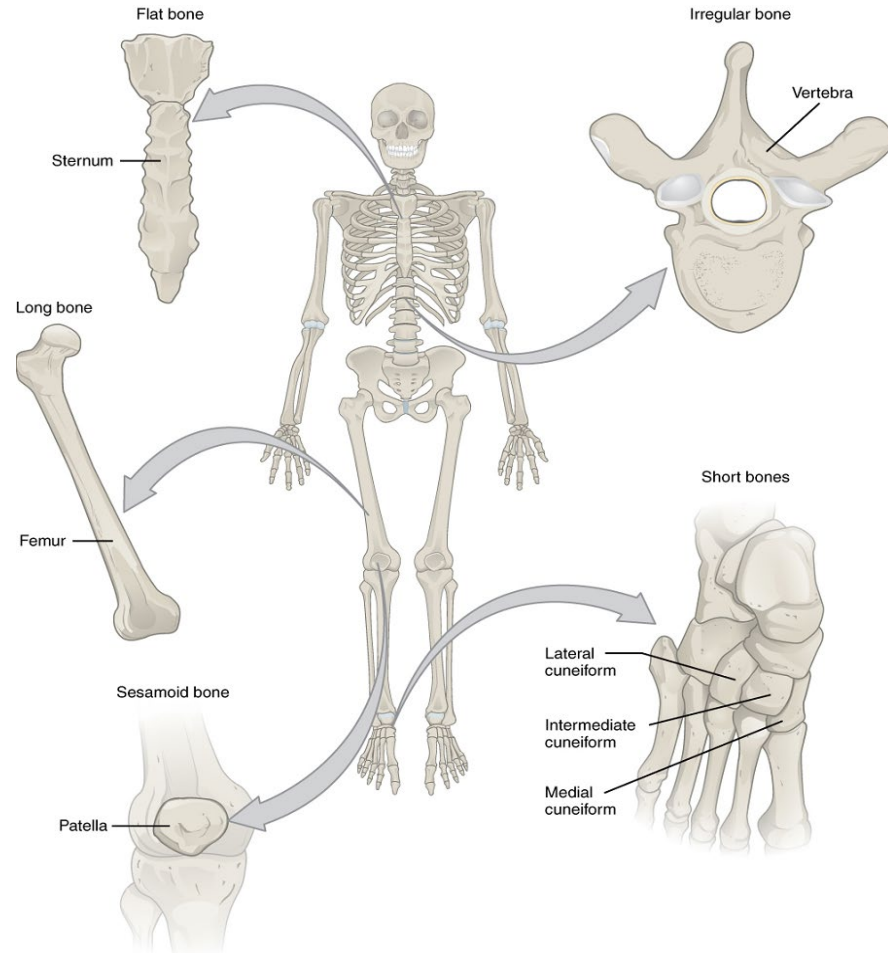


# BIOLOGY 1103/1109

## Human Anatomy and Physiology I

### UNIT 12

### Skeletal system



# Skeletal system

## Objectives

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1. Describe the functions of the skeletal system and the five basic shapes of human bones.
2. Describe the structure and histology of the skeletal system.
3. Define and identify the following parts of a long bone: diaphysis, epiphysis, metaphysis, articular cartilage, periosteum, medullary cavity, and endosteum.
4. Compare the composition and function of compact bone versus spongy bone
5. Define ossification, compare intramembranous ossification with endochondral ossification, describe how a long bone grows in length and width, and specify how various factors might affect the rate of ossification and, by extension, the height of a mature individual.
6. Describe four types of bone fractures.

# Skeletal system

## Objectives

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7. Specify the components of the axial and appendicular skeletons, describe the general function of each skeleton, and name and describe the principle components of the axial skeleton.
8. Describe the structure and function of a typical vertebra and explain how these differ in the case of the atlas and axis.
9. Describe the components and functions of the pectoral girdle and the pelvic girdle.
10. Specify all bones and structures in the human skeleton covered in this Unit.
11. Describe the differences between the pelvis of a human female and that of a human male.
12. Describe the major differences between the skeleton of a baby and that of an adult.

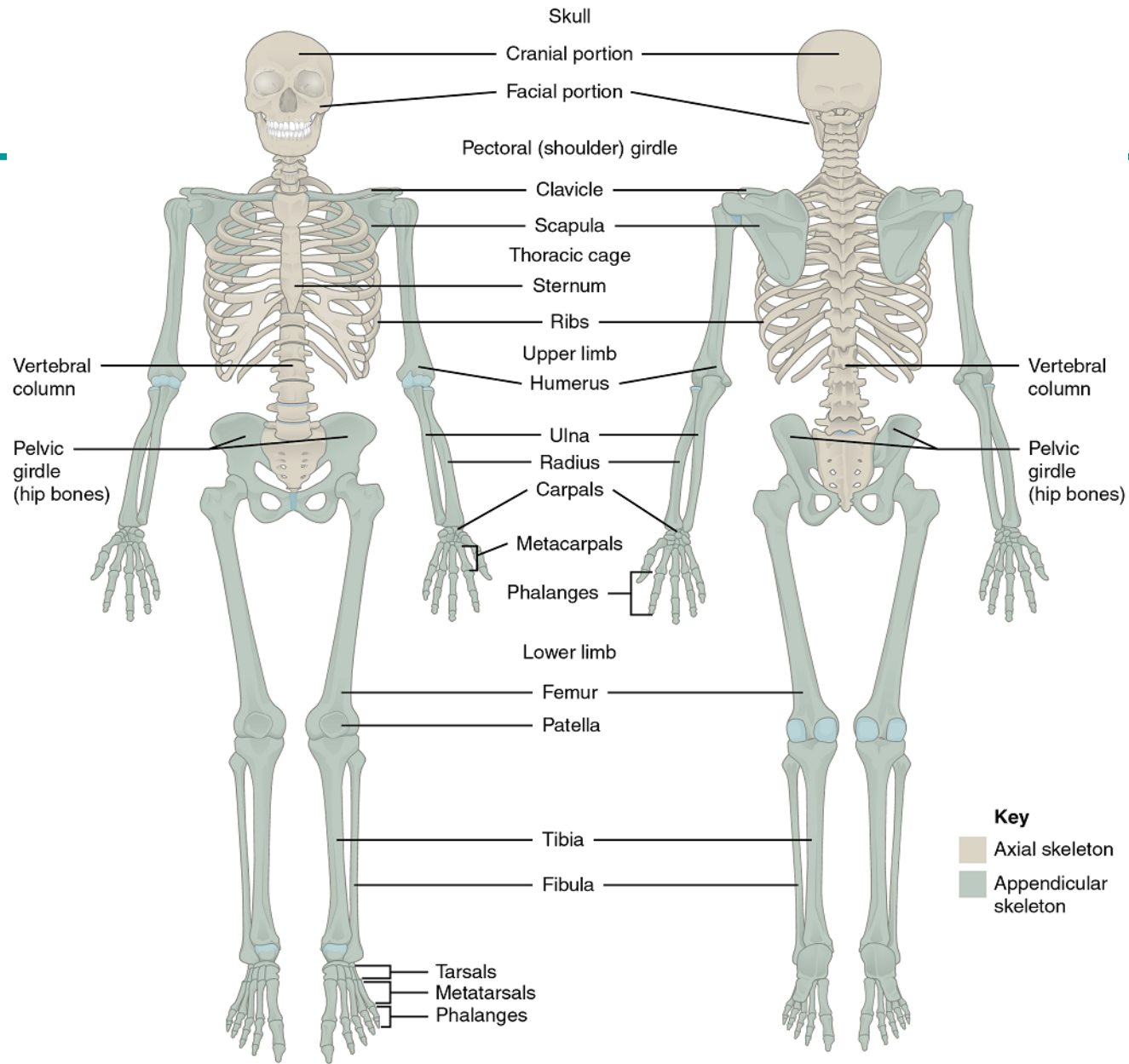


Figure 17

Anterior view

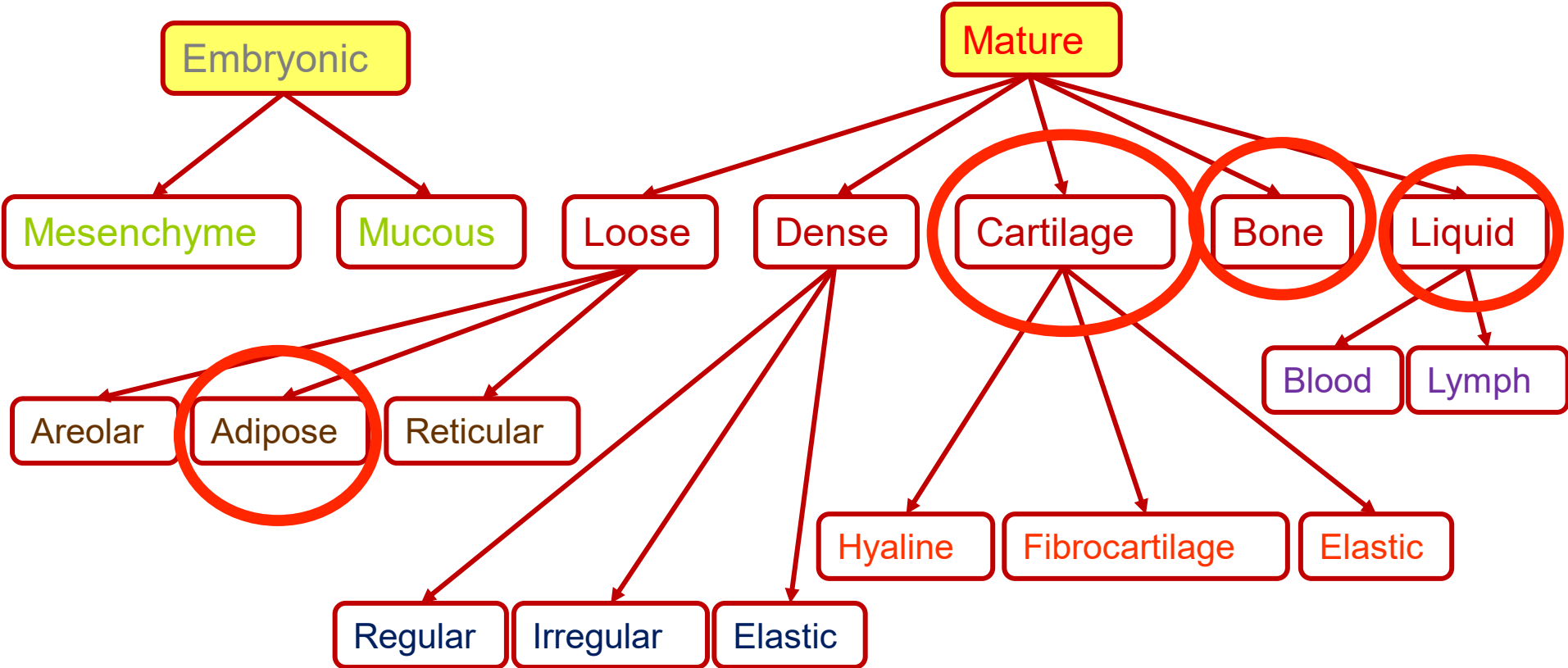
Posterior view

Epithelial  
Covers, linings  
and secretions

Connective  
Protection  
and support

Muscular  
Movement  
and heat

Nervous  
Information flow  
and control



---

What are the functions of the bones in the human body?

# Functions of the skeletal system

- Support

- Protection

- Assistance in movement

- Production of blood cells  
(Hematopoiesis)

- Mineral homeostasis

- Storage of fat

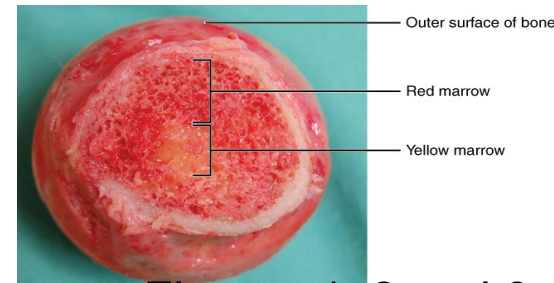
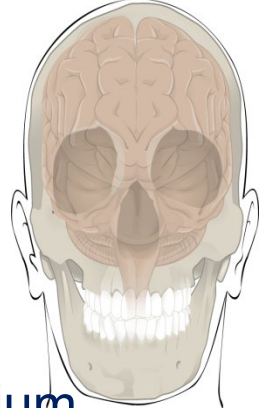
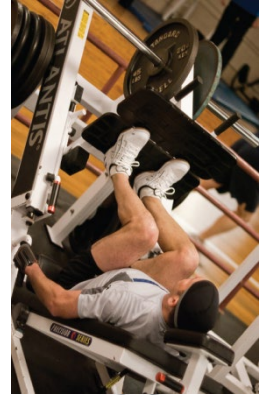
{ E.g. Rib cage and heart,  
skull and brain

{ Muscles attach to  
bones

{ In the red bone marrow

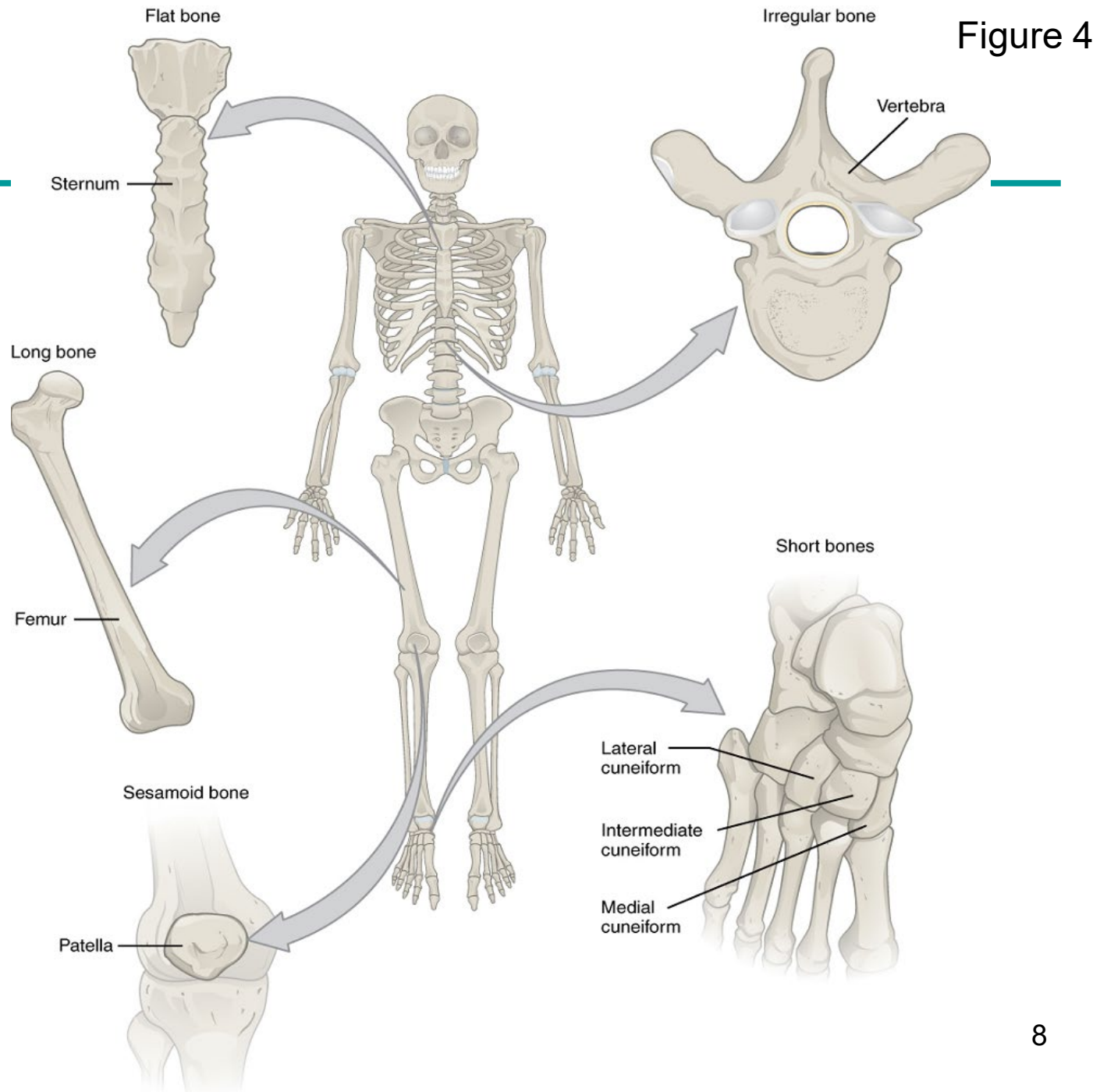
{ Bones store and release calcium  
and phosphate

{ In the yellow bone  
marrow



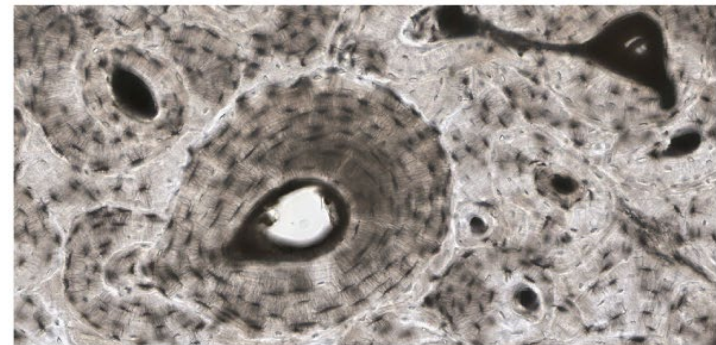
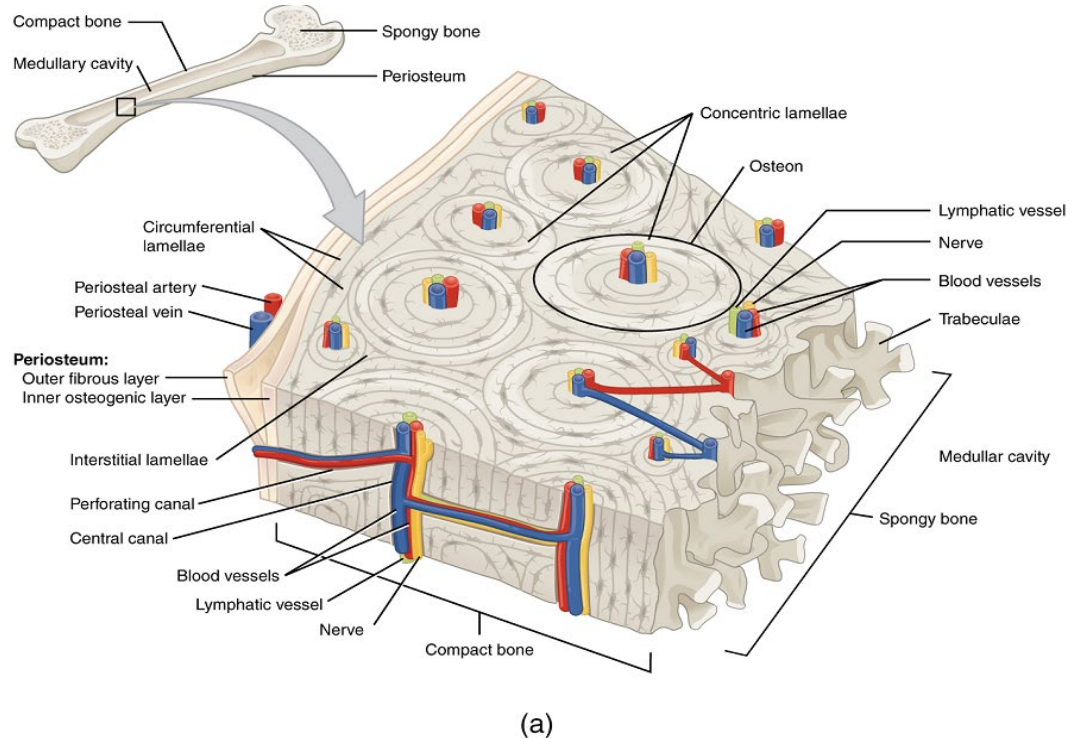
Figures 1, 2 and 3

# Types of bones



# Composition of bone

- A type of connective tissue as seen by widely spaced cells separated by matrix
- Matrix of 15% water, 30% organic material (collagen fibers and ground substances) & 55% crystalized mineral salts (calcified)
- 4 types of cells in bone tissue

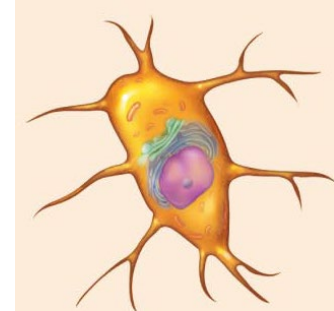


# Structure of Bones

## types of cells in bone tissue

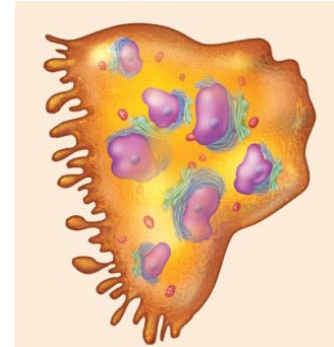
### Osteocytes

- Mature cells no longer secreting ECM
- Main cells in bone
- Cells lie within lacunae
- mature bone cells, main cells in bone tissue



### Osteoclasts

- Very large cells with several nuclei
- Derived from fusion of Monocytes (WBC)
- Mostly in Endosteum
- Function in bone resorption



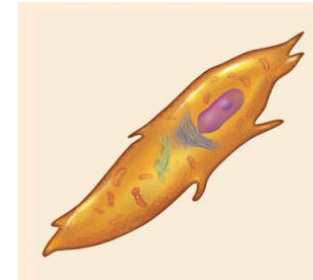
# Structure of Bones

## types of cells in bone tissue

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### Osteogenic cells

- Undifferentiated cells
- Divide & become osteoblasts
- Inner layer of Periosteum & Endosteum

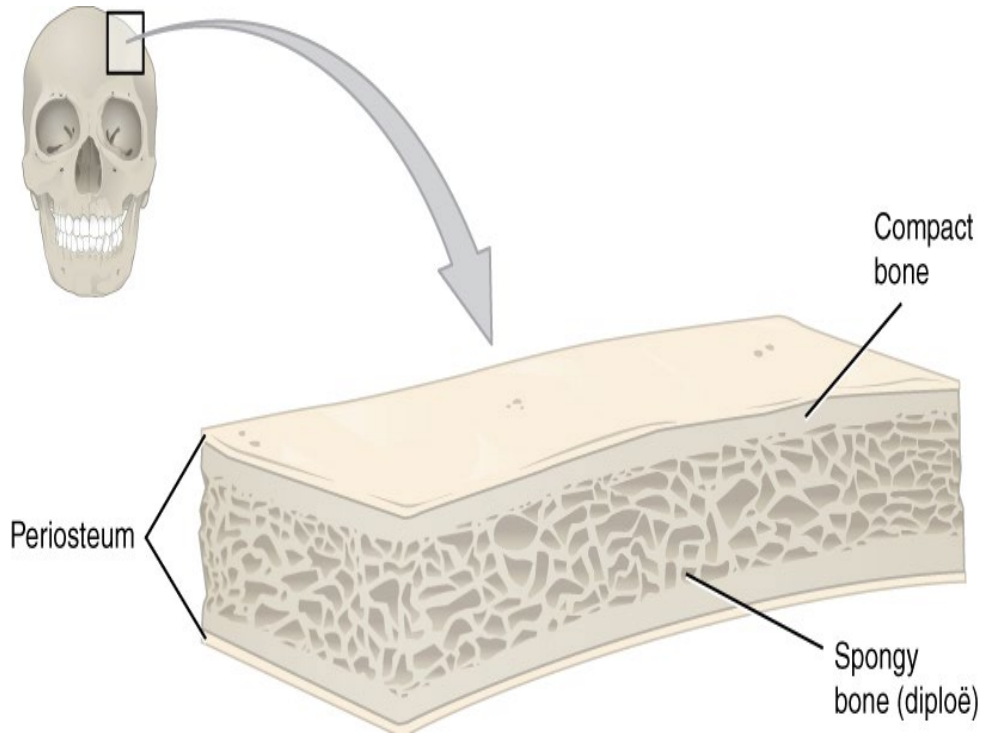


### Osteoblasts

- Immature bone cells
- Form & secrete ECM
- Bone-building cells, make collagen fibers



# Types of bone tissue



- **Compact bone** = few spaces and very strong
- **Spongy bone** = large spaces in the interior of the bone, surrounded by a layer of compact bone

Figure 7

# Composition of compact bone

## Haversian (Osteon) systems in compact bone

- Osteon is concentric rings (lamellae) of calcified matrix surrounding a vertically oriented blood vessel
- Osteocytes found in spaces called lacunae
- Osteocytes communicate through canaliculi filled with extracellular fluid that connect one cell to the next cell

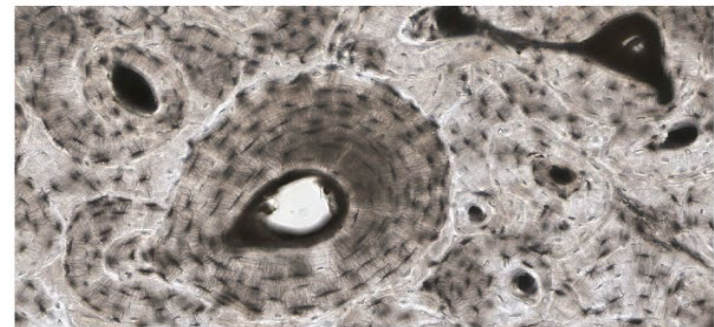
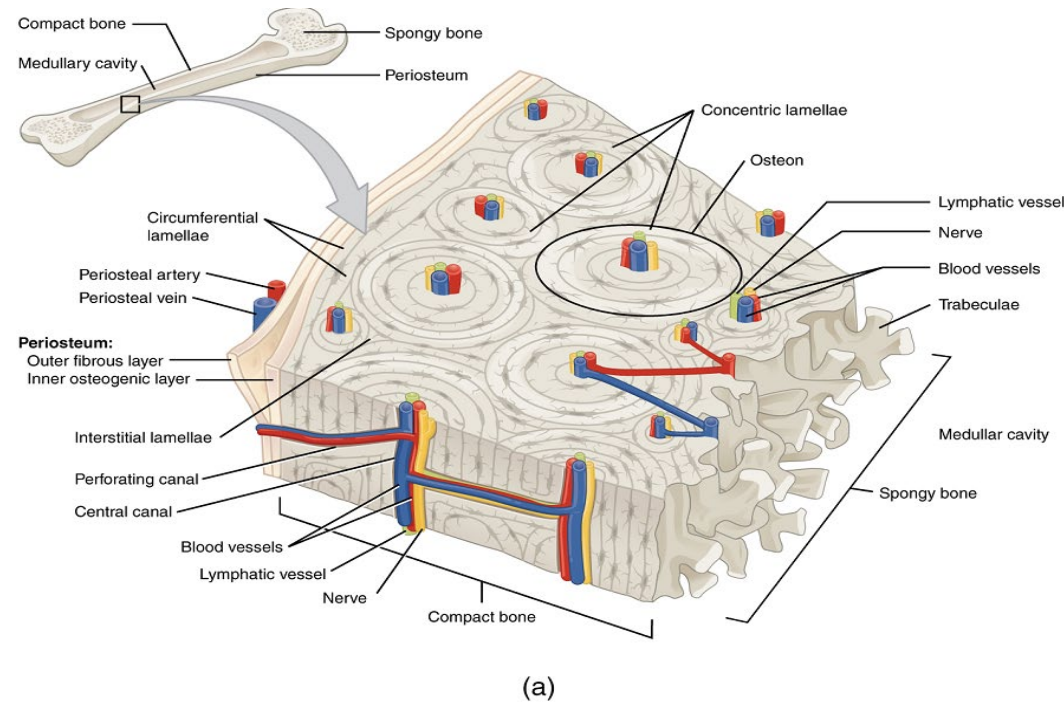


Figure 9

(b)

# Structure of the Bones

compact bone; long bone

## Properties

- Strongest bone tissue
- **Makes up frame of long bones**
- Resists stress produced by weight & movement
- Provides support & protection

- Note the Endosteum and Periosteum

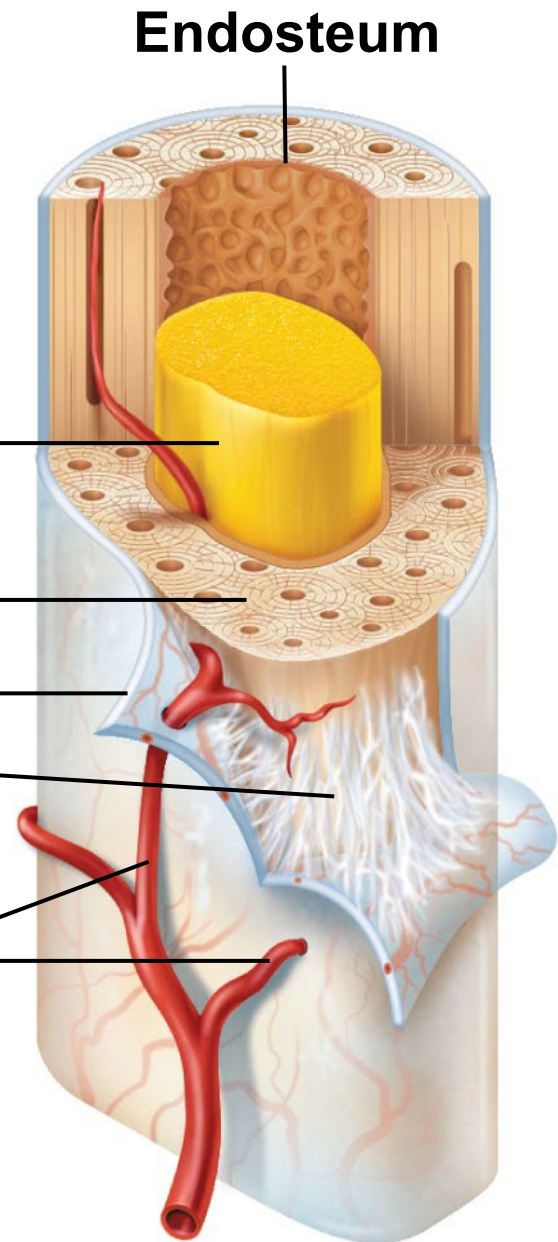
**Yellow**  
**bone marrow**

**Compact bone**

**Periosteum**

**Perforating**  
**(Sharpey's)**  
**fibers**

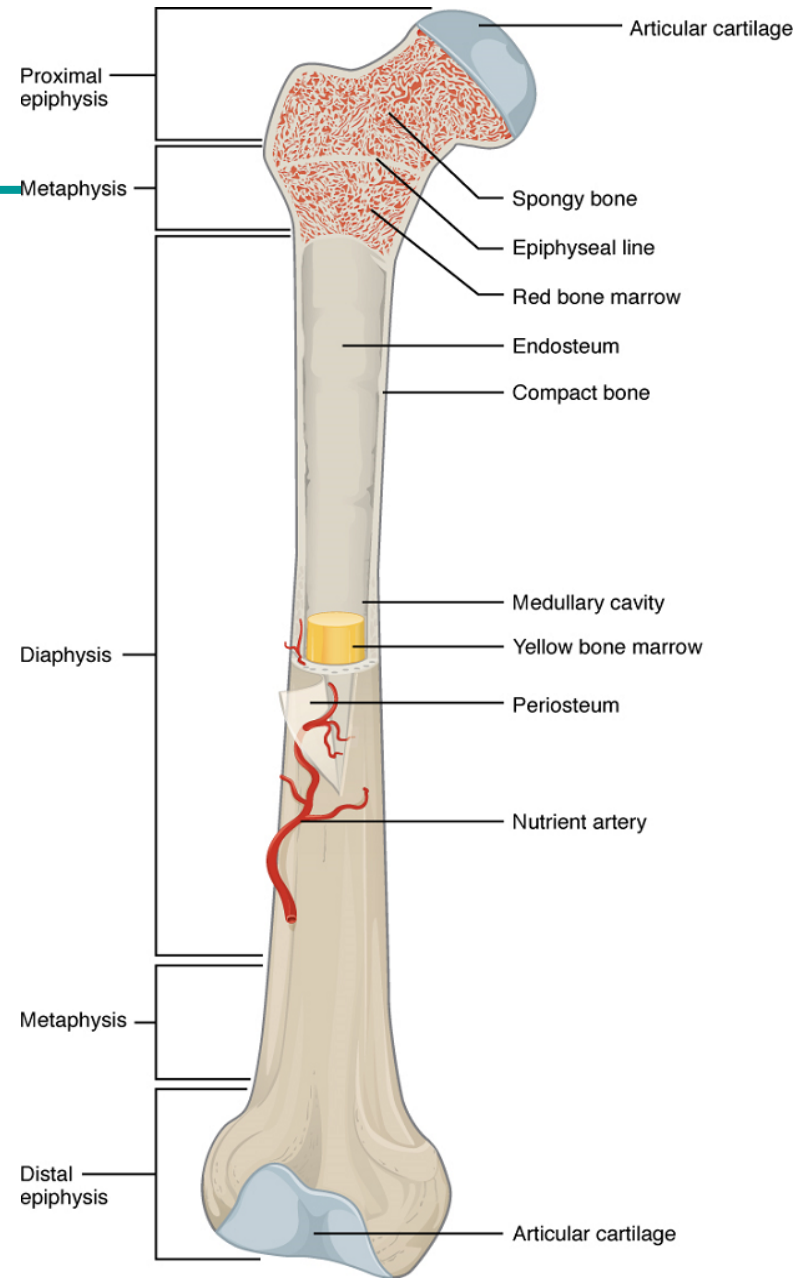
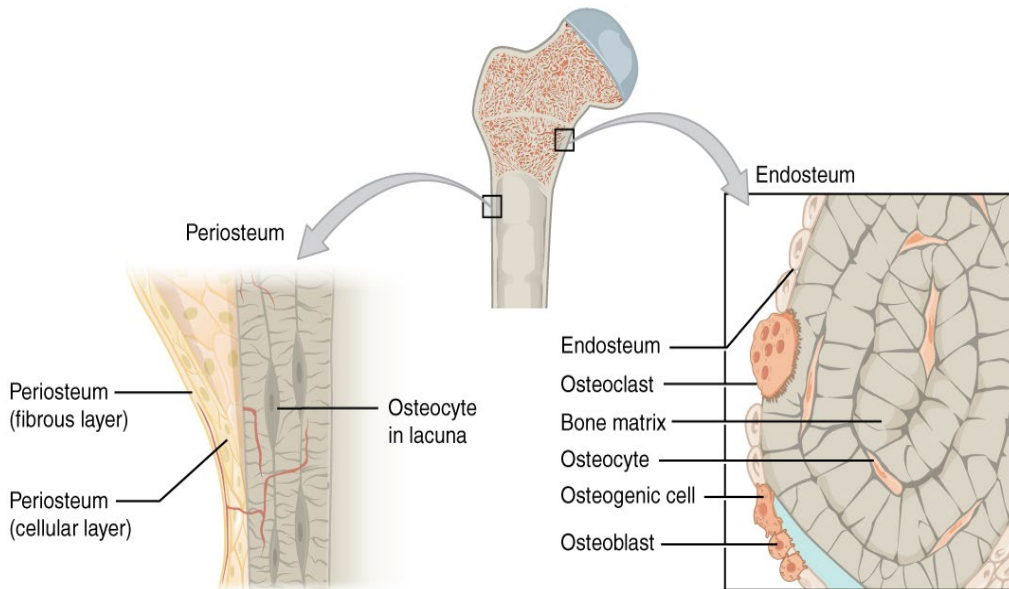
**Nutrient**  
**arteries**



**(c)**

Marieb, Figure 6.5c

# Parts of a long bone

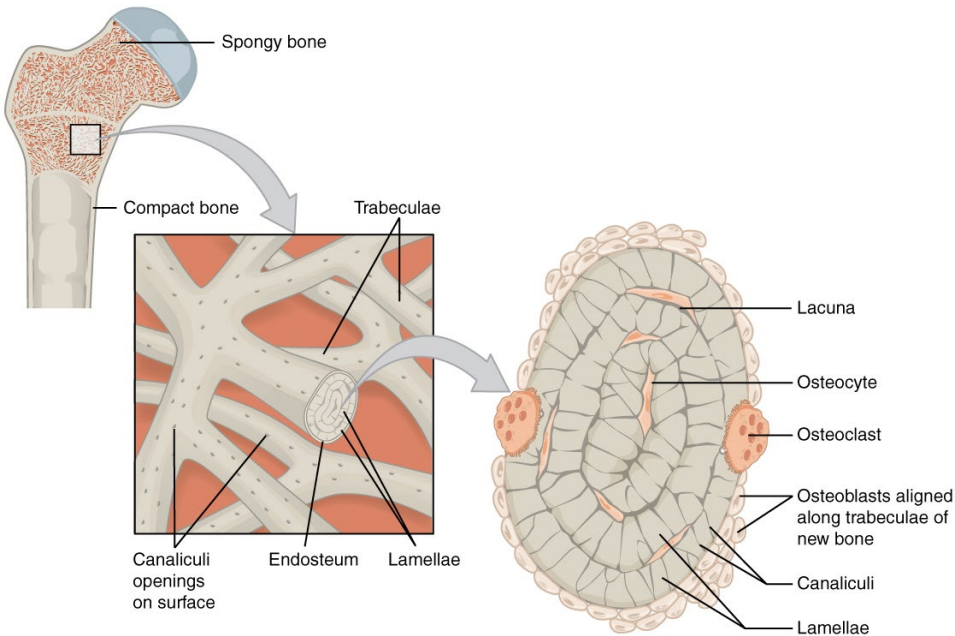


Figures 5 and 6

# General anatomy of a bone

Part	Description
Diaphysis	Bone shaft
Epiphysis	End of long bone
Metaphysis	Growth (epiphyseal) plate region
Articular cartilage	Hyaline cartilage over joint surfaces Reduces friction & absorbs shocks
Medullary cavity	Yellow bone marrow cavity
Endosteum	Inside lining of medullary cavity Bone cells
Periosteum	Tough membrane covering bone Outer fibrous layer made of CT Inner osteogenic layer (bone cells & blood vessels) Protects & nourishes bone Attachment point for tendons & ligaments

# Spongy bone



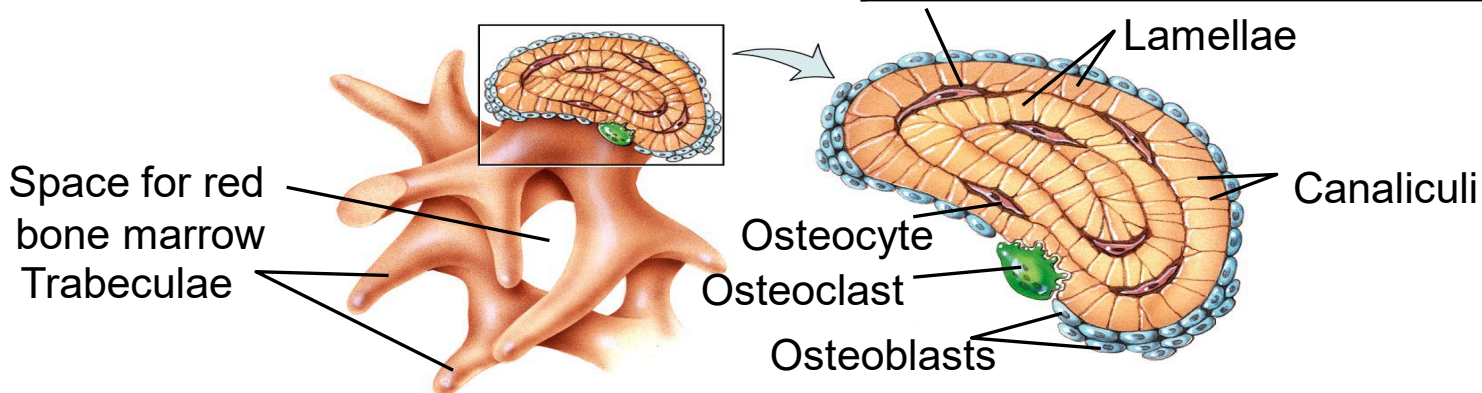
## Properties

- Light bone tissue inside a bone
- Protected by compact bone
- Area of low stress or stress from many directions
- Ends of long bones
- Inside of flat & short bones
- Supports & protects bone marrow

## Trabeculae

- Latticework of thin plates
- Concentric lamellae with osteocytes in lacunae

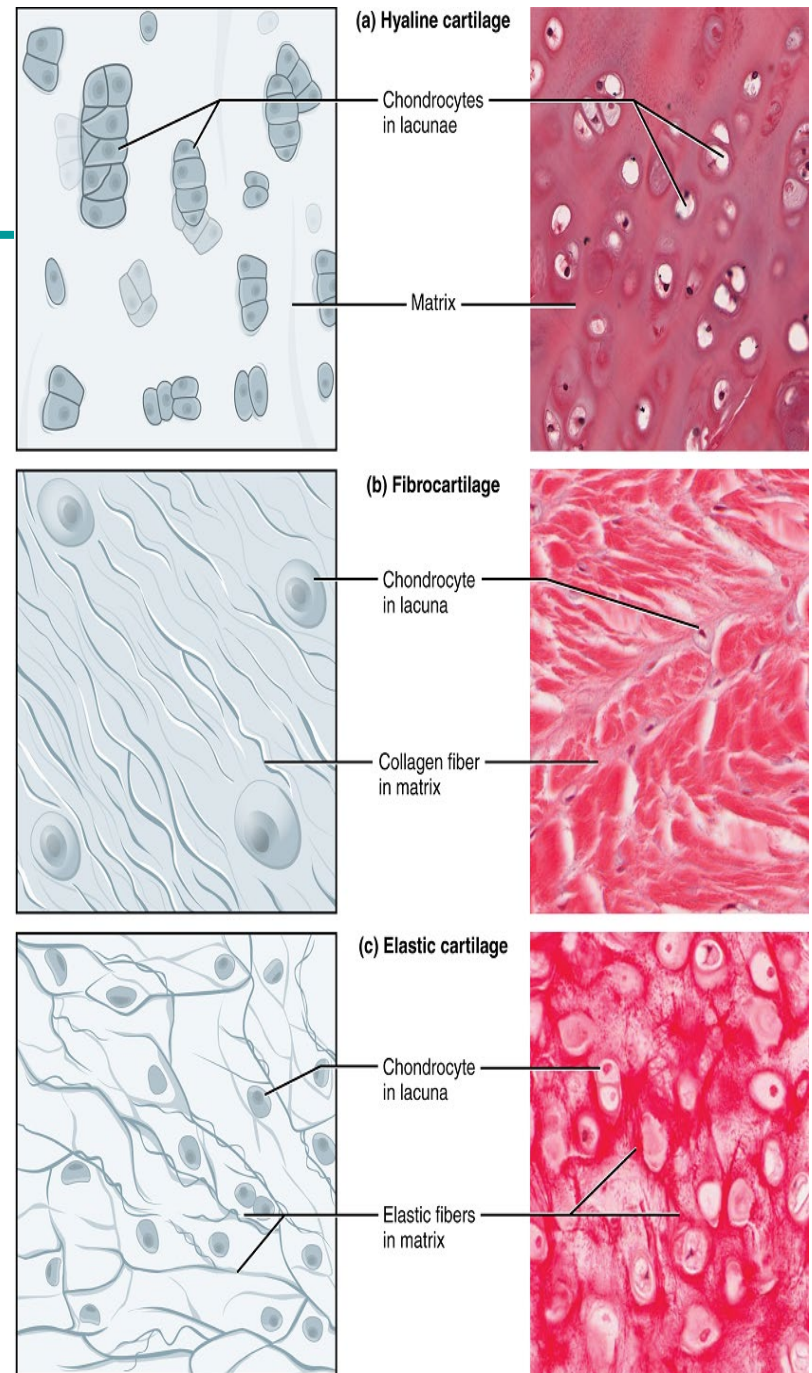
Figure 10



# Cartilage

## characteristics

- Main cell type:  
chondrocyte
- Extracellular matrix:  
collagen and elastic fibers  
(embedded in chondroitin sulphate)
- Chondrocytes reside in lacunae.
- It is surrounded by perichondrium.
- It lacks blood vessels and nerves  
(except perichondrium)
- Flexible and resistant



# Cartilage

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## General structure

- Chondroblasts & chondrocytes in lacunae
- Dense network of fibers in ECM
- Ground substance contains lots of H<sub>2</sub>O & chondroitin sulfate
- No blood vessels & no nerve fibers

## Main functions

- Provides support & reduces friction at joints
- Bone precursor

## Three types of cartilage

- Hyaline cartilage
- Fibrocartilage
- Elastic cartilage

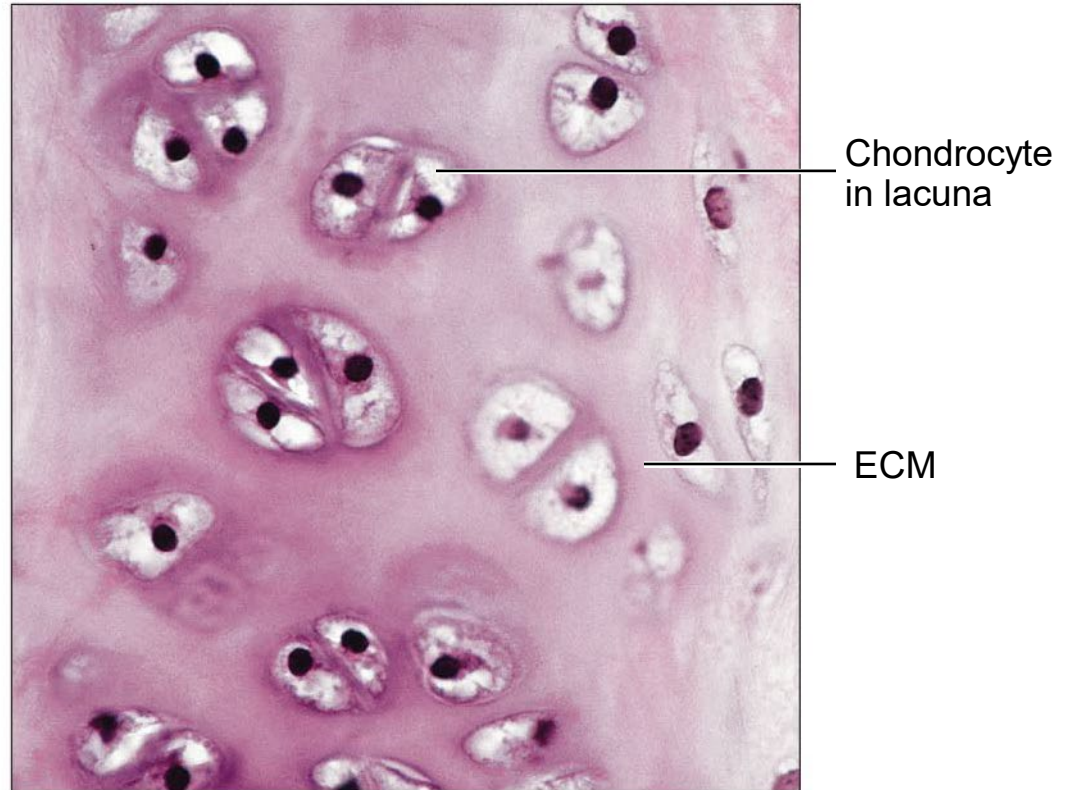
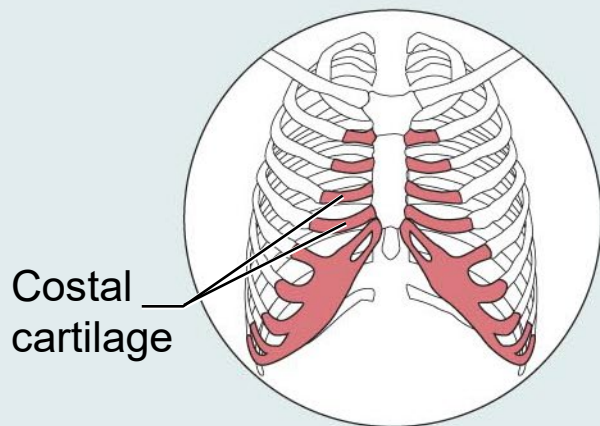
# Hyaline cartilage

most abundant cartilage, but weakest

**Function:** Support & reinforce;  
Resist compressive stress.

**Location:** Covers ends of long bones in joint cavities; costal cartilage of ribs; cartilage of nose, trachea & larynx.

## Perichondrium



Photomicrograph (470x)

# Fibrocartilage

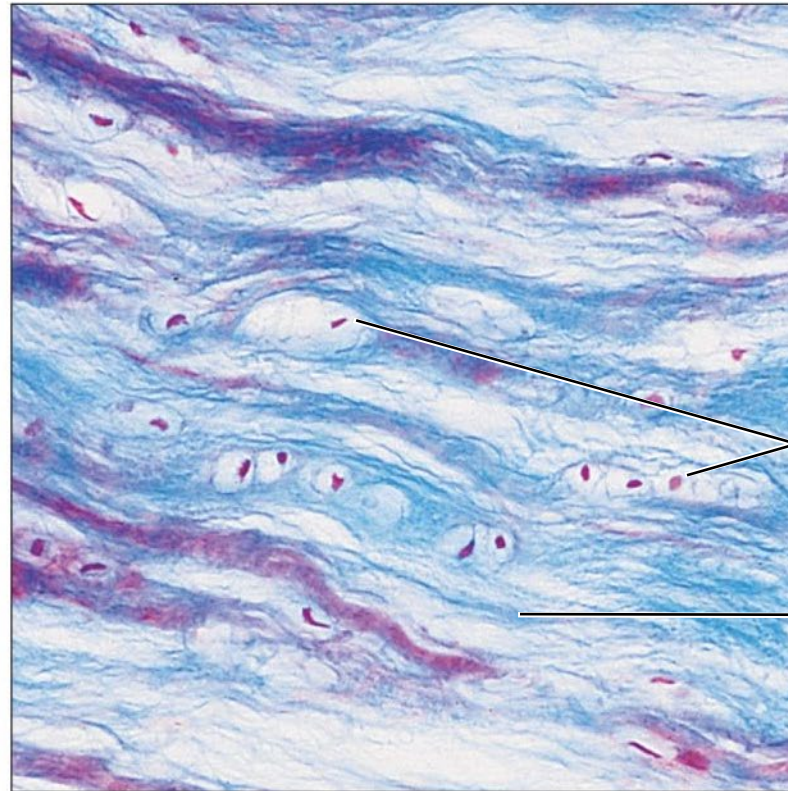
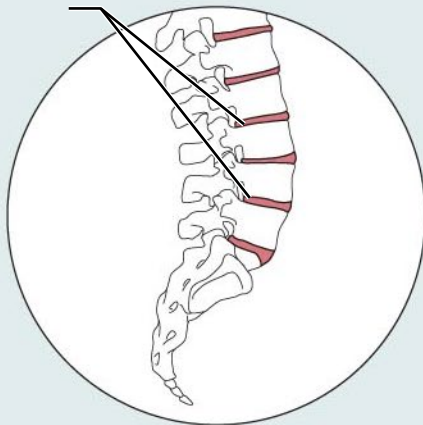
strongest cartilage, lots of collagen

**Function:** Tensile strength allows it to absorb compressive shock.

**Location:** Intervertebral discs; pubic symphysis; menisci of knee joint.

**No Perichondrium**

Intervertebral discs



Photomicrograph (125x)

Marieb, Figure 4.11i  
21

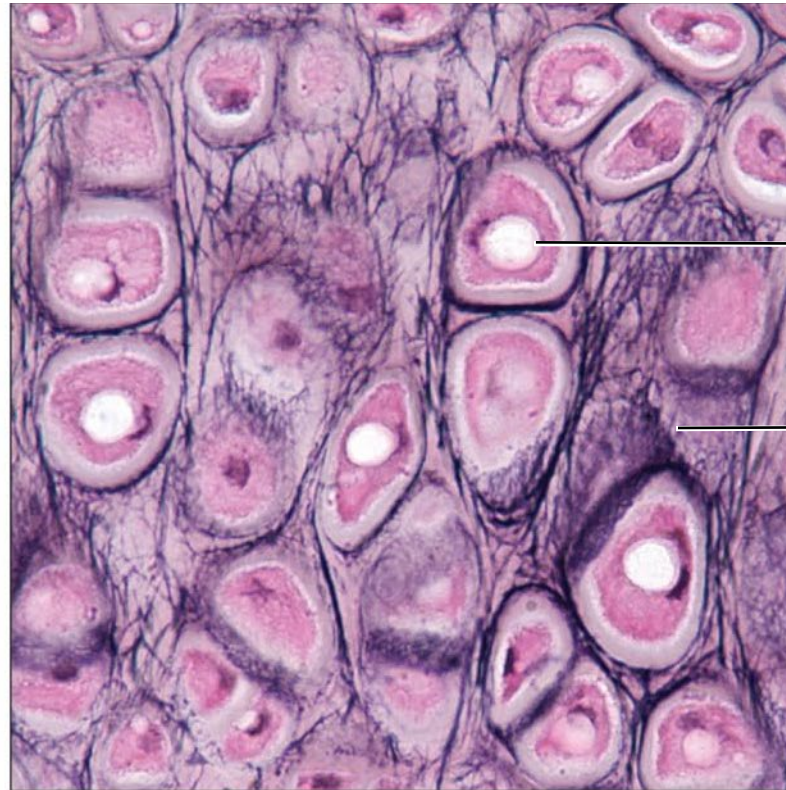
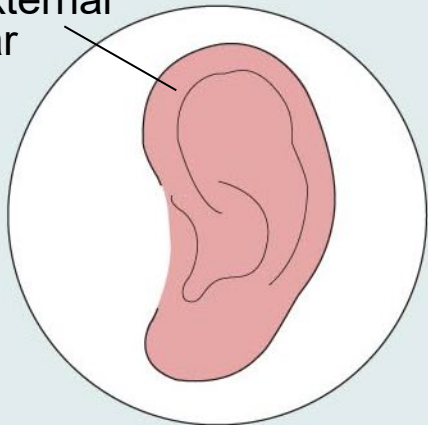
Elastic cartilage  
allows stretching, lots of elastic fibers

**Function:** Maintains shape of a structure while allowing great flexibility.

**Location:** Supports the external ear; epiglottis.

**Perichondrium**

External ear



Chondrocyte in lacuna

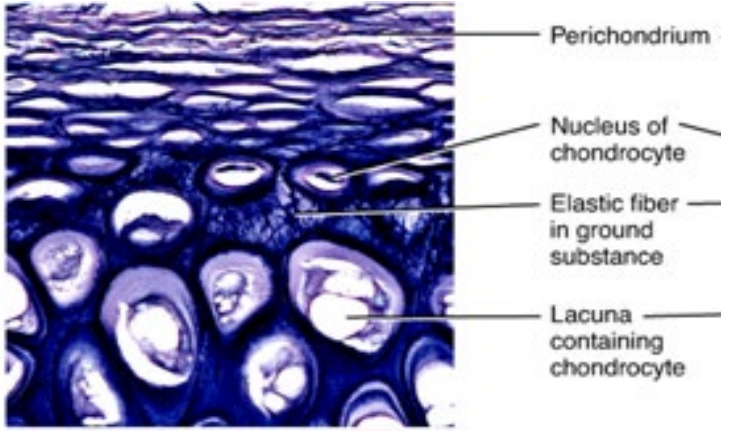
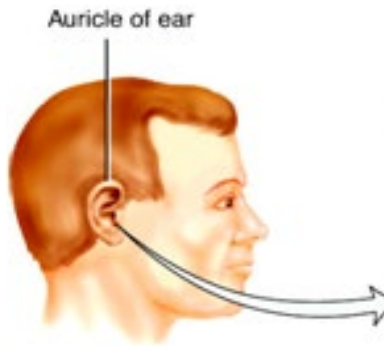
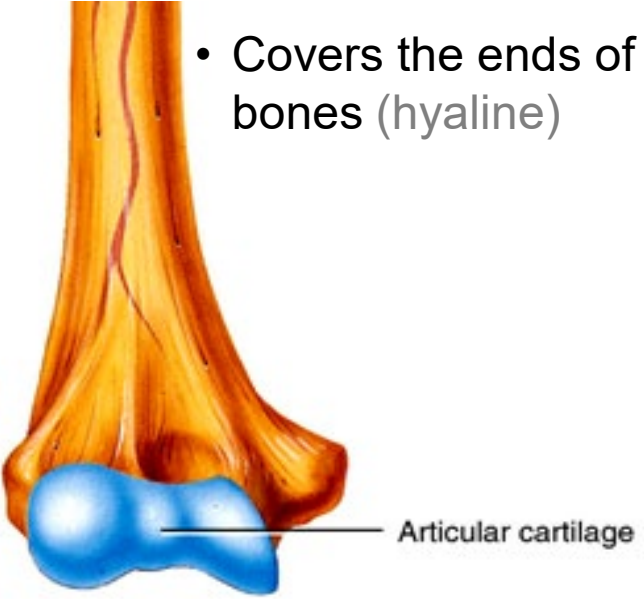
ECM

Photomicrograph (800x)

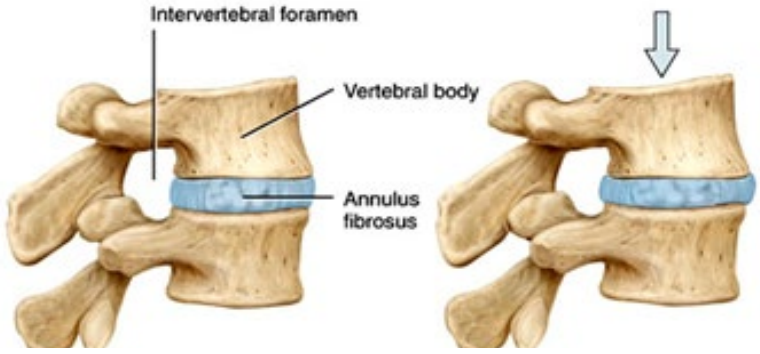
Marieb, Figure 4.11h 22

# Cartilage

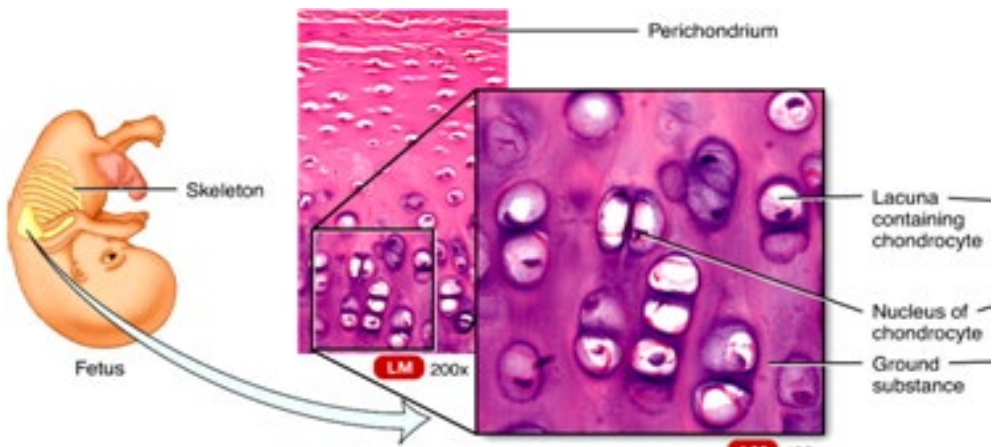
## functions



- Provides support and flexibility (elastic)



- Provides cushioning in joints (fibrocartilage)



- It forms the embryonic skeleton (hyaline)

# Ossification (osteogenesis)

---

Ossification = Process of bone formation

## Initial bone formation

- Starts around week 7 of embryonic development
- Two ossification methods:
  - Intramembranous
  - Endochondral

## Bone growth

- From infancy to adulthood
- Two processes:
  - Growth in length
  - Growth in width

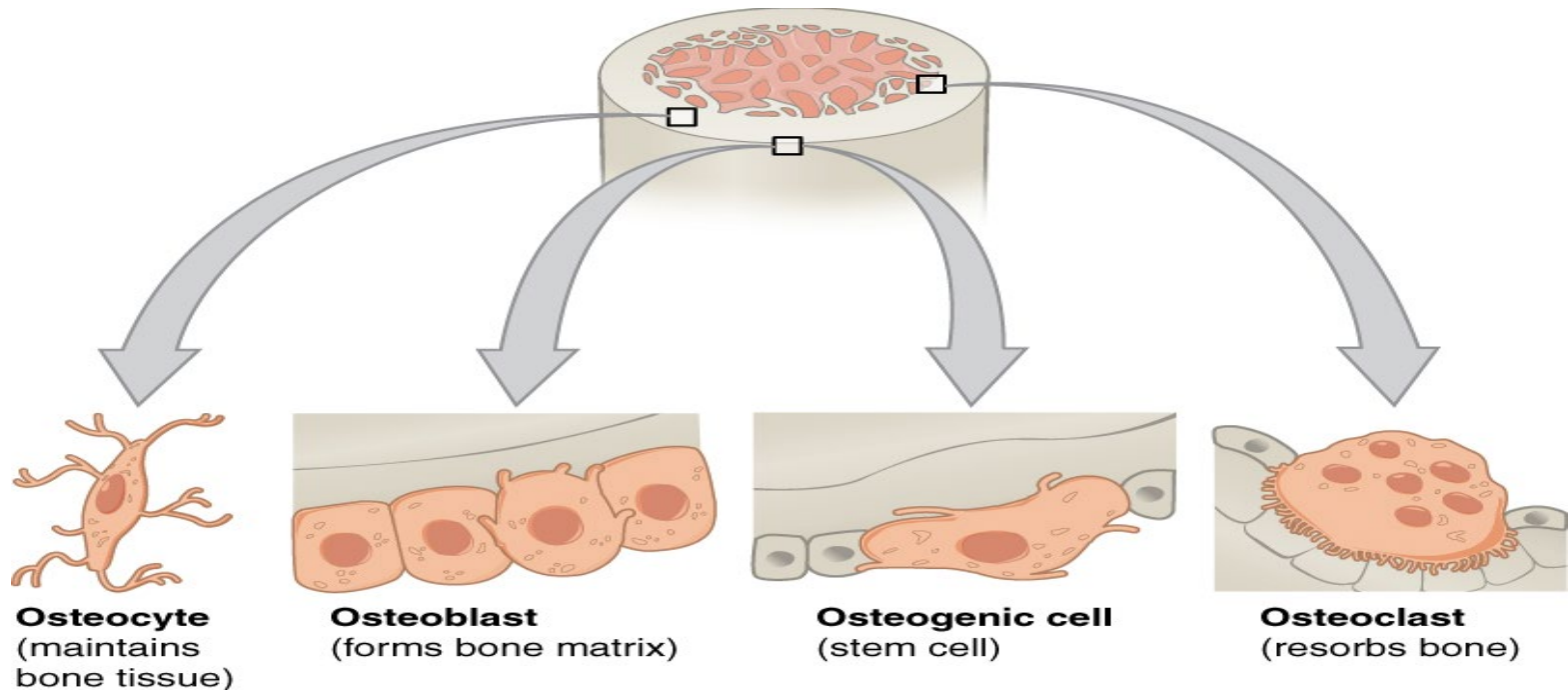
## Remodeling & repair

- Throughout life
- Replacement of old bone tissue
- Repair of fractures

# Structure of Bones

## types of cells in bone tissue

Figure 8



- **Osteoblasts** – bone-building cells, make collagen fibers
- **Osteocytes** – mature bone cells, main cells in bone tissue
- **Osteoclasts** – huge cells make enzymes to resorb bone matrix

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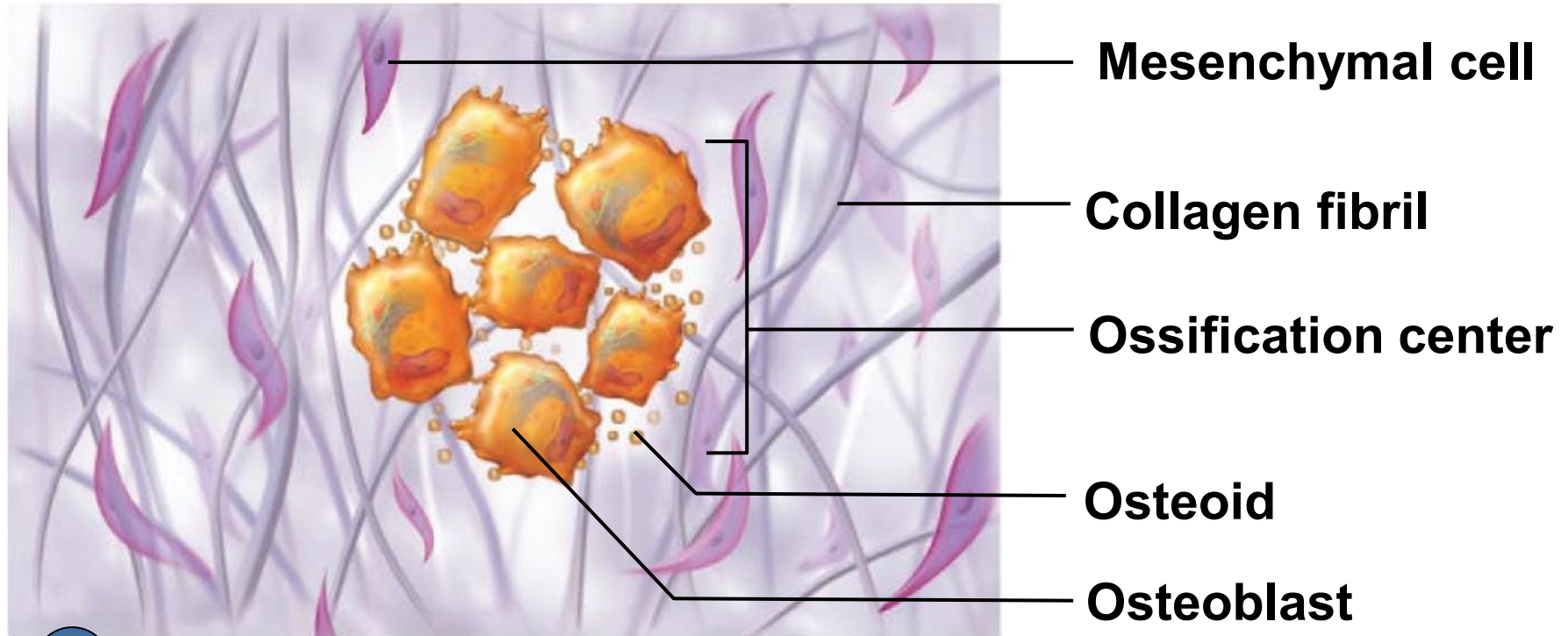
## Patterns of New (Embryonic) Bone Formation

	<b>Intramembranous Ossification</b>	<b>Endochondral Ossification</b>
<b>Tissue that bone originates from</b>	Mesenchyme	Cartilage
<b>Function</b>	Originates flat bones during development.	Originates all bones, except flat bones, during development. Bone growth.

- Both types of ossification start with pre-existing **connective tissue**

# Intramembranous ossification

Marieb, Figure 6.11



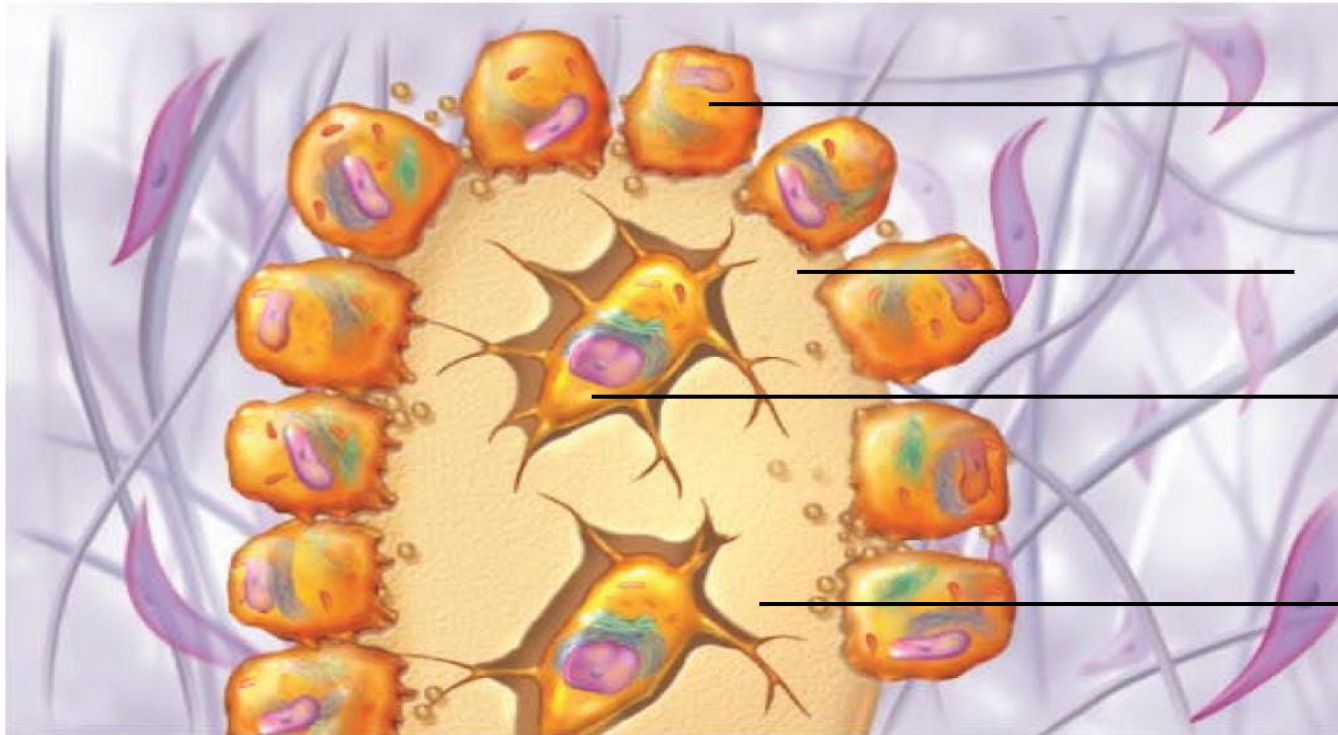
1

## Development of ossification center :

- Specific chemical messages cause mesenchymal cells (stem cells that can turn into either chondrocytes or osteocytes) to differentiate into osteogenic cells and then into osteoblasts
- Clusters of osteoblasts secrete matrix

# Intramembranous ossification

Marieb, Figure 6.11



Osteoblast

Osteoid

Osteocyte

Newly calcified  
bone matrix

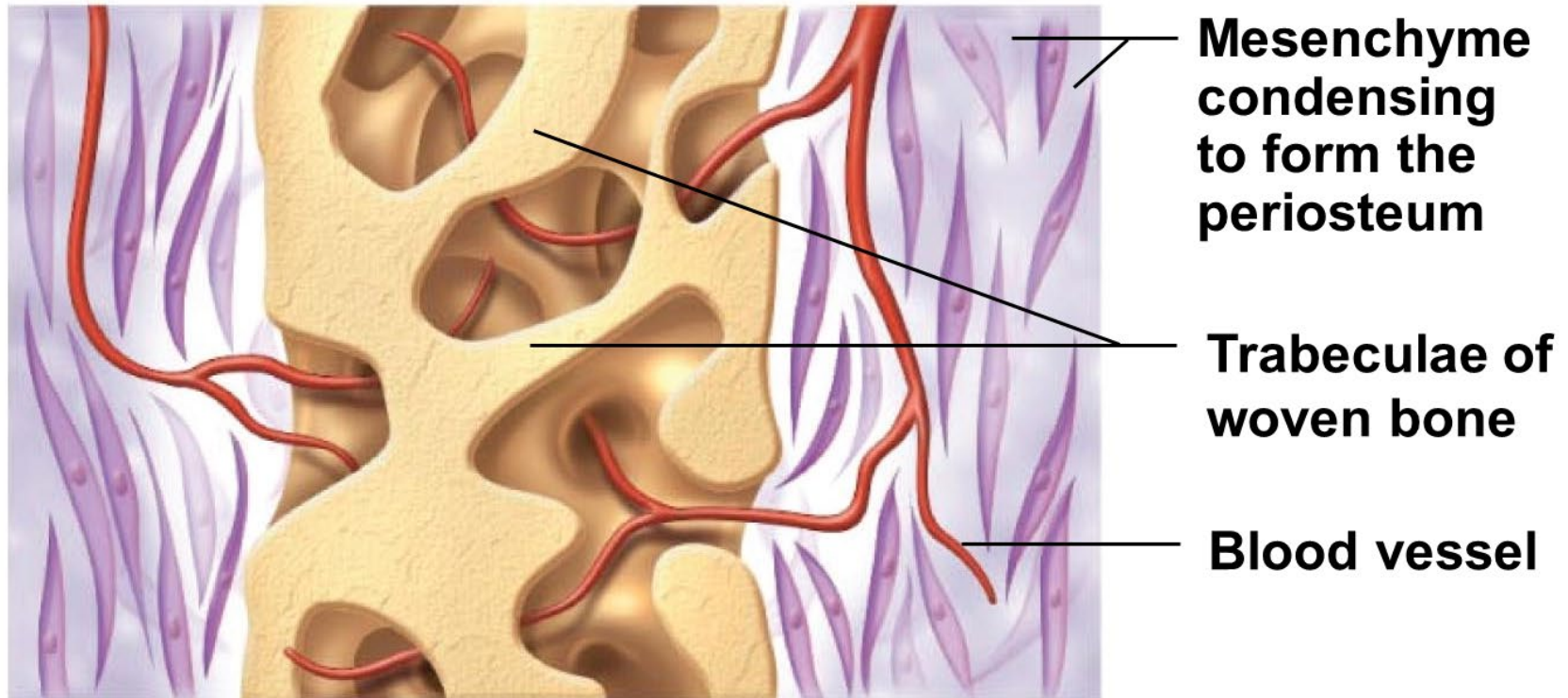
2

## Calcification :

- Osteoblasts differentiate into osteocytes
- Formation of lacuna and canaliculi
- Deposition of minerals (calcium and phosphorus) in matrix causing matrix to harden or “calcify”

# Intramembranous ossification

Marieb, Figure 6.11



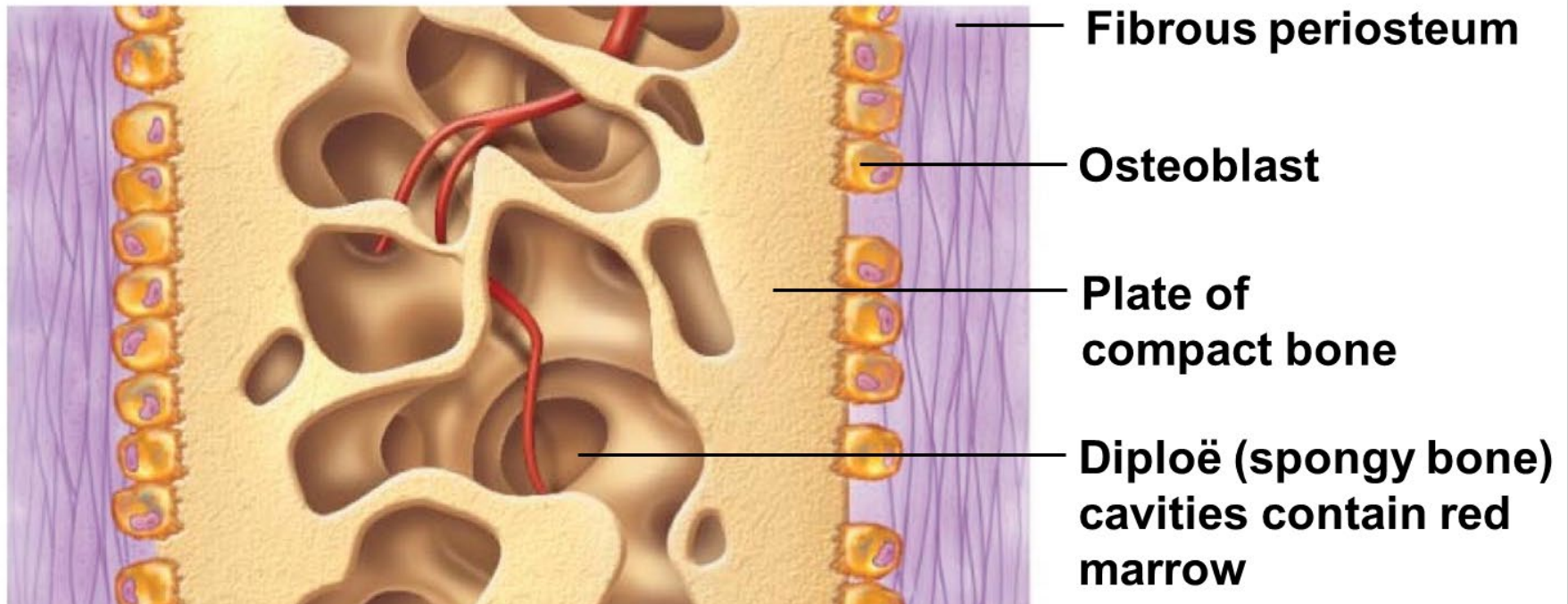
3

## Formation of trabeculae (spongy bone)

- As bone extracellular matrix forms, it develops into trabeculae that fuse with one another to form spongy bone around the network of blood vessels in the tissue

# Intramembranous ossification

Marieb, Figure 6.11



4

Development of the periosteum : (at the same time as 3 )

- Some mesenchyme condenses at periphery of bone and develops into periosteum
- A thin layer of compact bone replaces the surface layer of the spongy bone
- Spongy layer remains sandwiched between compact bone layers

# Intramembranous ossification

## Intramembranous ossification

- Bone forms within mesenchyme
- Formation of most skull bones & part of clavicle

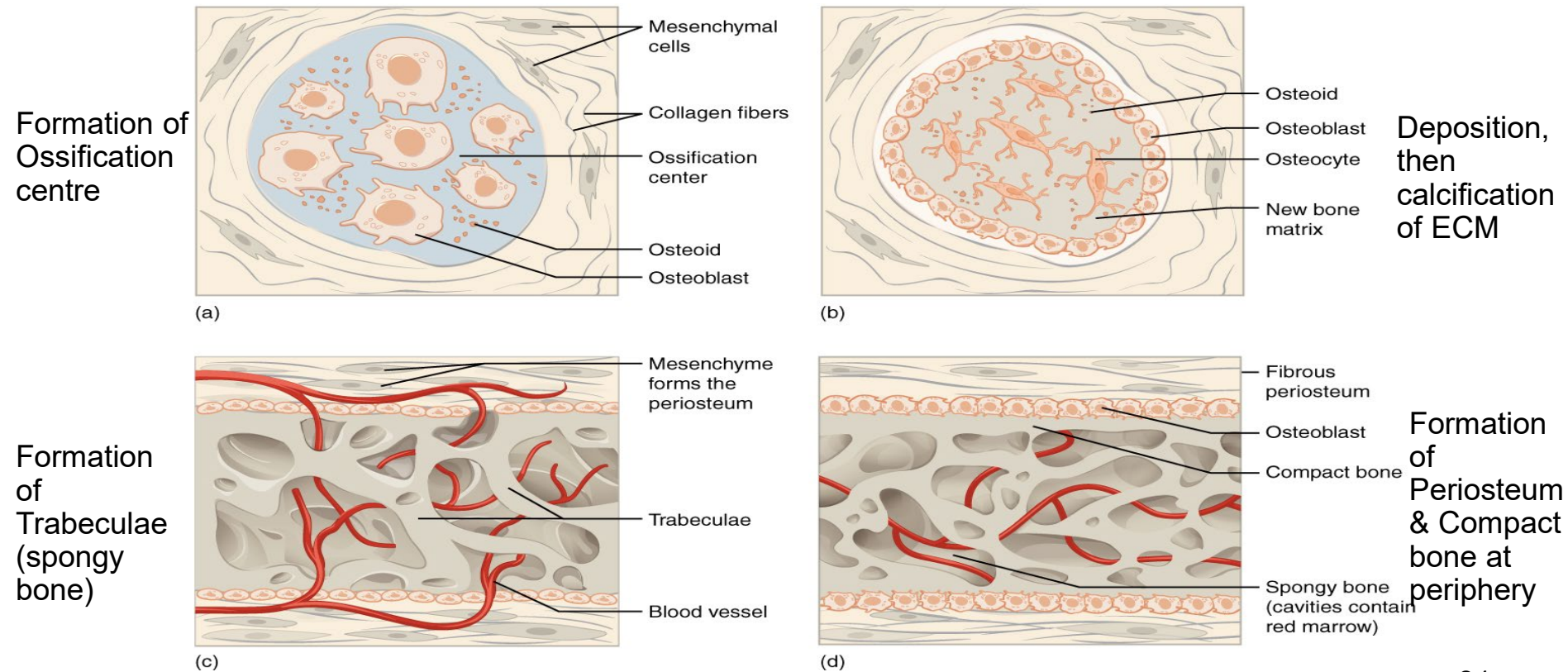


Figure 12

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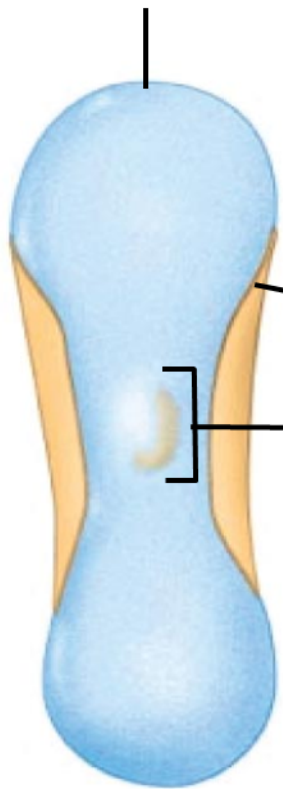
## Patterns of New (Embryonic) Bone Formation

	Intramembranous Ossification	Endochondral Ossification
Tissue that bone originates from	Mesenchyme	Cartilage
Function	Originates flat bones during development.	Originates all bones, except flat bones, during development. Bone growth.

- Both types of ossification start with **pre-existing connective tissue**

## Week 9

Hyaline cartilage



Bone collar

Primary ossification center

# Endochondral ossification

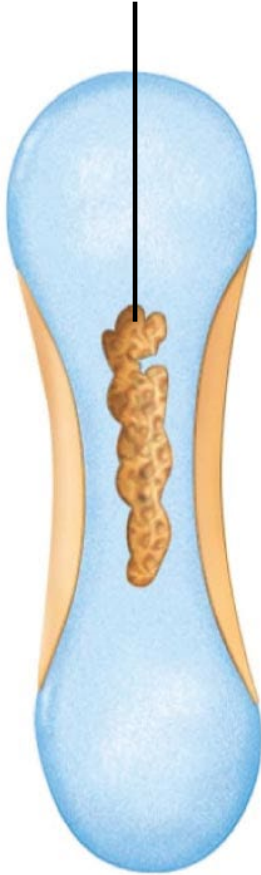
1

Development of cartilage model:

- Mesenchyme cells differentiate into chondroblasts
- Chondroblasts secrete cartilage matrix
- Result: a model made up of hyaline cartilage

# Endochondral ossification

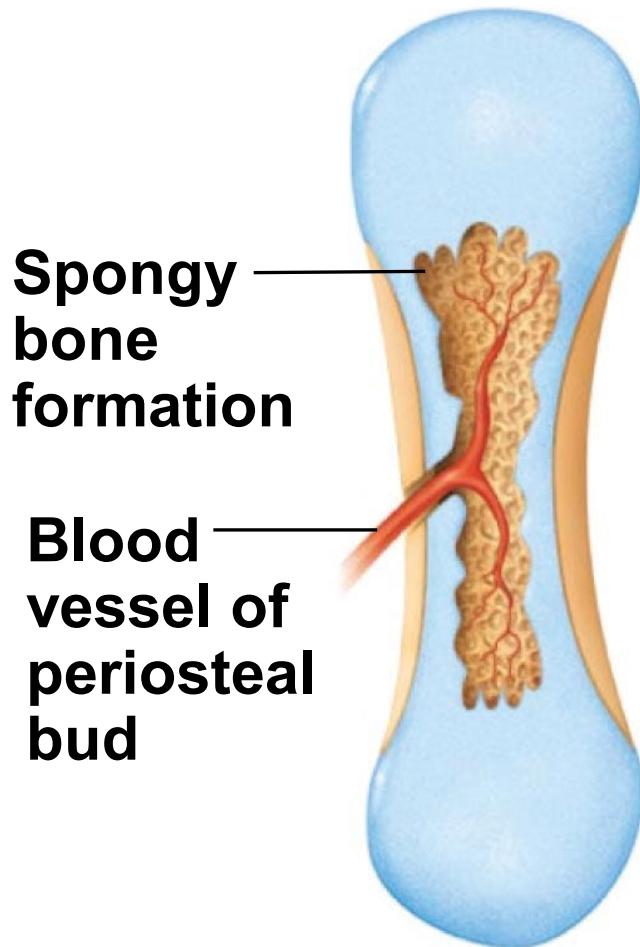
Area of deteriorating cartilage matrix



- 2** Growth of cartilage model:
  - Model gets larger and longer due to continual division of chondrocytes
  - The matrix in the middle begins to calcify, causing the chondrocytes in the middle to start dying

**Month 3**

# Endochondral ossification



- 3 Development of primary ossification center:
- Blood vessels invade cartilage model
  - Osteogenic cells in perichondrium (layer of cartilage which becomes periosteum) differentiate into osteoblasts
  - Osteoblasts secrete bone matrix
  - Spongy bone starts to replace the cartilage and spreads to both ends of the bone

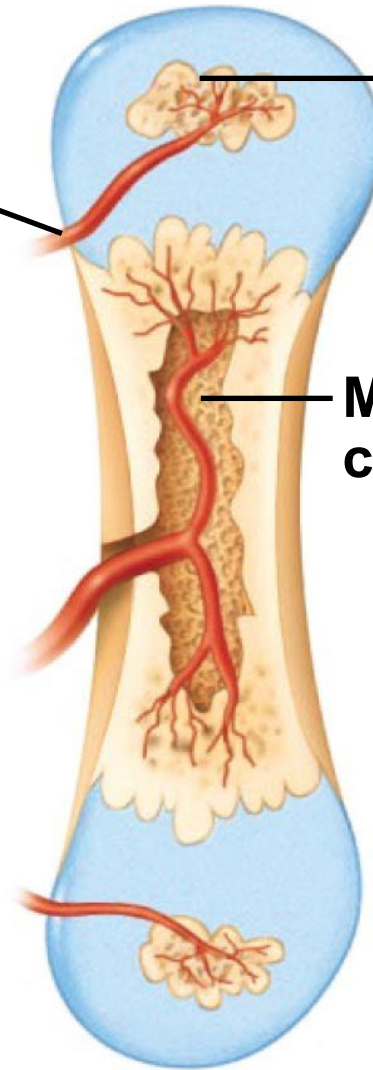
# Endochondral ossification

**Birth**

**Epiphyseal blood vessel**

**Secondary ossification center**

**Medullary cavity**



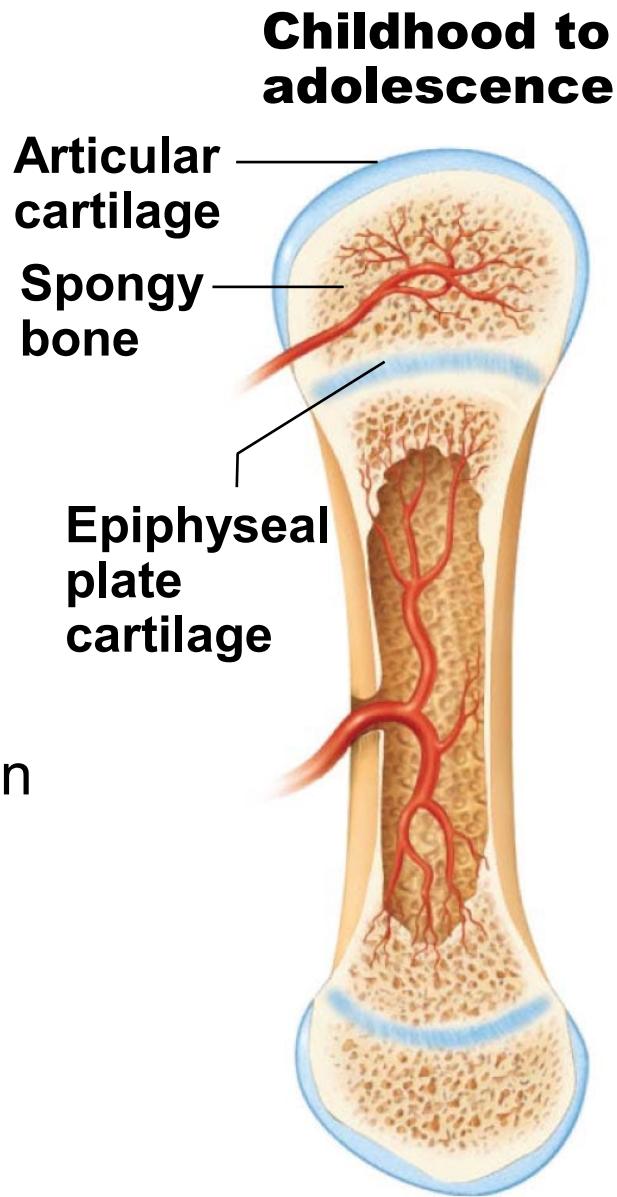
4

Development of the medullary (marrow) cavity:

- Spongy bone reaches the ends of the bones
- Osteoclasts breakdown some of the inside spongy bone, creating the medullary cavity
- Spongy bone at diaphysis replaced by compact bone

# Endochondral ossification

- 5 Development of secondary ossification centers:
- More clusters of osteoblasts in the epiphyses



# Endochondral ossification

**Endochondral ossification**

- Bone forms within hyaline cartilage (replaces cartilage)
- Formation of most bones in body

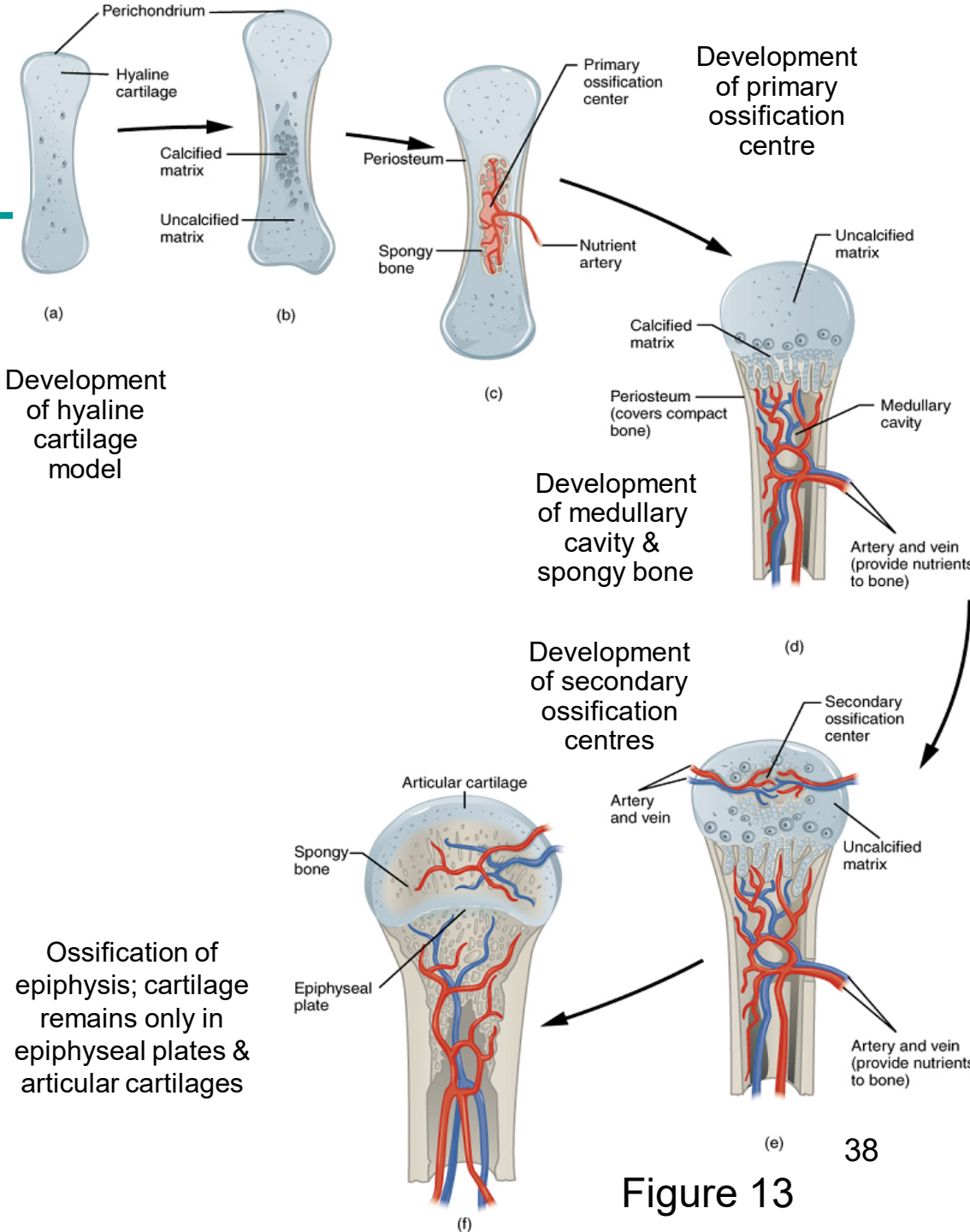


Figure 13

# Ossification (osteogenesis)

---

Ossification = Process of bone formation

## Initial bone formation

- Starts around week 7 of embryonic development
- Two ossification methods:
  - Intramembranous
  - Endochondral

## Bone growth

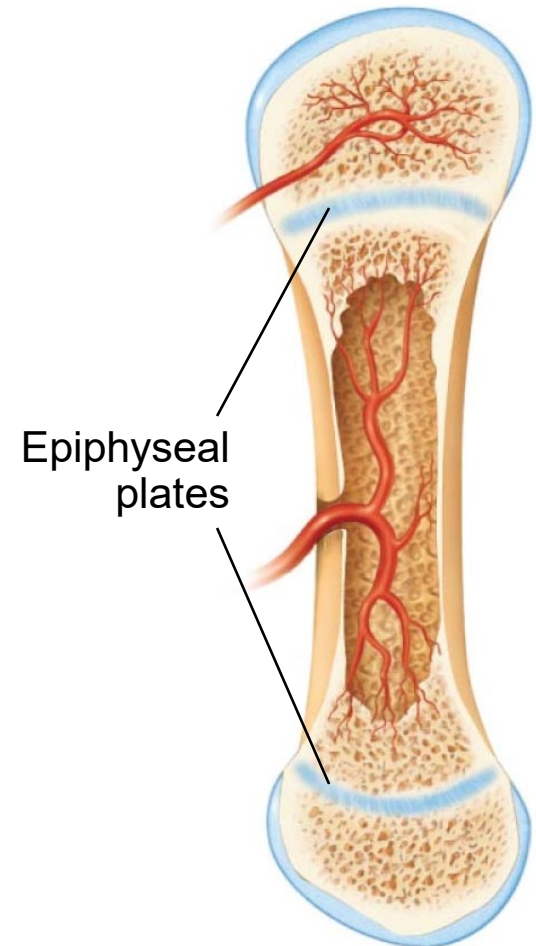
- From infancy to adulthood
- Two processes:
  - Growth in length
  - Growth in width

## Remodeling & repair

- Throughout life
- Replacement of old bone tissue
- Repair of fractures

# Long bone growth in length

<b>Location</b>
<u>Epiphyseal</u> plates
<b>Major events</b>
<b>1) Cartilage growth</b> New chondrocytes produced by mitosis (cell division)
<b>2) Replacement of cartilage</b> Chondrocytes die within calcified cartilage Calcified cartilage replaced by bone tissue <ul style="list-style-type: none"><li>- Osteoclasts erode calcified cartilage</li><li>- Osteoblasts secrete bone ECM</li></ul>



Marieb, Figure 6.10

# Bone growth

growth in length

Stops at  
~18 ♀  
~21 ♂

Proliferation of chondrocytes in the **proliferation zone**

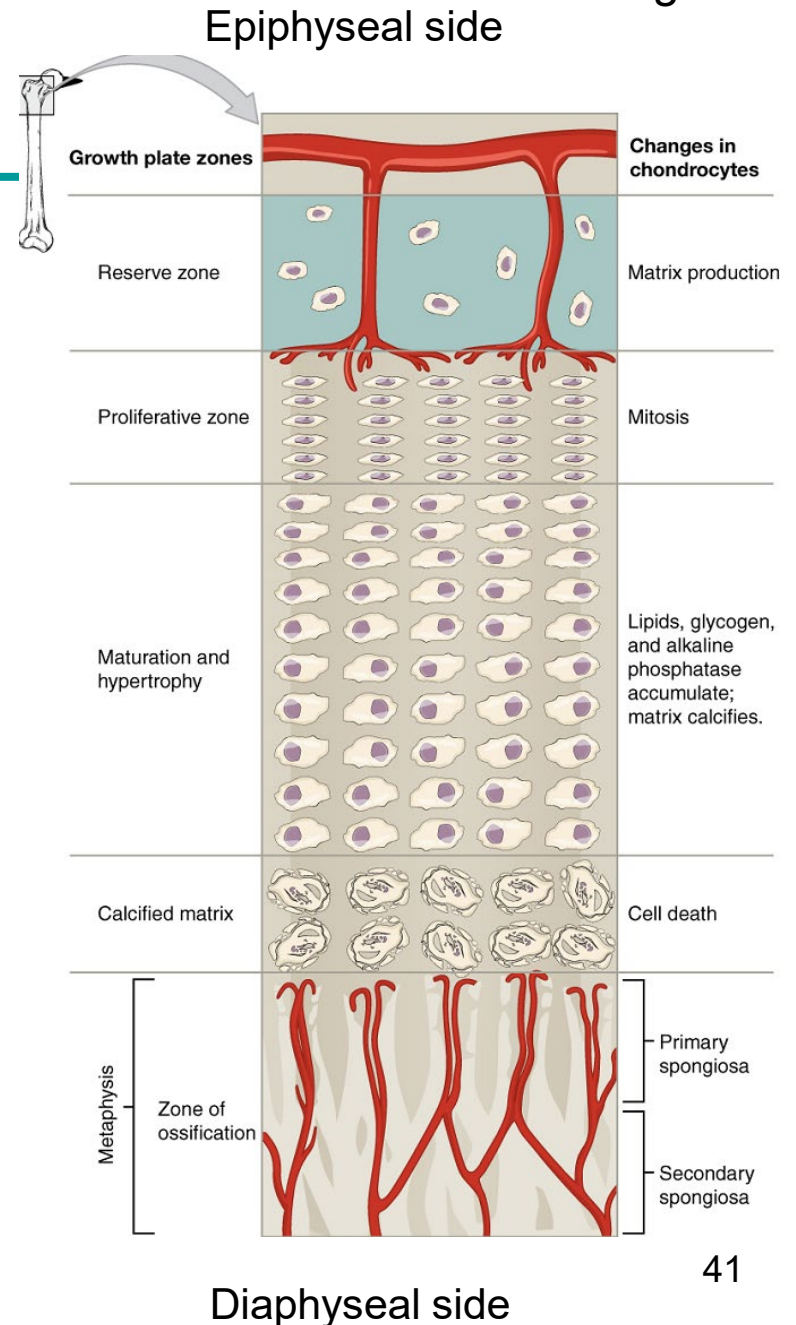
Growth of chondrocytes in the **hypertrophic zone**

Calcification of extracellular matrix and death of chondrocytes in the **calcification zone**

Dissolution of calcified matrix by osteoclasts and invasion of osteoblasts, which form new bone in the **ossification zone**

Osteoblasts differentiate into osteocytes.

Figure 14



# Bone growth

## growth in length

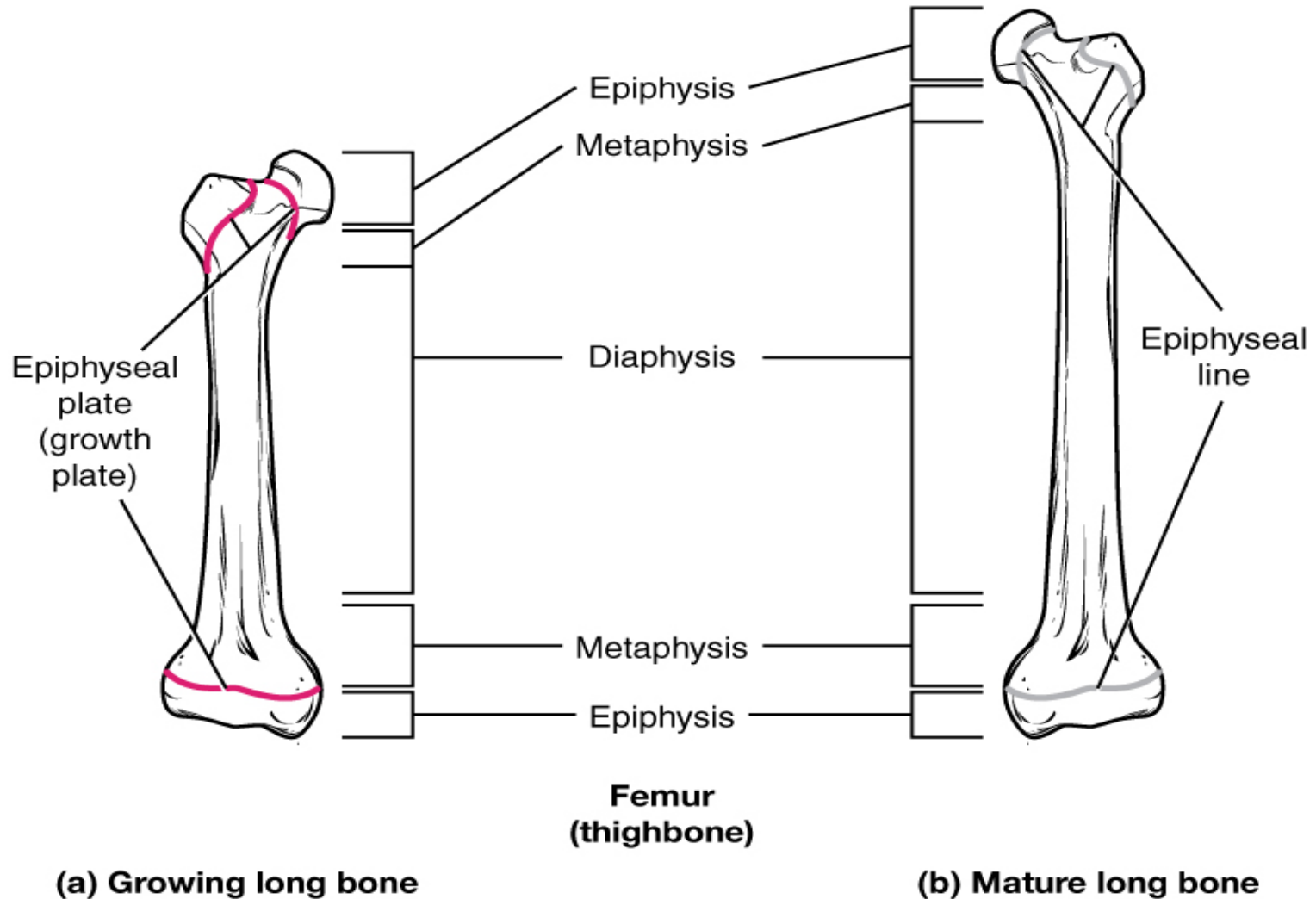
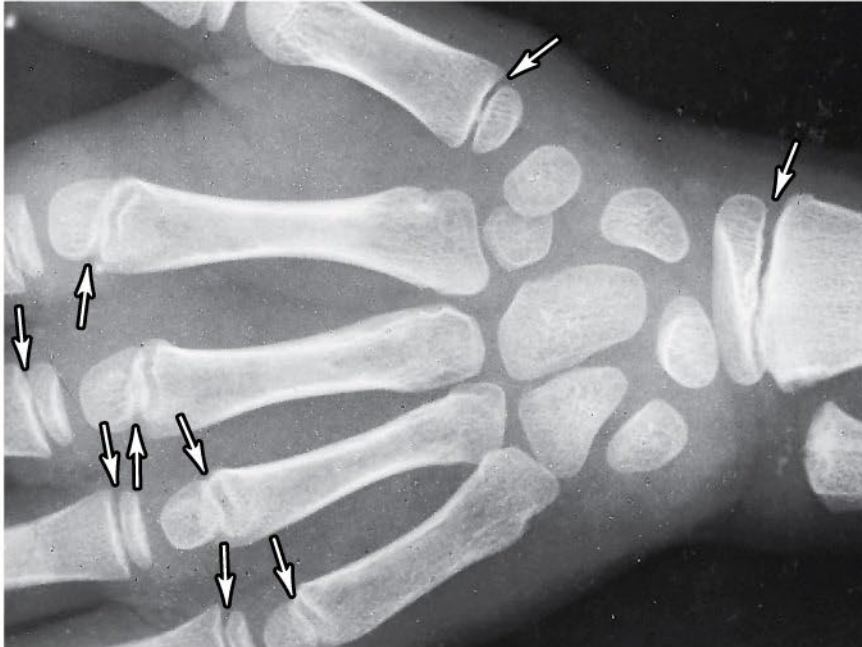


Figure 15

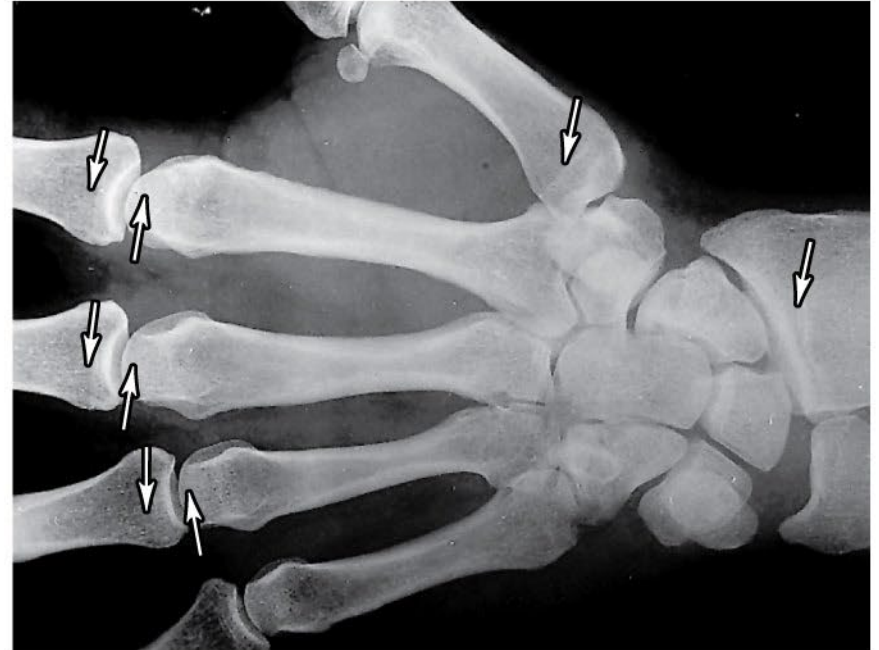
# Long bone growth in length

## X-rays

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Growing epiphyseal plates (arrows)

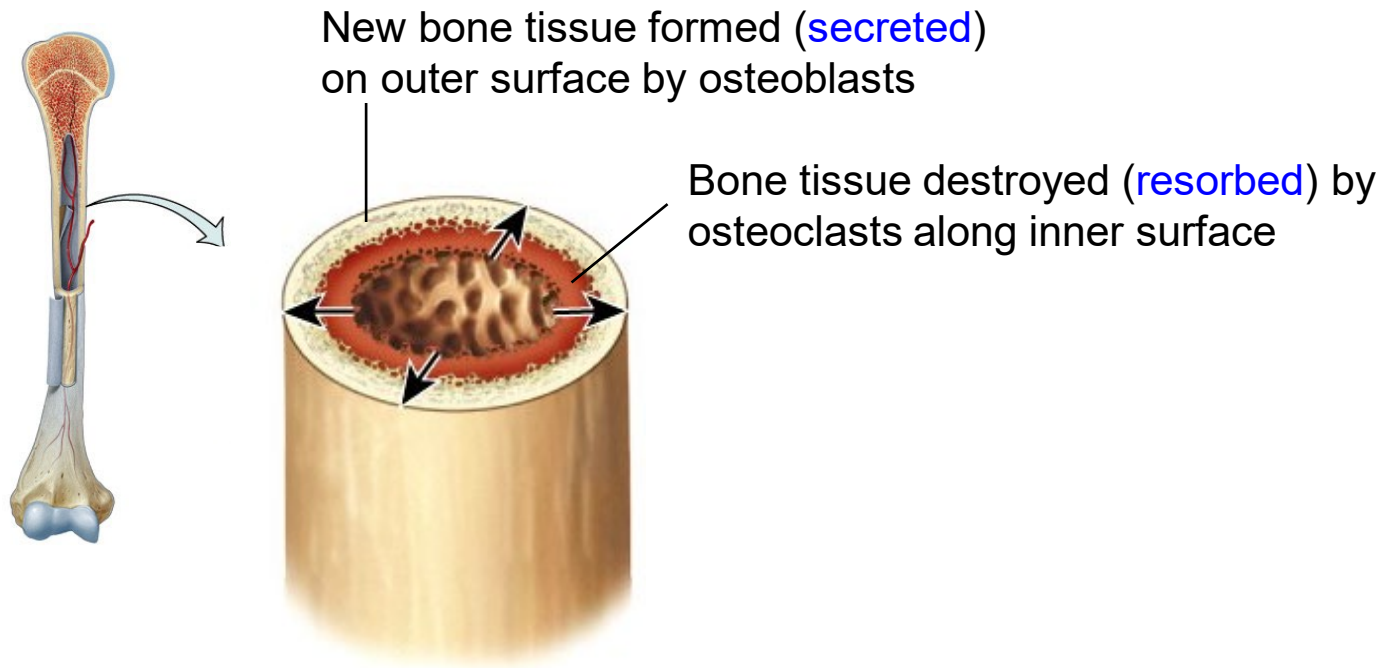


Epiphyseal lines in an adult (arrows)

# Long bone growth in width

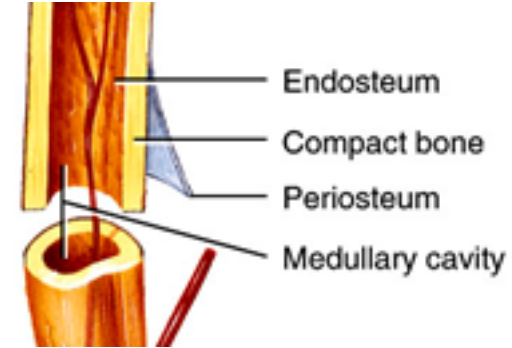
Appositional growth

---



# Bone growth

growth in girth (appositional growth)



## Events in the Periosteum

Periosteum cells differentiate into osteoblasts.

**Osteoblasts** lay down new compact bone around periosteal blood vessels.

Osteoblasts differentiate into **osteocytes**.

## Events in the Endosteum

**Osteoclasts** erode endosteum.

Calcium is released into the blood stream.

Medullary cavity enlarges.

Ca<sup>2+</sup>

# Bone growth

## growth in girth (appositional growth) Periosteum

---

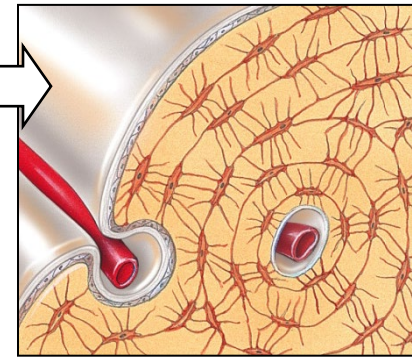
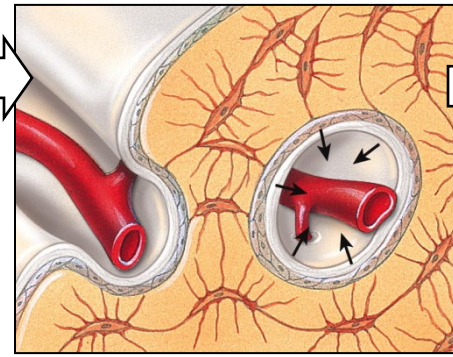
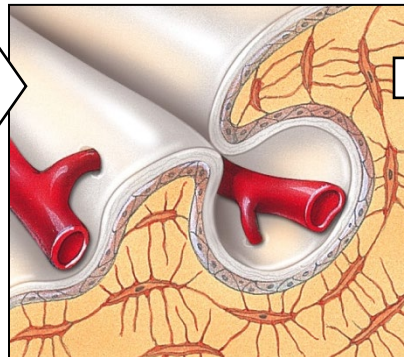
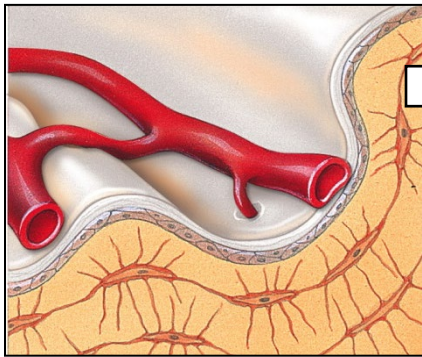
Periosteal cells  
differentiate into  
osteoblasts

Formation of ridge,  
then tunnel

Periosteum becomes  
Endosteum

Osteoblasts deposit  
ECM, forming lamellae

Tunnel fills in with  
lamellae, forming  
an osteon



# Ossification (osteogenesis)

---

Ossification = Process of bone formation

## Initial bone formation

- Starts around week 7 of embryonic development
- Two ossification methods:
  - Intramembranous
  - Endochondral

## Bone growth

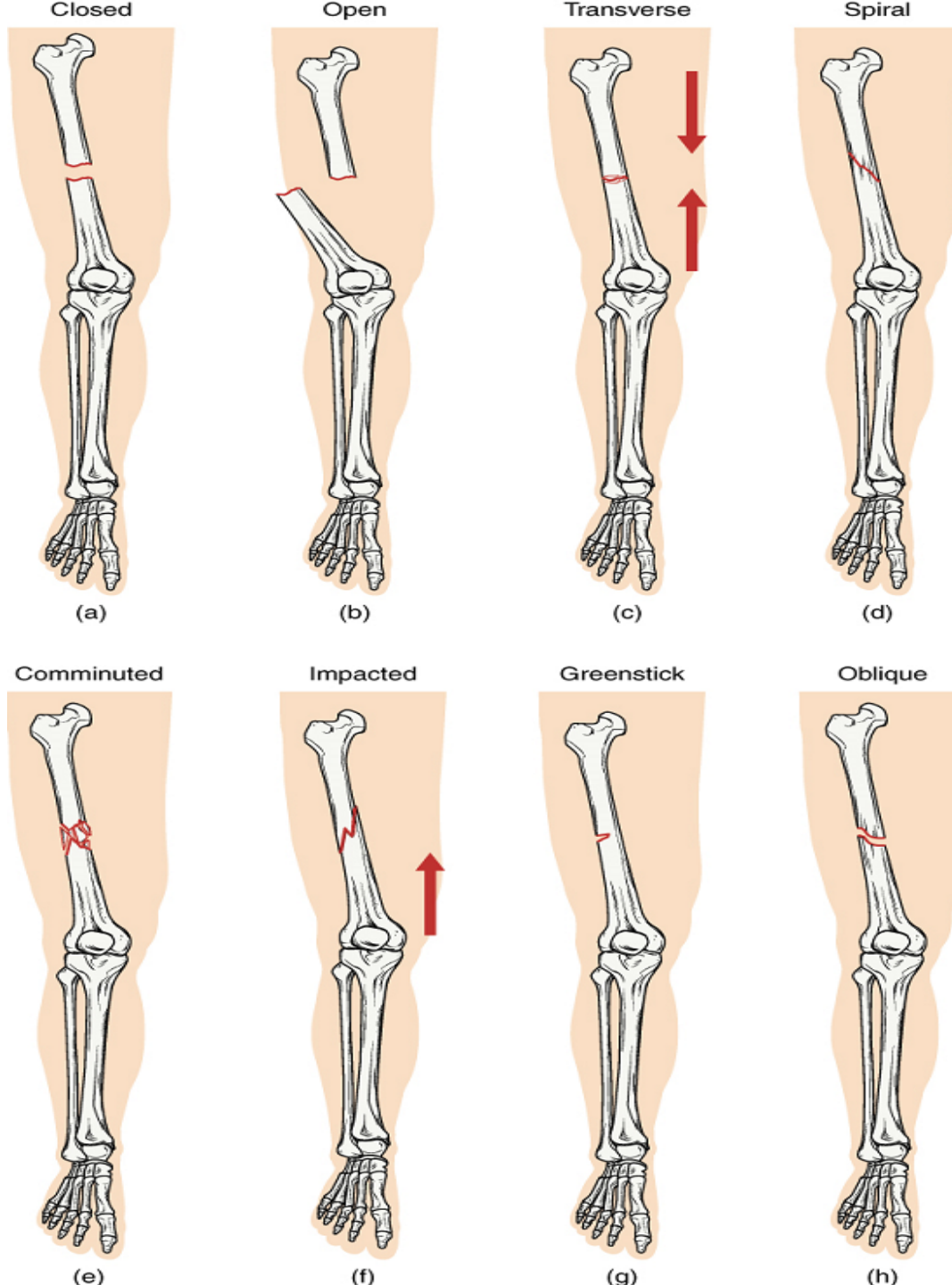
- From infancy to adulthood
- Two processes:
  - Growth in length
  - Growth in width

## Remodeling & repair

- **Throughout life**
- Replacement of old bone tissue
- Repair of fractures

# Bone

## fractures



- Closed
- Open
- Comminuted
- Greenstick



Figure 16

# Divisions of the skeletal system

## Axial vs. Appendicular Skeleton

**TABLE 7.1**

The Bones of the Adult Skeletal System

DIVISION OF THE SKELETON	STRUCTURE	NUMBER OF BONES	DIVISION OF THE SKELETON	STRUCTURE	NUMBER OF BONES
<b>Axial Skeleton</b> 	<b>Skull</b>		<b>Appendicular Skeleton</b> 	<b>Pectoral (shoulder) girdles</b>	
	Cranium	8		Clavicle	2
	Face	14		Scapula	2
	<b>Hyoid</b>	1		<b>Upper limbs</b>	
	<b>Auditory ossicles</b>	6		Humerus	2
	<b>Vertebral column</b>	26		Ulna	2
	<b>Thorax</b>			Radius	2
	Sternum	1		Carpals	16
	Ribs	<u>24</u>		Metacarpals	10
		Subtotal = 80		Phalanges	28
		<b>Pelvic (hip) girdle</b>			
		Hip, pelvic, or coxal bone	2		
		<b>Lower limbs</b>			
		Femur	2		
		Patella	2		
		Fibula	2		
		Tibia	2		
		Tarsals	14		
		Metatarsals	10		
		Phalanges	<u>28</u>		
			Subtotal = 126		
			<b>Total in an adult skeleton = 206</b>		

Function:

Framework: support and protection

Function:

Locomotion

# Axial skeleton

## Axial skeleton

- 80 bones along longitudinal axis
- Components
  - Skull
  - Hyoid
  - Auditory ossicles
  - Vertebral column
  - Thoracic cage

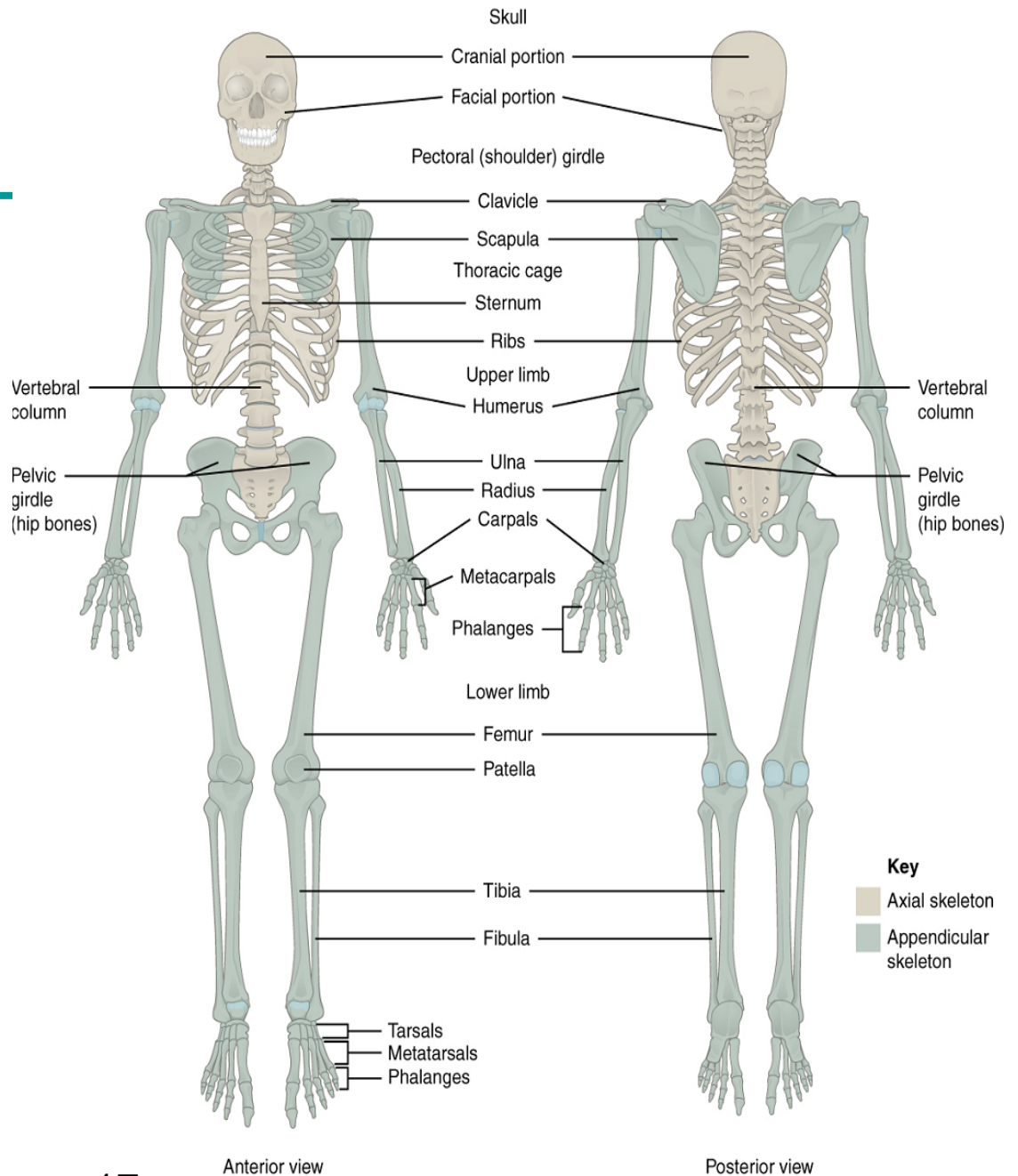


Figure 17

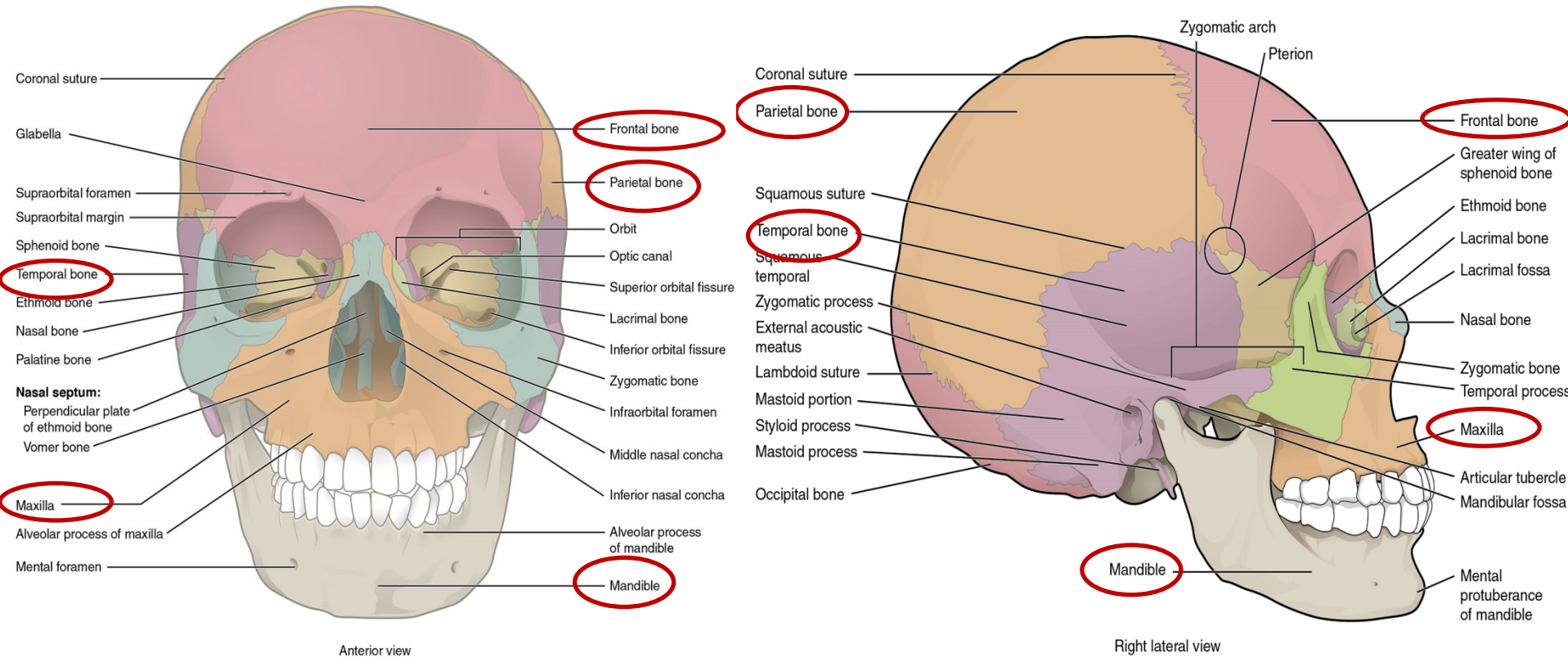
Anterior view

Posterior view

# Axial skeleton

## skull

Figures 20 and 21



# Axial skeleton

## vertebral column

Figure 24

- Function is to enclose and protect the spinal cord, support the skull and provide attachment for the ribs and muscles.

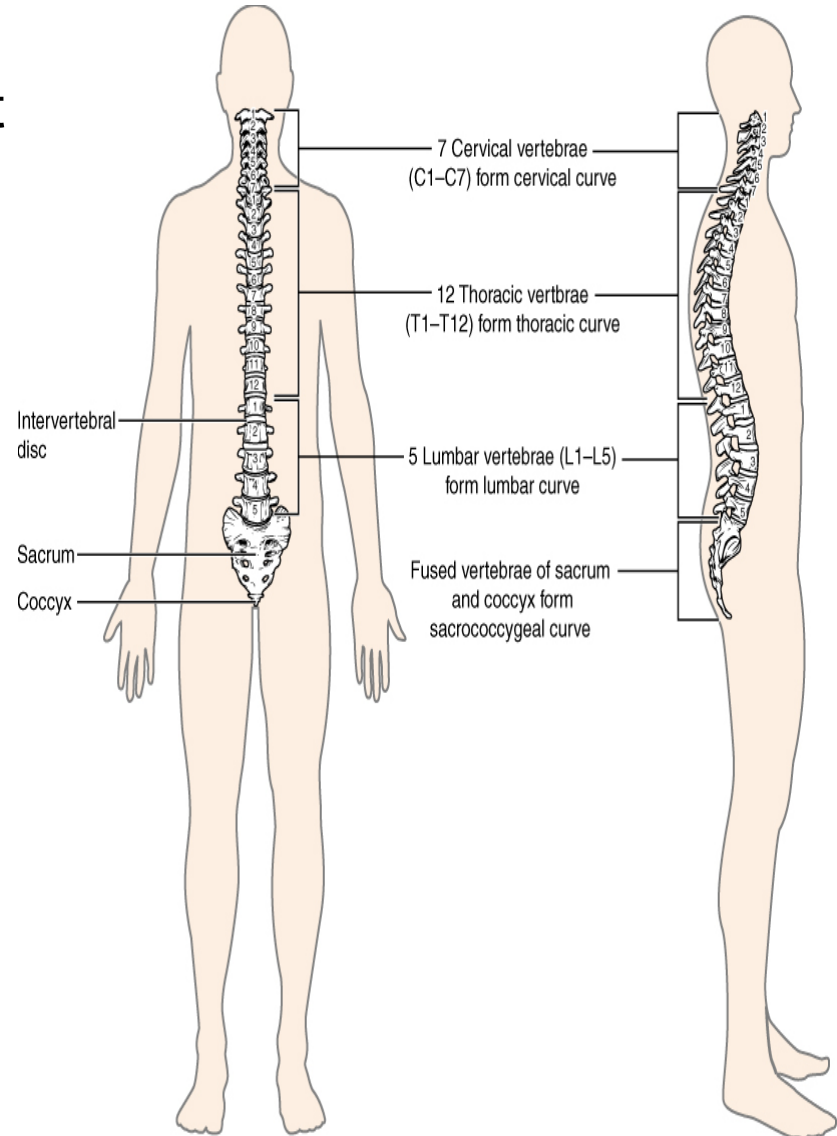
### Backbone

- 26 Vertebrae

### Five vertebral regions

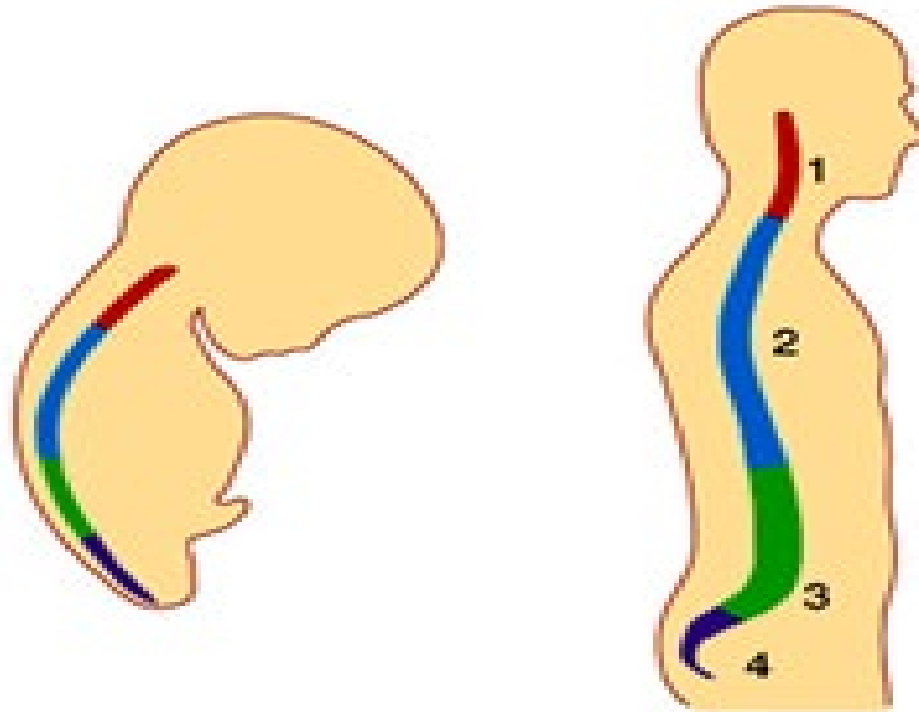
(Number of vertebrae)

- Cervical (7)
- Thoracic (12)
- Lumbar (5)
- Sacrum (5, fused)
- Coccyx (4, fused)



# Curves of the vertebral column

---



Single curve in fetus

Four curves in adult

... Fetal and adult curves

# Axial skeleton

## structure of a typical vertebra

### Body (centrum)

- Bears the weight

### Vertebral arch

- Pedicle
- Lamina

### Vertebral foramen

- Central opening for spinal cord

### Vertebral processes

- Transverse (2)
  - Spinous (1)
  - Articular (4)
- } Attachment points for muscles & ligaments
- } Form joints between neighboring vertebrae

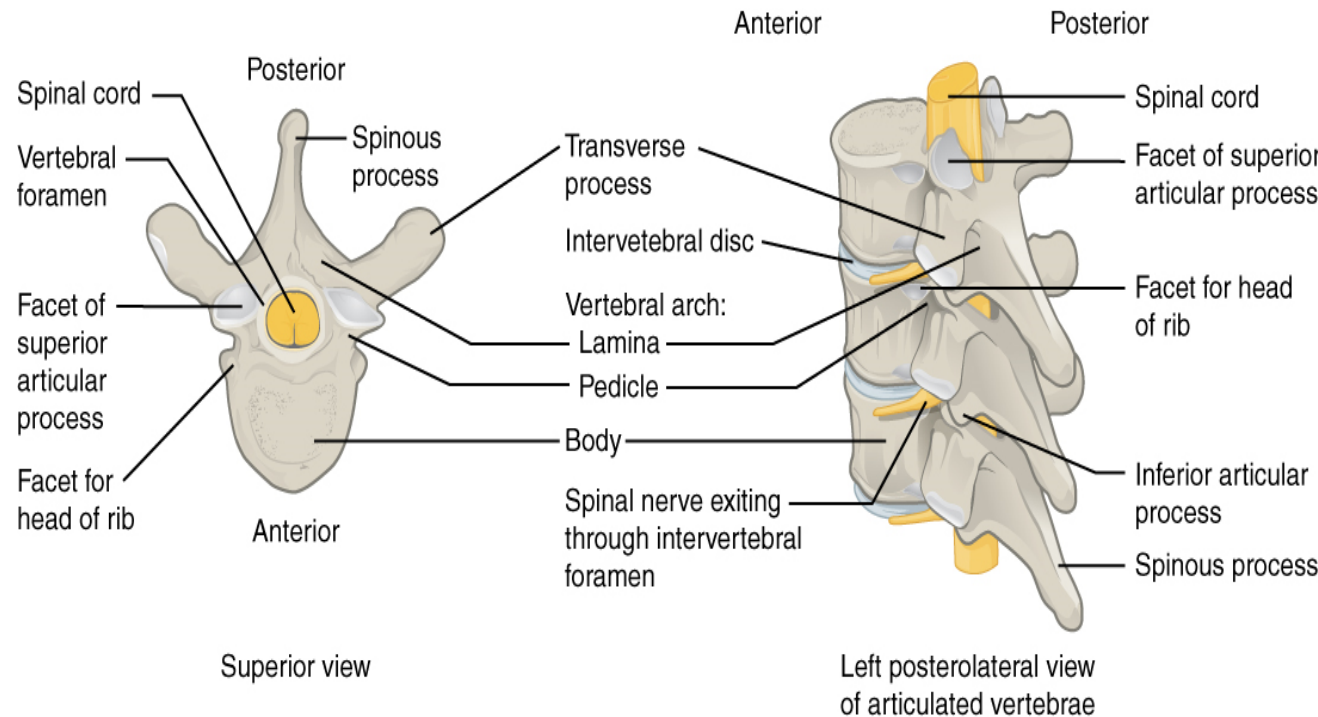
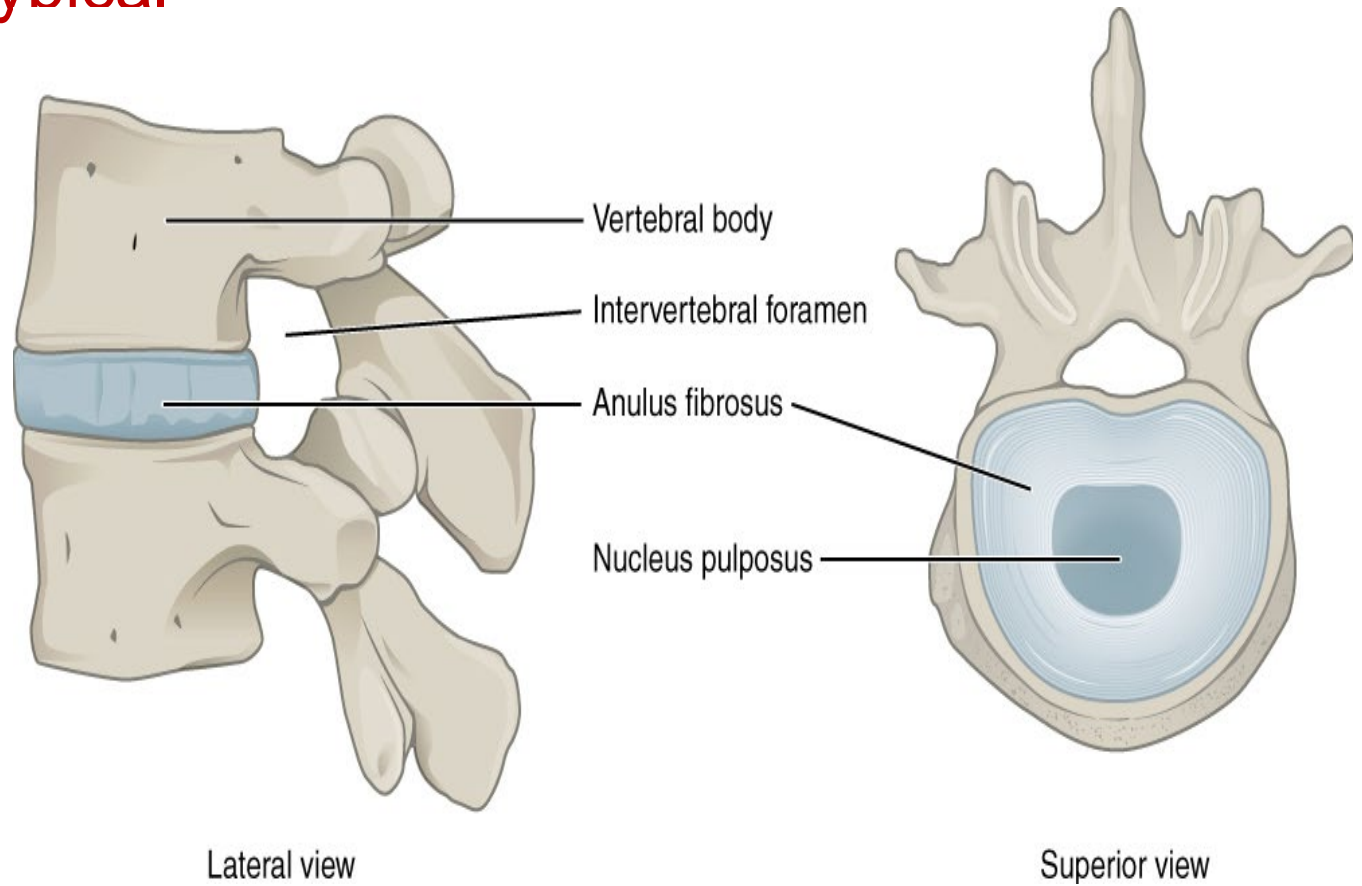


Figure 25

# Axial skeleton

Figure 26

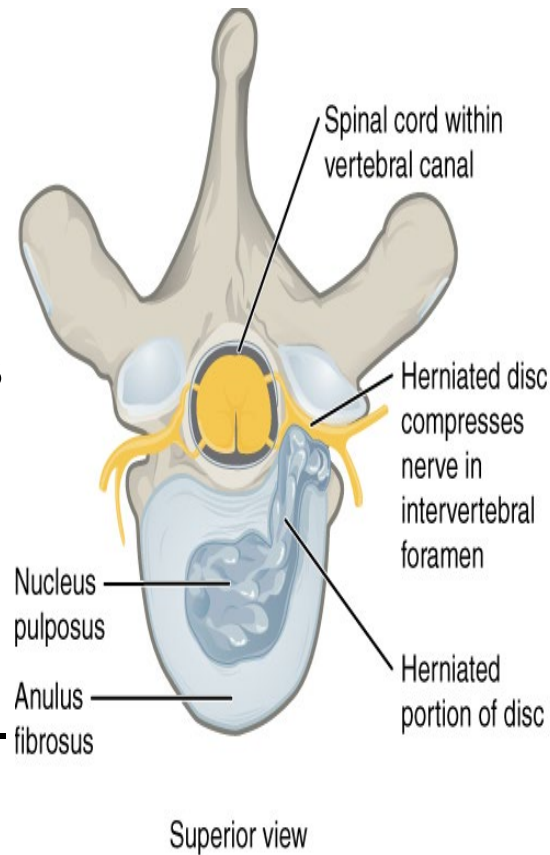
## structure of a typical vertebra



# Axial skeleton

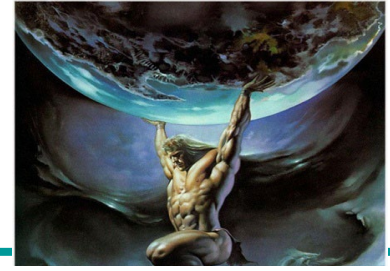
## structure of a typical vertebra

- Centre of all vertebrae are stacked to form the main axis of the column
- Rough surface for attachment of intervertebral discs (made of fibrocartilage).



# Cervical vertebrae

## Atlas (C1) and Axis (C2)



### Atlas (C<sub>1</sub>)

- No body
- No spinous process
- **Direct support of skull**
- The “yes” bone
- Contains two sockets for skull (condyles)

### Axis (C<sub>2</sub>)

- Very small body
- **Dens**
- Pivot for rotation of Atlas
- The “no” bone

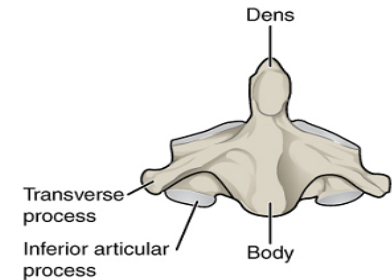
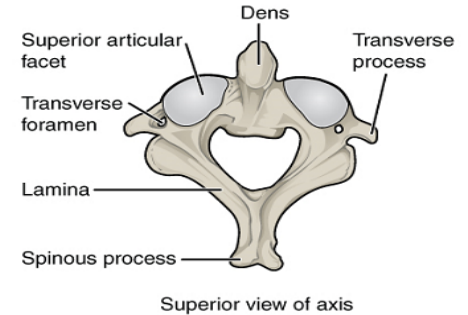
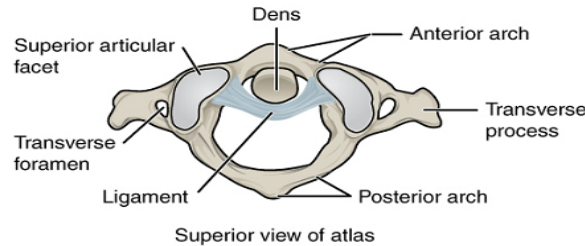
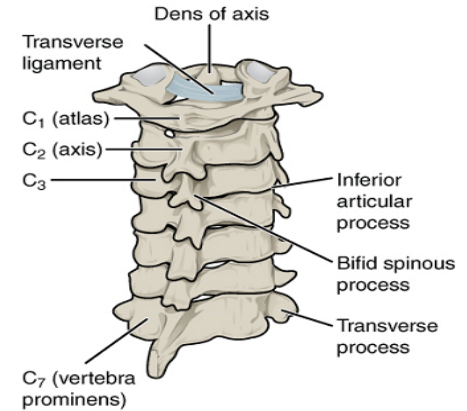
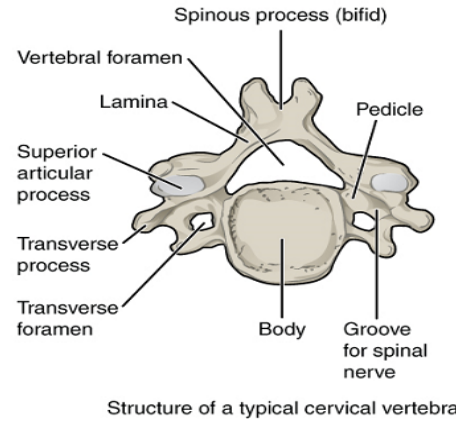


Figure 27

# Axial skeleton

## Atlas vs. axis vs. typical vertebra

---

	Atlas	Axis	Typical vertebra
<b>Body</b>	No	Yes (small)	Yes
<b>Spinous process</b>	No	No	Yes
<b>Articular sockets</b>	Yes	Yes	Yes
<b>Other properties</b>	Articulates with occipital <u>condyles</u> ('yes' motion)	<u>Dens</u> articulates with atlas ('no' motion)	

# Axial skeleton

## Thorax

Figure 28

**Sternum**

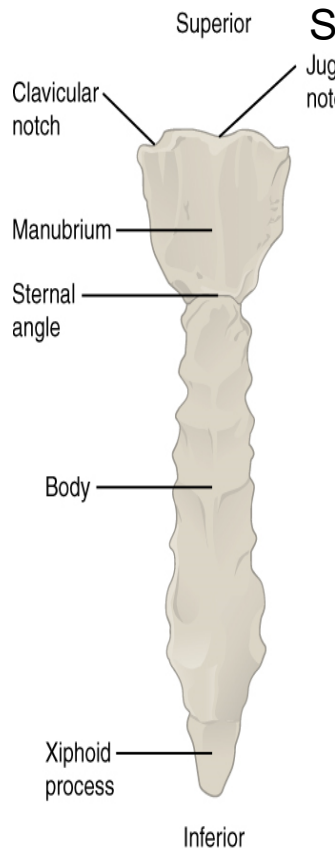
- Flat bone at midline

**Twelve ribs**

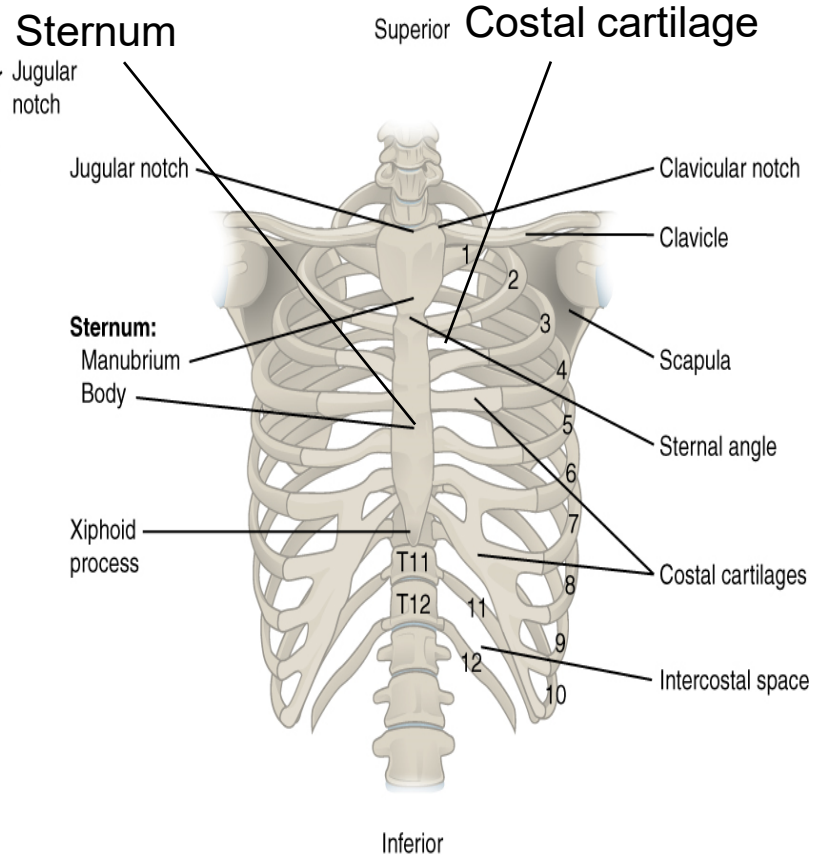
- True ribs (1-7)
- False ribs (8-10)
- Floating ribs (11-12)

**Costal cartilage**

- Hyaline cartilage



(a) Anterior view of sternum



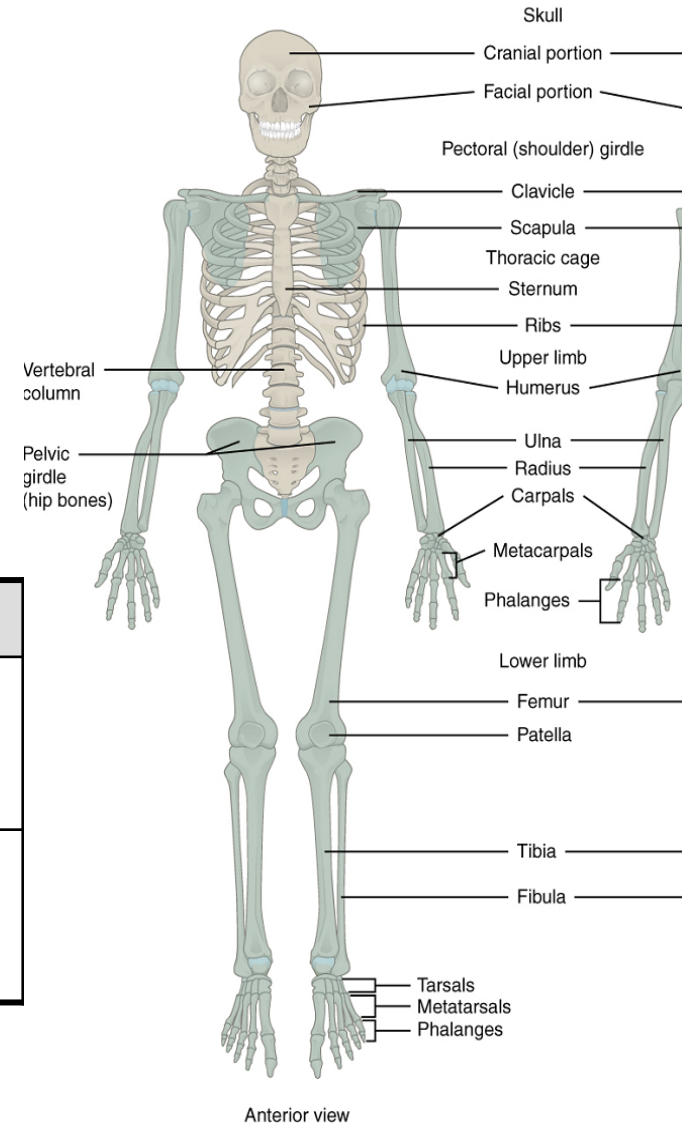
(b) Anterior view of skeleton of thorax

Figure 29

**Appendicular skeleton**

- 126 bones along appendages
- Components
  - Pectoral girdle
  - Pelvic girdle
  - Upper limbs
  - Lower limbs

Structure	Main functions
<b>Pectoral girdle</b>	- Attach upper limbs to axial skeleton - Allow upper limbs to articulate with axial skeleton
<b>Pelvic girdle</b>	- Attach lower limbs to axial skeleton - Transmit weight of upper body to lower limbs



# Appendicular skeleton

## pectoral (shoulder) girdle

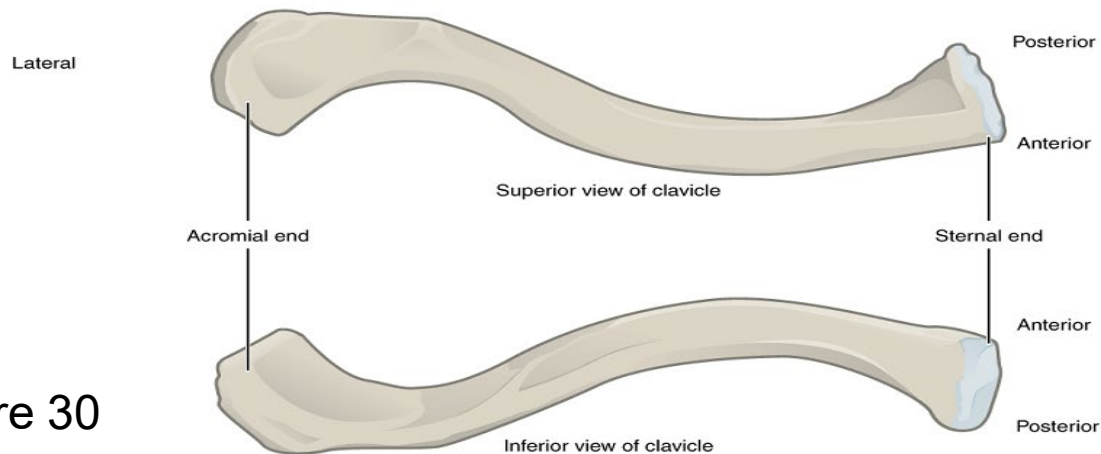
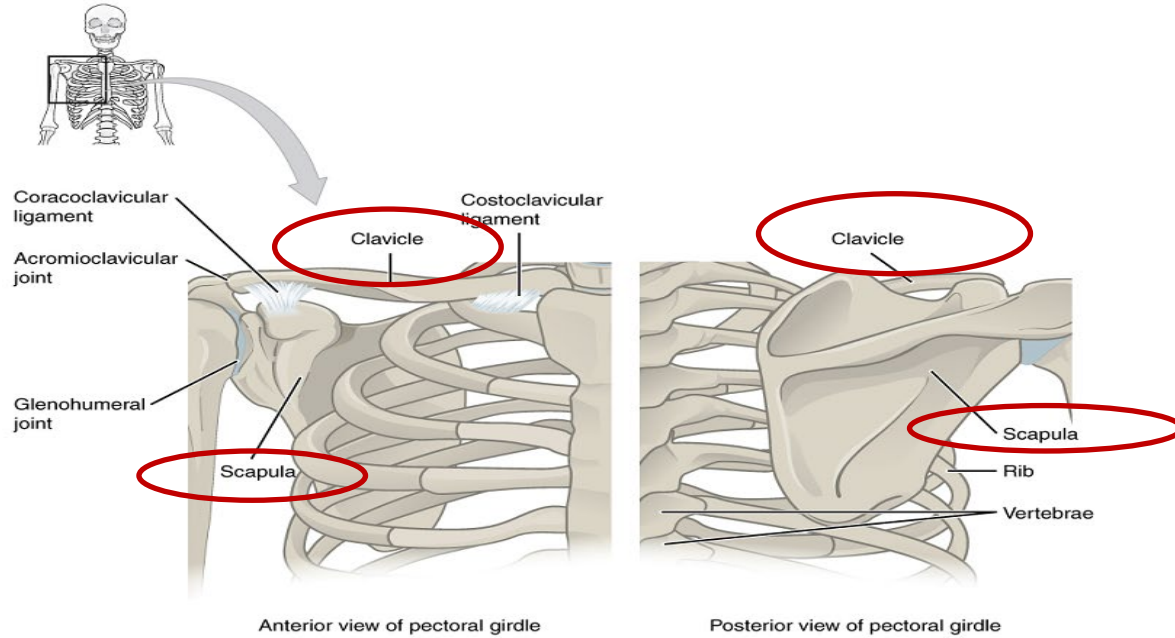
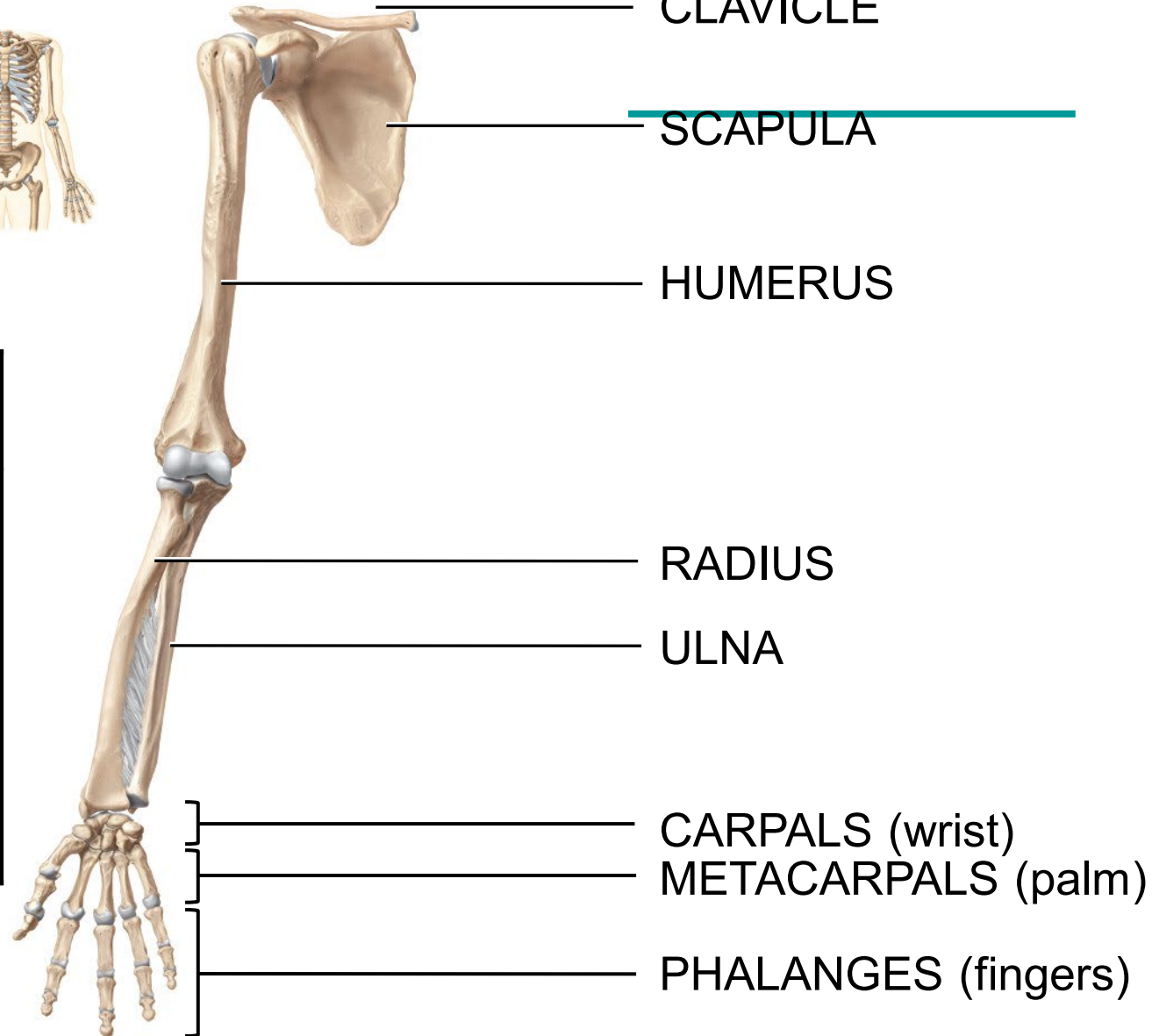


Figure 30

# Appendicular skeleton Upper limbs



## Bones (30 per limb)

- Humerus (arm)
- Radius & Ulna (forearm)
- Carpals (wrist)
- Metacarpals (palm)
- Phalanges (fingers)

Anterior view of free upper limb

# Appendicular skeleton

## pelvic (hip) girdle

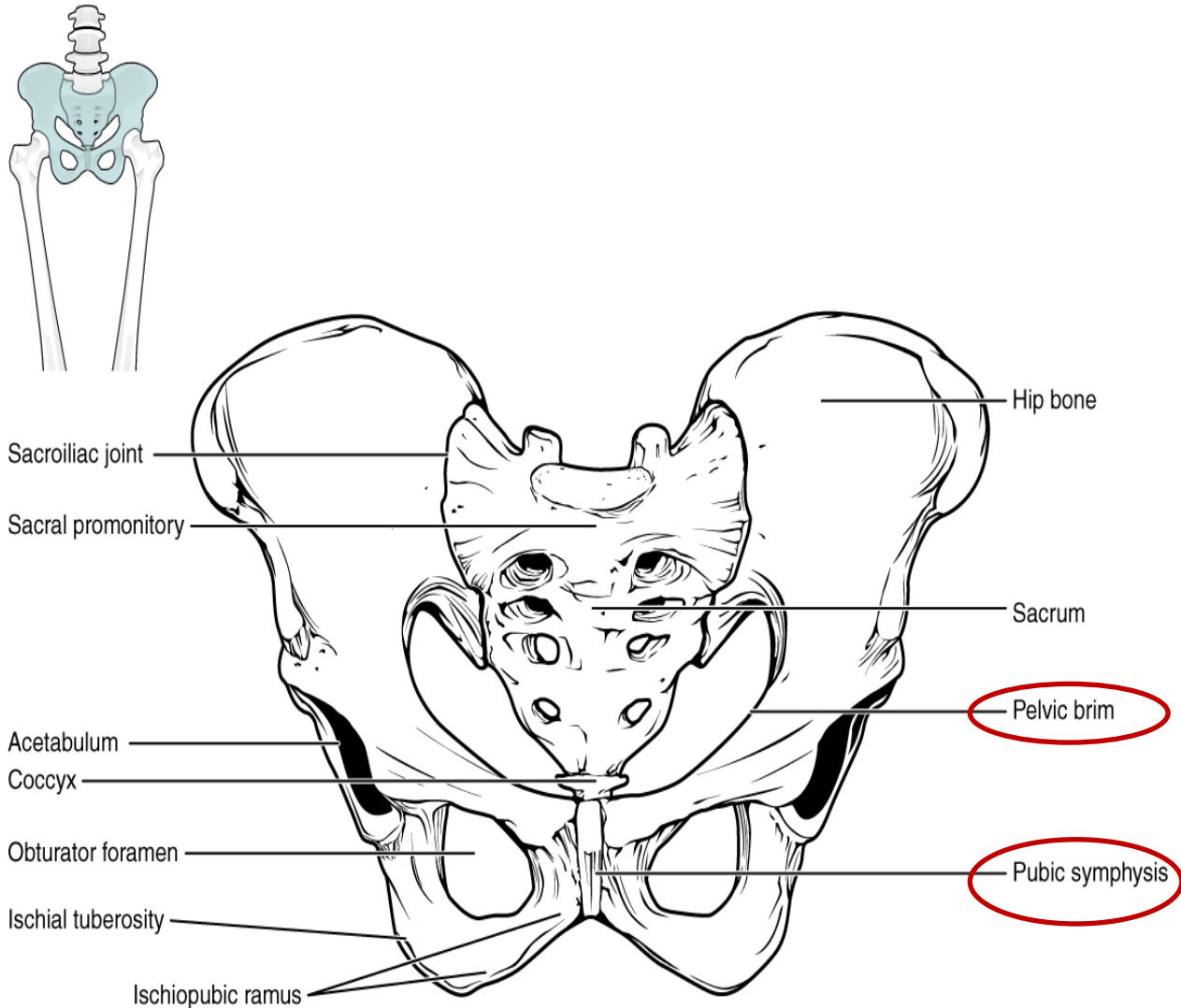


Figure 36

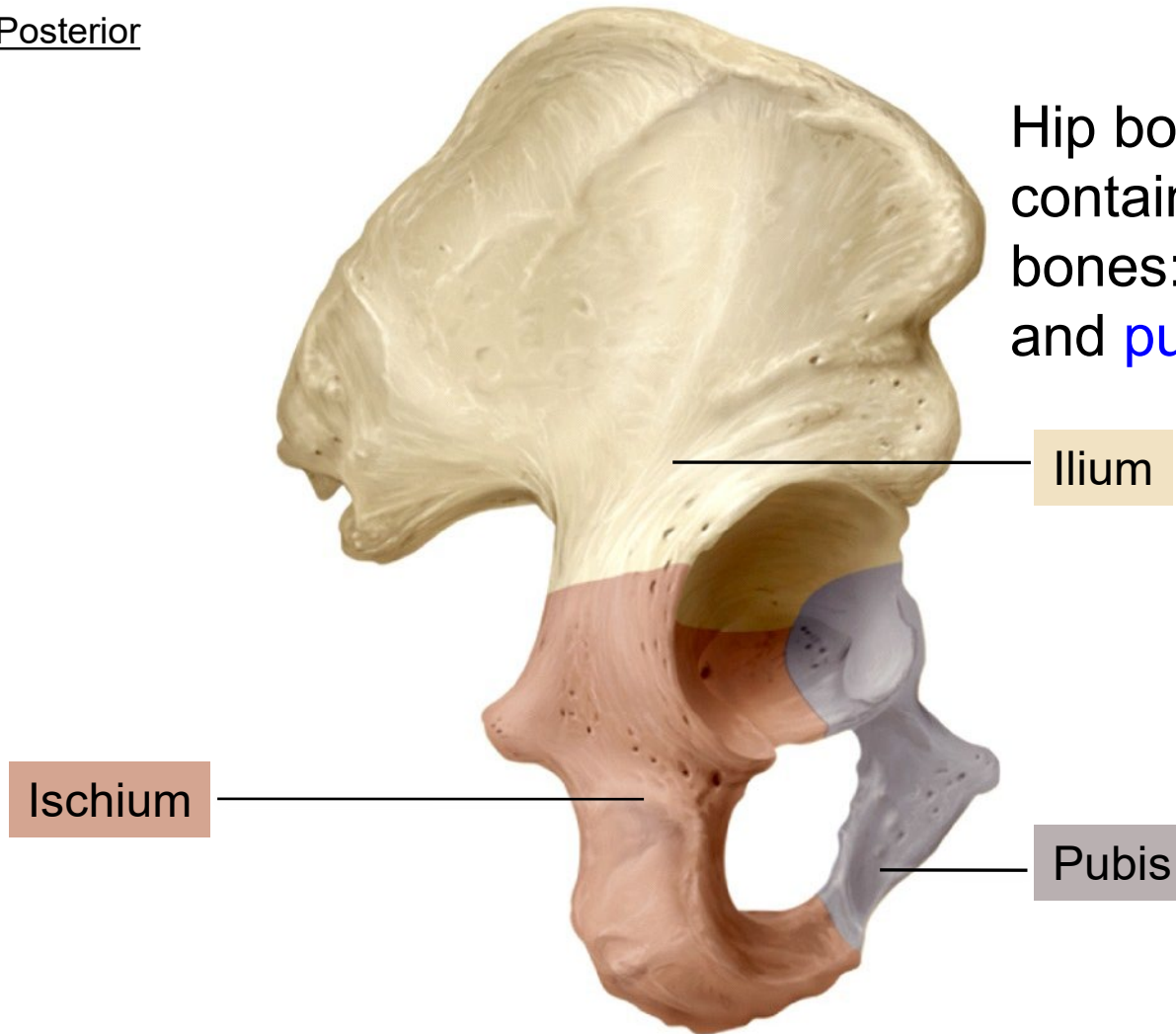
# Appendicular skeleton

## pelvic (hip) girdle

Posterior

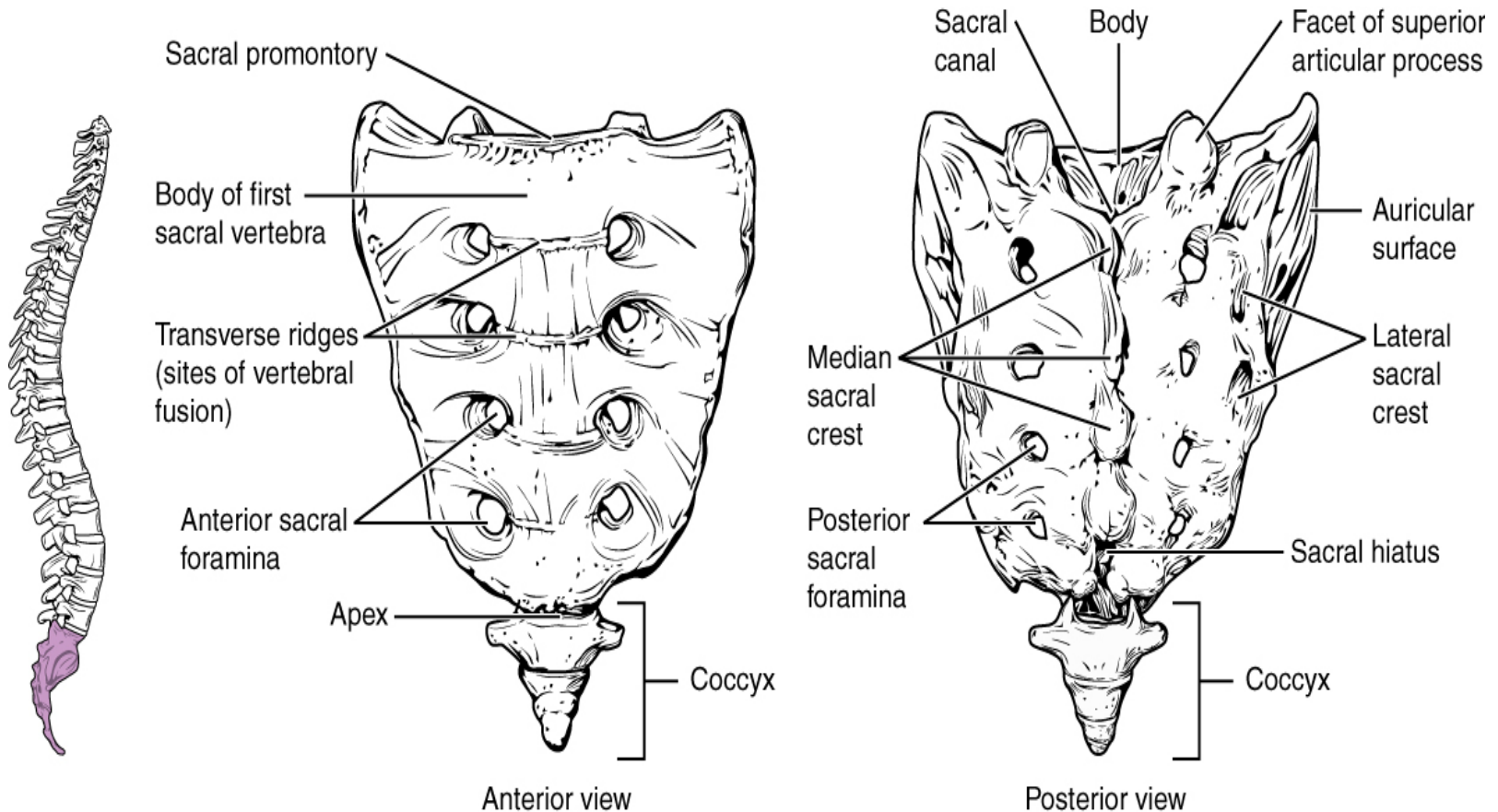
Anterior

Hip bone (innominate) contains three fused bones: **ilium**, **ischium**, and **pubis**



# Sacrum and coccyx

**Sacrum** = 5 fused vertebrae, **Coccyx** = 4 fused vertebrae



Points inferiorly in females and anteriorly in males

# Gender differences in the skeleton

## pelvis

Table 10.5: Overview of Differences between the Female and Male Pelvis

	Female pelvis	Male pelvis
<b>Pelvic weight</b>	Bones of the pelvis are lighter and thinner	Bones of the pelvis are thicker and heavier
<b>Pelvic inlet shape</b>	Pelvic inlet has a round or oval shape	Pelvic inlet is heart-shaped
<b>Lesser pelvic cavity shape</b>	Lesser pelvic cavity is shorter and wider	Lesser pelvic cavity is longer and narrower
<b>Subpubic angle</b>	Subpubic angle is greater than 80 degrees	Subpubic angle is less than 70 degrees
<b>Pelvic outlet shape</b>	Pelvic outlet is rounded and larger	Pelvic outlet is smaller

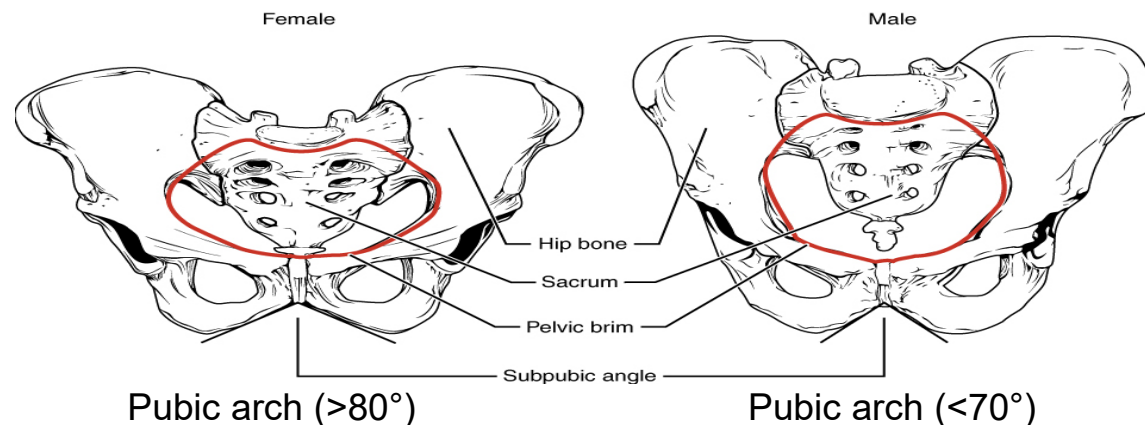






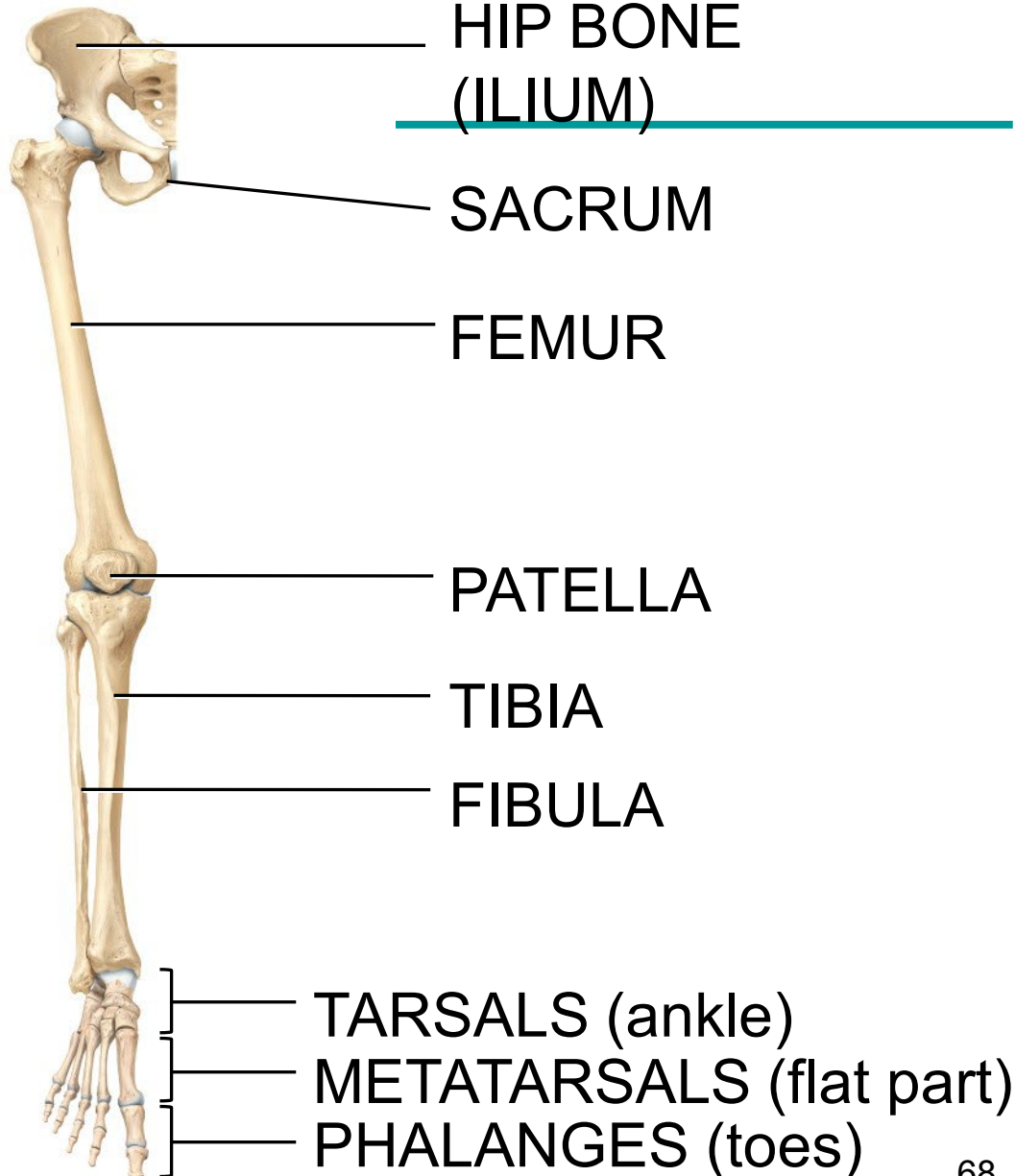
Figure 38

**Table 7.4** Comparison of the Male and Female Pelves (continued)

CHARACTERISTIC	FEMALE	MALE
Sacrum	Wider; shorter; sacral curvature is accentuated	Narrow; longer; sacral promontory more ventral
Coccyx	More movable; projects inferiorly	Less movable; projects anteriorly
Greater sciatic notch	Wide and shallow	Narrow and deep
Left lateral view		
Pelvic inlet (brim)	Wider; oval from side to side	Narrow; basically heart shaped
Pelvic outlet	Wider; ischial tuberosities shorter, farther apart and everted	Narrower; ischial tuberosities longer, sharper, and point more medially
Posteroinferior view		

# Appendicular skeleton

## Lower limbs



HIP BONE  
(ILIUM)

SACRUM

FEMUR

PATELLA

TIBIA

FIBULA

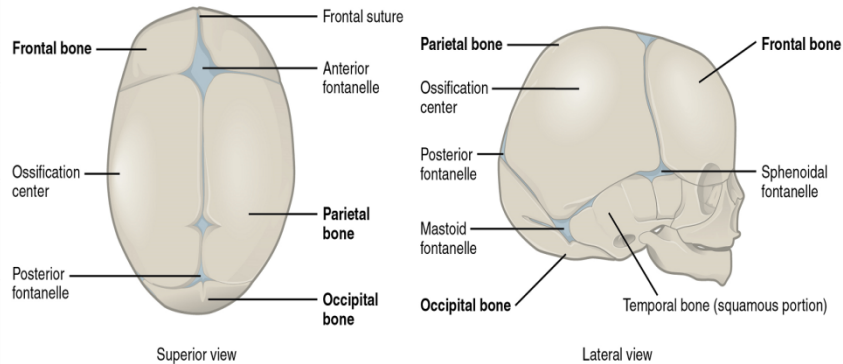
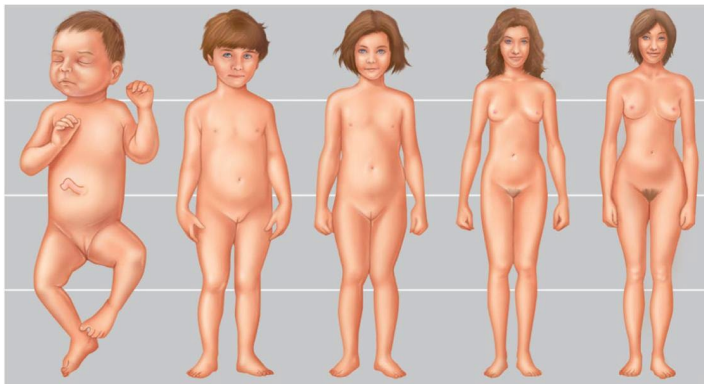
TARSALS (ankle)  
METATARSALS (flat part)  
PHALANGES (toes)

Bones (30 per limb)
• Femur (thigh)
• Patella (kneecap)
• Tibia & Fibula (leg)
• Tarsals (foot)
• Metatarsals (forefoot)
• Phalanges (toes)

Anterior view of free lower

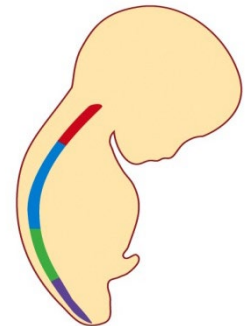
# Differences between the neonatal and the adult skeletons

	Neonatal	Adult
A) Proportion of the skull	25% of skeleton length	12% of skeleton length
B) Ossification	Soft gaps between bones	Fully ossified
C) Curves in the vertebral column	<u>Only</u> anterior concave curve (2 total)	<u>Four</u> curves



Newborn      2 yrs      5 yrs      15 yrs      Adult

(b) Marieb, Figure 7.40b



# Skeletal system

## Objectives

---

1. Describe the functions of the skeletal system and the five basic shapes of human bones.
2. Describe the structure and histology of the skeletal system.
3. Define and identify the following parts of a long bone: diaphysis, epiphysis, metaphysis, articular cartilage, periosteum, medullary cavity, and endosteum.
4. Compare the composition and function of compact bone versus spongy bone
5. Define ossification, compare intramembranous ossification with endochondral ossification, describe how a long bone grows in length and width, and specify how various factors might affect the rate of ossification and, by extension, the height of a mature individual.
6. Describe four types of bone fractures.

# Skeletal system

## Objectives

---

7. Specify the components of the axial and appendicular skeletons, describe the general function of each skeleton, and name and describe the principle components of the axial skeleton.
8. Describe the structure and function of a typical vertebra and explain how these differ in the case of the atlas and axis.
9. Describe the components and functions of the pectoral girdle and the pelvic girdle.
10. Specify all bones and structures in the human skeleton covered in this Unit.
11. Describe the differences between the pelvis of a human female and that of a human male.
12. Describe the major differences between the skeleton of a baby and that of an adult.