General osteology

Human Anatomy Department

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Plan of the lecture

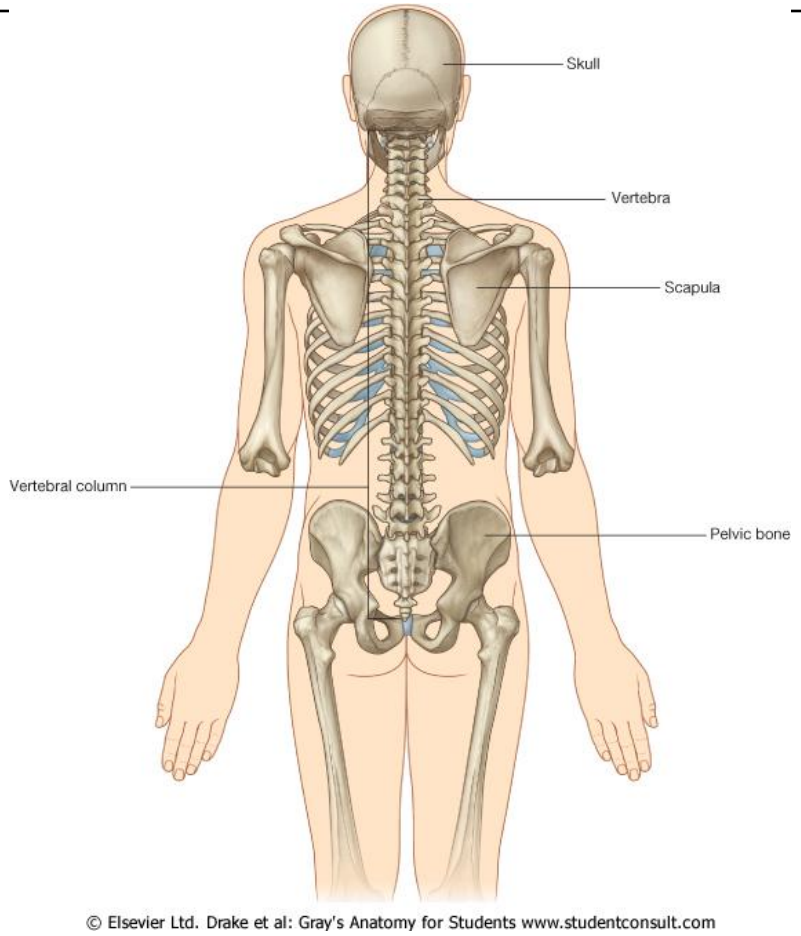
1. General concepts about skeleton
2. Bone as an organ
3. Functions of the skeleton
4. Classification of bones
5. Types of bone ossification
6. Development of bones

THE LOCOMOTOR APPARATUS – ITS COMPONENETS AND FUNCTIONAL ROLE

- **The skeleton is a complex of hard structures that is of mesenchymal origin and possesses a mechanical significance.**
- The term skeleton comes from a Greek word meaning “dried up”.
- **NB:** *All the bones and joints of the body make up the passive part of the locomotor apparatus*.

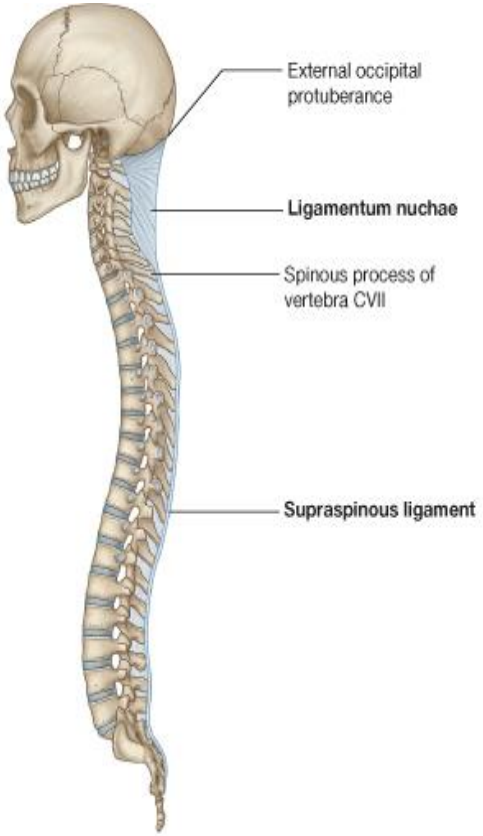
The skeleton

- The science concerned with the study of bones is termed **osteology.**
- The skeletal system of an adult is composed of approximately **206 bones**. Each bone is an organ of the skeletal system.
- The skeleton is divided into *axial* and *appendicular parts*.



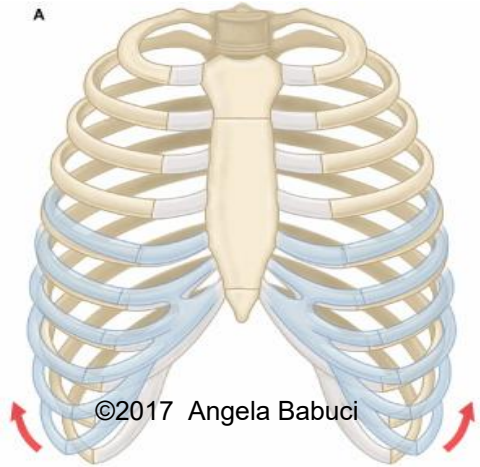
The axial skeleton

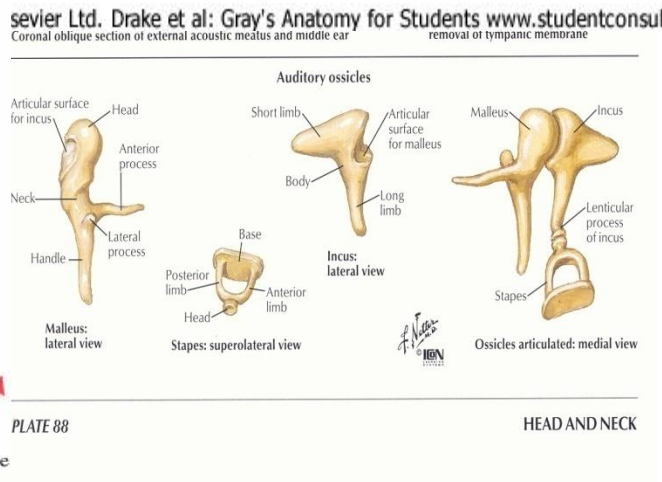
The **axial skeleton** consists of **80 bones** that form the axis of the body, which supports and protects the organs of the head, neck, and trunk.



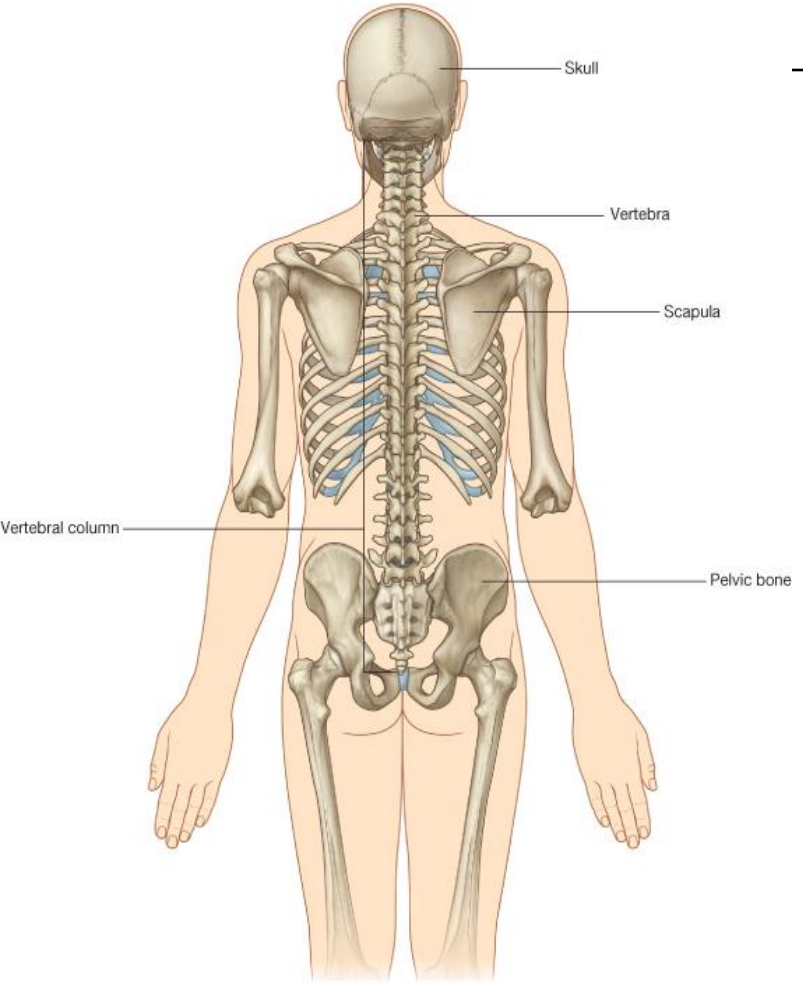
Components of the axial skeleton:

- Skull
- Auditory ossicles
- Hyoid bone
- Vertebral column
- Thoracic cage





The appendicular skeleton



The *appendicular skeleton* is composed of <u>126 bones</u> of the upper and lower limbs and the bony girdles, which anchor the appendages to the axial skeleton.

- **The shoulder girdle** (the scapula and clavicle).
- **The upper limb** (the humerus, ulna, radius and bones of the hand).
- **The pelvic girdle** (the hip bone).
- **The lower limb** (the femur, tibia, fibula and bones of the foot).

BONE AS AN ORGAN
STRUCTURE OF A BONE AND STRUCTURE OF THE PERIOSTEUM

- **Bone** (*osis*) is one of the hardest structures of the body.
- It possesses also a certain degree of toughness and elasticity.
- Its color, in a fresh state, is pinkish-white externally, and red within.

Types of bone tissue

There are **two types** of bone tissue:

a) compact bony tissue

b) spongy bony tissue

The names imply that the two types differ in density, or how tightly the tissue is packed together.

There are three types of cells that contribute to bone homeostasis.

a) osteoblasts are bone-forming cell

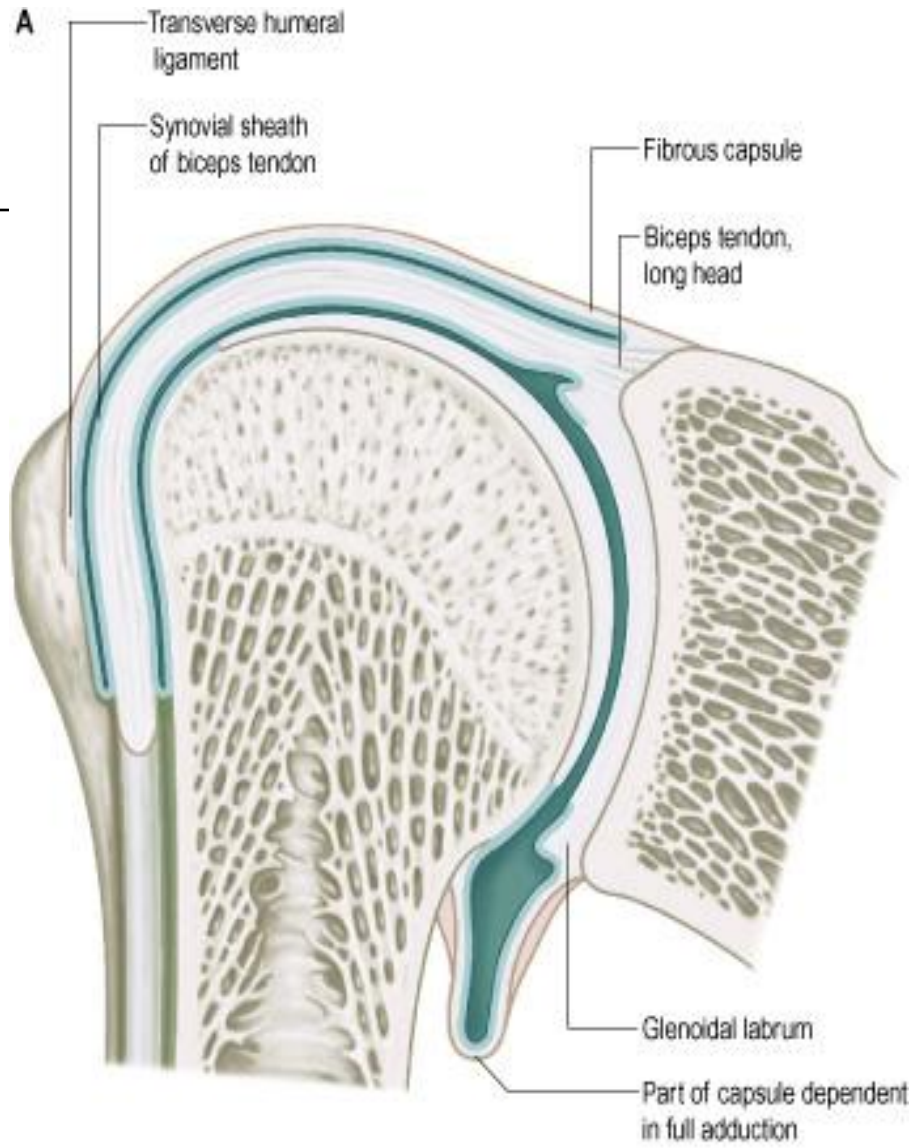
b) osteoclasts resorb or break down the bone

c) osteocytes are mature bone cells.

An equilibrium between osteoblasts and osteoclasts maintains the bone tissue.

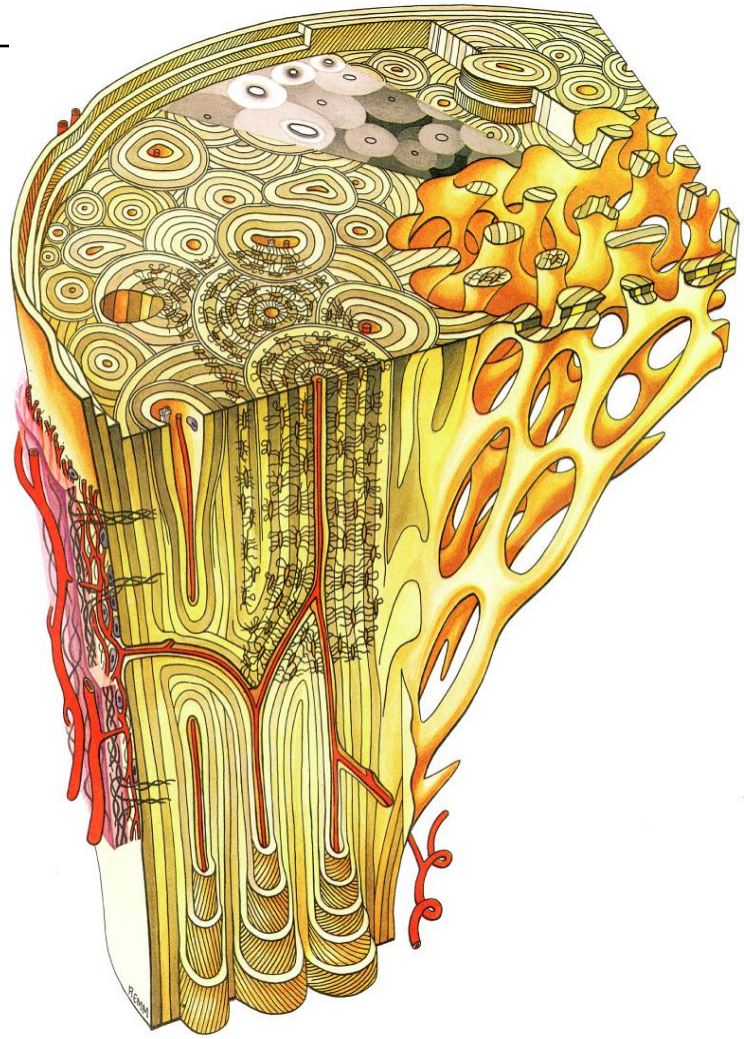
Structure of bone

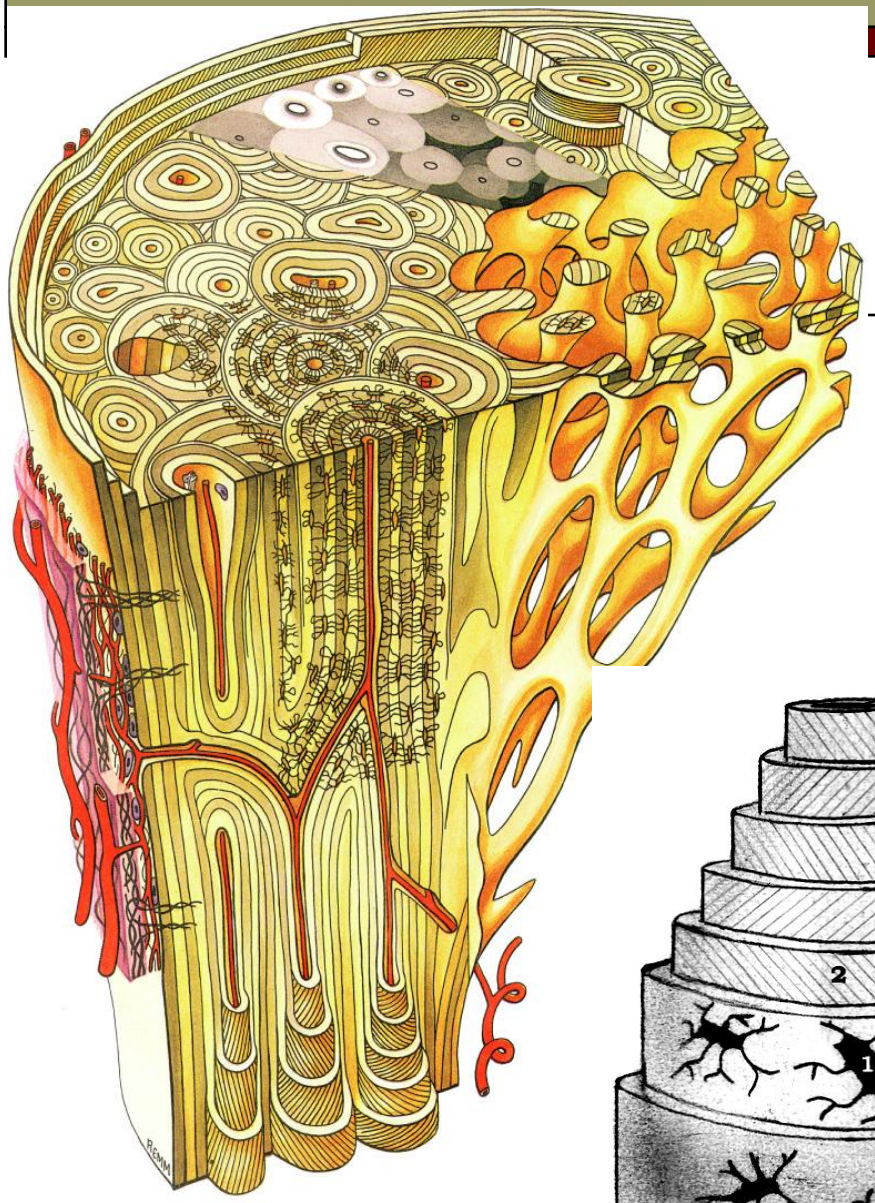
- On examining a cross section of any bone, it is composed of two kinds of bony tissue:
- **Compact tissue**, it is dense in texture and it is always placed on the exterior of the bone.
- **Cancellous tissue** consists of slender fibers and lamellae, which join to form a reticular structure and it is placed in the interior of the bone

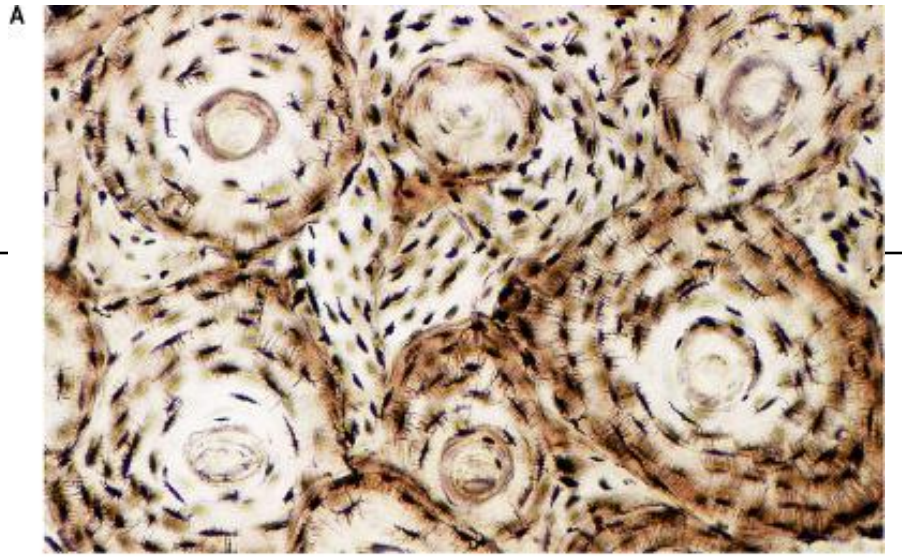


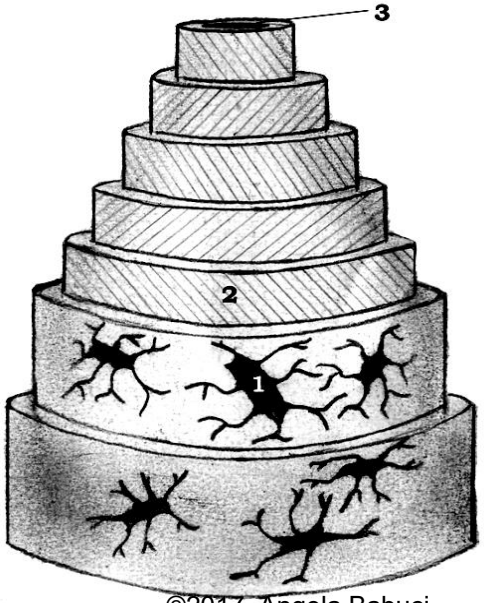
Macromicroscopic structure of a bone

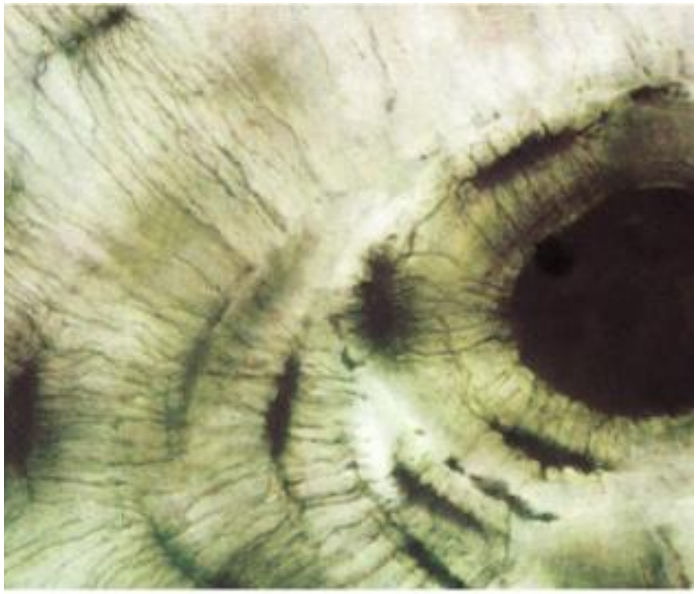
- The **morphofunctional unit** of the bone is the **osteon**, or **Haversian system**.
- The osteon consists of a system of bony lamellae arranged concentrically around a canal, which is called ***Haversian canal*** and this canal contains nerves and blood vessels.
- The bone lamellae consist of osteocytes, their lacunae, and interconnecting canaliculi and matrix.



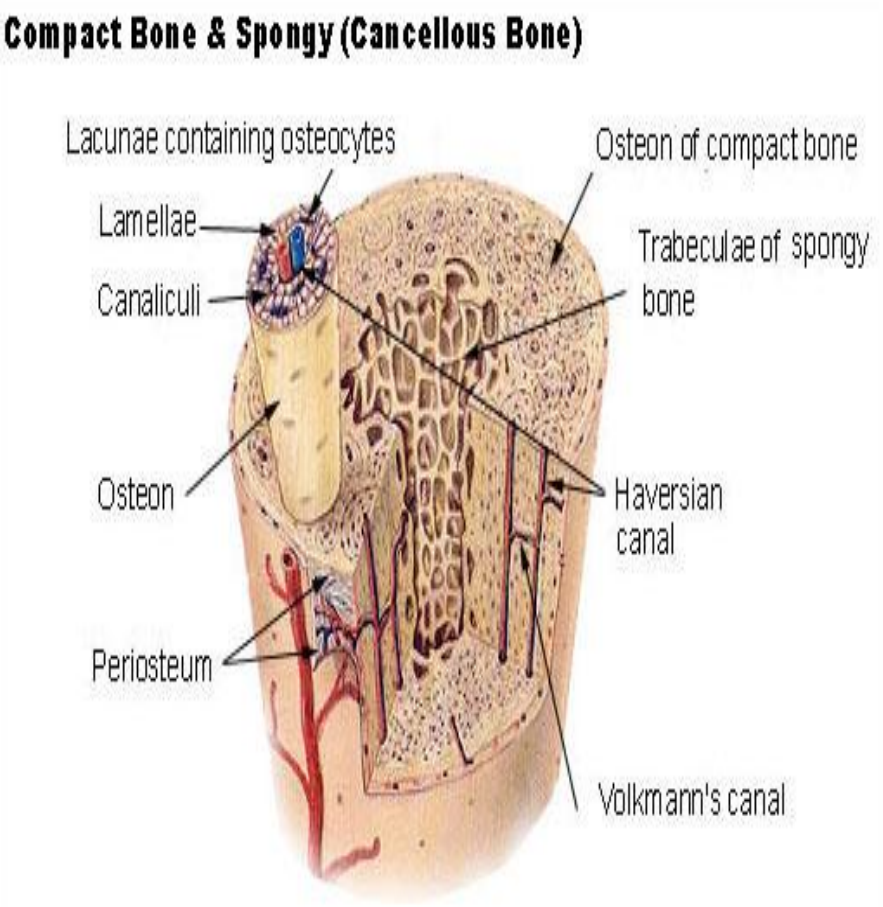




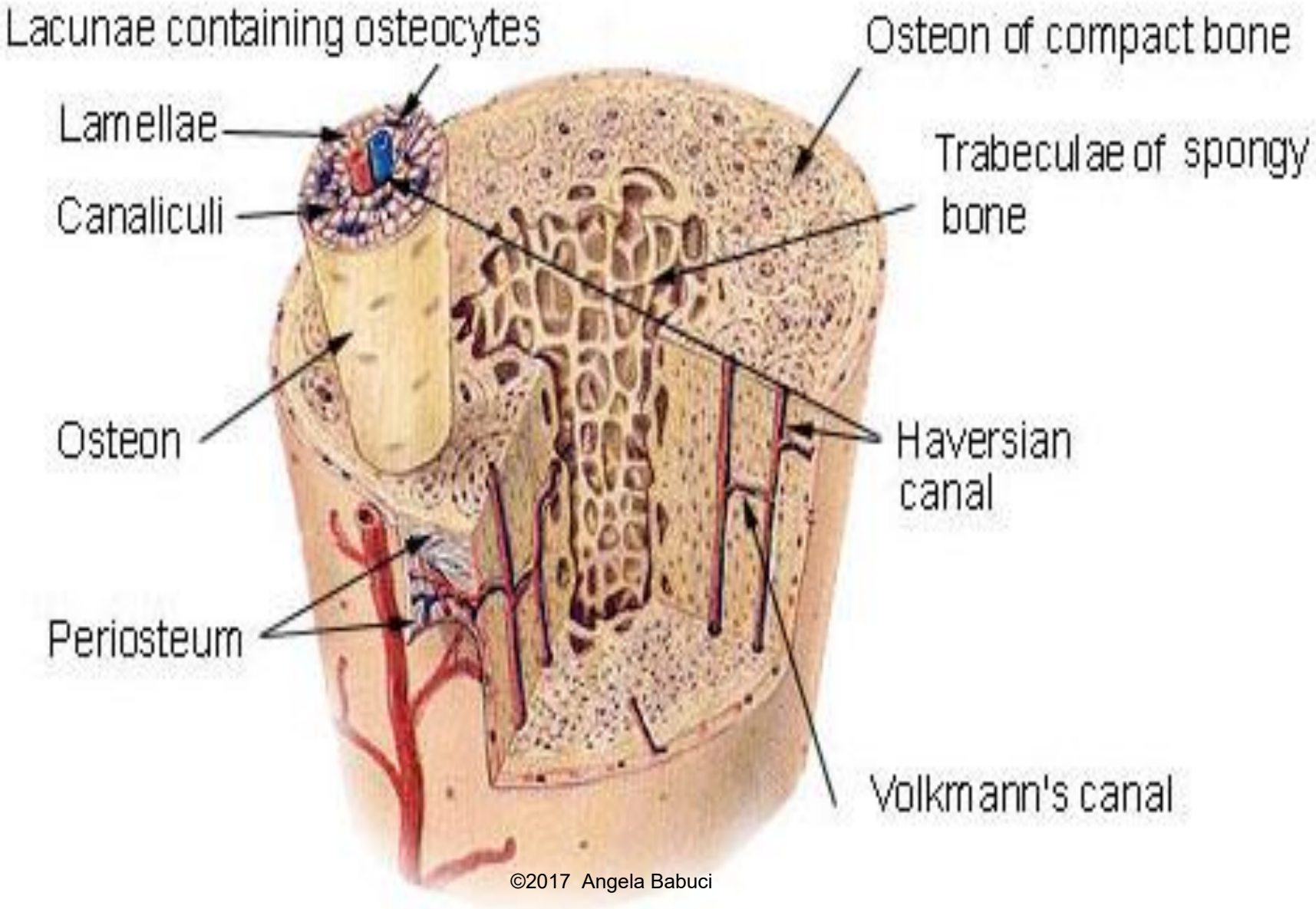




- From the periosteum into the bone matter, in special canals called Volkmann's canals, pass blood vessels and nerves.
- The blood vessels conveyed in the Volkmann‘s and Haversian canals provide for metabolism in the bone.
- The canaliculi permit substances to pass from one cell to another and from the blood vessels in the Haversian canals.
- In this way the living cells get rid of their waste products and receive the nourishment they must have to maintain normal function.

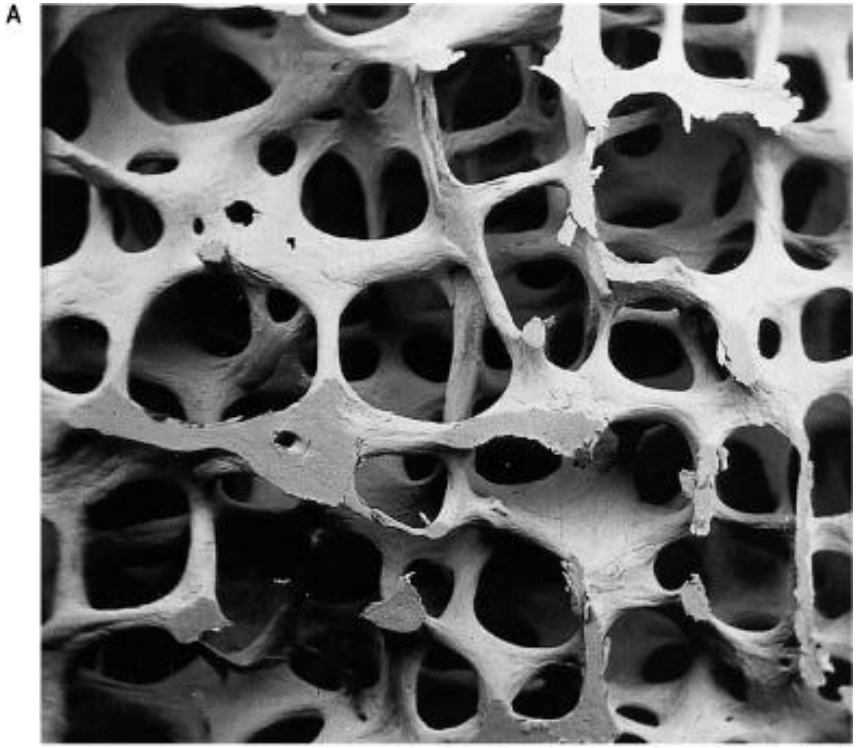


Compact Bone & Spongy (Cancellous Bone)

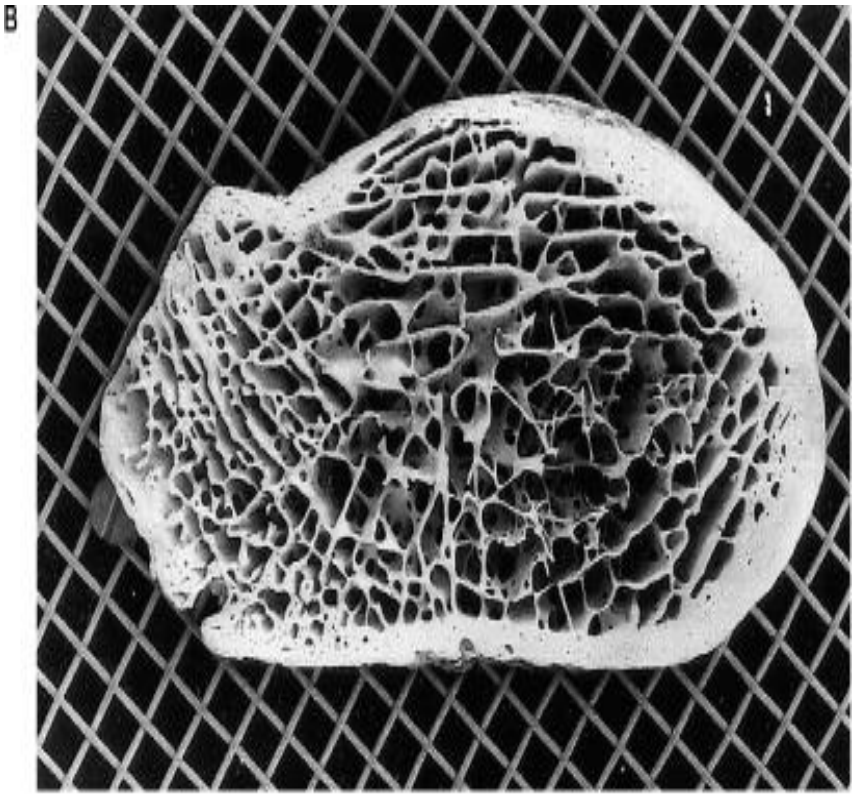


The spongy bone tissue

- Spongy (cancellous) bone is lighter and less dense than compact bone.
- Spongy bone consists of plates (trabeculae) and bars of bone adjacent to small, irregular cavities that contain red bone marrow.
- The canaliculi connect to the adjacent cavities, instead of a central haversian canal, to receive their blood supply.



The spongy bone tissue



- It may appear that the trabeculae are arranged in a haphazard manner, but they are organized to provide maximum strength similar to braces that are used to support a building. The trabeculae of spongy bone follow the lines of stress and can realign if the direction of stress changes.

The periosteum

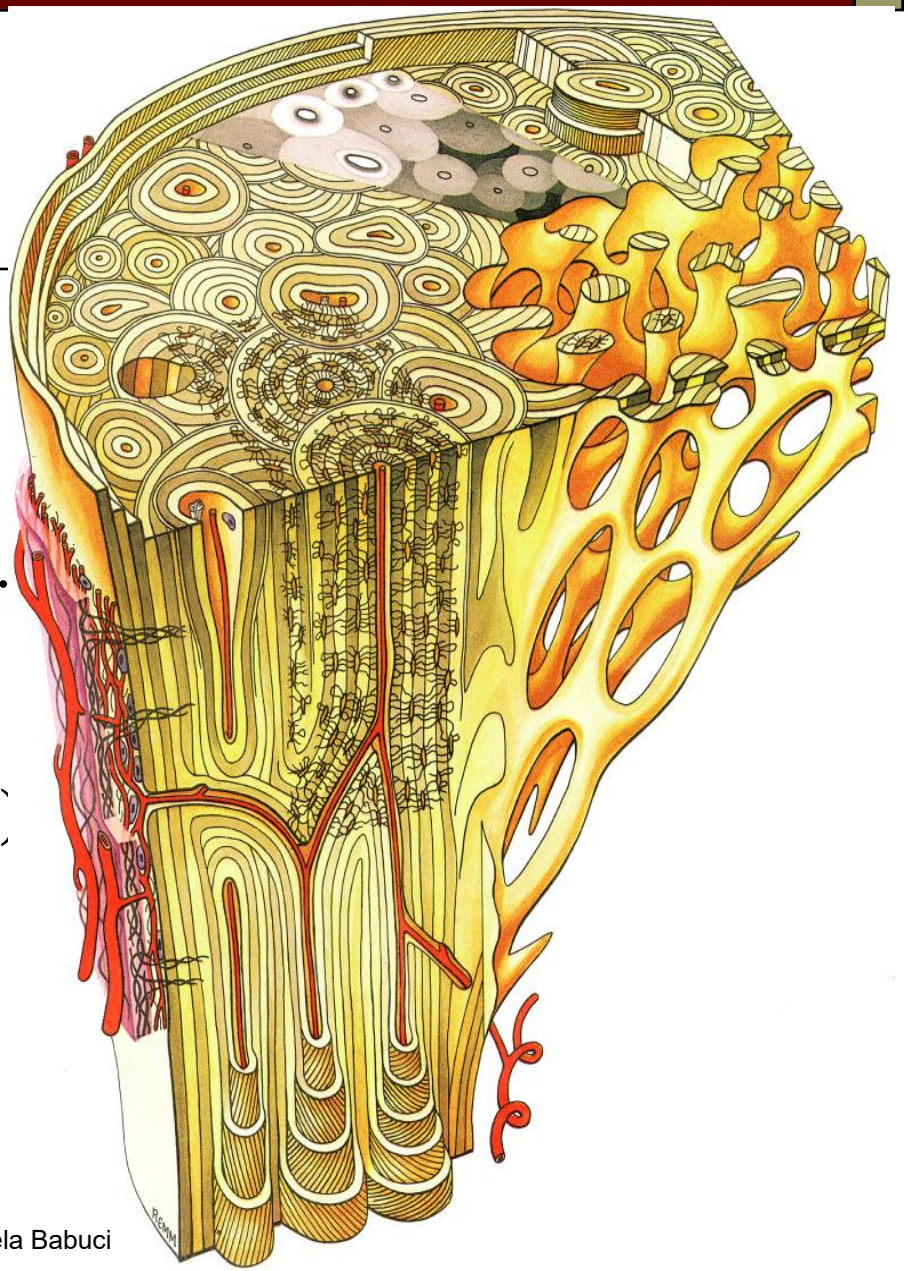
- Externally bone is covered by **periosteum** (except articular surfaces). The periosteum adheres to the surface of the bones.
- It consists of two layers closely united together:

a) The *outer layer* **fibrous layer**

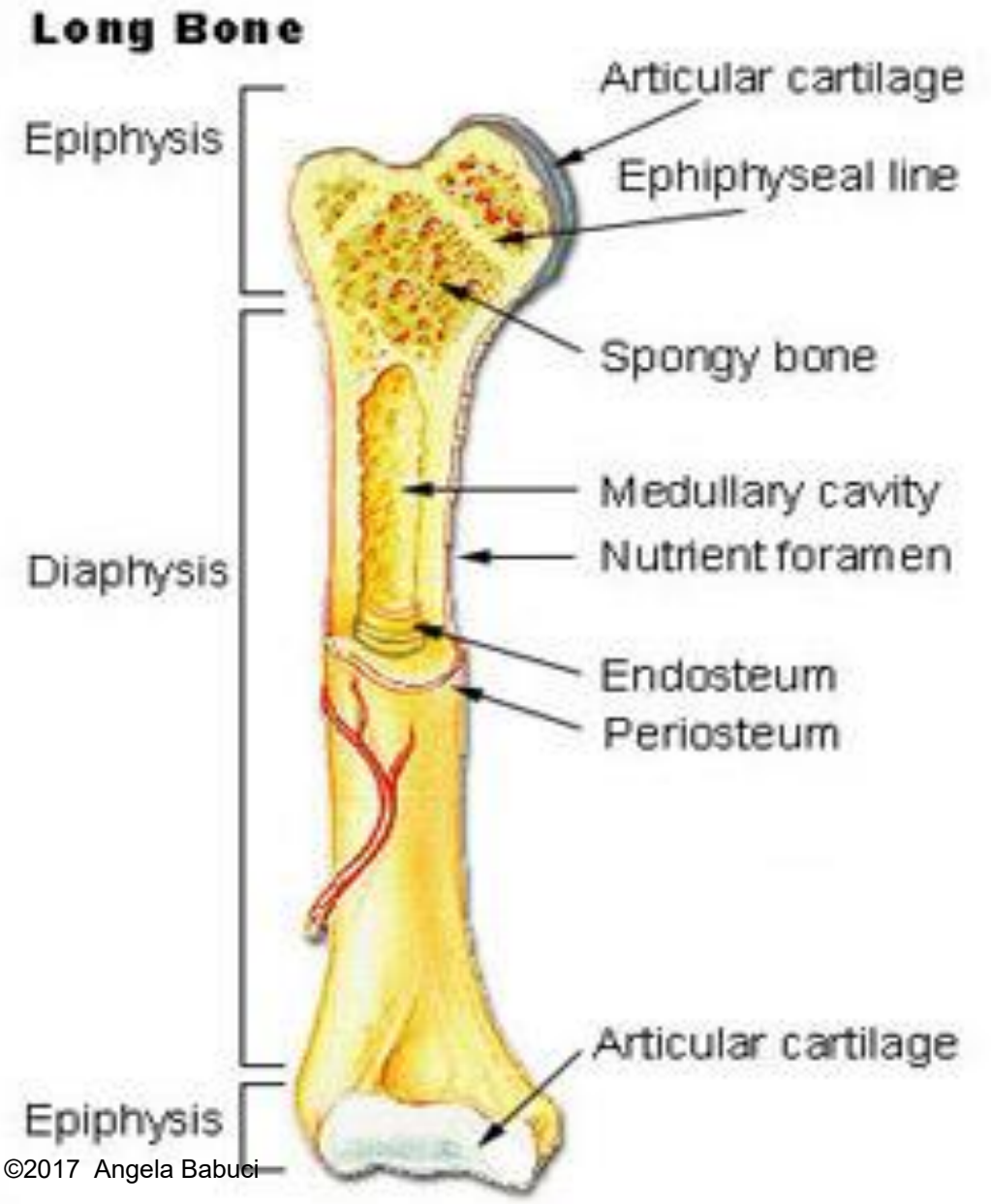
b) The *inner layer* or **bone-forming layer** (cambial)

Structure of the periosteum

- The periosteum is rich in vessels and nerves, and it contributes to the nutrition and growth of the bone in thickness.
- Nutrients are conveyed by blood vessels penetrating in great number the outer (cortical) layer of the bone from the periosteum through numerous vascular openings (*foramina nutricia*).



- The interior of each long tubular bone of the limbs presents a cylindrical cavity named **marrow cavity** and it is lined with the medullary membrane called **endosteum**.



CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF BONE

Bone matter consists of two types of chemical material:

- **Organic** – 1/3, mainly ***ossein*** (it provides elasticity to the bone).
- **Inorganic** – 2/3, mainly ***calcium phosphate*** in particular 51.04% (provides hardness to the bone).
- The bone contains vitamins A, D and C.
- A lack of salts or vitamin D in the period of growth reduces the bone hardness and causes deformities of bones (rickets) in children.
- Vitamin A deficiency leads to abnormal thickness of bones, and the bone cavities and canals become empty.

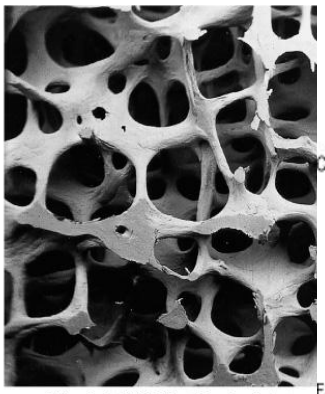
Functions of the skeleton

- **Biological functions**
- **Mechanical functions**

Biological functions of the skeleton

a) Haematopoiesis

b) Mineral storage



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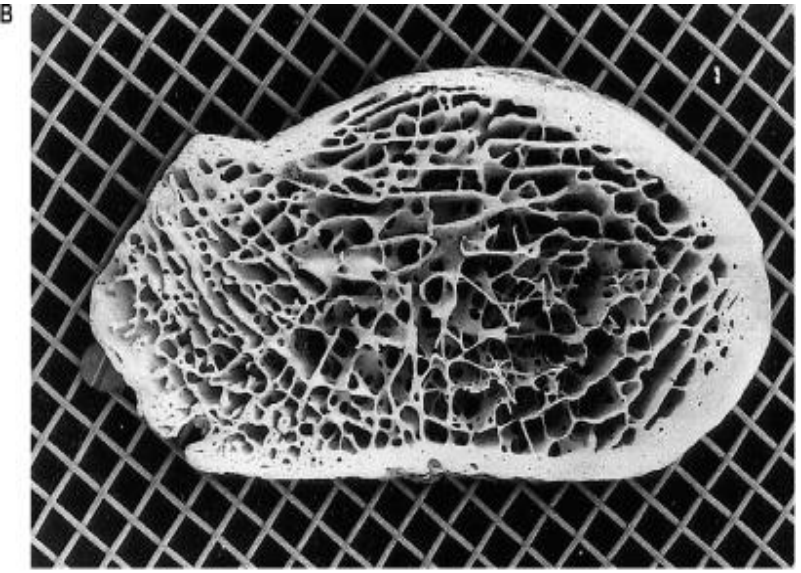

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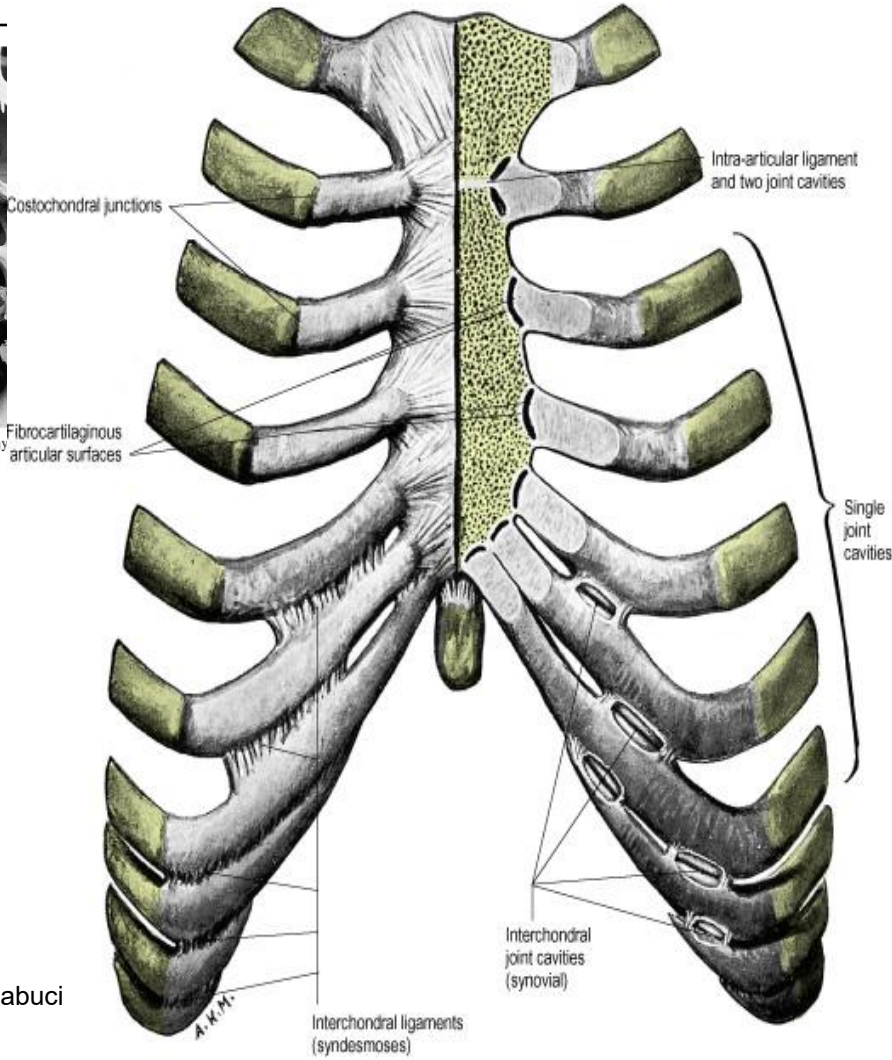

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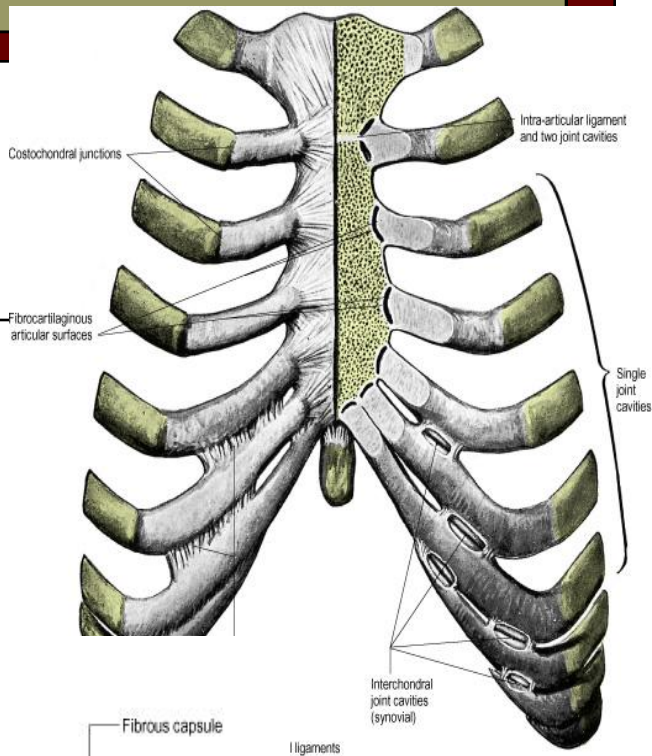
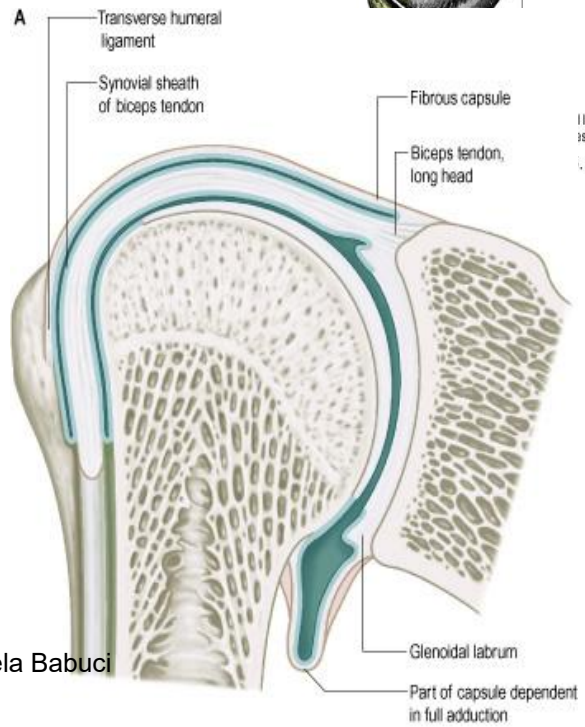
The bone marrow

- The bony compartments contain bony marrow, *medulla ossium.* Two types of bone marrow can be distinguished:
- **red bone marrow**
- **white bone marrow**

- The white, or **yellow marrow** fills up the **medullary cavities** of the shafts of the long tubular bones.

- The red marrow is located within the cancellous tissue and extends into the larger bony canals (Haversian canals) that contain blood vessels.





Haematopoiesis

- The **bone marrow** provides **haematopoiesis** function and biological protection of the organism.
- It takes part in nutrition, development and growth of the bone.
- The red marrow concerned with haematopoiesis and bone formation, has an active role in the healing of fractures.
- Red marrow predominates in infants and in children, with growth of child the red marrow is gradually replaced by yellow marrow.

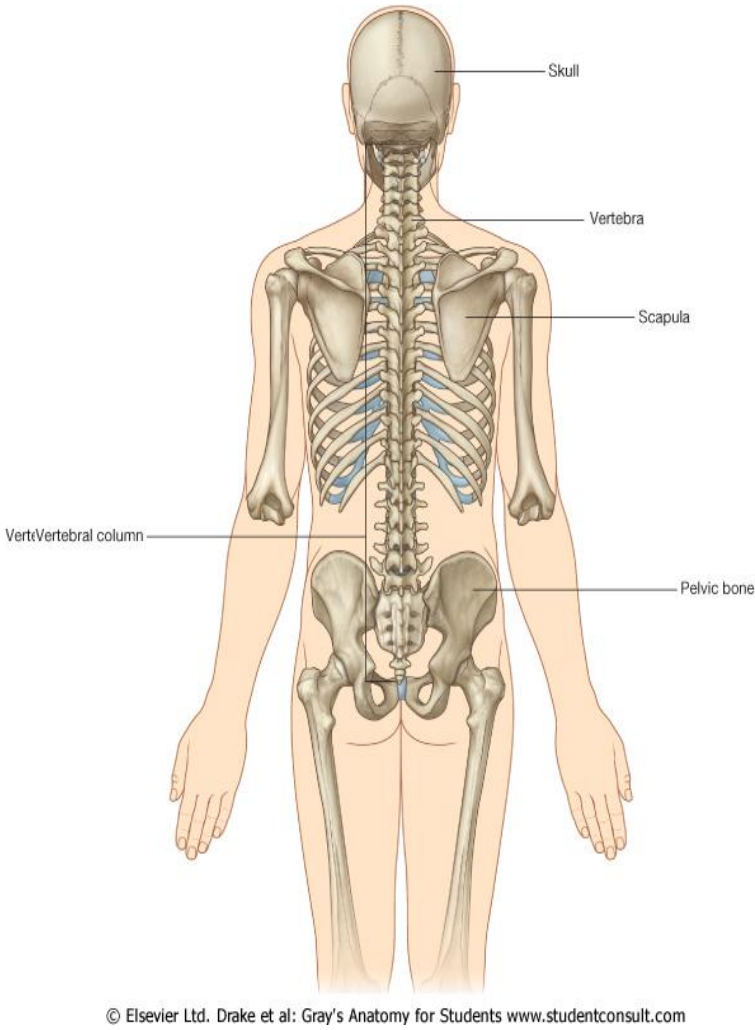
NB: The bones of the embryo and new-born contain only red marrow.

Haematopoiesis

- The red bone marrow of an adult produces white blood cells, red blood cells, and platelets.
- In an infant, the spleen and liver produce red blood cells, but as the bones mature, the bone marrow performs this task.
- It is estimated that an average of *1 million blood cells are produced every second* by the bone marrow to replace those that are worn out and destroyed by the liver.

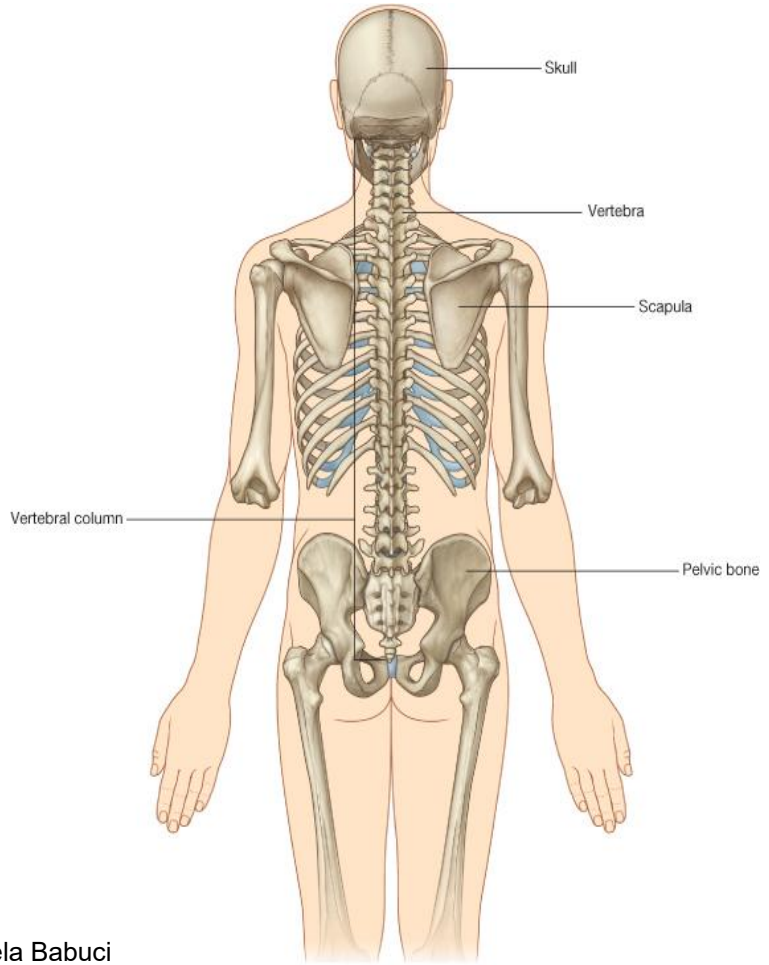
Mineral storage

- The inorganic matrix of bone is composed primarily of minerals **calcium** and **phosphorus**. These minerals give bone rigidity and account for approximately two-thirds of the weight of bone.
- About 95% of the calcium and 90% of the phosphorus, within the body, are stored in the bones and teeth.
- In addition to calcium and phosphorus, lesser amounts of magnesium and sodium salts are stored in bones.

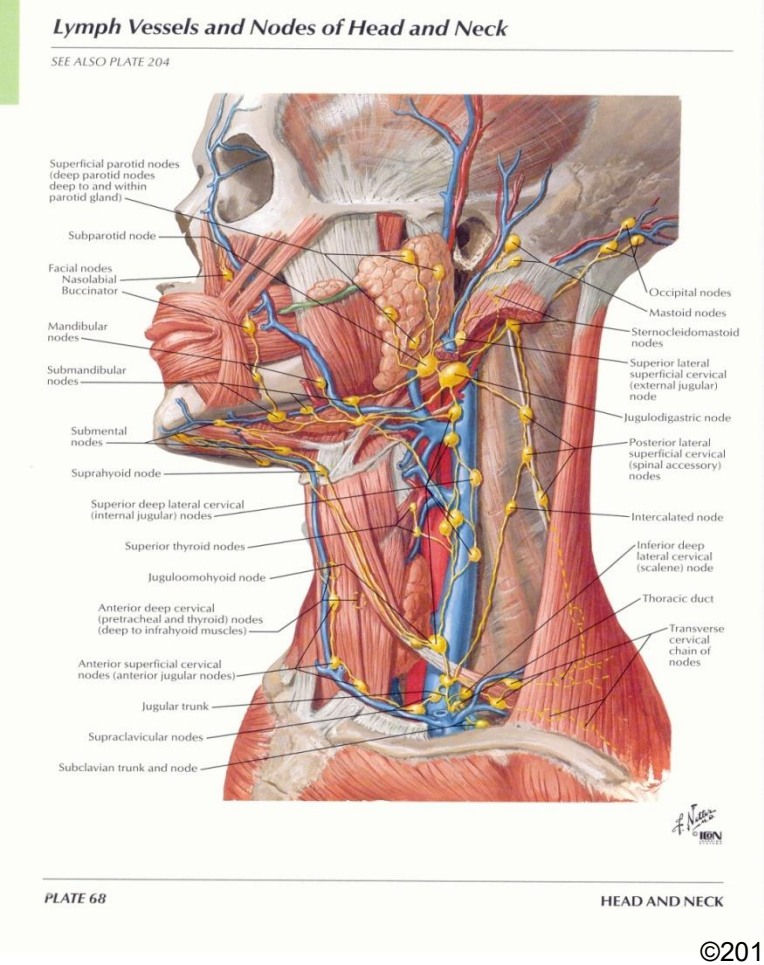


Mechanical functions of the skeleton

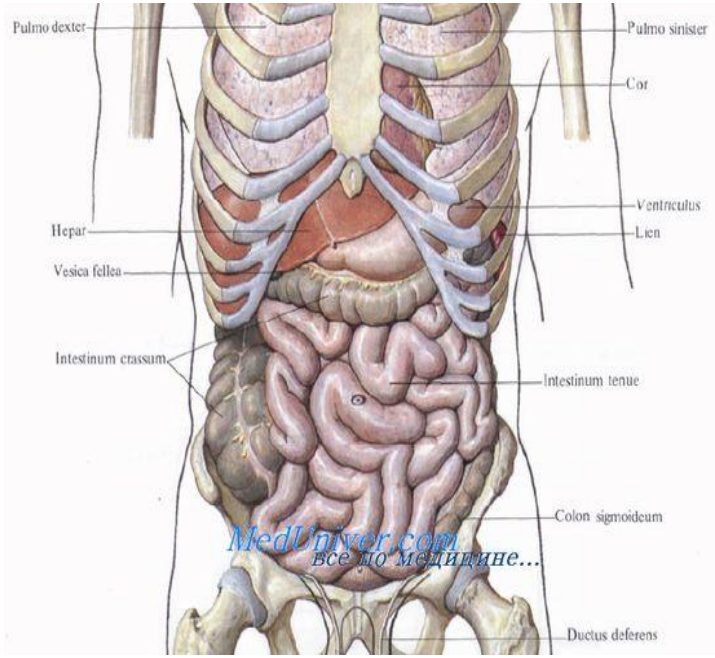
a) Support
b) Protection
c) Body movement



Support (weight bearing)



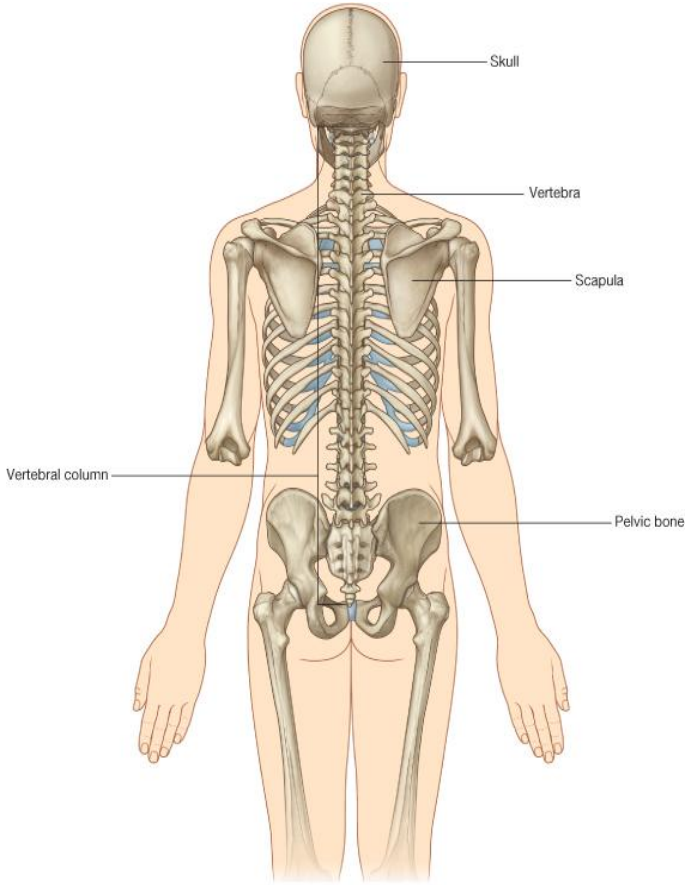
- The skeleton forms a rigid framework to which are attached the soft tissues and organs of the body.



Protection

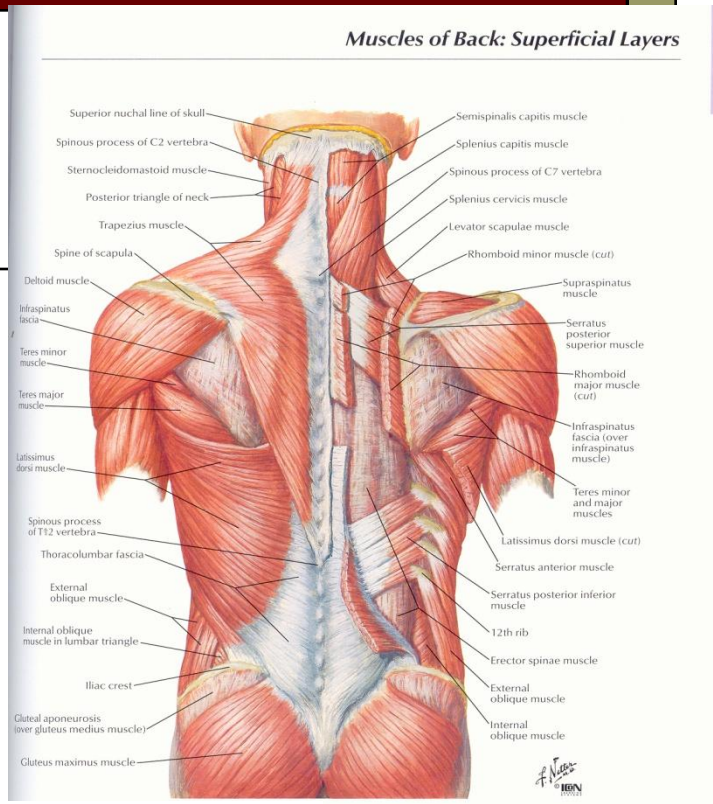
Protection is assured by the property of the bones to form body cavities which protects the vital important organs.

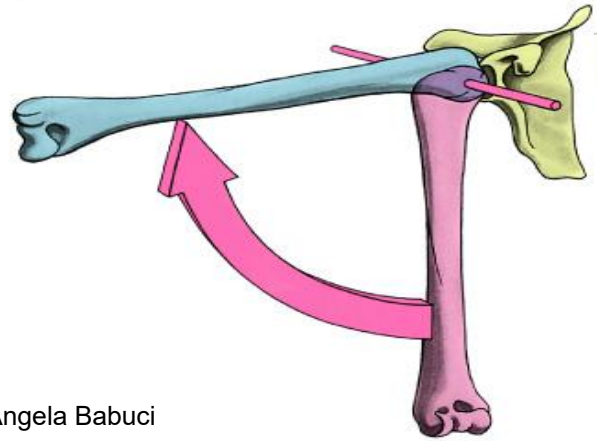
- The skull and vertebral column enclose the central nervous system.
- The thoracic cage protects the heart, lungs, great vessels, liver and spleen.
- The pelvic cavity supports and protects the pelvic organs.
- Even the site where blood cells are produced is protected within the central portion of certain bones.



Body movement

- Bones serve as anchoring attachments for most skeletal muscles. In this capacity, the bones act as levers, with the joints functioning as pivots, when muscles, which are regulated by the nervous system, contract to cause the movement.





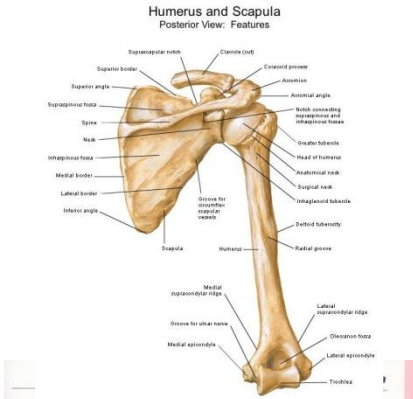
Classification of tubular bones

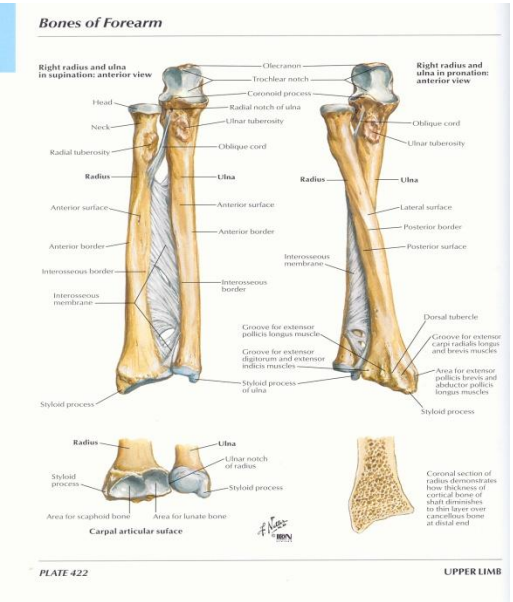
a) **Long tubular bones**

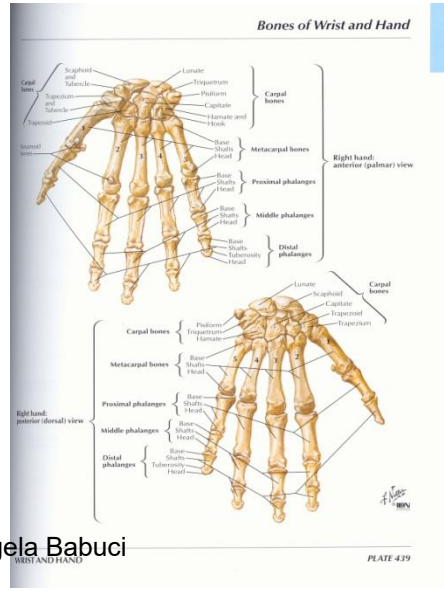
- Humerus,
- radius, ulna,
- femur,
- tibia, fibula

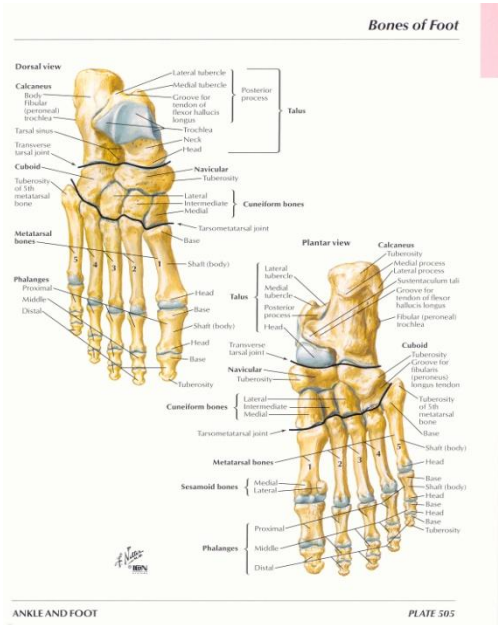
b) **Short tubular bones**

- Metacarpal,
- metatarsal bones and phalanges









Classification of spongy bones

a) **Long spongy bones**

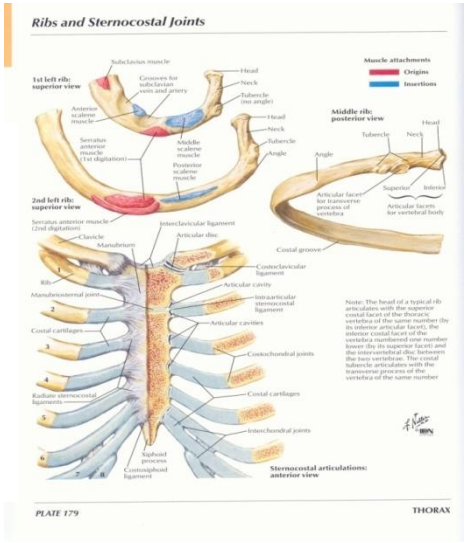
- sternum,
- ribs, etc

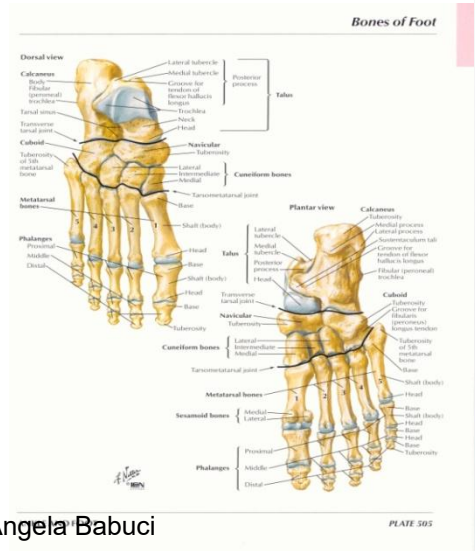
b) **Short spongy bones**

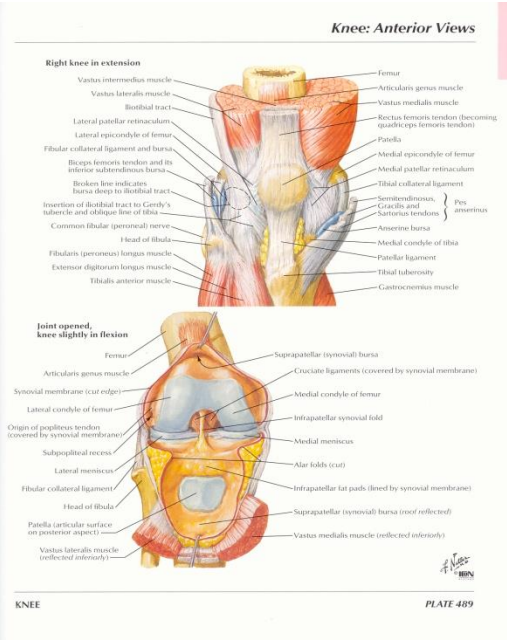
- carpal and tarsal bones

c) **Sesamoid bones**

- knee-cap
- pisiform bone, etc.







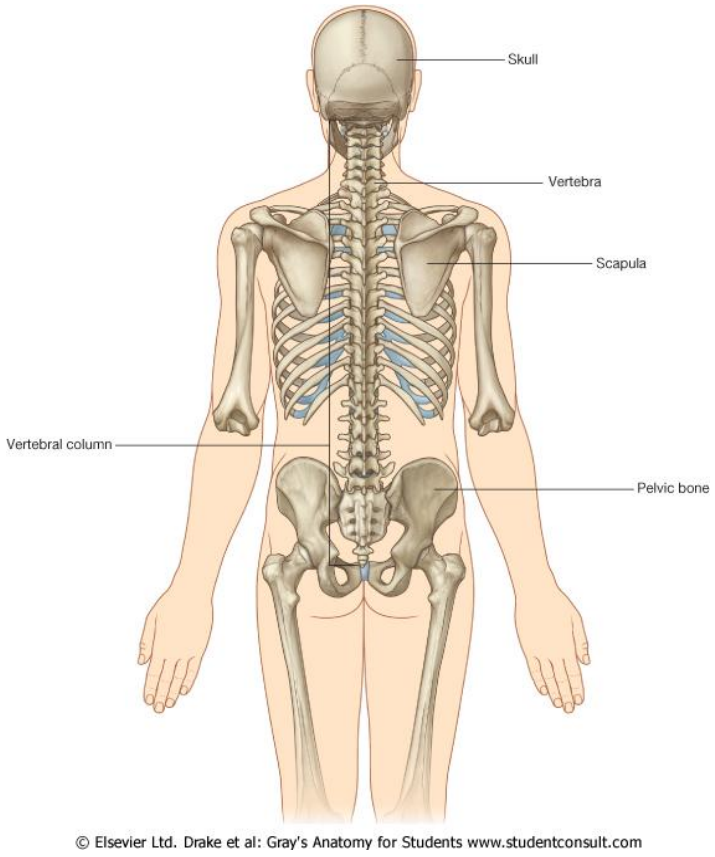
Classification of flat bones

Skull bones

- Bones of the vault of the skull

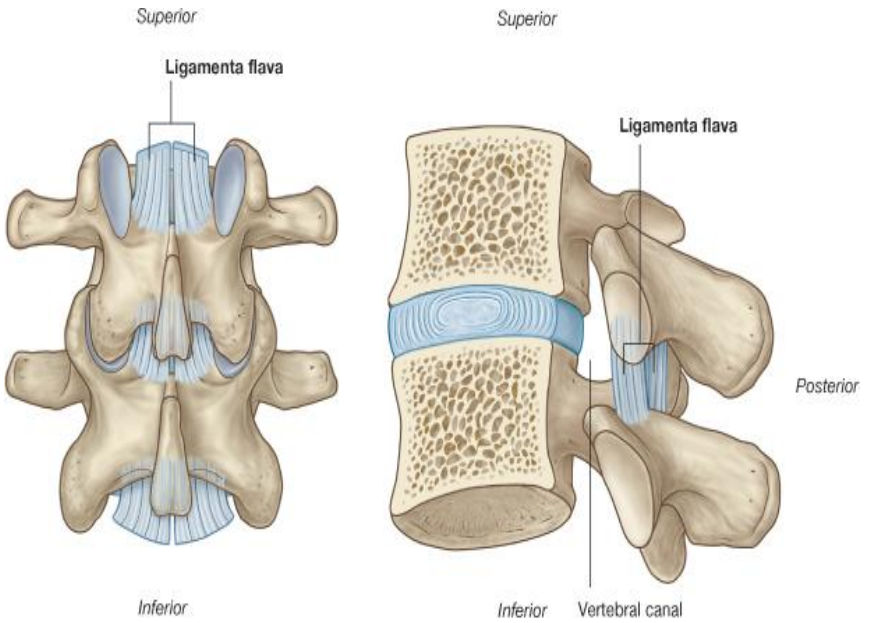
Girdle bones

- The scapula
- The hip bone, etc.



Classification of bones

The vertebrae are mixed, or irregular bones (their bodies are referred to spongy bones, but their arches and processes are referred to flat bones).



Classification of bones

- **Pneumatic bones**

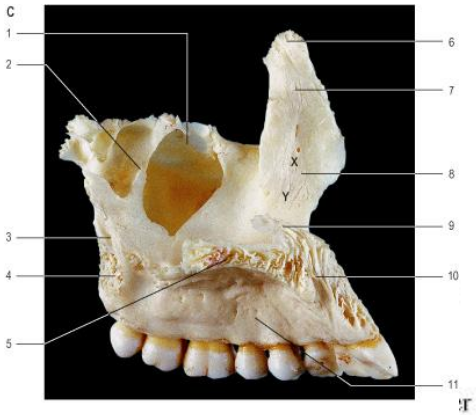
a) The ethmoid bone

b) The sphenoid bone

c) The frontal bone

d) The maxilla

e) The mastoid process of the temporal bone



1. Maxillary sinus.
2. Bony partition in sinus.
3. Greater palatine groove.
4. Tuberosity.
5. Palatine process.
6. Frontal process.
7. Ethmoidal crest.
8. Conchal crest.
9. Nasal crest.
10. Incisive canal emerging at incisive fossa.
11. Alveolar process and teeth.

X. Middle meatus.
Y. Inferior meatus.

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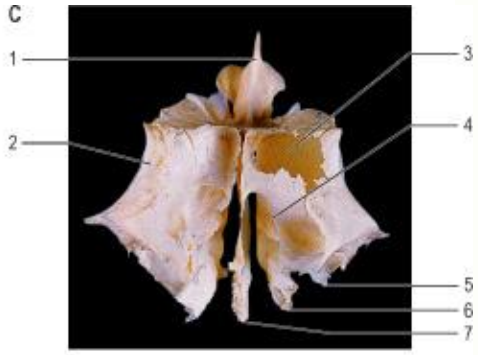

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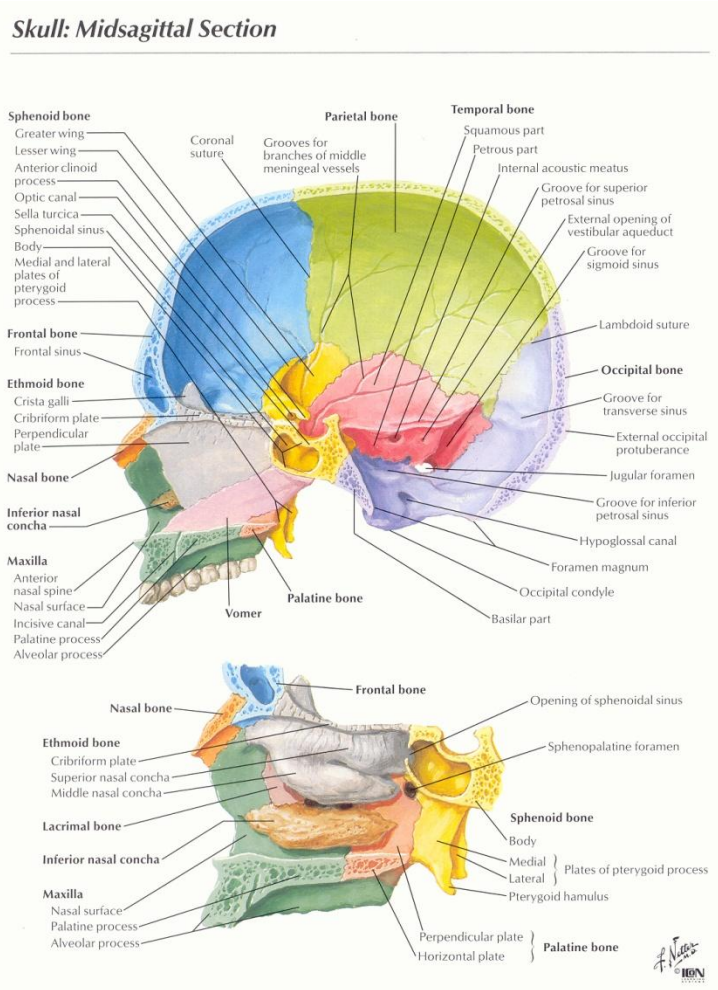


Classification of bones

- **Dependent on development:**

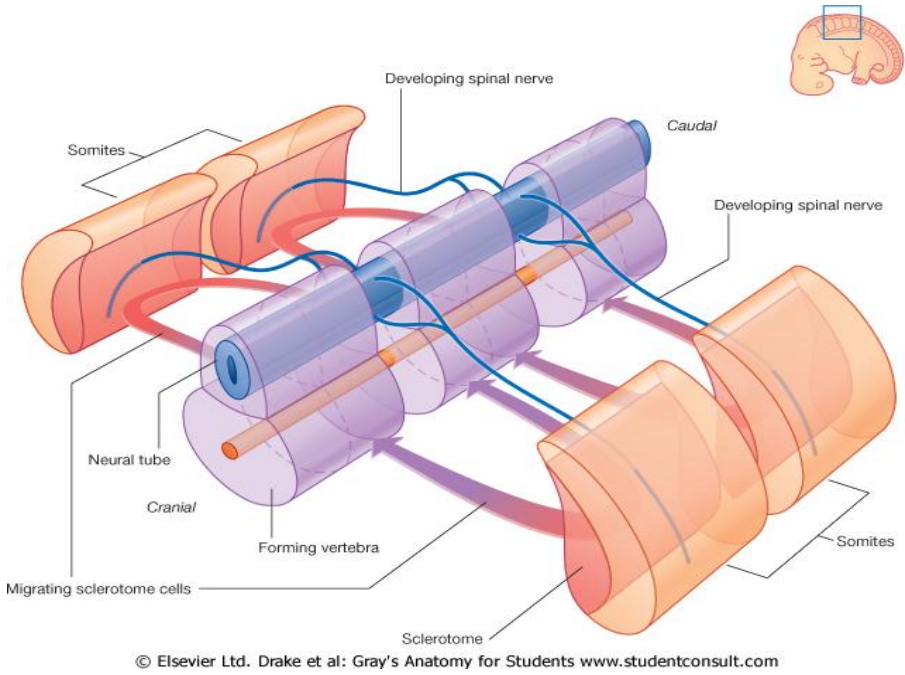
a) **Desmal** (tegumentary, or primary bones)

b) **Chondral** (secondary bone)

c) **Chondro-desmal** bone (the vertebrae, the bones of the base of the skull, the clavicle)

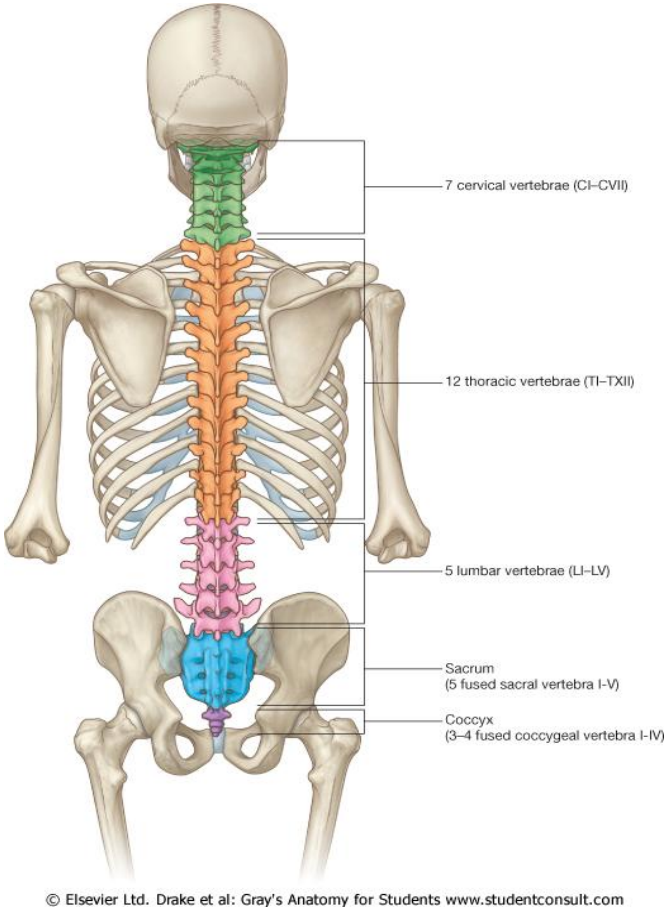
GENERAL NOTIONS CONCERNING DEVELOPMENT OF BONES AND THEIR ABNORMALITIES

- The **sclerotome** derives from the **paraxial mesoderm**.
- At the end of the 4th week the **sclerotome** give rise to the **mesenchyme,** or embryonic connective tissue.
- The mesenchymal cells migrate and differentiate in many ways.
- They may become **fibroblasts, chondroblasts,** or **osteoblasts** (bone-forming cells).



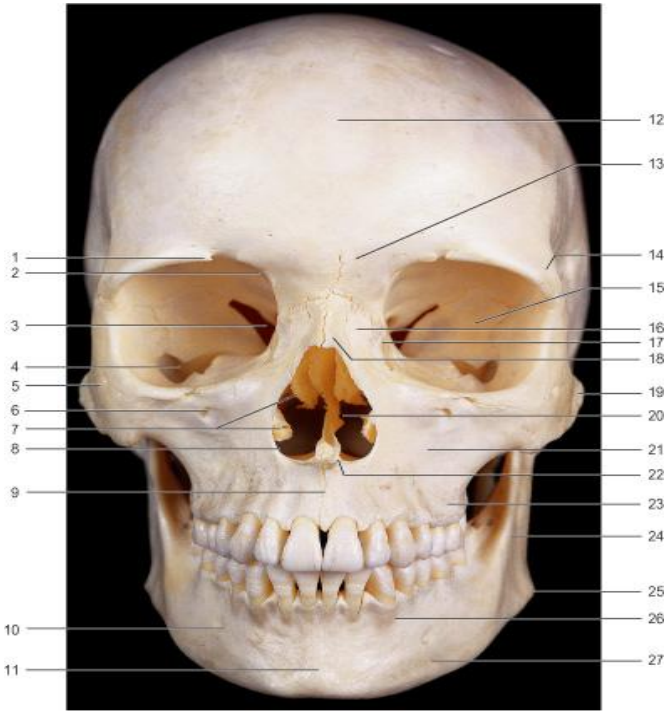
Derivatives of the lateral plate mesoderm

- **Lateral plate mesoderm** gives rise to the pelvic and shoulder girdles, and long bones of the upper and lower limbs.



Derivatives of the neural crests in the head region

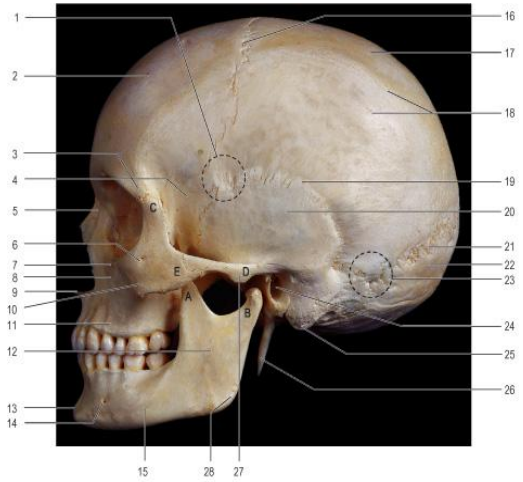
- **Neural crests in the head region** differentiate into mesenchyme and participate in formation of bones of the face and skull.



1. Supraorbital notch.
2. Frontal notch.
3. Superior orbital fissure.
4. Inferior orbital fissure.
5. Zygomaticofacial foramen.
6. Infraorbital foramen.
7. Nasal conchae.
8. Anterior nasal aperture.
9. Intermaxillary suture.
10. Mental foramen.
11. Mental protuberance.
12. Frontal bone.
13. Glabella.
14. Zygomatic process of frontal bone.
15. Greater wing of sphenoid bone.
16. Frontal process of maxilla.
17. Lacrimal bone.
18. Nasal bone.
19. Zygomatic bone.
20. Nasal septum.
21. Body of maxilla.
22. Anterior nasal spine.
23. Alveolus of maxilla (upper jaw).
24. Ramus of mandible.
25. Angle of mandible.
26. Alveolus of mandible (lower jaw).
27. Body of mandible.

Derivatives of the occipital somites and **somitomeres**

- **Occipital somites** and **somitomeres** contribute to formation of the cranial vault and base of the skull.



1. Pterion.
2. Frontal bone.
3. Zygomatic process of frontal bone.
4. Greater wing of sphenoid bone.
5. Nasal bone.
6. Zygomaticofacial foramen.
7. Infraorbital foramen.
8. Zygomatic process of maxilla.
9. Anterior nasal spine.
10. Zygomatic bone.
11. Maxilla.
12. Ramus of mandible.
13. Mental protuberance.
14. Mental foramen.
15. Body of mandible.
16. Coronal suture.
17. Parietal bone.
18. Superior and inferior temporal lines.
19. Squamosal suture.
20. Squamous part of temporal bone.
21. Lambdoid suture.
22. Occipital bone.
23. Asterion.
24. External acoustic meatus and tympanic plate.
25. Mastoid process of temporal bone.
26. Styloid process of temporal bone.
27. Zygomatic arch (zygomatic process of temporal bone).
28. Angle of mandible.
    - A. Coronoid process of mandible.
    - B. Condylar process of mandible in mandibular fossa.
    - C. Frontal process of zygomatic bone.
    - D. Articular eminence.
    - E. Temporal process of zygomatic bone.

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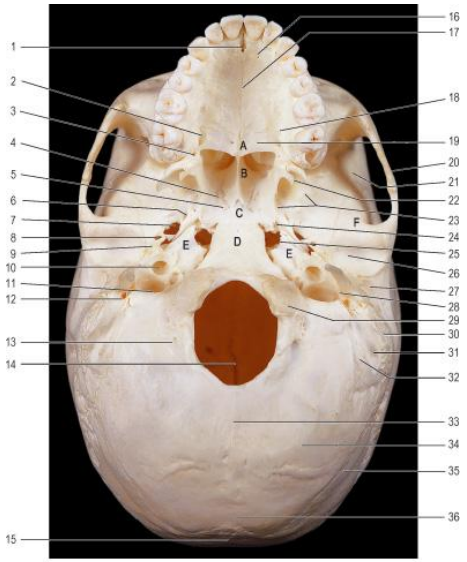

1. Incisive fossa.
2. Greater palatine foramen.
3. Lesser palatine foramen.
4. Palatovaginal canal.
5. Vomerovaginal canal.
6. Sphenoidal foramen.
7. Foramen ovale.
8. Foramen spinosum.
9. Spine of sphenoid.
10. Carotid canal.
11. Jugular foramen.
12. Stylomastoid foramen.
13. Condylar canal.
14. Foramen magnum.
15. External occipital protuberance.
16. Palatine process of maxilla.
17. Median palatine suture.
18. Transverse palatine suture.
19. Horizontal plate of palatine bone.
20. Zygomatic arch.
21. Greater wing of sphenoid.
22. Pterygoid hamulus.
23. Medial and lateral pterygoid plates of sphenoid bone.
24. Opening of pterygoid canal.
25. Foramen lacerum.
26. Mandibular fossa.
27. External acoustic meatus.
28. Styloid process of temporal bone.
29. Occipital condyle.
30. Mastoid process of temporal bone.
31. Mastoid notch.
32. Groove for occipital artery.
33. External occipital crest.
34. Inferior nuchal line.
35. Superior nuchal line.
36. Squamous part of occipital bone.
    - A. Posterior nasal spine.
    - B. Vomer contributing to nasal septum.
    - C. Body of sphenoid.
    - D. Basilar part of occipital bone.
    - E. Petrous processes of temporal bones.
    - F. Articular eminence.

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Stages of development of the human skeleton

- Bone formation, or **ossification**, begins at about the 4th week of embryonic development, but ossification centers cannot be readily observed until about the tenth week.
- **Three stages** of development of the human skeleton are encountered:
- **Connective-tissue** (membranous)
- **Cartilaginous**
- **Bony**

NB: Bones which do not go through the cartilaginous stage of development are named membrane, or **primary bones.**

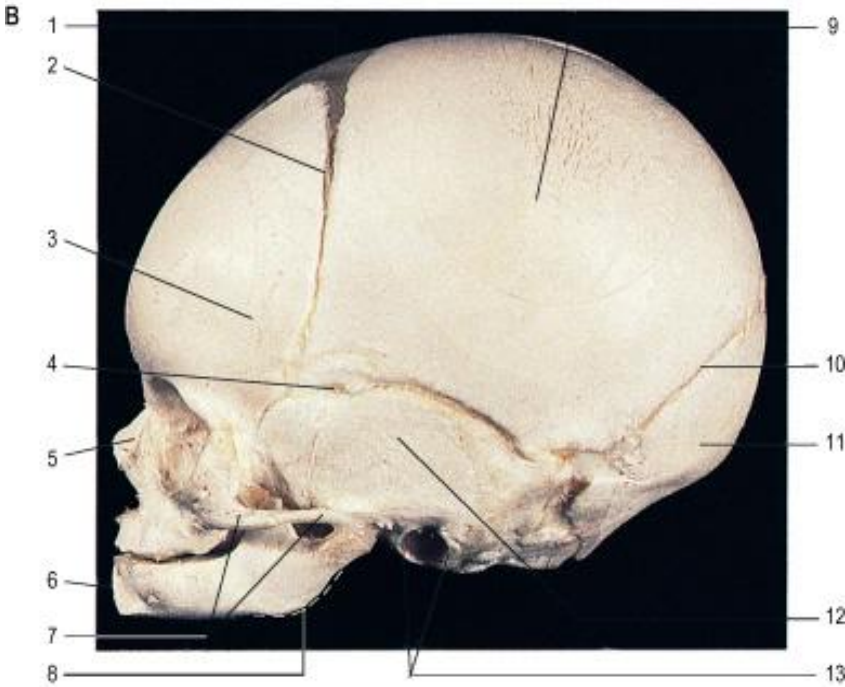
That bones which during their development undergo through all three stages of development are named **secondary bones.**

THE LOWS GOVERNING THE DEVELOPMENT OF THE BONES AND THEIR ABNORMALITIES

- According to the three developmental stages of the skeleton bones may develop from connective or cartilaginous tissue. Four types of ossification (osteogenesis) are distinguished:
- *Intramembranous*
- *Perichondral*
- *Periosteal*
- *Encondral*, or *endochondral*

Intramembranous or **endesmal ossification**

- **Intramembranous** or desmal ossification (Gk en in, into, desmos band) occurs in the connective tissue of the primary (membrane) bones.
- The future bones are first formed as connective tissue membranes, that are replaced with bony tissue. Bones formed in this manner are called **intramembranous** bones. They include certain flat bones of the skull and some of the irregular bones.
- The osteoblasts migrate to the membranes and deposit bony matrix around themselves.
- As a result of osteoblastic activity appear *points* or *nuclei of ossification*.



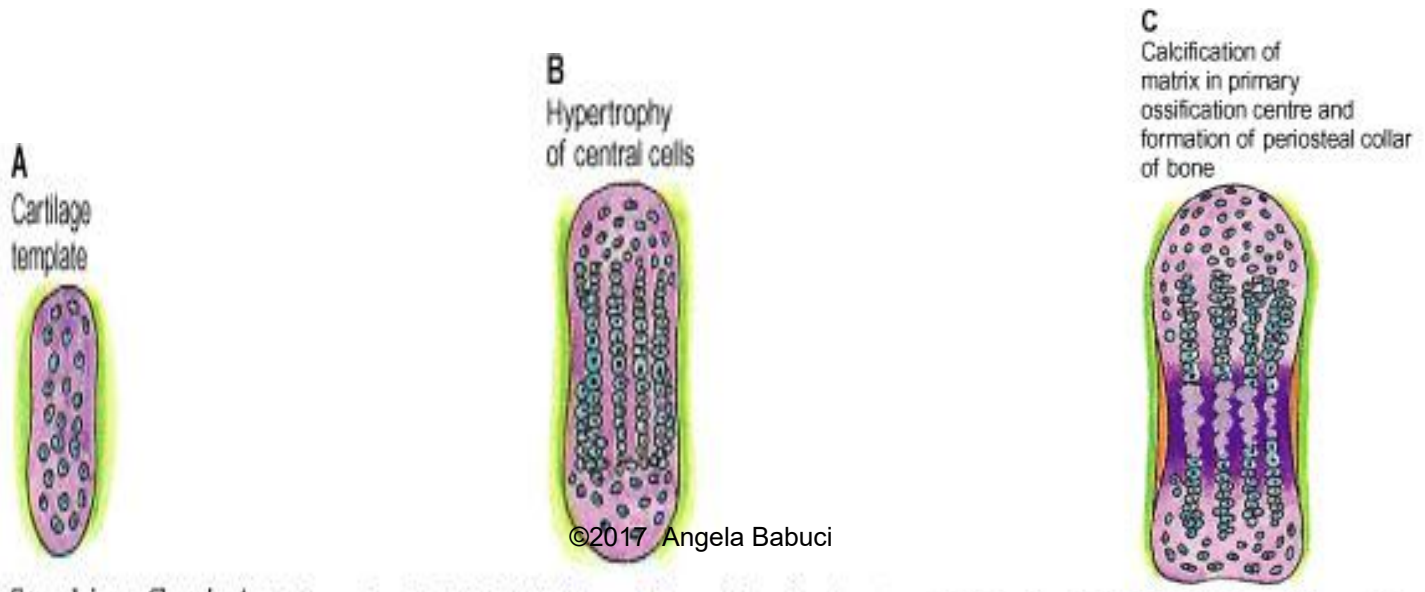
1. Anterior fontanelle.
2. Coronal suture.
3. Left frontal bone.
4. Future pterion: closing sphenoidal fontanelle.
5. Nasal bone.
6. Symphysis menti.
7. Zygomatic arch.
8. Gonial contour.
9. Parietal tuber.
10. Lambdoid suture.
11. Occipital squama.
12. Temporal squama.
13. Tympanic ring.

- **Perichondral ossification** (Gk peri around, chondros cartilage) takes place on the outer surface of the cartilaginous bone germs with the participation of the perichondrium.
- The perichondral osteoblasts covering the cartilage replace the cartilaginous tissue gradually and form a compact bony substance.

- With the conversion of the cartilaginous model to a bone model, the perichondrium becomes the periosteum, and further deposition of bone tissue is accomplished by the periosteum; this is **periosteal ossification.**
- The perichondral and periosteal types of ossification are therefore connected and one follows the other chronologically.

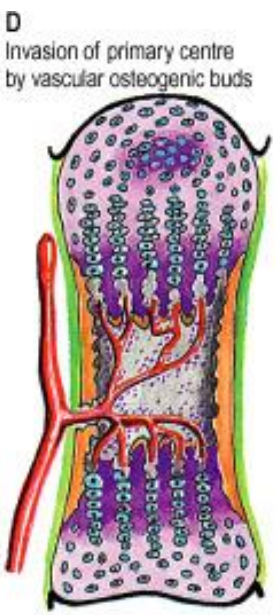
Endochondral ossification

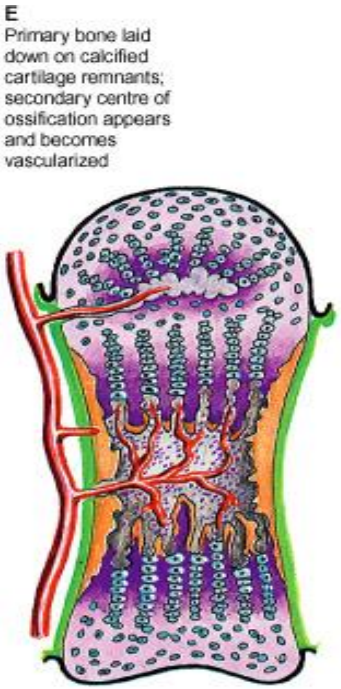
Endochondral or **enchondral ossification** involves the replacement of hyaline cartilage with bony tissue. Most of the bones of the skeleton are formed in this manner. These bones are called endochondral bones. In this process, the future bones are first formed as hyaline cartilage models.



Endochondral ossification

During the third month after conception, the **perichondrium** that surrounds the hyaline cartilage "models" becomes infiltrated with blood vessels and osteoblasts and changes into a periosteum. The osteoblasts form a collar of compact bone around the diaphysis. At the same time, the cartilage in the center of the diaphysis begins to disintegrate.

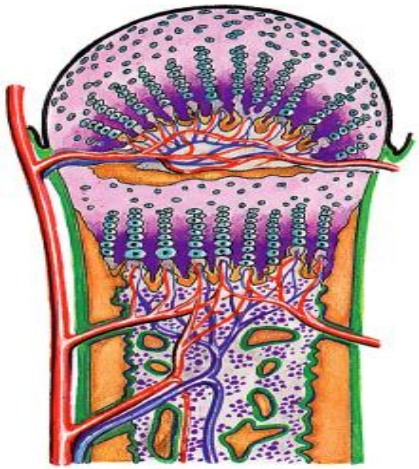




Endochondral ossification

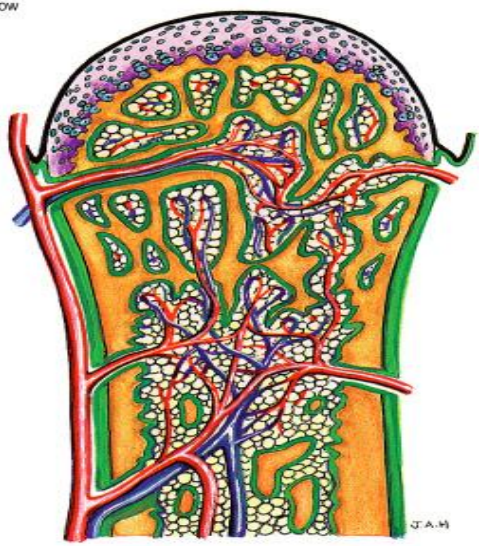
The osteoblasts penetrate the disintegrating cartilage and replace it with spongy bone. This forms a primary ossification center. Ossification continues from this center toward the ends of the bones. After spongy bone is formed in the diaphysis, osteoclasts break down the newly formed bone to open up the medullary cavity.

F
Continued growth of cartilage of epiphyseal plate and epiphysis; proliferation of red bone marrow



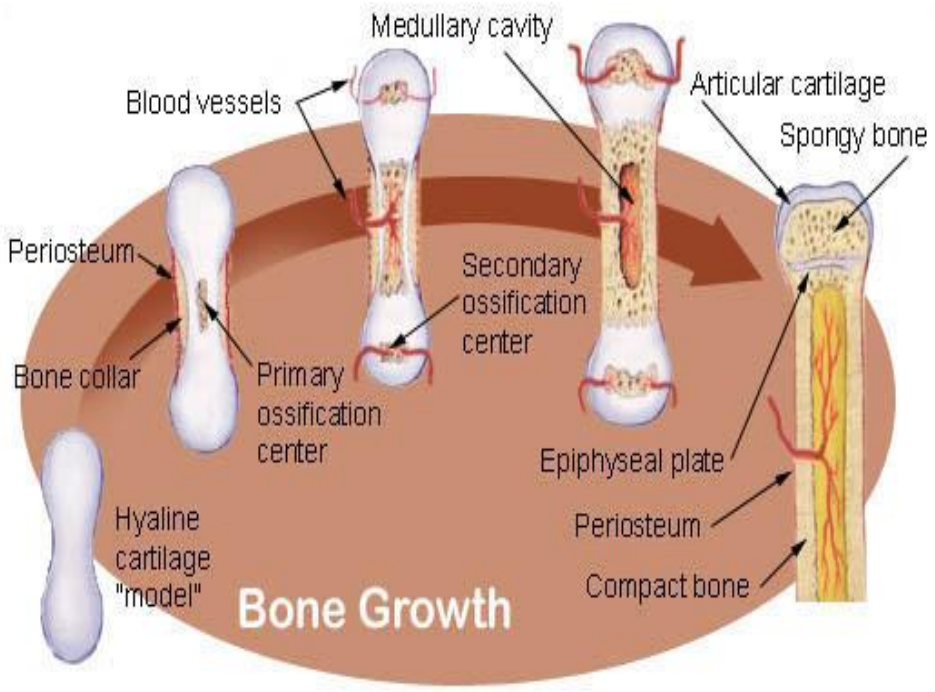
	Zone
Cell division: interstitial and appositional growth Cell columns (palisades)	**Growth**
Cell hypertrophy Calcification of matrix	**Transformation**
Chondrolysis Vascularization Osteogenesis	**Ossification**
Erosion and deposition	**Remodelling**

G
Cessation of cartilage growth and complete ossification of epiphyseal plate (fusion of the epiphysis). Replacement of red bone marrow with yellow, adipose marrow in most adult long bones



Primary centers of ossification

- In the second month of the intrauterine life, the **primary points** of ossification appear first, in the shafts, or *diaphyses* of tubular bones, and in the *metaphyses*.
- They ossify by **perichondral** and **enchondral osteogenesis.**



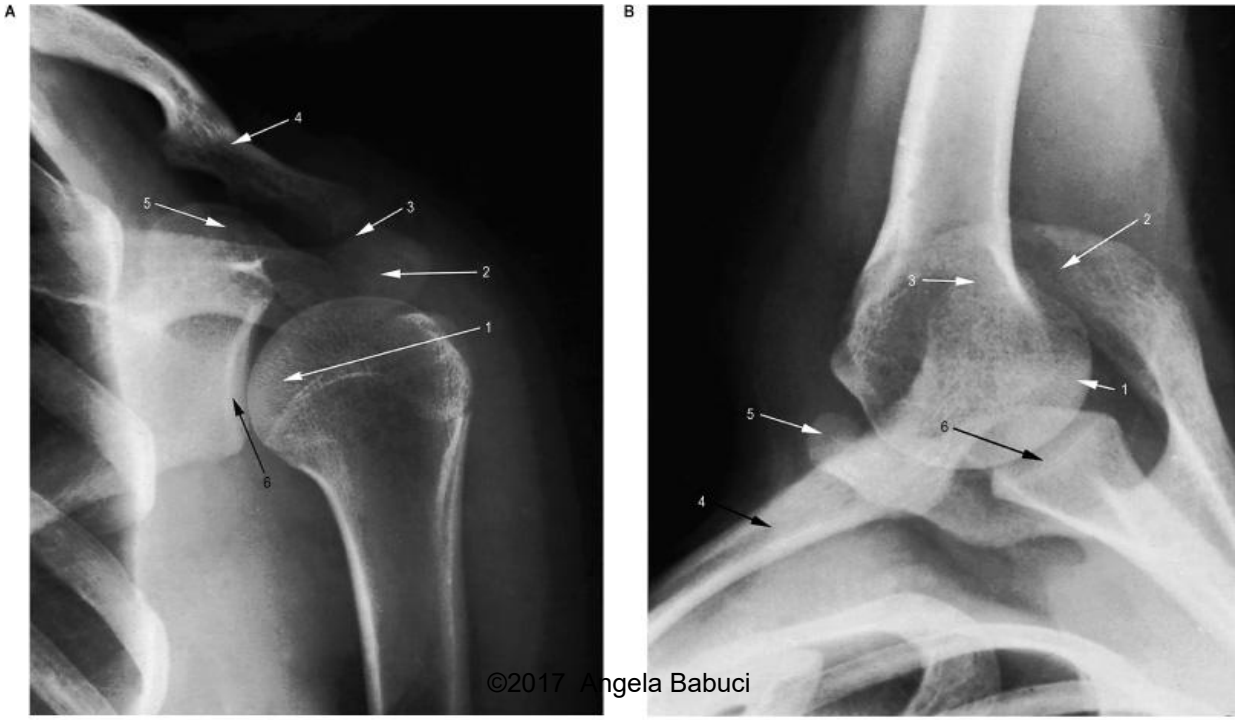
Secondary and accessory points of ossification

- **The secondary points** of ossification appear shortly before birth or during the first years after birth and they develop by **encondral osteogenesis.**

- The **accessory points** of ossification appear in children, adolescents, and even adults in the appophyses of bones (e.g. tubercles, trochanters, the accessory processes of the lumbar vertebrae).

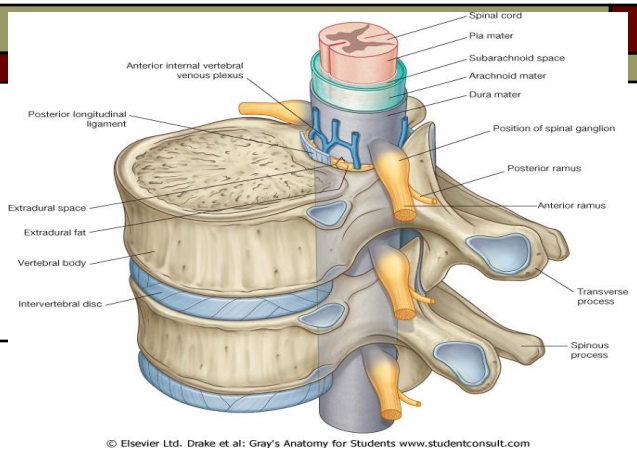
Growth of bone

When secondary ossification is complete, the hyaline cartilage is totally replaced by bone except in two areas. A region of hyaline cartilage remains over the surface of the epiphysis as the articular cartilage and another area of cartilage remains at the level of the **metaphysis.**



1. Head of humerus. **2.** Acromion. **3.** Acromioclavicular joint. **4.** Clavicle. **5.** Coracoid process. **6.** Glenoid (osseous, subchondral) articular surface.

DEVELOPMENT OF THE VERTEBRAE



- The mesenchyme (sclerotome) gives rise to the skeleton around the notochord. The vertebral column in its primitive form is made up of upper and lower cartilaginous arches, which are arranged in a metameric fashion on the ventral and dorsal aspects of the notochord.
- The bodies of the vertebrae grow around the notochord and compress it.
- As a result the notochord is replaced by the vertebral bodies and remains only between the vertebrae as pulpy nucleus (*nucleus pulposus*) in the center of the intervertebral discs.
- The **upper neural arches** give rise to the **spinous process**, to the **paired articular** and **transverse processes.**
- The **lower ventral arches** give rise to the **ribs**.
- After going through the cartilaginous stage, the vertebral column becomes bony, except the intervertebral discs connecting them.

- **Abnormality** is a deviation from the norm and it can be of different degrees.

- Abnormalities of bones are the result of improper development of bony system.

- Different abnormalities of bones are distinguished: e.g. subdevelopment of bone, absence of bone, abnormal location of bone, bones can vary in number (to be more or less that usually), additional bones can form etc.

VARIANTS AND DEVELOPMENTAL ABNORMALITIES OF THE VERTEBRAE

- **Assimilation of the atlas** by the cranium, when the first cervical vertebra fusses with the occipital bone.
- **Lumbalization** when the first sacral vertebra does not fuse with the sacrum and there are 6 lumbar vertebrae instead of five; or when the last thoracic vertebra is not joined with a rib and transforms into a lumbar vertebra.
- **Sacralization** when there are 6-7 sacral vertebrae, because the last lumbar vertebrae fuse with the sacral bone and in this case the number of the lumbar vertebrae decreases.
- **Spina bifida** – results from a failure of the vertebral arches to fuse. This abnormality is more commonly for the lumbar and sacral vertebrae.
- **Intervertebral disc herniation** involves the prolapse of the nucleus pulposus through the defective annulus fibrosus into the vertebral canal.
- **Spondylolistesis** occurs when the pedicles of the vertebral arches fail to fuse with the vertebral body. Congenital spondylolistesis usually occurs at the level of L5-S1vertebrae.
- **Asomia** is the absence of the vertebral body.
- **Hemisomia** is the absence of a half of the vertebral body.

DEVELOPMENT OF THE STERNUM AND RIBS

- The **ribs** develop from costal processes that form at all vertebral levels, but only in the thoracic region the costal processes grow into ribs.

- The **sternum** develops from two sternal bars which form in the ventral body wall independent of the ribs and clavicle. The sternal bars fuse with each other in a craniocaudal direction to form the manubrium, the body and the xiphoid process by week of 8^{th}.

VARIANTS AND DEVELOPMENTAL ABNORMALITIES OF THE STERNUM AND RIBS

- The **ribs** can vary in number to be more or less than normal number (12 pairs).
- **Cervical ribs** on one or on both sides, when the VIIth cervical vertebra joins with a rib.
- In case of presence of the cervical ribs, then the VIIth cervical vertebra has appearances of a thoracic vertebra.
- **Lumbar ribs** in case the Ist lumbar vertebrae joins with a rib.
- In rare cases the XIIth rib can be absent from one or from both sides, and more rarely are cases when the XIth rib is absent.
- If there are XIIIth pairs of ribs, then the number of thoracic vertebrae as well increases.
- The anterior extremities of the ribs can fuse to each other, or on the contrary to bifurcate.

Abnormalities of the sternum

- **Sternal cleft** occurs when the sternal bars do not fuse completely and the body of the sternum is split into two halves, it is a rare abnormality.

- Sometimes in the body of the sternum is present an **orifice**.

- In the **xiphoid process** can be present an **orifice**, or it can **be bifurcated**.