

Skeletal System

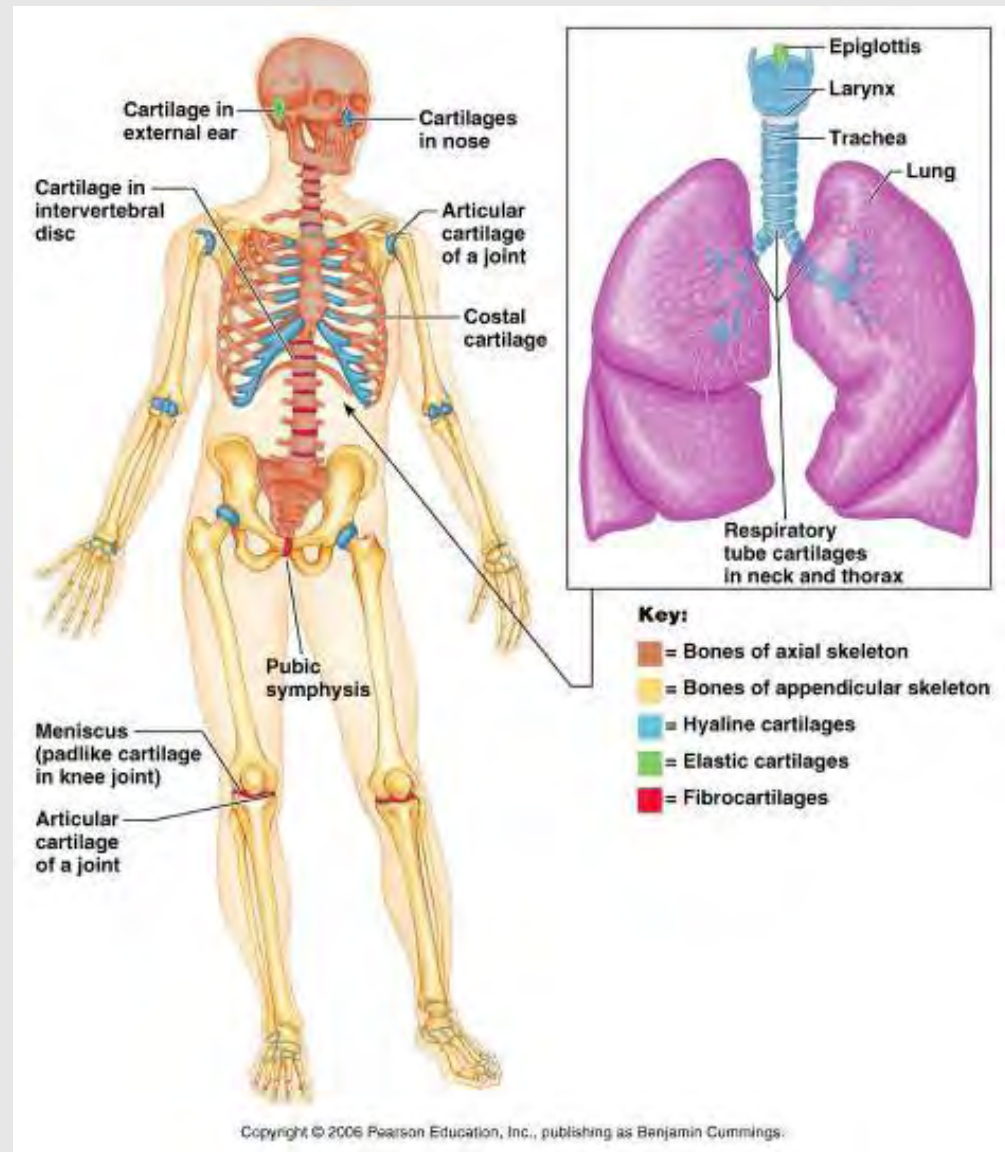
Structure, Function &
Malfunction

Functions of the Skeletal System

1. Support
2. Storage of minerals (Ca^{2+})
3. Storage of lipids (yellow marrow)
4. Blood cell production (red marrow)
5. Protection (heart & lungs enclosed in rib cage)
6. Leverage (force of motion)

Overview

- Components:
 - **Bones**
 - **Cartilages**
 - Shock absorber
 - **Ligaments**
 - Bind bone to bone
 - **Tendons**
 - Bind bone to muscle



Skeletal system

- **All components are connective tissues**
- **Extracellular matrix determines characteristic of CT**
 - H_2O
 - **Collagen** - tough, cordlike protein (what type of common microstructure should these proteins have?)
 - **Proteoglycans** - polysaccharide "barbs" surrounding protein core (trap H_2O)
 - **Minerals** - Ca^{2+} , P, Mg, S

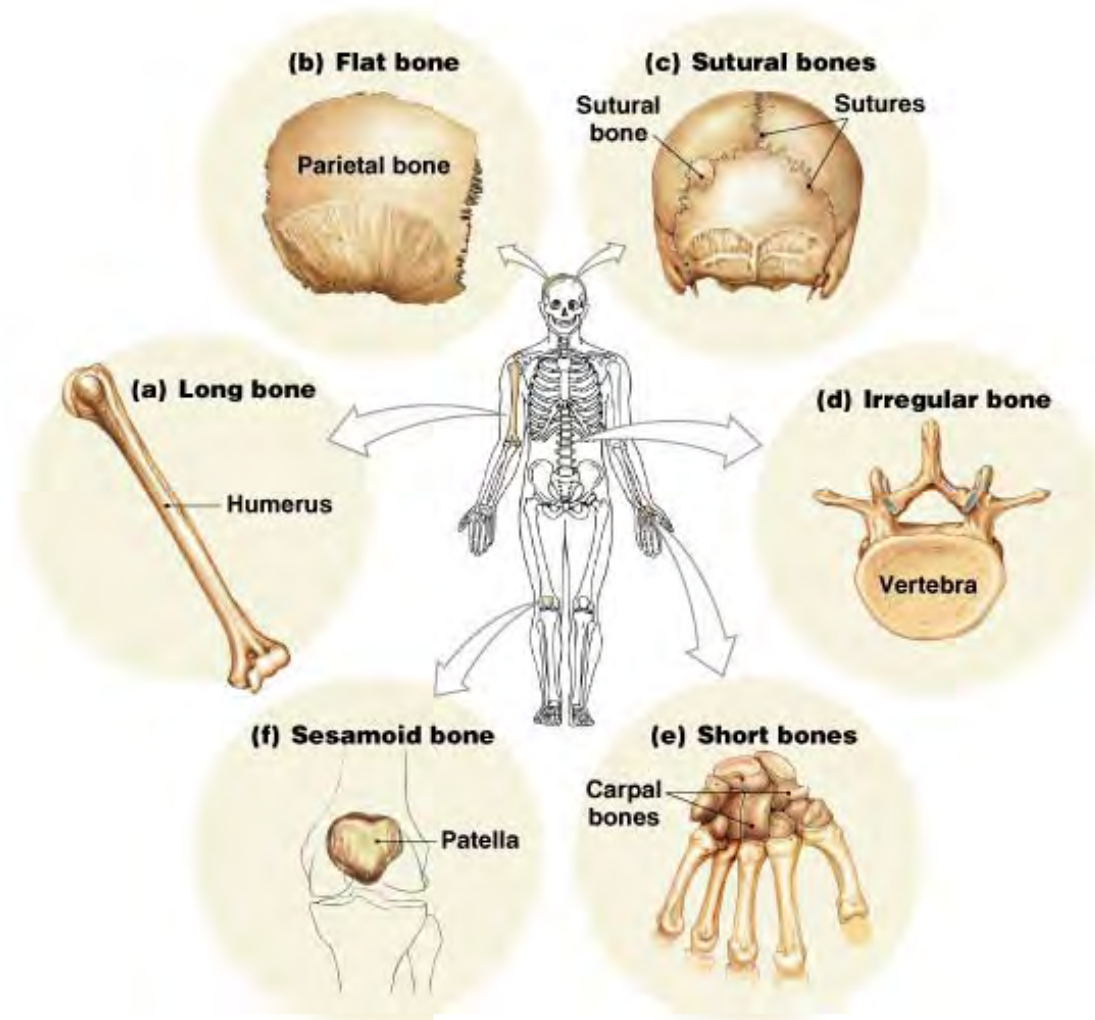
Who's got what?

- **Tendons & ligaments** - mostly collagen; makes them tough; withstand tensile forces
- **Cartilage** - Collagen and proteoglycans; tough, but smooth and resilient
- **Bones** - collagen and minerals (Ca^{2+} , P; hydroxyapatite crystals) make it resistant to compression, but flexible

Classification of Bones

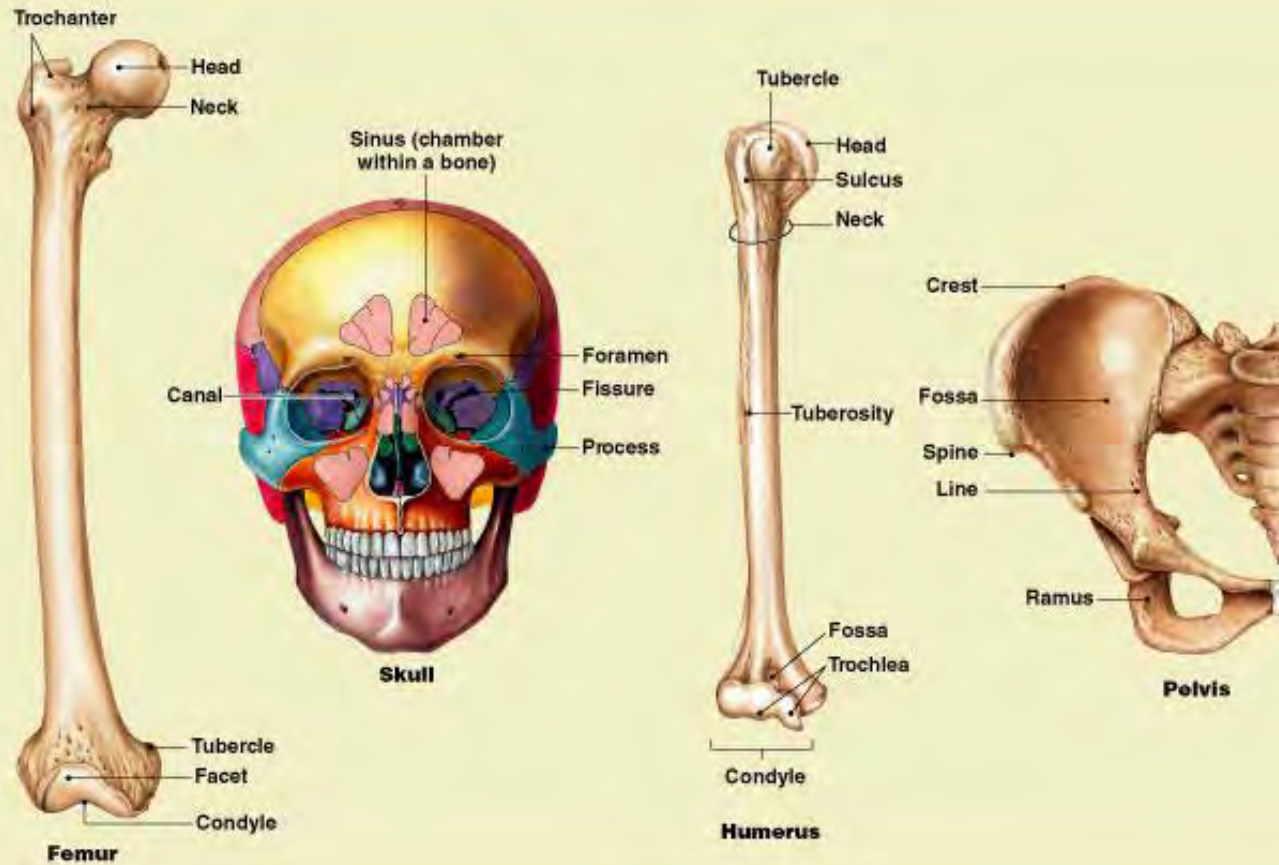
- Identified by:
 - Shape
 - Bone markings
 - Internal arrangement

Bone Shapes



Bone surface features

TABLE 6-1 An Introduction to Bone Surface Features



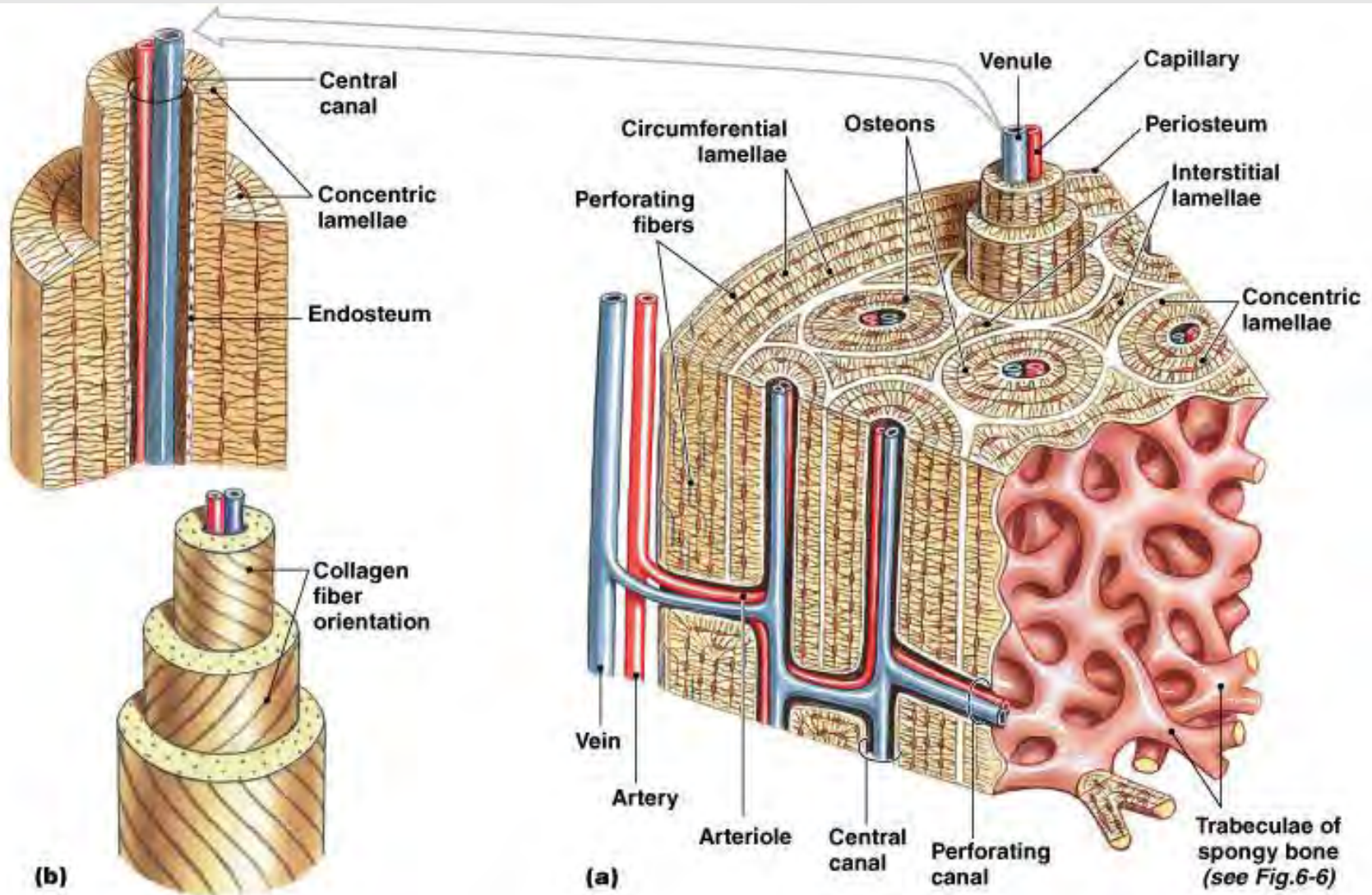
Internal Arrangement: *Compact bone* *vs. spongy bone*

What is their arrangement,
where do they occur, what does
each do?

Compact Bone

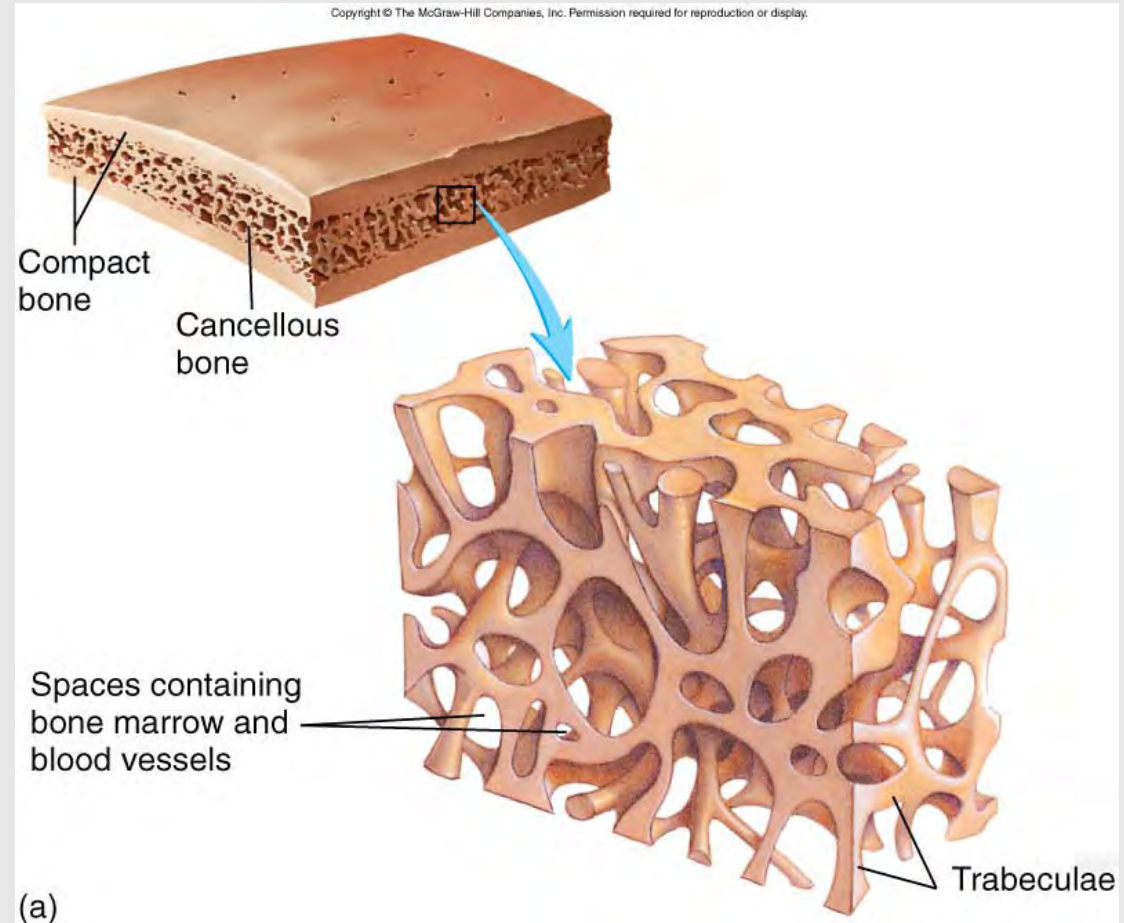
- Composed of **osteons (haversian system)**: Basic unit of mature compact bone
 - **Osteocytes**: mature bone cells arranged in **concentric lamellae (layers)**
 - Surround a **central canal** containing blood vessels (deliver nutrients [like what?]; remove waste)

Compact Bone (x.s. & l.s.)



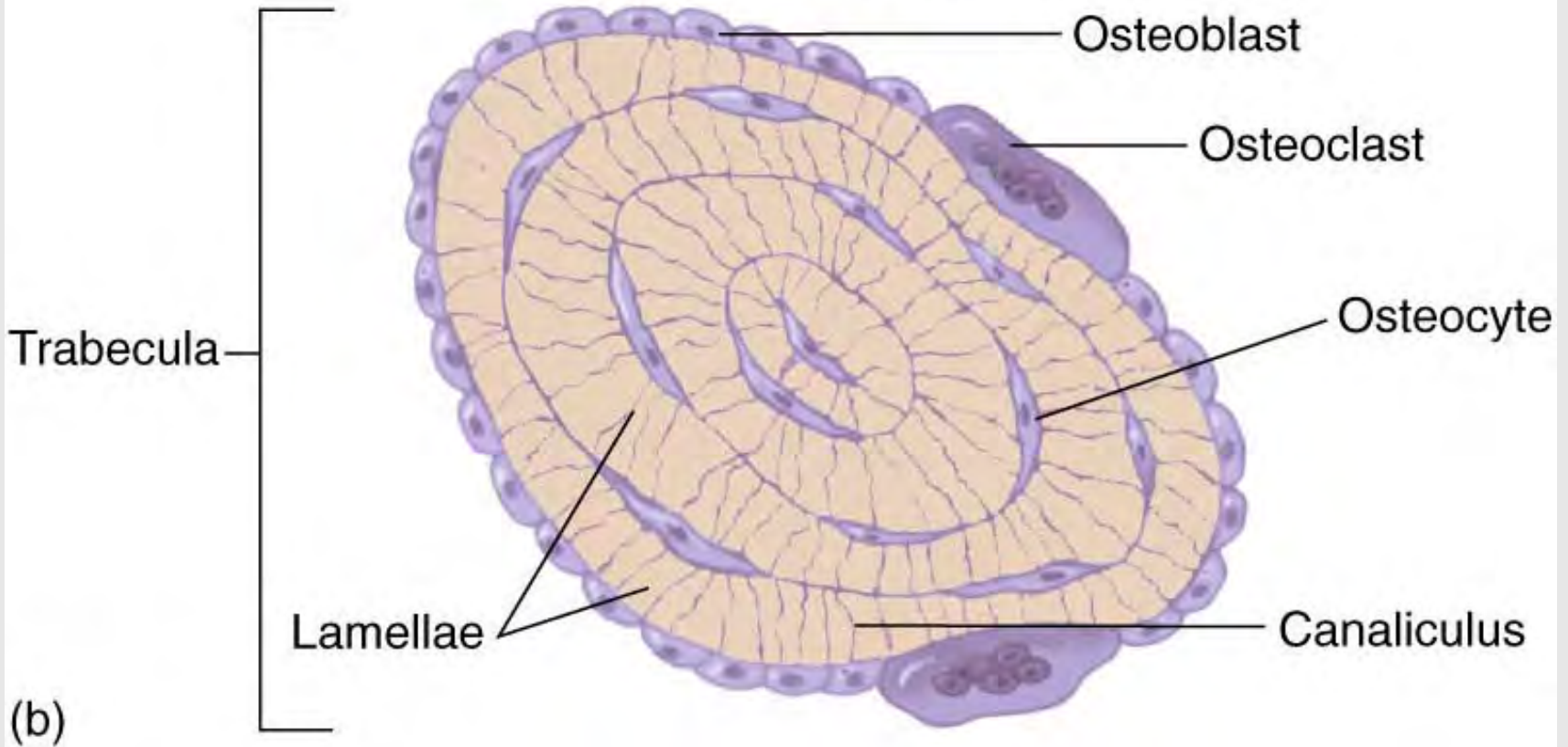
Spongy (Cancellous) Bone

- NO osteons
- Matrix forms open network of **trabeculae**
- Trabeculae **NOT** vascularized



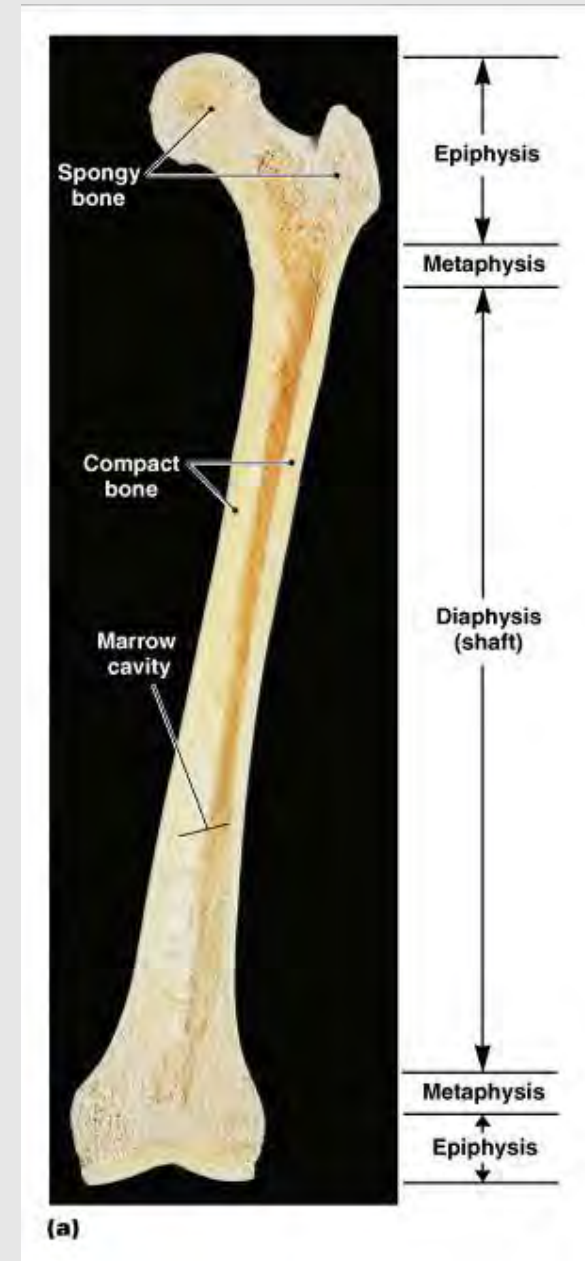
Spongy (Cancellous) Bone

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



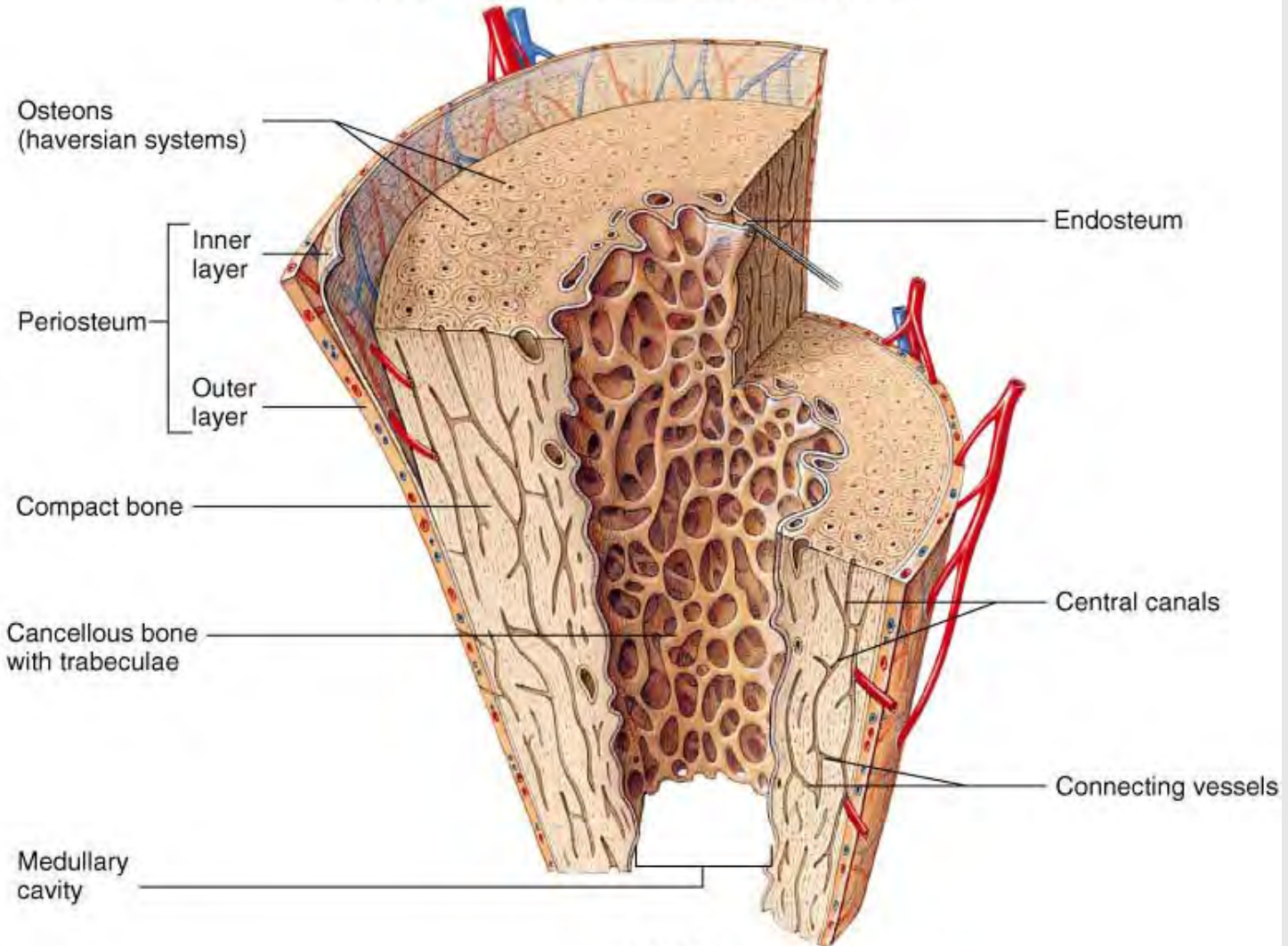
Long Bones

- **Diaphysis:**
 - the shaft
- **Epiphysis:**
 - wide part at each end
 - articulates with other bones
- Outer layer = compact bone
- Inner layer = spongy bone



Internal structure

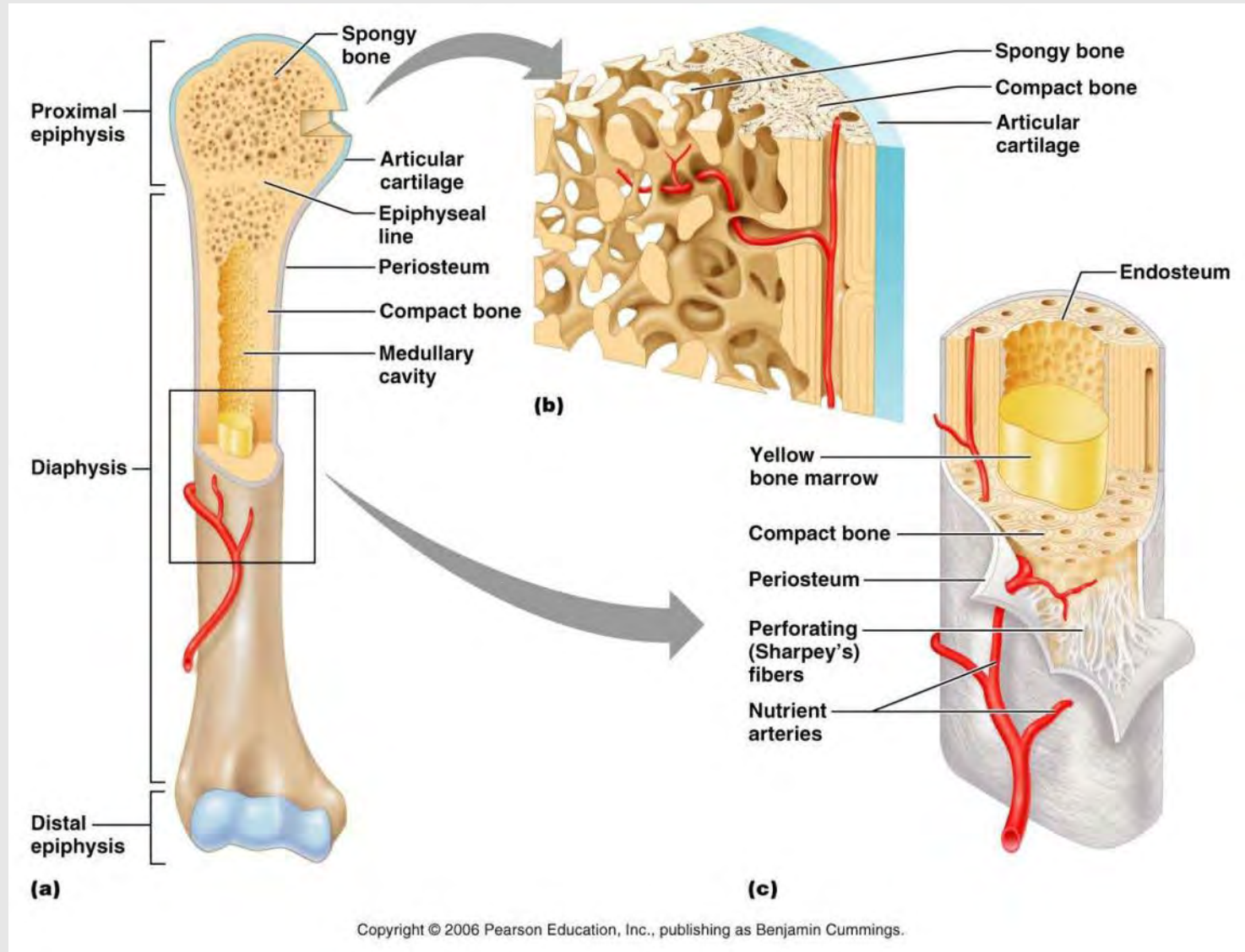
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



(c)

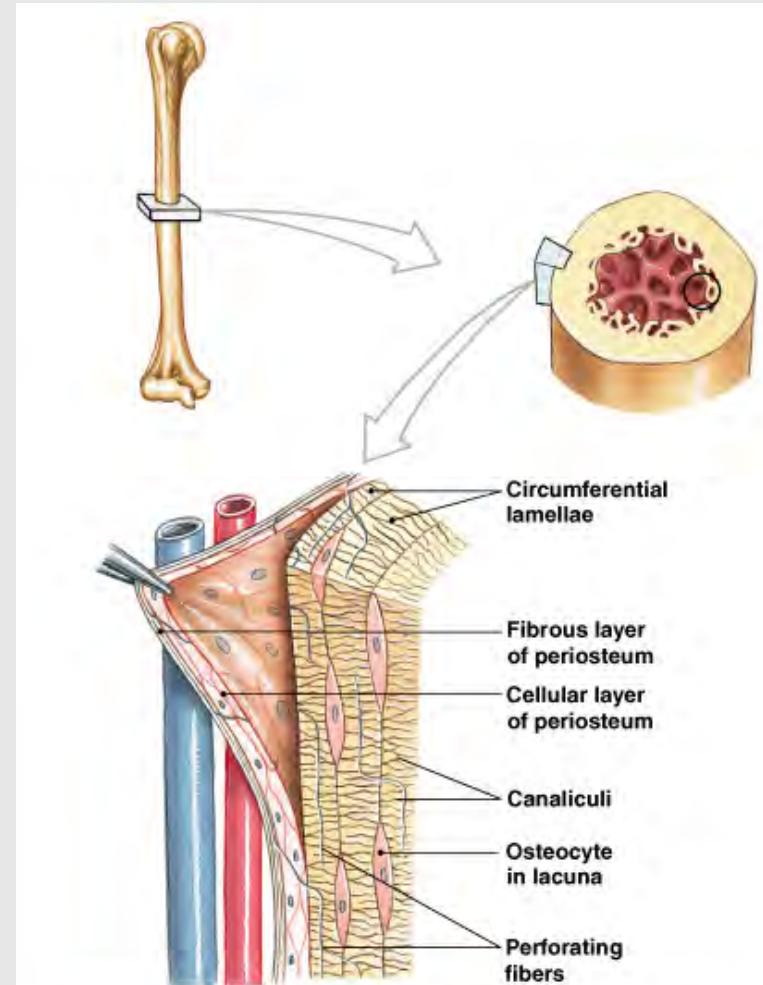
Adult bone

Internal structure



Arrangement of Bone

- **Dense matrix**, containing:
 - deposits of Ca^{2+} salts
 - Osteocytes within **lacunae** surrounding blood vessels
- **Canaliculi**:
 - pathways for osteocyte connections
- **Periosteum**:
 - covers **outer** surface of bone
 - Has an outer *fibrous* + inner *cellular* layer



(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.

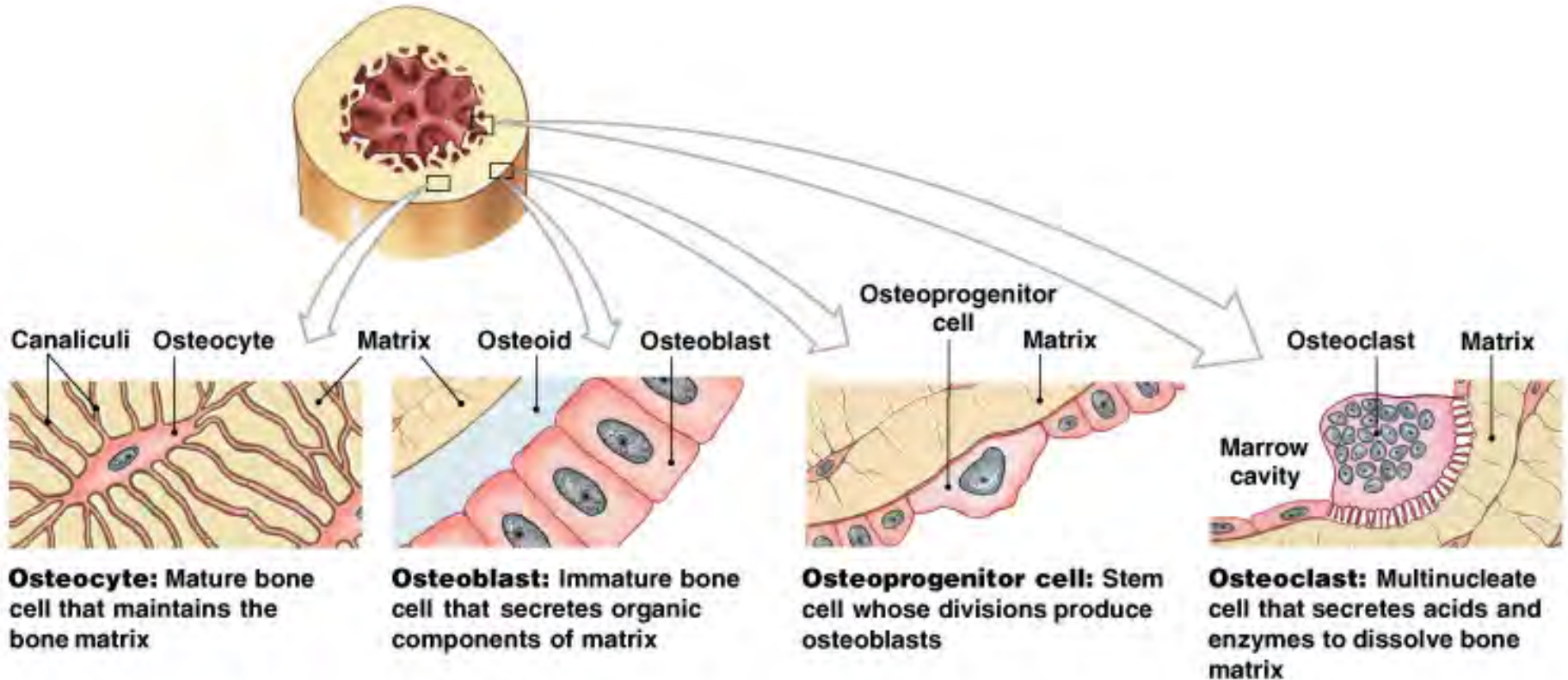
Matrix = Minerals + Proteins

- 2/3 of bone *matrix* is calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$
 - calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$ + calcium hydroxide, $\text{Ca}(\text{OH})_2$ = hydroxyapatite, $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$
 - Which adds other calcium salts and ions
- 1/3 of bone *matrix* is protein fibers (collagen)

Bone Cells

- Only 2% of bone mass:
 - **Osteocytes** - mature cells; maintain matrix; stimulate deposition of hydroxyapatite
 - **Osteoblasts** - produce *organic* products of matrix (**collagen**)
 - **Osteoprogenitor** cells - produce osteoblasts; fracture repair
 - **Osteoclasts** - remove and recycle matrix; derived from germ cells

Bone Cells



Red & Yellow Marrow

- Medullary cavity filled with **red bone marrow**:
 - has blood vessels
 - forms red blood cells (RBC)
 - supplies nutrients to osteocytes
- As we age, **yellow marrow** replaces most red marrow in distal bones:
 - stores FAT

Periosteum and Endosteum

- Compact bone is covered with membranes:
 - **periosteum** outer layer
 - **endosteum** inner layer

Flat Bones

- Ex: the parietal bone of the skull
- sandwich of spongy bone between 2 layers of compact bone

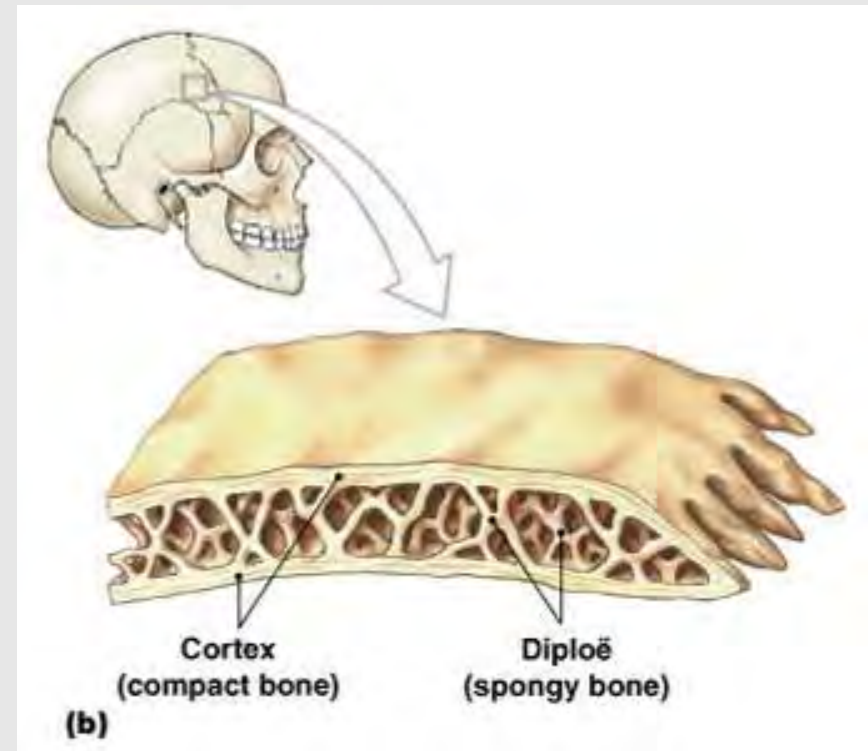


Figure 6-2b

Functions of the Skeletal System

1. Support
2. Storage of minerals (Ca^{2+})
3. Storage of lipids (yellow marrow)
4. Blood cell production (red marrow)
5. Protection (heart & lungs in rib cage)
6. Leverage (force of motion)

Homeostasis

- Bone building, by **osteocytes**, and bone recycling, by **osteoclasts**, must balance:
 - If more breakdown than building, then bones become weak
 - Exercise induces osteocytes to build bone
 - See article for more

*intramembranous vs.
endochondral ossification*

Ossification

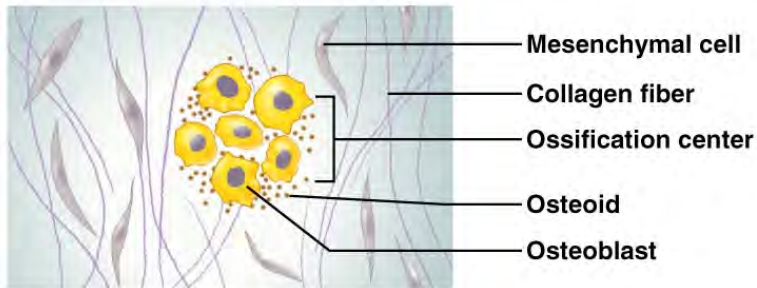
- Formation of bone by **osteoblasts**
- 2 main forms of ossification:
 - intramembranous ossification
 - endochondral ossification



Intramembranous Ossification

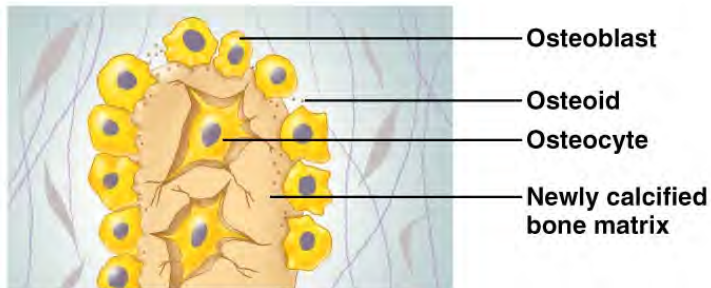
- Also called **dermal ossification**
 - produces **dermal bones** such as cranial bones and clavicle
- Forms bone within connective tissue membranes
 - Ex: bones of the skull
- 3 steps in intramembranous ossification

Intramembranous Ossification



① **An ossification center appears in the fibrous connective tissue membrane.**

- Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center.

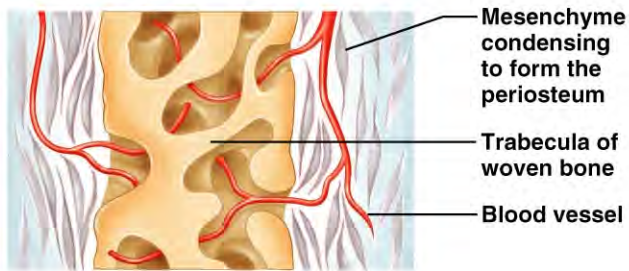


② **Bone matrix (osteoid) is secreted within the fibrous membrane.**

- Osteoblasts begin to secrete osteoid, which is mineralized within a few days.
- Trapped osteoblasts become osteocytes.

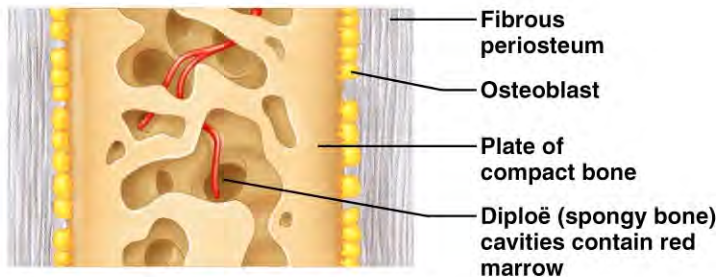
- Osteoprogenitor cells aggregate:
 - differentiate into osteoblasts (ossification center)
 - Osteoblasts secrete organic matrix (what is that?)
 - develop projections of trabeculae

Intramembranous Ossification:



③ Woven bone and periosteum form.

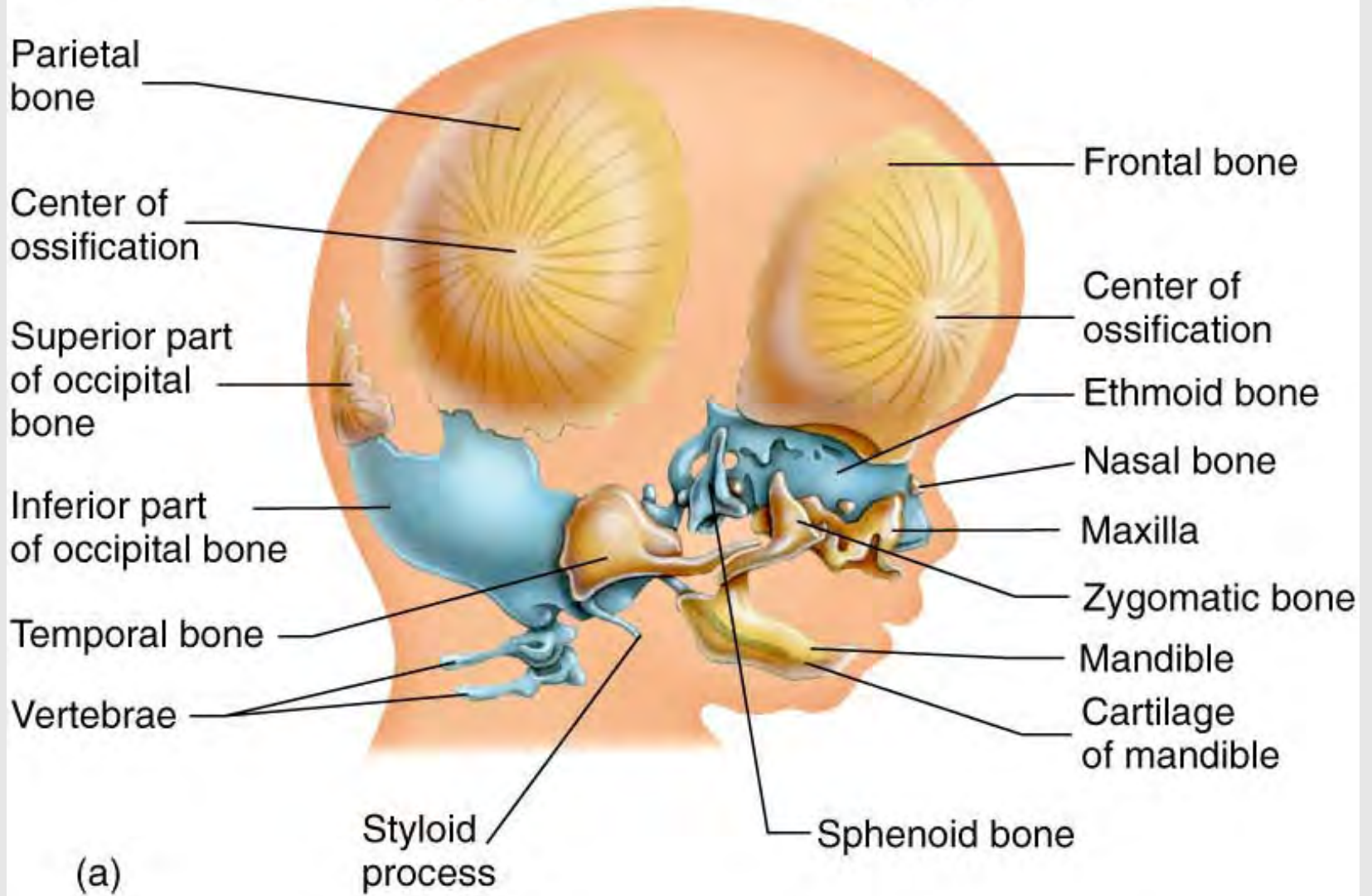
- Accumulating osteoid is laid down between embryonic blood vessels, which form a random network. The result is a network (instead of lamellae) of trabeculae.
- Vascularized mesenchyme condenses on the external face of the woven bone and becomes the periosteum.



④ Bone collar of compact bone forms and red marrow appears.

- Trabeculae just deep to the periosteum thicken, forming a woven bone collar that is later replaced with mature lamellar bone.
- Spongy bone (diploë), consisting of distinct trabeculae, persists internally and its vascular tissue becomes red marrow.

- Blood vessels invade area; supply osteoblasts with nutrients
- Trabeculae connect:
 - trap blood vessels inside bone
- Resulting spongy bone is remodeled into:
 - osteons of compact bone
 - periosteum
 - or marrow cavities



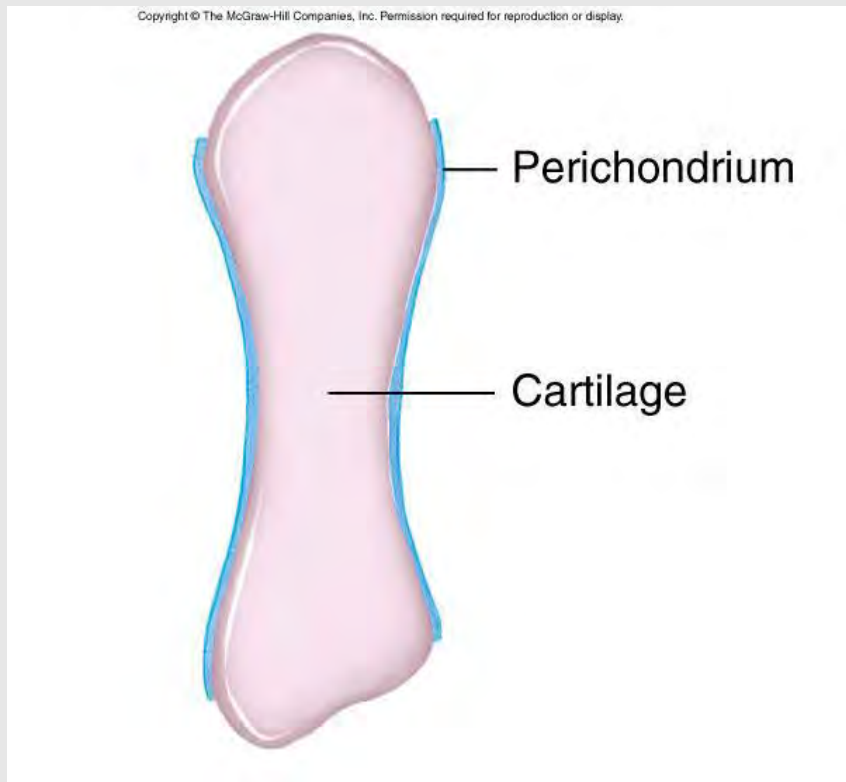
*How does bone form and
grow?*

Endochondral Ossification

- Growth and ossification of long bones
- Begins with *hyaline cartilage model*
- Proceeds via expansion of cartilage matrix (**interstitial growth**) and production of new cartilage at outer surface (**appositional growth**).

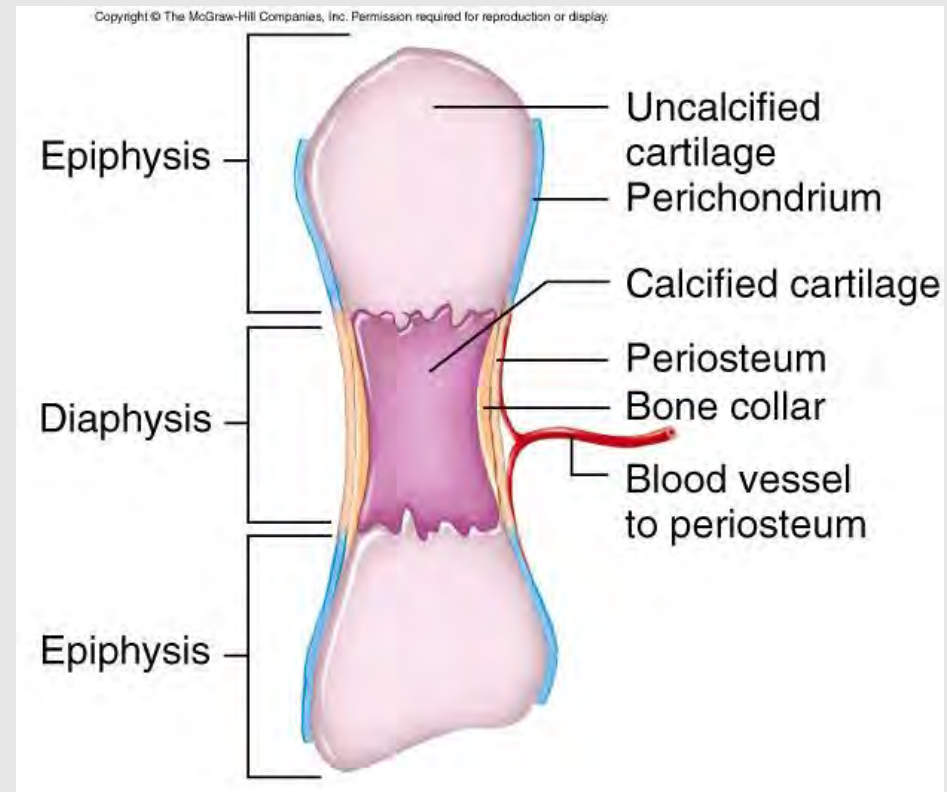
Endochondral Ossification

- **Chondrocytes** in the center of hyaline cartilage:
 - enlarge
 - form struts & calcify
 - die, leaving cavities in cartilage



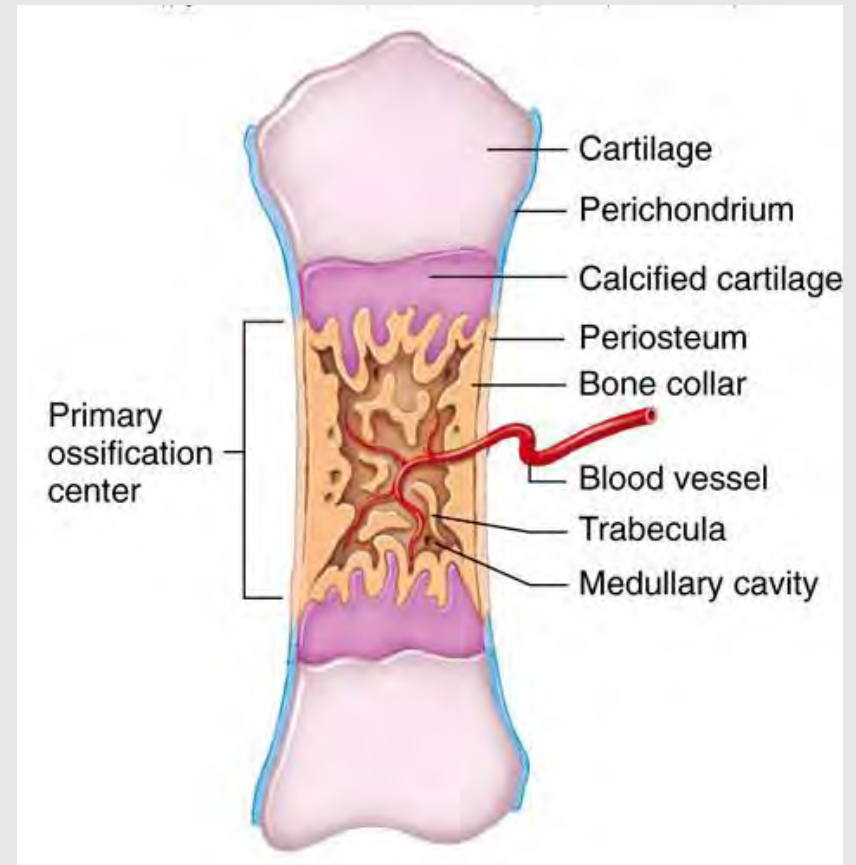
Endochondral Ossification

- Blood vessels surround edges of cartilage
- Fibroblasts of perichondrium become osteoblasts:
 - Produce layer of superficial bone around shaft
 - Eventually becomes compact bone (appositional growth)

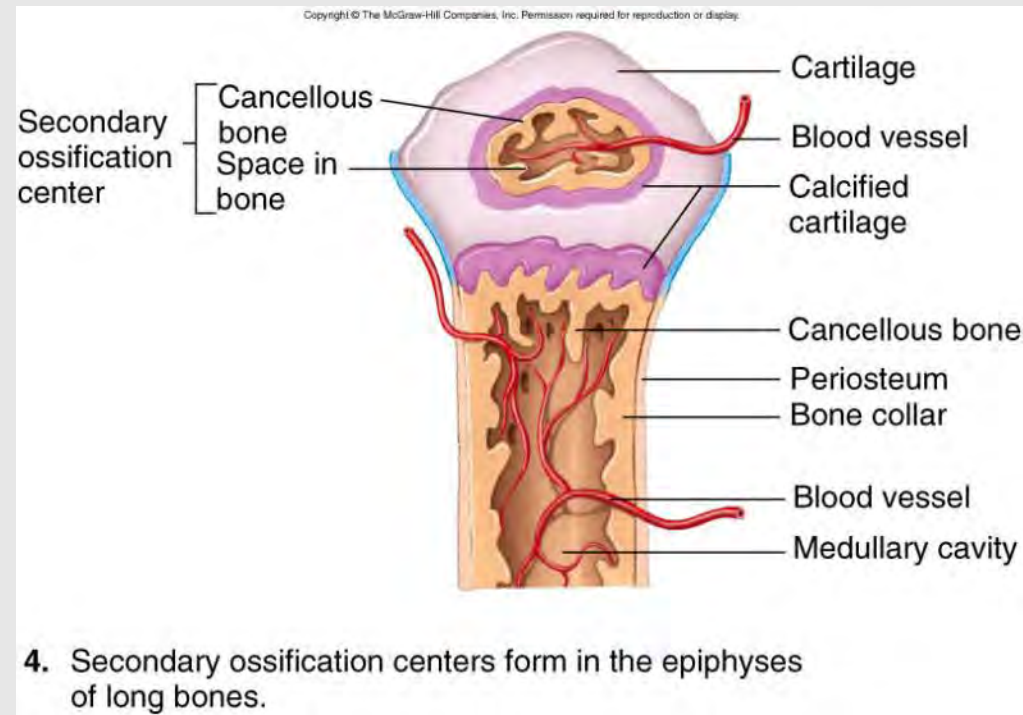


Endochondral Ossification

- Blood vessels enter the cartilage:
 - bring fibroblasts that become osteoblasts
 - spongy bone develops at the **primary ossification center**



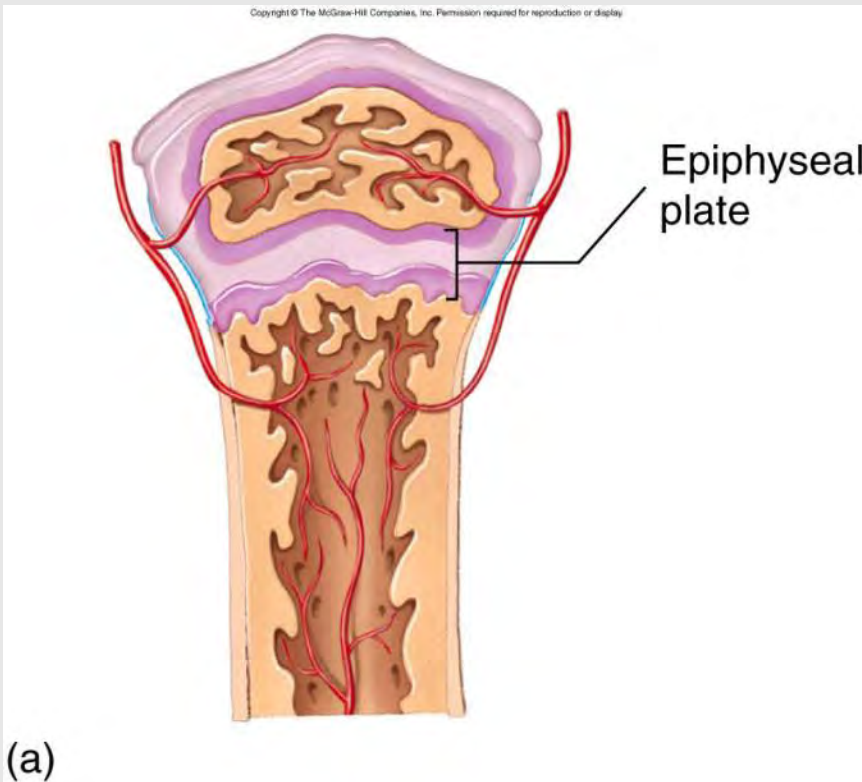
Endochondral Ossification:



- Remodeling creates a **marrow cavity**:
 - bone replaces cartilage at the **metaphyses**
- Capillaries and osteoblasts enter the epiphyses:
 - create **secondary ossification centers**

Endochondral Ossification:

- Epiphyses fill with spongy bone:
 - cartilage within joint cavity is **articular cartilage**
 - cartilage at metaphysis is **epiphyseal cartilage**



Bones Grow via E.O.

1. New cartilage produced on epiphyseal side of plate
2. Chondrocytes mature & enlarge
3. Matrix calcifies; chondrocytes die
4. Cartilage on diaphyseal side replaced by bone

