Skeletal System

Biology 260

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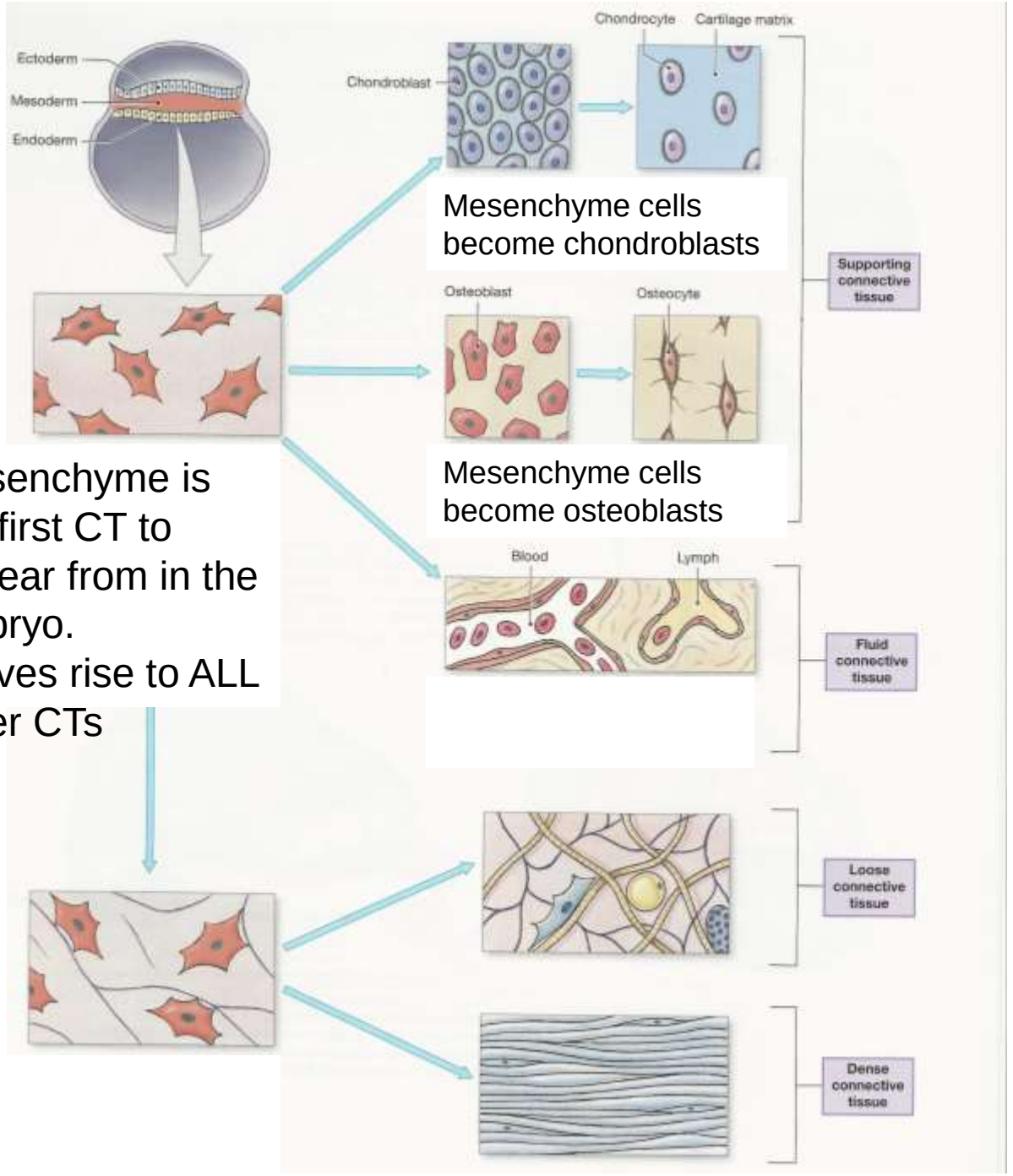
Embryonic Development



Mesenchyme is the first CT to appear from in the embryo.
It gives rise to ALL other CTs

Embryonic CT develops as when more fibers start to appear. Gives rise to

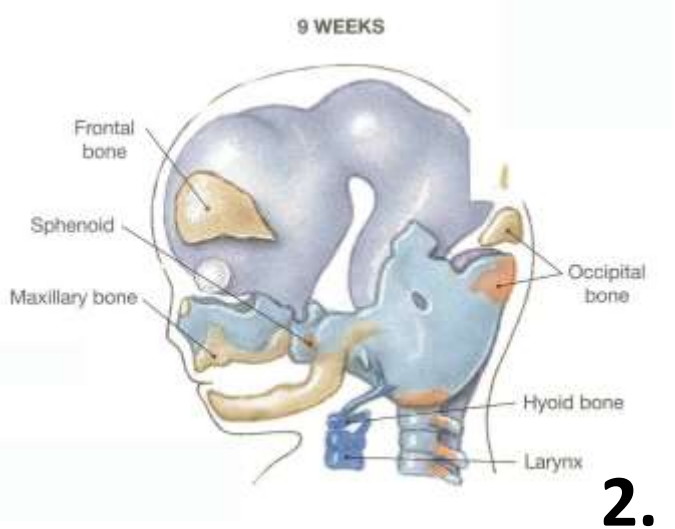
Development of the Skeletal System

- **Ossification** (**osteogenesis**) - process of bone tissue formation

- Timing of Events:
  - **Embryonic (FETAL)** bone development
    - Two Types: **Endochondral** & **Intramembranous**
  - **Postnatal** = bone development & growth until adulthood
  - **Adulthood** = NO GROWTH but bones are remodeled
    - Blood calcium levels
    - Mechanical stress caused by muscles or gravity

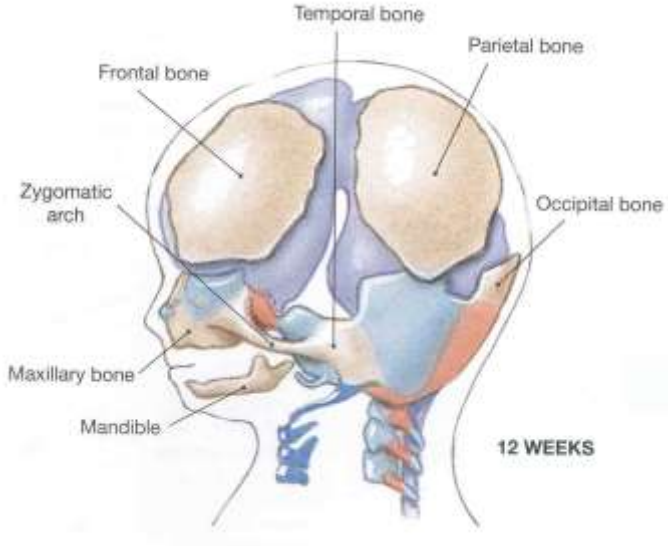
Types of Fetal Bone Development

1. Intramembranous ossification

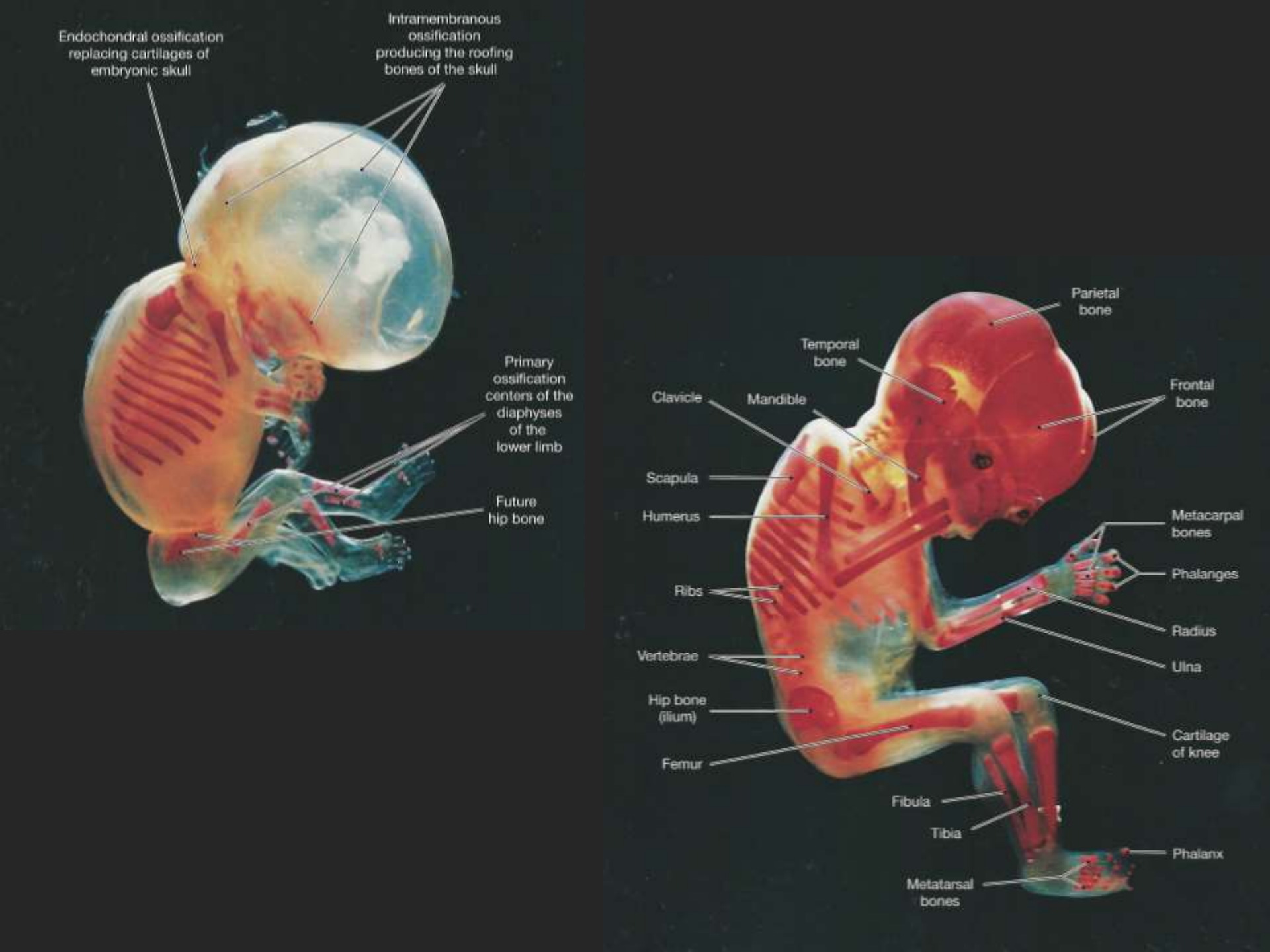


- Bone replaces *mesenchymal membrane* composed of embryonic connective tissue
- Bones are called **membrane bones**
- Skull and clavicle only

2. Endochondral ossification

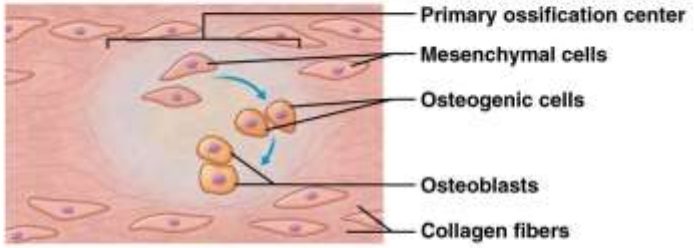


- Mesenchyme creates hyaline cartilage models
- Hyaline cartilage is replaced by bone
- Bones are called **cartilage** (**endochondral**) **bones**
- Forms most of the bones of the skeleton

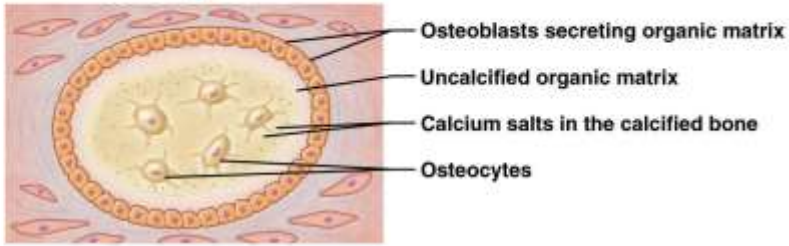

Endochondral ossification replacing cartilages of embryonic skull
Intramembranous ossification producing the roofing bones of the skull
Primary ossification centers of the diaphyses of the lower limb
Future hip bone
Parietal bone
Temporal bone
Frontal bone
Clavicle
Mandible
Scapula
Humerus
Metacarpal bones
Phalanges
Ribs
Radius
Ulna
Vertebrae
Hip bone (ilium)
Cartilage of knee
Femur
Fibula
Tibia
Phalanx
Metatarsal bones

Intramembranous Ossification

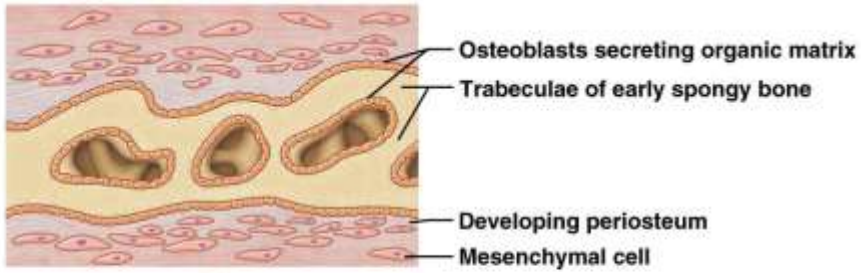
1. Osteoblasts develop in the primary ossification center.



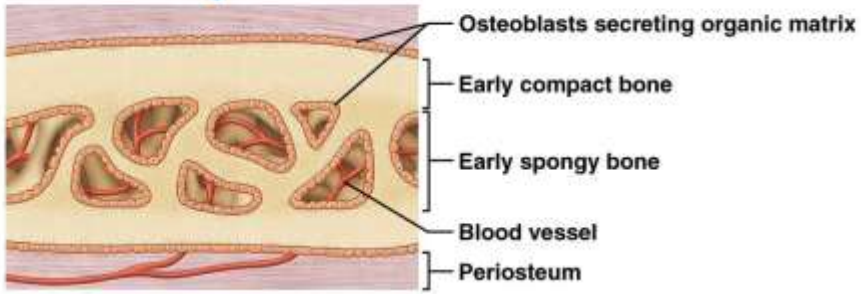
2. Osteoblasts secrete organic matrix, which calcifies.



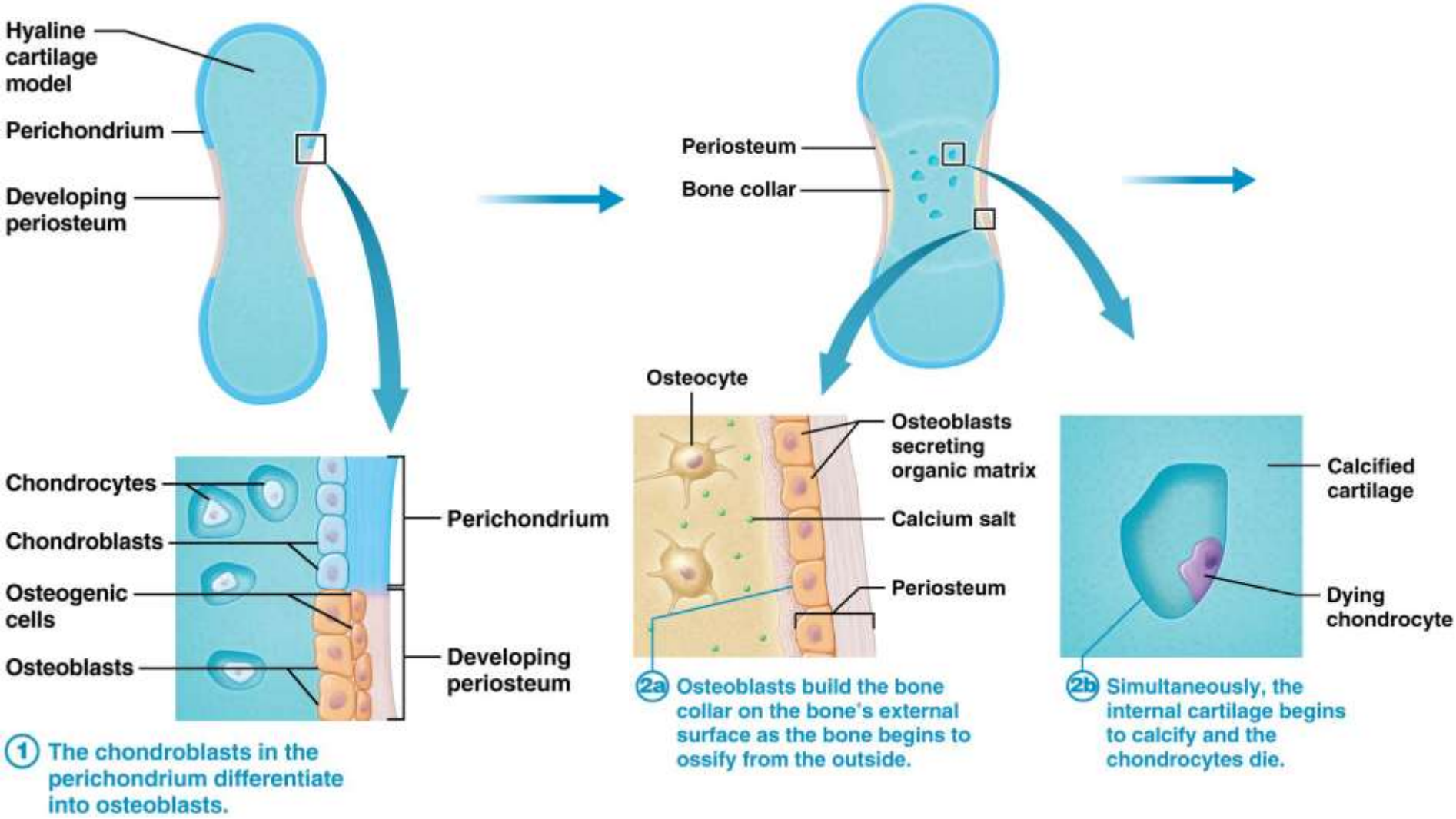
3. Early spongy bone is formed.



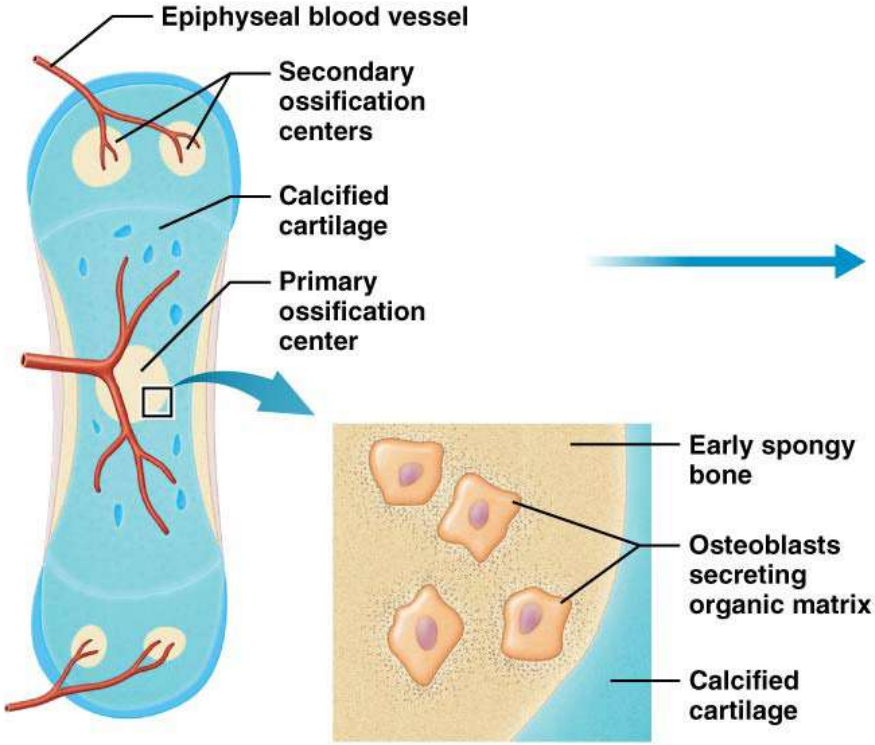
4. Early compact bone is formed.



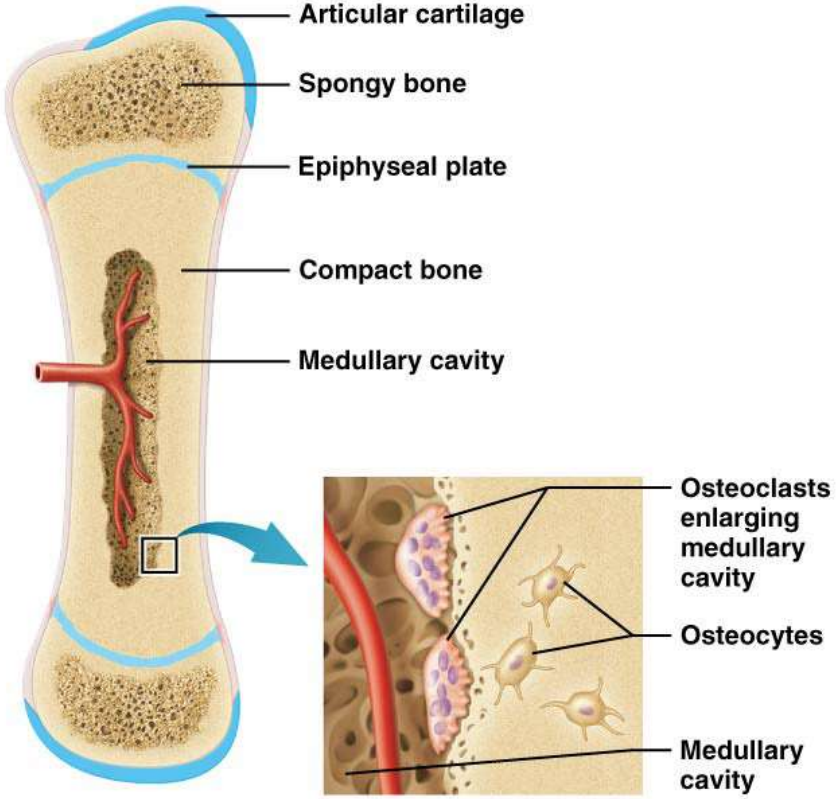
Endochondral Ossification



Endochondral Ossification



3 In the primary ossification center, osteoblasts replace the calcified cartilage with early spongy bone; the secondary ossification centers and medullary cavity develop.

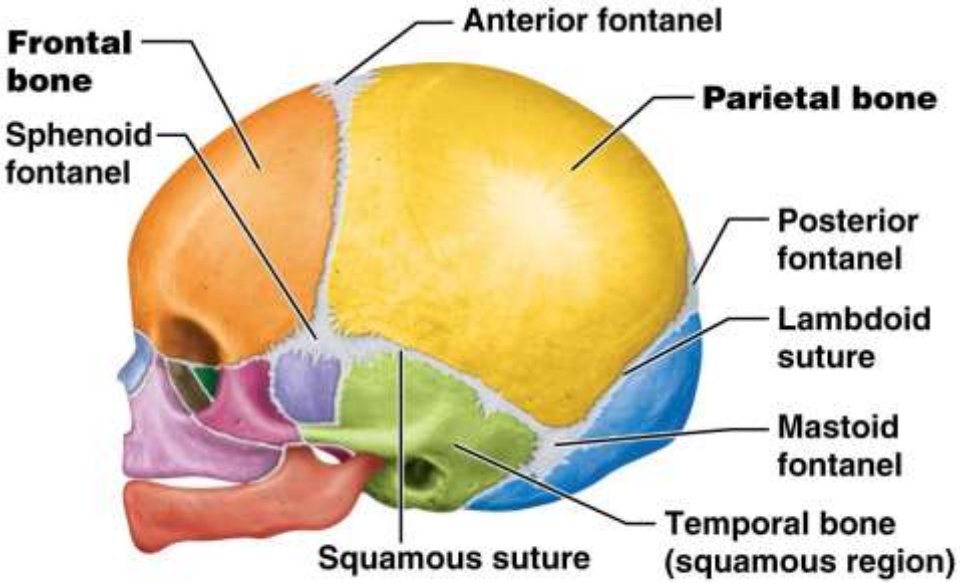


4 As the medullary cavity enlarges, the remaining cartilage is replaced by bone; the epiphyses finish ossifying.

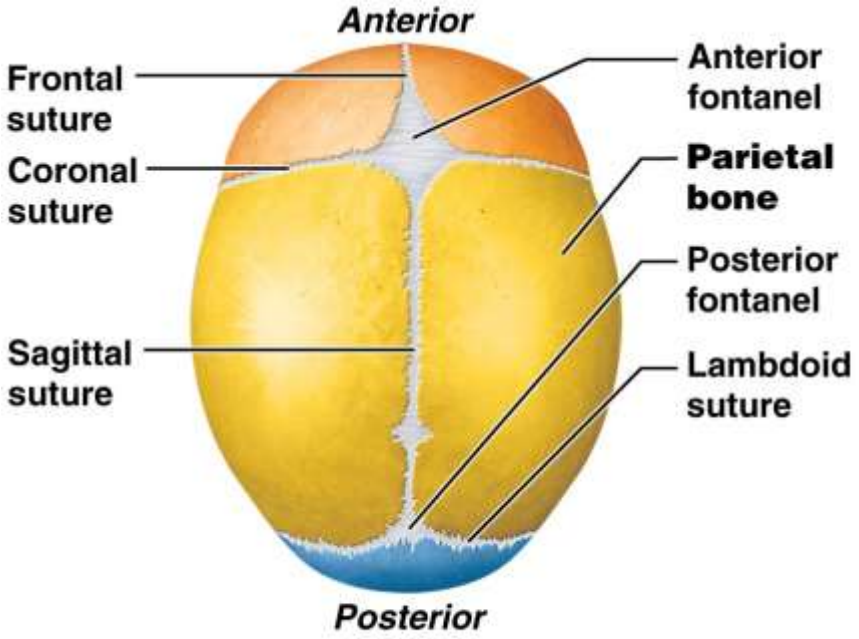
Infant Skull

- Infant skull has more bones than adult skull
  - Skull bones such as mandible and frontal bones are unfused
  - Skull bones connected by sutures and **fontanelles**
    - Remnants of fibrous membranes
    - Ease birth and allow brain growth

Infant Skull



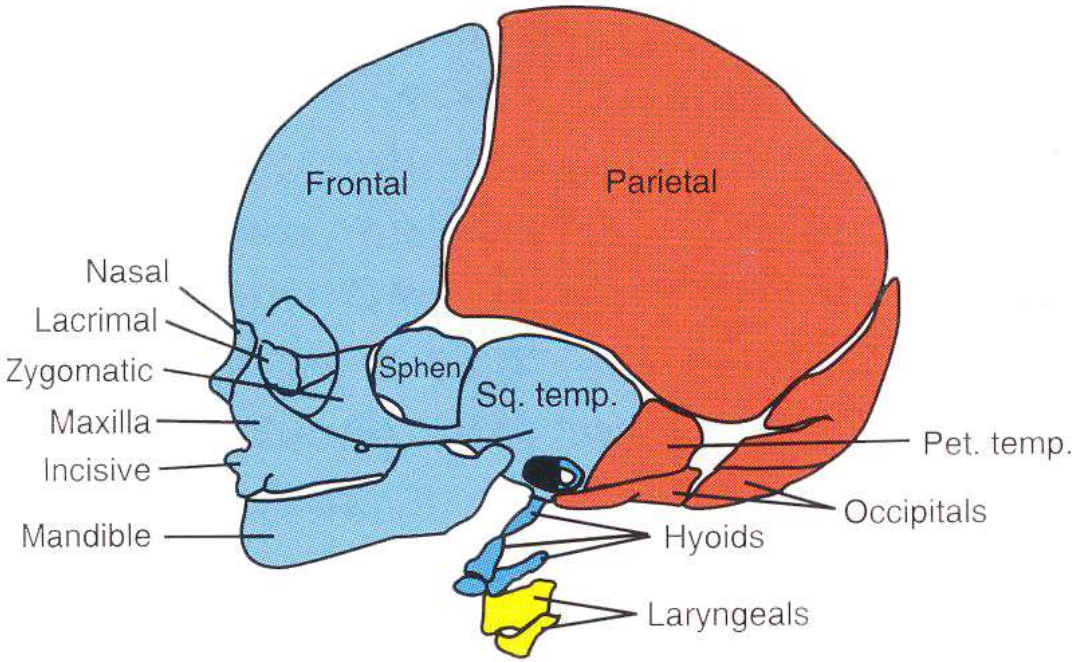
(a) Fetal skull, lateral view

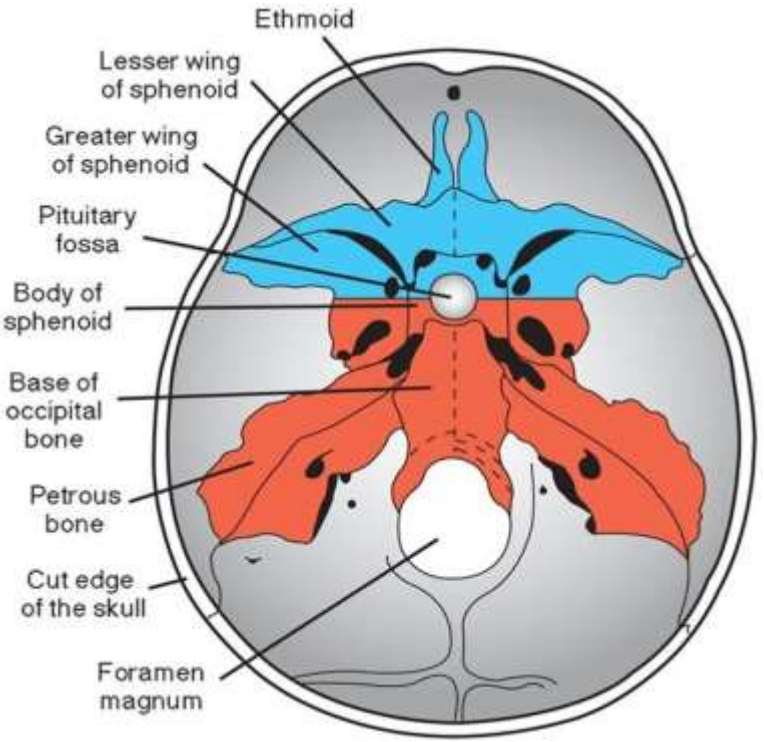


(b) Fetal skull, superior view

Embryological Derivation	Mode of Formation	Germ Layer Origin.	BONES
Chondrocranium = Cartilage bones base of skull / braincase	Endochondral	Neural crest	Ethmoid Sphenoid - lesser wing
		Mesoderm	Sphenoid – base Temporal - petrous portion Occipital - base
Dermatocranium = membrane bones flat bones of skull	Intramembranous	Neural crest	Nasal Lacrimal Zygomatic Temporal - squamous portion Vomer Maxilla Palatine Mandible Frontal
		Mesoderm	Parietal (M) Occipital; squamous portion (M)
Splanchnocranium = gill arch bones	Endochondral	Neural crest	Sphenoid - greater wing Temporal - styloid process Middle Ear Ossicles Hyoid

Fetal Bone Development





Red: Mesoderm

Blue: Ectoderm - Neural crest

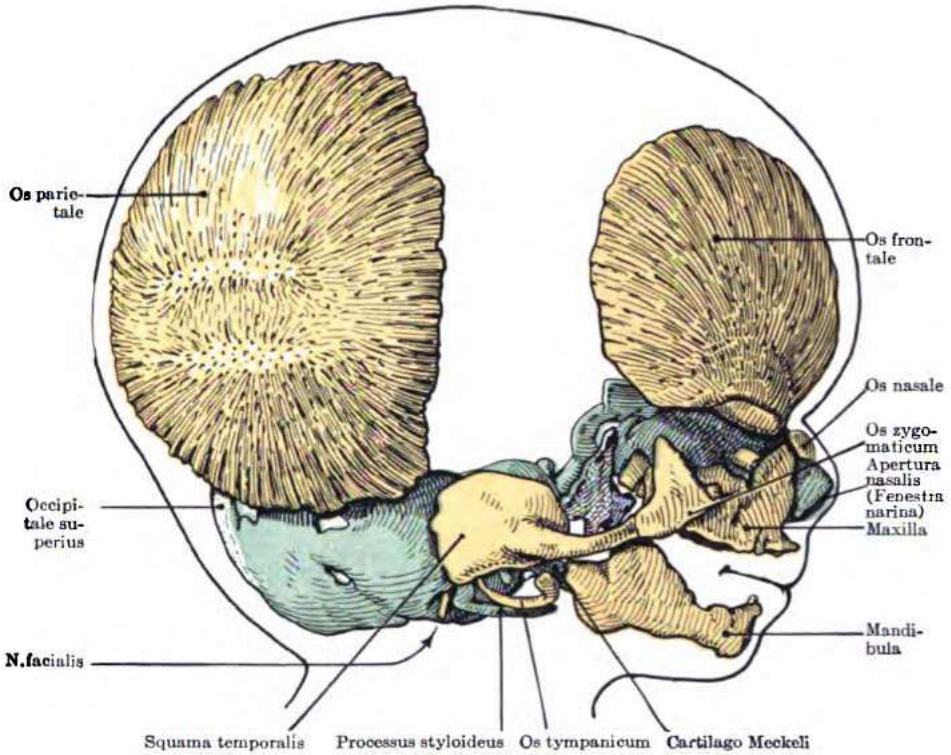
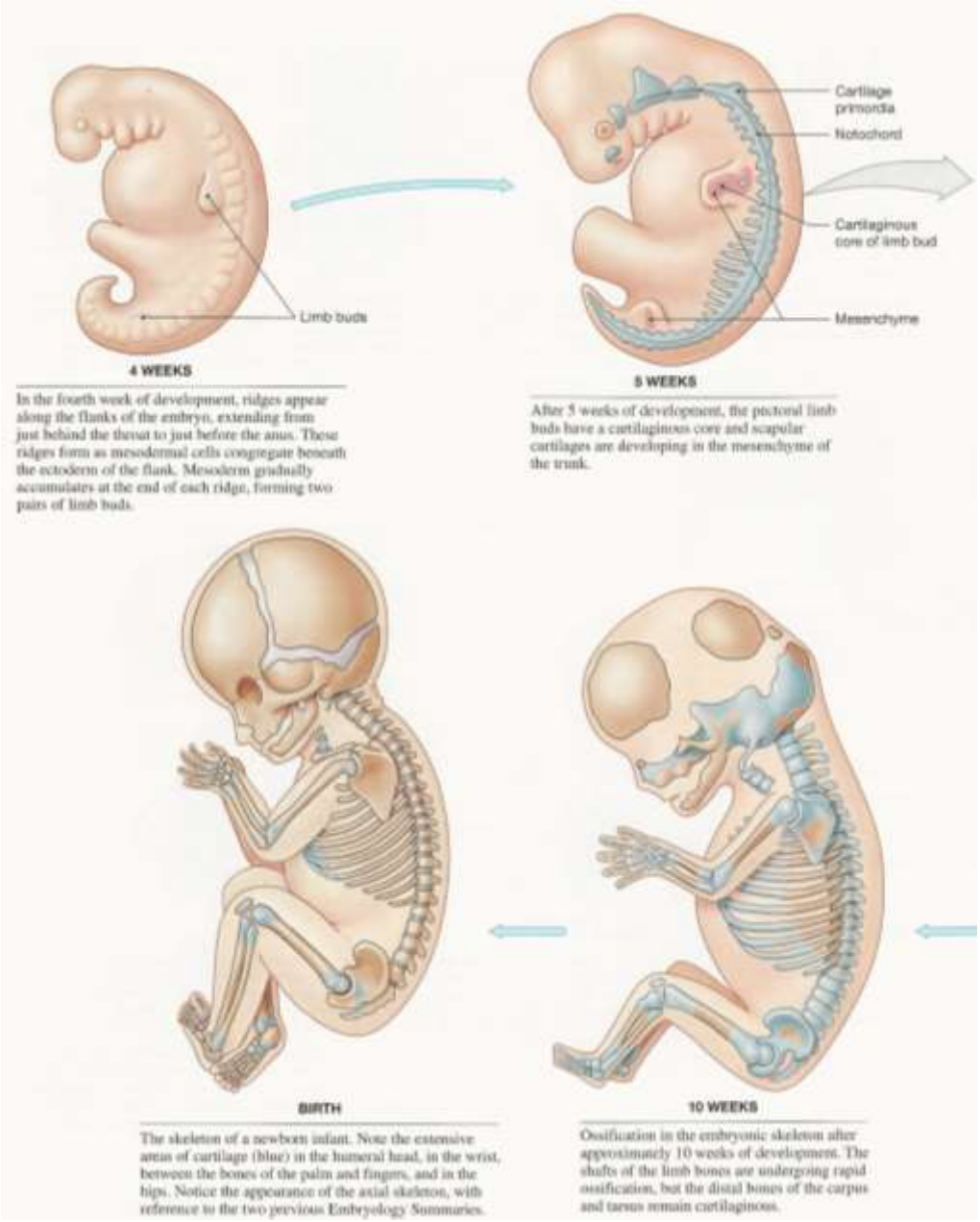
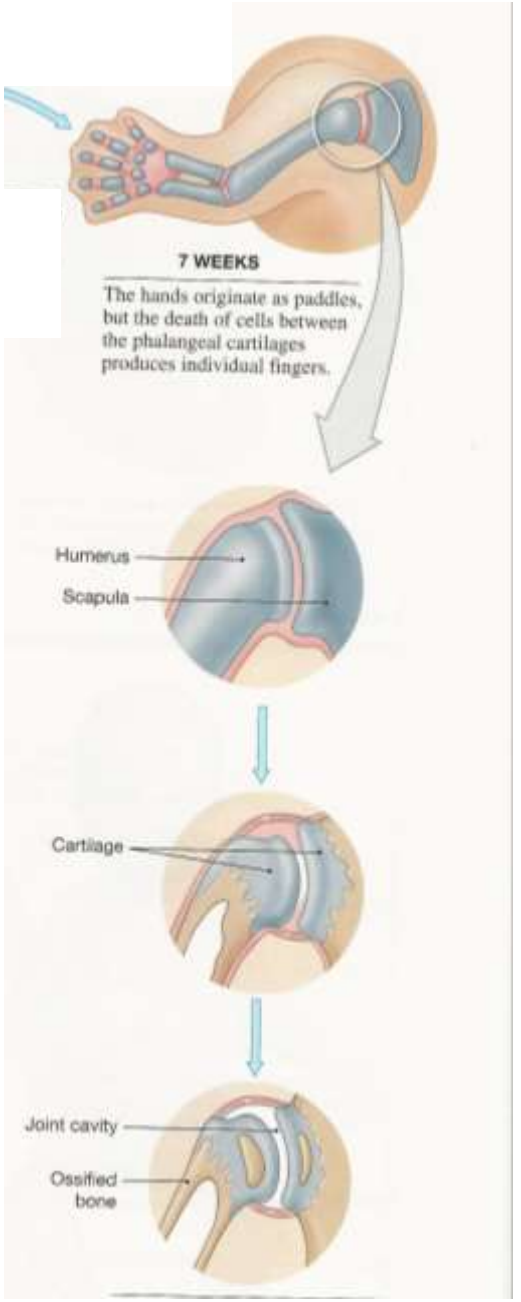


FIG. 321.—(After Hertwig's model, from Kollmann's Handatlas, 1907, Fig. 263.) Lateral view of the cranium of a human fetus 80 mm. long. The chondrocranium and the overlying membrane bones are shown. The parietal shows two centres of ossification.

Fetal Bone Development





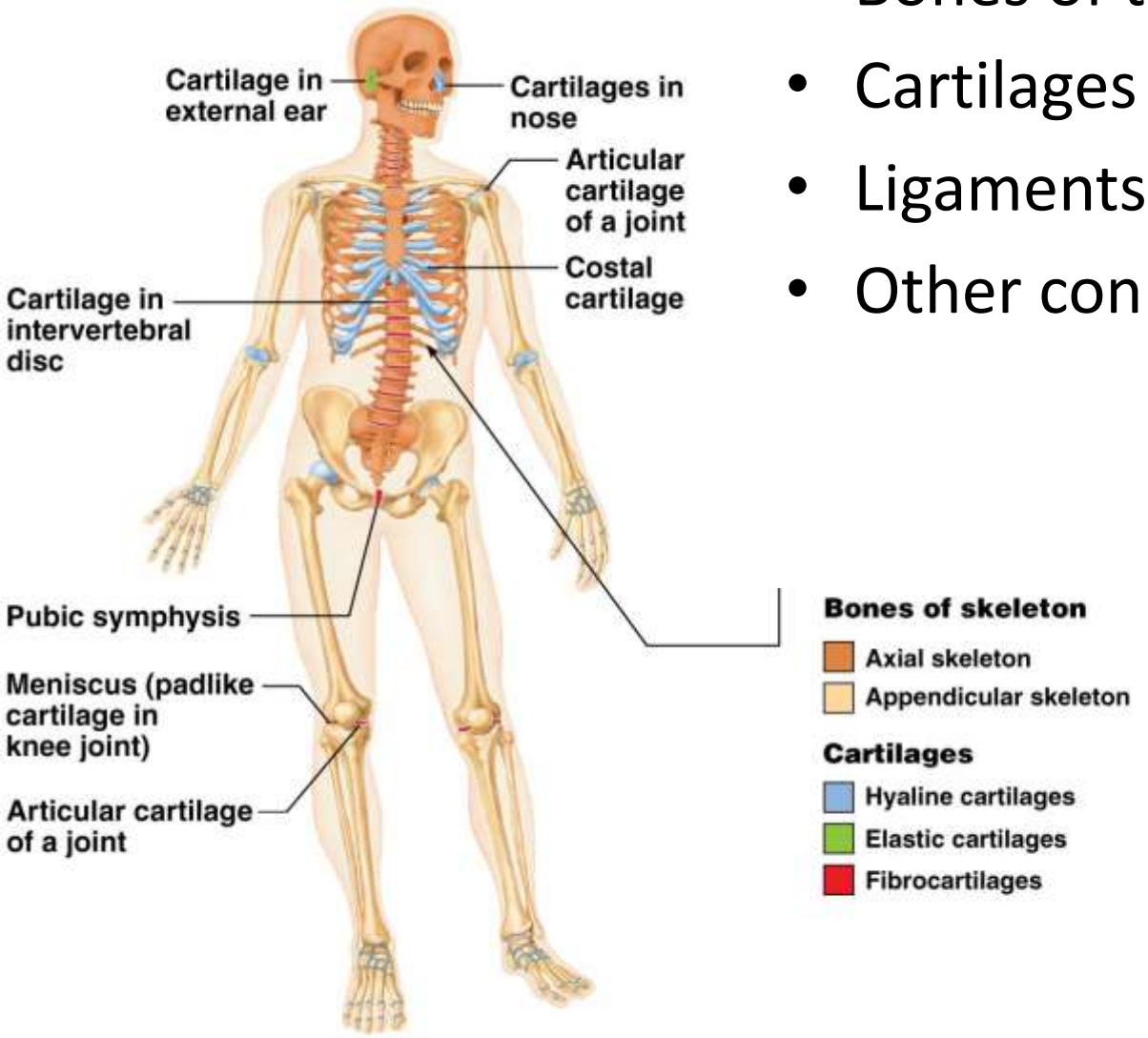
Comparison of Fetal Bone Development

Endochondral

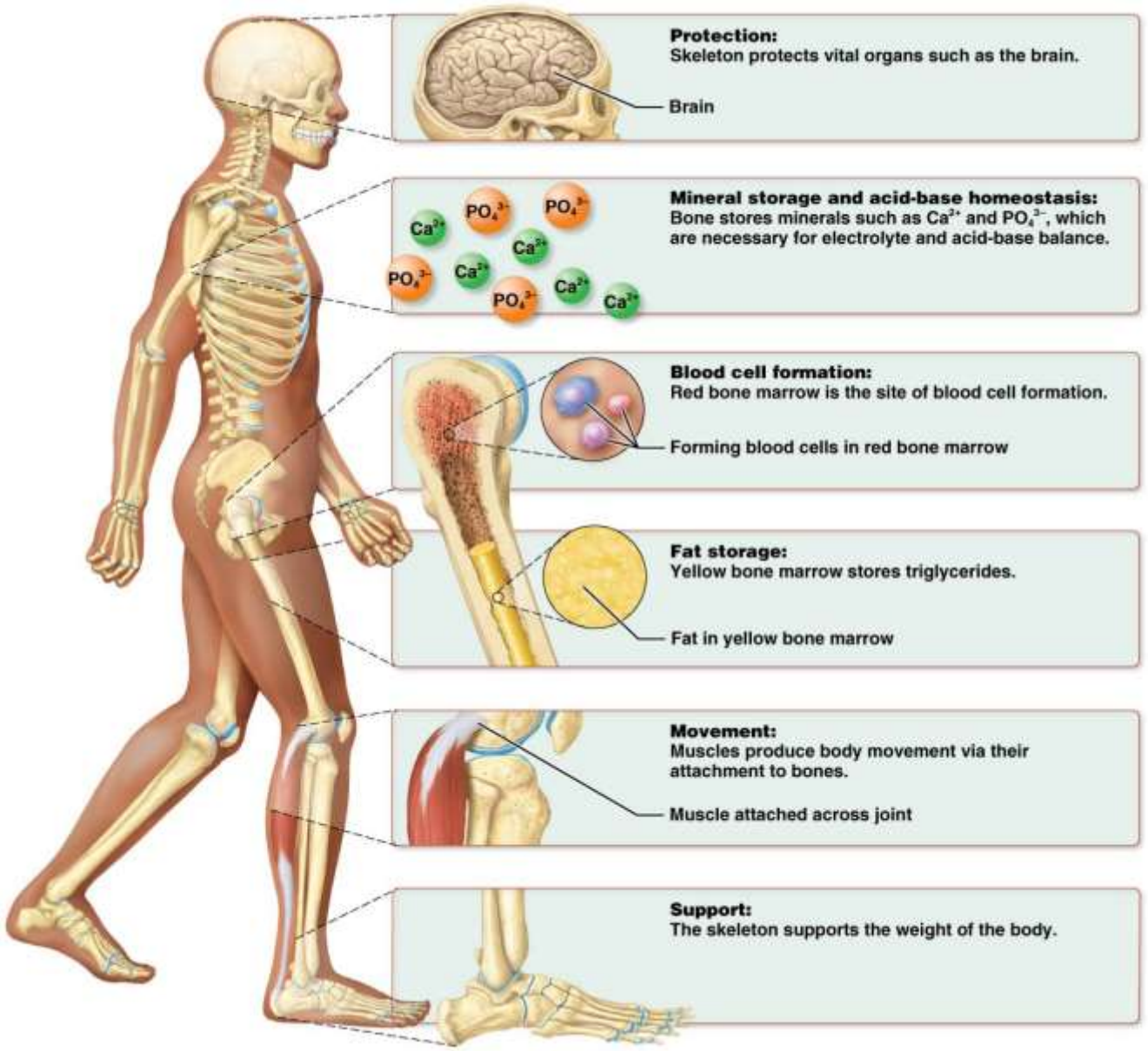
Intramembranous

Anatomy of the Skeletal System

- Bones of the skeleton
- Cartilages
- Ligaments
- Other connective tissues



Function of the Skeletal System



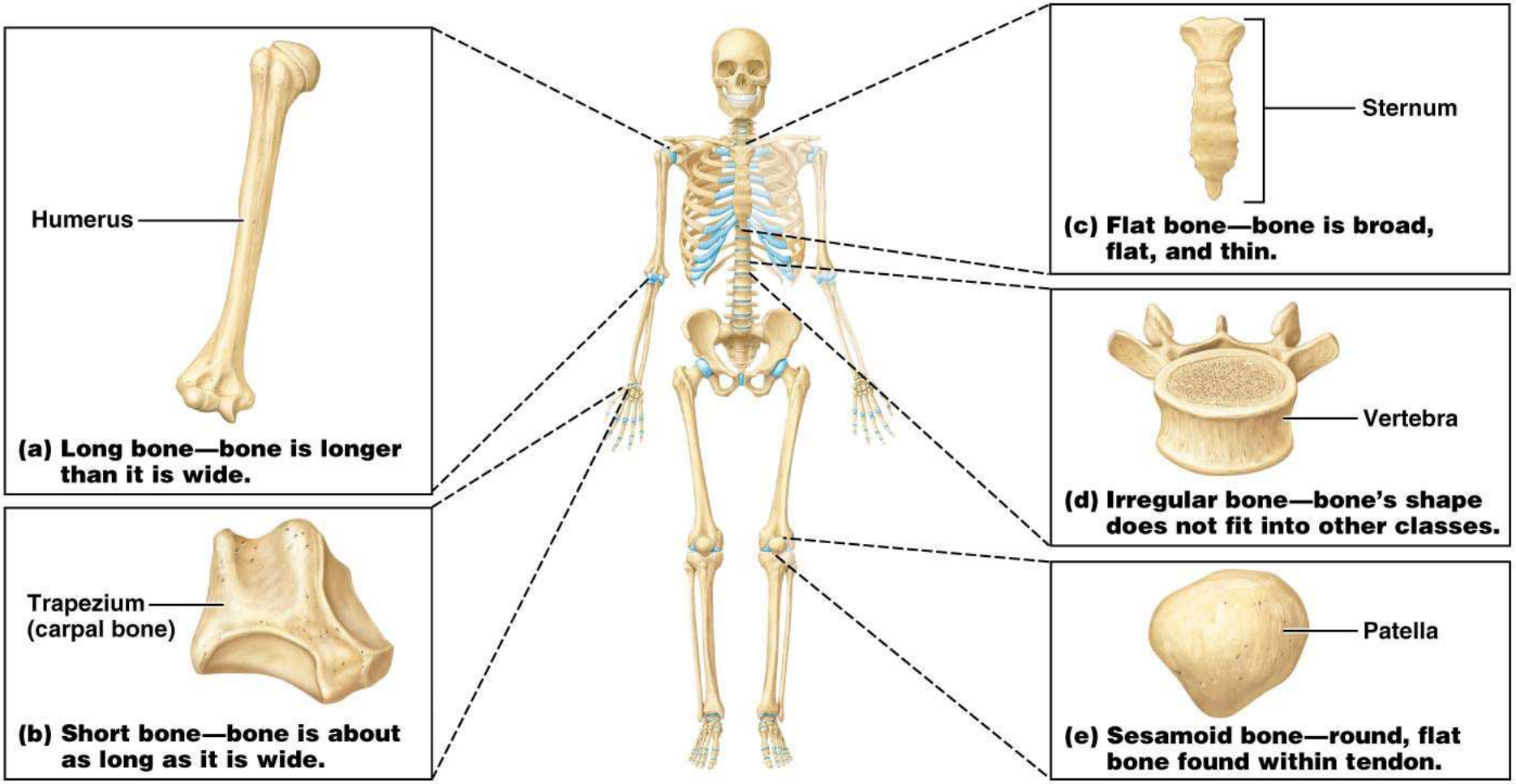
Bones as Organs

- Contain different types of tissues:
  - Bone (**osseous**) tissue
  - Nervous tissue
  - Cartilage
  - Dense fibrous connective tissue
  - Blood vessels

Classification of Bones

- 206 bones in human skeleton
  - Grouped by bone shape
    - **Short, long, irregular, flat** and **sesamoid**

- Divided into two groups based on location
  - **Axial skeleton**
    - What bones are included?
  - **Appendicular skeleton**
    - What bones are included?


Humerus
(a) Long bone—bone is longer than it is wide.
Trapezium (carpal bone)
(b) Short bone—bone is about as long as it is wide.
Sternum
(c) Flat bone—bone is broad, flat, and thin.
Vertebra
(d) Irregular bone—bone's shape does not fit into other classes.
Patella
(e) Sesamoid bone—round, flat bone found within tendon.

Typical Structures of a Long Bone

- **Diaphysis**: tubular shaft that forms long axis of bone
  - Outer layer of compact bone covering spongy bone surrounding
    - A hollow, central **medullary cavity**
      - Filled with yellow marrow in adults
      - Filled with red marrow in children
- **Epiphyses**: proximal & distal ends of the long bone
  - Outer layer of compact bone covering spongy bone
    - Filled with red marrow
- Small region between the diaphysis and epiphysis is
  - **Epiphyseal Line** = bone tissue

  OR
  - **Epiphyseal Plate** = hyaline cartilage

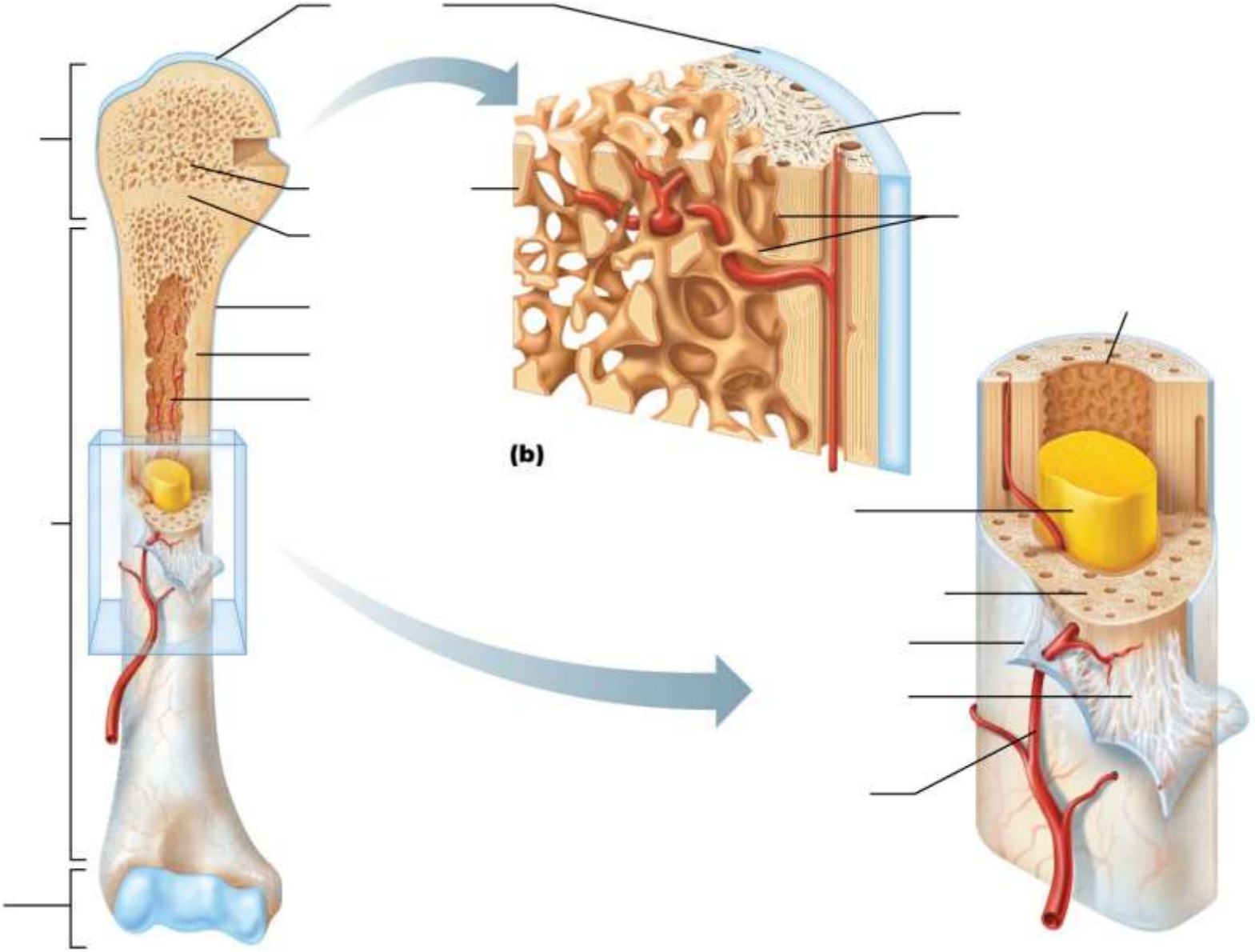
Typical Long Bone Structure

- **Periosteum**: double-layered membrane that covers the outer surface of the diaphysis, not found at joint surfaces
  - **Fibrous layer**: superficial layer of dense irregular CT
  - **Osteogenic layer**: deep layer, contains **osteogenic** cells

- **Articular cartilage**: thin layer of hyaline cartilage that covers the epiphysis surface
  - Located where two bones meet = articular / joint surface

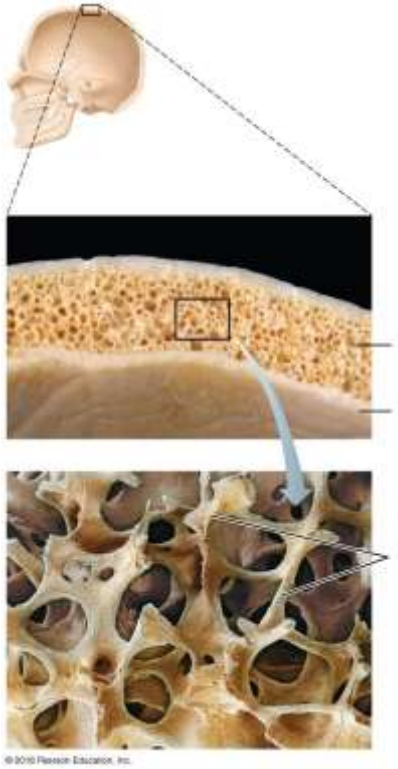
- **Endosteum:** thin, CT membrane covering the internal bone surfaces
  - Covers trabeculae of spongy bone, canals and medullary cavity
  - Also, contains osteogenic cells

Typical Long Bone Structures



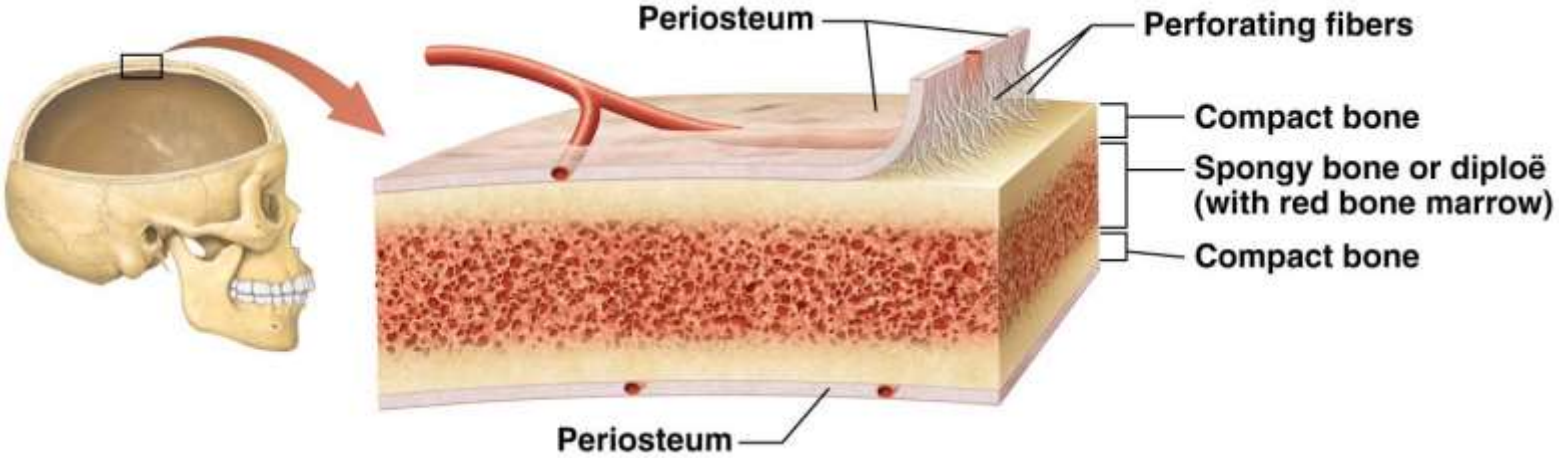
Draw and label a typical Long Bone

Structure of short, irregular, and flat bones

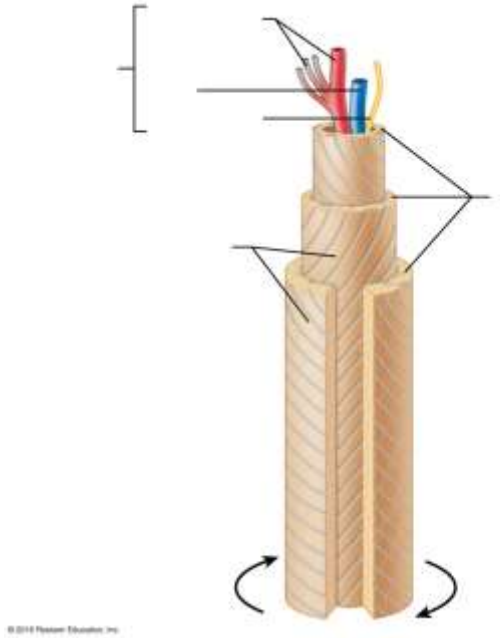


- Sandwich of compact bone filled with spongy bone (**diploe**)
  - ***Periosteum** covers external bone surfaces
  - ***endosteum** covers internal bone surfaces

* Same as membranes covering or lining of long bones



Microscopic Anatomy of Bone Tissue



- **Organic components** (35%)
  - Cells
    - osteogenic, osteoblasts, osteocytes, osteoclasts
  - Osteoid
    - Ground substance
    - Collagen fibers
      - Enhances hardness, and allows for flexibility, resist stretch & twisting

- **Inorganic components** (65%)
  - Calcium and phosphorus salts exist as large molecules of a mineral called **hydroxyapatite crystals** [$Ca_{10}(PO_4)_6(OH)_2$]
  - Responsible for hardness and resistance to compression

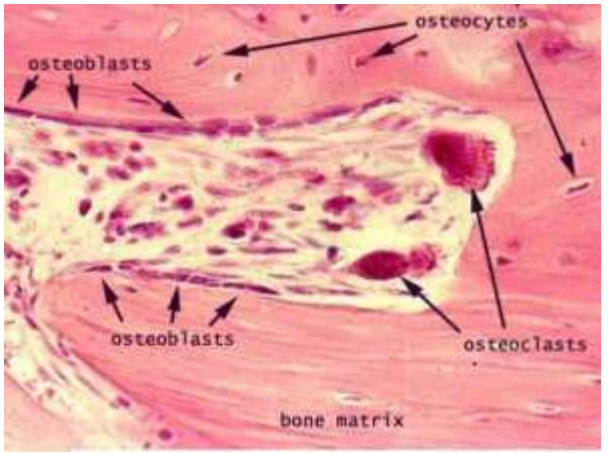
Types of Bone Cells

- **Osteogenic cells = Osteoprogenitor**
  - Stem cells that divide and specialize into osteoblasts

- **Osteoblasts**
  - Synthesize new matrix
  - High metabolic rate

- **Osteocytes**:
  - Mature bone cells surrounded by matrix and entrenched in lacunae, connected by canaliculi
  - Maintain matrix levels, low metabolic rate

- **Osteoclasts**
  - Differentiate from macrophages (WBCs)
  - Dissolve bone matrix



Types of Bone Cells

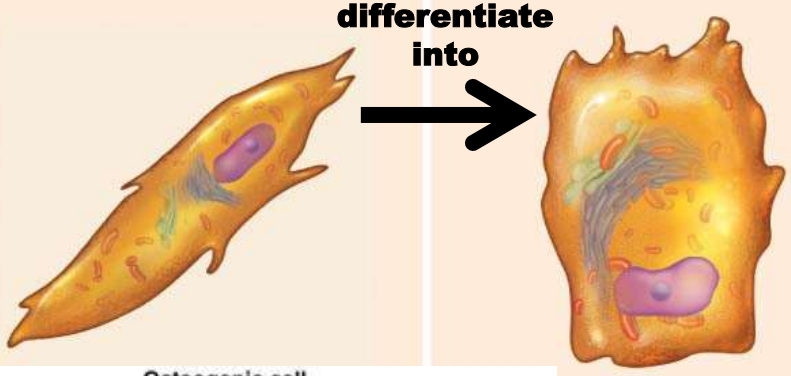
(a) Osteogenic cell

Stem cell

(b) Osteoblast

Matrix-synthesizing cell responsible for bone growth

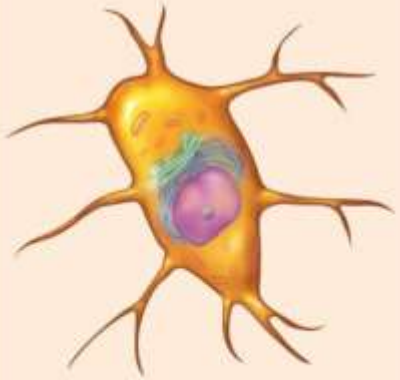
Can differentiate into



When osteoblast gets surrounded/ trapped in matrix

(c) Osteocyte

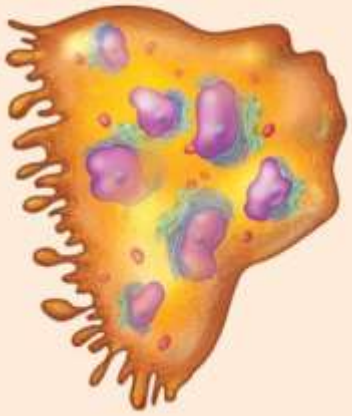
Mature bone cell that monitors and maintains the mineralized bone matrix

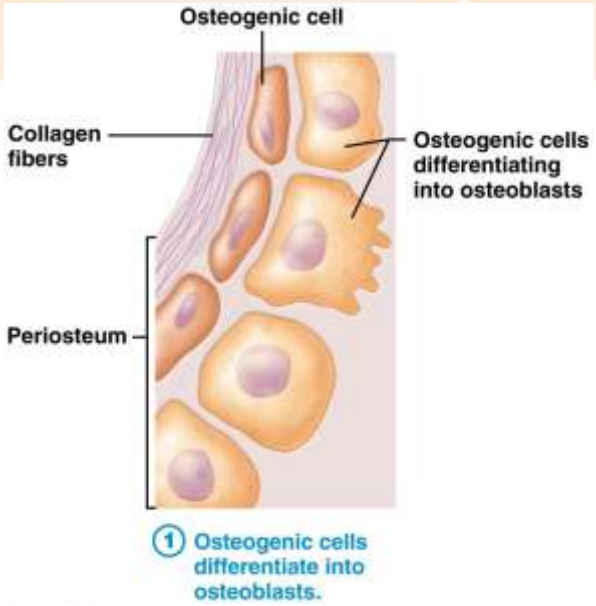


Develop from White blood cells

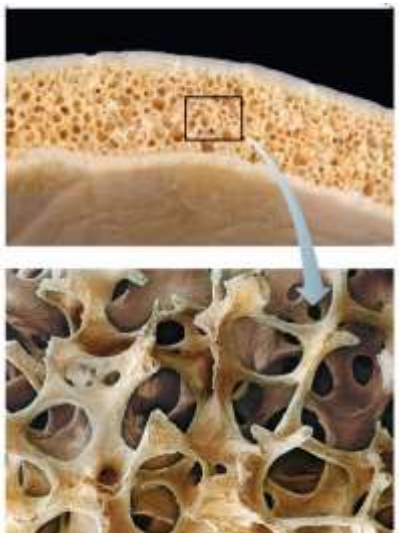
(d) Osteoclast

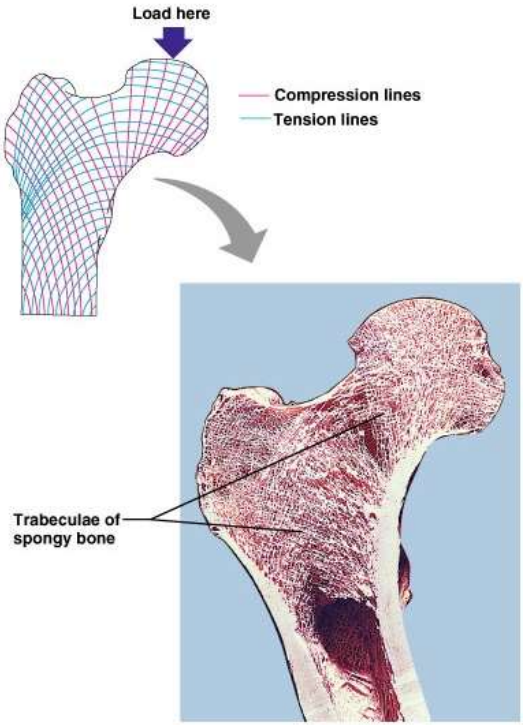
Bone-resorbing cell



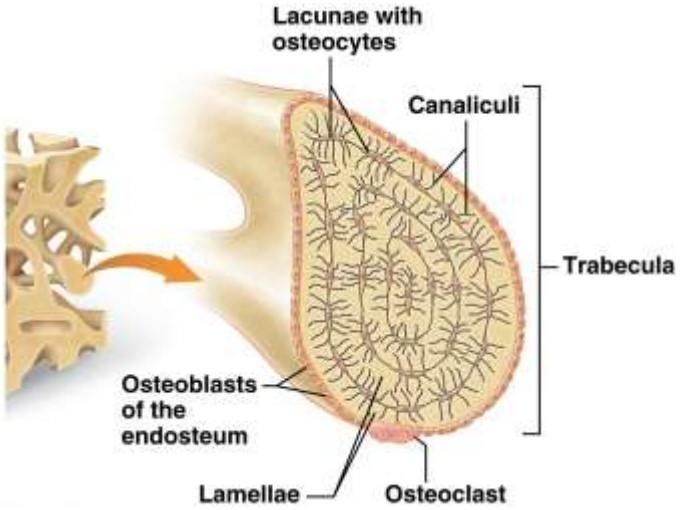


Gross Anatomy of Bone Tissue





- **Spongy bone**: honeycomb, of needle-like or flat **trabeculae** and open spaces
  - No osteons, irregularly arranged lamellae and osteocytes connected by canaliculi
  - Organized along compression and tension lines to help bone resist any stress
  - Filled with yellow or red marrow



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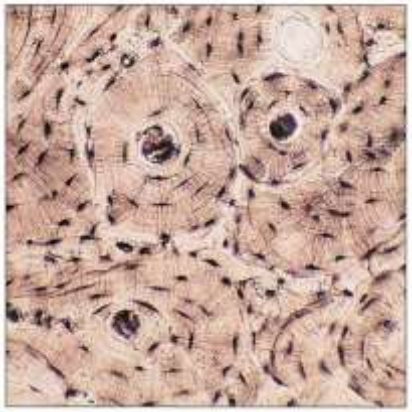
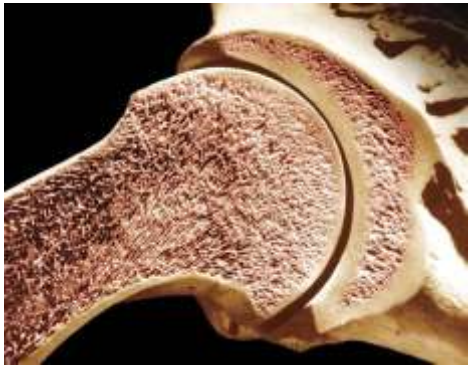
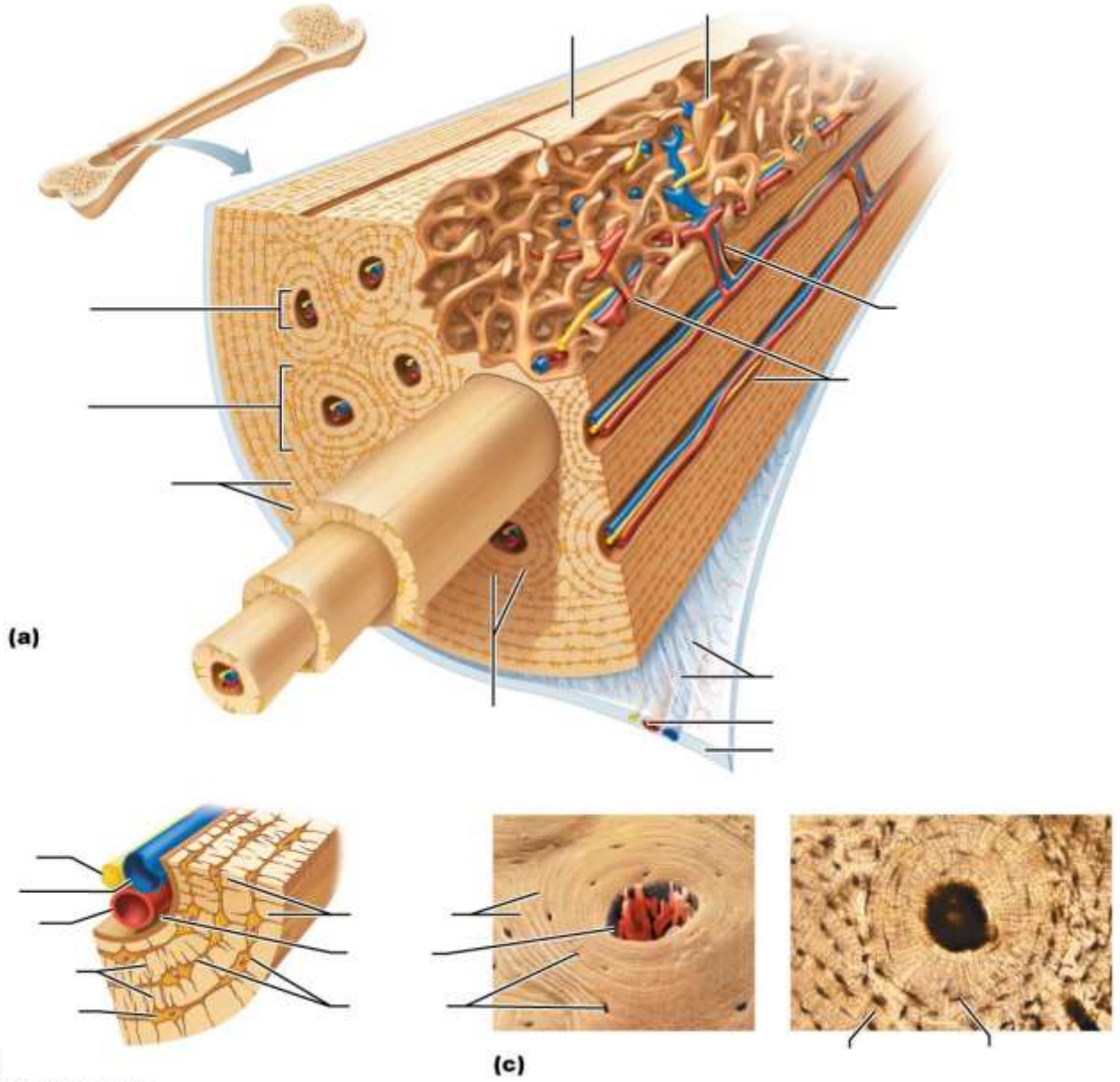


- **Compact (lamellar) bone**: Made up of densely packed, **osteons**
  - Appears dense, and smooth
  - **Osteon** - elongated cylinders that runs parallel to long axis of bone
    - **Central canal** runs through center and contains blood vessels and nerves
    - **Lacunae**: small cavities that hold osteocytes
      - **Canaliculi:** small canals that connect lacunae to each other
    - **Lamellae:** rings of bone matrix
    - **Perforating** (**Volkmann's**) **canals**: canals at right angles to central canal contain blood vessels and nerves

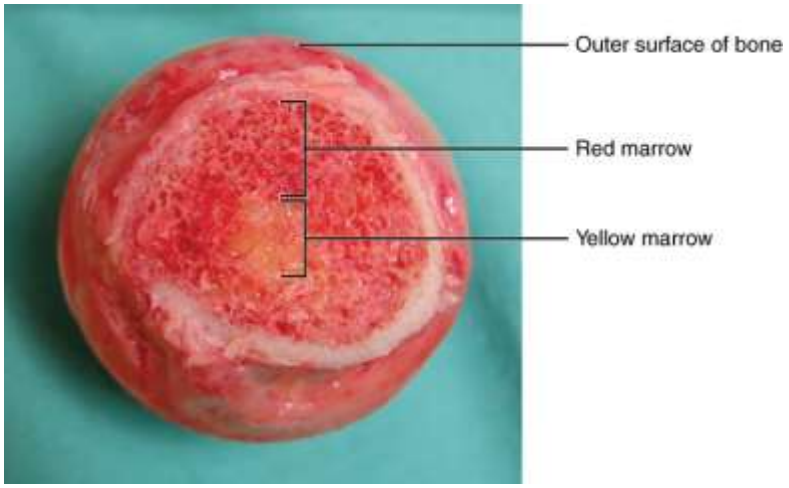


Microscopic Structure of Compact Bone Tissue



Other Tissues of the Bone

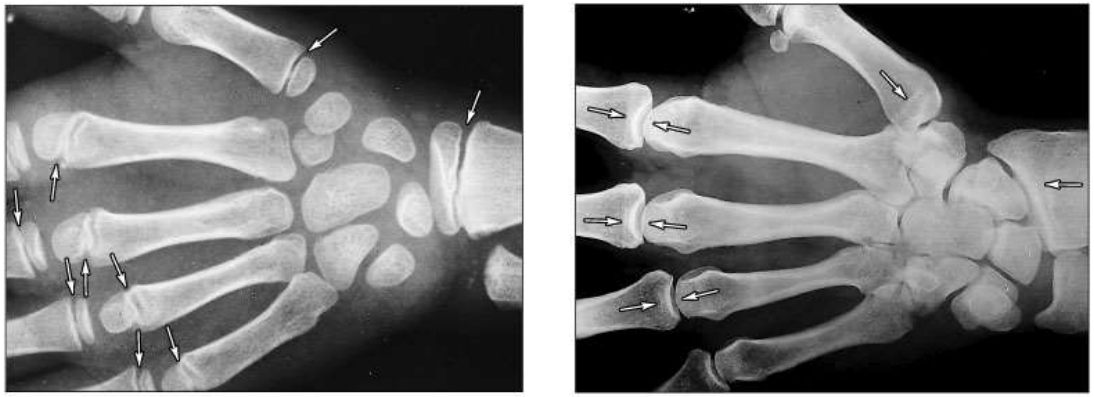
- **Hematopoietic tissue** = Red marrow
  - Reticular tissue with hematopoietic stem cells
  - Found within trabecular cavities of spongy bone
    - In newborns, **medullary cavities** and all spongy bone contain red marrow



- **Yellow marrow** = Adipose tissue
  - Found within medullary cavity of long bones
  - Can convert to red marrow, if person becomes anemic

Postnatal Bone Development

- Bone development & growth from birth to adolescence
  - Bones grow in length
    - Length-wise growth is from the epiphyseal plate (hyaline cartilage)



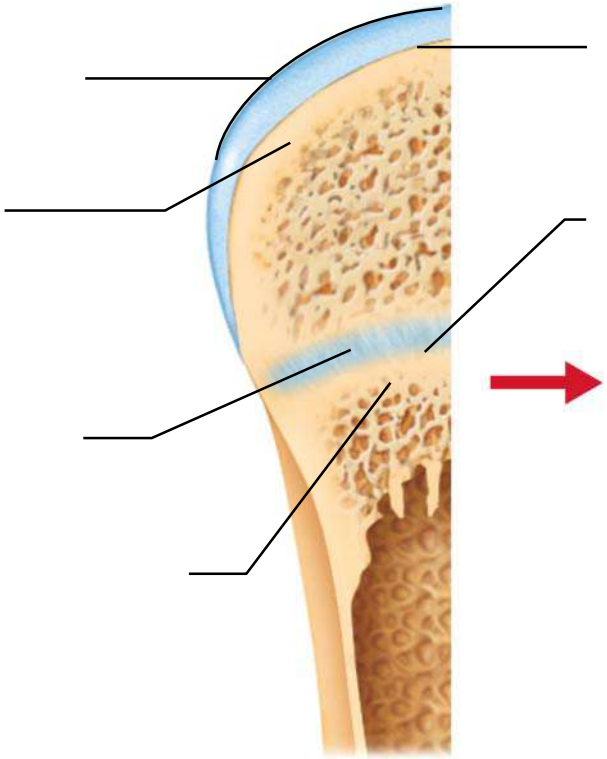
(a) Epiphyseal cartilages

(b) Epiphyseal lines

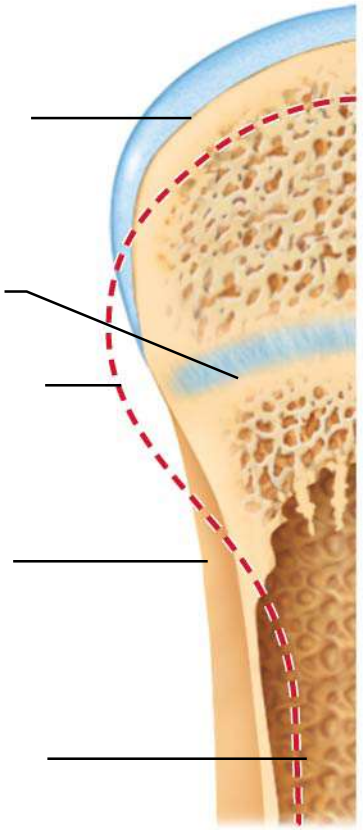
  - Bones grow in width (appositional)
    - Osteoblasts beneath periosteum secrete bone matrix on external bone
    - Osteoclasts remove bone on endosteum surface

Long bone Growth and Remodeling

Bone growth

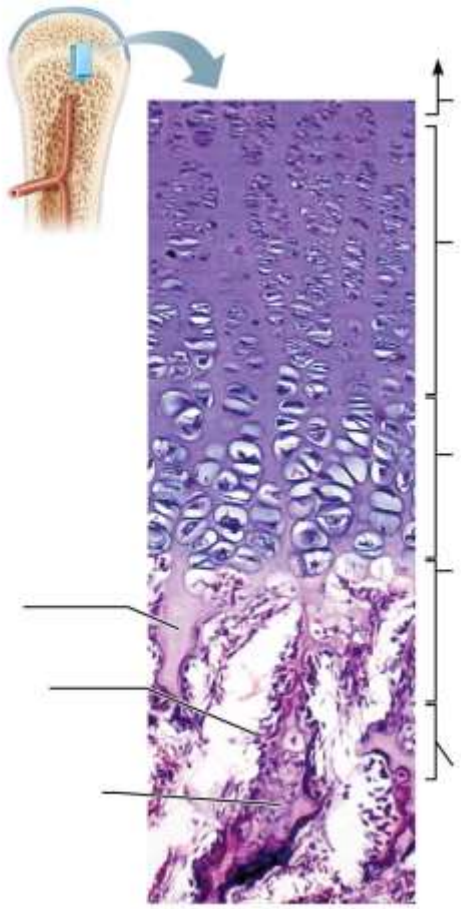


Bone remodeling



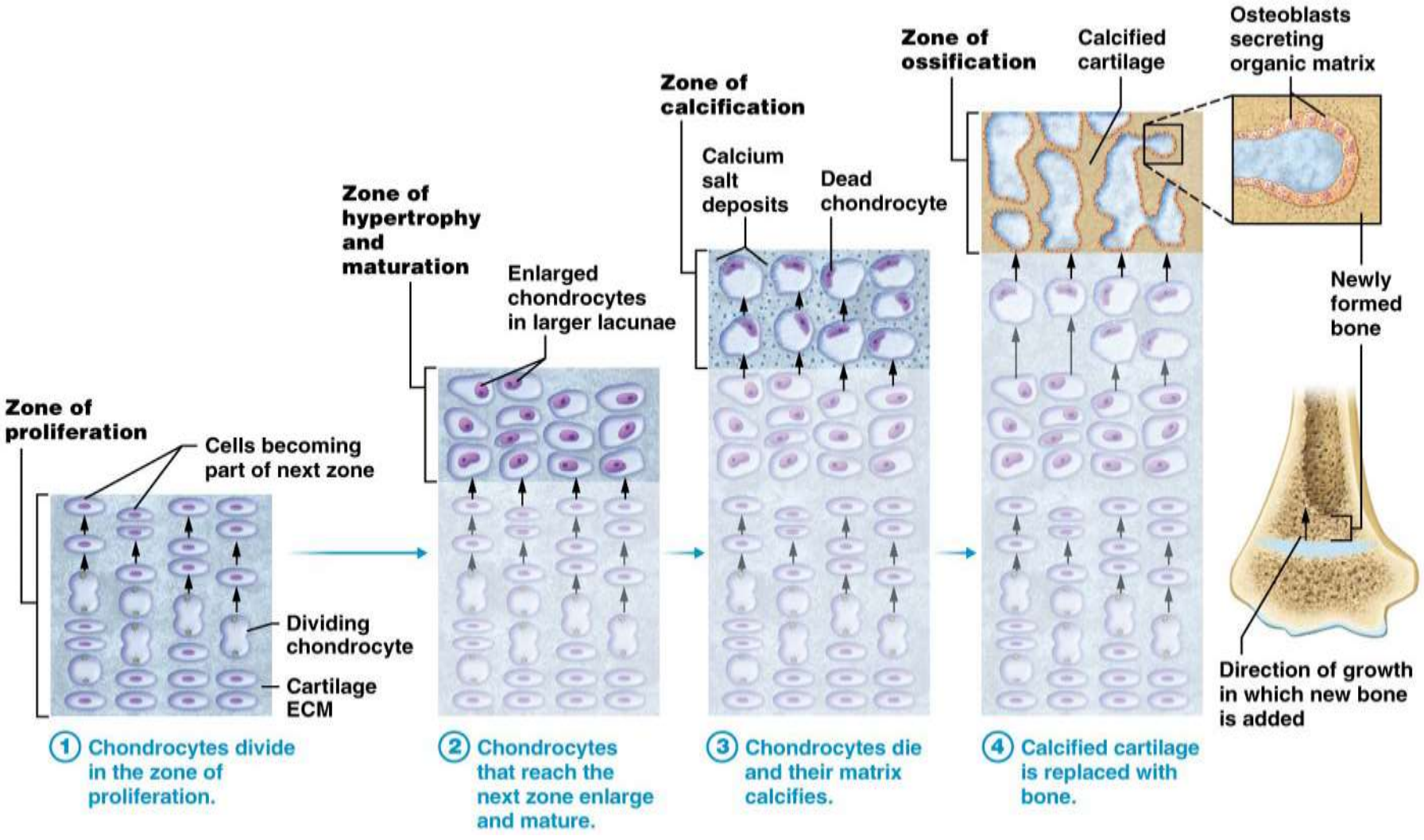
Growth at the Epiphyseal Plate

- Epiphyseal plate maintains constant thickness
  - Hyaline cartilage thickens on one side and replaced by bone on other



- Epiphyseal plate consists of five zones:
  1. **Resting (quiescent) zone**
  2. **Proliferation (growth) zone**
  3. **Hypertrophic zone**
  4. **Calcification zone**
  5. **Ossification (osteogenic) zone**

Growth at the Epiphyseal Plate

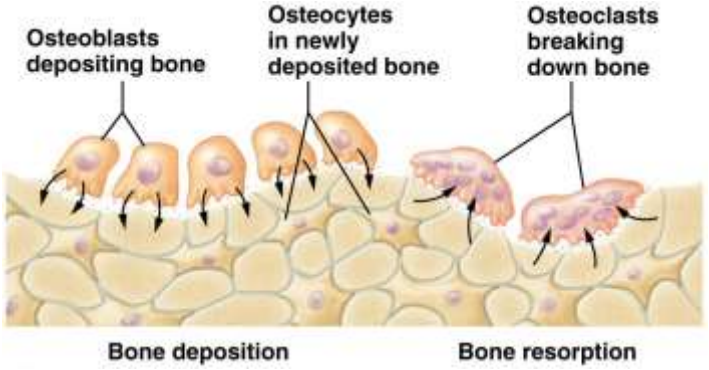


Nutrition, Sex, and Bone Growth

Sex	Nutrition	
	Good	Poor
Male	Continued Growth, Greater Height	Reduced Growth, SHORTER than normal height
Female	Energy to Reproduction and Supporting Fat Reserves	Delayed onset of reproductive ability; continued bone growth = TALLER

Adult Bone Remodeling

- Bone remodeling consists of both **bone deposit** and **bone resorption**
  - Occurs deep to both periosteum and endosteum
  - **Remodeling units**: packets of adjacent osteoblasts and osteoclasts coordinate remodeling process



- Occurs due to:
  1. Blood calcium levels
     - Under the control of endocrine hormones
  2. Mechanical stress
     - Bones grow or remodel in response to demands placed on them

Fracture Classification

Three “either/or” fracture classifications

- Whether skin is penetrated
  - *Open* (*compound*): skin is penetrated
  - *Closed* (*simple*): skin is not penetrated

- Position of bone ends after fracture
  - *Displaced*: ends are out of normal alignment
  - *Nondisplaced*: ends retain normal position

DISPLACED FRACTURE

NON-DISPLACED FRACTURE

- Completeness of break
  - *Complete*: broken all the way through
  - *Incomplete*: not broken all the way through

Bone Repair

- **Fractures** are breaks
  - During youth, most fractures result from trauma
  - In old age, most result from weakness of bone due to bone thinning

- Treatment by **reduction**
  - Closed reduction: physician manipulates to correct position
  - Open reduction: surgical pins or wires secure ends

- **Immobilization** of bone by cast or traction is needed for healing

Check your understanding

- Contrast endochondral and intramembranous ossification.

- Compare and contrast the gross and microscopic anatomy of cranial bones and all the other bones in the body.
  - Can you explain why they have distinct anatomical features given what you know about their embryological development?
  - Can you explain where spongy bone and compact bone is located for different bones given what you know about their embryological development?

- Do bones change for adults? How?

Check your understanding

Looking at an X-ray how would you know if the individual is a child or an adult?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