Bone Ossification

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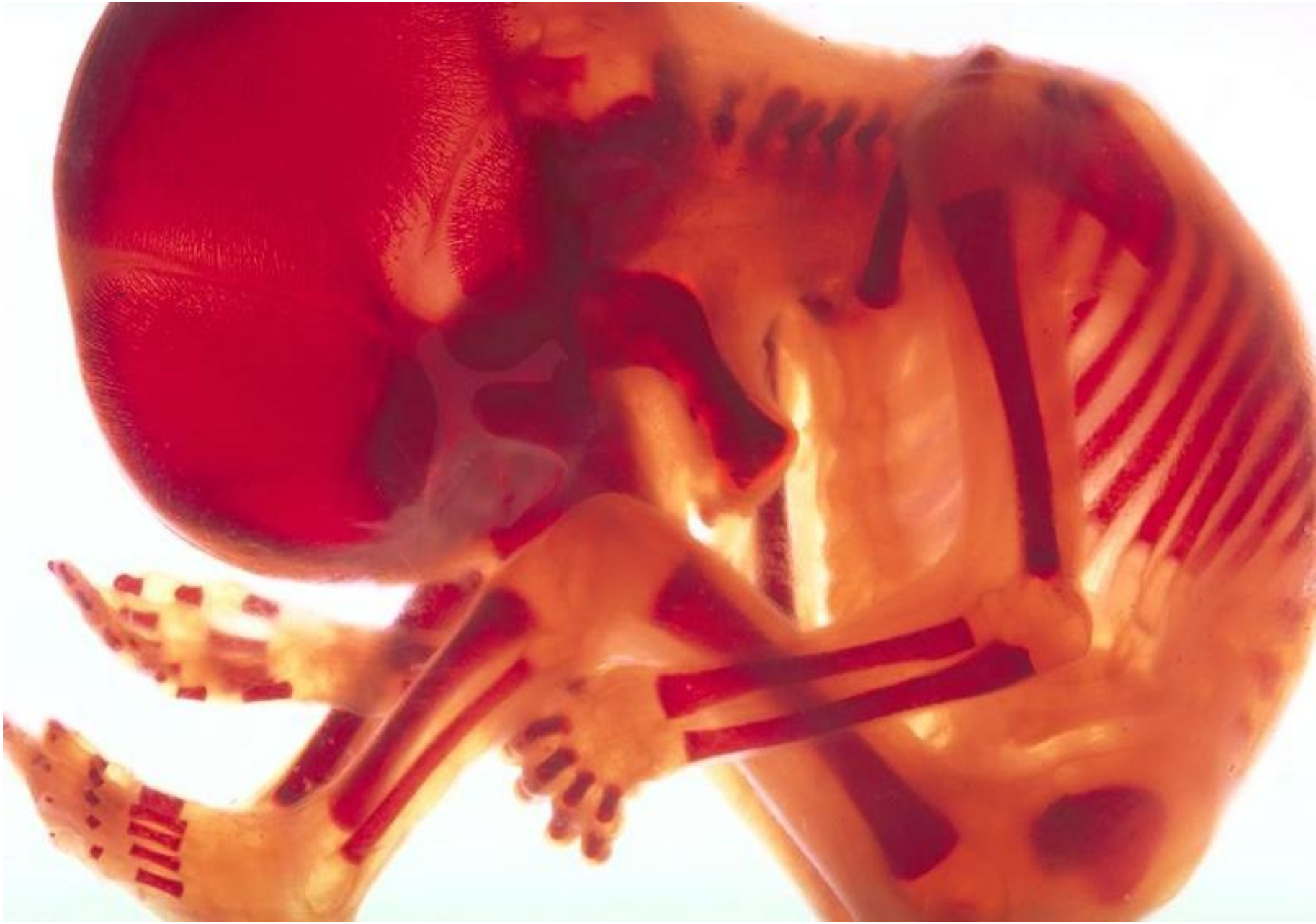


Pre-natal Ossification

Osteogenesis= Ossification=Bone tissue formation

Embryonic skeleton:

- fashioned from fibrous membranes or cartilage to accommodate mitosis.
- 2 types of pre-natal ossification (bone formation)

1. Intramembranous
   - Bone develops from fibrous membrane
   - Forms bones of skull and clavicle (most flat bones)
   - Contributes to the growth of short bones and thickening of long bones
   - Begins at 8 week of development

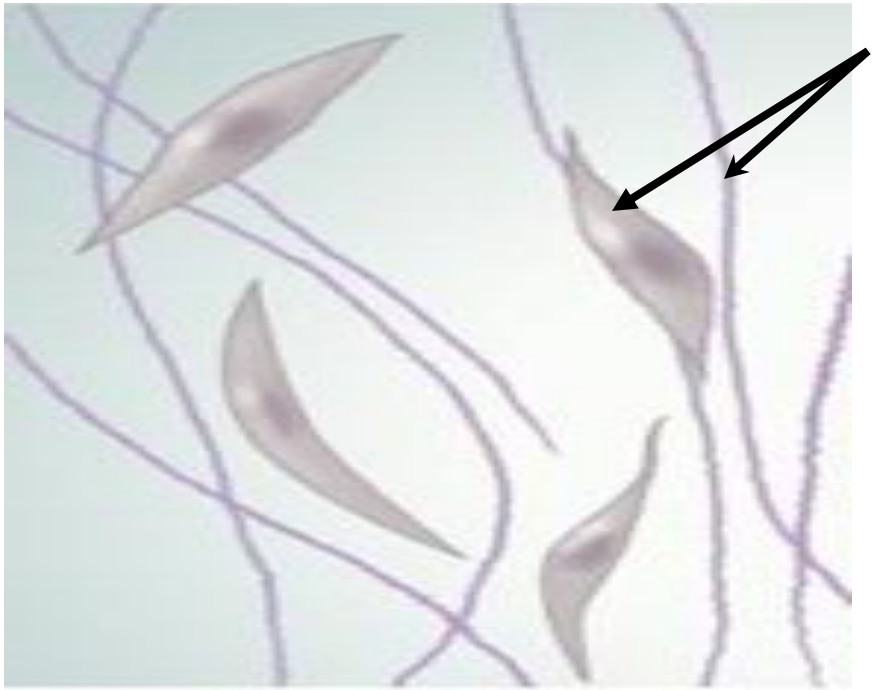
2. Endochondral
   - Bone develops from hyaline cartilage
   - Responsible for the formation of short and long bones
   - Begins 2nd month of development

Intramembranous Ossification

(prenatal)

Intramembranous Ossification

(prenatal)

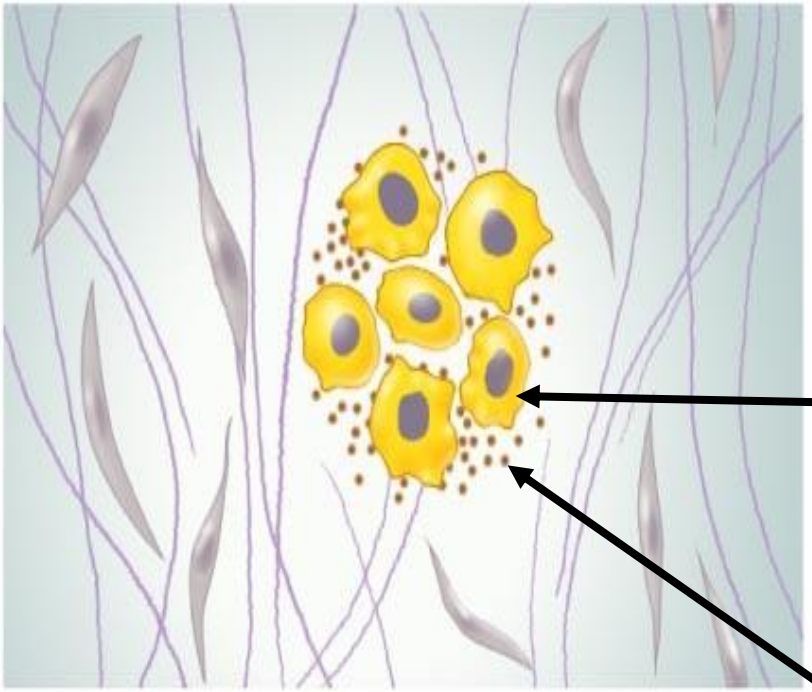


Mesenchymal cells create fibrous CT framework for ossification

Fibrous connective tissue membrane

Intramembranous Ossification

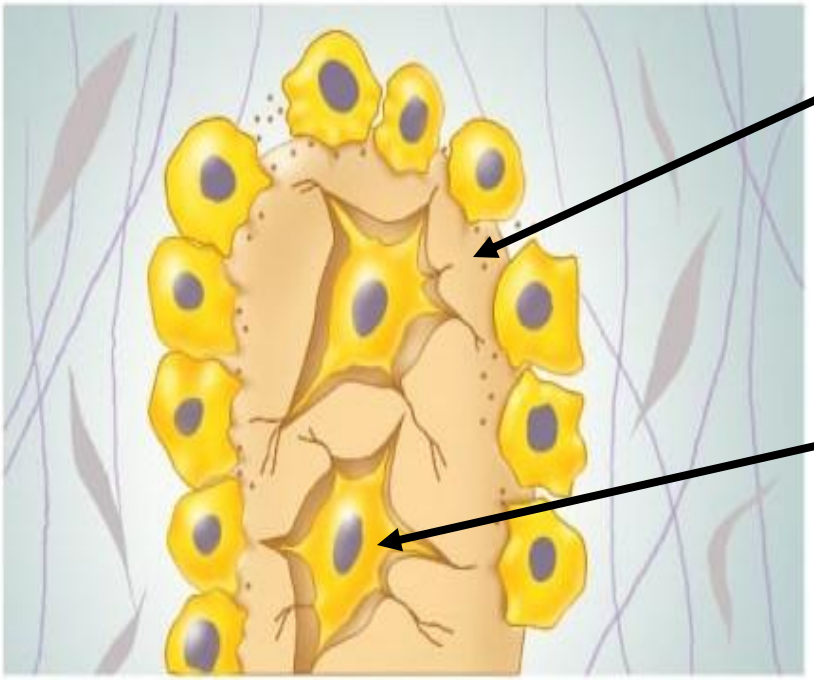
(prenatal)



Some mesenchymal cells differentiate into osteoblasts in an ossification center

Osteoblasts secrete bone matrix, osteoid

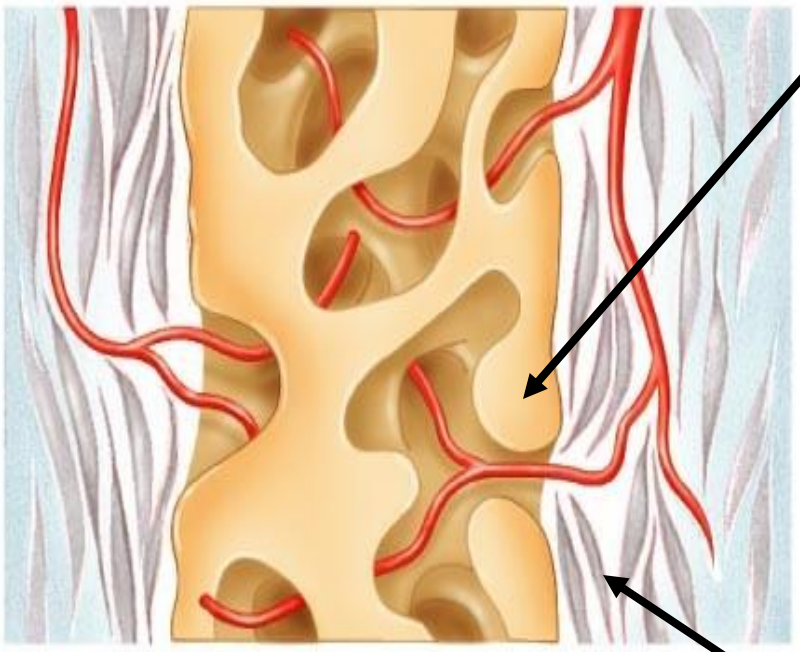
Intramembranous Ossification (prenatal)



Mineralization and calcification of osteoid

Trapped osteoblasts become osteocytes

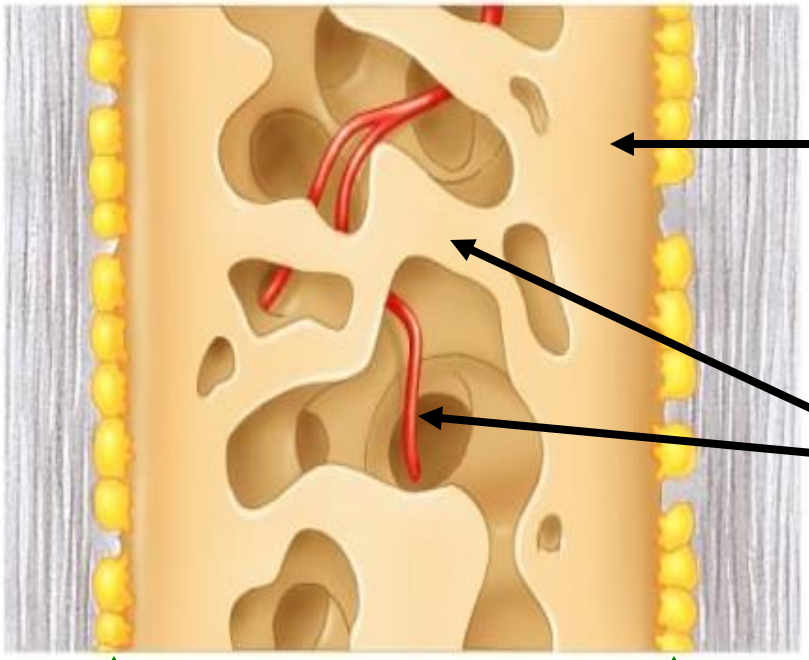
Intramembranous Ossification (prenatal)



Several points of ossification occur and fuse forming spongy bone around embryonic blood vessels

Mesenchyme on bone surface condenses and differentiates into periosteum

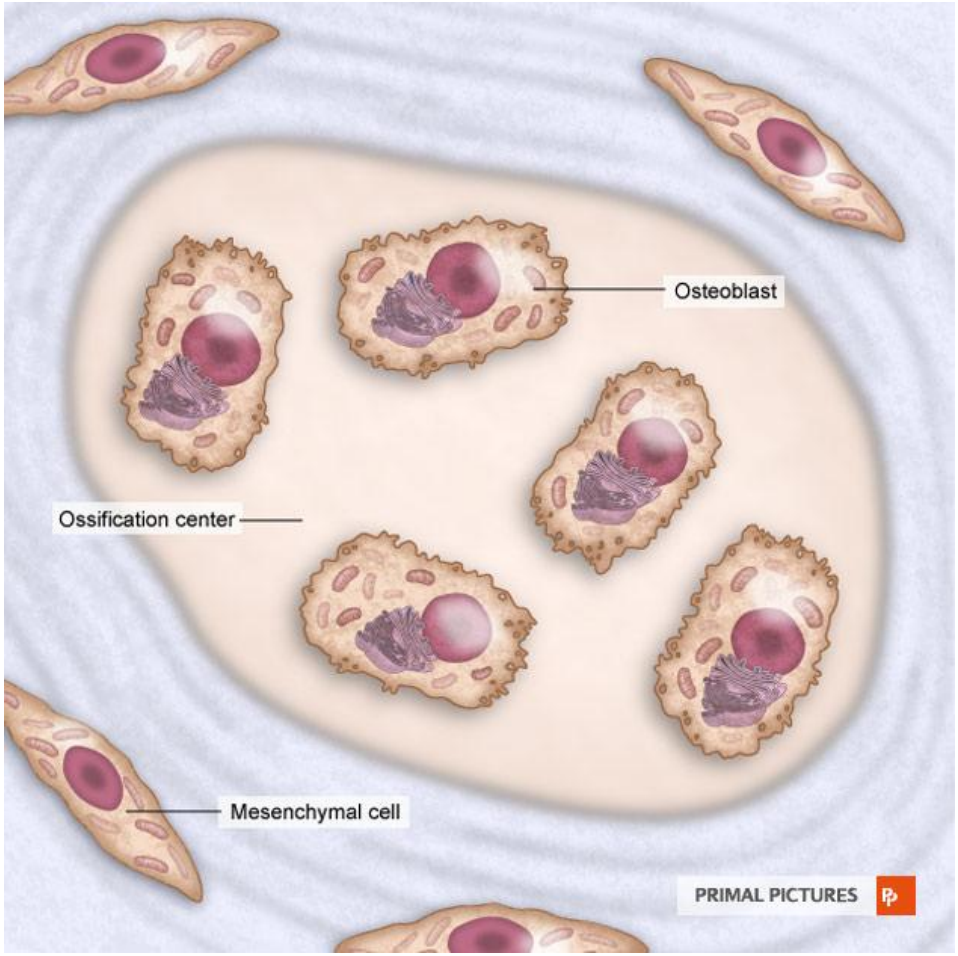
Intramembranous Ossification (prenatal)

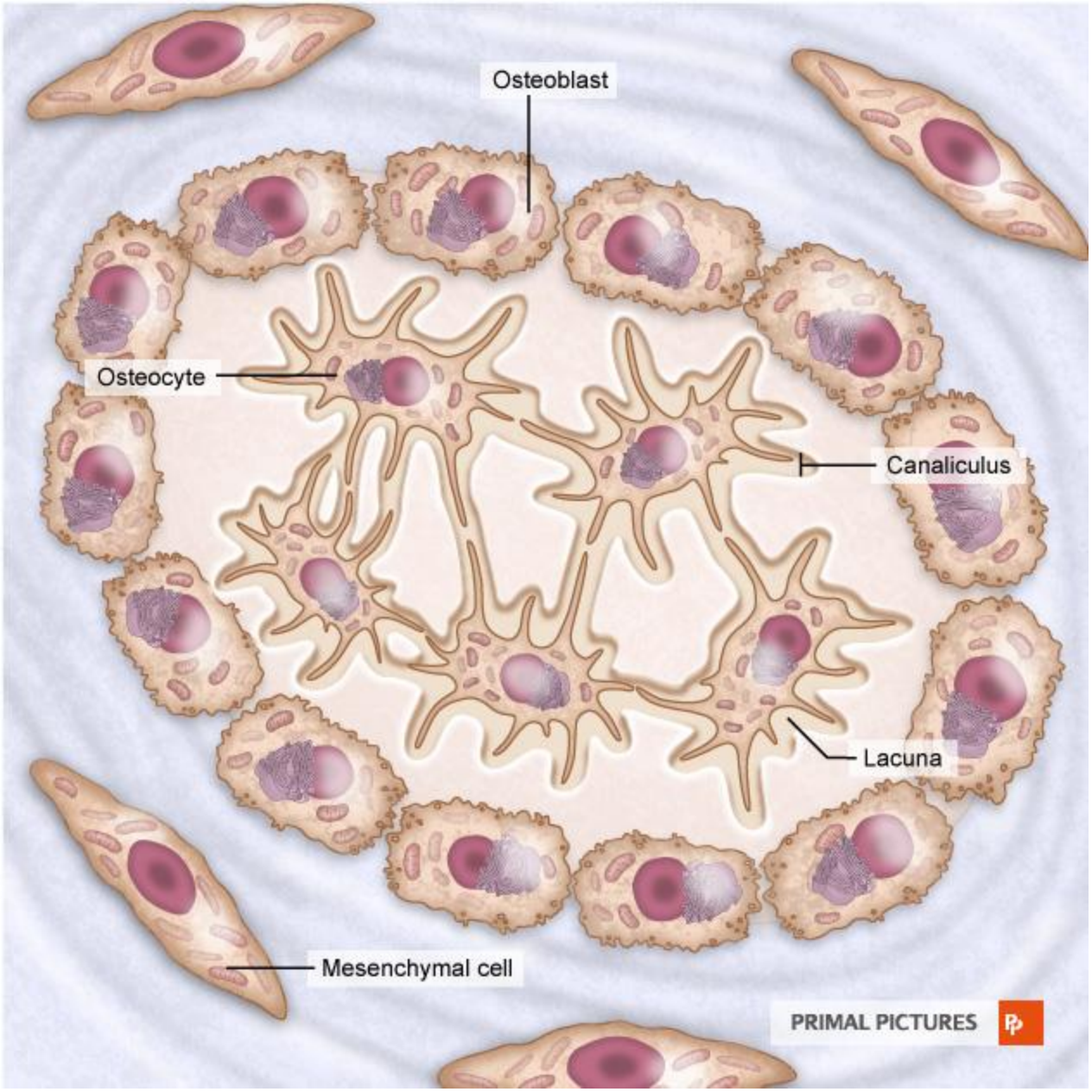


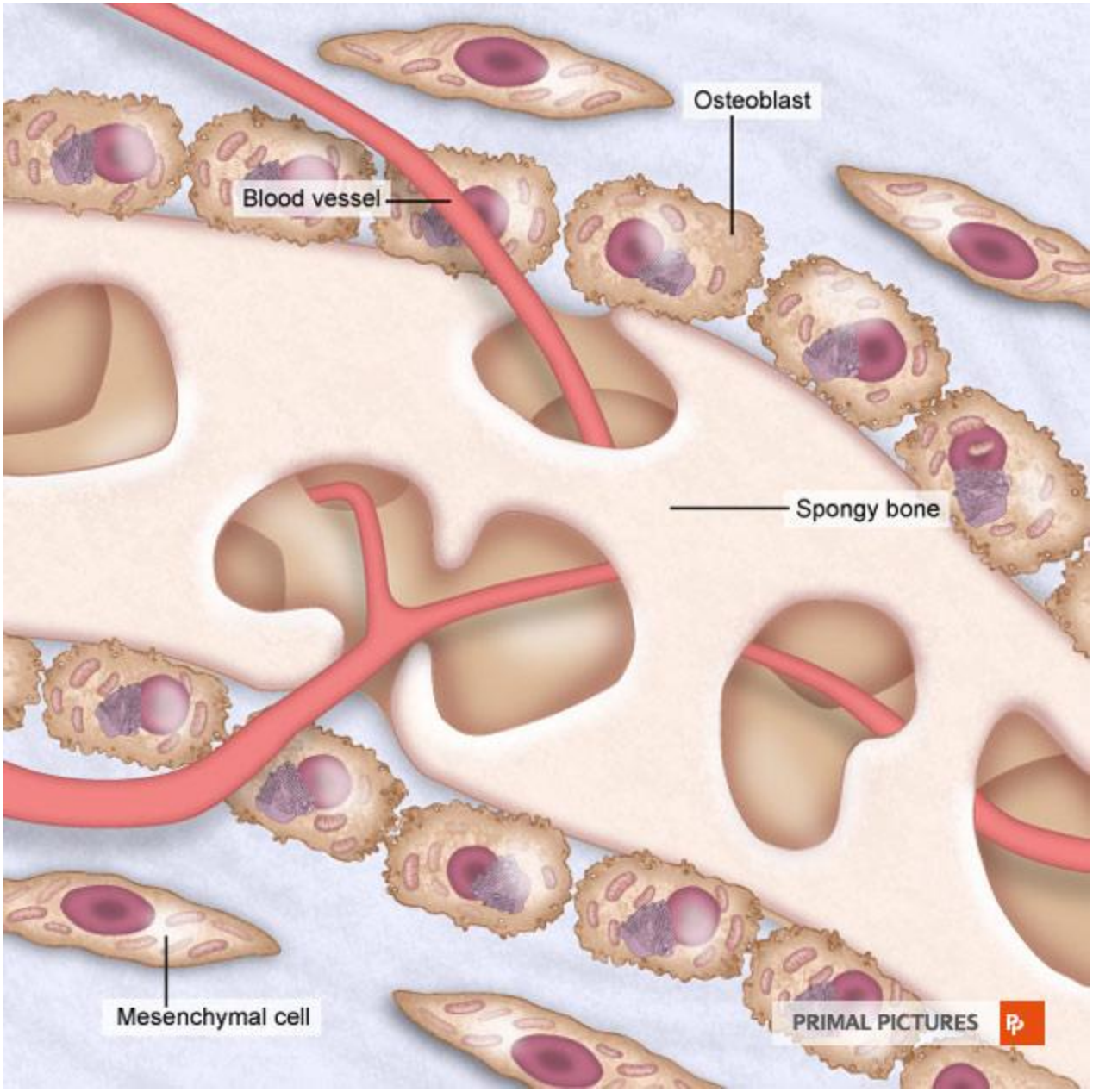
The woven bone at the outer edge is remodeled and replaced by compact bone

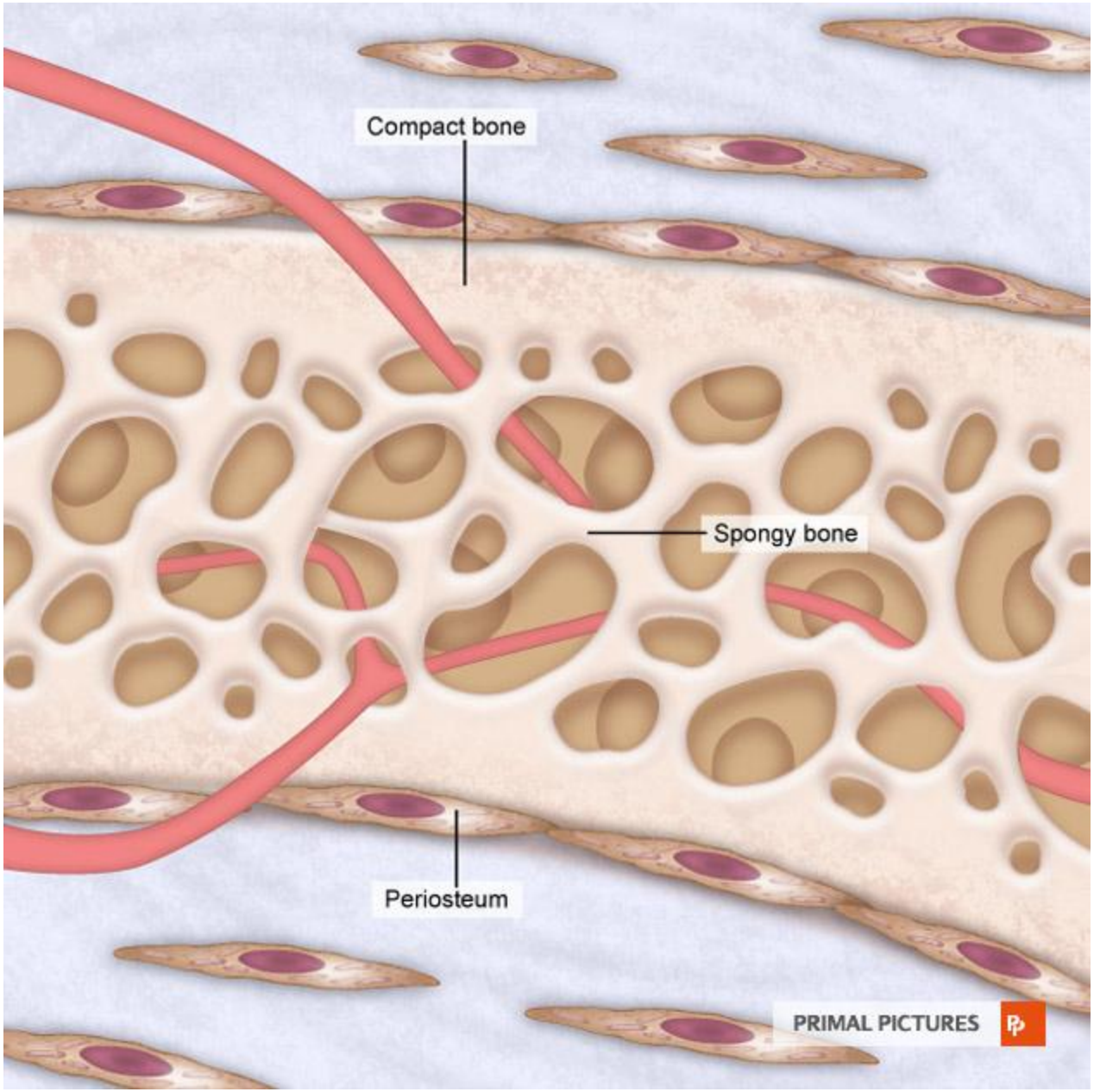
Spongy bone (diploë), consisting of distinct trabeculae, persists internally and its vascular tissue becomes red marrow

Note :Osteoblasts remain on bone surface to grow/remodel when needed


Osteoblast
Ossification center
Mesenchymal cell
PRIMAL PICTURES


Osteoblast
Osteocyte
Canaliculus
Lacuna
Mesenchymal cell
PRIMAL PICTURES

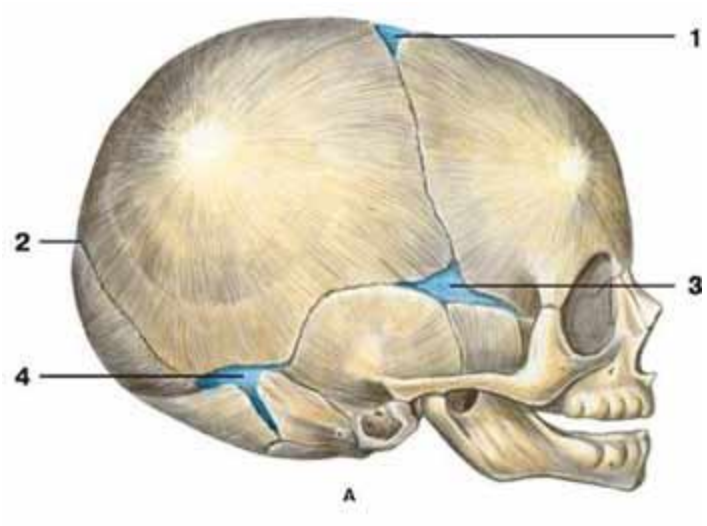

Osteoblast
Blood vessel
Spongy bone
Mesenchymal cell
PRIMAL PICTURES

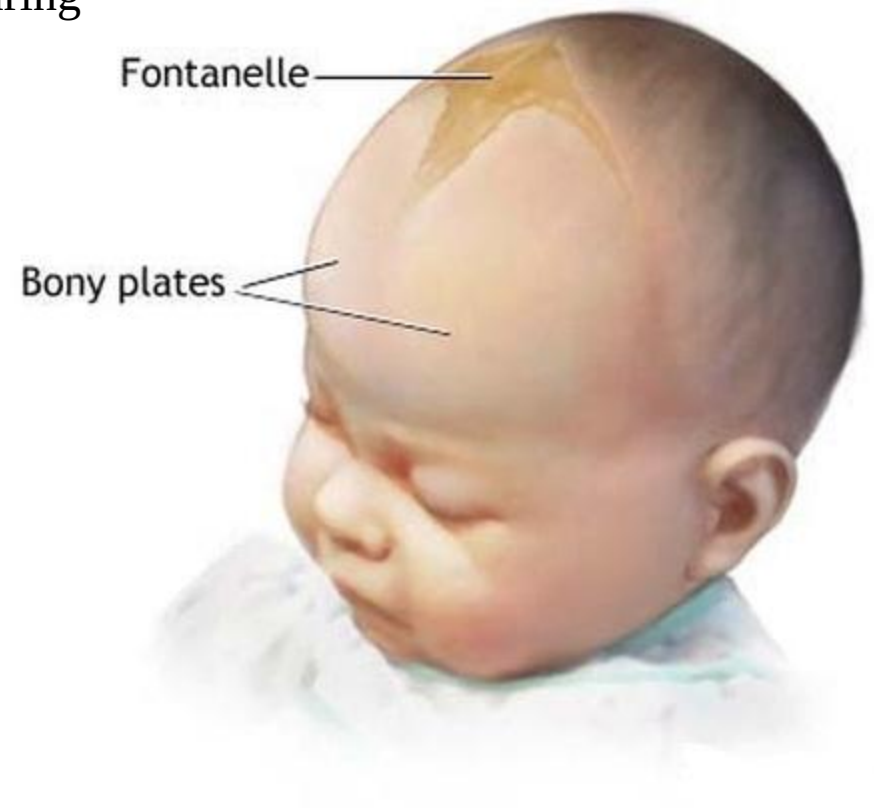

Compact bone
Spongy bone
Periosteum
PRIMAL PICTURES

An anatomical feature of the infant human skull comprising any of the soft membranous gaps (sutures) between the cranial bones of an infant

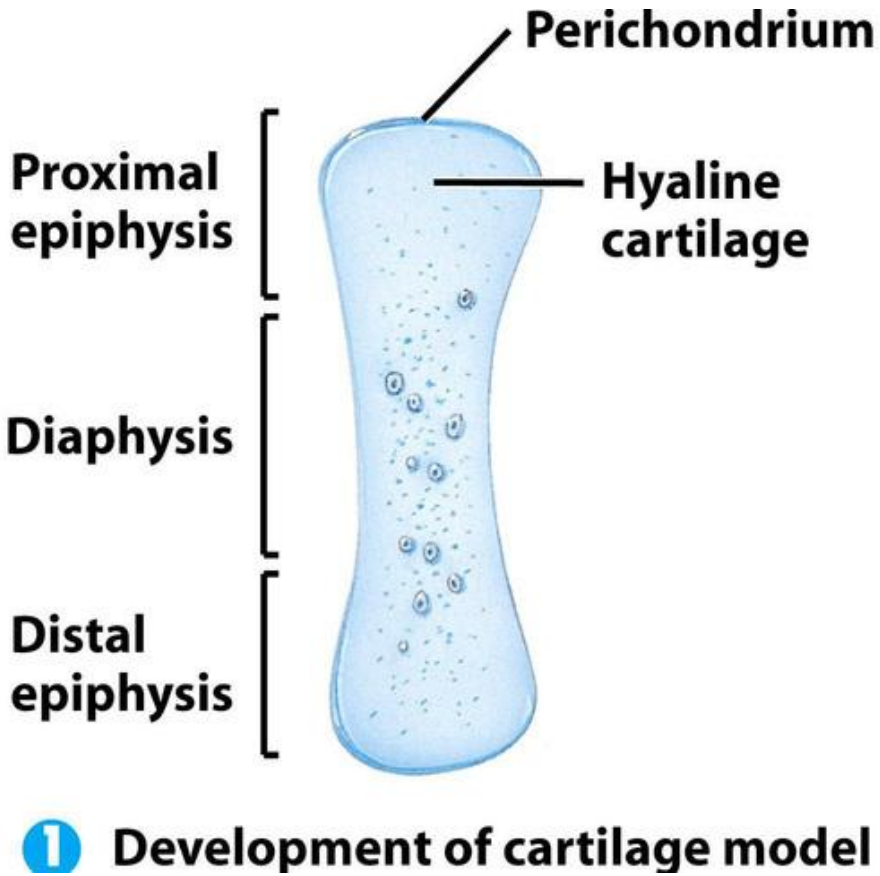
Fontanelles:

1. Allow room for the baby's brain to grow
2. Enable the head to be compressed during delivery





Endochondral Ossification



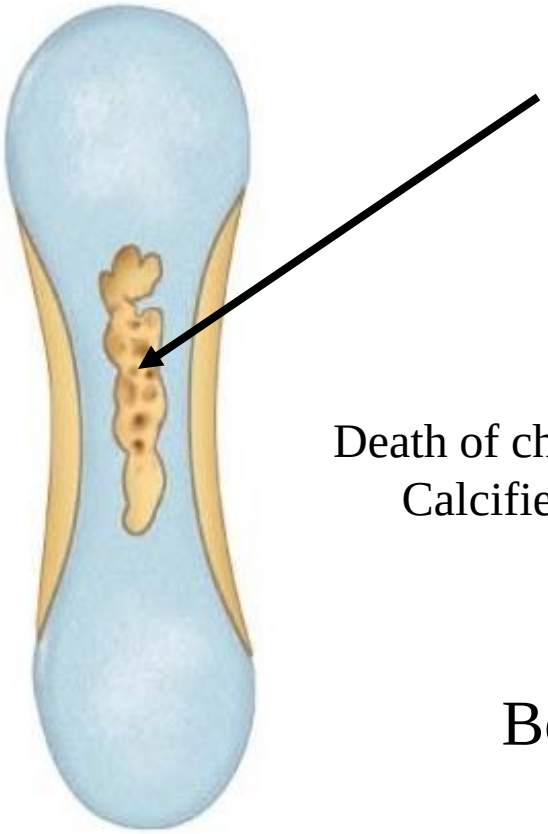
Endochondral Ossification

Bone collar formed around diaphysis by osteoblasts located on inner side of perichondrium

The collar impedes diffusion of oxygen and nutrients to the underlying cartilage, promoting degenerative changes there

Endochondral Ossification

Primary ossification center



Cartilage calcifies, then the cells die and cavities form (cavitates)

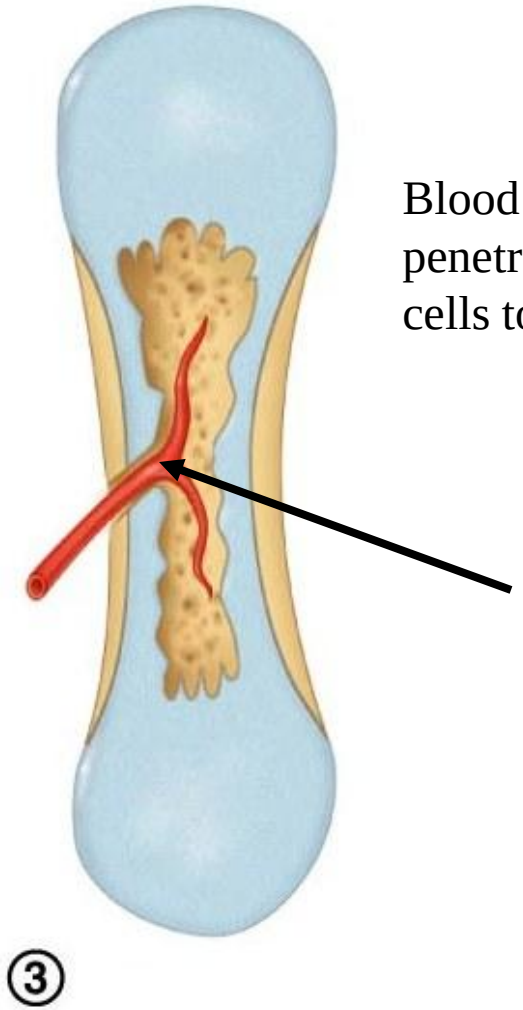
Death of chondrocytes creates a porous structure consisting of Calcified cartilage remnants which become covered by a layer of osteoblast

Bone collar provides stability during cavitation

②

Cartilage elsewhere continues to elongate

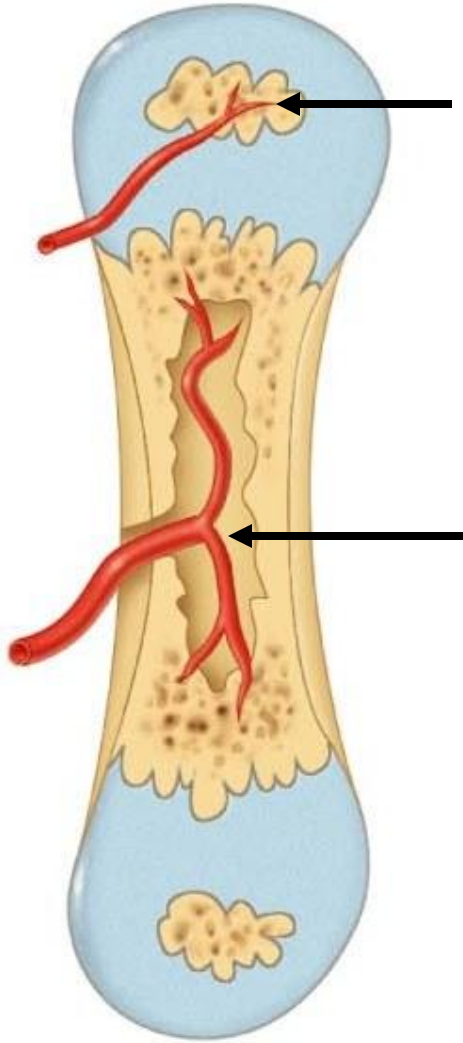
Endochondral Ossification



Blood vessels from perichondrium (now the periosteum) penetrate through the bone collar, bringing osteoproginator cells to the porous central region

Periosteal bud (lymph, blood vessels, nerves, red marrow, osteoblasts and osteoclasts) enters cavity and builds spongy bone

Endochondral Ossification

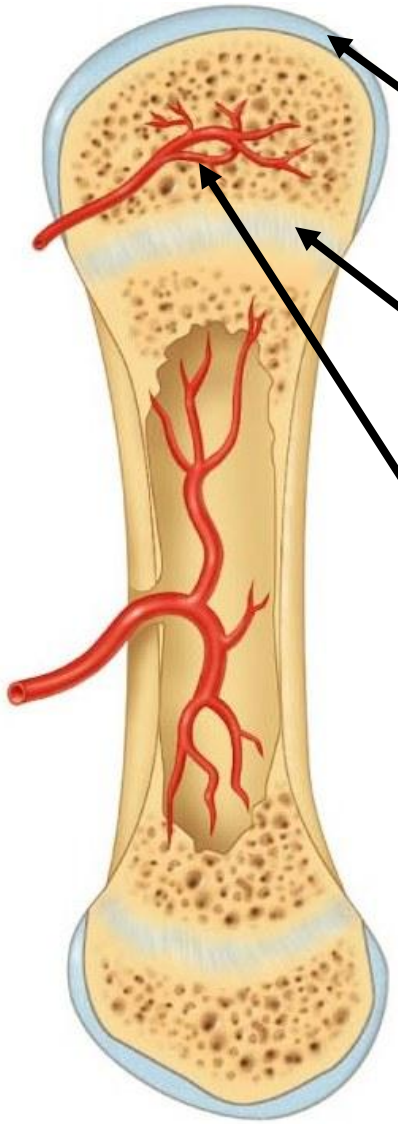


Secondary Ossification Center forms in epiphysis

Osteoclasts dissolve spongy bone to create medullary cavity

④

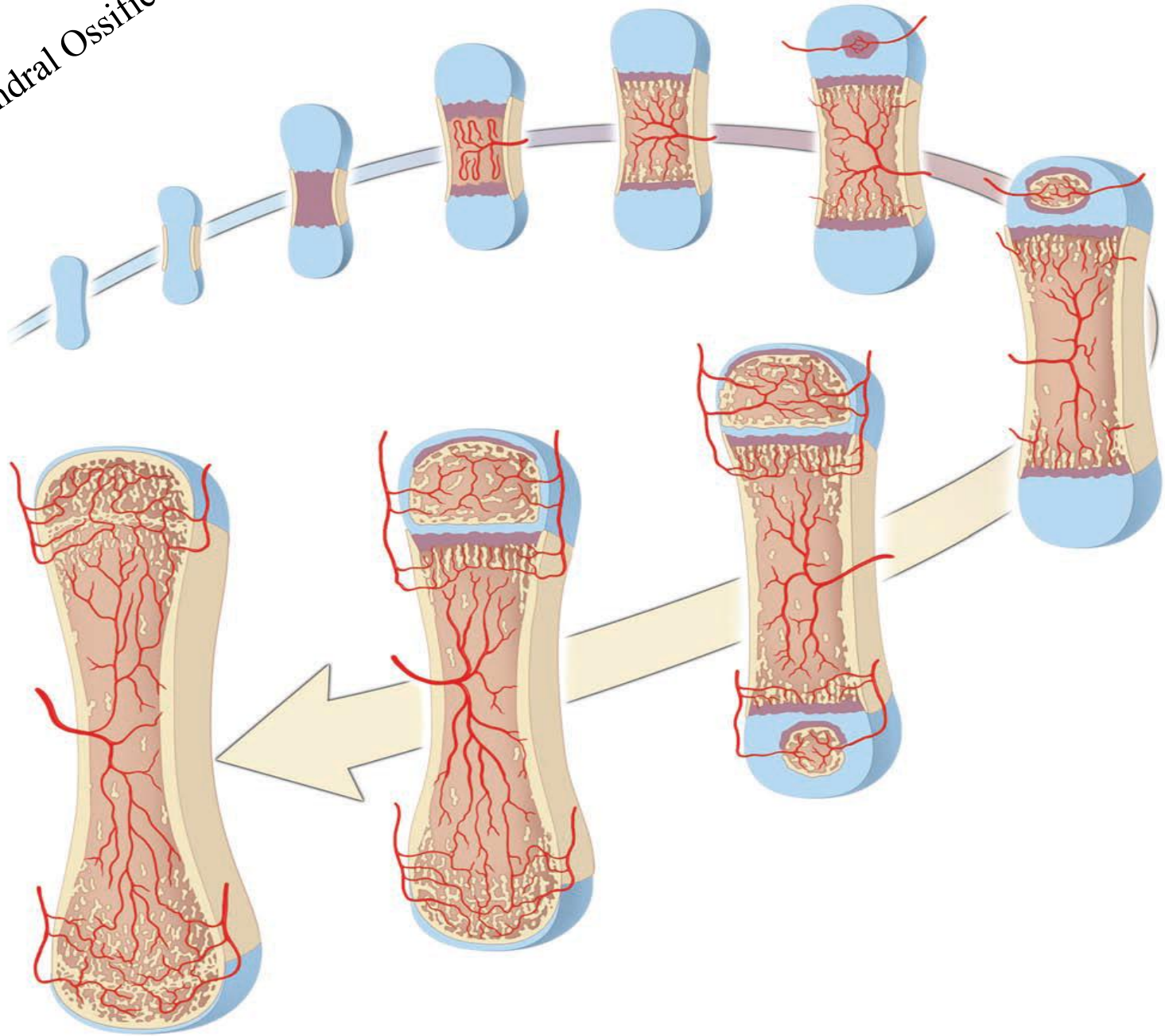
Endochondral Ossification



Hyaline only remains on epiphyseal surface (articular cartilage) and at diaphysis and epiphysis junction, to form the epiphyseal plates.

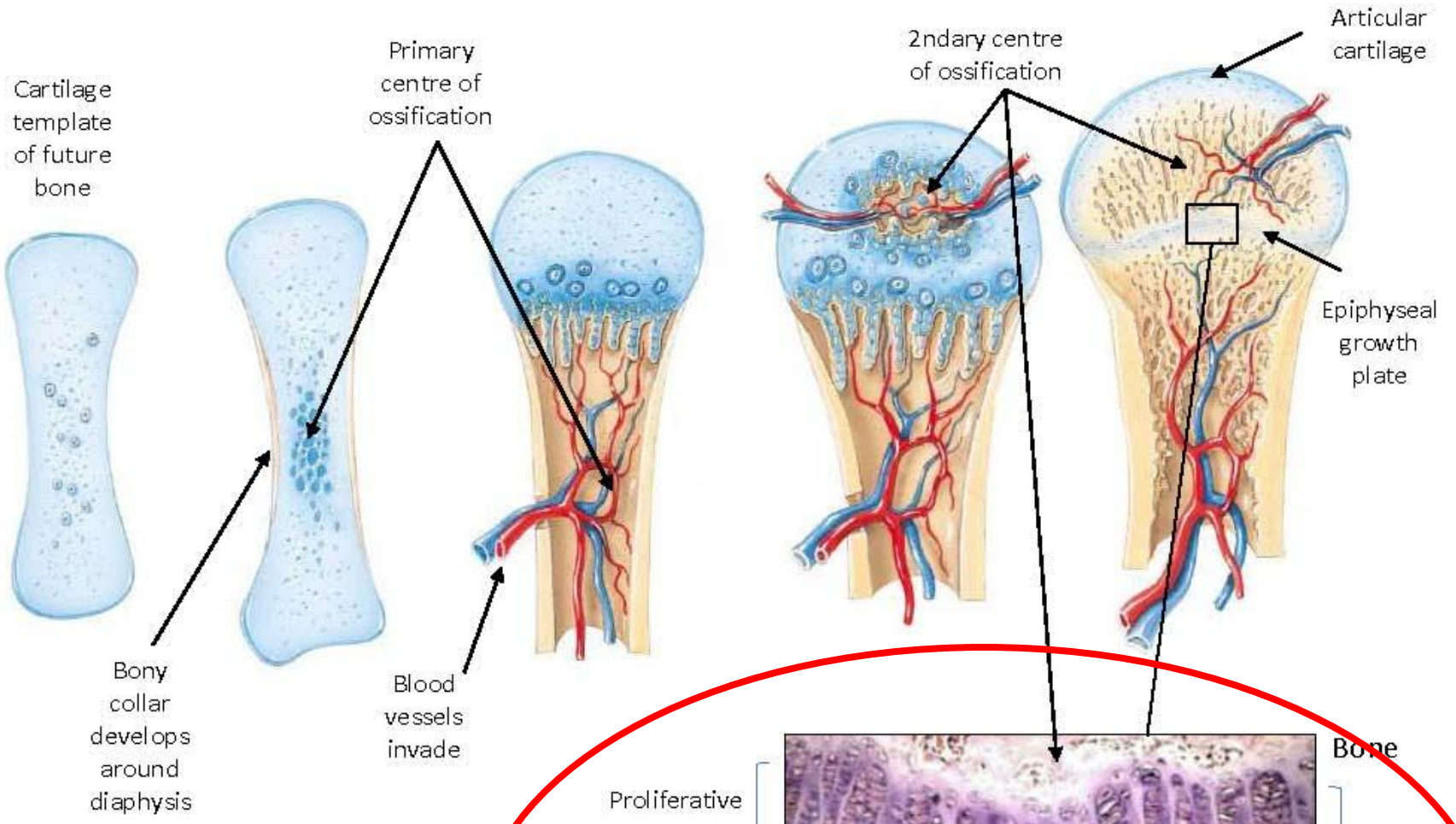
Secondary Ossification Center

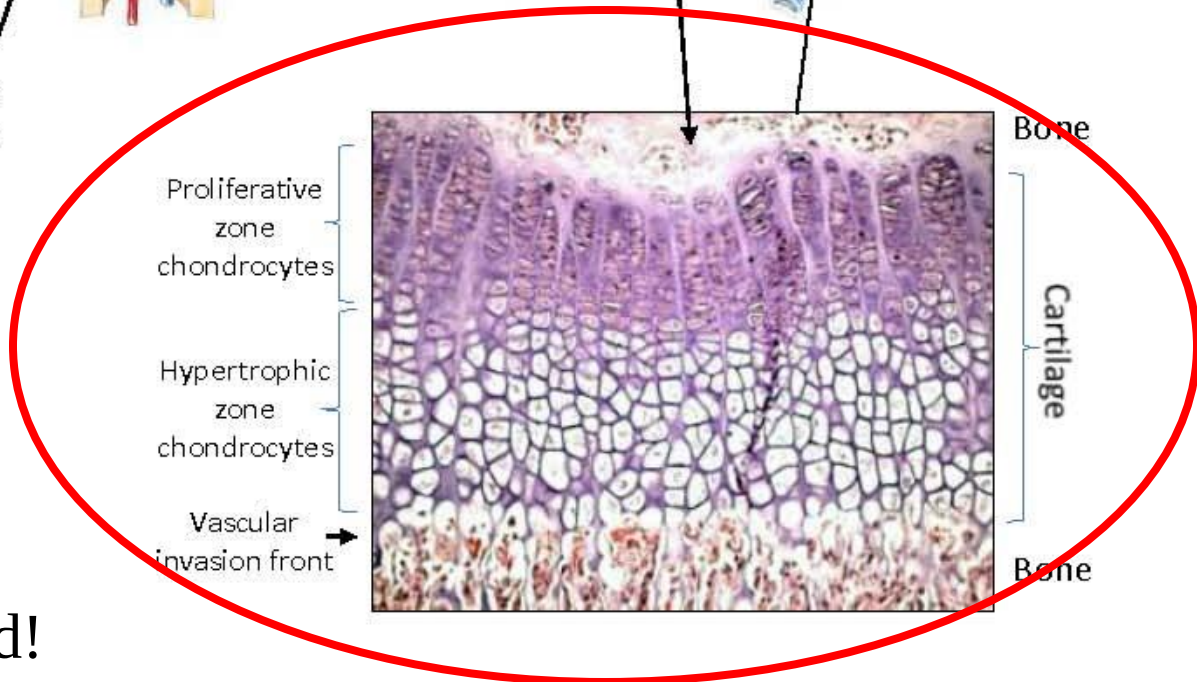
Endochondral Ossification



Postnatal Bone Growth

- Interstitial growth:
  - ↑ length of long bones
- Appositional growth:
  - ↑ thickness and remodeling of all bones by osteoblasts and osteoclasts on bone surfaces





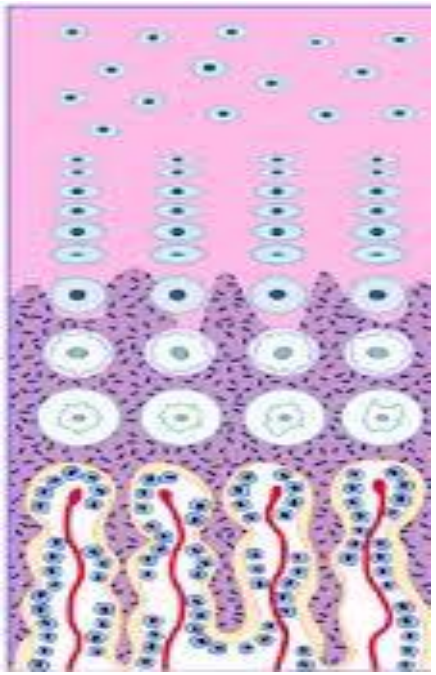
Endochondral Ossification:
the process by which most bones in the body grow

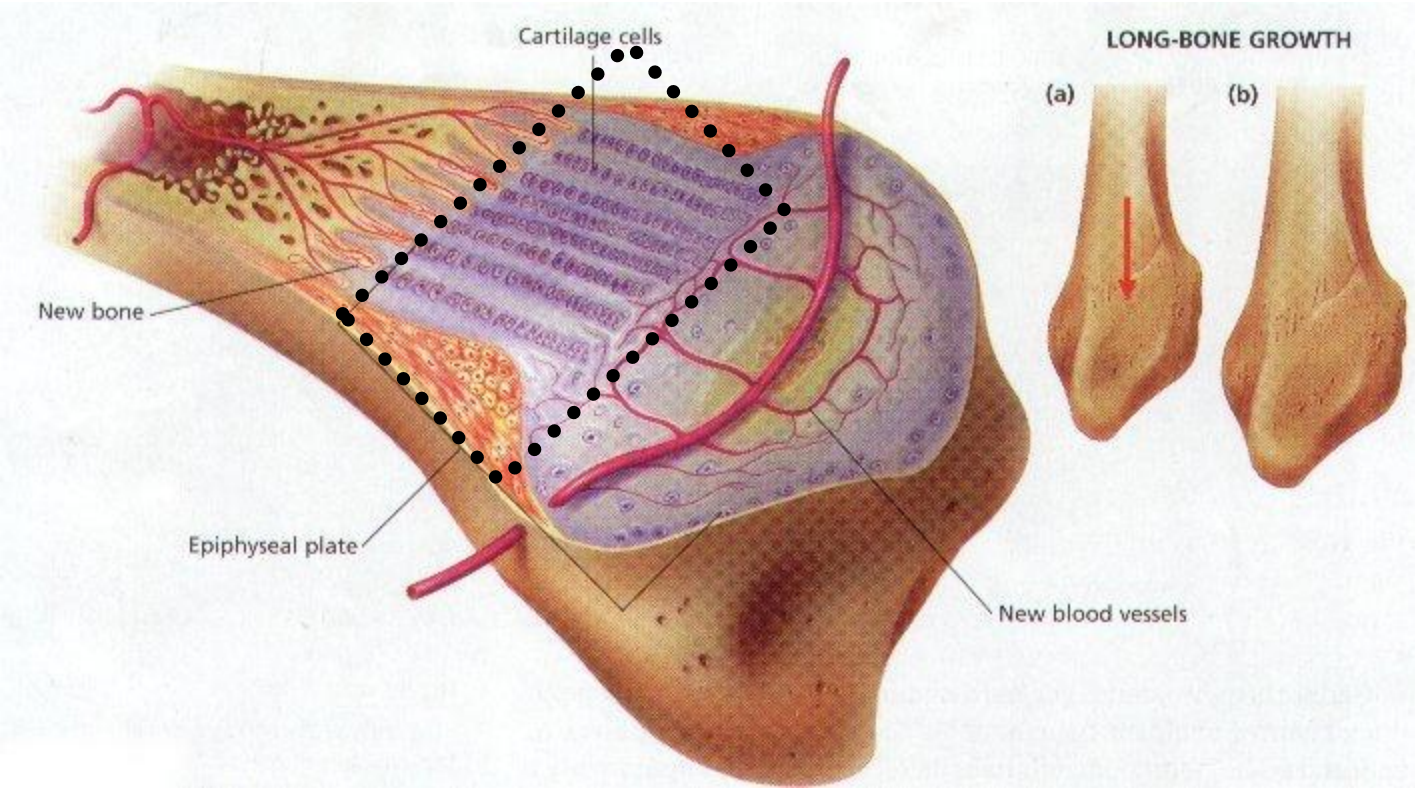
Growing taller throughout childhood!

Growing Taller!

(A closer look at the epiphyseal plate)

Lots of activity!





Growing Taller!

(A closer look at the epiphyseal plate)

Typical hyaline cartilage (resting)

1- Resting zone

Rapidly mitotic cartilage, lengthening bone; chondrocytes form columns

2- Growth zone

Enlarging size of chondrocytes (hypertrophy), this hypertrophy compresses the matrix into thin septa between chondrocytes

3- Hypertrophy zone

Matrix of cartilage calcifies and cells die forming small cavities

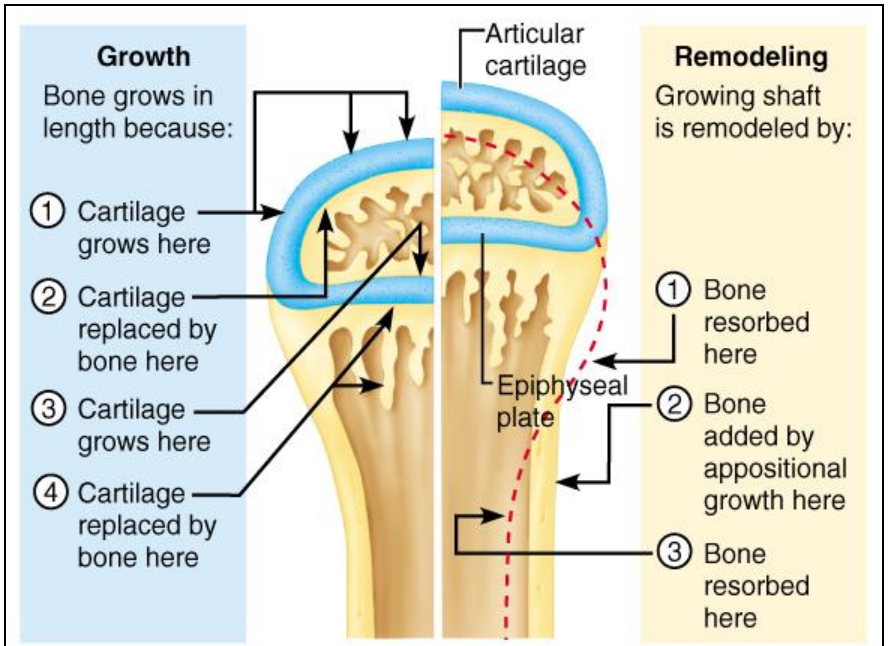
4- Calcification zone

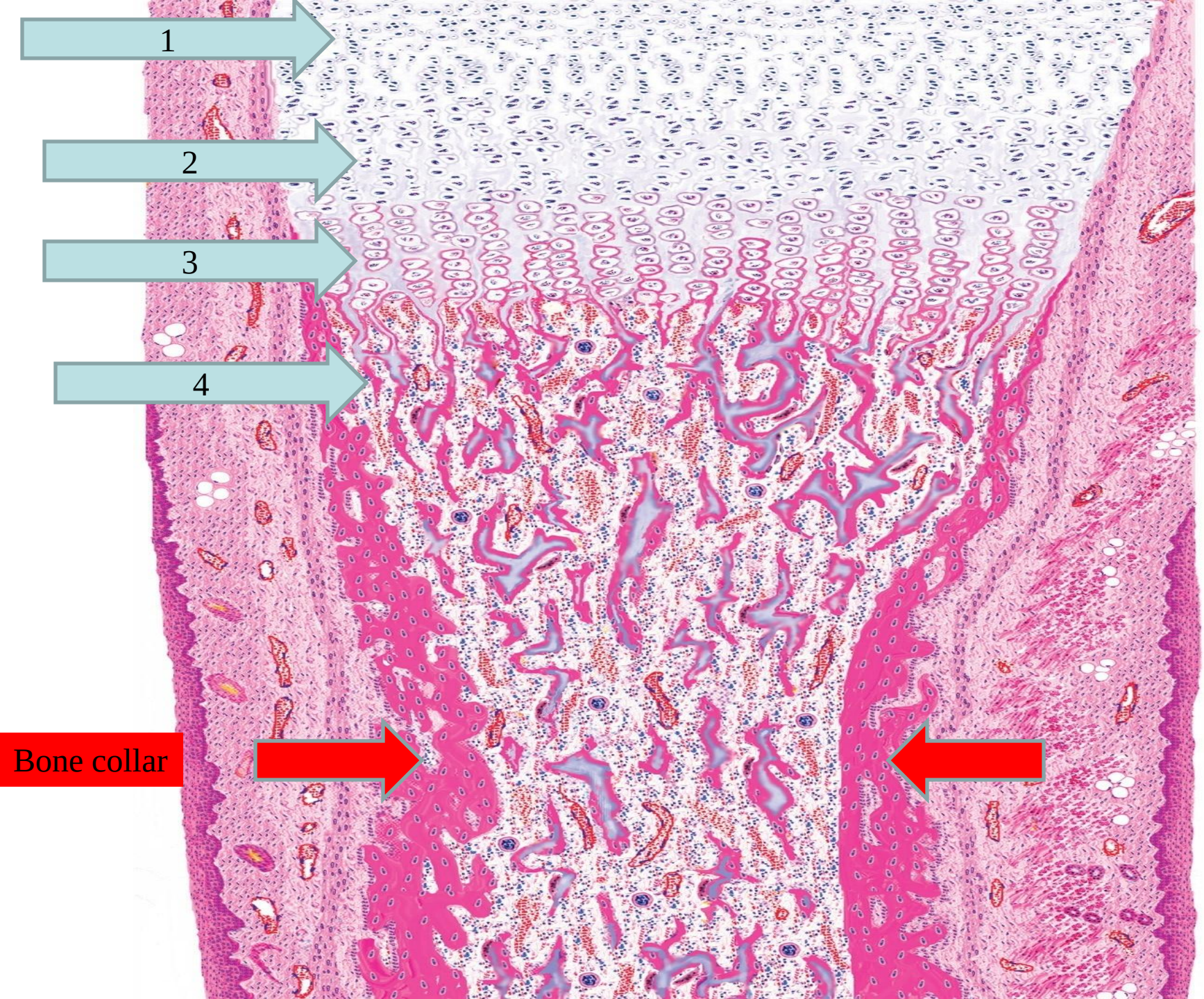
Osteoblasts adhere to the remnants of calcified cartilage matrix and produce woven bone. Later this bone reshapes into spongy bone or compact bone later as bone grows.

5- Ossification zone

Longitudinal Bone Growth

- Longitudinal Growth (interstitial) – cartilage continually grows and is replaced by bone
  - Bones lengthen entirely by growth of the **epiphyseal plates**
  - Cartilage is replaced with bone as quickly as it grows
  - *Epiphyseal plate maintains constant thickness*



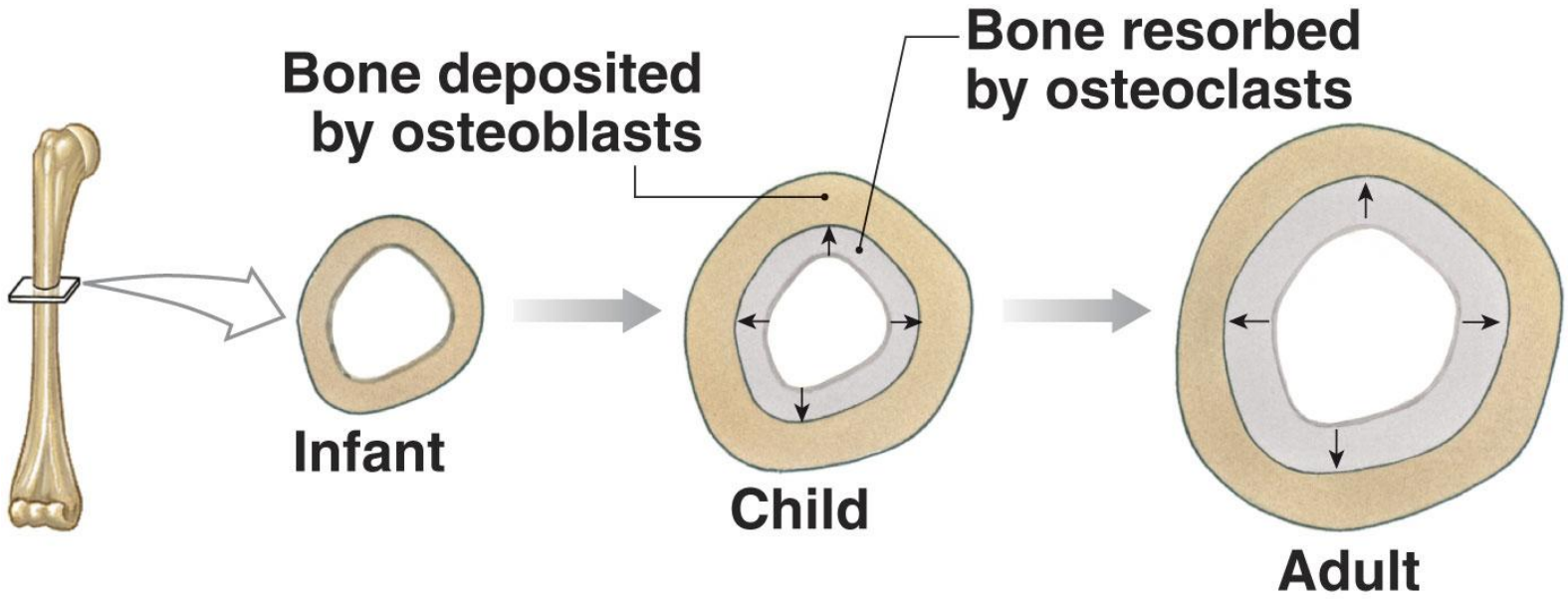

1
2
3
4
Bone collar

When does lengthening stop?

- End of adolescence - lengthening stops
  - Chondrocytes stop mitosis.
  - Plate thins out and replaced by bone
  - Diaphysis and epiphysis fuse to be one bone
    - Epiphyseal plate closure (18 yr old females, 21 yr old males)
- Thickening of bone continuous throughout life

Appositional Bone Growth

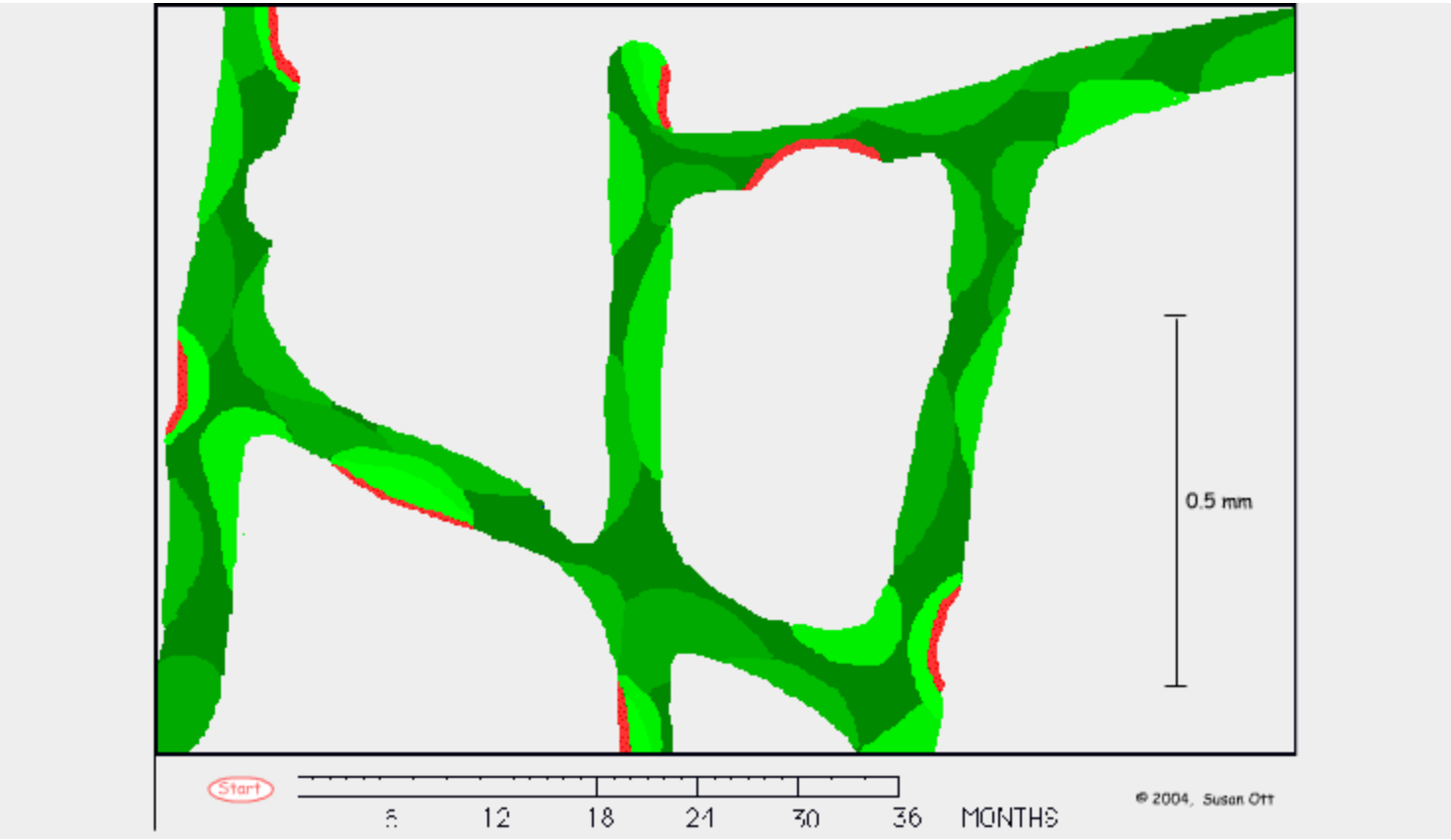
- Growing bones widen as they lengthen
- Appositional growth – growth of a bone by addition of bone tissue to its surface
- Bone is resorbed at endosteal surface and added at periosteal surface
  - Osteoblasts – add bone tissue to the external surface of the diaphysis
  - Osteoclasts – remove bone from the internal surface of the diaphysis



Bone Remodeling

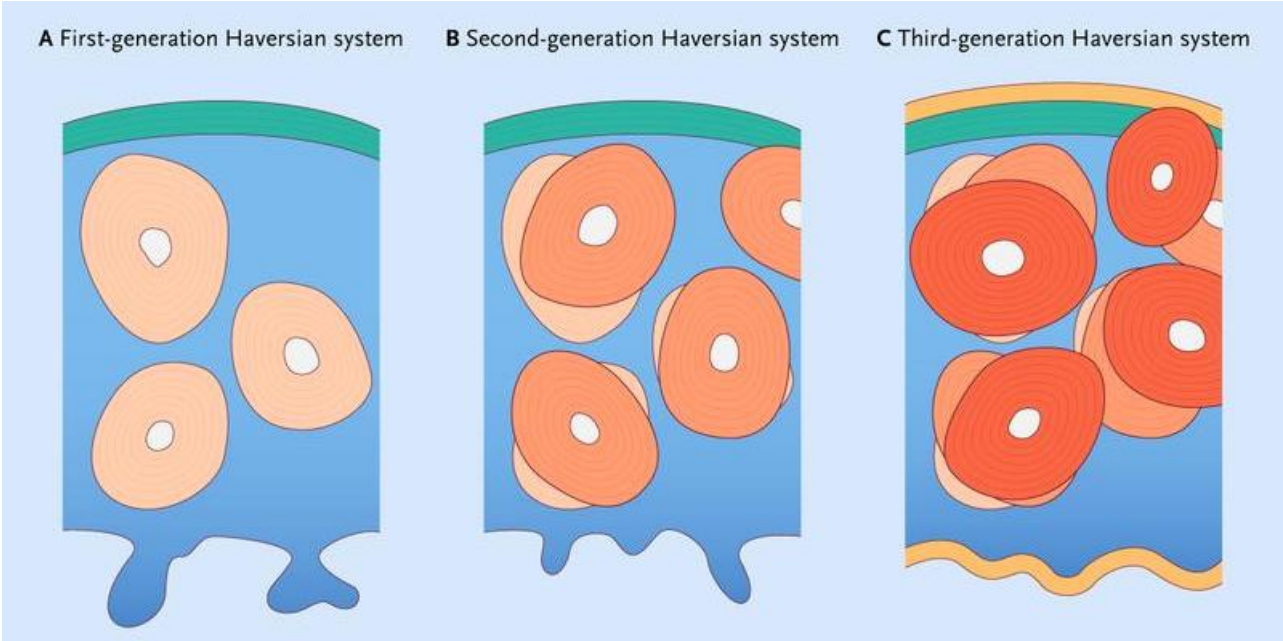
- **Reshaping of the skeleton during growth**
- **Maintain calcium levels**
- **Repair of microfractures caused by everyday stresses**

Involves:
Dissolving/destroying bone
New bone growth



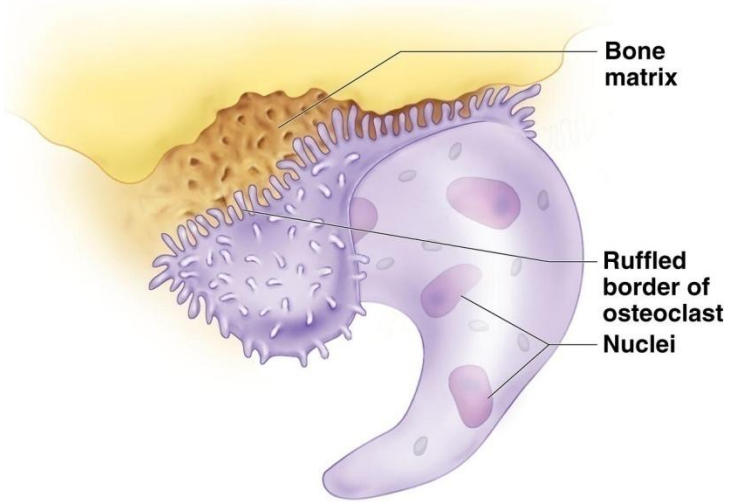
Dissolved material passed through osteoclasts and into bloodstream for reuse by the body (endocytosis and transcytosis)

compact bone remodelling



Bone Remodeling

- Bone Depostition
  - Occurs when bone is injured or extra strength is needed
  - Requires a healthy diet - protein, vitamins C, D, and A, and minerals (calcium, phosphorus, magnesium, manganese, etc.)
- Bone Resorption
  - Accomplished by Osteoclasts (multinucleate phagocytic cells)
  - Resorption involves osteoclast secretion of:
    - Lysosomal enzymes that digest organic matrix
    - HCl that converts calcium salts into soluble forms
  - Dissolved matrix is endocytosed and transcytosed into the interstitial fluid → the blood



To summarize:

- Bone formation—begins around 8th week of development
- Postnatal bone growth—until early adulthood
- Bone remodeling and repair—lifelong

Bone is Dynamic!

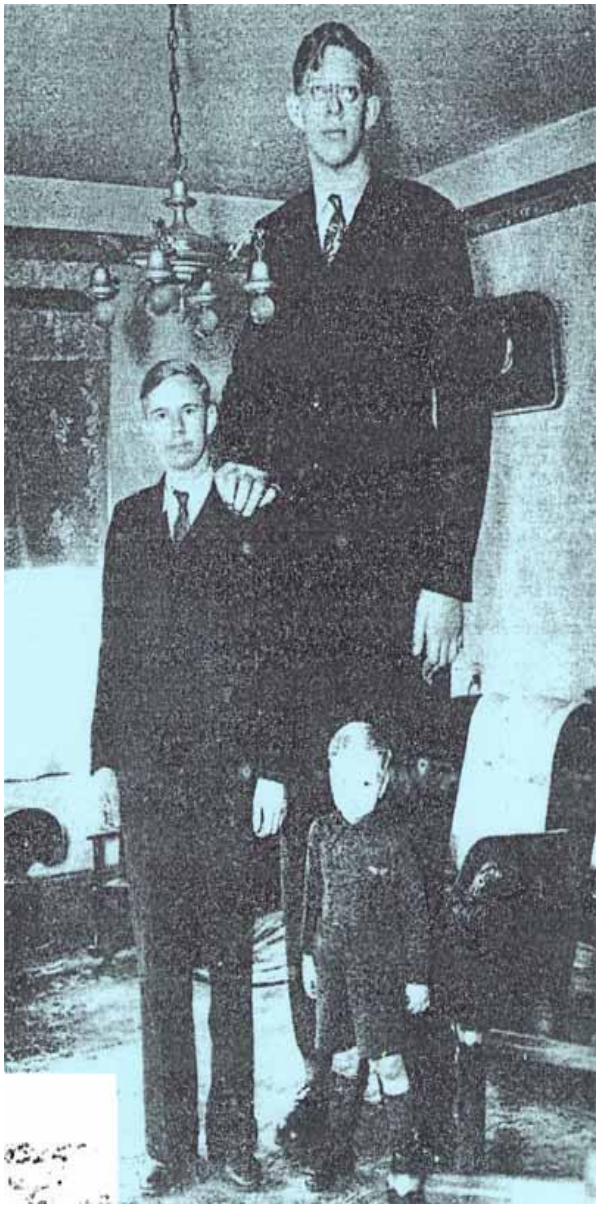
Bone is constantly remodeling and recycling

- Coupled process between:
  - Bone deposition (by osteoblasts)
  - Bone destruction/resorption (by osteoclasts)
- 5-7% of bone mass recycled weekly
- All spongy bone replaced every 3-4 years.
- All compact bone replaced every 10 years.

Prevents mineral salts from crystallizing; protecting against brittle bones and fractures

Bone growth regulated by hormones

- Human Growth Hormone (HGH): from pituitary gland in brain promotes epiphyseal plate activity
- Thyroid hormones: regulate HGH for proper bone proportions
- Puberty: Testosterone or Estrogen cause adolescent growth spurt and skeletal differences between the sexes:
  - Wider shoulders, larger bones, narrow pelvis in men
  - Wider hips, smaller upper body in women
- Excesses in any hormones can cause abnormal skeletal growth
  - Ex. gigantism or dwarfism



Robert Wadlow, world's tallest man 8 ft 11 inches

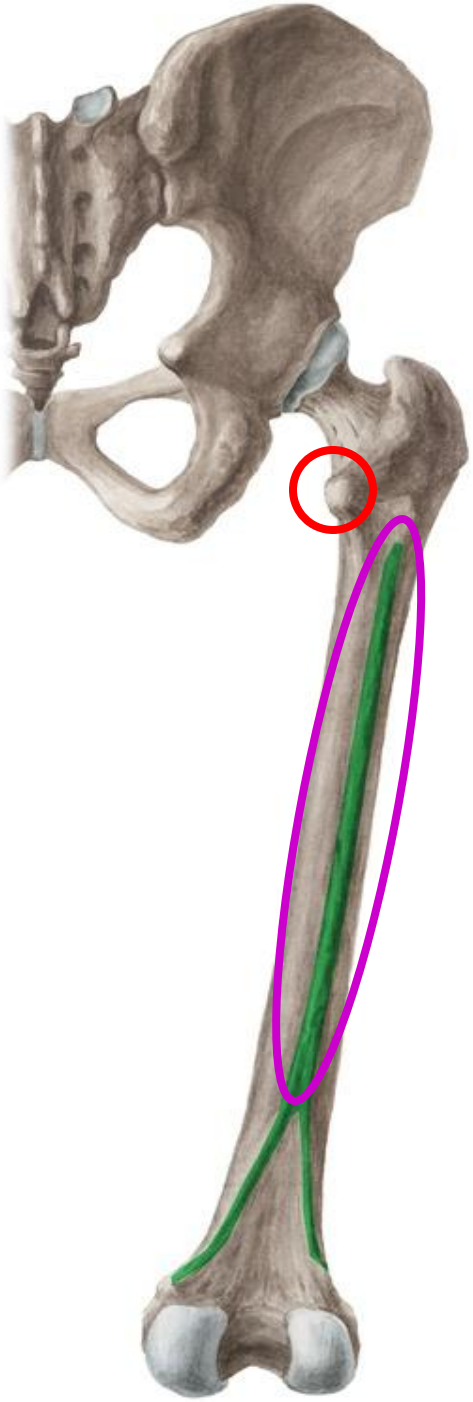
Yao Defen, gigantess currently in treatment for pituitary tumor in China. 7 ft 7 inches 396 lbs

Response to Mechanical/Gravitational Forces

  - Bones respond to muscles pulling on them (mechanical stress) and to gravity by keeping the bones strong where they are being stressed.
- Weight bearing activities → stronger projections where muscles/ligaments attach
- High rate of bone deposition in specific areas.

Bones respond to muscles pulling on them (mechanical stress)

What you don't use, you lose. The stresses applied to bones during exercise are essential to maintaining bone strength and bone mass



Clinical Application

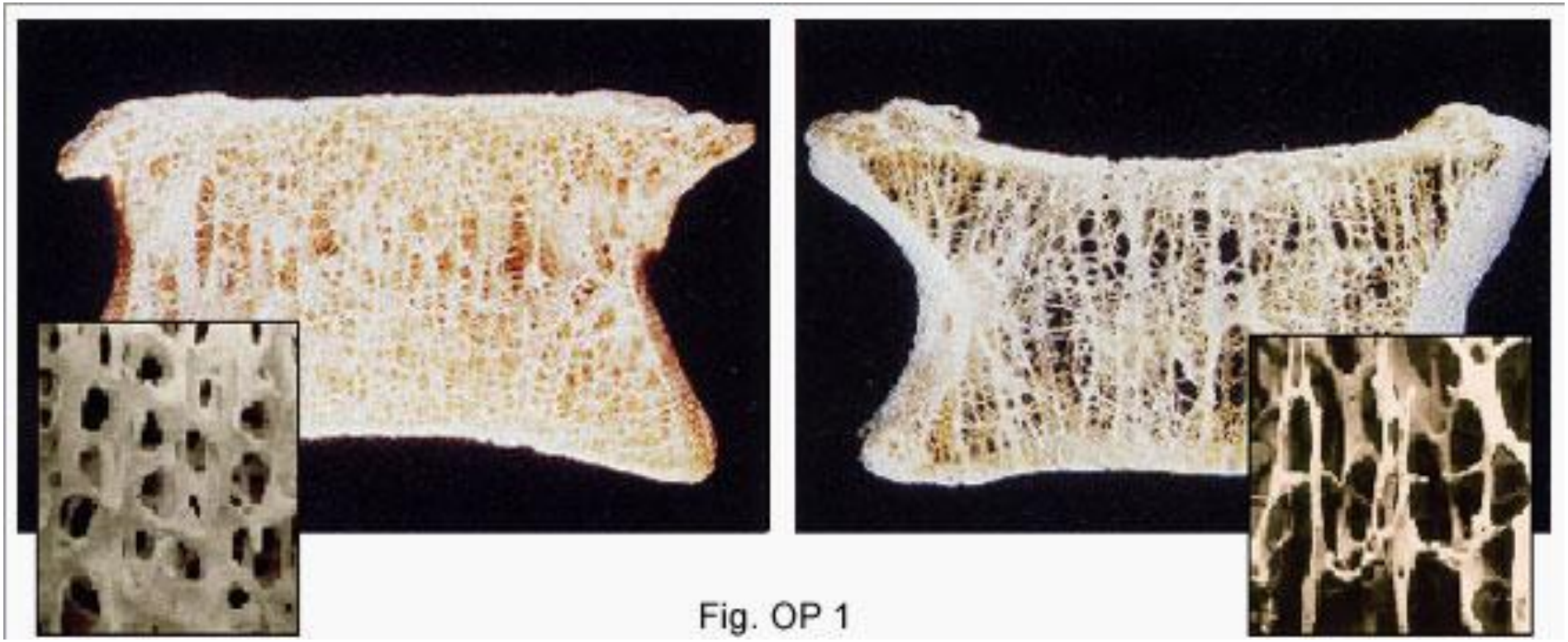


Fig. OP 1

Osteoporosis

Animations

http://depts.washington.edu/bonebio/ASBMRed/growth/newlongbone2.swf

http://depts.washington.edu/bonebio/ASBMRed/growth/newBMUbu.swf

http://highered.mheducation.com/sites/dl/free/0072495855/291136/BoneGrowth.swf

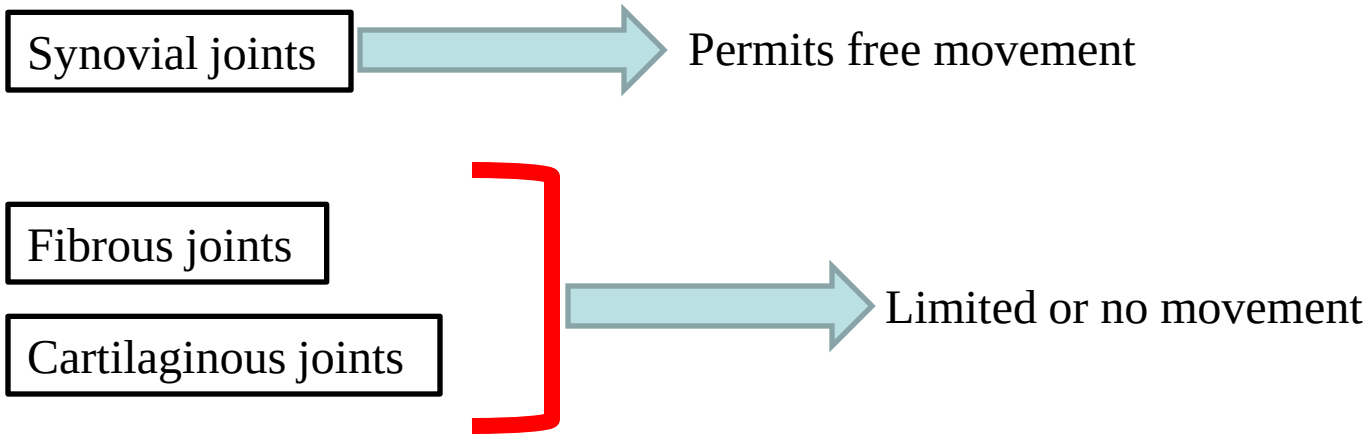
Recommended
http://www.johnwiley.net.au/highered/interactions/media/Support/content/Support/skel2a/frameset.htm

http://www.doitpoms.ac.uk/tlplib/bones/flash/EndochondralOssification.swf

Joints

A joint is where two or more bones meet. Also known as an articulation

Joints can be classified either by:
the tissue that holds the bones together
or the degree of movement they provide



The tissue that holds the bones together

Fibrous joints are connected by dense connective tissue and have no joint cavity.
Cartilaginous joints are connected by cartilage and have no joint cavity.
Synovial joints have a synovial, fluid-filled cavity that surrounds the articulating bones.

The degree of movement they provide

Synarthrosis: Joints that do not provide any movement.
Amphiarthrosis: Joints that only provide a small degree of movement.
Diarthrosis: Joints that allow free movement

FIBROUS JOINTS

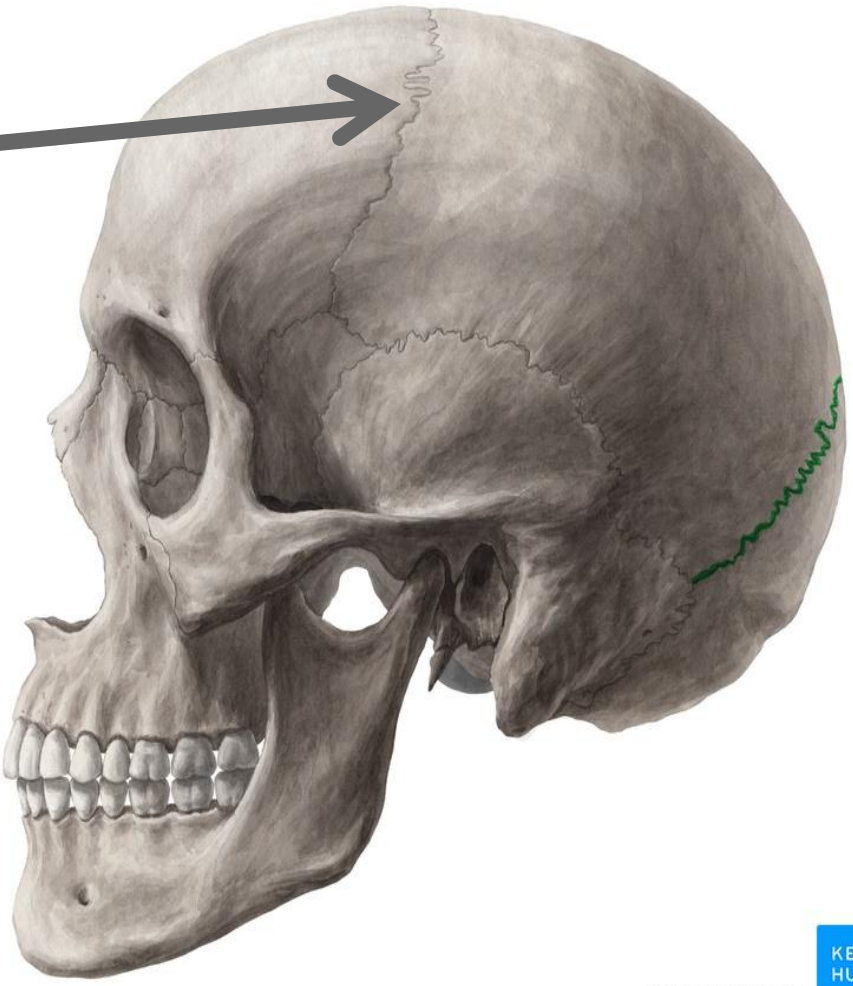
In a fibrous joint, the two bones are connected by dense fibrous connective tissue. These joints can be either synarthrotic or amphiarthrotic.

There are three different types of fibrous joints:

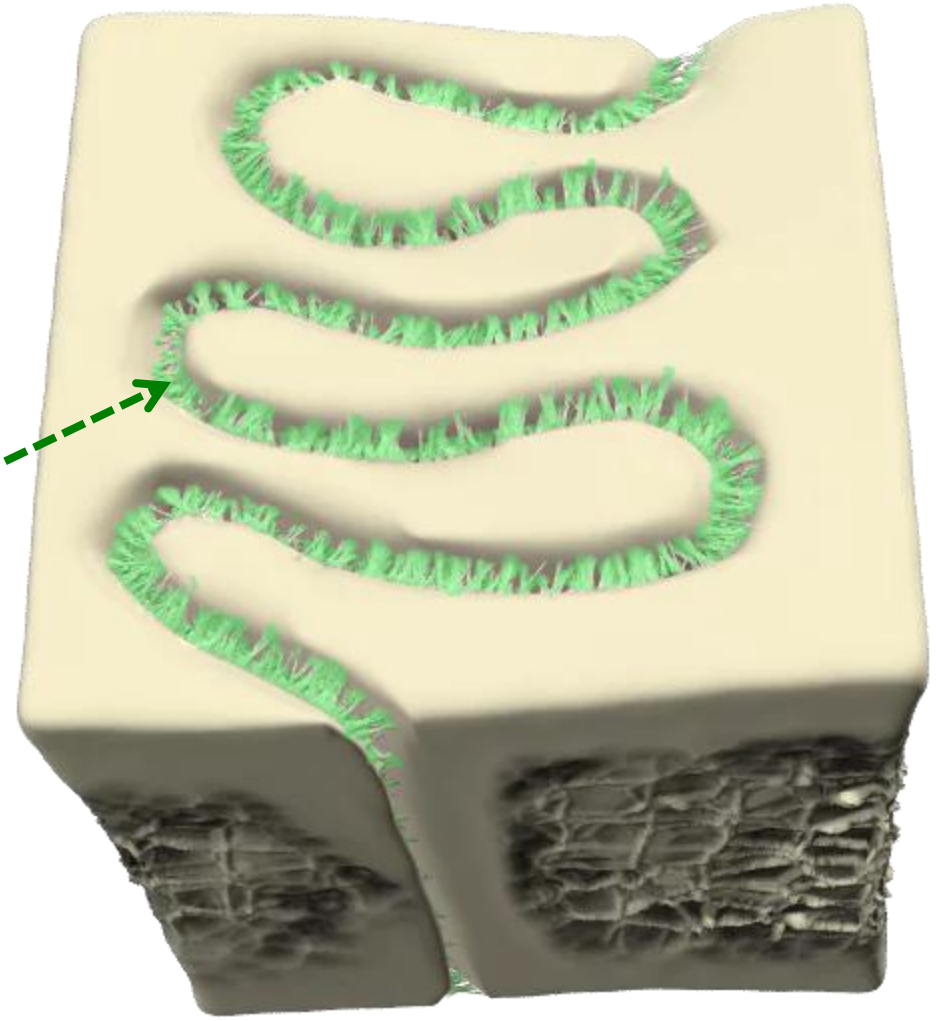
Suture: between the flat bones of the skull

Gomphosis: The roots of a tooth and the alveolar sockets in the maxilla or mandible

Syndesmosis: interosseous membrane



☆Sutures

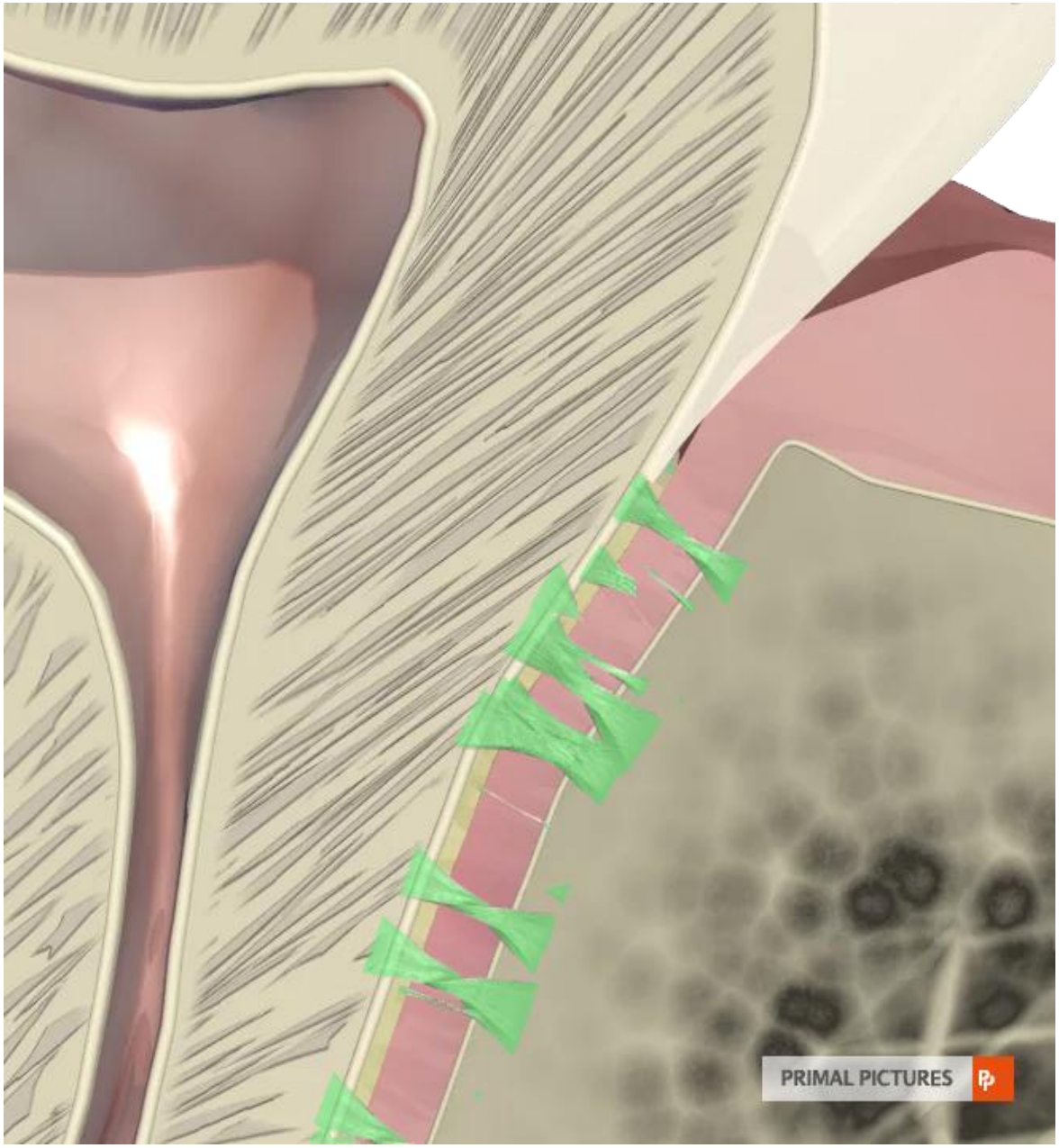


These joints are synarthrotic

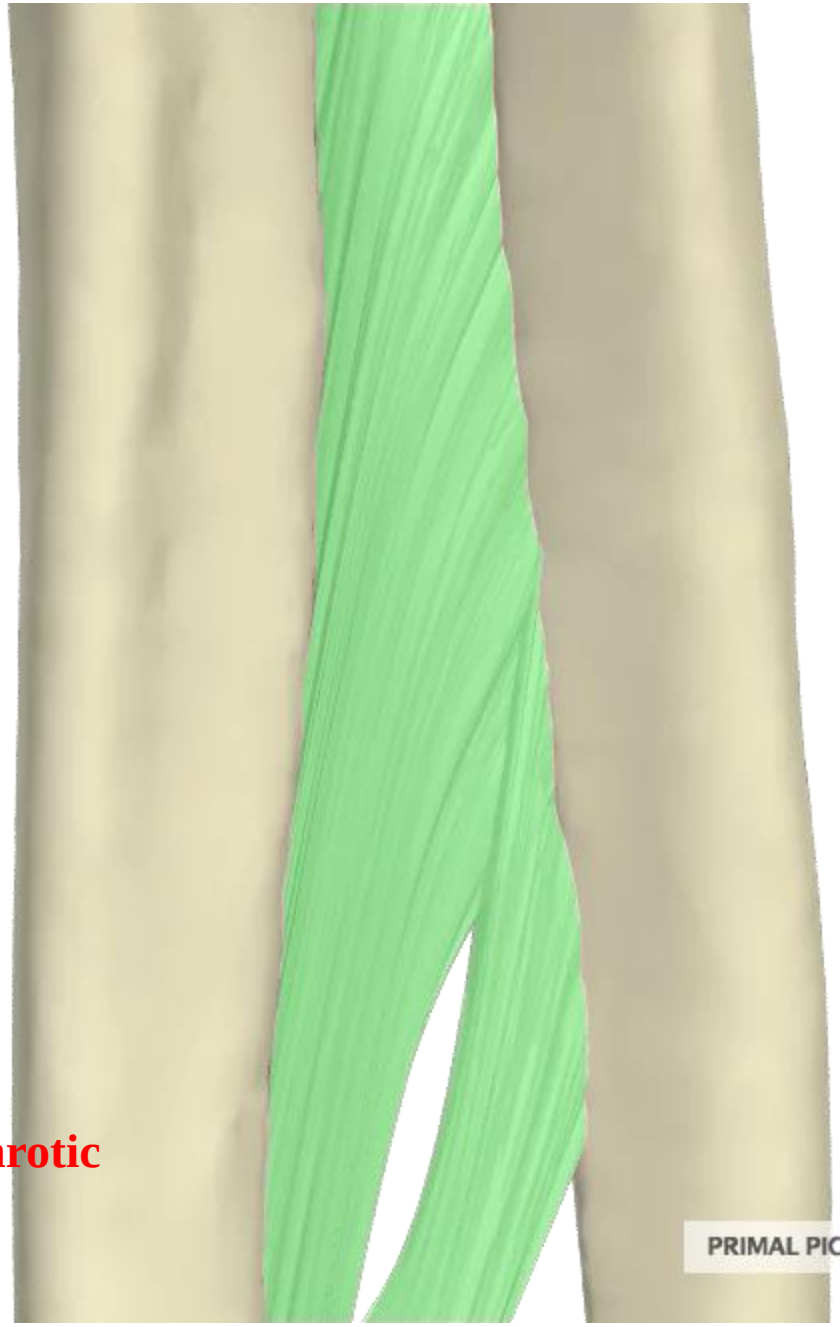
Gomphoses

Gomphoses occur only between the teeth and adjacent bone. In these joints, short collagen tissue fibers in the periodontal ligament run between the root of the tooth and the bony socket..

These joints are synarthrotic



Syndesmoses



These joints are amphiarthrotic

CARTILAGINOUS JOINTS

In a cartilaginous joint, the two bones are connected by cartilage.

These joints can be either synarthrotic or amphiarthrotic.

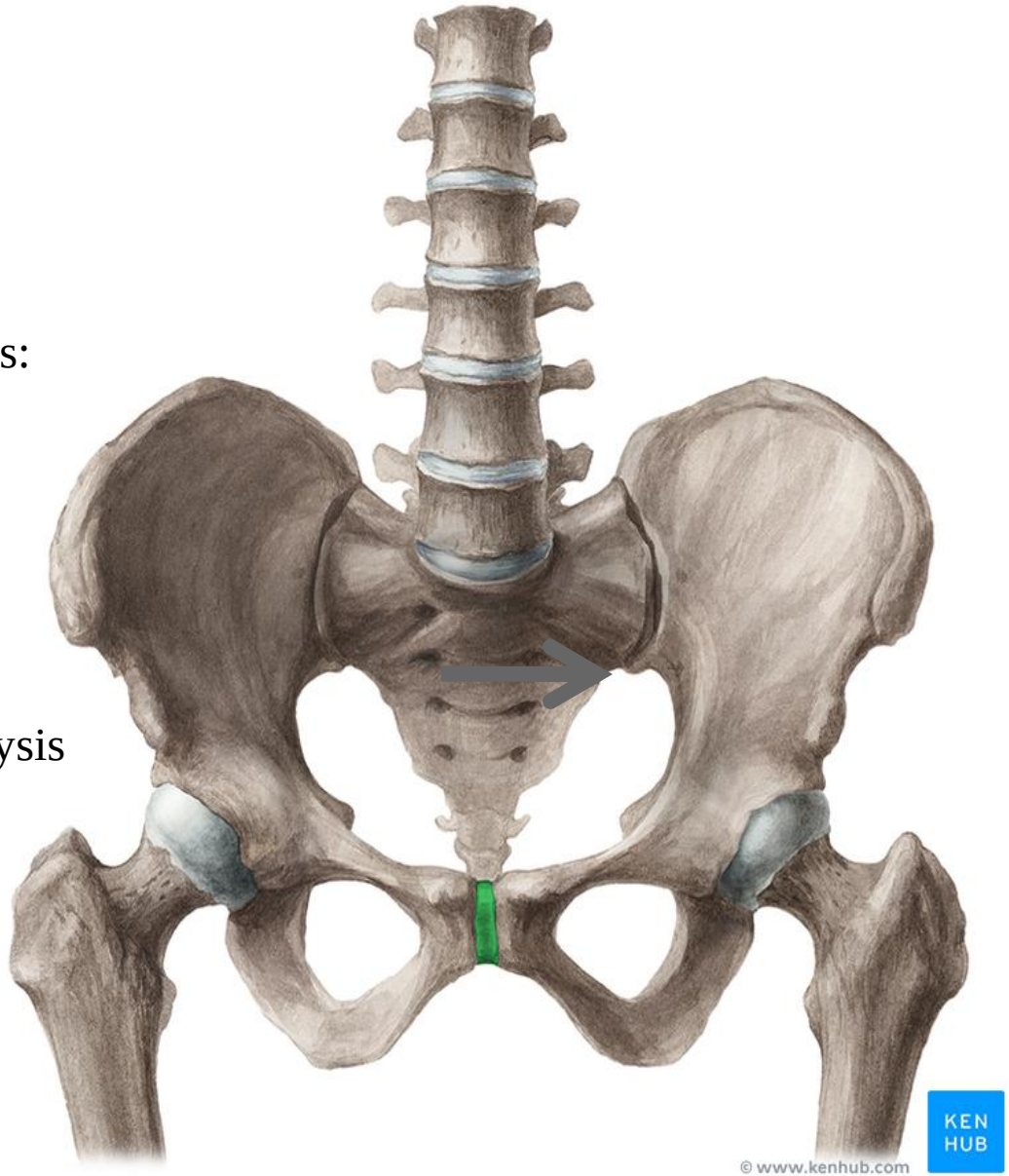
There are two types of cartilaginous joints:

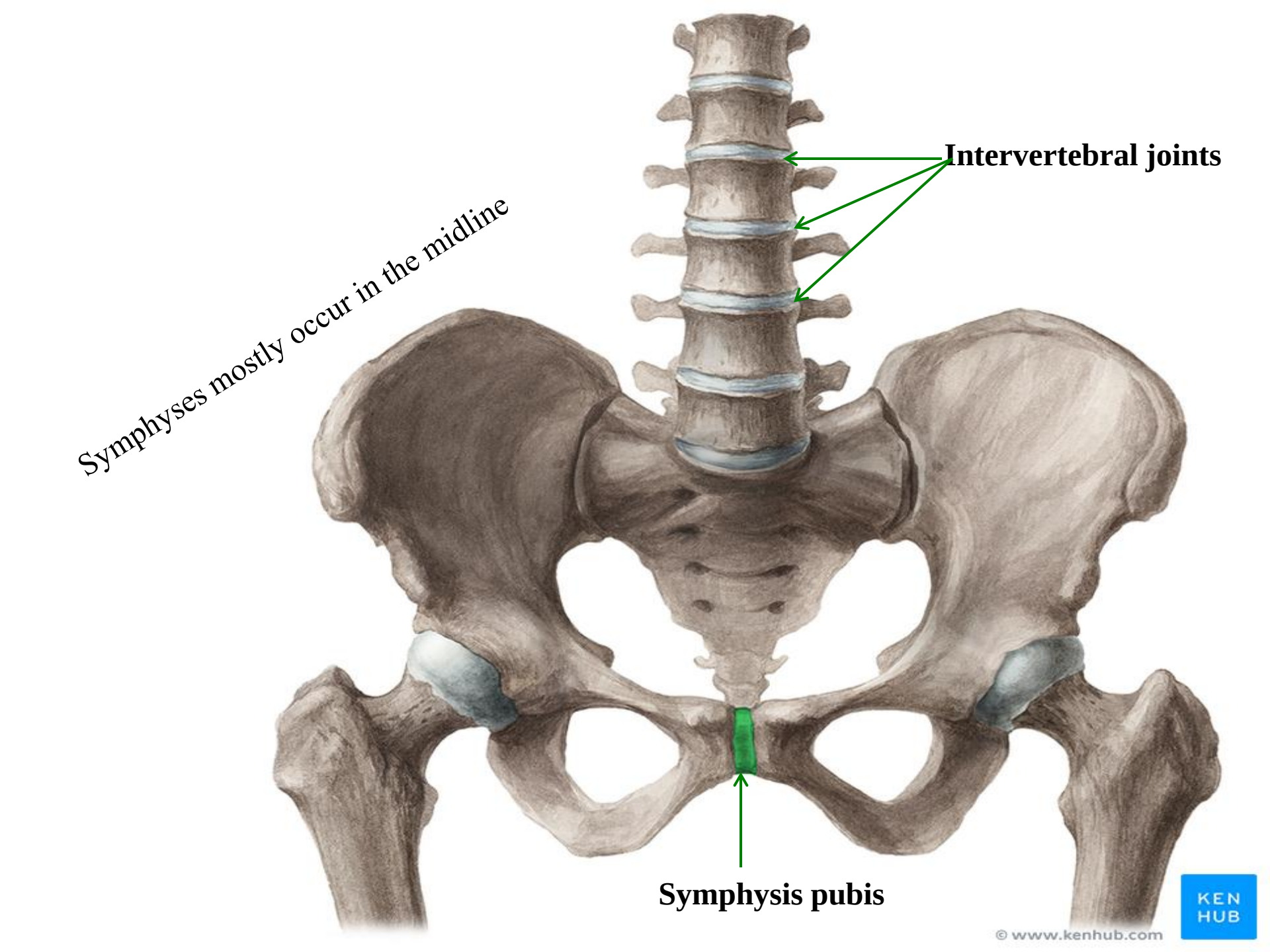
Synchondroses: growth plate

Hyaline cartilage

Symphyses: intervertebral joints, symphysis pubis

Fibrocartilage




Symphyses mostly occur in the midline
Intervertebral joints
Symphysis pubis
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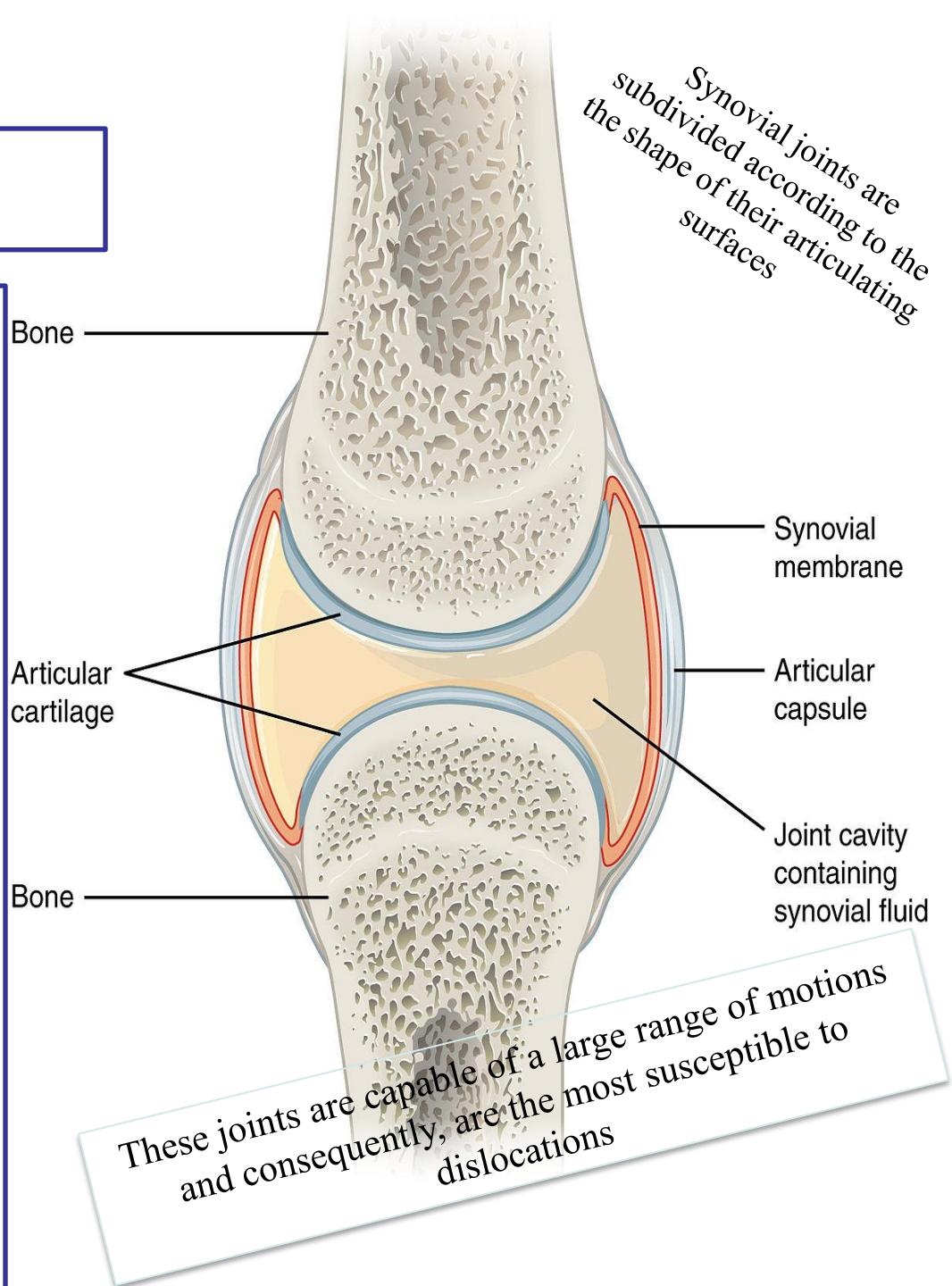
☆Synovial joints

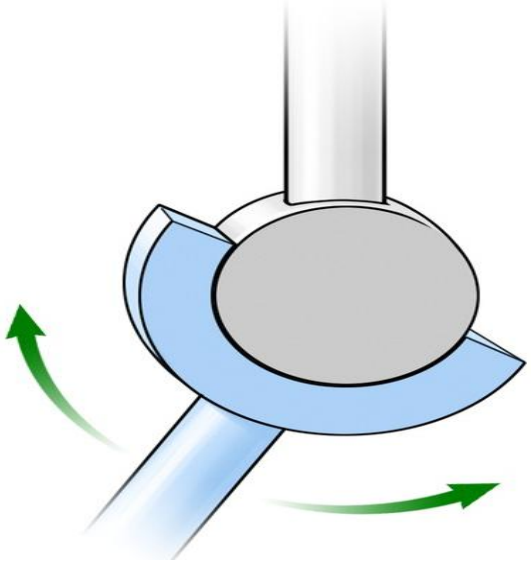
Synovial joints are most commonly found throughout the limbs.

In order for the joint to be classified as synovial:

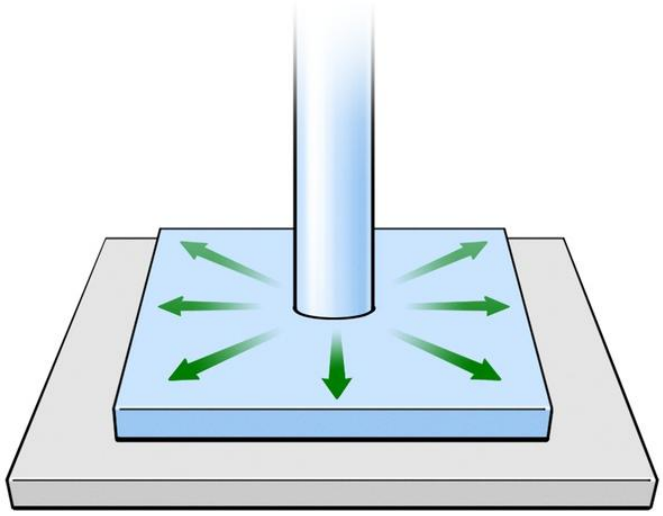
✓ Both adjacent bones participating in the joint must be lined with **hyaline cartilage (articular cartilage)**
✓ The joint is encompassed in a **capsule** that encases the joint cavity.
✓The interior of the capsule is lined with a **synovial membrane** that is responsible for producing and secreting **synovial fluid**
✓ **Synovial fluid** lubricates the joint, which aids in reducing the friction between the bones' ends as they articulate with each other
✓Further reinforcement of the capsule is provided by **ligaments**, **tendons** and **skeletal muscle**



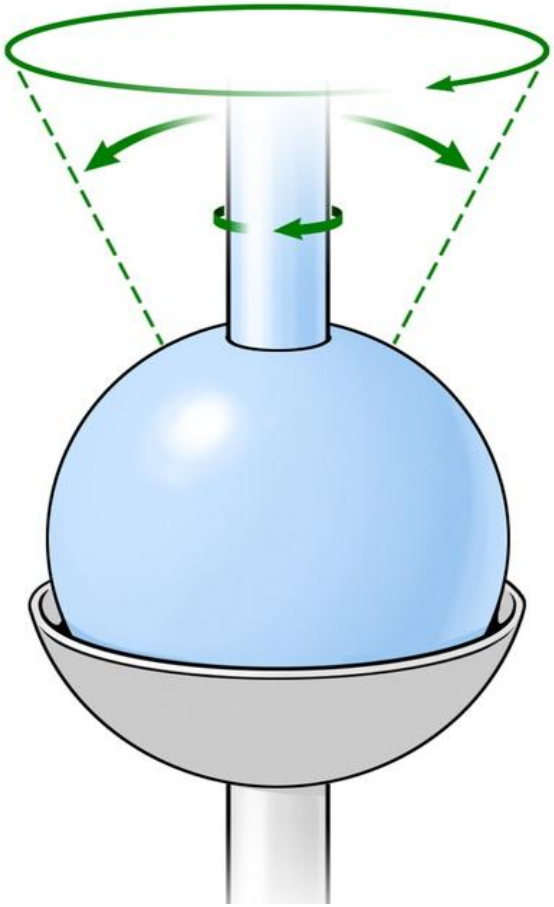
Synovial joints



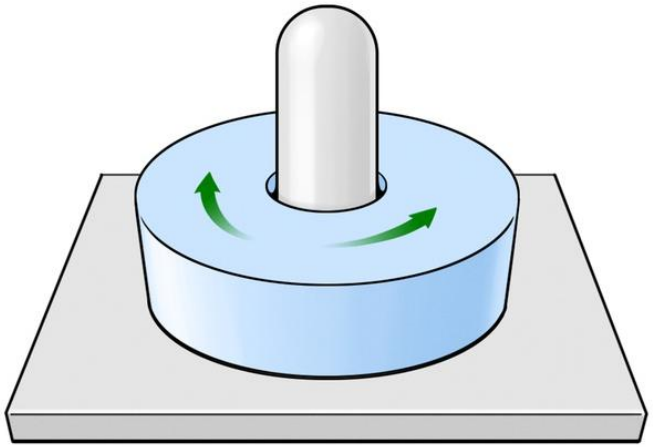
Hinge Joint
Example: elbow and knee joints



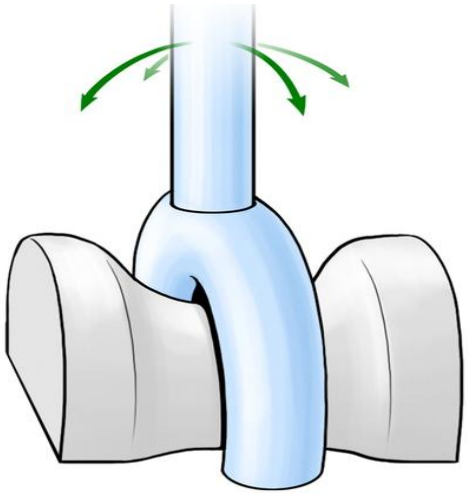
Gliding (plane) Joint



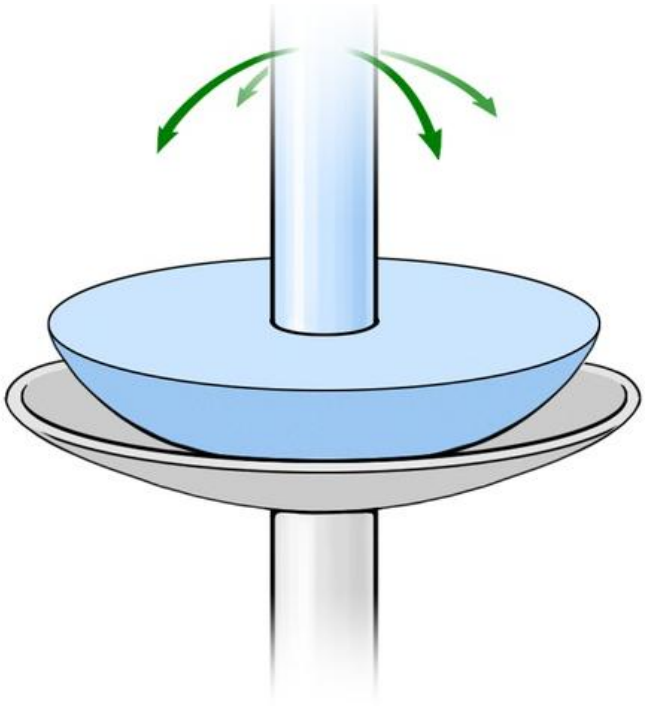
Ball and Socket Joint
Example: shoulder and hip joints



Pivot Joint
Example: atlanto-axial joint



Saddle Joint



Ellipsoid Joint:

Example: wrist joint