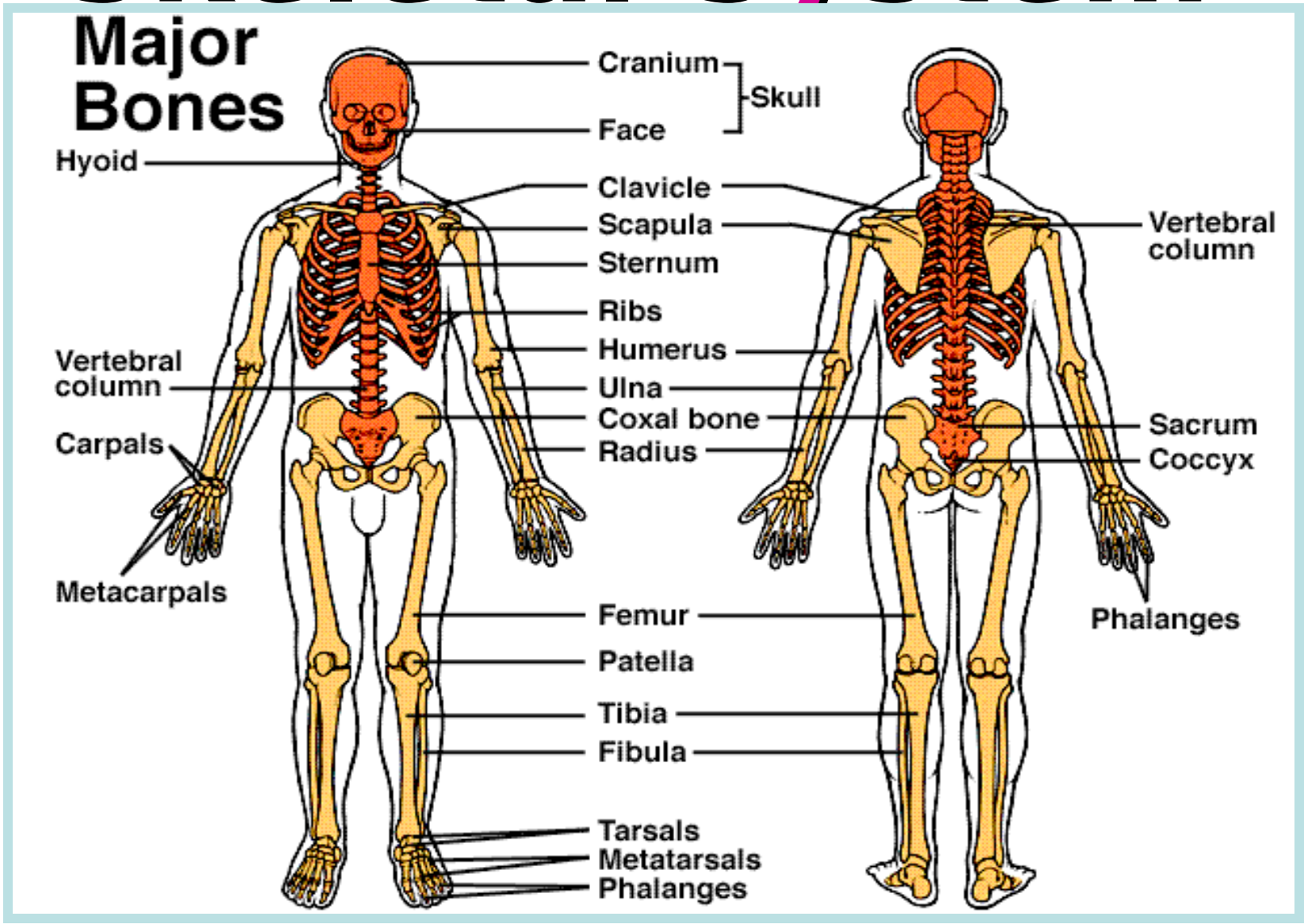
Skeletal System



- **The term skeleton is applied to a structure that provides a supportive framework. In its commonest usage it refers to the bony skeleton, that includes *bones, cartilages & ligaments*. This system can be approached in different ways :**
- **Musculoskeletal system –** where the muscular & skeletal systems are studied together.
- **Locomotory system –** where bones, joints & muscles are studied together

Skeletal system have the following five major functions

1. **Formation of the supportive framework and permanent shape of the body.**
2. **Protection of some soft & delicate organs.**

   E.g. the skull protects the brain, Ribs protect the lungs & heart…., Vertebral column protects the spinal cord
3. **Storage of minerals**
4. **production of blood cells (hematopoiesis)**
5. **To provide an attachment site for muscles & act as a rigid lever to move the body & its parts.**

CLASSIFICATIONs OF BONES

Bones can be classified according to their:

I. Location

II. Structural appearances

(Macroscopic appearances)

III. Microscopic Appearances

IV. Developmental Origin

V. Forms and shapes

CLASSIFICATION OF BONES

I. According to their location

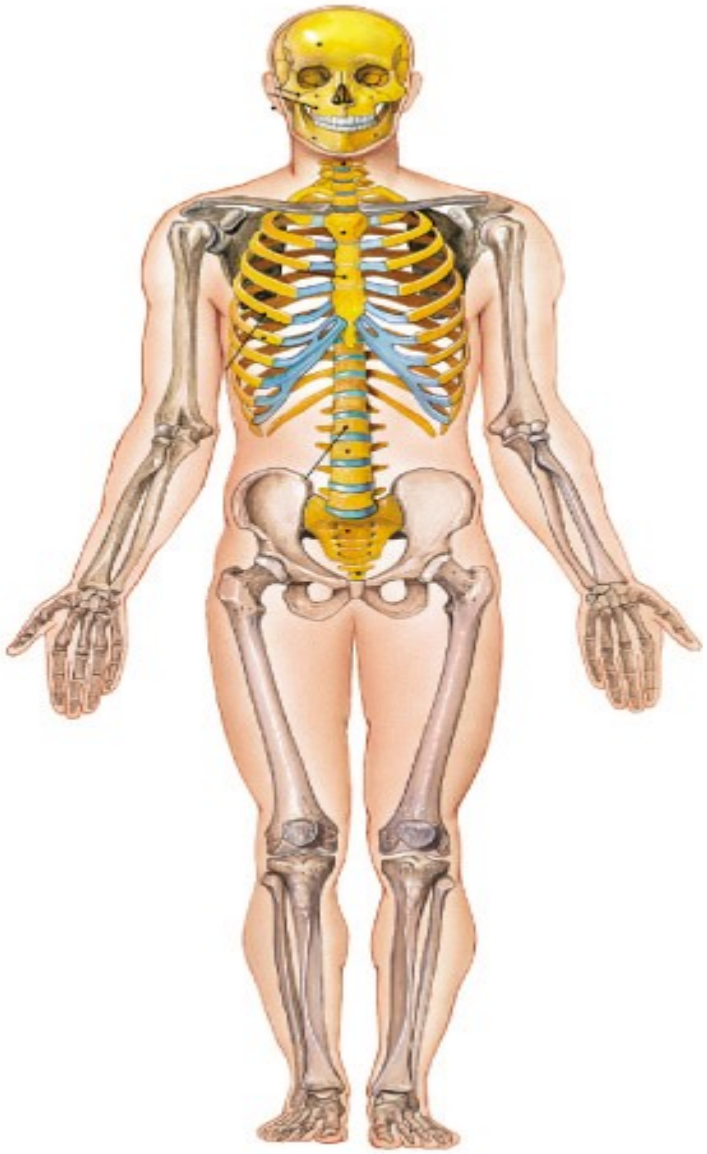
A. Axial skeleton – this is located around the longitudinal axis of the body, i.e. most of the bones of the axial skeleton constitute the central bony core of the body, the axis.

A. Axial skeleton

Consists of:

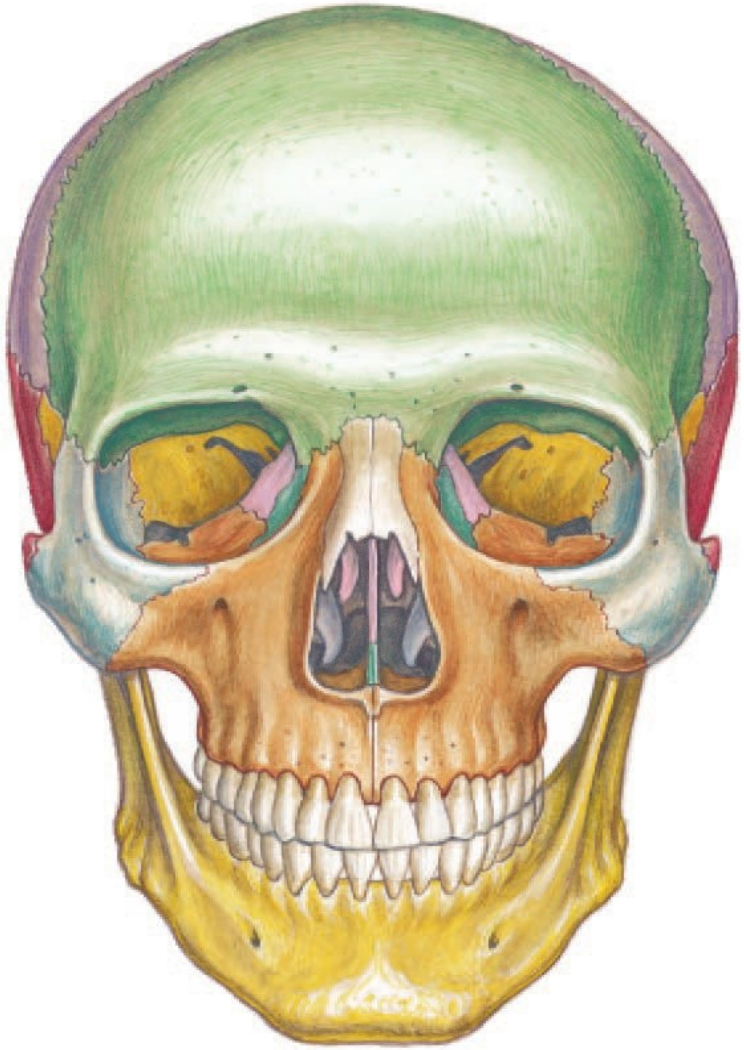
1. **Skull _____22**
    1. **Facial bones_14**
    2. **Cranial bones_8**
2. **Vertebral column__26**
3. **Thoracic cage_____25**
    1. Ribs_____24
    2. Sternum___1
4. **Hyoid bone_____1**
5. **Ear ossicles_____6**

Total =80



1. SKULL

- It is comprised of eight **cranial** and fourteen **facial bones**



Cranial bones

The cranial bones makeup the protective frame of bone around the brain.

The cranial bones are:

1. **Frontal bone**
   - The frontal forms part of the cranial cavity as well as the forehead, the brow ridges and the nasal cavity.
2. **Parietal bones**
   - The left and right parietal forms much of the superior and lateral portions of the cranium.

3. Temporal bones

- The left and right temporal form the lateral walls of the cranium as well as housing the external ear.

4. Occipital bone

- The occipital forms the posterior and inferior portions of the cranium. Many neck muscles attach here as this is the point of articulation with the neck.

5. Sphenoid bone

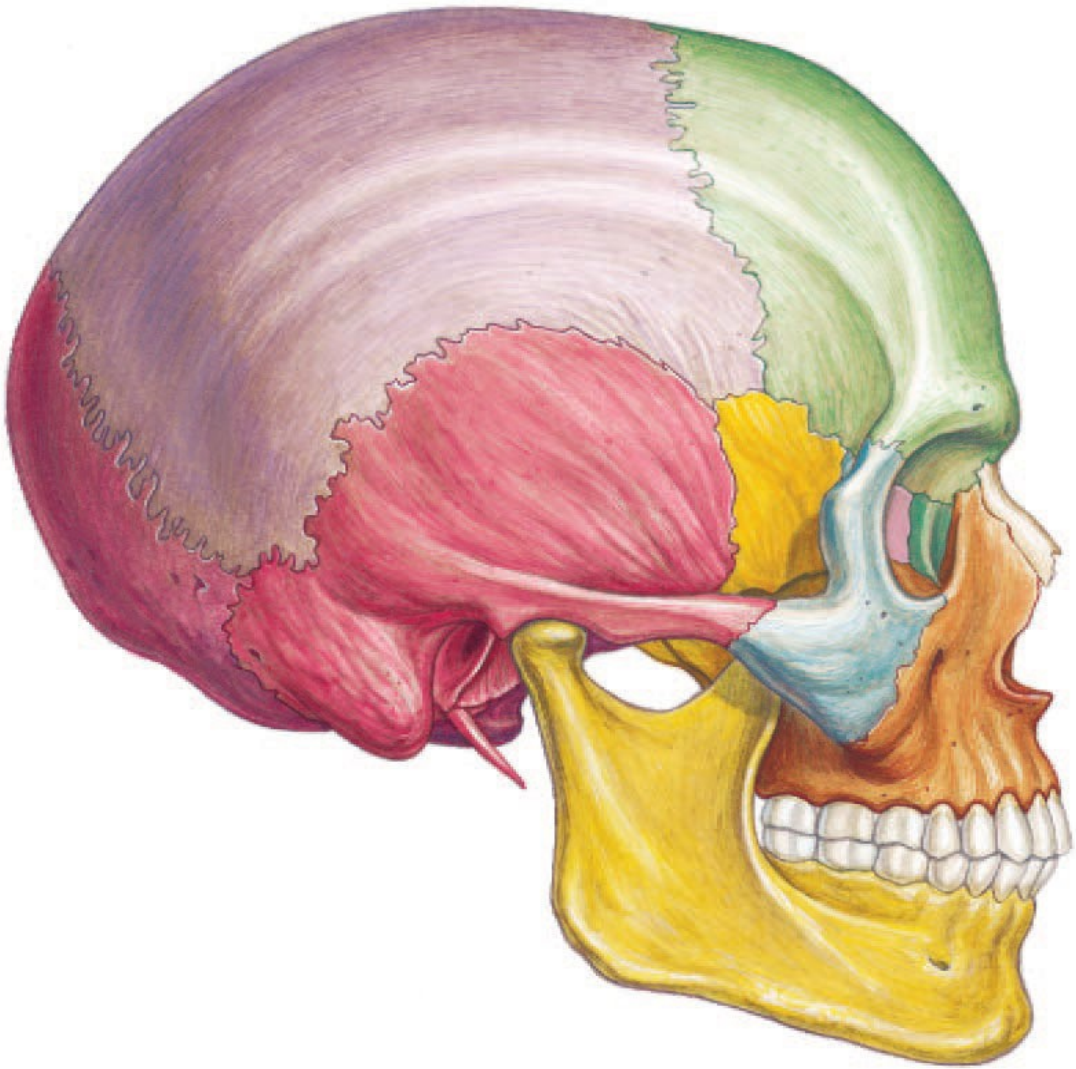
- The sphenoid forms part of the eye orbit and helps to form the floor of the cranium.

6. Ethmoid bone

- The ethmoid forms the medial portions of the orbits and the roof of the nasal cavity, and superior & middle **conchas** of the nasal cavity

- **Pterion**
  - Area at which bones forming the floor of the temporal fossa articulate (frontal, parietal, temporal and sphenoid)
  - **H shaped suture**
  - Clinically important landmark because anterior branch of middle meningeal artery lies in a groove on internal aspect of this area. Thus, it is vulnerable to tearing if there is fracture and results in extradural hematomas which can exert pressure on cerebral cortex

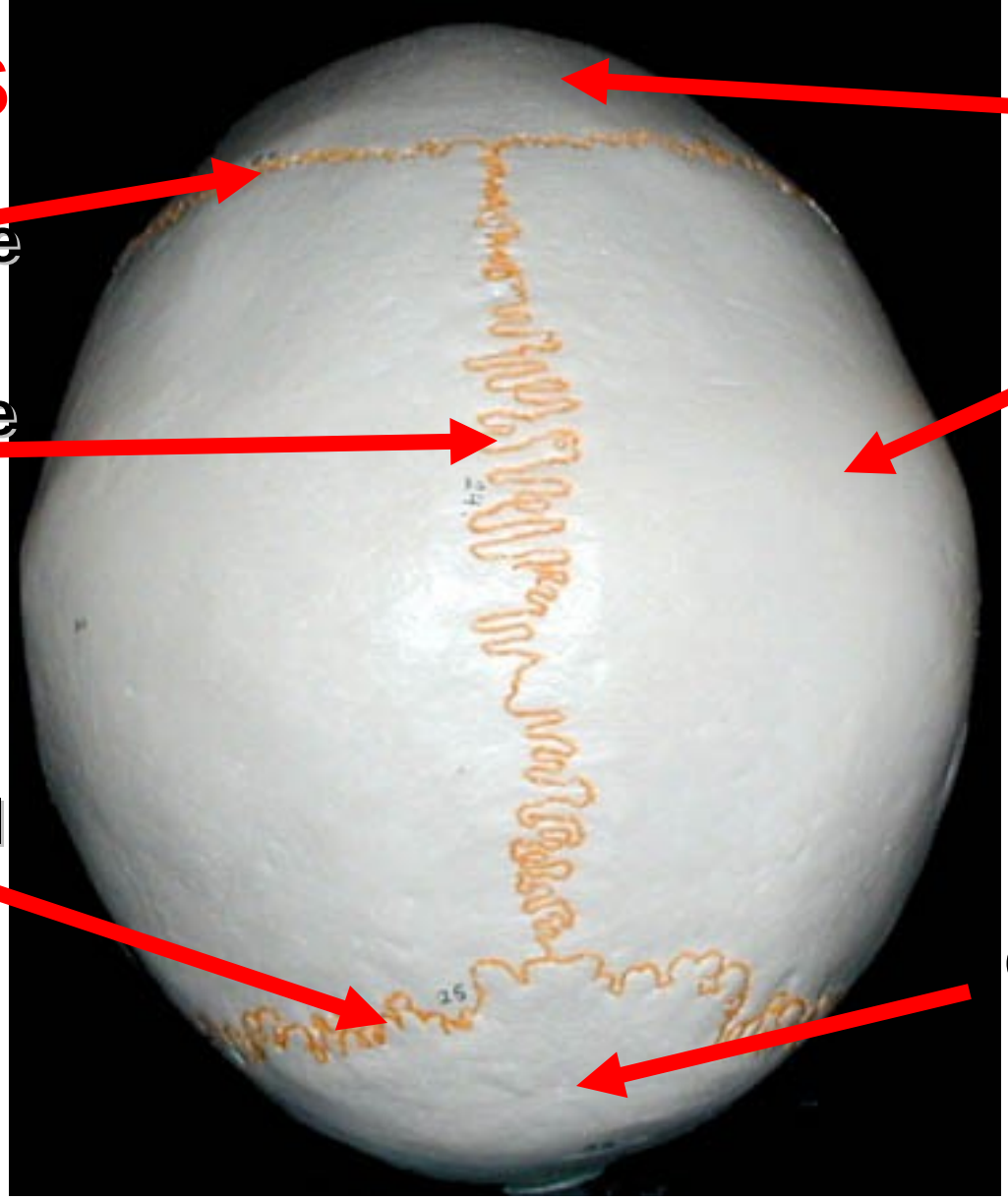
Pterion



Skull joints

- **Sutures**
  - Immovable joint between skull bones
  - 4 prominent sutures:
    - **Coronal suture -** between frontal and the two parietal bones
    - **Sagittal suture -** between the two parietal bones
    - **Lambdoid suture -** between the two parietals and occipital bone
    - **Squamous suture -** between parietal and temporal bones
- **Temporomandibular Joint (TMJ)**
  - The only movable joint of the skull

Sutures



Frontal bon

Coronal suture

Parietal bone

Sagittal suture

Lambdoidal suture

Occipital bone

Facial bones

- The facial bones makeup the upper and lower jaw and other facial structures.
  The facial bones are:

1. Mandible

- The mandible is the lower jawbone. It articulates with the temporal bones at the temporomandibular joints. This forms the only freely moveable joint in the head. It provides the chewing motion.

2. Maxillae

- The left and right maxilla are the upper jaw bones. They form part of the nose, orbits, and roof of the mouth.

Facial bones

3. Zygomatic bones

- The left and right zygomatic are the cheek bones. They form portions of the orbits as well.

4. Nasal bones

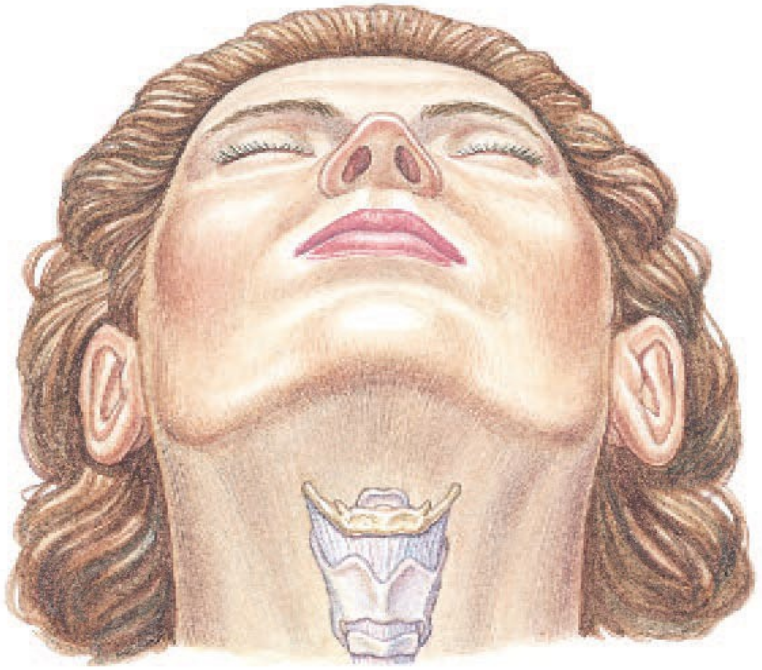
- The left and right nasal form the superior portion of the bridge of the nose.

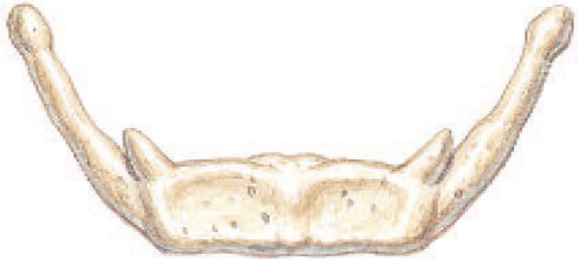
5. Lacrimal bones

- The left and right lacrimal help to form the medial wall of the orbits.

The **Hyoid** bone

- Located at the angle b/n the mandible and neck
- **U-shaped bone** positioned at the base of the tongue and above the thyroid cartilage that supports the tongue and its muscles



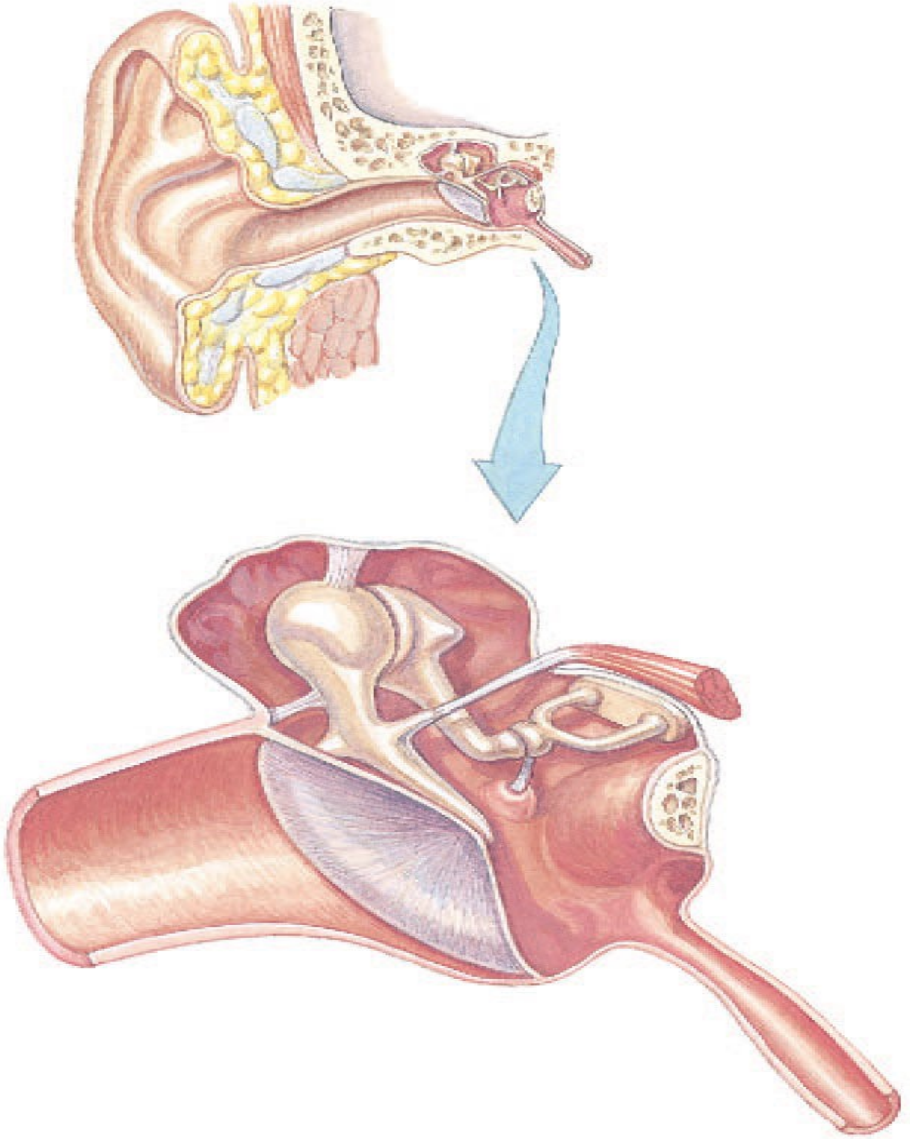


Auditory Ossicles

Bony chain in middle ear.

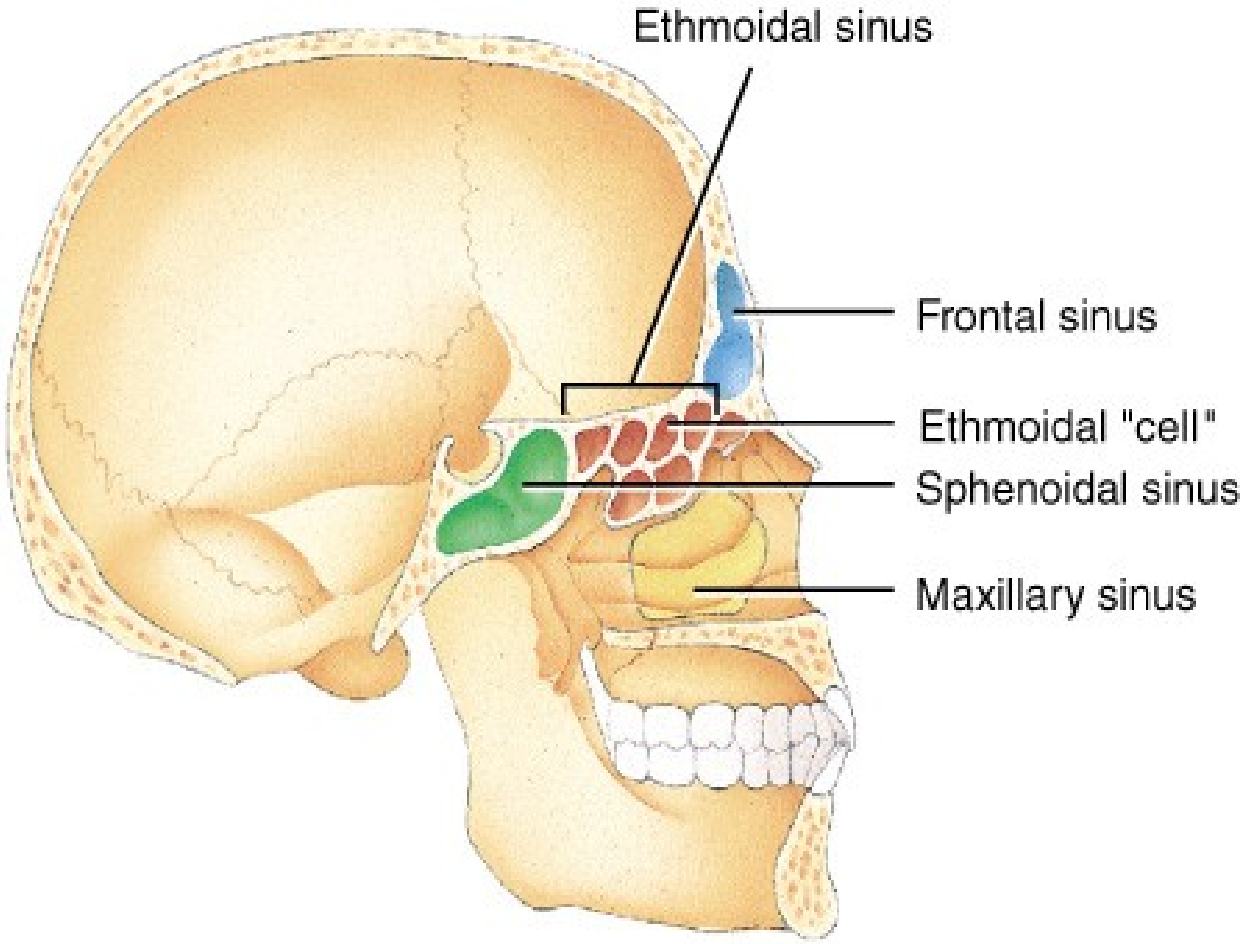
Includes:

1. **Malleus,**
2. **Incus and**
3. **Stapes**

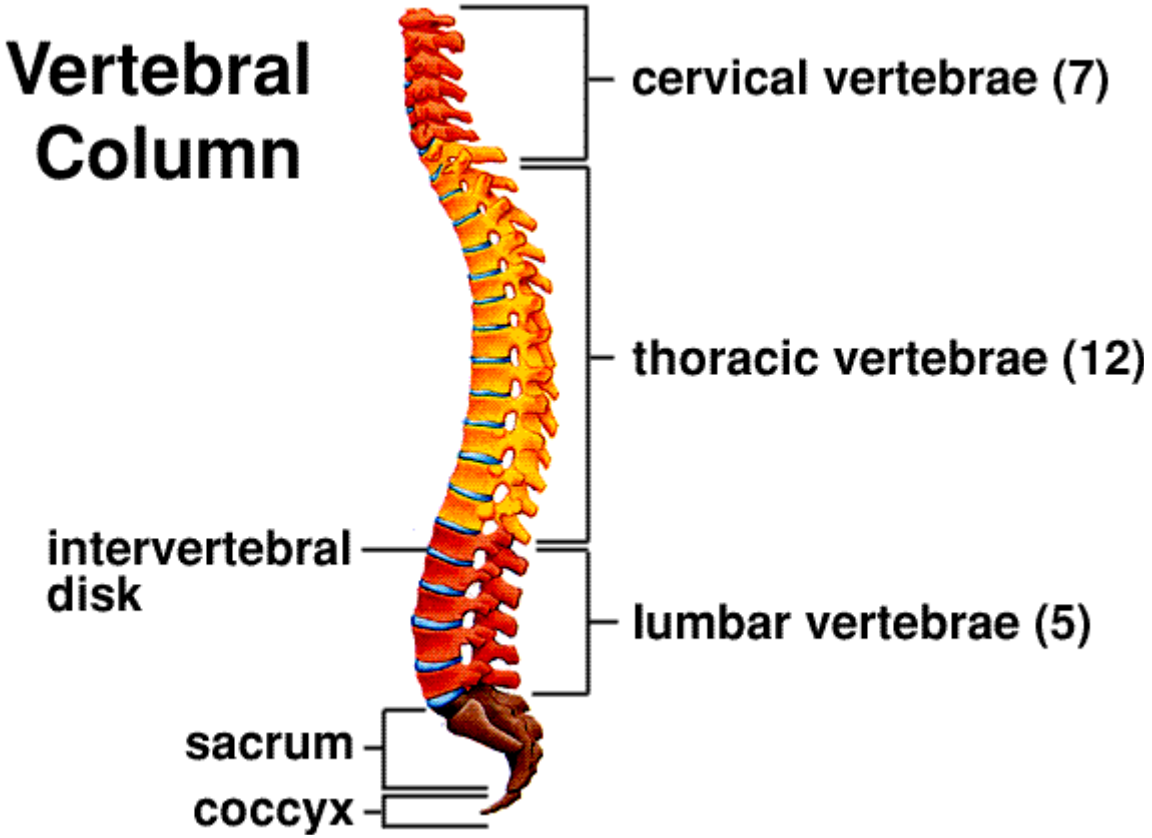


PARANASAL AIR SINUSES

- Cavities filled with air in the bones of the face and skull
- **Sinusitis?**



Vertebral Column



Vertebral Column

- The vertebral column (also called the backbone, spine, or spinal column) consists of a series of 33 irregularly shaped bones, called vertebrae. These 33 bones are divided into five categories depending on where they are located in the backbone.
- The first seven vertebrae are called the cervical vertebrae. Located at the top of the spinal column, these bones form a flexible framework for the neck and support the head. The first cervical vertebrae is called the atlas and the second is called the axis. The atlas' shape allows the head to nod "yes" and the axis' shape allows the head to shake "no".

Vertebral Column

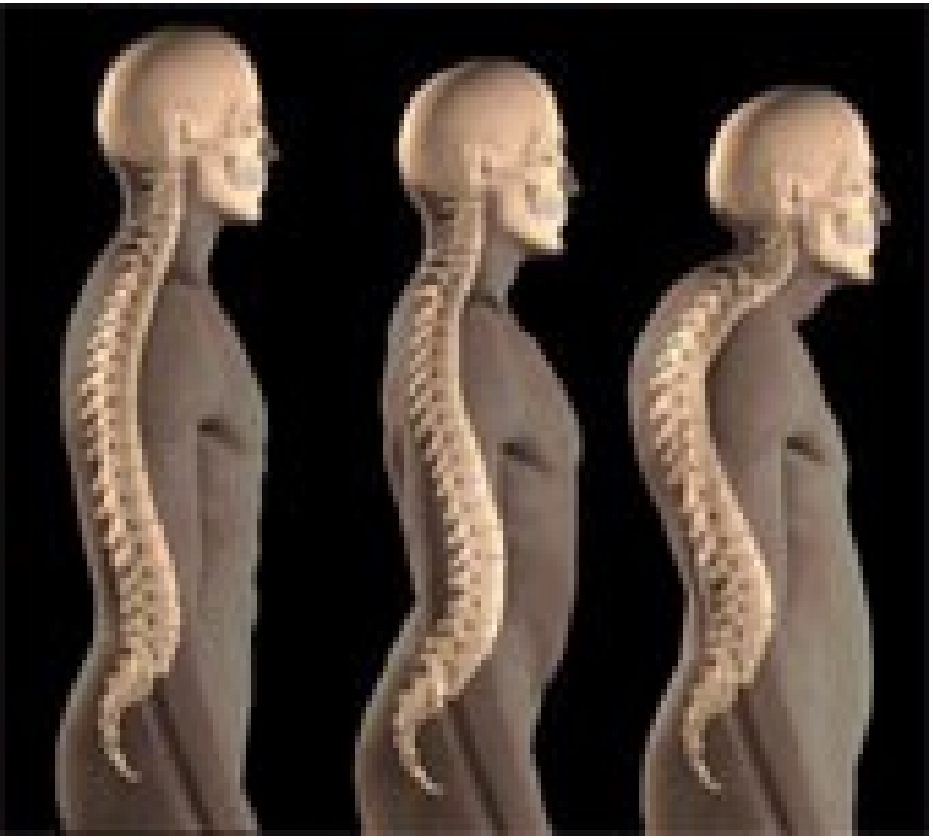
- The next twelve vertebrae are called the thoracic vertebrae. These bones move with the ribs to form the rear anchor of the rib cage. Thoracic vertebrae are larger than cervical vertebrae and increase in size from top to bottom.
- After the thoracic vertebrae, come the lumbar vertebrae. These five bones are the largest vertebrae in the spinal column. These vertebrae support most of the body's weight and are attached to many of the back muscles.
- The sacrum is a triangular bone located just below the lumbar vertebrae. It consists of four or five sacral vertebrae in a child, which become fused into a single bone after age 26. The sacrum forms the back wall of the pelvic girdle and moves with it.

- The bottom of the spinal column is called the coccyx or tailbone. It consists of 3-5 bones that are fused together in an adult. Many muscles connect to the coccyx.
- These bones compose the vertebral column, resulting in a total of 26 movable parts in an adult. In between the vertebrae are intervertebral discs made of fibrous cartilage that act as shock absorbers and allow the back to move. As a person ages, these discs compress and shrink, resulting in a distinct loss of height (generally between 0.5 and 2.0cm) between the ages of 50 and 55.
- In addition to allowing humans to stand upright and maintain their balance, the vertebral column serves several other important functions. It helps to support the head and arms, while permitting freedom of movement. It also provides attachment for many muscles, the ribs, and some of the organs and protects the spinal cord, which controls most bodily functions.

Vertebral Column

- When looked at from the side, the spine forms four curves. These curves are called the cervical, thoracic, lumbar, and pelvic curves. The cervical curve is located at the top of the spine and is composed of cervical vertebrae. Next come the thoracic and lumbar curves composed of thoracic and lumbar vertebrae respectively. The final curve called the pelvic or sacral curve is formed by the sacrum and coccyx. These curves allow human beings to stand upright and help to maintain the balance of the upper body. The cervical and lumbar curves are not present in an infant. The cervical curves forms around the age of 3 months when an infant begins to hold its head up and the lumbar curve develops when a child begins to walk.

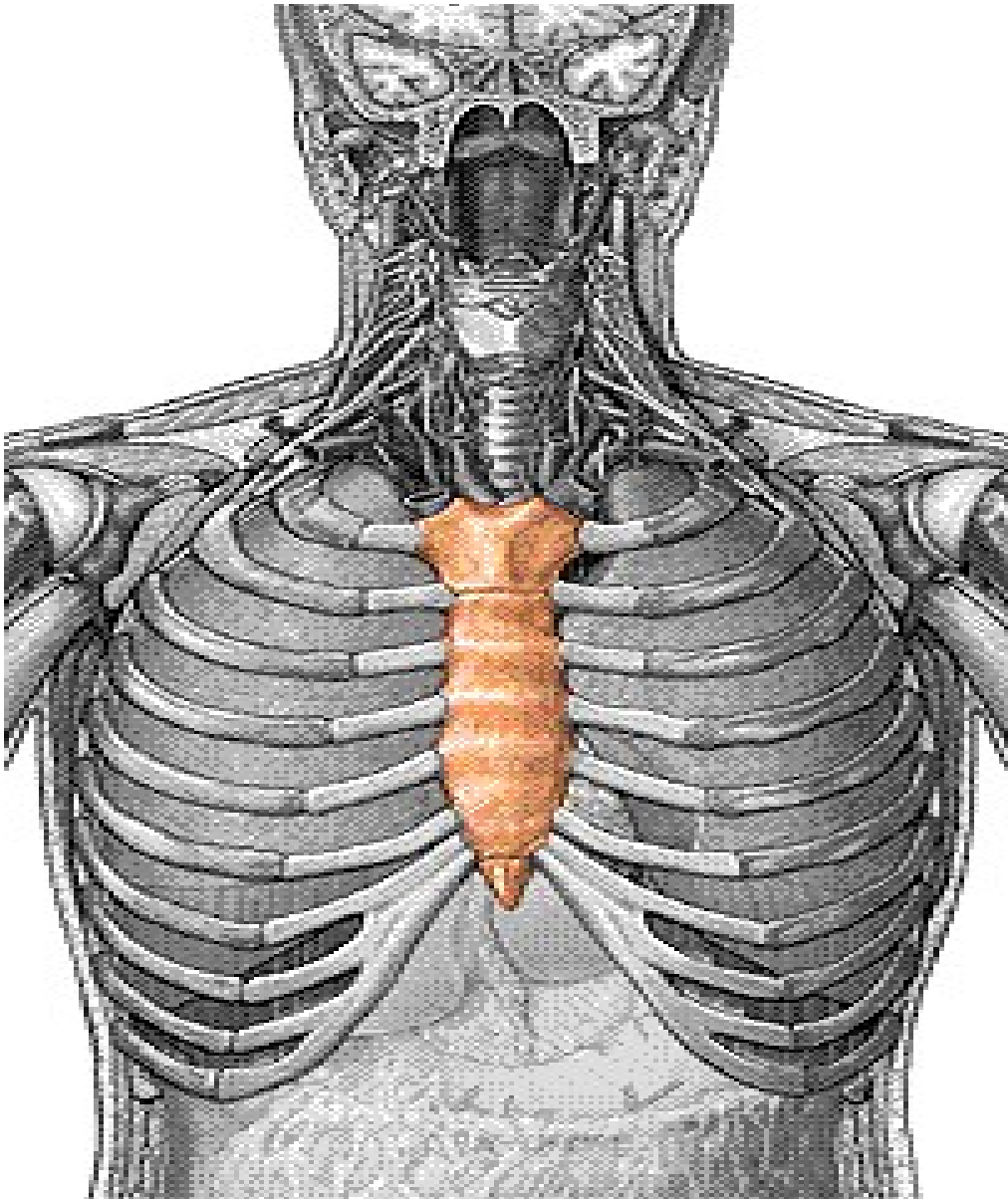
Abnormal Vertebral Curvatures



- **Scoliosis**-abnormal lateral curve of more than 10°
  - "twisted disease"
- **Kyphosis**-exaggerated thoracic curve
  - "humped disease"
- **Lordosis**-accentuated lumbar curve
  - "bent-backward disease"

Thoracic Cage

- **Sternum**
- **12 pairs of ribs**
  - **True vs. false ribs?**
  - **Vertebrosternal, vertebrochondral, vertebral**



Sternum

- The sternum is a flat, dagger shaped bone located in the middle of the chest. Along with the ribs, the sternum forms the rib cage that protects the heart, lungs, and major blood vessels from damage.
- The sternum is composed of three parts:
- The manubrim, also called the "handle", is located at the top of the sternum and moves slightly. It is connected to the first two ribs.

Sternum

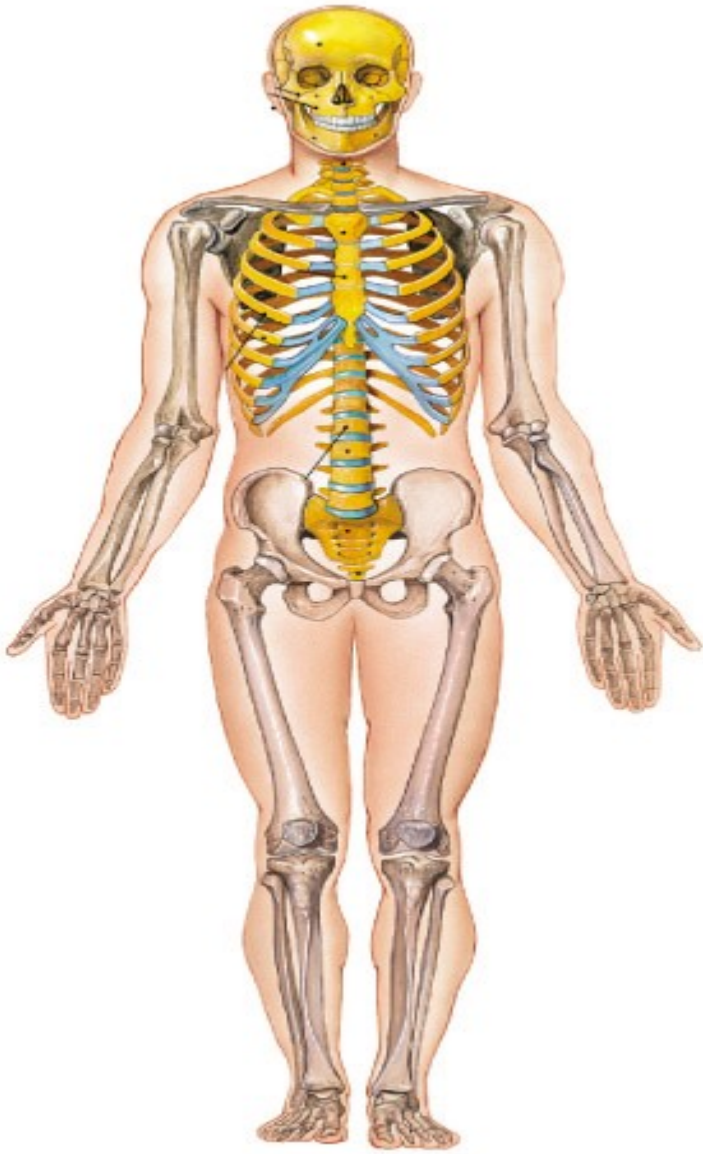
- The body, also called the "blade" or the "gladiolus", is located in the middle of the sternum and connects the third to seventh ribs directly and the eighth through tenth ribs indirectly.
- The xiphoid process, also called the "tip", is located on the bottom of the sternum. It is often cartilaginous (cartilage), but does become bony in later years.
- These three segments of bone are usually fused in adults

B. Appendicular Skeleton

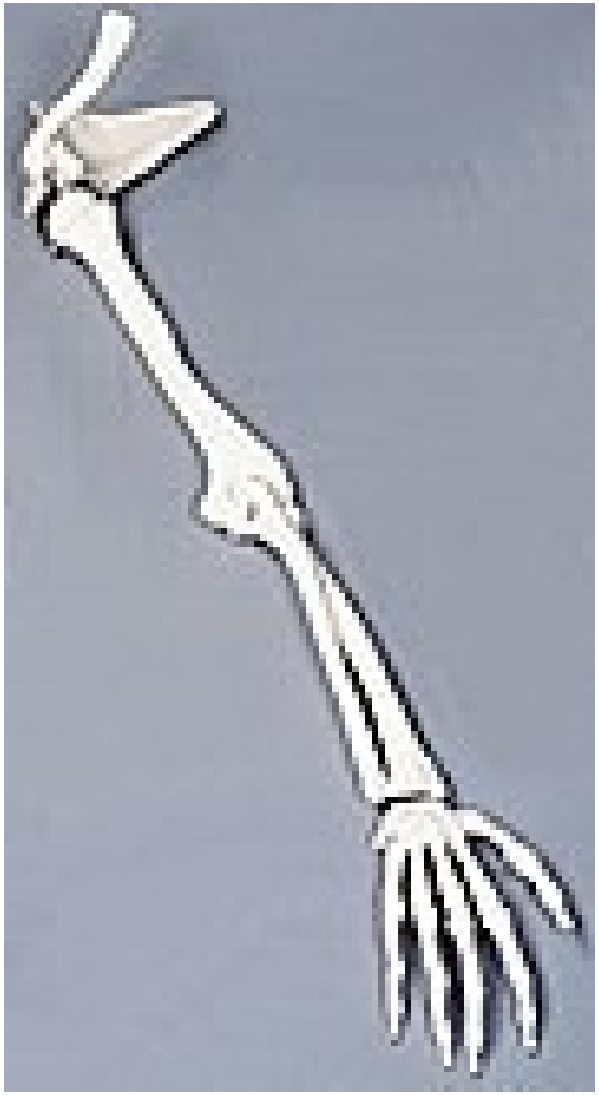
Consists of grdles with their associated extremities

1. **Pectoral girdle___4**
   1. **Clavicle _2**
   2. **Scapula _2**
2. **Pelvic girdle_____2**
   1. **Os coxae__2**
3. **Upper limbs _____60**
4. **Lower limbs _____60**

Total =126



Upper Limb Skeleton

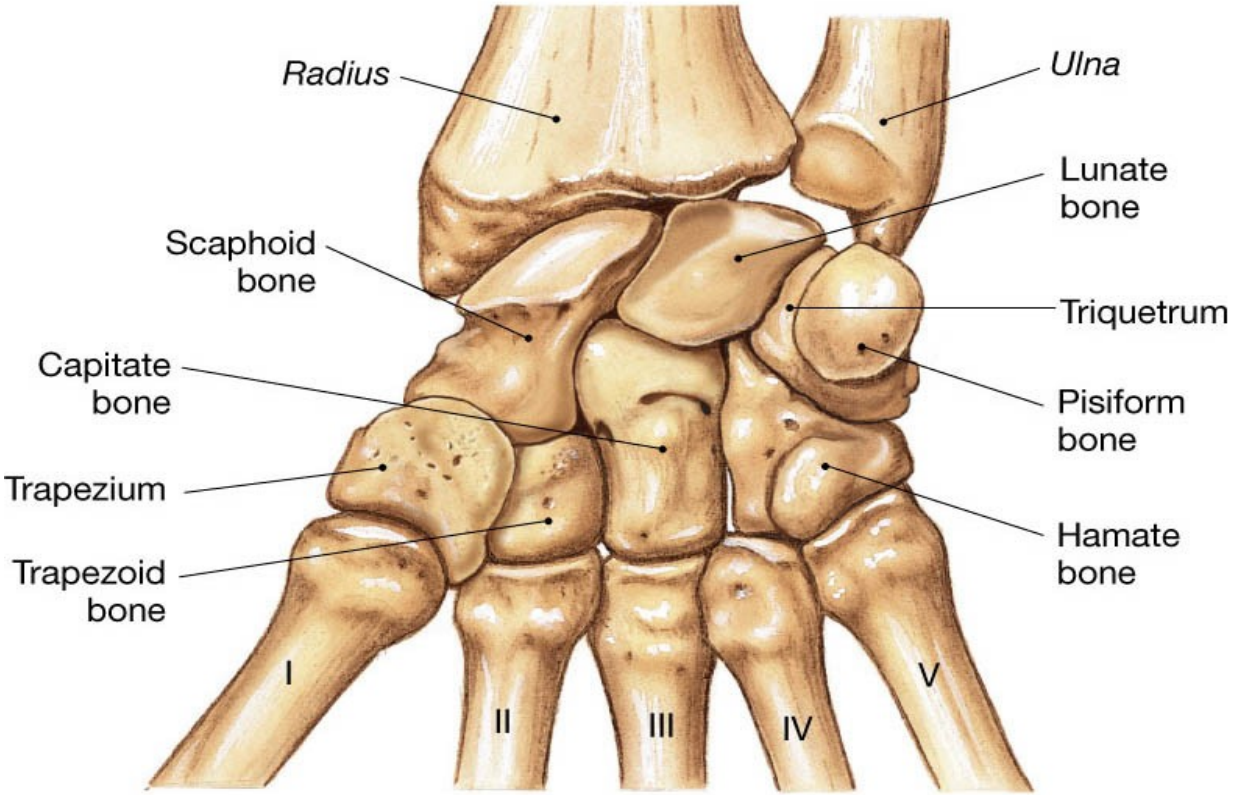


- Pectoral Girdle
  - Scapula
  - Clavicle
- Humerus
- Radius, ulna
- Carpals--proximal, distal
- Digits
  - Metacarpals
  - Phalanges

8 carpal (or wrist) bones:

From lateral to medial, first proximal then distal

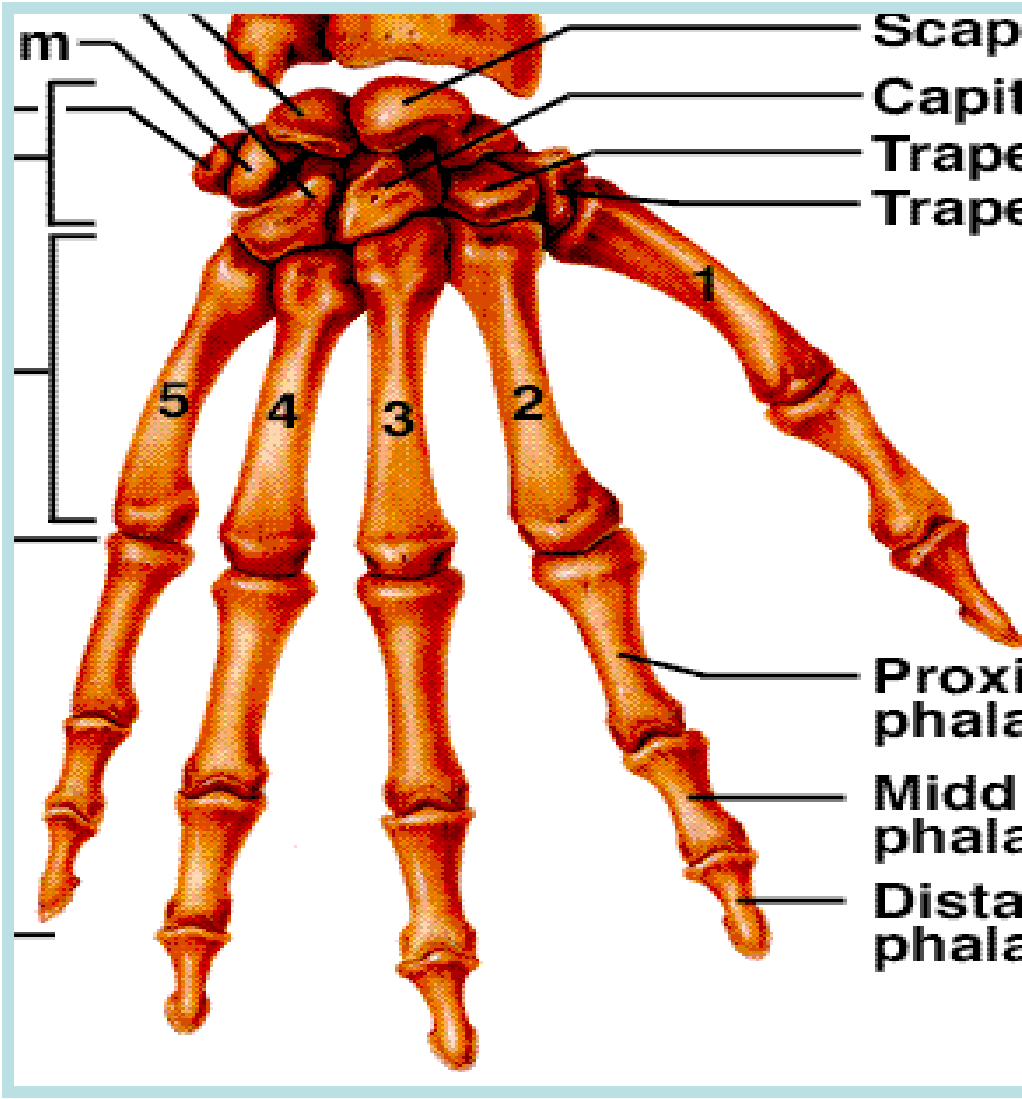
- **Proximal row:**
  - Scaphoid
  - Lunate
  - Triquetrum
  - Pisiform
- **Distal row**
  - Trapezium
  - Trapezoid
  - Capitate
  - Hamate



(a) Right wrist, anterior (palmar) view

The Hand

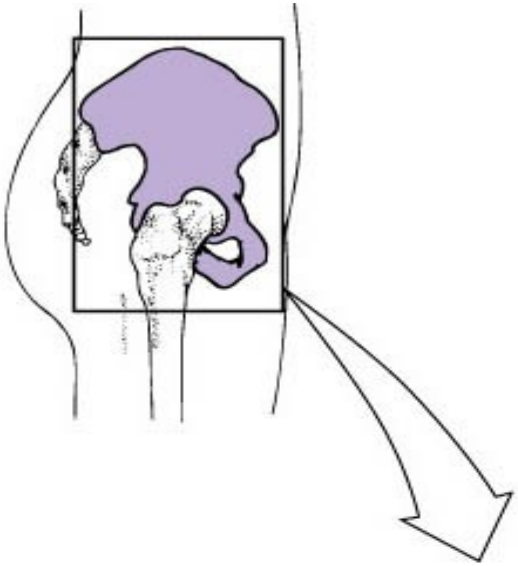
- **Metacarpals:** bones in palm of hand
  - Numbered from lateral to medial
- **14 Phalanges**
  - Numbering same as with metacarpals, additionally: proximal, middle and distal phalanx
- **Thumb has only two phalanges**
  - Has not middle phalanx

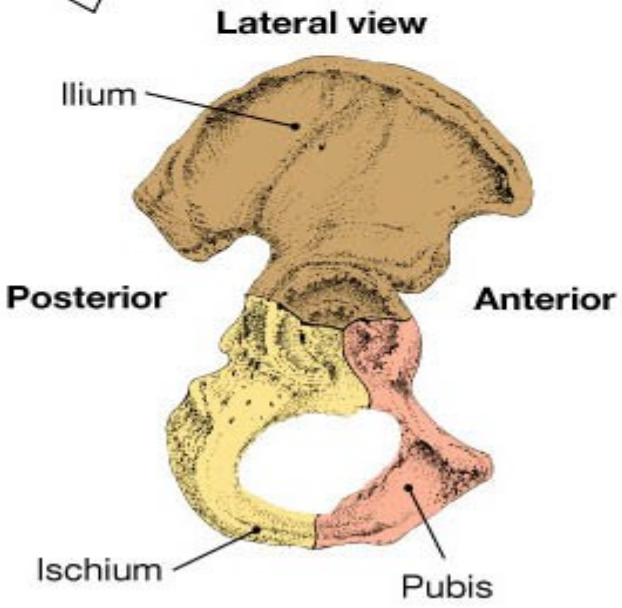


The Pelvic Girdle

- Two os coxae are made up of 3 fused bones; each
    1. ileum
    2. ischium
    3. pubis

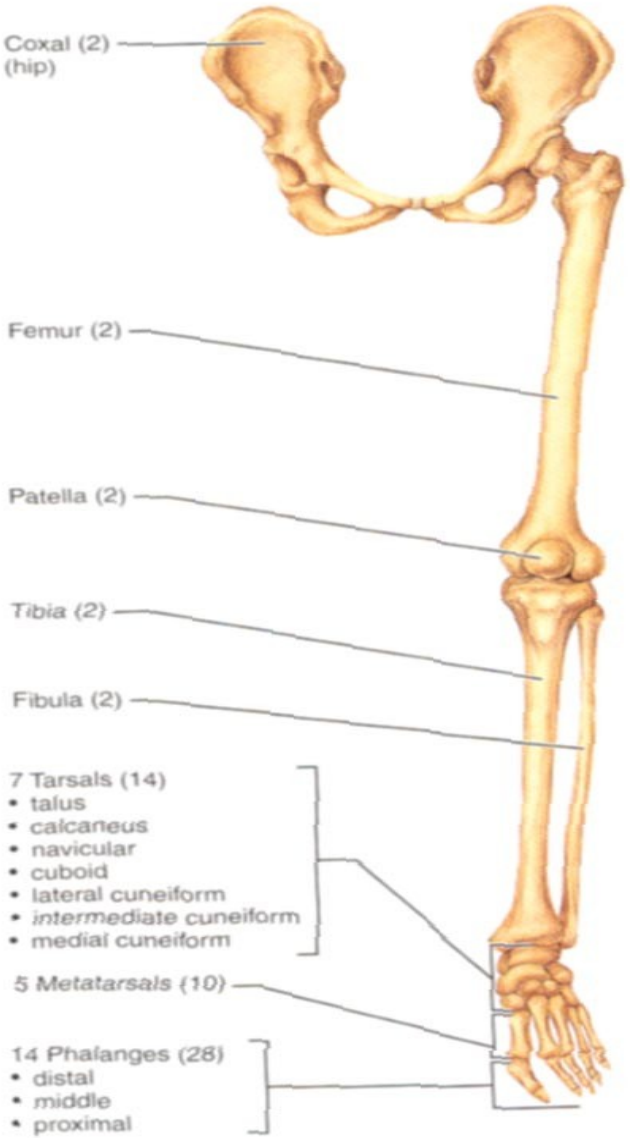
- Compare Male and female pelvis?





Bones of the **thigh** and **leg**

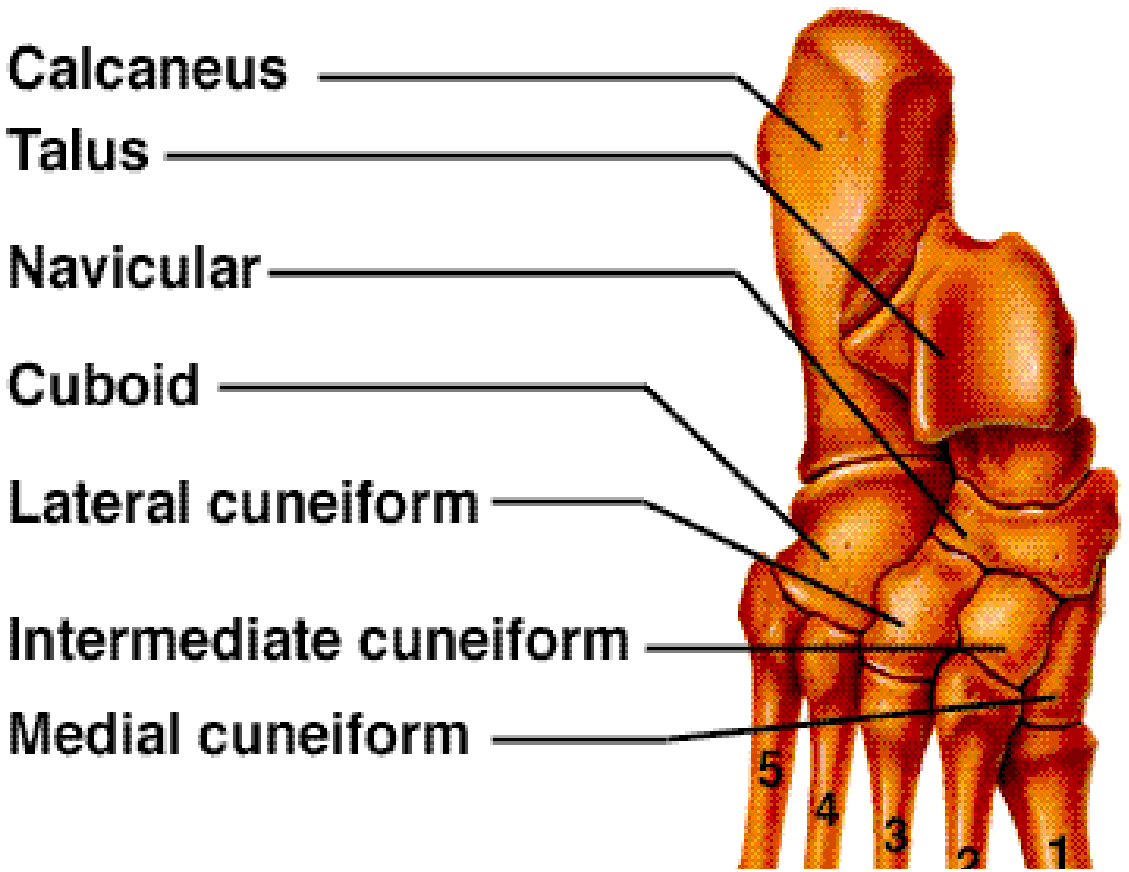
- **Femur**
- **Patella**
- **Tibia: medial**
- **Fibula: lateral**



7 tarsal (or “ankle”) bones:

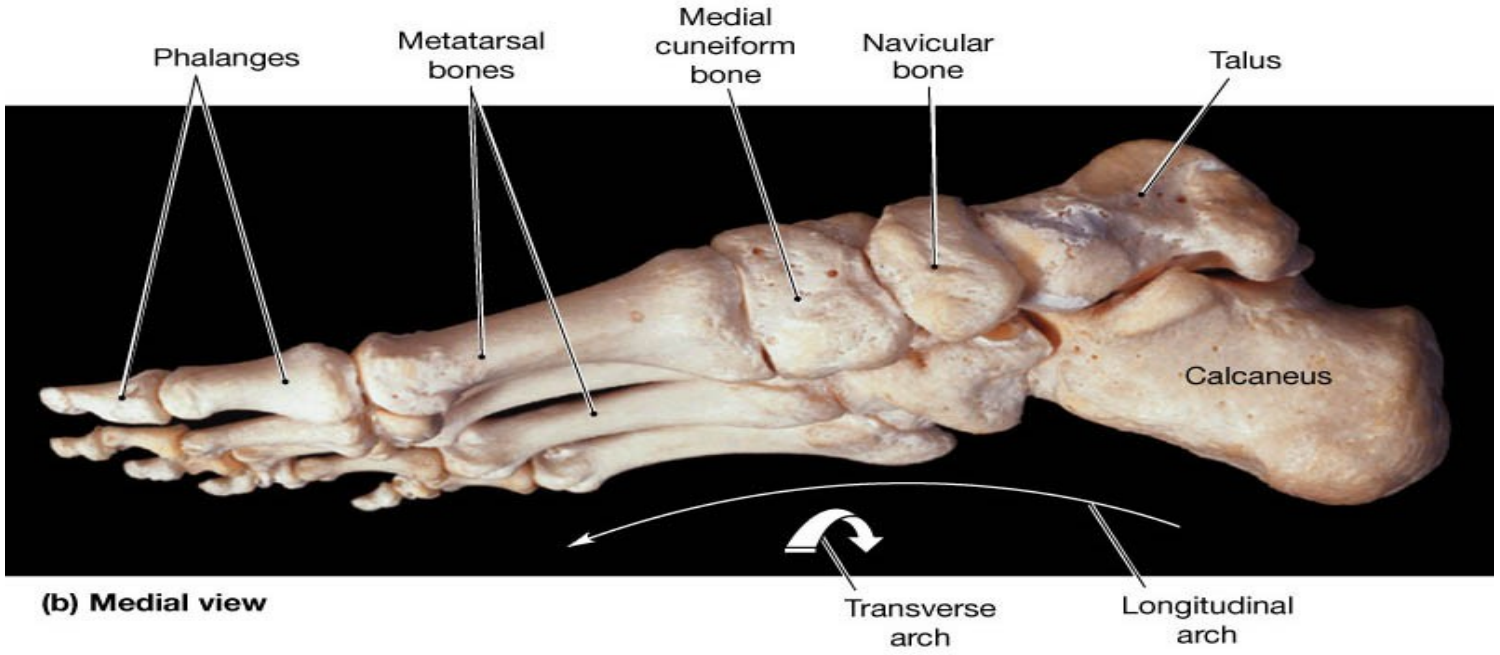
From lateral to medial, first proximal then distal:

- **Proximal row:**
  - Calcaneus
  - Talus
  - Navicular
- **Distal row:**
  - Cuboid
  - 3 Cuneiforms (lateral, intermediate, medial)



Foot

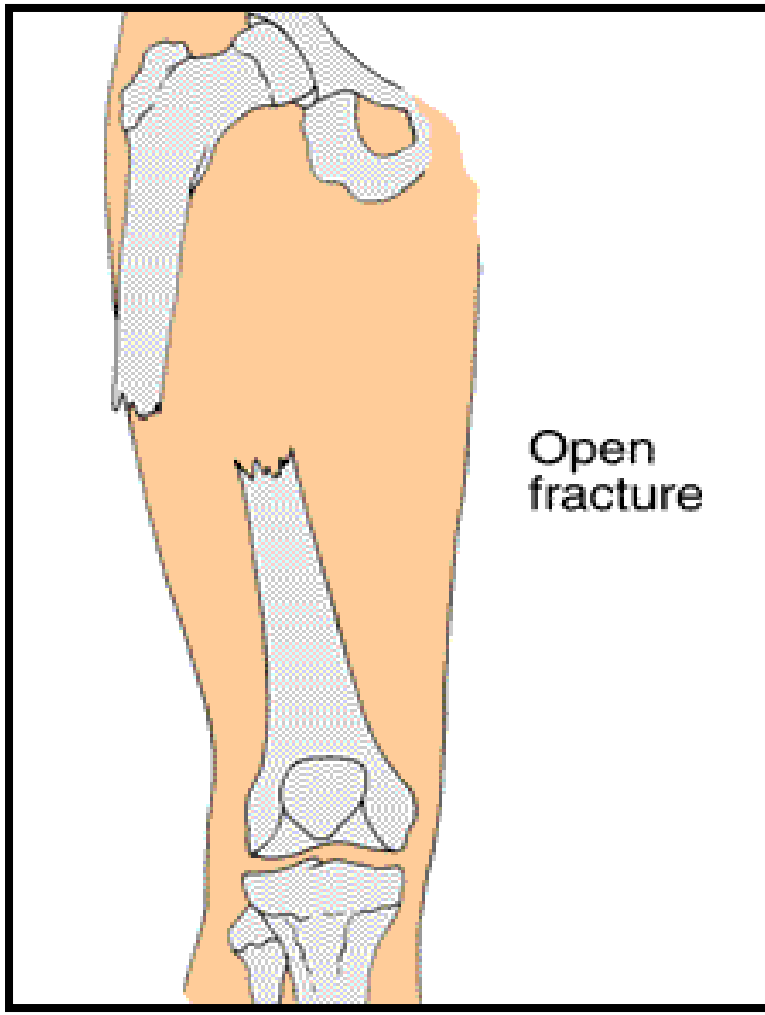
- Naming and numbering of metatarsals and phalanges analogous to hand
- **Hallux** has only two phalanges



Fractures

Fracture Types

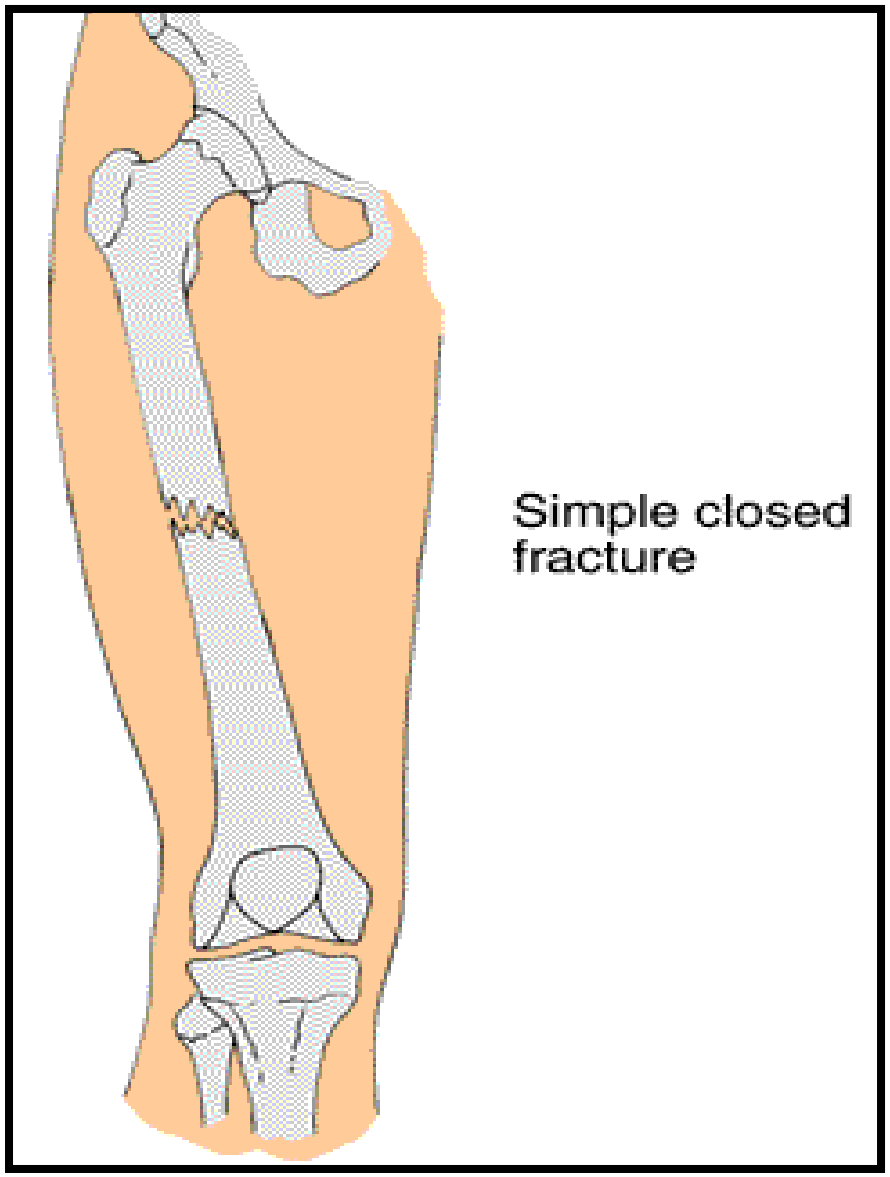
- Classified according to the position of the bone ends after the break:
  1. **Open (compound)**
     ➔ bone ends penetrate the skin.



Fracture Types

2. Closed (simple) ➔ bone ends don't penetrate the skin.

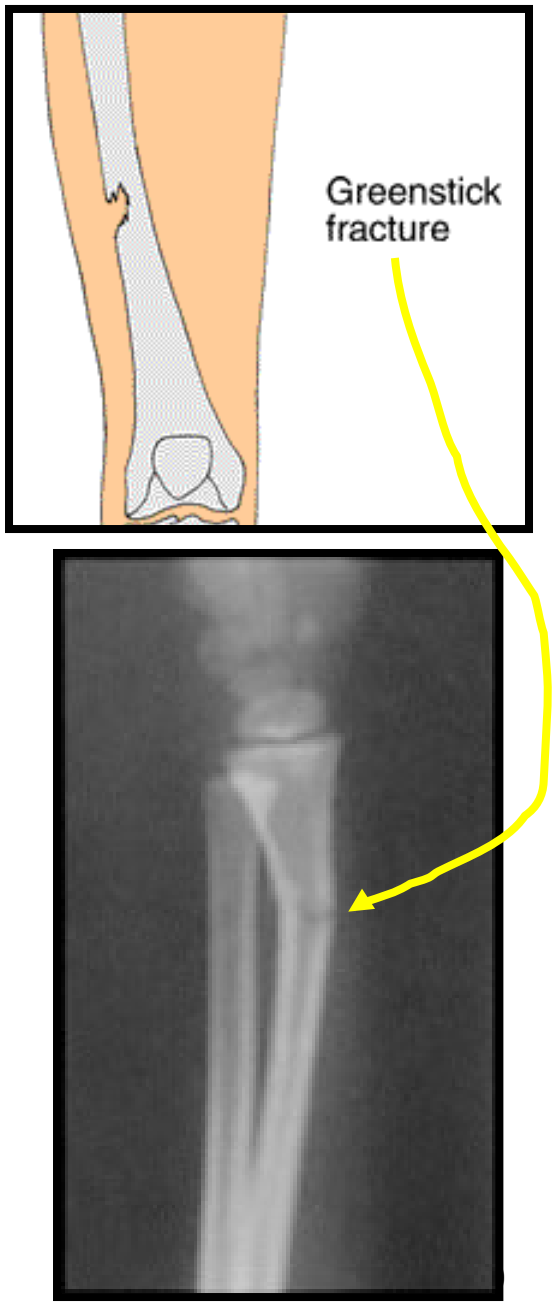
3. Comminuted ➔ bone fragments into 3 or more pieces



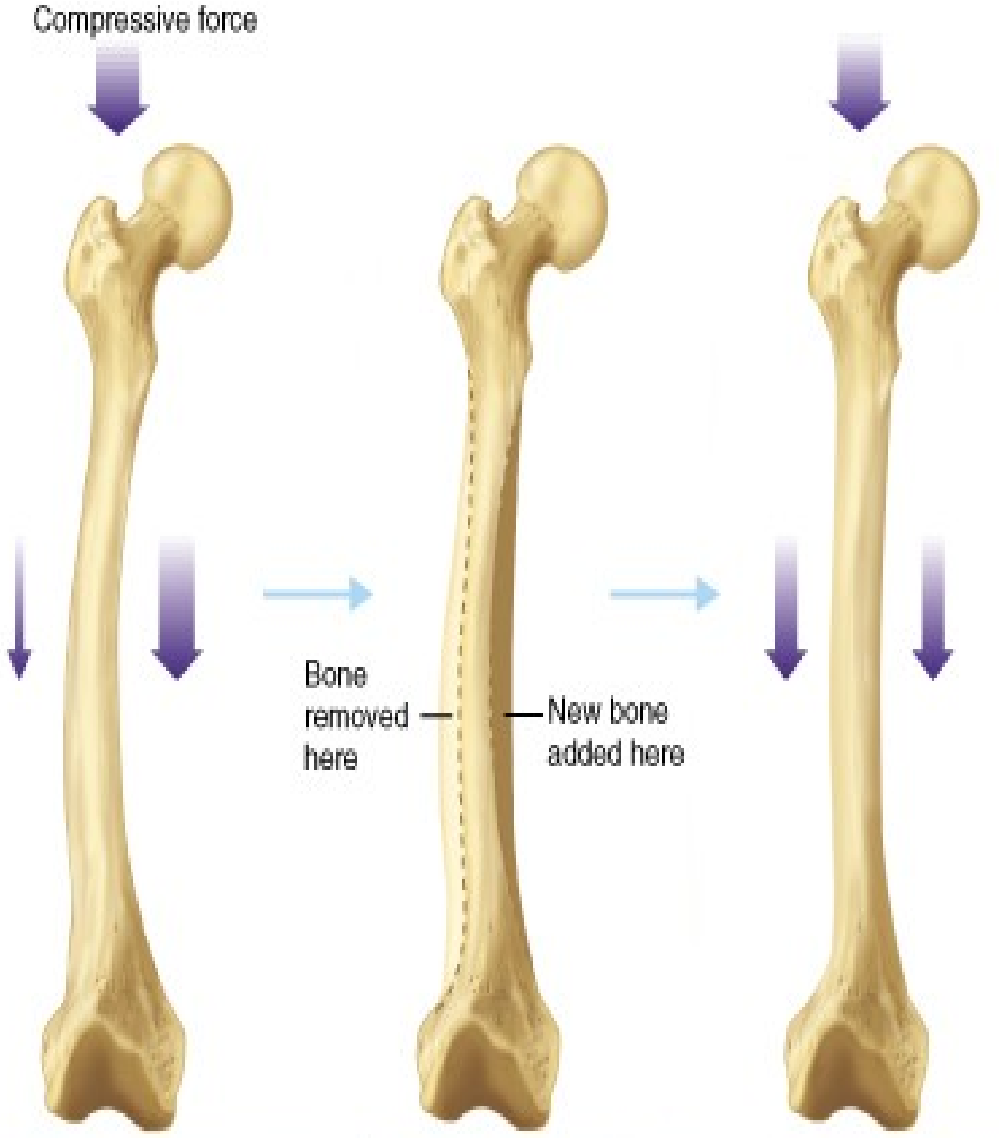
4. Greenstick ➔ bone breaks incompletely.

5. Spiral ➔ ragged break caused by excessive twisting forces.

6. Impacted ➔ one bone fragment is driven into the medullary space or spongy bone of another.



Bone Remodeling



- **Bone is a dynamic tissue.**
  - ***What does that mean?***
- **Wolff's law holds that bone will grow or remodel in response to the <u>forces or demands</u> placed on it. *Examine this with the bone on the left.***

II. According to their structural appearances

(Macroscopic appearances)

- **Each bone has a dense & smooth outer layer that looks solid & an inner layer with honey comb like appearance to the naked eye.**

a) COMPACT BONE :

outer dense layer that looks smooth & homogenous to the naked eye.

b) SPONGY (Trabecular, cancellous)

Is the inner layer composed of small needle like spicules of bones & numerous openings having a spongy appearance to the naked eye.

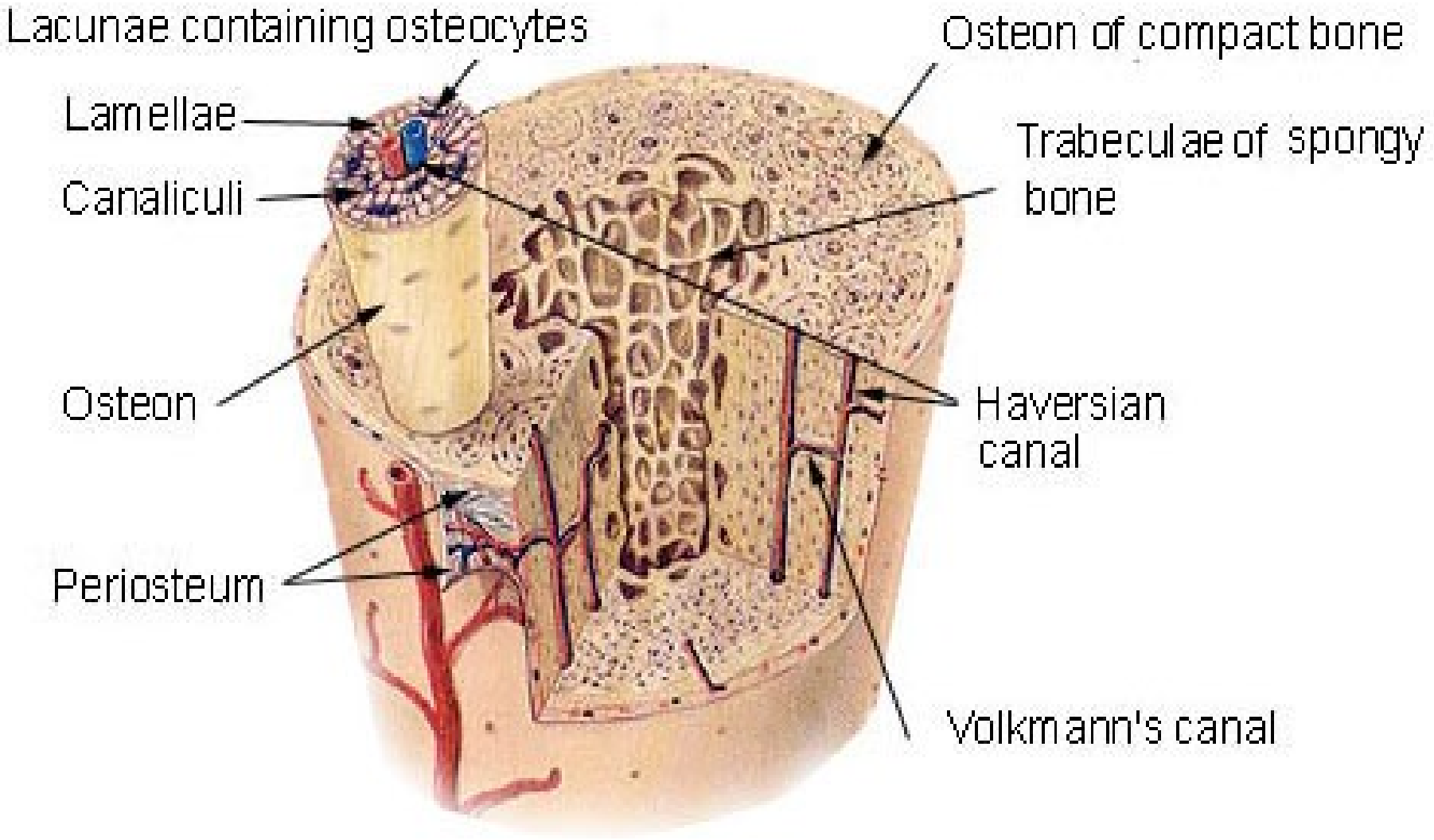
Bones = outer compact + Inner spongy layers.

III- According to their Microscopic Appearances

Microscopic Structure of Compact Bone

- Consists of multiple cylindrical structural units known as **osteons** or **haversian systems.**
- Imagine these osteons as weight-bearing pillars that are arranged parallel to one another along the long axis of a compact bone.

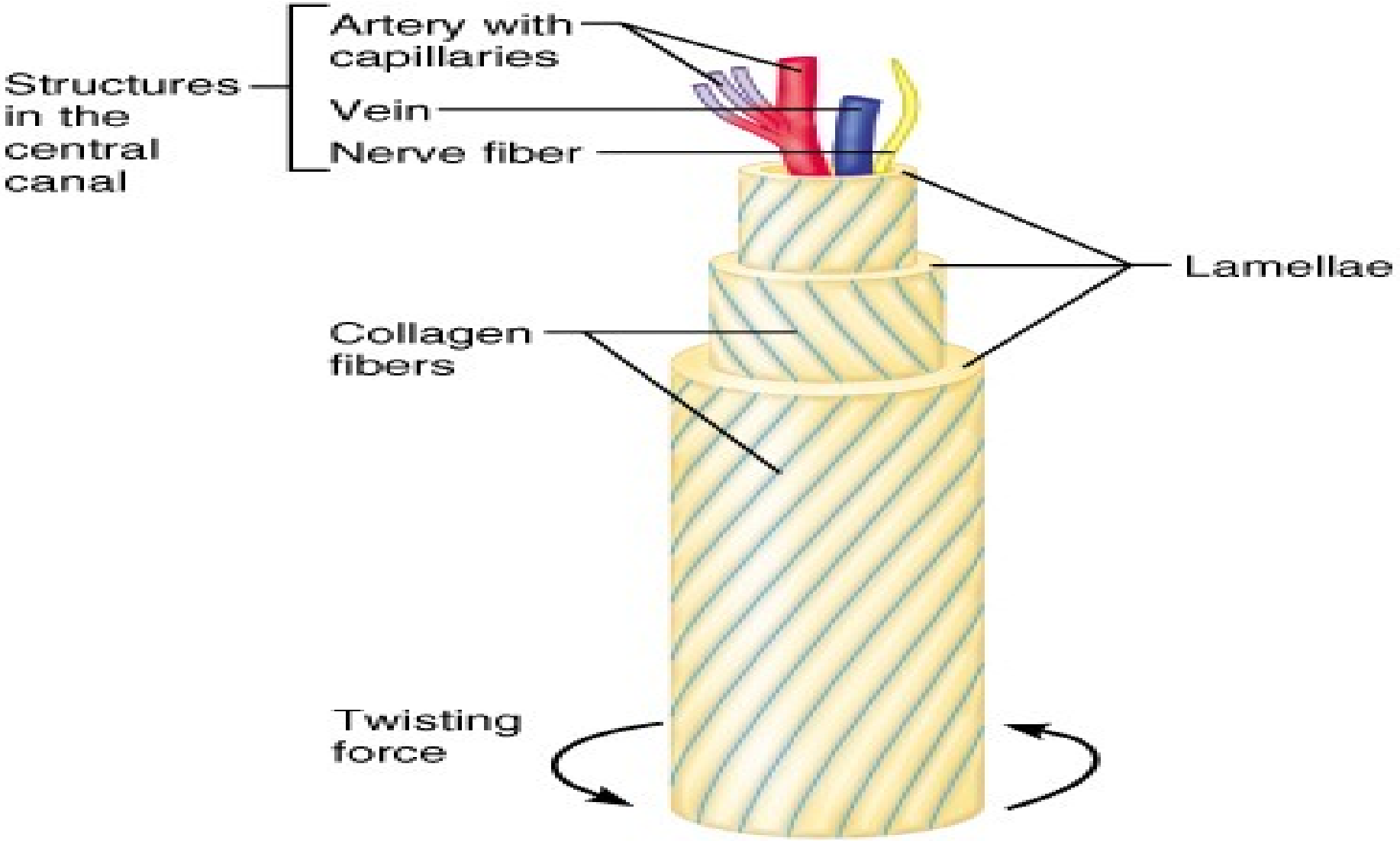
Osteon


Lacunae containing osteocytes
Lamellae
Canaliculi
Osteon
Periosteum
Osteon of compact bone
Trabeculae of spongy bone
Haversian canal
Volkmann's canal

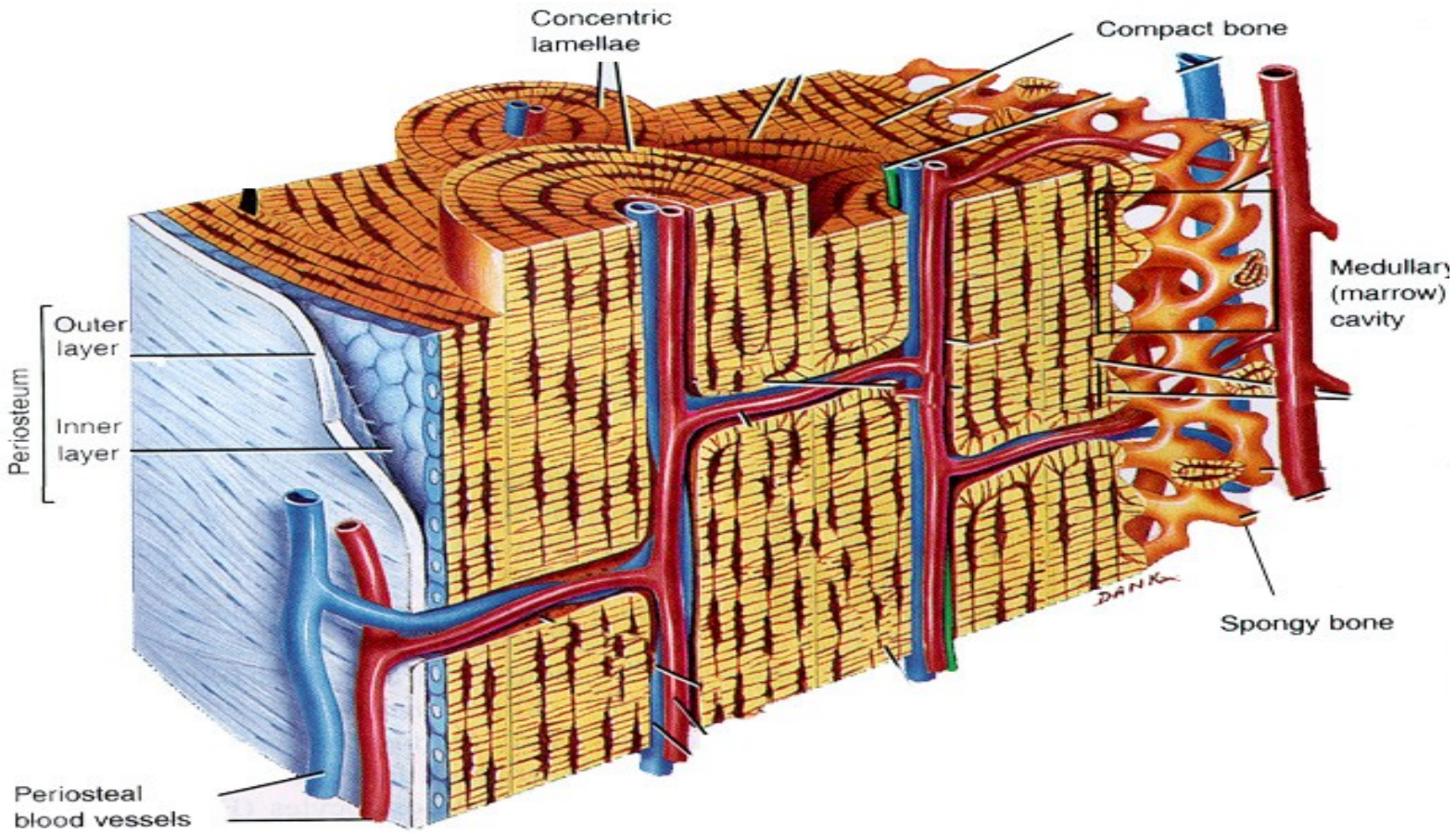
Osteon

- Each osteon consists of a single central canal, known as a **haversian canal**, surrounded by concentric layers of calcified bone matrix.
  - Haversian canals allow the passage of blood vessels, lymphatic vessels, and nerve fibers.
  - Each of the concentric matrix “tubes” that surrounds a haversian canal is known as a lamella.
  - All the collagen fibers in a particular lamella run in a single direction, while collagen fibers in adjacent lamellae will run in the opposite direction. This allows bone to better withstand twisting forces.

Osteon


Structures in the central canal
Artery with capillaries
Vein
Nerve fiber
Lamellae
Collagen fibers
Twisting force

haversian canals & Volkmann's canals



Running perpendicular to the **haversian canals** are **Volkmann's canals**. They connect the blood and nerve supply in the periosteum to those in the haversian canals and the medullary cavity.

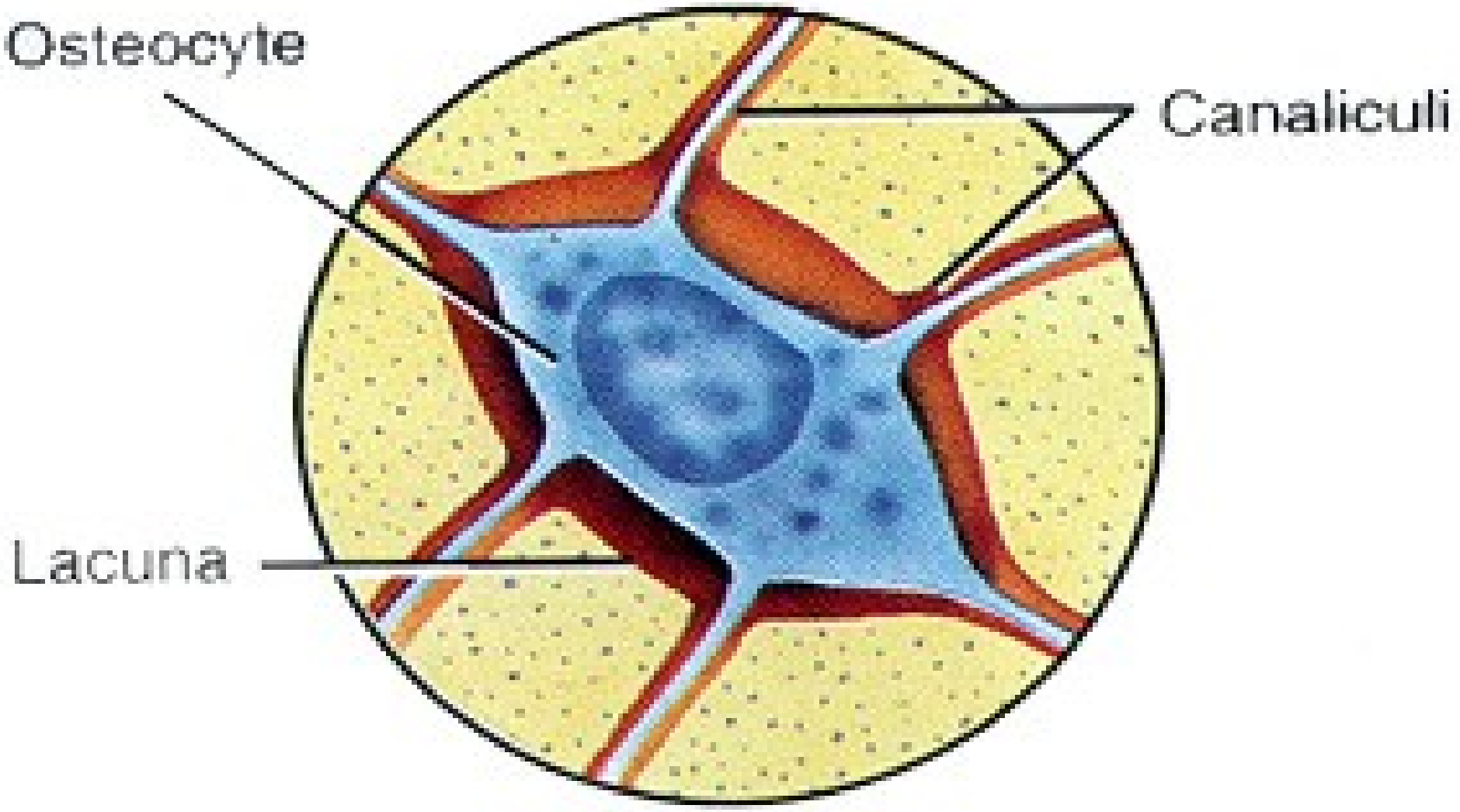
Osteon

- Lying in between intact osteons are incomplete lamellae called interstitial lamellae. These fill the gaps between osteons or are remnants of bone remodeling.
- There are also circumferential lamellae that extend around the circumference of the shaft. There are inner circumferential lamellae surrounding the endosteum and outer circumferential lamellae just inside the periosteum.

Osteon

- Spider-shaped osteocytes occupy small cavities known as lacunae at the junctions of the lamellae. Hairlike canals called canaliculi connect the lacunae to each other and to the central canal.
- Canaliculi allow the osteocytes to exchange nutrients, wastes, and chemical signals to each other via intercellular connections known as gap junctions.

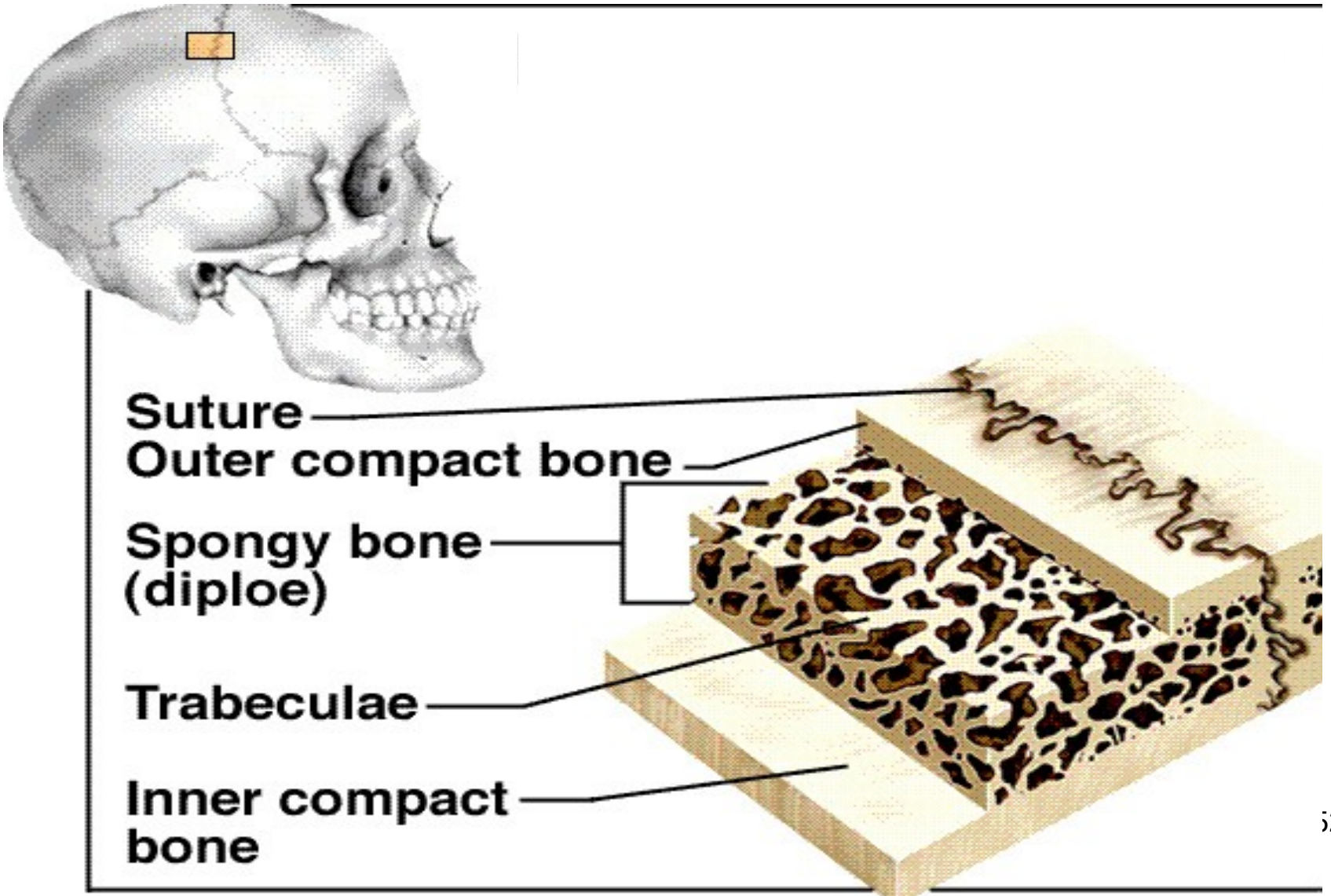
Con…



Microscopic structure of spongy bone

- Appears poorly organized compared to compact bone.
- Lacks osteons.
- Trabeculae align along positions of stress and exhibit extensive cross-bracing.
- Trabeculae are a few cell layers thick and contain irregularly arranged lamellae and osteocytes interconnected by canaliculi.
- *No haversian or Volkmann's canals*

Cont…


Suture
Outer compact bone
Spongy bone
(diploe)
Trabeculae
Inner compact
bone

Bone Tissue

- Bone tissue is a type of connective tissue, so it must consist of **cells** plus a significant amount of extracellular **matrix.**

Bone cells

1. **Osteoblasts**
   - Bone-building cells.
   - Synthesize and secrete collagen fibers and other organic components of bone matrix.
   - Initiate the process of calcification.
   - Found in both the periosteum and the endosteum

Cont…

2. Osteocytes

- Mature bone cells.
- Osteoblasts that have become trapped by the secretion of matrix.
- No longer secrete matrix.
- Responsible for maintaining the bone tissue.

3. Osteoclasts

- Huge cells derived from the fusion of as many as 50 monocytes (a type of white blood cell).
- Cells that digest bone matrix – this process is called bone resorption and is part of normal bone growth, development, maintenance, and repair.

Cont…

- **Osteoclasts**
  - Concentrated in the endosteum.
  - On the side of the cell that faces the bone surface, the PM is deeply folded into a ruffled border. Here, the osteoclast secretes digestive enzymes to digest the bone matrix. It also pumps out hydrogen ions to create an acid environment that eats away at the matrix.

Bone Matrix

- Consists of organic and inorganic components.
- 1/3 organic and 2/3 inorganic by weight.
  - Organic component consists of several materials that are secreted by the osteoblasts:
    - Collagen fibers and other organic materials
      - » These (particularly the collagen) provide the bone with resilience and the ability to resist stretching and twisting.

Bone Matrix

- **Inorganic component of bone matrix**
  - Consists mainly of 2 salts: calcium phosphate and calcium hydroxide. These 2 salts interact to form a compound called hydroxyapatite.
  - Bone also contains smaller amounts of magnesium, fluoride, and sodium.
  - These minerals give bone its characteristic hardness and the ability to resist compression.

IV- According to their Developmental Origin

1. **Membranous (mesenchymal, dermal)**
2. **Cartilaginous (chondral)**

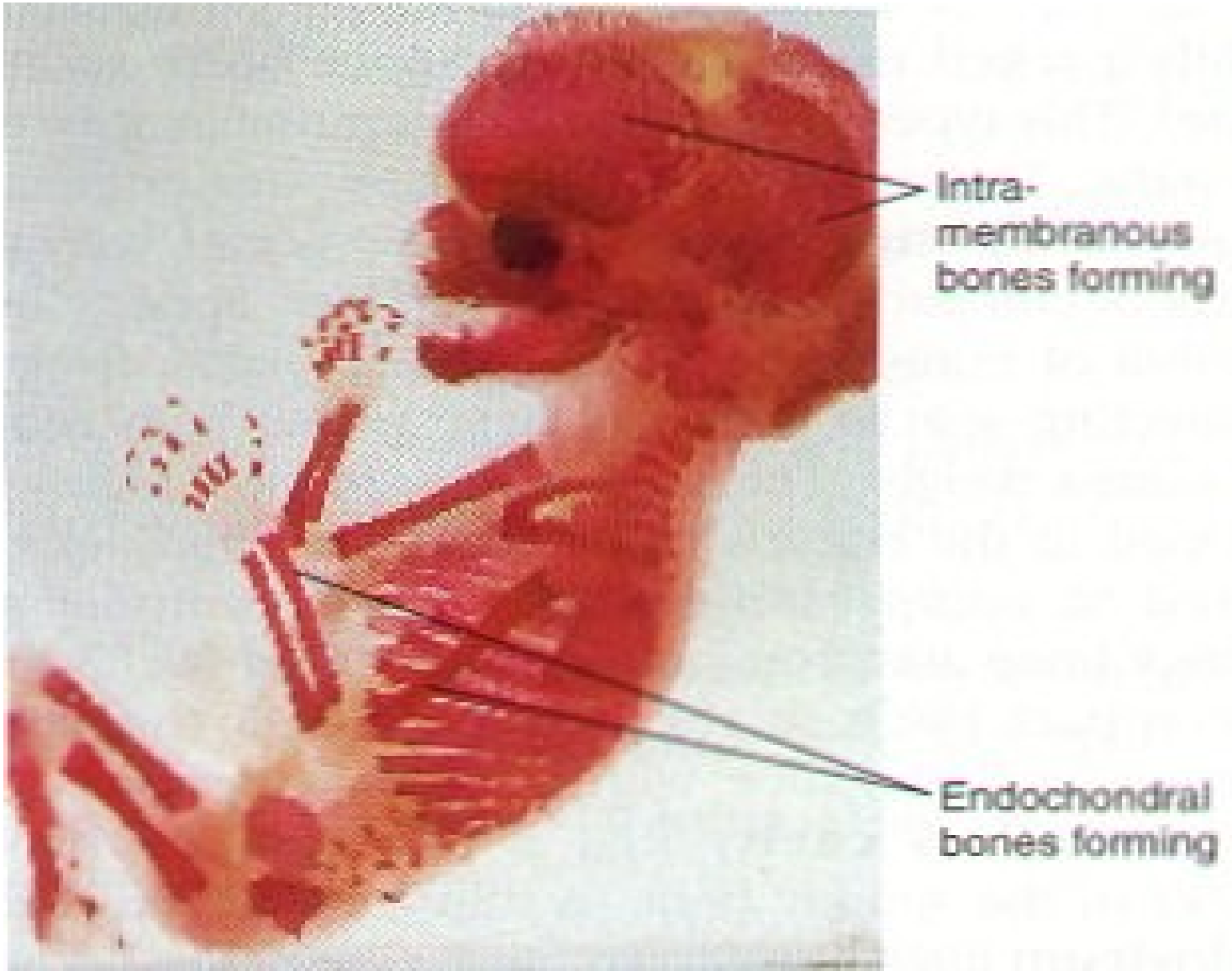
Osteogenesis (ossification):

- The process of bone tissue formation.
- In embryos this leads to the formation of the bony skeleton.
- In children and young adults, ossification occurs as part of bone growth.
- In adults, it occurs as part of bone remodeling and bone repair.

FORMATION OF THE BONY SKELETON

- **Before week 8, the human embryonic skeleton is made of fibrous membranes and hyaline cartilage.**
- **After week 8, bone tissue begins to replace the fibrous membranes & hyaline cartilage.**
  - **The development of bone from a fibrous membrane is called intramembranous ossification.**

- The replacement of hyaline cartilage with bone is known as **endochondral ossification (Chondral)**



V. Classification according to their forms and shapes

1. **LONG BONES** – to this belong bones like humerus, femur, radius , ulna, tibia , fibula, metacarpals, metatarsals, phalanges & the clavicle.

   - They are generally longer than wider.
   - long bones consist of **three parts**, a middle part called **diaphysis**, **shaft or body** mostly containing the medullary or marrow cavity & two enlarged ends called **epiphysis**.

Structure of Long Bones

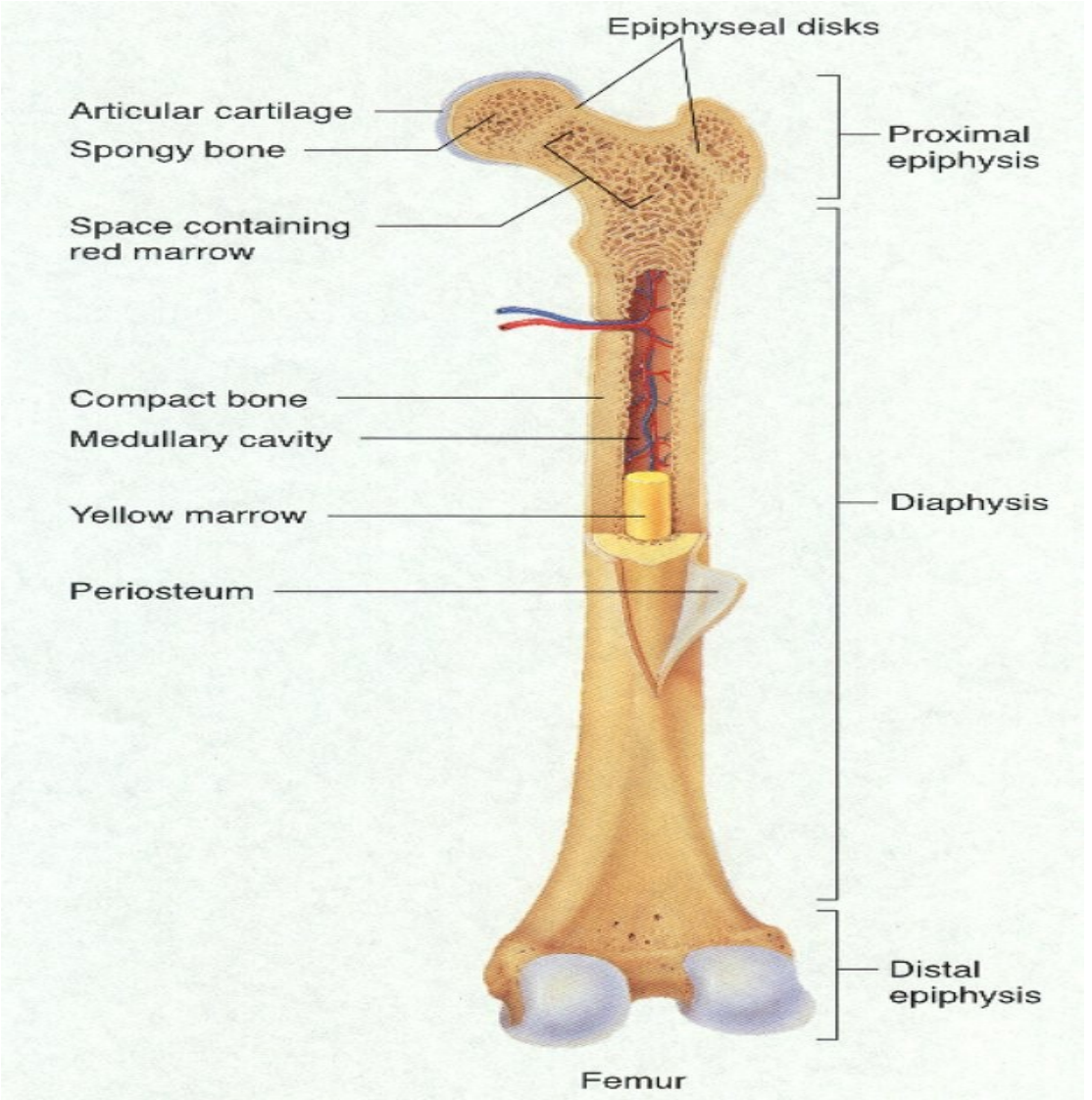
- The external surface of the entire bone except for the joint surfaces of the epiphyses is covered by a double-layered membrane known as the periosteum.
  - Outer fibrous layer is dense irregular connective tissue.
  - Inner cellular layer contains osteoprogenitor cells and osteoblasts.
  - Periosteum is richly supplied with nerve fibers, lymphatic vessels and blood vessels.
    - These enter the bone of the shaft via a nutrient foramen.
  - Periosteum is connected to the bone matrix via strong strands of collagen.

Structure of Long Bones

- Internal bone surfaces are covered with a delicate connective tissue membrane known as the endosteum.
  - Covers the trabeculae of spongy bone in the marrow cavities and lines the canals that pass through compact bone.
- Contains both **osteoblasts** and **osteoclasts**.

Bone marrow

- Bone marrow is a general term for the soft tissue occupying the medullary cavity of a long bone, the spaces amid the trabeculae of spongy bone, and the larger haversian canals.
- There are 2 main types: red & yellow.



1. Red bone marrow

- Red bone marrow = blood cell forming tissue = hematopoietic tissue
  - Red bone marrow looks like blood but with a thicker consistency.
  - It consists of a delicate mesh of reticular tissue saturated with immature red blood cells and scattered adipocytes.
  - red marrow limited to vertebrae, ribs. sternum, part of the pelvic girdle, and the proximal ends of the humerus and femur

2. Yellow bone marrow

- Yellow bone marrow- in adults most of the medullary cavities are replaced with yellow bone marrow.
    - Yellow marrow no longer produces blood, although in the event of severe or chronic anemia, it can transform back into red marrow
- By old age most of the yellow marrow is replaced by reddish jells, which is known as **gelatinous marrow**

Distribution of bone marrow

- In a child, the medullary cavity of nearly every bone is filled with red bone marrow.
- In young to middle-aged adults, the shafts of the long bones are filled with fatty yellow bone marrow.
- In adults, red marrow is limited to the axial skeleton, pectoral girdle, pelvic girdle, and proximal heads of the humerus and the femur.

2. SHORT BONES

composed of a layer of compacta covering an underlying spongiosa.

E.g. Carpal bones, Tarsal bones

3. FLAT BONES

– formed by an inner & outer lamina of compact bone between which lies a spongy substance. In case of skull bones this spongy substance is called diploe.

E.g. skull , scapula, hip bones , ribs

4. IRREGULAR BONES – they have similar structure to short bones except that their surfaces are irregular

E. g. vertebral bones

5. Sesamoid bones (e.g., patella, or kneecap)

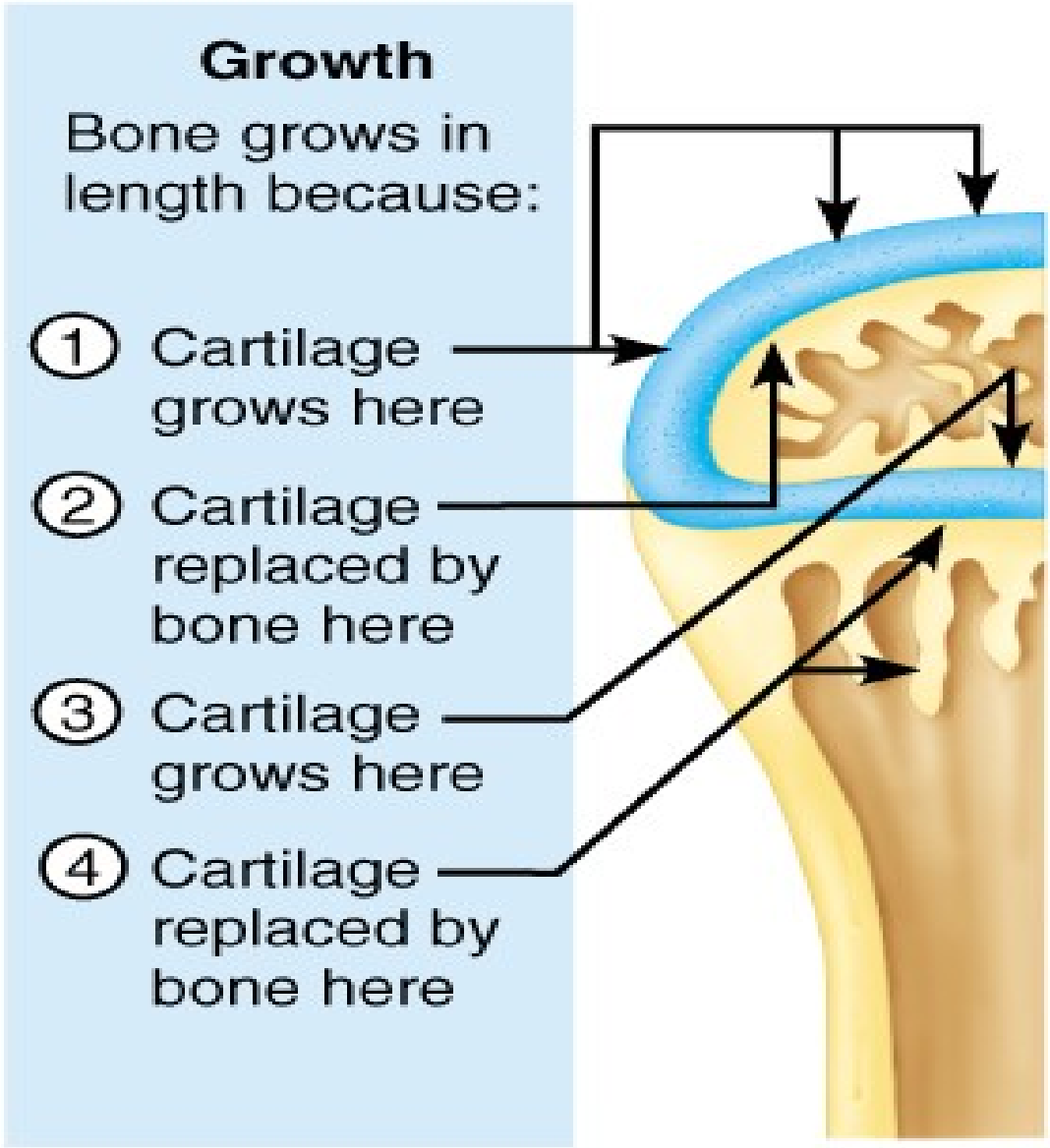
- develop in certain tendons.
- These bones protect the tendons from excessive wear

Structure of short, flat and irregular bones

- Thin plates of periosteum-covered compact bone on the outside and endosteum-covered spongy bone within.
- Have no diaphysis or epiphysis because they are not cylindrical.
- Contain bone marrow between their trabeculae, but no marrow cavity.
- In flat bones, the internal spongy bone layer is known as the diploë, and the whole arrangement resembles a stiffened sandwich.

Growth in Bone Length

- Epiphyseal cartilage (close to the epiphysis) of the epiphyseal plate divides to create more cartilage, while the diaphyseal cartilage (close to the diaphysis) of the epiphyseal plate is transformed into bone. This increases the length of the shaft.



At puberty, growth in bone length is increased dramatically by the combined activities of growth hormone, thyroid hormone, and the sex hormones.

As a result osteoblasts begin producing bone faster than the rate of epiphyseal cartilage expansion. Thus the bone grows while the epiphyseal plate gets narrower and narrower and ultimately disappears. A remnant (epiphyseal line) is visible on X-rays *(do you see them in the adjacent femur, tibia, and fibula?)*

Epiphyseal line



Growth in Bone Thickness

- Osteoblasts beneath the periosteum secrete bone matrix on the external surface of the bone. This obviously makes the bone thicker.
- At the same time, osteoclasts on the endosteum break down bone and thus widen the medullary cavity.
- This results in an increase in shaft diameter

BLOOD SUPPLY OF BONES

In contrary to cartilages bone is highly vascularised.

- Vessels supplying bones arise from the periosteal vessels & run through the Volkman's canals, where they divide into branches that join vessels in the central canal (Haversian canal) & supply the compacta.
- Blood vessels of bones are accompanied by many nerve fibers