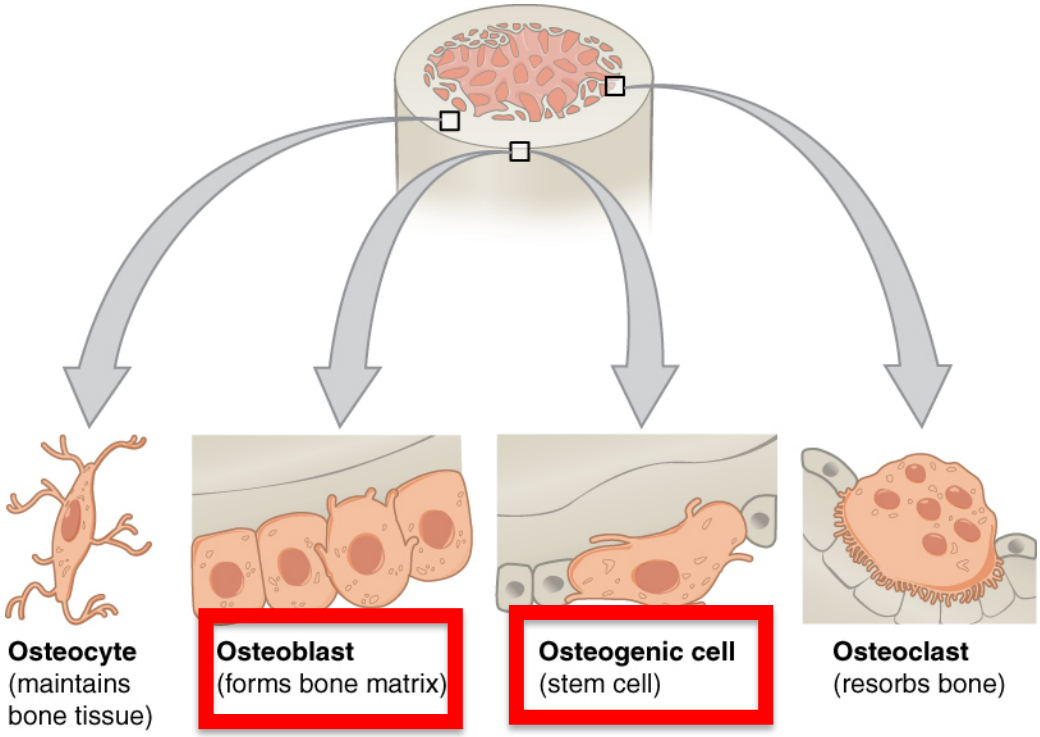
EXAMPLE: Red Bone Marrow



CONCEPT: BONE CELLS

- There are four types of bone cells in bone connective tissue
  - □ **Osteoprogenitor cells** are stem cells that came from mesenchyme
    - When they divide, one cell will mature into an osteoblast, and the other will remain an osteoprogenitor
    - Localized in bone surface: periosteum and endosteum
  - □ **Osteoblasts** are responsible for creating and secreting bone (*osteoid).*
    - **Osteoid** is a semisolid initial form of the bone matrix. It will calcify, trapping osteoblasts in their lacunae
      - The trapped osteoblasts will differentiate into osteocytes, which maintains the bone matrix.
    - Osteoblasts are single nucleated *cuboidal* cells that line the surfaces of bone.
      - Cuboidal cell *when active and flattened when inactive*
    - Osteo**b**last **b**uilds bone and live only for a few months.

EXAMPLE:



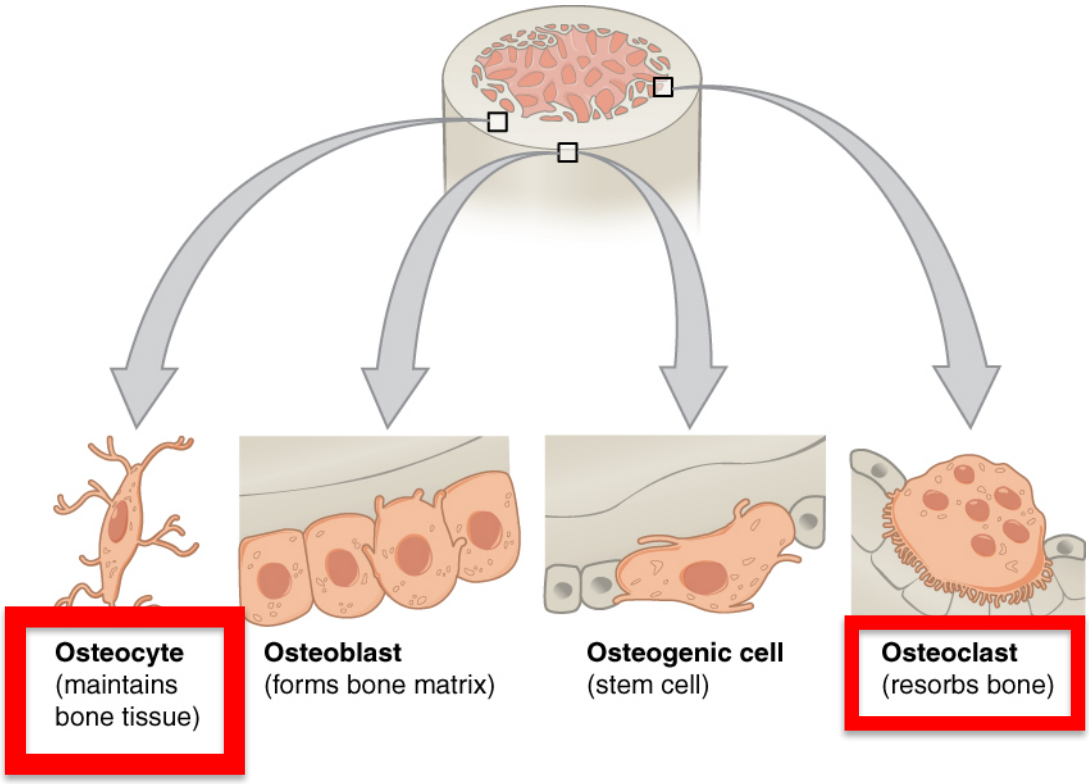
□ **Osteocytes** are mature bone cells that maintain the bone matrix and respond to stress by triggering more matrix.

- Most numerous of the 3 bone cell types
- Osteocytes are all interconnected via long cytoplasmic extensions called canaliculi
- Remain alive for up to 15- 20 years

□ **Osteoclasts** are large phagocytic cells that breakdown bone through *bone resorption.*

- Bone resorption is a process by which bone tissue is broken down, releasing its minerals into the blood.
- Located in a **resorption lacuna** (**Howship Lacunae**), which is a pit on the bone surface.
- Osteoclasts are giant, motile, multinucleated cells with ruffled border.
- They live for only a few months and function in maintenance, repair and remodeling of bone.

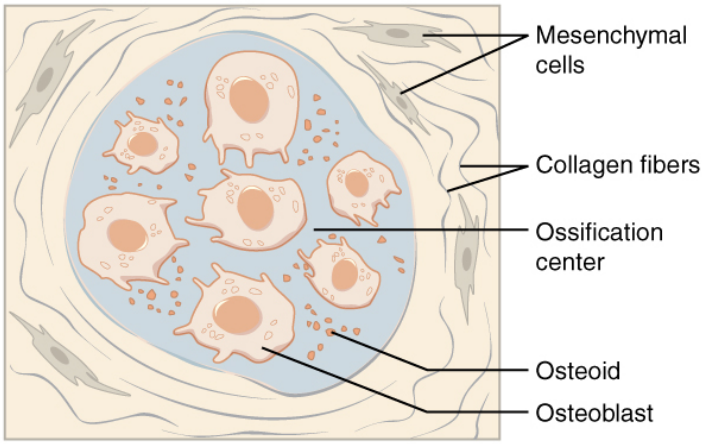
EXAMPLE:

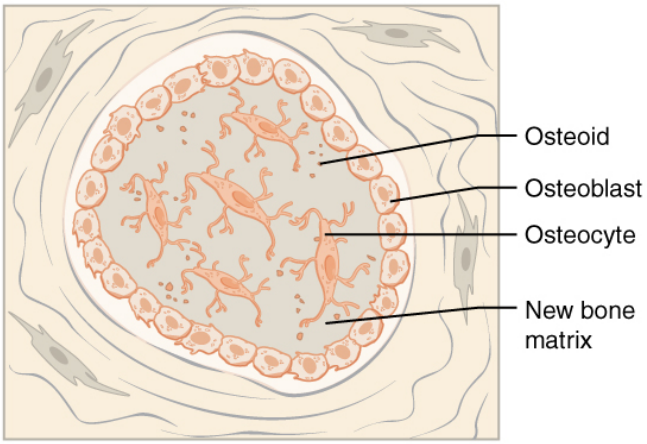


CONCEPT: BONE MATRIX

- The bone matrix is the extracellular matrix of the bone connective tissue
    - □ It is composed of the osteoid and salt crystals
        - The *osteoid* is composed of collagen, proteoglycans, and glycoproteins
            - Provides tensile strength to the bone connective tissue
        - The main salt crystal is **hydroxyapatite**, which is made up of calcium phosphate and calcium hydroxide
            - Other salts are included during calcification
            - The salts harden the matrix and provide rigidity to the bone
    - □ It is crucial there is a proper balance between the osteoid and the salt crystals

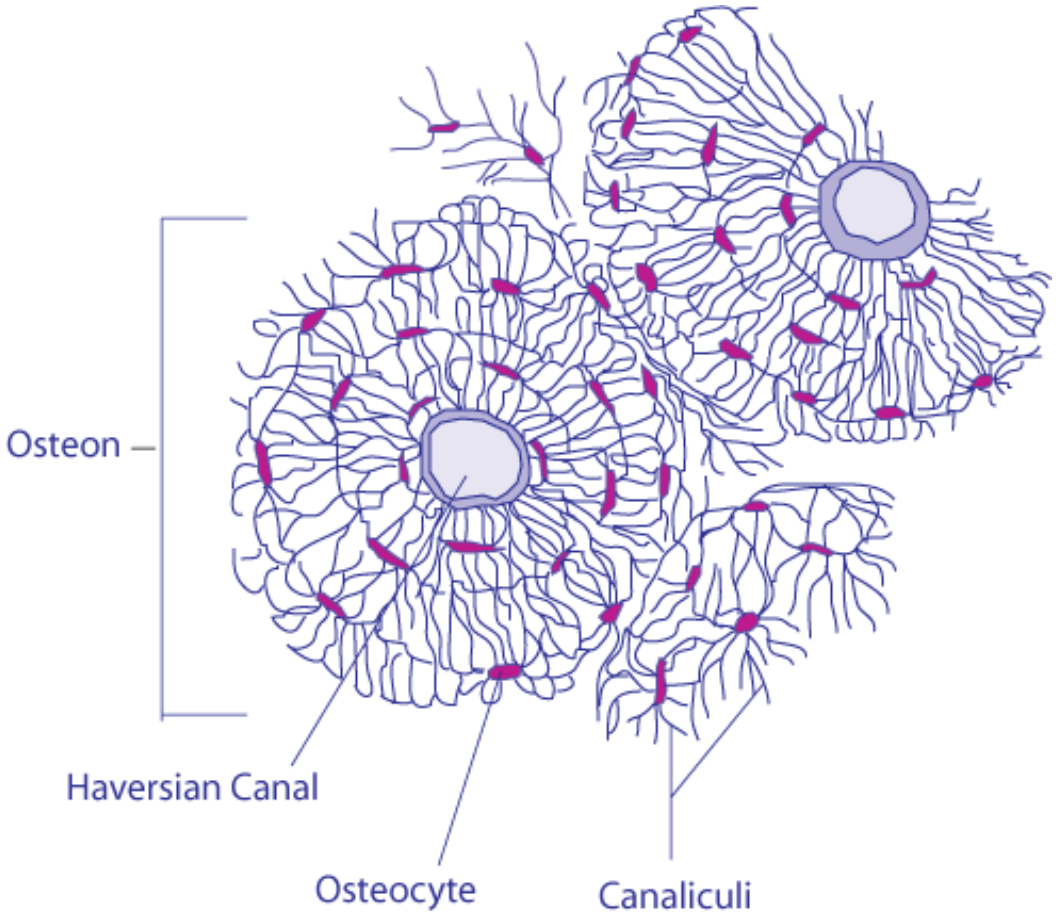
EXAMPLE:





- Compact (Cortical) bone has a distinct appearance and is responsible for 80% of total bone mass.
- **Osteons** (*Haversian systems)* are the cylindrical structures that make up compact bone
    - □ Run parallel to the diaphysis – cross section view looks like a bull's-eye
    - □ Osteons have several structures
        - **Central (Haversian) canal** is the channel that runs through the center of the osteon.
            - Contains blood vessels and nerves
        - **Concentric lamellae** are the rings of connective tissue that surround the central cannel
        - **Osteocytes** are bone cells found between lamellae
            - They sit in **lacunae**, which are small spaces that house the osteocyte
        - **Canaliculi** are tiny channels that connect lacuna to other lacuna and to the central canal
            - Contain the dendritic processes of osteocytes.
            - They transport nutrients, gasses, minerals, and wastes through gap junctions

EXAMPLE:



□ **Perforating (**Volkmann's**) canals** that run perpendicular to central canals to connect adjacent osteons.

- Forms vascular and innervation connections

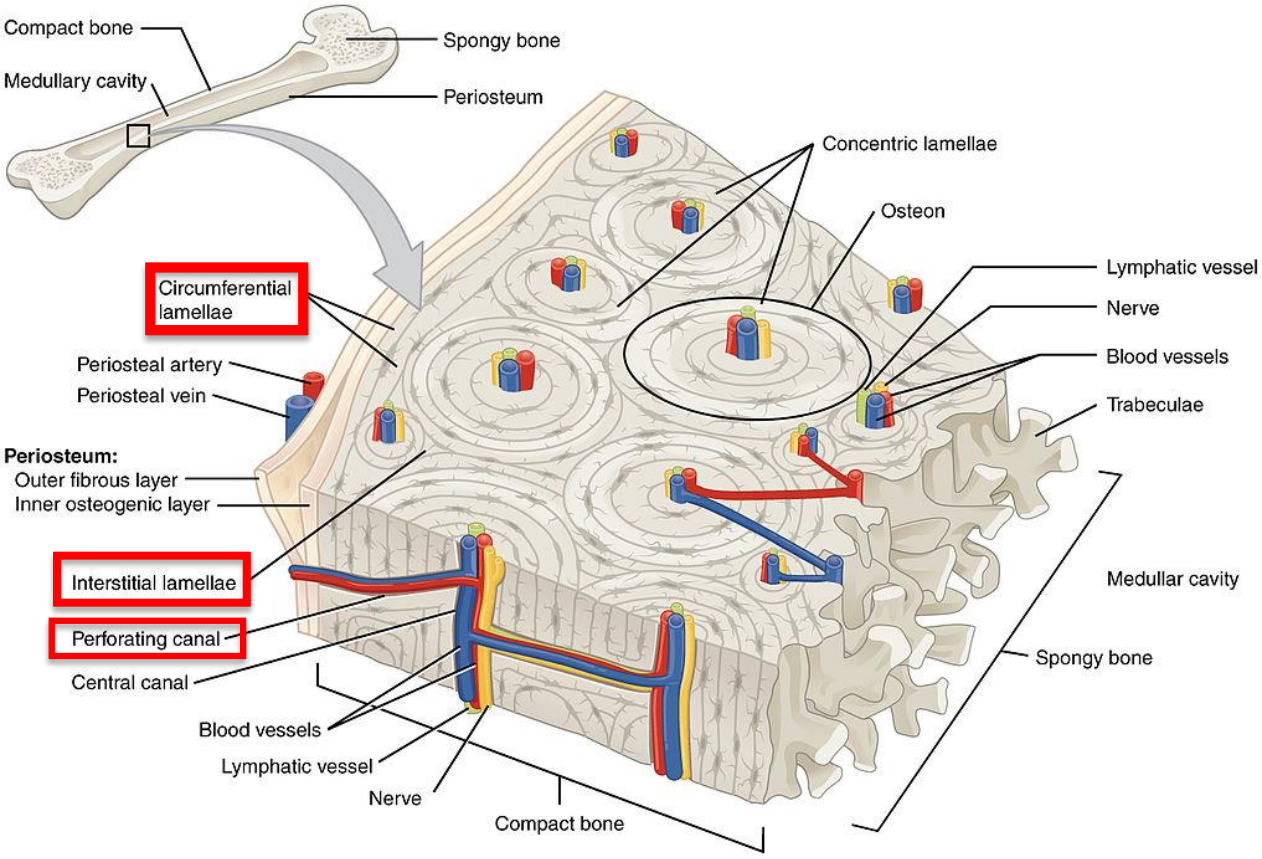
□ **Circumferential lamella**

- External: found underneath the periosteum (*external*) or

- Inner: around the marrow cavity *(not seen here)*

□ **Interstitial lamella** sit between osteons and have no central canal

Example:



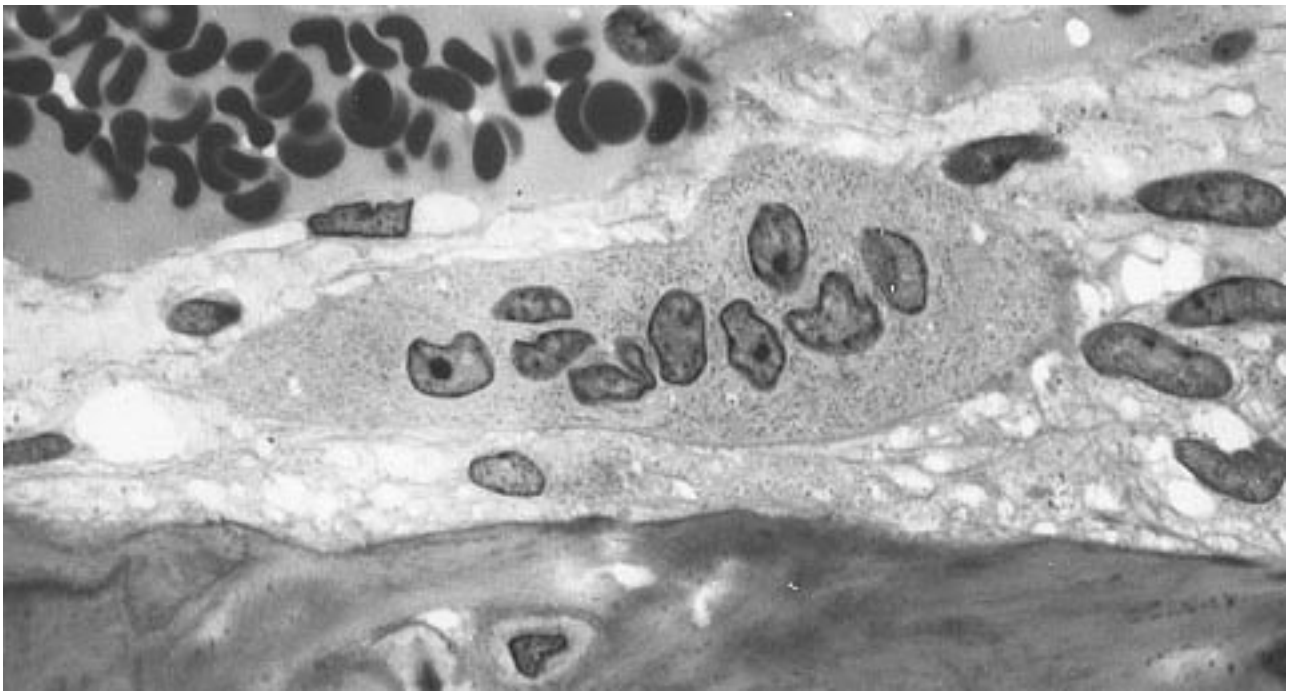
CONCEPT: BONE MATRIX FORMATION AND RESORPTION

- Bone formation begins with the creation of the _____
  - □ **Osteoid** is the initial semisolid organic bone matrix created by the osteoblasts
  - □ Calcification occurs when salt crystals (hydroxyapatite) settle in the bone matrix
    - After this, the osteoblasts differentiate into _____
  - □ *Osteocytes* can no longer create bone, but they can detect mechanical stress and signal for new bone matrix
    - They can signal to neighboring osteoblasts

EXAMPLE: Osteoblasts creating an osteoid

- **Bone resorption** is the process of destroying the bone matrix
  - □ *Osteoclasts* sit within **resorption lacuna**, which is a pit within the bone surface
    - They release enzymes and proteins that digest the organic and inorganic components of the matrix
  - □ Can occur when calcium levels are _____

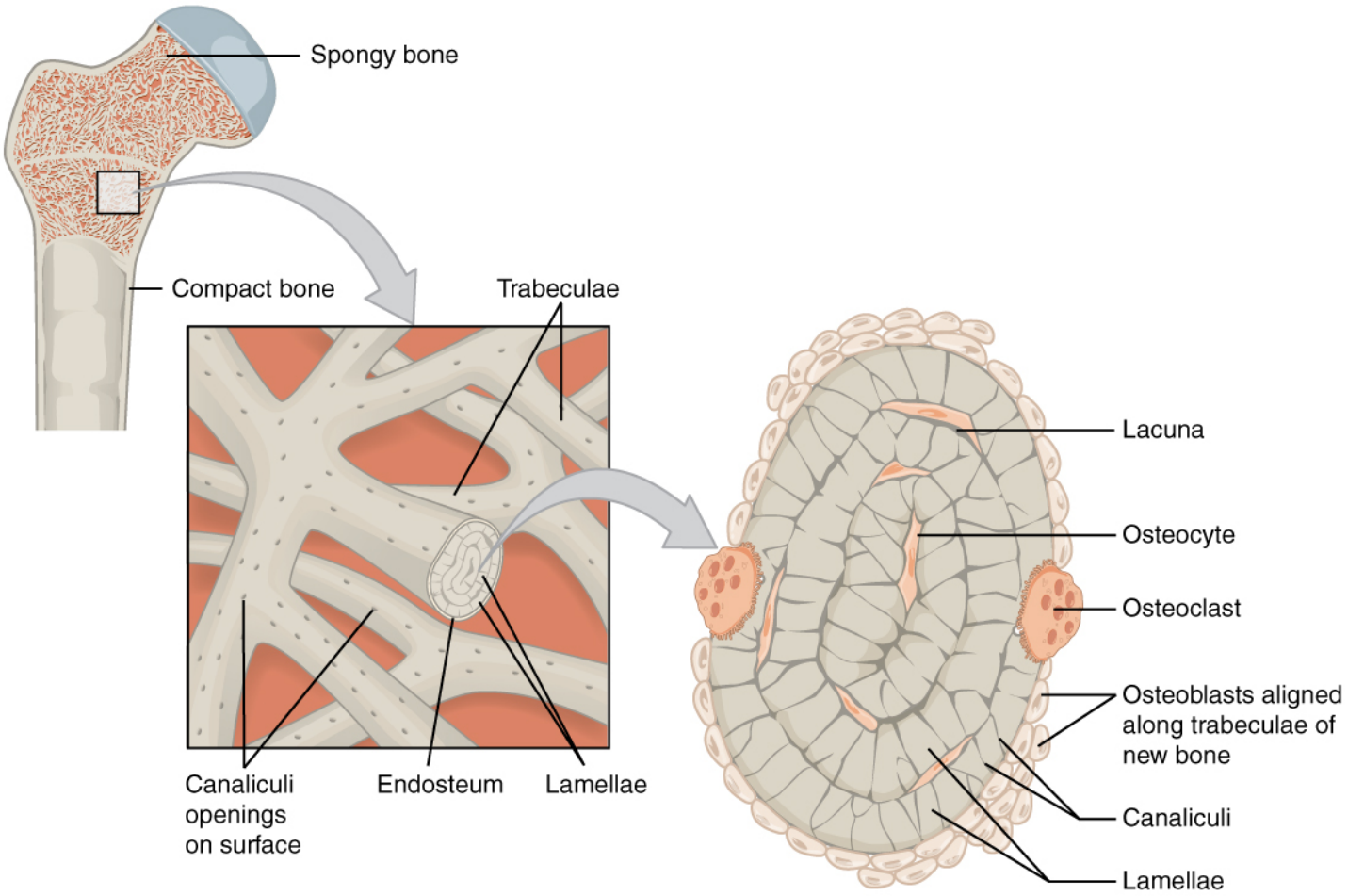
EXAMPLE: Multi-nucleated osteoclast



CONCEPT: SPONGY BONE

- The structure of spongy bone is less complex than compact bone
  - □ **Trabeculae** is an open network of bone rods and plates
    - Bone marrow fills the spaces between trabeculae
    - Distributes stress throughout the entire bone
  - □ **Parallel lamellae** composed of bone matrix run across spongy bone
    - Contain osteocytes in lacunae and canaliculi
  - □ No osteons

EXAMPLE:



CONCEPT: OVERVIEW OF BONE FORMATION:

- During bone formation, one of two processes can occur:
    - □ Endochondral ossification: Hyaline cartilage is created and then invaded by osteoblast that calcifies it
        - Produces most bones in the body (ex: long bones in the skeleton)
    - □ Intramembranous ossification: Osteoblasts differentiate directly from the mesenchyme and builds bone
        - Produces certain flat bones
- Both ossifications can grow in two ways:
    - □ **Interstitial growth:** responsible for lengthening the bone
        - Occurs near the epiphyseal plate
    - □ **Appositional growth:** responsible for increasing the bone's thickness (width)
        - Occurs near the perichondrium

CONCEPT: ENDOCHONDRAL OSSIFICATION:

● **Endochondral ossification** begins with hyaline cartilage and produces most bones in the body (long bones in skeleton)

□ Creates a cartilage matrix template that is later replaced by bone

□ Process begins in the developing fetus and continues into early adulthood

Stage 1: Hyaline cartilage grows in the epiphyseal plate, moving towards the diaphysis (interstitial growth)

□ **Zone of resting cartilage:** nearest the epiphysis

- Has small chondrocytes
- Attaches epiphysis to epiphyseal plate

□ **Zone of proliferating cartilage:** parallel to diaphysis.

- Chondrocytes undergo rapid mitotic division
- Appears like stacks of coins
- Growth comes from: cell division of chondrocytes

□ **Zone of hypertrophic cartilage:**

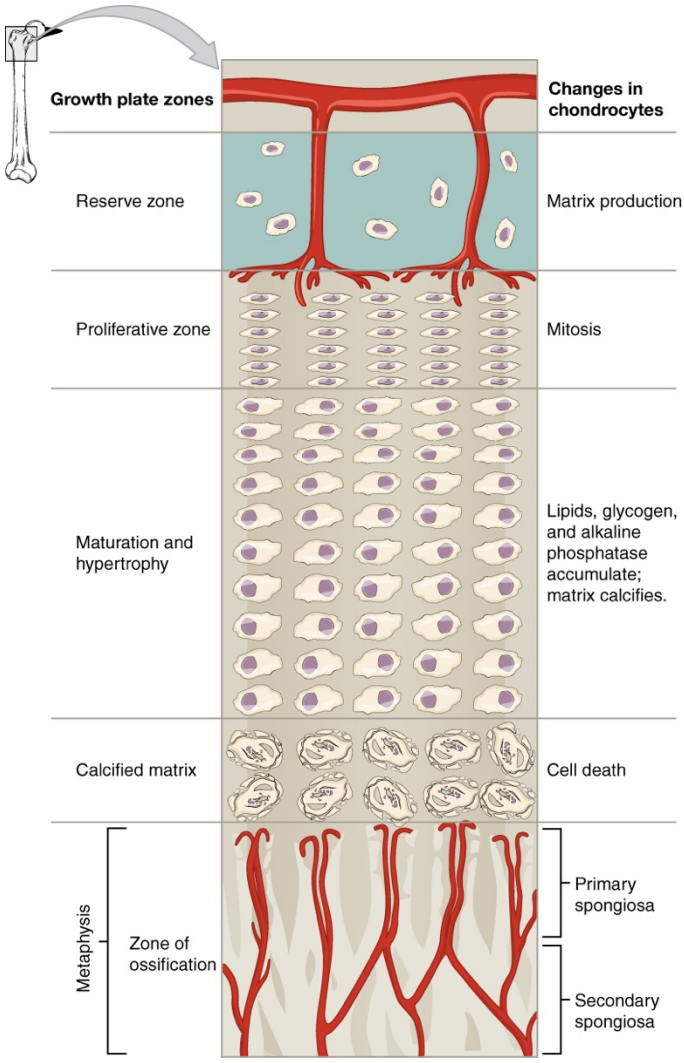
- Chondrocytes get larger and stop dividing
- Resorb matrix and lacunae becomes thinner
- Growth comes from: hypertrophy of chondrocytes

□ **Zone of calcified cartilage:**

- 2-3 layers of dead chondrocytes, due to calcified matrix
- This zone connects the epiphyseal plate to the diaphysis

□ **Zone of ossification:**

- Walls of the lacunae break down
- Spaces invaded by osteoprogenitor cells that will give rise to osteoblasts
- Growth comes from: new bone



Stage 2: Ossification at the cartilaginous diaphysis

1. Osteoprogenitor cells in the perichondrium divide to become osteoblasts.

2. Cartilage calcifies and forms a **periosteal bone collar**.

    - A harden osteoid around the cartilage shaft

3. **Periosteal bud** arises from the bone collar.

    - It is made up of capillary and osteoblast and forms the **primary ossification center**

    - Primary ossification center is formed at the core of the cartilaginous template.

4. Bone is deposited from primary ossification center towards the epiphysis

5. Once at the epiphysis, same process is repeated, giving rise to a **secondary ossification center.**

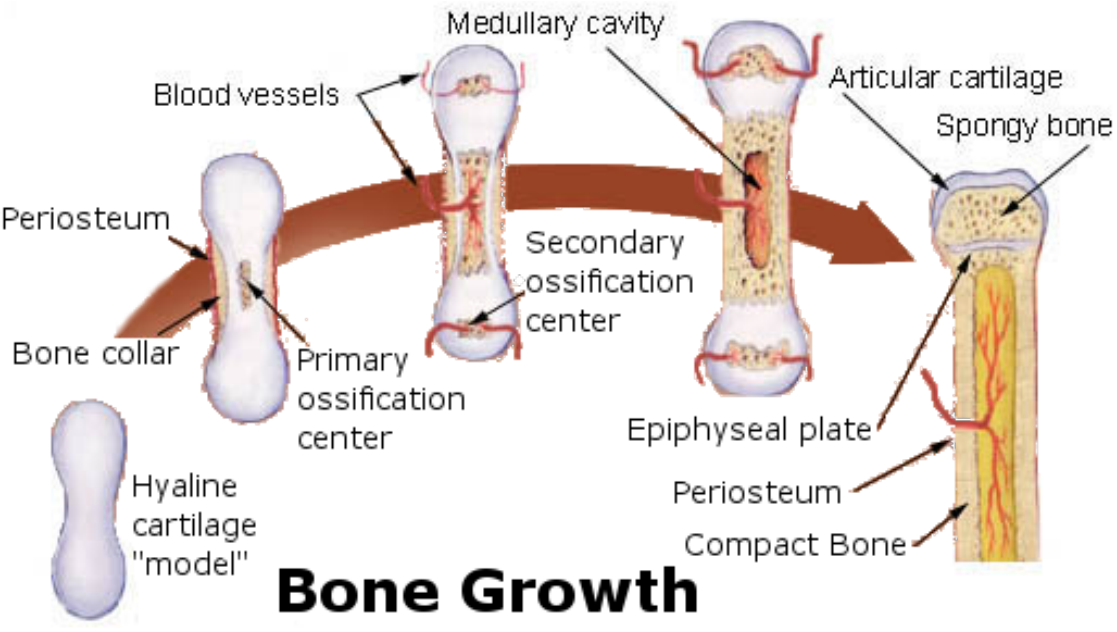
    - Occurs after birth

    - All cartilage is replaced with spongy bone, except the articular cartilage and epiphyseal plate.

6. Bone growth and remodeling continuous at the epiphyseal plates until early adulthood

    - Adult bones are completely ossified and bone growth stops.

    - Epiphyseal plate becomes epiphyseal line

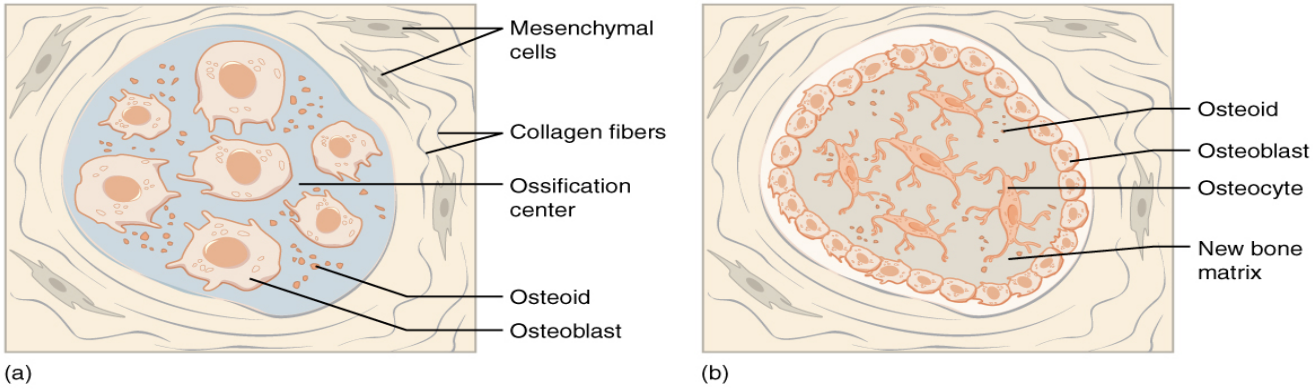


CONCEPT: INTRAMEMBRANOUS OSSIFICATION

- **Intramembranous ossification** is the growth of bone in the mesenchyme
  - □ It produces _____ bones in the skull, face (zygomatic bone, maxilla), lower jaw (mandible) and collarbone (clavicle)
  - □ Forms two compact bone layers (external) and a spongy bone layer (internal)

1. An **ossification center** forms in thickened regions of the mesenchyme (8 week of development)
   - Created when mesenchymal cells differentiate to osteoblasts
   - The primary area where bone will first starts calcifying and hardening
2. Osteoblast start depositing osteoid
   - Osteoblast are then trapped in the osteoid and become osteocytes
3. The osteoid calcifies
   - Calcium deposits into the osteoid and crystalizes
   - The calcification forms **spicules** of bone
   - Spicules aggregate to form **trabeculae**

EXAMPLE:



4. **Woven bone** (primary, immature bone)

- Result from the thickening of the trabeculae

- Made up of unorganized collagen fibers

- Weak bone

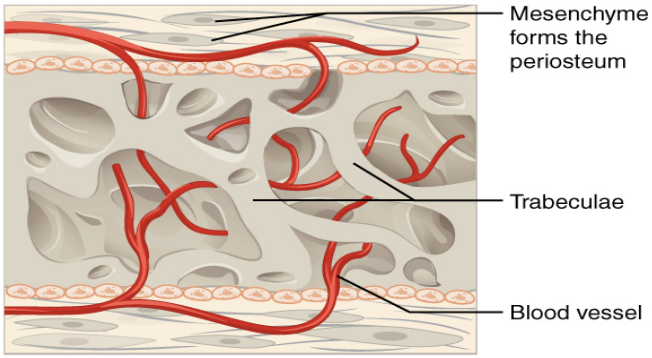
5. **Lamellar bone** replaces woven bone

- The spaces between the trabeculae fill and it becomes compact bone

- Form what we recognize as bone with osteons

- Strong bone

EXAMPLE:



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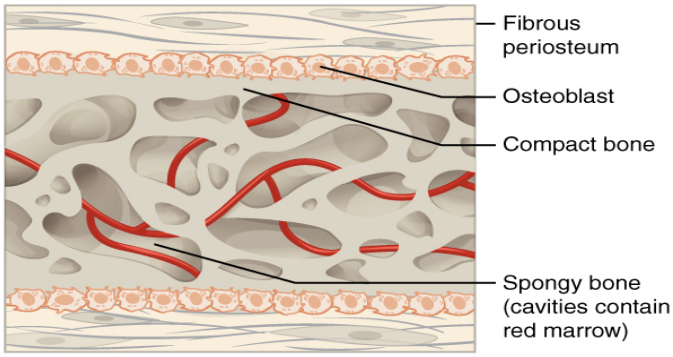

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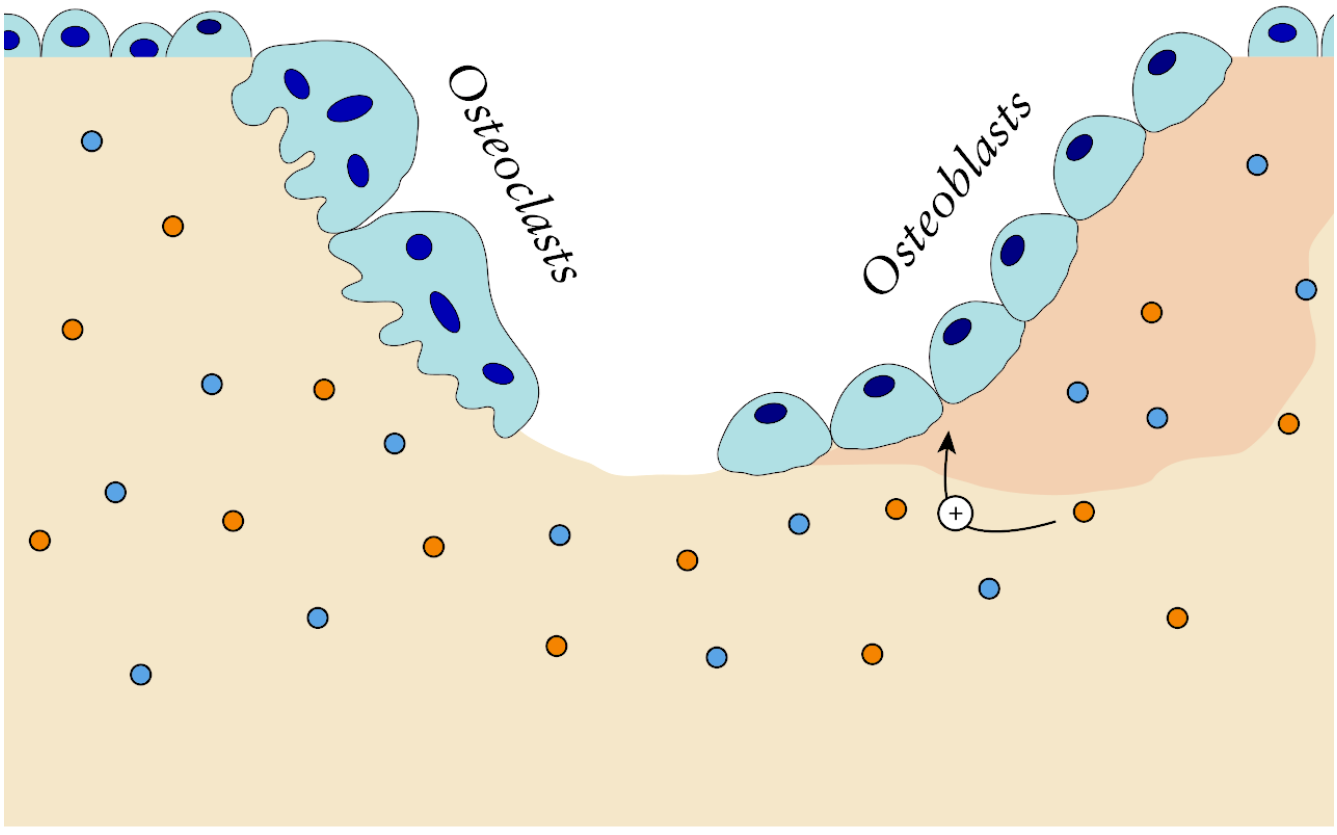
CONCEPT: BONE REMODELING

- **Bone remodeling** is the continual removal of old bone (resorption) and addition of new bone tissue (deposition)
  - □ Around 20% of an adult human's bone is replaced each year
    - Compact bone remodels at a faster rate than spongy bone
  - □ **Mechanical stress** is put on the bone from weight-bearing movements and exercise
    - Detected by osteocytes, which signal to osteoblasts to increase the osteoid and produce more bone
    - More bone is added in response to mechanical stress (ex: athletes have thicker bones)
    - The less mechanical stress, the weaker the bone

EXAMPLE:



□ Hormones also affect bone remodeling

- Growth hormones (*somatropin*) stimulates the growth of cartilage in epiphyseal plate
- **Insulin-like growth factor (IGF)** stimulates the growth of cartilage in epiphyseal plate
- Thyroid hormones stimulate bone growth by increasing metabolism of bone cells
- Sex hormones (estrogen/testosterone) accelerate bone growth at puberty
    - Bone formation occurs faster than cartilage and triggers demise of epiphyseal plate
- Glucocorticoids (steroid hormones) stimulate bone loss

CONCEPT: BONE FRACTURES

- **Fractures** are breaks in the bone due to unusual stress or a sudden _____
  - □ **Stress fracture** is a thin break due to repetitive stresses from physical activity (Ex: runners)
  - □ **Pathological fracture** can occur in diseased bone
  - □ **Simple fracture** occurs when the broken bone does not go through the skin
  - □ **Compound fracture** occurs when the broken bone does go through the skin

EXAMPLE:

Stress

Figure 1 Fracture of the middle third of both radius and ulna, suffered by a 52-year-old woman involved in a car accident.

Simple

● Bone fractures are repaired in _____ steps

1. **Formation of fracture hematoma**: Bleeding from damaged blood vessels, clots
2. **Fibrocartilaginous (soft) callus forms:** New blood capillaries enter the clot
    - Fibroblasts produce collagen to connect broken bone ends
    - Chondrocytes produce more dense regular connective tissue
    - This stage lasts three weeks
3. **Hard (bony) callus forms:**
    - Osteoprogenitor cells become osteoblasts to produce trabeculae
    - Trabeculae replaces the soft callus to form the hard callus
    - Thickens over several months
4. **Bone is remodeled**:
    - Osteoclasts remove excess bone
    - Compact bone replaces primary bone
    - A slight thickening of the bone may sometimes be detected via X-ray

EXAMPLE: