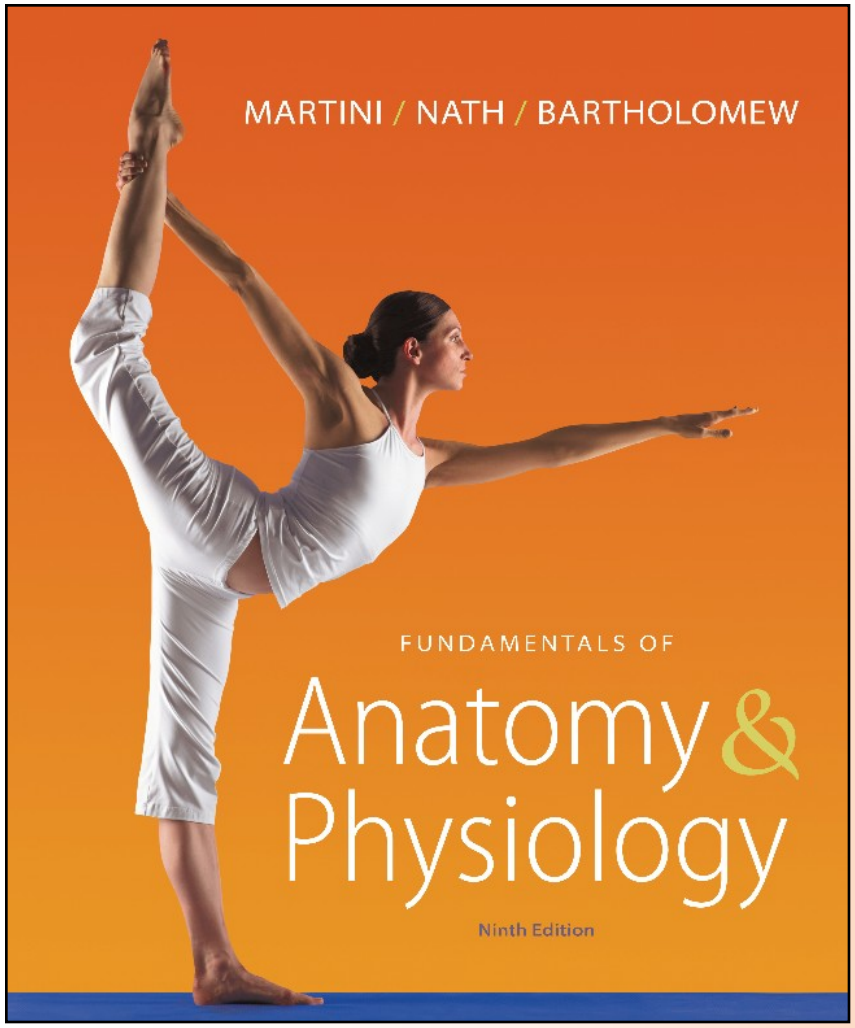


6

Osseous Tissue and Bone Structure

PowerPoint® Lecture Presentations prepared by Jason LaPres

Lone Star College—North Harris

An Introduction to the Skeletal System

- The Skeletal System
  - Includes:
    - Bones of the skeleton
    - Cartilages, ligaments, and connective tissues

6-1 Functions of the Skeletal System

- Five Primary Functions of the Skeletal System
  1. *Support*
  2. *Storage of Minerals* (calcium) *and Lipids* (yellow marrow)
  3. *Blood Cell Production* (red marrow)
  4. *Protection*
  5. *Leverage* (force of motion)

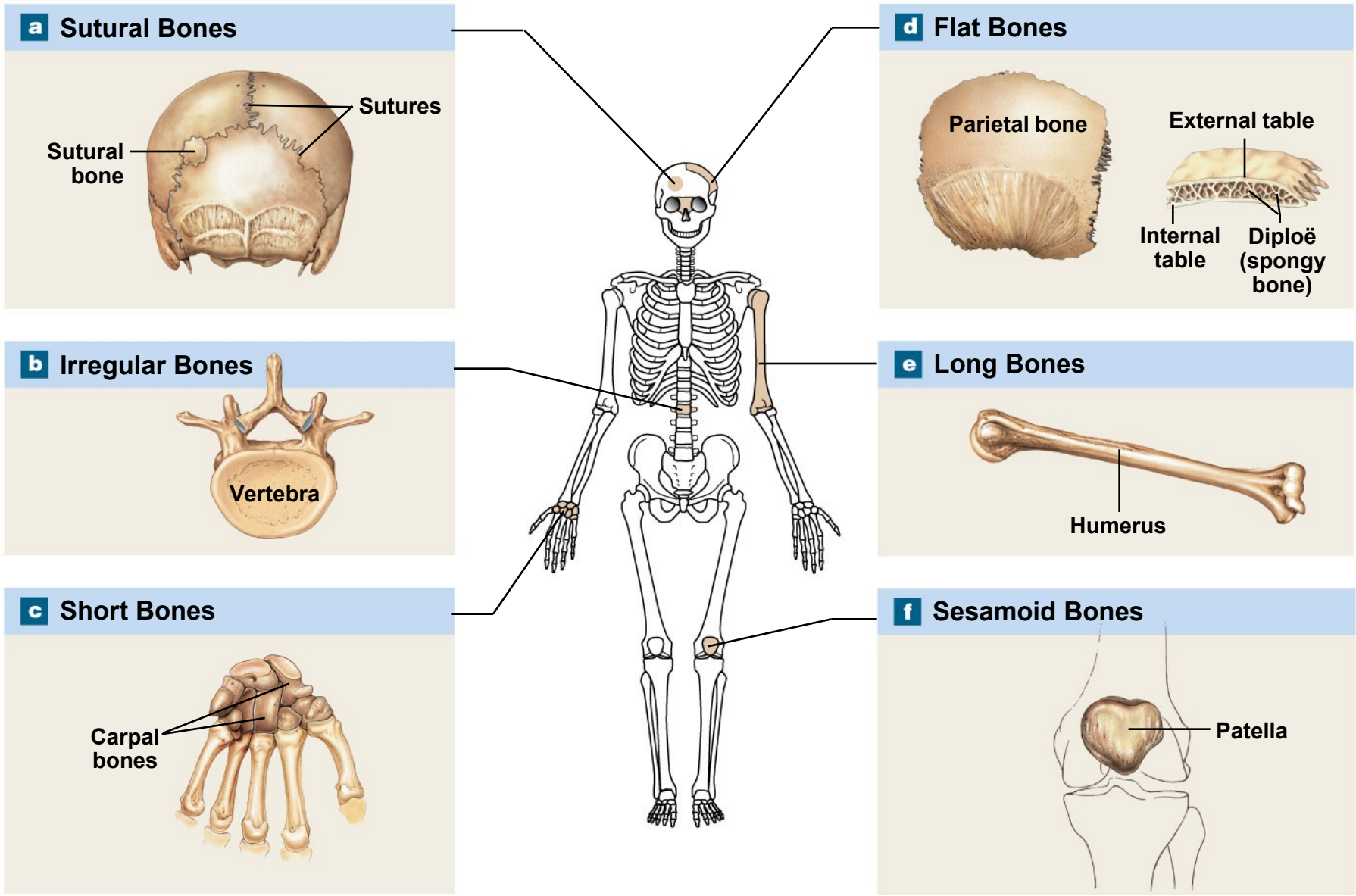
6-2 Classification of Bones

- Bones
  - Are classified by:
    - Shape
    - Internal tissue organization
    - Bone markings (surface features; marks)

6-2 Classification of Bones

- Six Bone Shapes
  1. **Sutural bones**
  2. **Irregular bones**
  3. **Short bones**
  4. **Flat bones**
  5. **Long bones**
  6. **Sesamoid bones**

Figure 6-1 A Classification of Bones by Shape



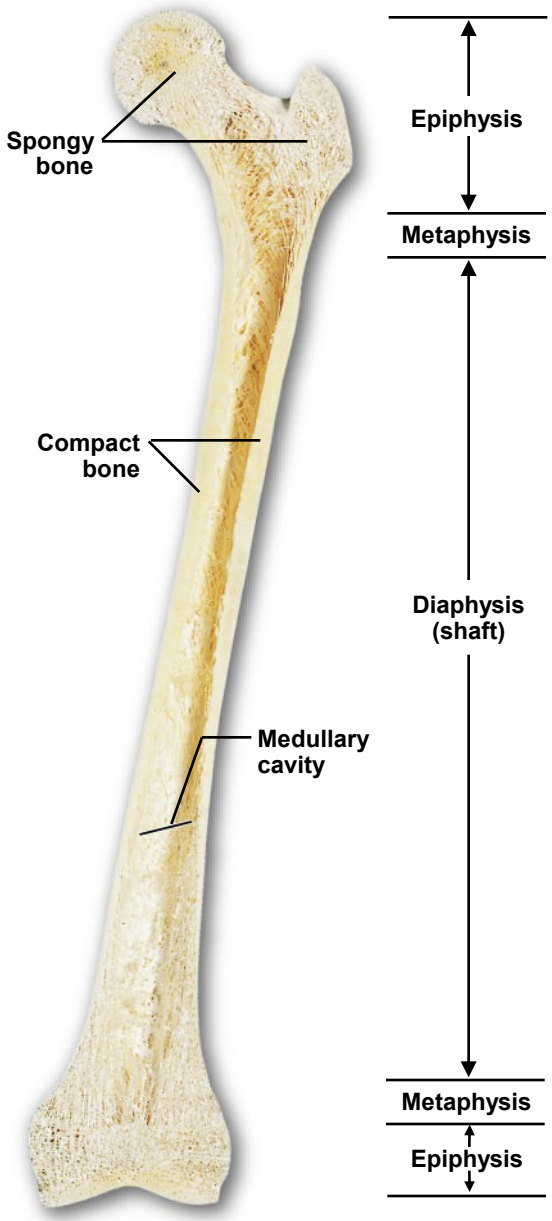
6-2 Classification of Bones

- Bone Markings
  - Depressions or grooves
    - Along bone surface
  - Elevations or projections
    - Where tendons and ligaments attach
    - At articulations with other bones
  - Tunnels
    - Where blood and nerves enter bone

6-2 Classification of Bones

- Structure of a Long Bone
  - **Diaphysis**
    - The shaft
    - A heavy wall of **compact bone**, or dense bone
    - A central space called **medullary** *(marrow)* **cavity**
  - **Epiphysis**
    - Wide part at each end
    - Articulation with other bones
    - Mostly **spongy** *(cancellous)* **bone**
    - Covered with compact bone (**cortex**)
  - **Metaphysis**
    - Where diaphysis and epiphysis meet

Figure 6-2a Bone Structure

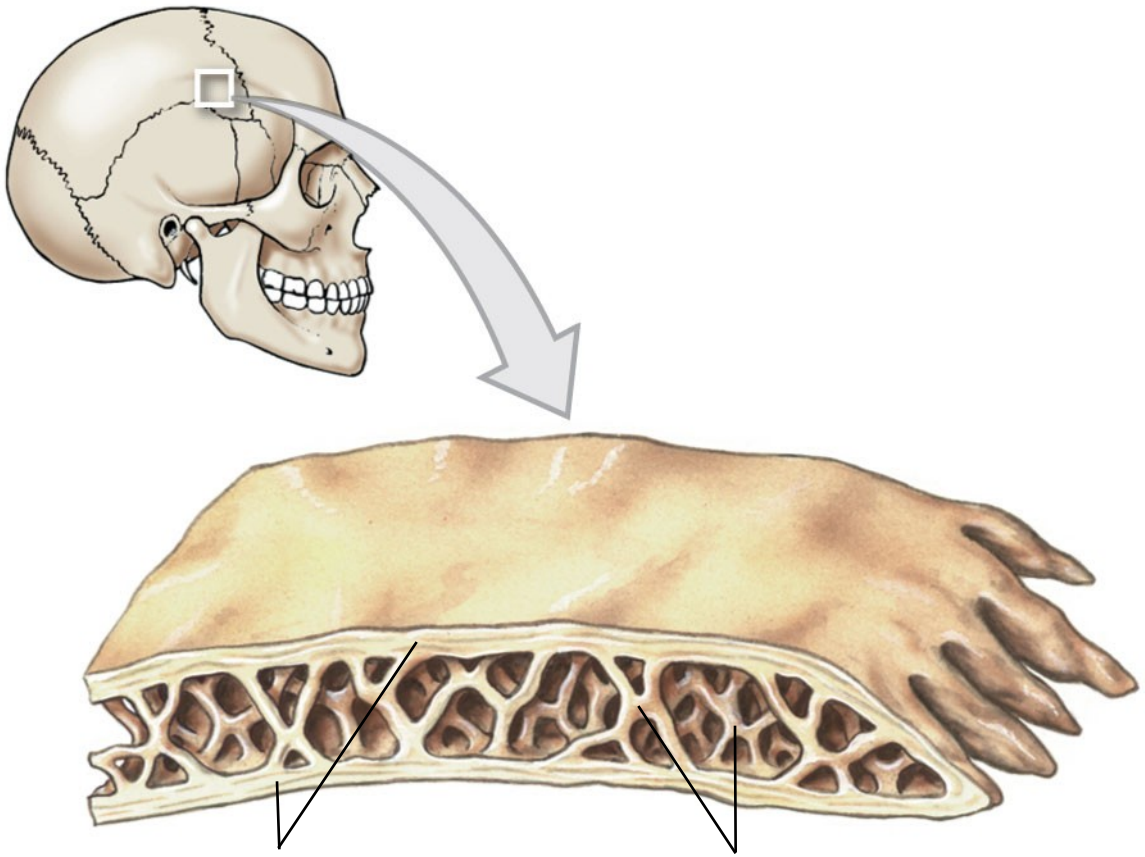


a The structure of a representative long bone (the femur) in longitudinal section

6-2 Classification of Bones

- Structure of a Flat Bone
  - The *parietal bone* of the skull
  - Resembles a sandwich of spongy bone
  - Between two layers of compact bone
  - Within the cranium, the layer of spongy bone between the compact bone is called the *diploë*

Figure 6-2b Bone Structure



b The structure of a flat bone (the parietal bone)

6-3 Bone (Osseous) Tissue

- Bone (Osseous) Tissue
  - Dense, supportive connective tissue
  - Contains specialized cells
  - Produces solid matrix of calcium salt deposits
  - Around collagen fibers

6-3 Bone (Osseous) Tissue

- Characteristics of Bone Tissue
  - Dense matrix, containing:
    - Deposits of calcium salts
    - *Osteocytes* (bone cells) within *lacunae* organized around blood vessels
  - *Canaliculi*
    - Form pathways for blood vessels
    - Exchange nutrients and wastes

6-3 Bone (Osseous) Tissue

- Characteristics of Bone Tissue
  - Periosteum
    - Covers outer surfaces of bones
    - Consists of outer fibrous and inner cellular layers

6-3 Bone (Osseous) Tissue

- Bone Matrix
  - Minerals
    - Two thirds of bone matrix is calcium phosphate, $Ca_3(PO_4)_2$
      - Reacts with calcium hydroxide, $Ca(OH)_2$
      - To form crystals of **hydroxyapatite**, $Ca_{10}(PO_4)_6(OH)_2$
      - Which incorporates other calcium salts and ions

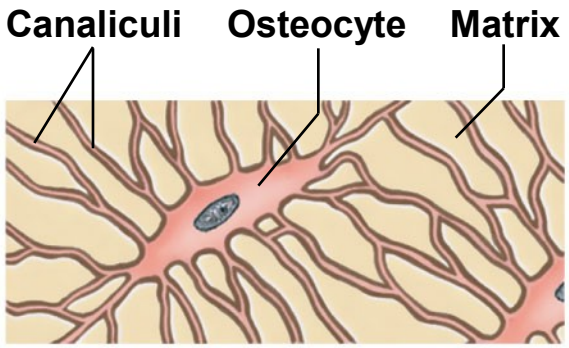
6-3 Bone (Osseous) Tissue

- Bone Matrix
  - Matrix Proteins
    - One third of bone matrix is protein fibers (collagen)

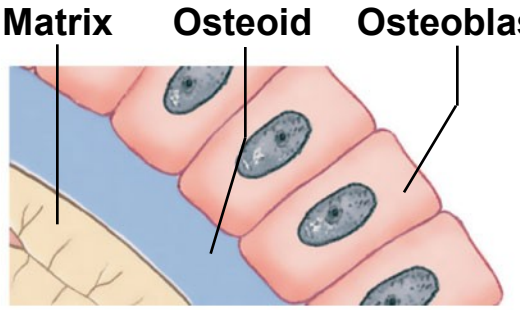
6-3 Bone (Osseous) Tissue

- Bone Cells
  - Make up only 2% of bone mass
  - Bone contains four types of cells
    1. **Osteocytes**
    2. **Osteoblasts**
    3. **Osteoprogenitor cells**
    4. **Osteoclasts**

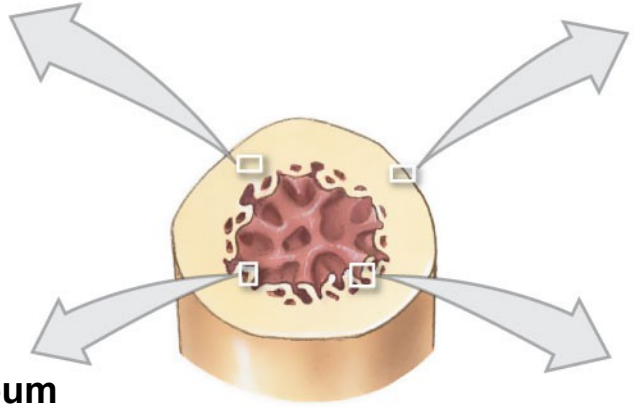
Figure 6-3 Types of Bone Cells

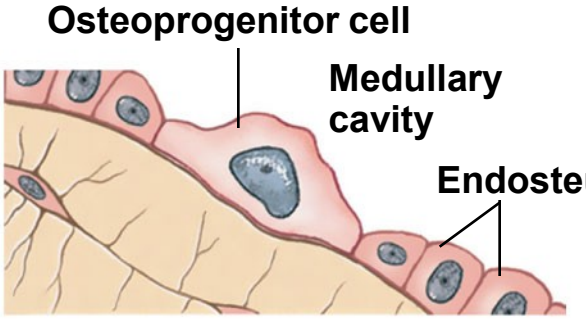


Osteocyte: Mature bone cell that maintains the bone matrix

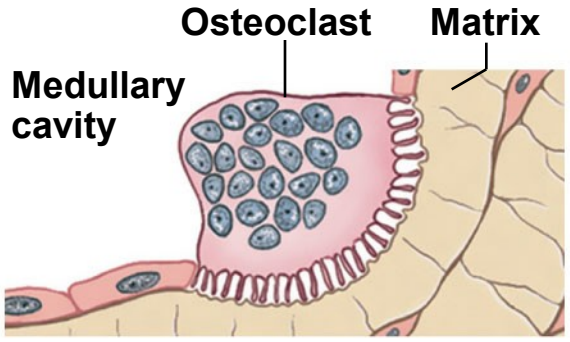


Osteoblast: Immature bone cell that secretes organic components of matrix





Osteoprogenitor cell: Stem cell whose divisions produce osteoblasts

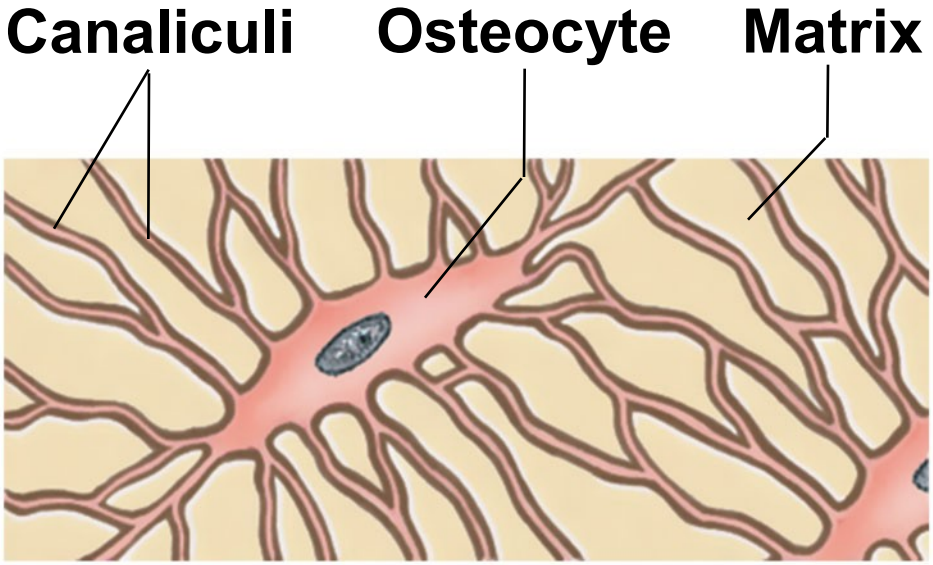


Osteoclast: Multinucleate cell that secretes acids and enzymes to dissolve bone matrix

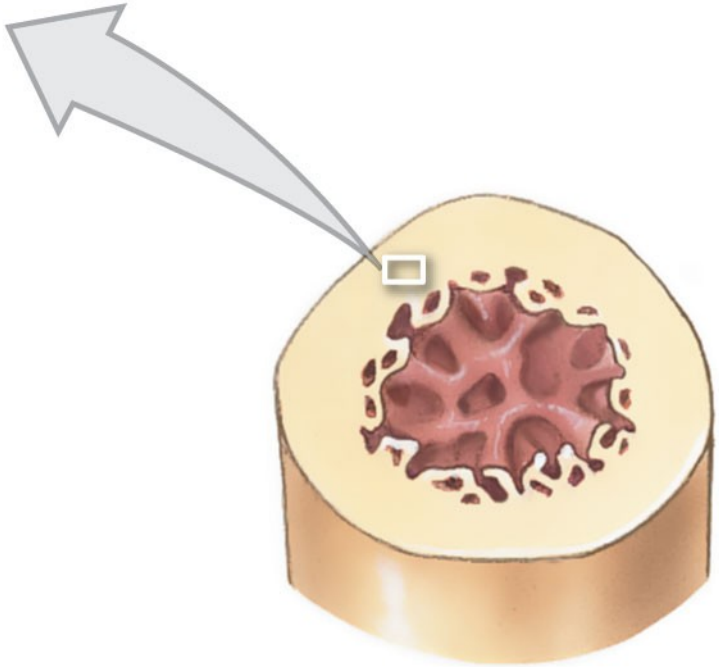
6-3 Bone (Osseous) Tissue

- **Osteocytes**
  - Mature bone cells that maintain the bone matrix
  - Live in lacunae
  - Are between layers (**lamellae**) of matrix
  - Connect by cytoplasmic extensions through **canaliculi** in lamellae
  - Do not divide

Figure 6-3 Types of Bone Cells



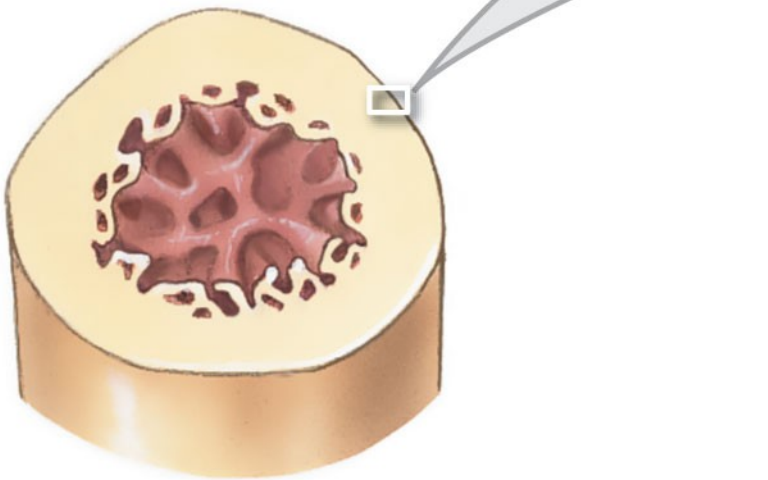
Osteocyte: Mature bone cell that maintains the bone matrix

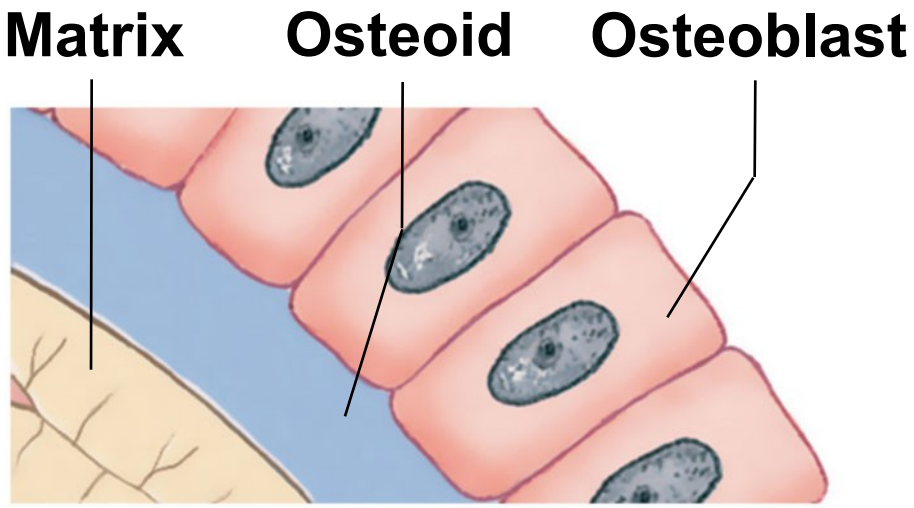


6-3 Bone (Osseous) Tissue

- **Osteoblasts**
  - Immature bone cells that secrete matrix compounds (**osteogenesis**)
  - **Osteoid** — matrix produced by osteoblasts, but not yet calcified to form bone
  - Osteoblasts surrounded by bone become osteocytes

Figure 6-3 Types of Bone Cells



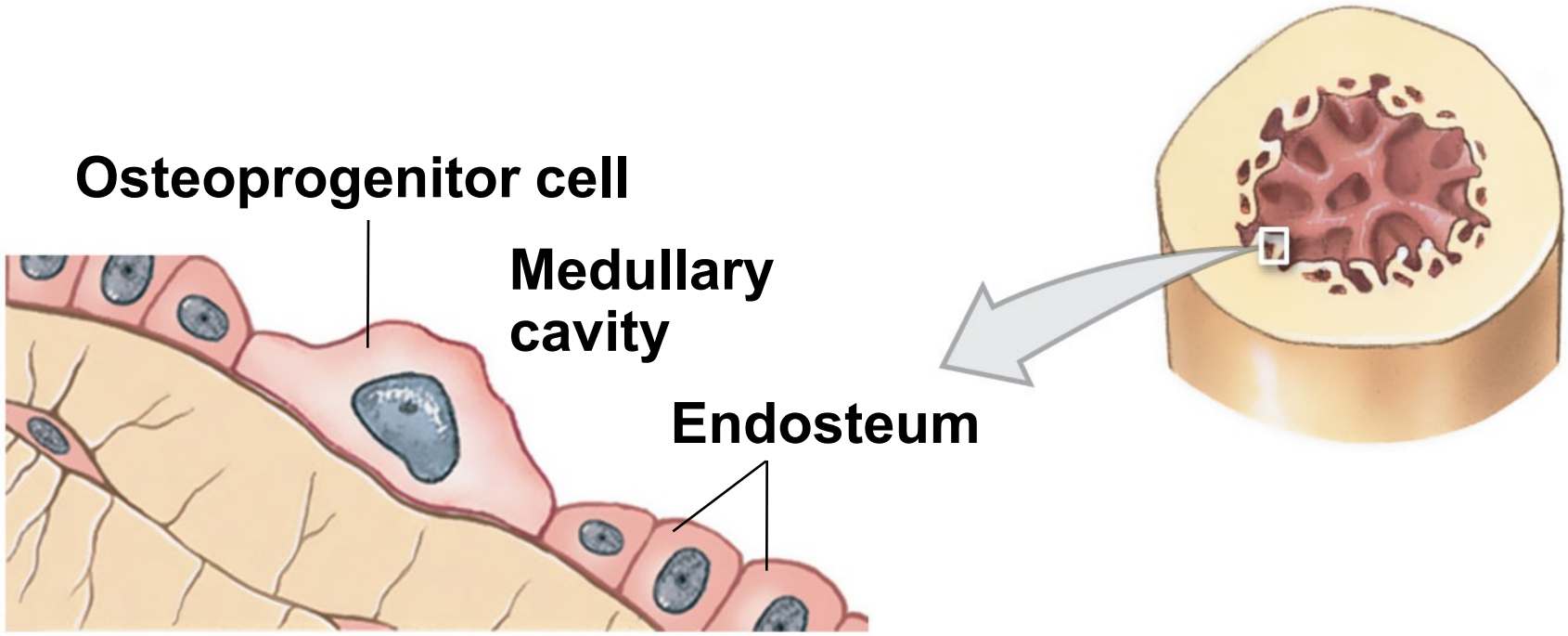


Osteoblast: Immature bone cell that secretes organic components of matrix

6-3 Bone (Osseous) Tissue

- **Osteoprogenitor Cells**
  - Mesenchymal stem cells that divide to produce osteoblasts
  - Located in *endosteum*, the inner cellular layer of periosteum
  - Assist in *fracture* repair

Figure 6-3 Types of Bone Cells

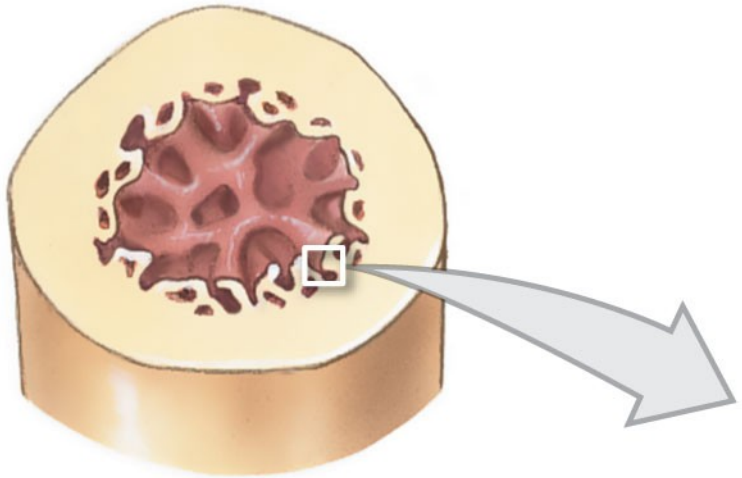


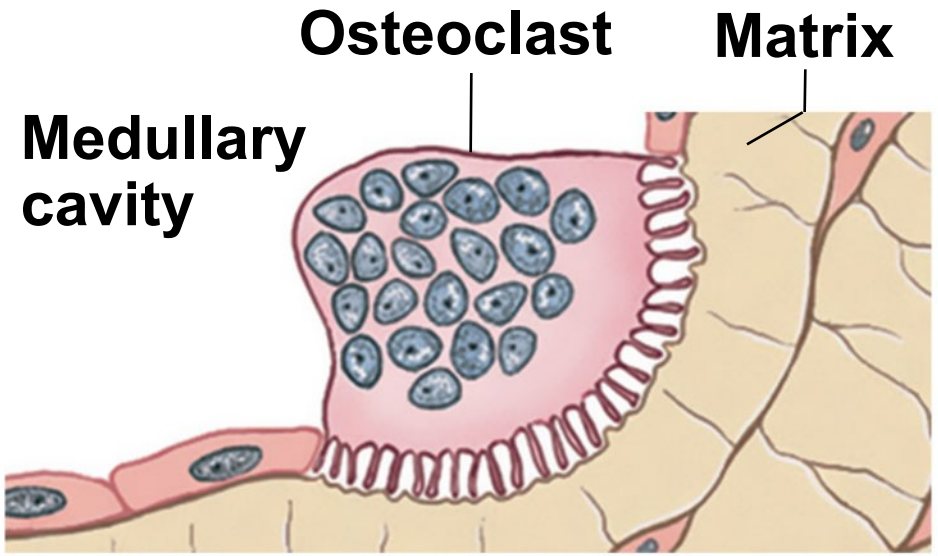
Osteoprogenitor cell: Stem cell whose divisions produce osteoblasts

6-3 Bone (Osseous) Tissue

- **Osteoclasts**
  - Secrete acids and protein-digesting enzymes
  - Giant, multinucleate cells
  - Dissolve bone matrix and release stored minerals (**osteolysis**)
  - Derived from stem cells that produce macrophages

Figure 6-3 Types of Bone Cells





Osteoclast: Multinucleate cell that secretes acids and enzymes to dissolve bone matrix

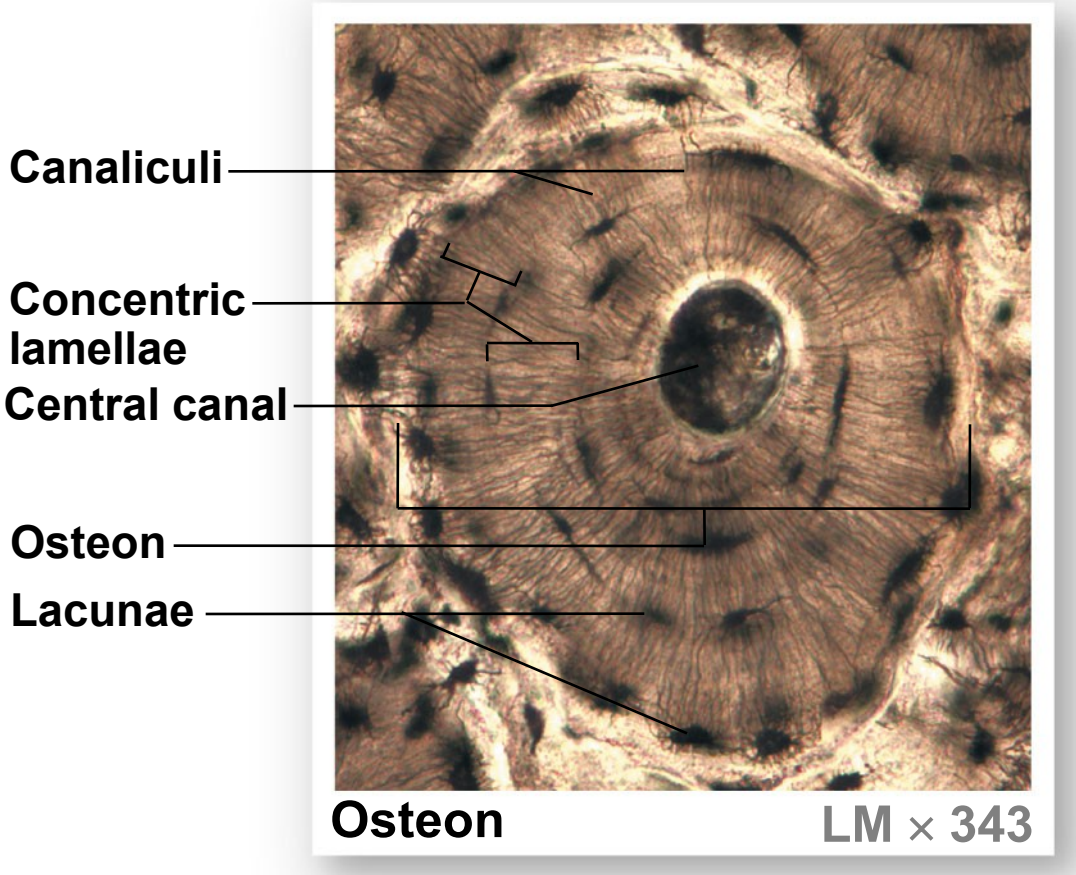
6-3 Bone (Osseous) Tissue

- Homeostasis
  - Bone building (by osteoblasts) and bone recycling (by osteoclasts) must balance
    - More breakdown than building, bones become weak
    - Exercise, particularly weight-bearing exercise, causes osteoblasts to build bone

6-4 Compact Bone and Spongy Bone

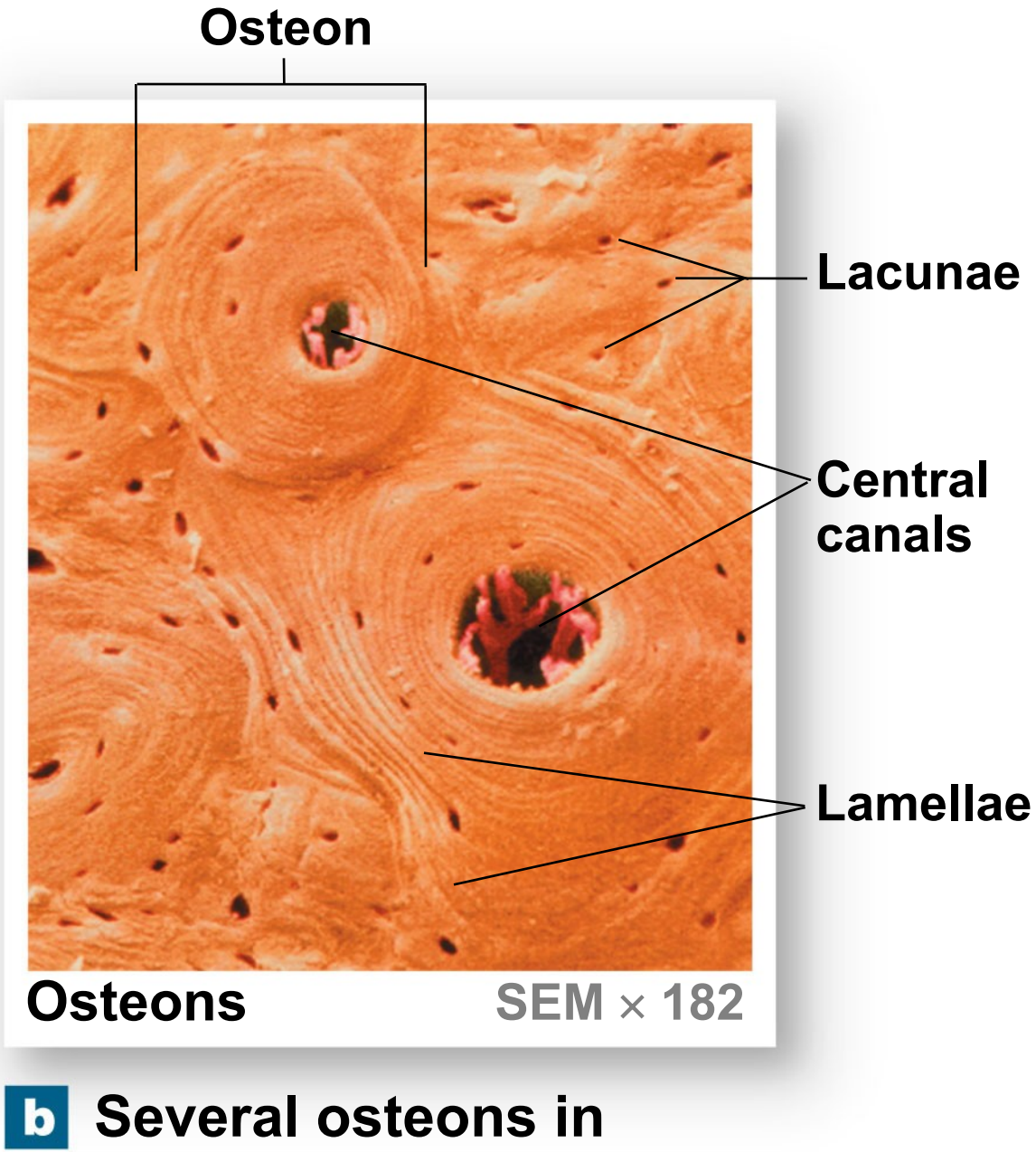
- The Structure of Compact Bone
  - **Osteon** is the basic unit
    - Osteocytes are arranged in *concentric lamellae*
    - Around a **central canal** containing blood vessels

Figure 6-4a The Histology of Compact Bone



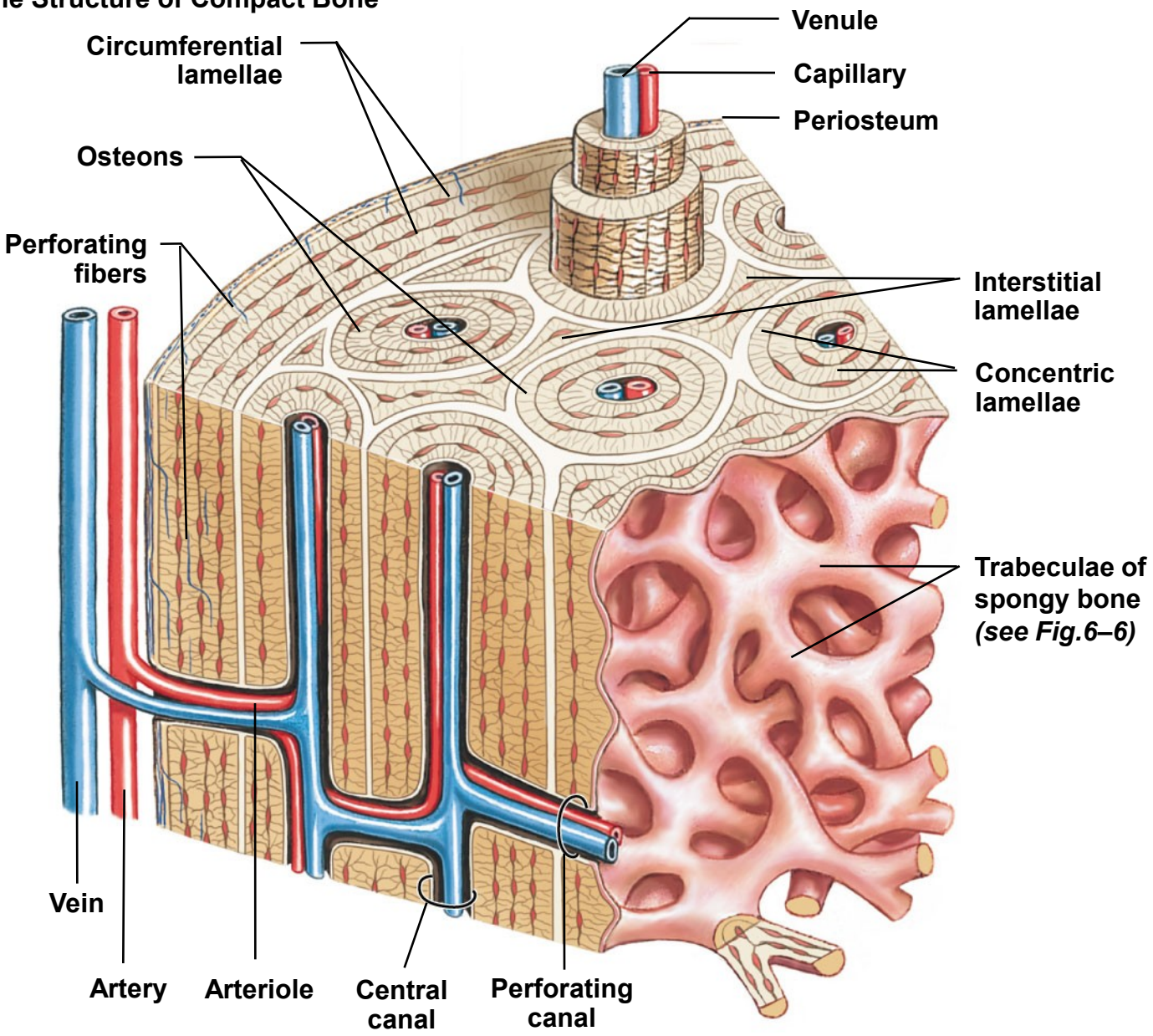
a A thin section through compact bone. By this procedure the intact matrix making up the lamellae appear white, and the central canal, lacunae, and canaliculi appear black due to the presence of bone dust.

Figure 6-4b The Histology of Compact Bone



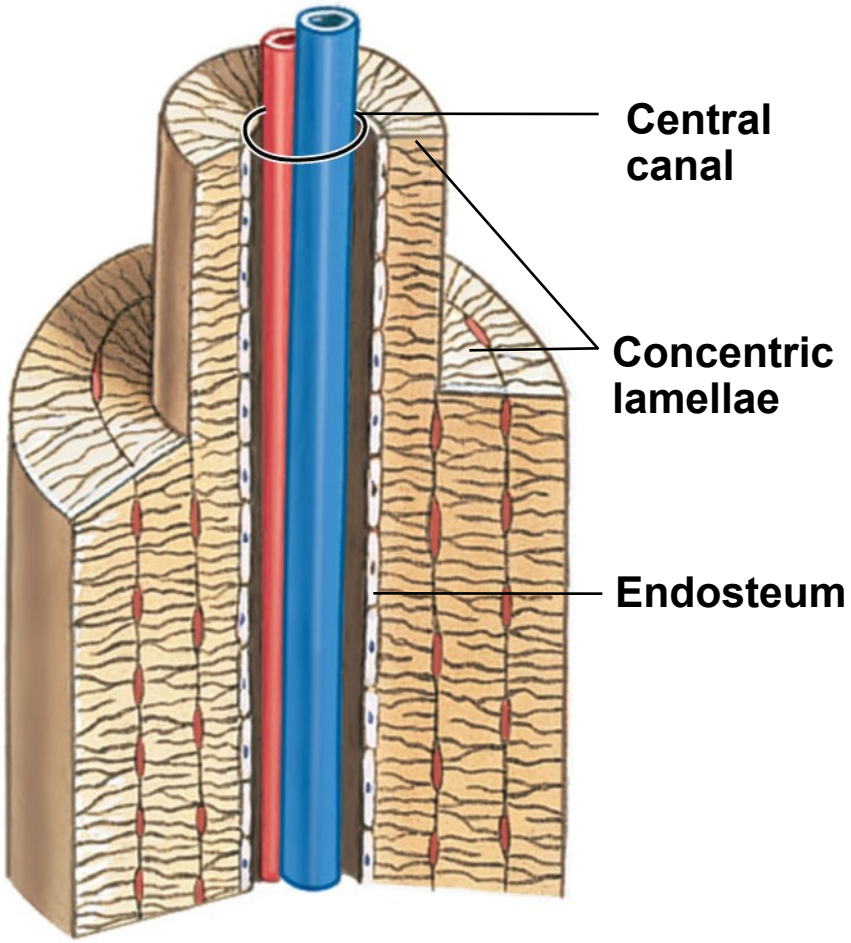
b Several osteons in compact bone.

Figure 6-5a The Structure of Compact Bone



a The organization of osteons and lamellae in compact bone

Figure 6-5a The Structure of Compact Bone

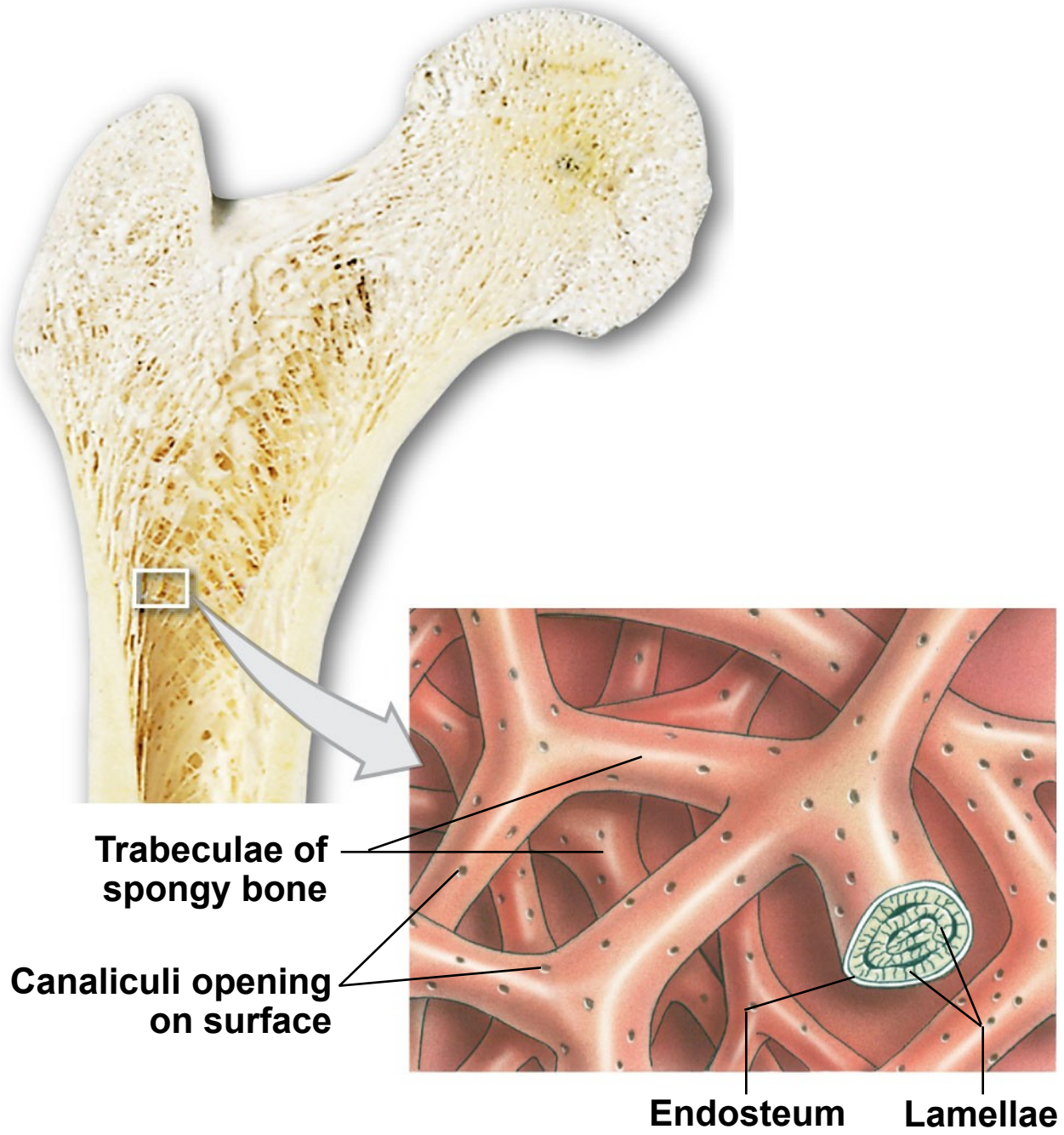


a The organization of osteons and lamellae in compact bone

6-4 Compact Bone and Spongy Bone

- The Structure of Spongy Bone
  - Does not have osteons
  - The matrix forms an open network of **trabeculae**
  - Trabeculae have no blood vessels
  - The space between trabeculae is filled with **red bone marrow**
    - Which has blood vessels
    - Forms red blood cells
    - And supplies nutrients to osteocytes

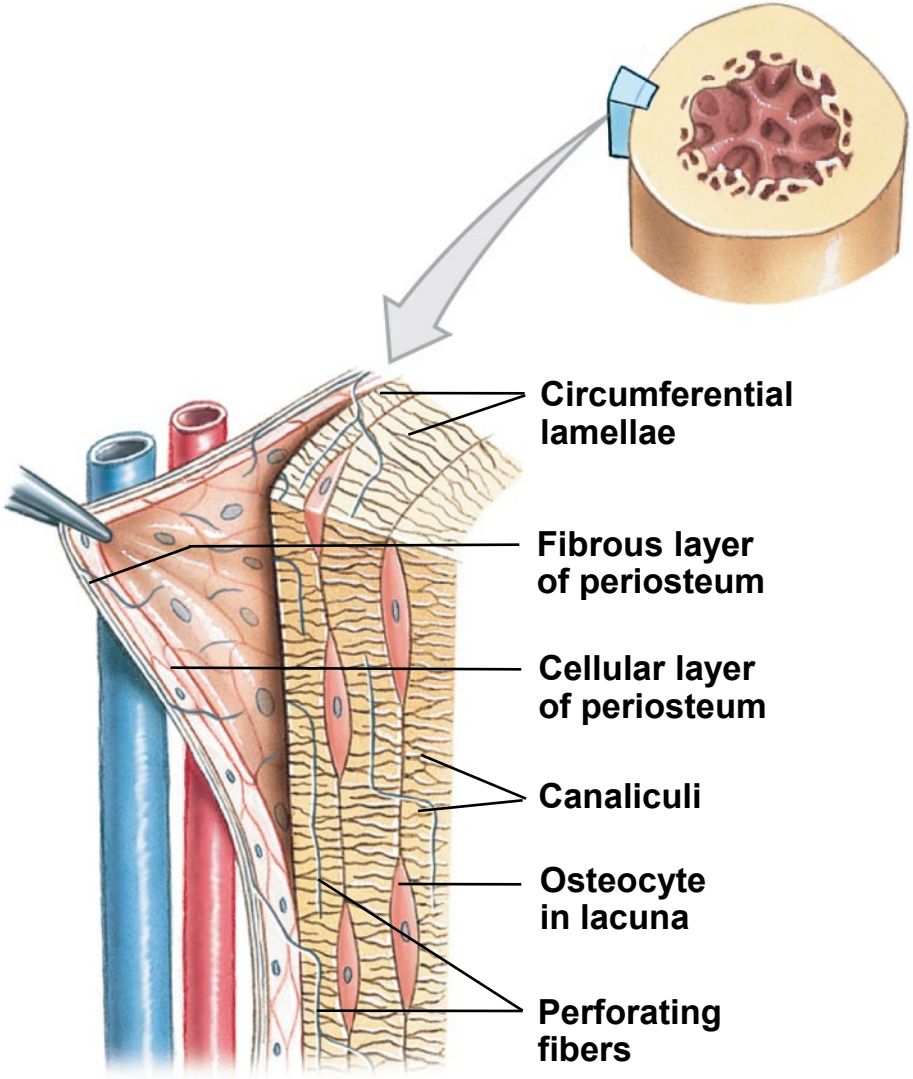
Figure 6-6 The Structure of Spongy Bone



6-4 Compact Bone and Spongy Bone

- Compact Bone is Covered with a Membrane
  - **Periosteum** on the outside
    - Covers all bones except parts enclosed in joint capsules
    - Made up of an outer, fibrous layer and an inner, cellular layer
    - *Perforating fibers*: collagen fibers of the periosteum
      - Connect with collagen fibers in bone
      - And with fibers of joint capsules; attach tendons, and ligaments

Figure 6-8a The Periosteum and Endosteum

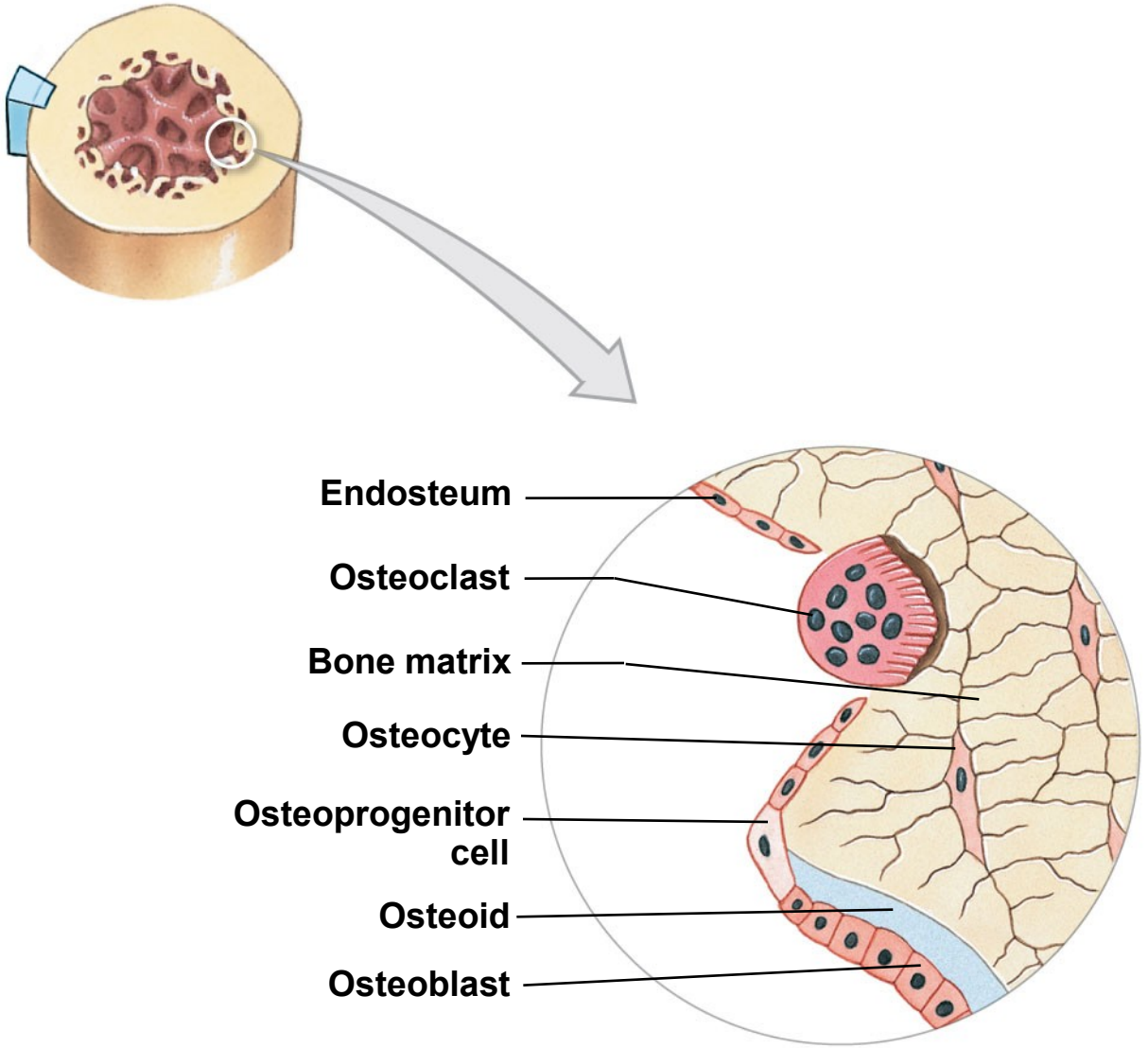


a The periosteum contains outer (fibrous) and inner (cellular) layers. Collagen fibers of the periosteum are continuous with those of the bone, adjacent joint capsules, and attached tendons and ligaments.

6-4 Compact Bone and Spongy Bone

- Compact Bone is Covered with a Membrane
  - **Endosteum** on the inside
    - Lines the medullary (marrow) cavity
    - Covers trabeculae of spongy bone
    - Lines central canals
    - Contains osteoblasts, osteoprogenitor cells, and osteoclasts
    - Active in bone growth and repair

Figure 6-8b The Periosteum and Endosteum



b The endosteum is an incomplete cellular layer containing osteoblasts, osteoprogenitor cells, and osteoclasts.

6-5 Bone Formation and Growth

- Bone Development
  - Human bones grow until about age 25
  - Osteogenesis
    - Bone formation
  - Ossification
    - The process of replacing other tissues with bone

6-5 Bone Formation and Growth

- Bone Development
  - **Calcification**
    - The process of depositing calcium salts
    - Occurs during bone ossification and in other tissues
  - Ossification
    - Two main forms of ossification
      1. **Endochondral ossification**
      2. **Intramembranous ossification**

6-5 Bone Formation and Growth

- **Endochondral Ossification**
  - Ossifies bones that originate as hyaline cartilage
  - Most bones originate as hyaline cartilage
  - There are six main steps in endochondral ossification

Figure 6-10 Endochondral Ossification

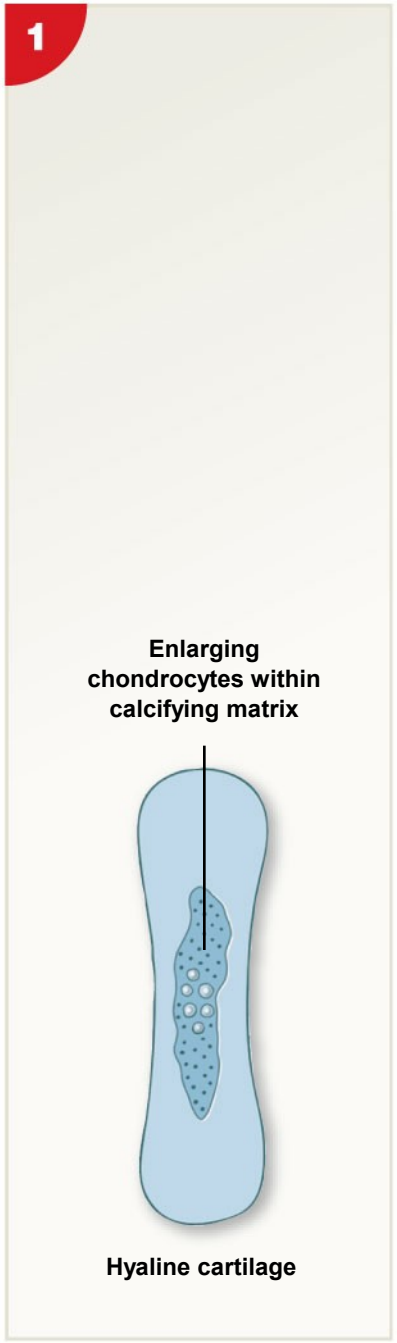


Figure 6-10 Endochondral Ossification

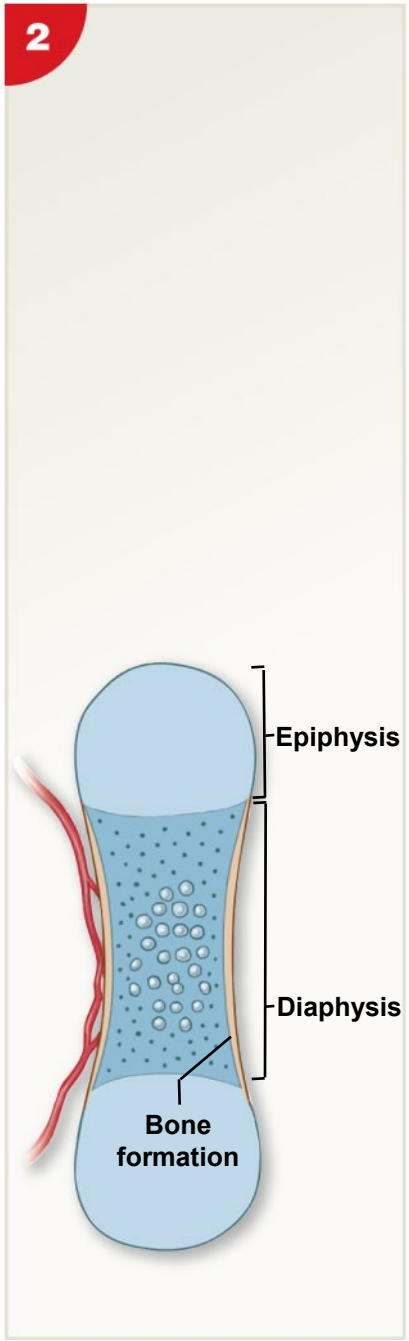


Figure 6-10 Endochondral Ossification

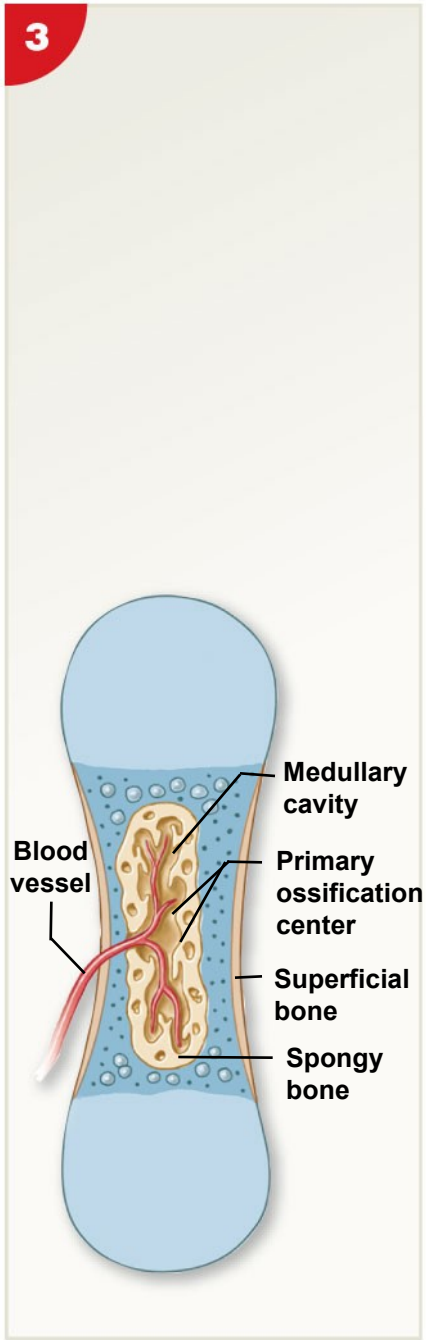


Figure 6-10 Endochondral Ossification

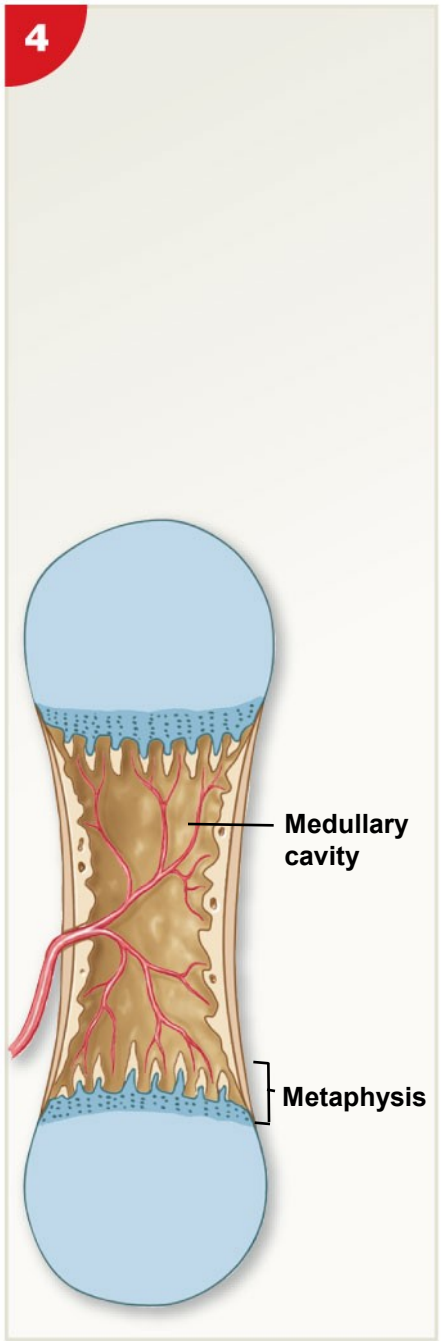


Figure 6-10 Endochondral Ossification

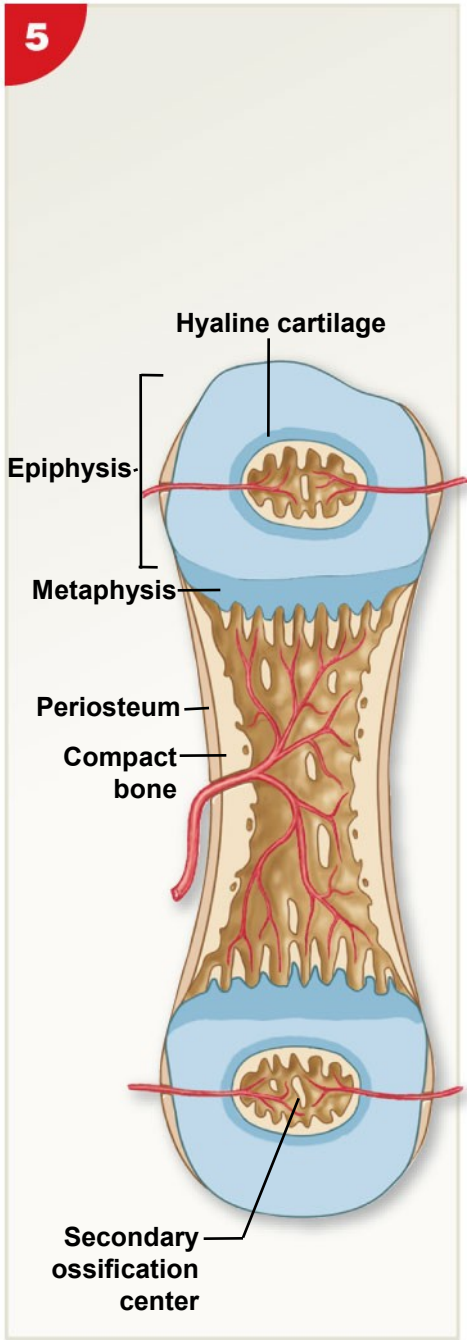


Figure 6-10 Endochondral Ossification

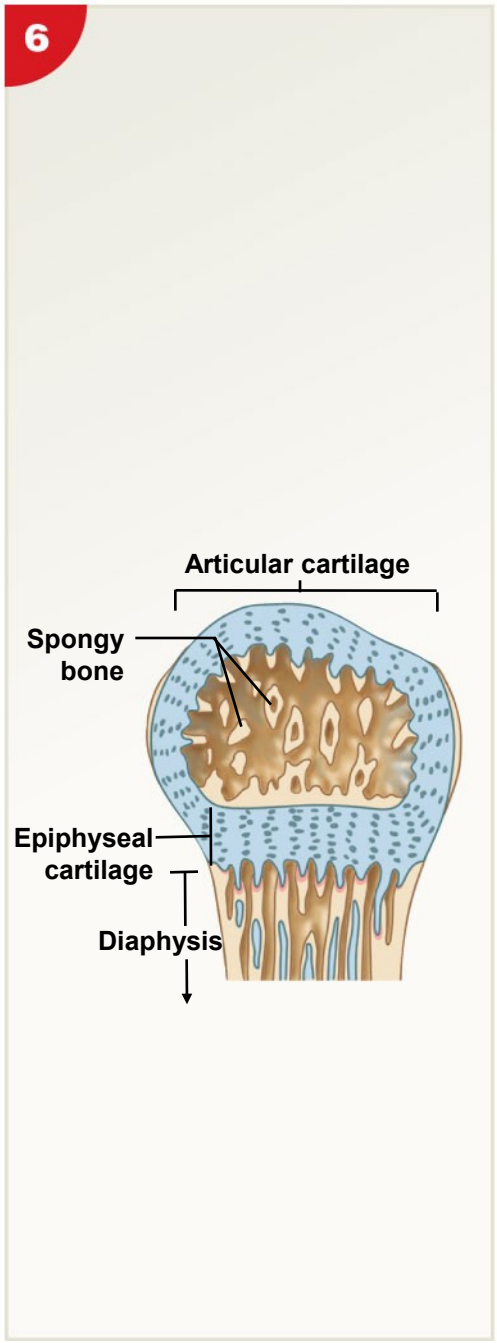
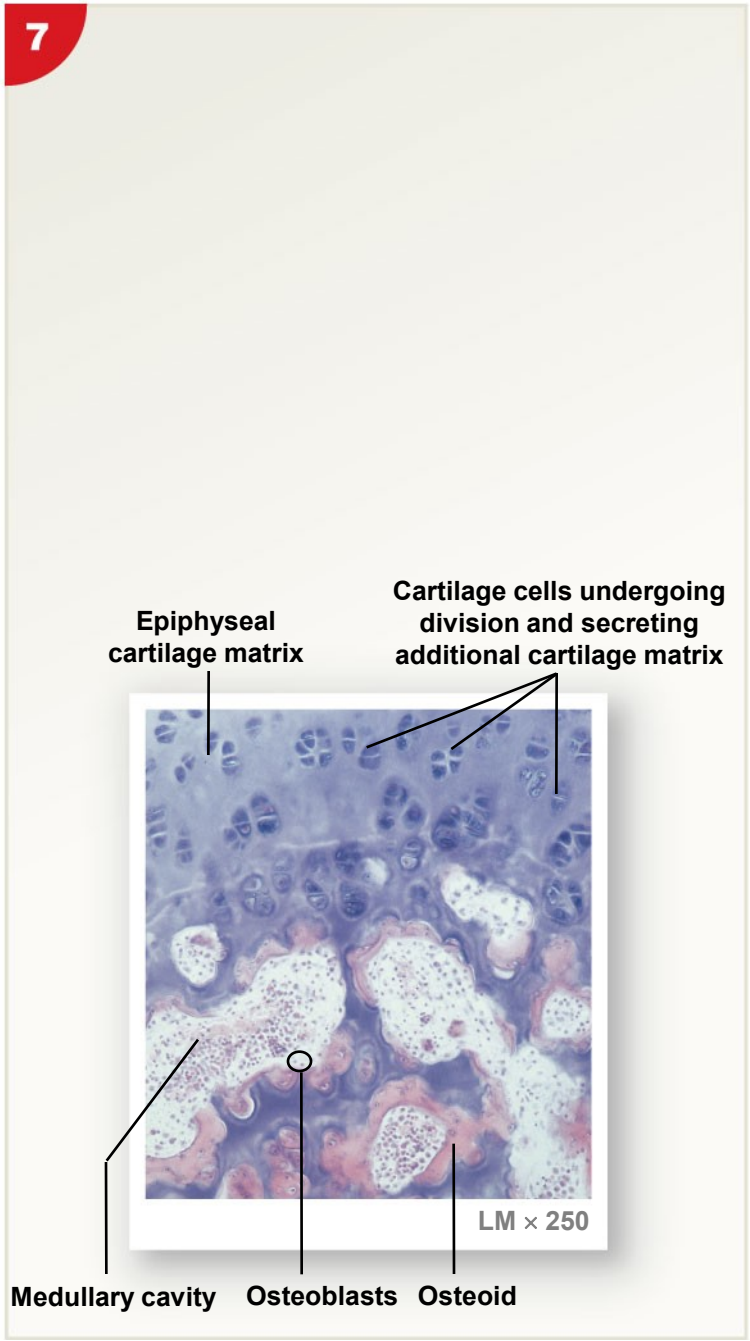


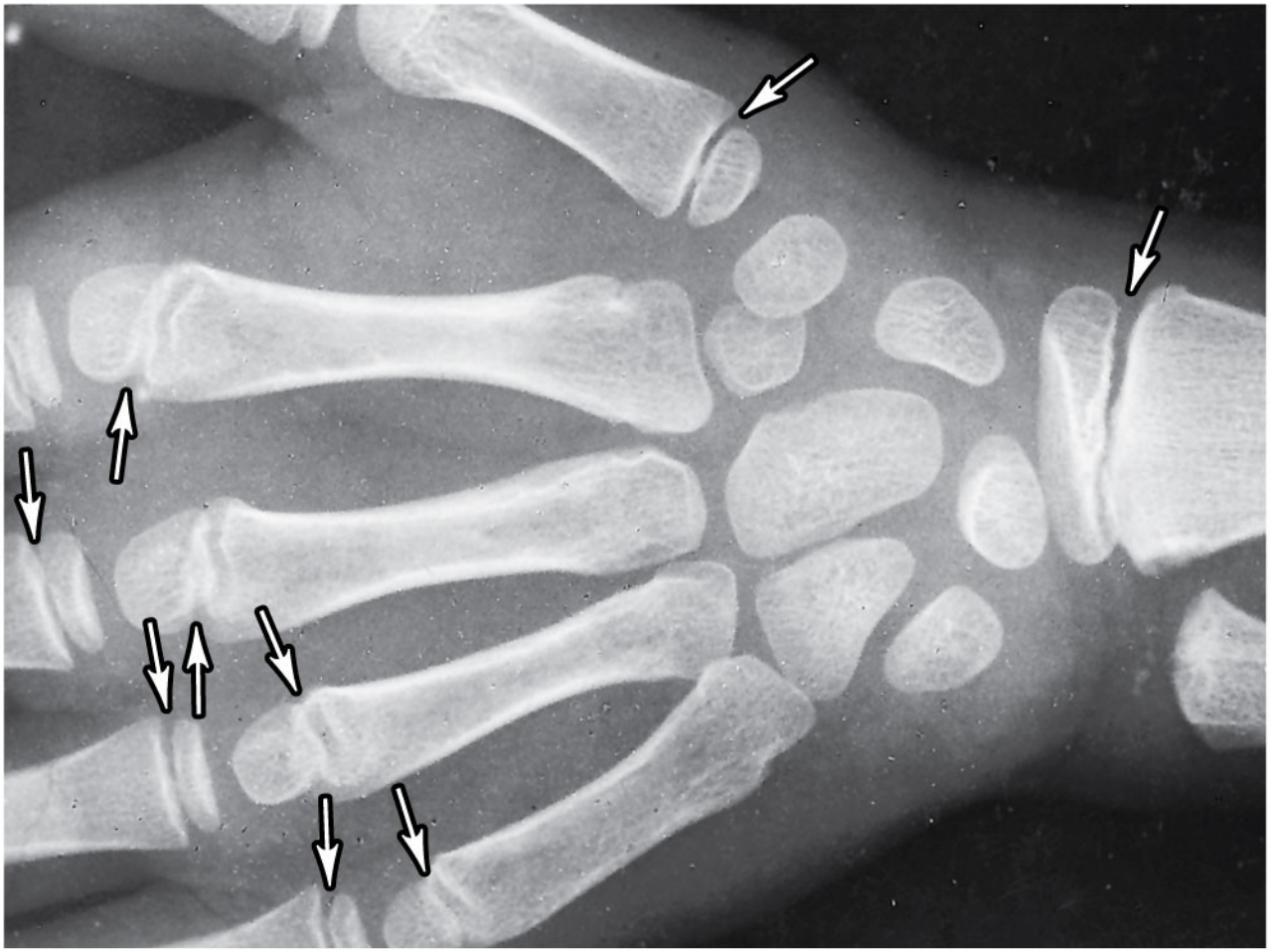
Figure 6-10 Endochondral Ossification



6-5 Bone Formation and Growth

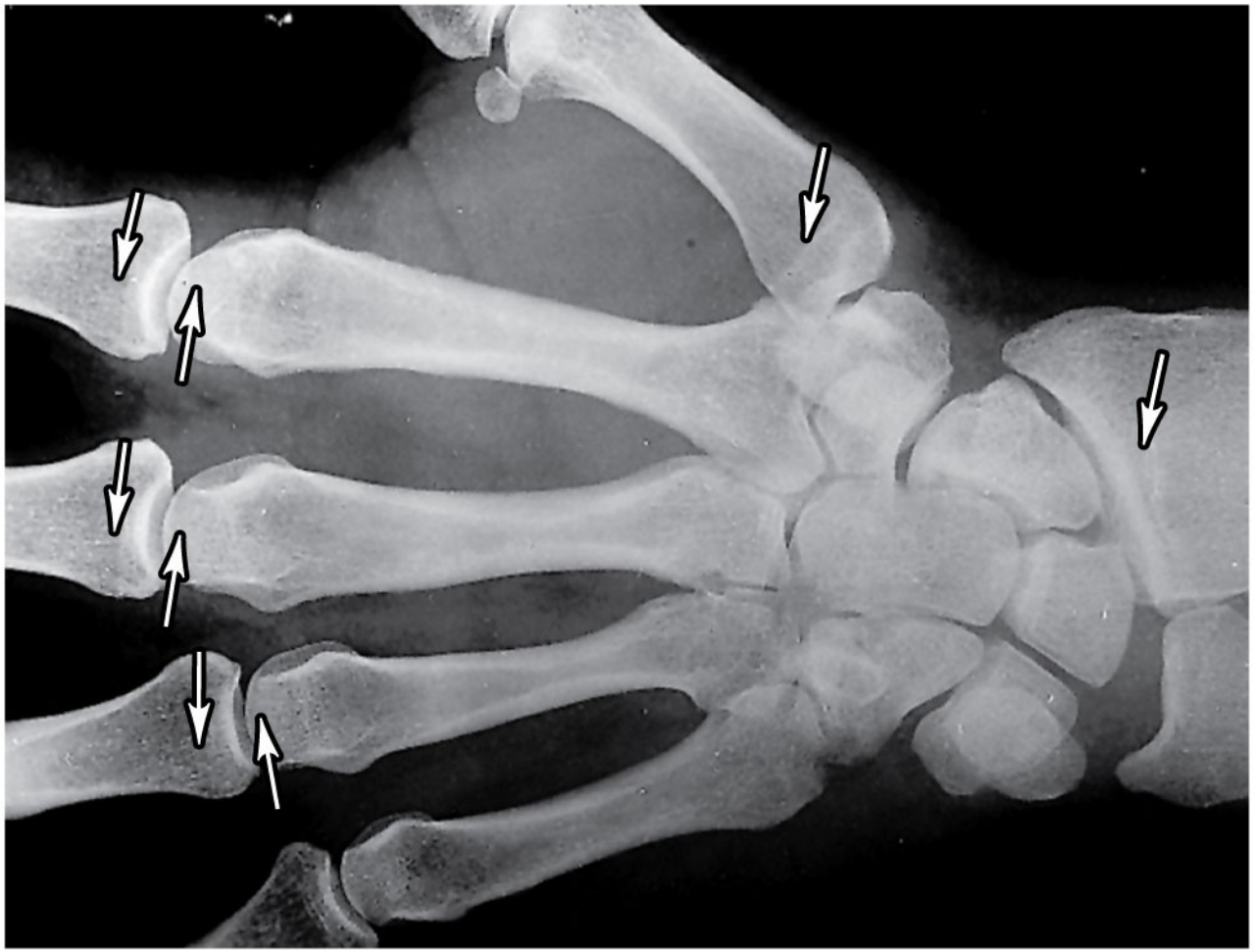
- *Appositional Growth*
  - Compact bone thickens and strengthens long bone with layers of circumferential lamellae

Figure 6-11a Bone Growth at an Epiphyseal Cartilage



a An x-ray of growing epiphyseal cartilages (arrows)

Figure 6-11b Bone Growth at an Epiphyseal Cartilage



b **Epiphyseal lines in an adult (arrows)**

6-5 Bone Formation and Growth

- **Intramembranous Ossification**
  - Also called *dermal ossification*
    - Because it occurs in the dermis
    - Produces **dermal bones** such as mandible (lower jaw) and clavicle (collarbone)
  - There are three main steps in intramembranous ossification

Figure 6-12 Intramembranous Ossification

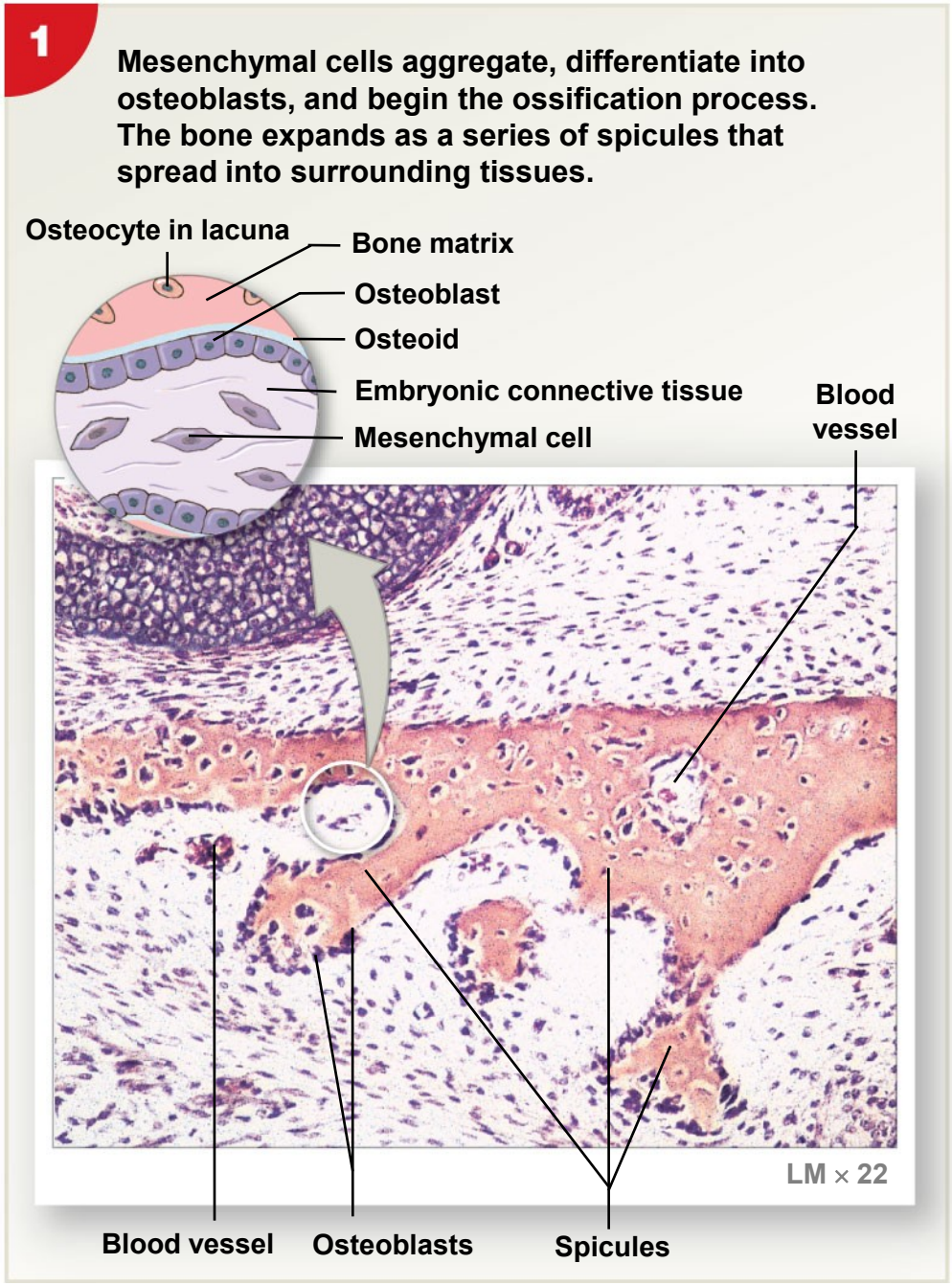


Figure 6-12 Intramembranous Ossification

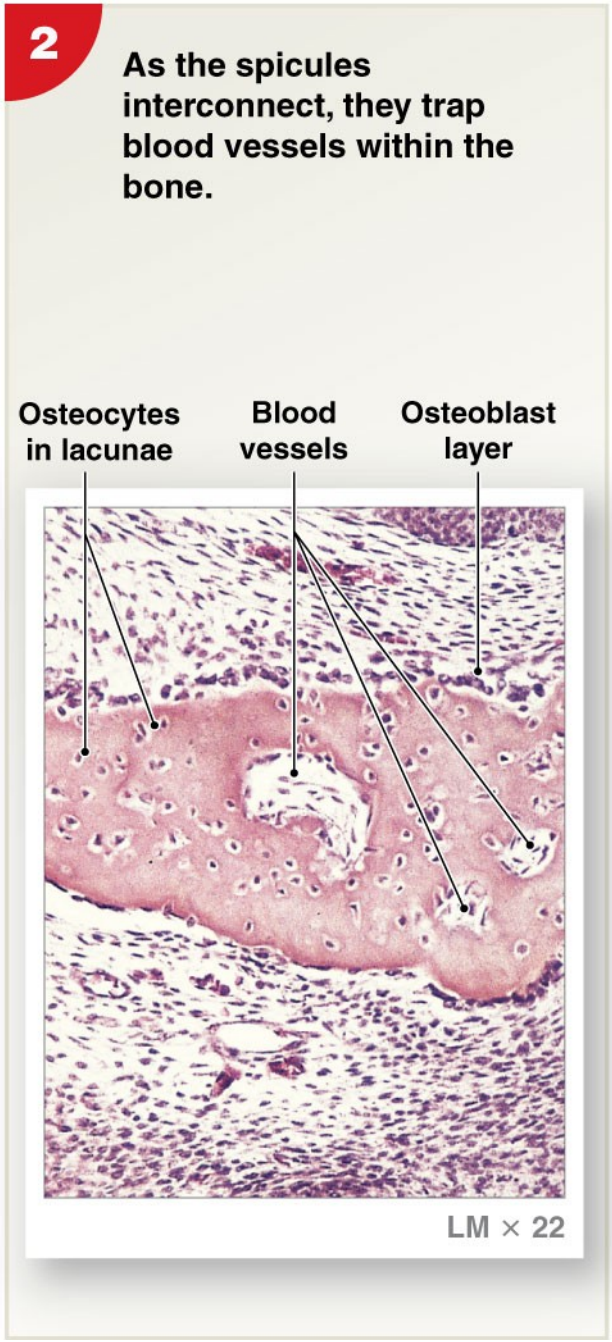


Figure 6-12 Intramembranous Ossification

3

Over time, the bone assumes the structure of spongy bone. Areas of spongy bone may later be removed, creating medullary cavities. Through remodeling, spongy bone formed in this way can be converted to compact bone.

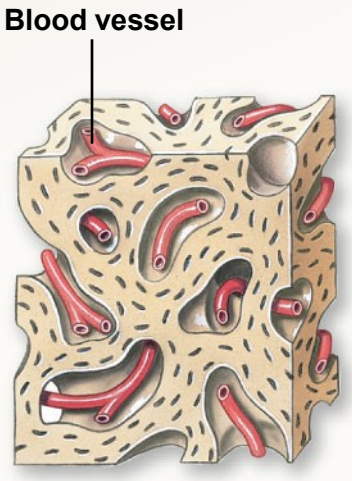
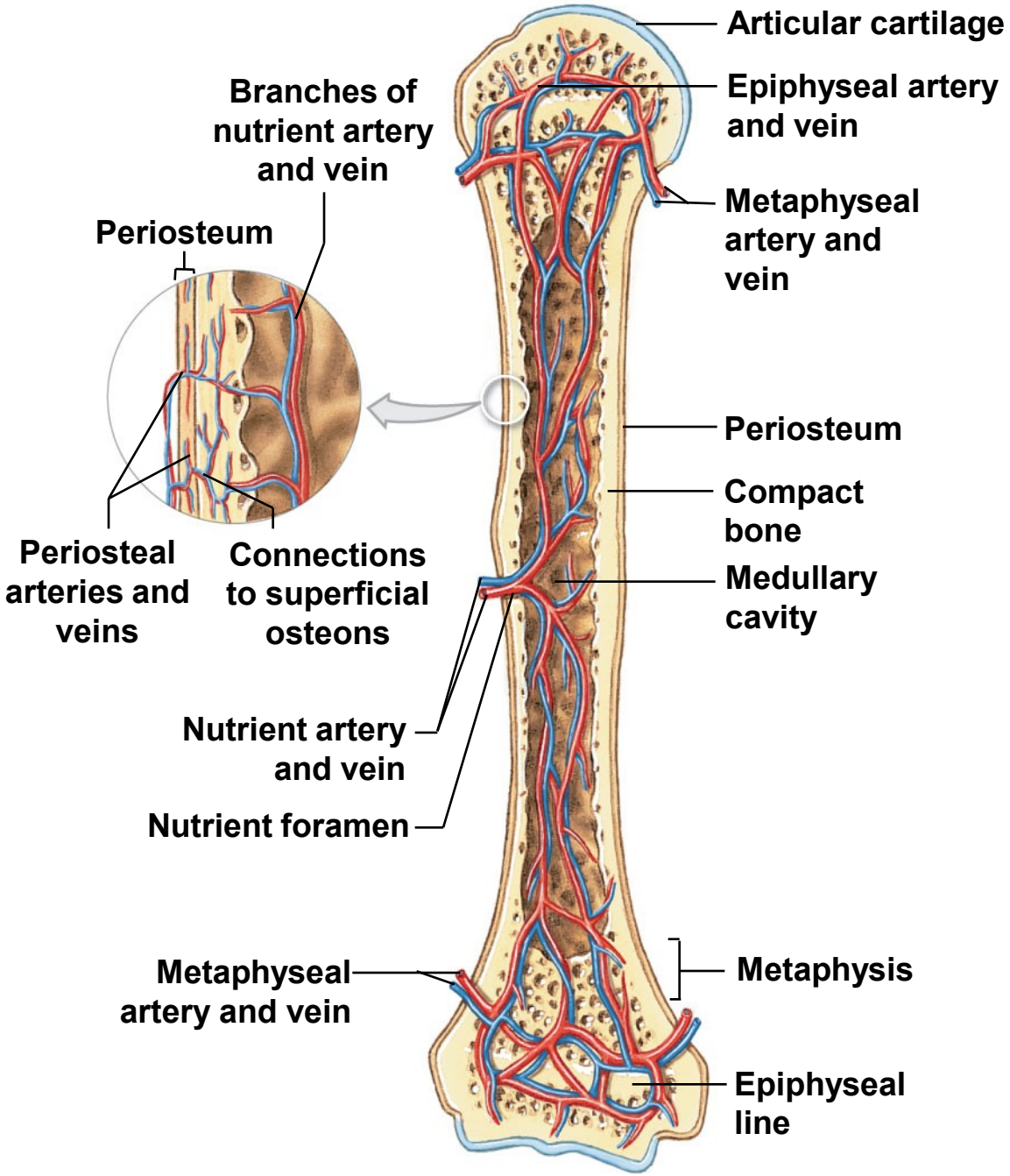


Figure 6-13 The Blood Supply to a Mature Bone



6-5 Bone Formation and Growth

- Lymph and Nerves
  - The periosteum also contains:
    - Networks of lymphatic vessels
    - Sensory nerves

6-6 Bone Remodeling

- Process of Remodeling
  - Bone continually remodels, recycles, and replaces
  - Turnover rate varies:
    - If deposition is greater than removal, bones get stronger
    - If removal is faster than replacement, bones get weaker

6-7 Exercise, Hormones, and Nutrition

- Effects of Exercise on Bone
  - Mineral recycling allows bones to adapt to stress
  - Heavily stressed bones become thicker and stronger
- Bone Degeneration
  - Bone degenerates quickly
  - Up to one third of bone mass can be lost in a few weeks of inactivity

6-7 Exercise, Hormones, and Nutrition

- Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors
  - A dietary source of calcium and phosphate salts
    - Plus small amounts of magnesium, fluoride, iron, and manganese

6-7 Exercise, Hormones, and Nutrition

- Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors
  - The hormone *calcitriol*
    - Made in the kidneys
    - Helps absorb calcium and phosphorus from digestive tract
    - Synthesis requires vitamin D_3 *(cholecalciferol)*

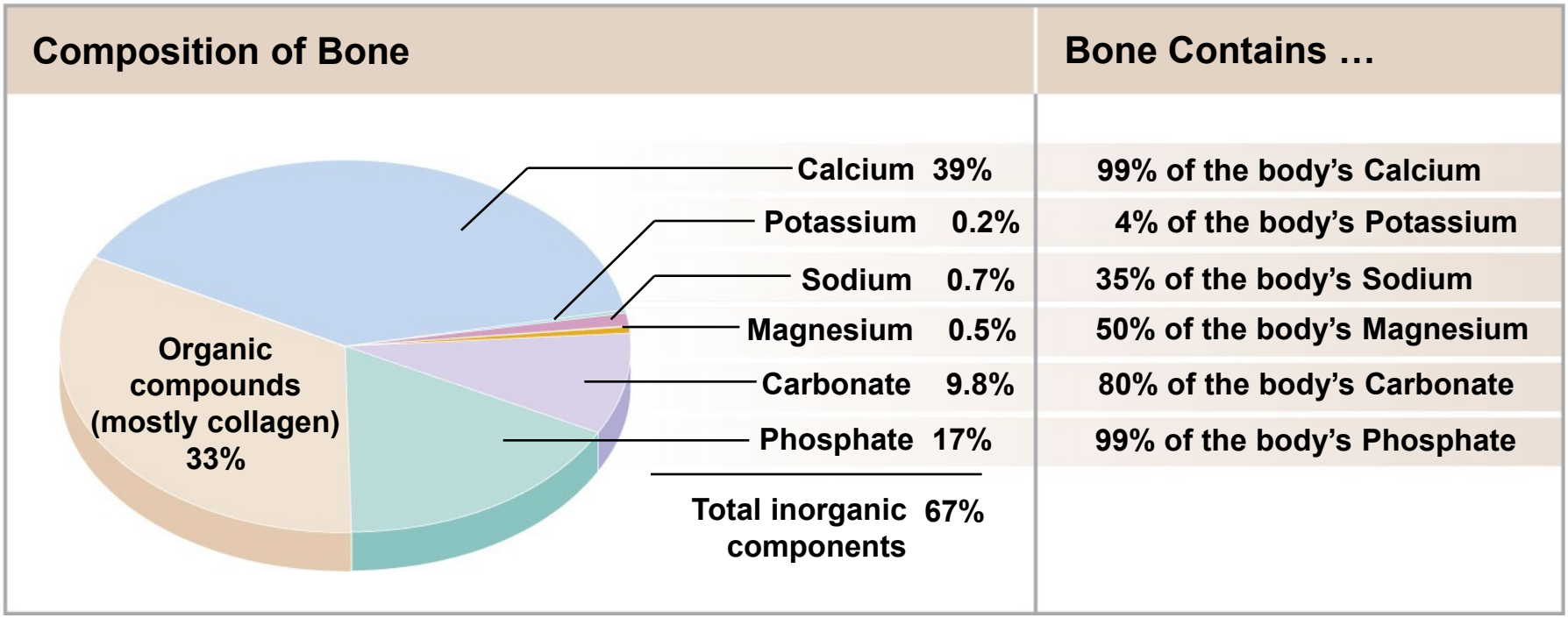
6-7 Exercise, Hormones, and Nutrition

- Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors
  - *Growth hormone* and *thyroxine* stimulate bone growth
  - *Estrogens* and *androgens* stimulate osteoblasts
  - *Calcitonin* and *parathyroid hormone* regulate calcium and phosphate levels

6-8 Calcium Homeostasis

- The Skeleton as a Calcium Reserve
  - Bones store calcium and other minerals
  - Calcium is the most abundant mineral in the body
    - Calcium ions are vital to:
      - Membranes
      - Neurons
      - Muscle cells, especially heart cells

Figure 6-15 A Chemical Analysis of Bone



6-8 Calcium Homeostasis

- Calcium Regulation
  - Calcium ions in body fluids
    - Must be closely regulated
  - Homeostasis is maintained
    - By **calcitonin** and **parathyroid hormone (PTH)**
    - Which control storage, absorption, and excretion

6-8 Calcium Homeostasis

- Calcitonin and Parathyroid Hormone Control
  - Affect:
    1. Bones
       - Where calcium is stored
    2. Digestive tract
       - Where calcium is absorbed
    3. Kidneys
       - Where calcium is excreted

6-8 Calcium Homeostasis

- **Parathyroid Hormone (PTH)**
  - Produced by parathyroid glands in neck
  - Increases calcium ion levels by:
    1. Stimulating osteoclasts
    2. Increasing intestinal absorption of calcium
    3. Decreasing calcium excretion at kidneys
- **Calcitonin**
  - Secreted by *C cells (parafollicular cells*) in thyroid
  - *Decreases* calcium ion levels by:
    1. Inhibiting osteoclast activity
    2. Increasing calcium excretion at kidneys

Figure 6-16a Factors That Alter the Concentration of Calcium Ions in Body Fluids

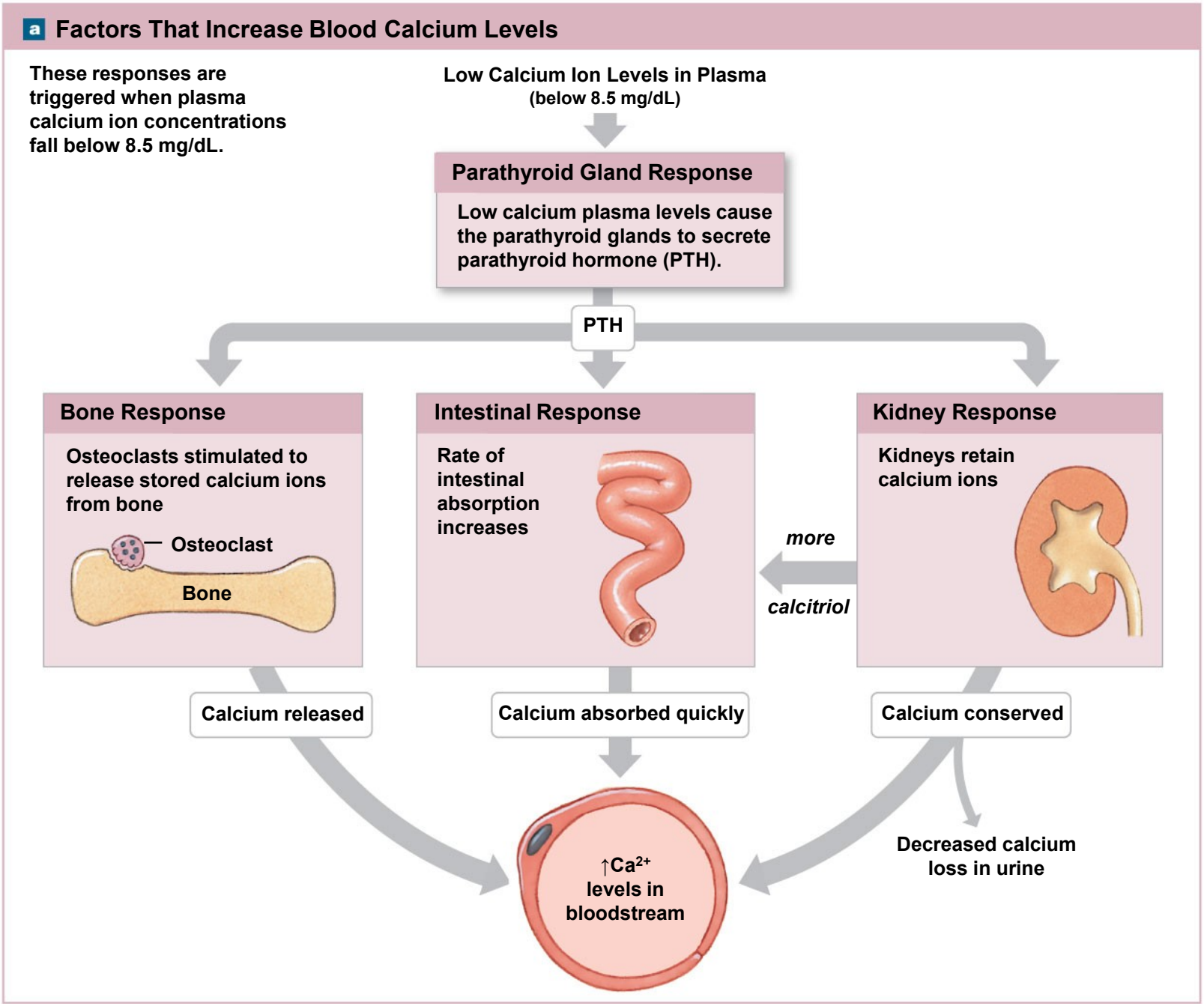
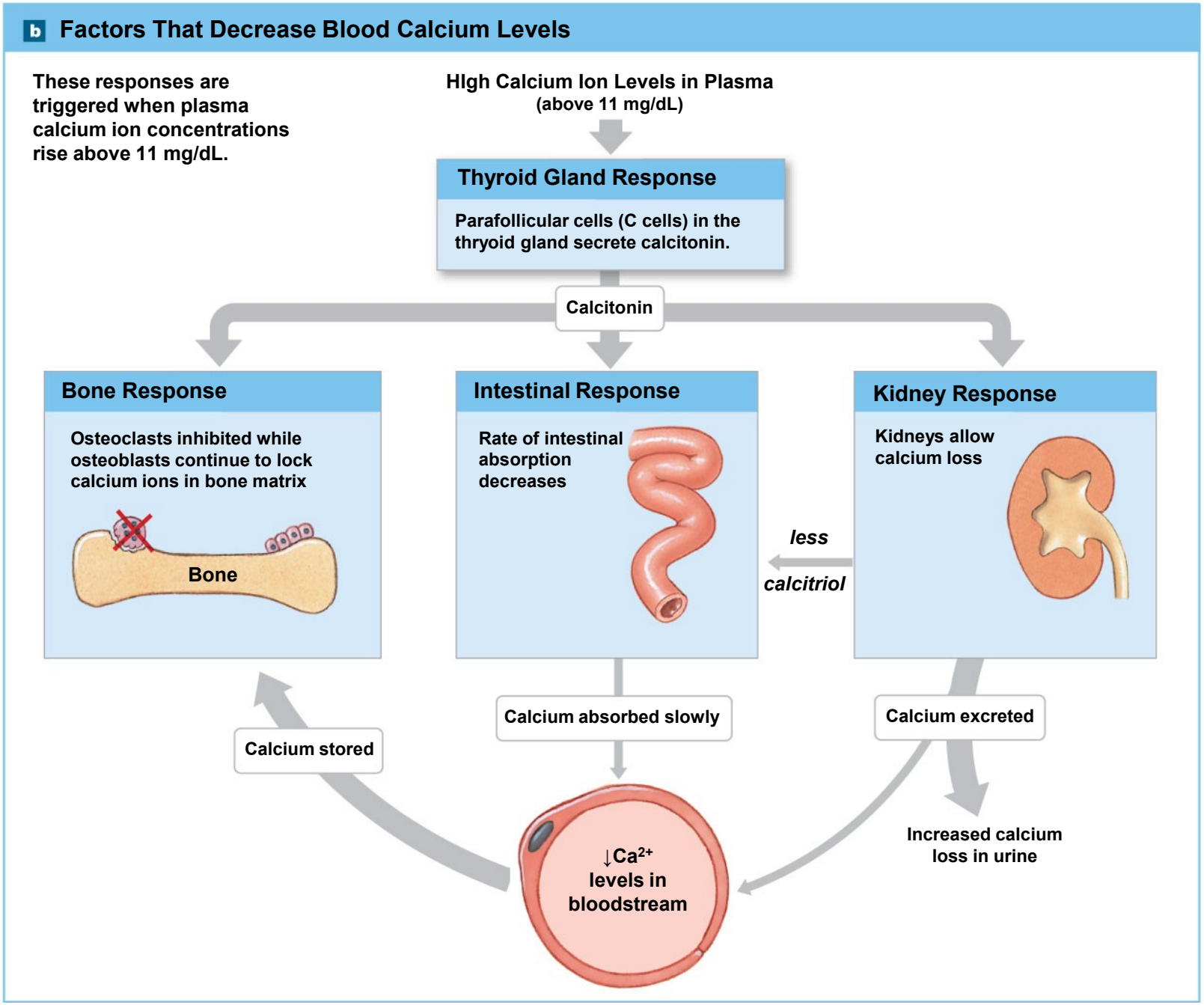


Figure 6-16b Factors That Alter the Concentration of Calcium Ions in Body Fluids



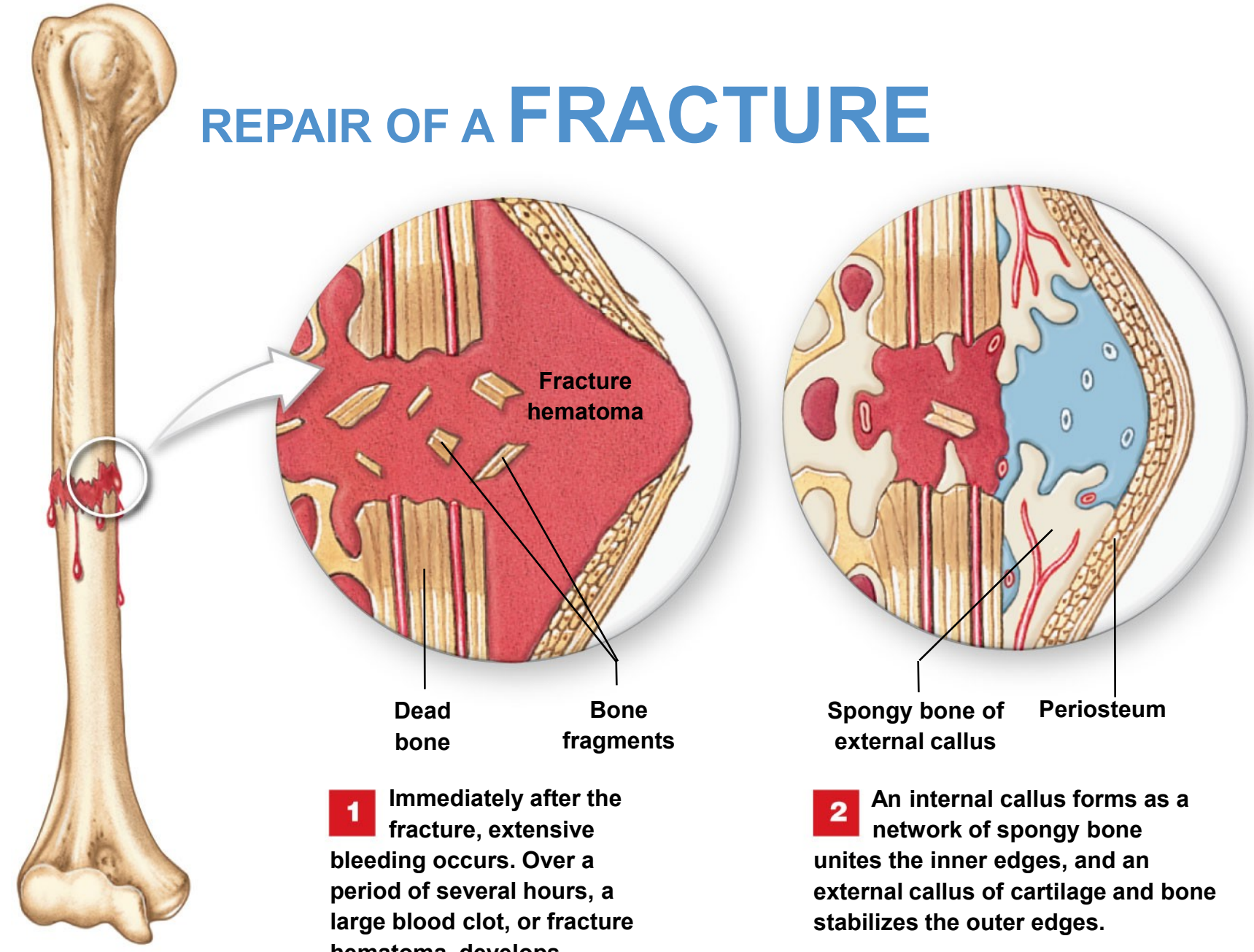
6-9 Fractures

- Fractures
  - Cracks or breaks in bones
  - Caused by physical stress
- Fractures are repaired in four steps
  1. Bleeding
  2. Cells of the endosteum and periosteum
  3. Osteoblasts
  4. Osteoblasts and osteocytes remodel the fracture for up to a year

6-9 Fractures

- Bleeding
  - Produces a clot (**fracture hematoma**)
  - Establishes a fibrous network
  - Bone cells in the area die
- Cells of the endosteum and periosteum
  - Divide and migrate into fracture zone

Figure 6-17 Types of Fractures and Steps in Repair

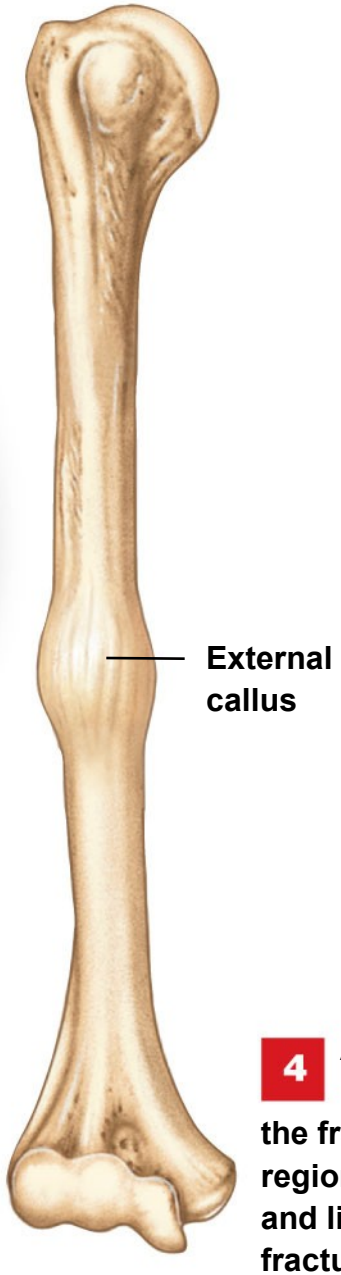


6-9 Fractures

- Osteoblasts
  - Replace central cartilage of external callus
  - With spongy bone
- Osteoblasts and osteocytes remodel the fracture for up to a year
  - Reducing bone calluses

Figure 6-17 Types of Fractures and Steps in Repair

3 The cartilage of the external callus has been replaced by bone, and struts of spongy bone now united the broken ends. Fragments of dead bone and the areas of bone closest to the break have been removed and replaced.



4 A swelling initially marks the location of the fracture. Over time, this region will be remodeled, and little evidence of the fracture will remain.

6-10 Effects of Aging on the Skeletal System

- Age-Related Changes
  - Bones become thinner and weaker with age
    - **Osteopenia** begins between ages 30 and 40
    - Women lose 8% of bone mass per decade, men 3%
  - The epiphyses, vertebrae, and jaws are most affected
    - Resulting in fragile limbs
    - Reduction in height
    - Tooth loss

6-10 Effects of Aging on the Skeletal System

- **Osteoporosis**
  - Severe bone loss
  - Affects normal function
  - Over age 45, occurs in:
    - **29% of women**
    - **18% of men**