Histology

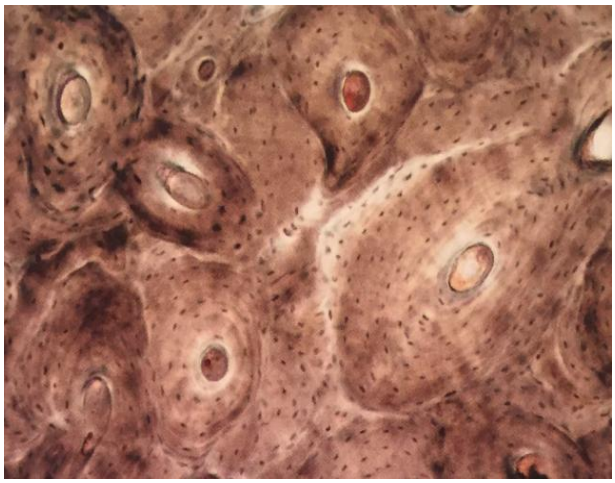
faculty of medicine - JU2015

Lecture 10

Bone – part 2

Rahaf AL-Qaryouti
Dr. HebaKalbouneh

#Lamellar bone= spongy bone + compact bone



- ✓ compact bone is composed of concentric lamellae (Osteons)
- ✓ spongy bone is composed of parallel lamellae
- ✓ in between lamellae are the bone cells (osteocytes)
- ✓ The outer cover is periosteum and the inner lining is endosteum

Bone Formation; Growth and Remodeling

Ossification (formation of bone)

- ➢ It starts in the pre-natal period (before birth)
  REM : post-natal means after birth
- ➢ The origin of bone is mesenchymal CT but not directly
- ➢ First, we need a tissue to form a model for the bone formation which could be **cartilage** or **fibrous c.t**
- ➢ We need a tissue that undergoes mitosis then becomes replaced by bone, then undergoes mitosis and becomes replaced by bone. And this is how the bone forms and grows
- ➢ Fetal skeleton is composed of two types of tissues: fibrous membrane or hyaline cartilage
  - Growth of bone within a fibrous membrane is called ***intramembranous ossification***
  - Growth of bone within a hyaline cartilage is ***endochondral ossification***

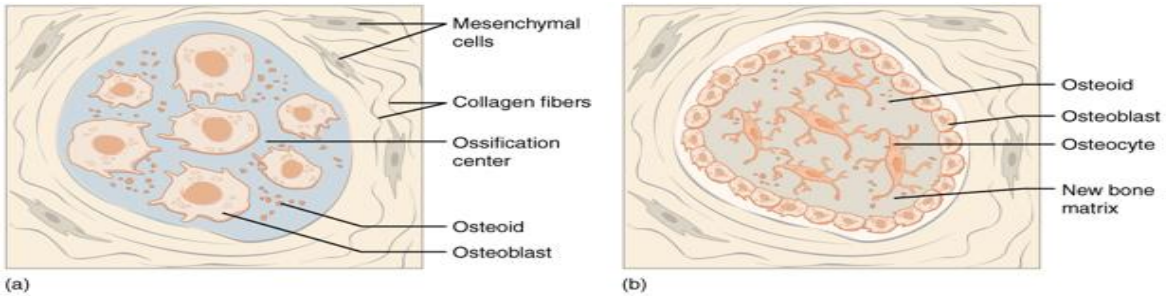
REM : Bone is classified according to its shape into: long, short, irregular, flat and sesamoid

- Long, short and irregular bones develop by ***endochondral ossification***

- ➢ Flat bones which are spongy bone sandwiched between two layers of compact bone are formed by intramembranous ossification

- In general , intramembranous ossification starts in the 8th week of development earlier than endochondral ossification which occurs in the 2nd month of development

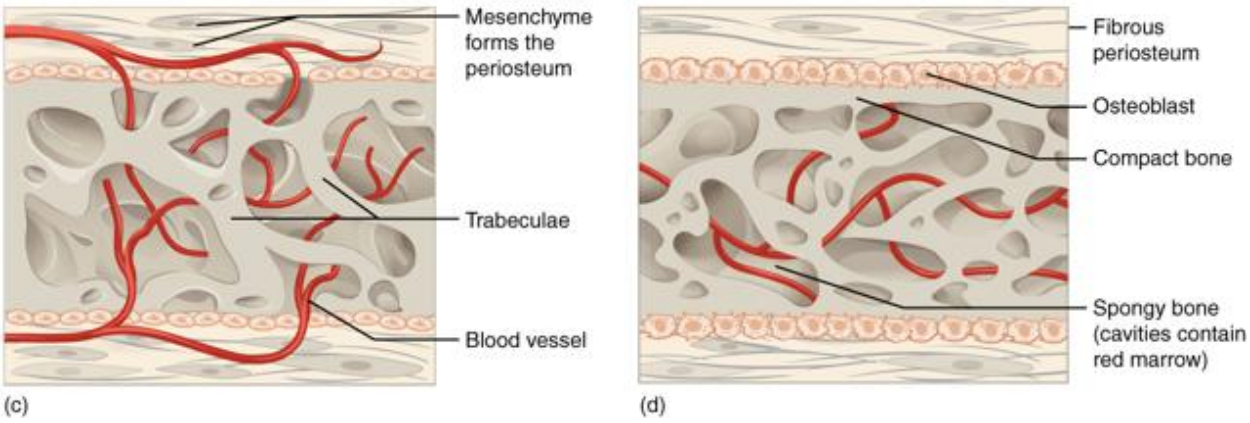
Intramembranous Ossification



- Formation of flat bone from fibrous membrane
- Fibrous membrane is composed of mesenchymal cells and ECM mainly fibers
- In order for the osteoblasts to synthesize bone, they need scaffold (hard surface)
- Some of these mesenchymal cells condense and differentiate into osteoblasts (synthesis of bone ECM) and form the ossification center

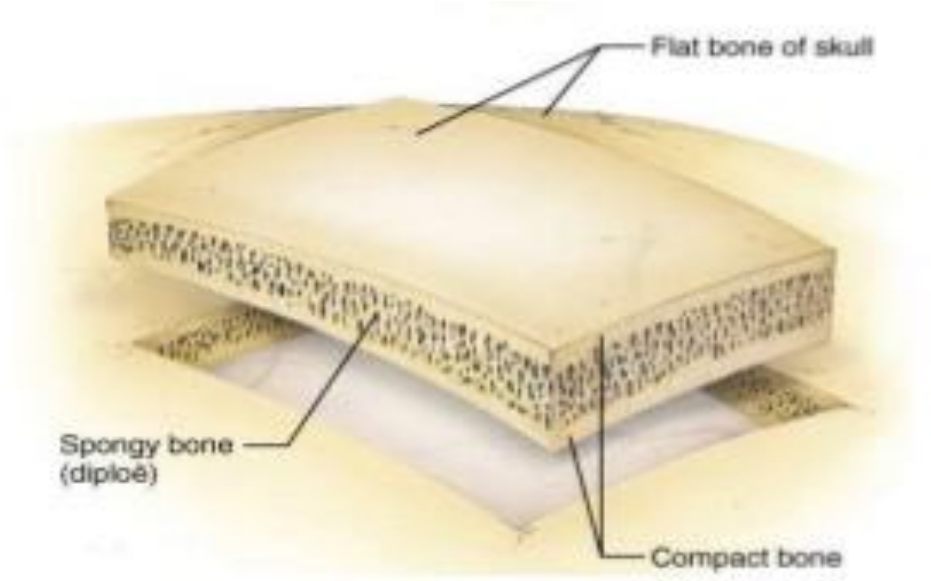
REM: ECM at the beginning is called osteoid and after calcification it is called the mineralized bone matrix

- The beginning of bone formation is called the <u>center of ossification</u>
- osteoblasts secrete osteoid (uncalcified bone matrix) then they calcify their matrix and then become entrapped within spaces or chambers called **lacunae**
- After the synthesis of ECM, these cells are called osteocytes
- Still we have osteoblasts on the edges (endosteum) in order to grow



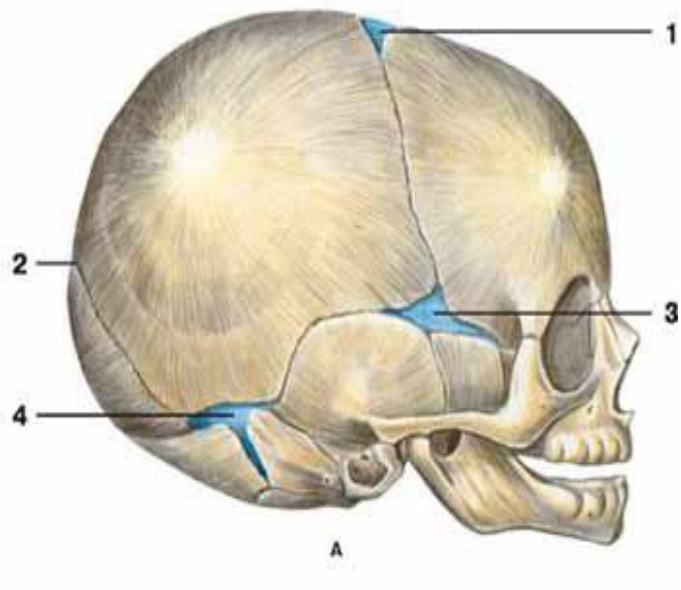
- These centers will fuse together to form the trabeculae of spongy bone surrounding the embryonic blood vessels that will differentiate into future red bone marrow

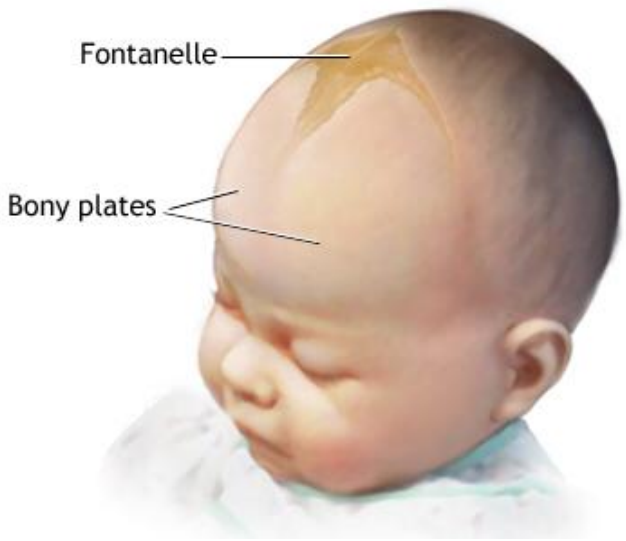
- Mesenchymal cells of the inner and outer edges will differentiate to form periosteum and endosteum



We know that flat bone is spongy bone covered by two layers of compact bone

- Osteoclasts will resorb the spongy bone at the outer and inner edges and the compact bone will be deposited by the osteoblasts until we have the final appearance of flat bone
- Still on the periosteum and endosteum we have osteoblasts in order for the bone to grow or thicken
- The skull is more than one bone connected by special immovable joints termed **sutures**

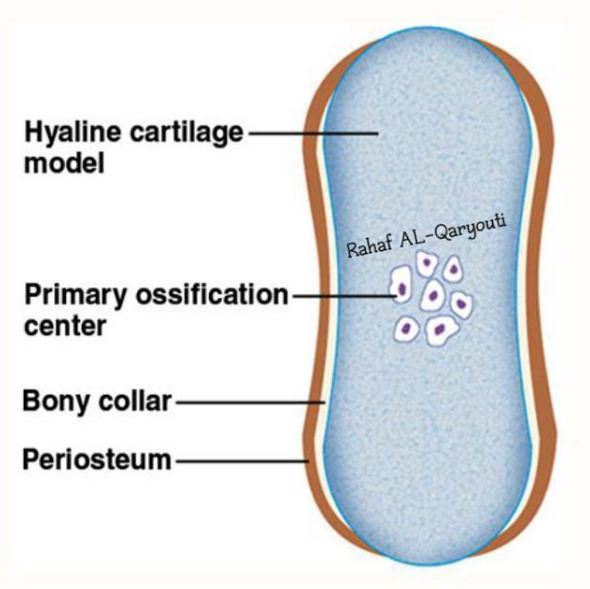




- At the time of birth, not all of fibrous membranes are replaced by bone yet
- Still there are spaces between bones filled with fibrous tissue and these areas are called soft spots or **fontanelles**
- Fontanelles are important to facilitate delivery and prevent the compression of baby's brain during delivery. also they give room for the baby's brain to grow especially in the 1st two years
- At the age of 2 years, fontanelles close completely

Endochondral Ossification

- Formation of bone within cartilage

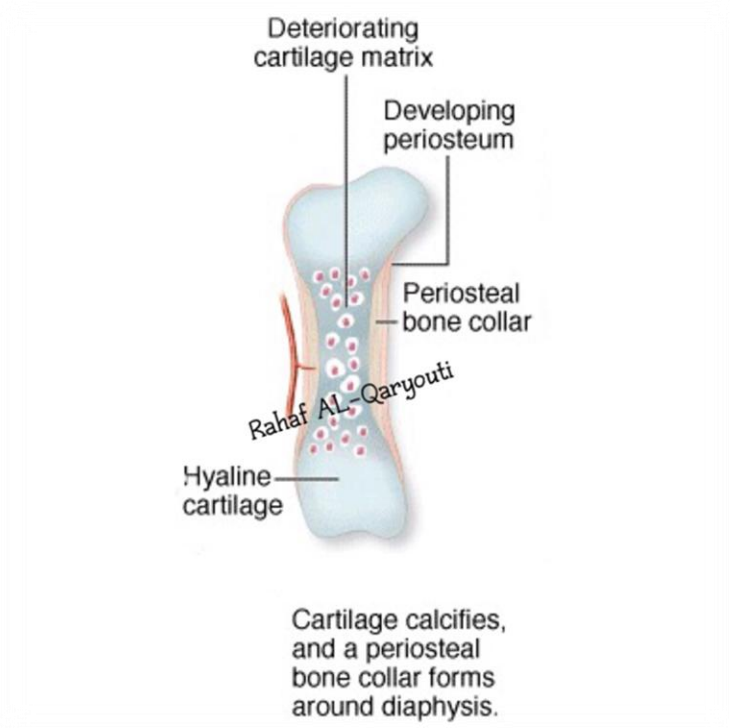


- We have hyaline cartilage model with the same shape of the future long bone (two epiphysis and diaphysis)

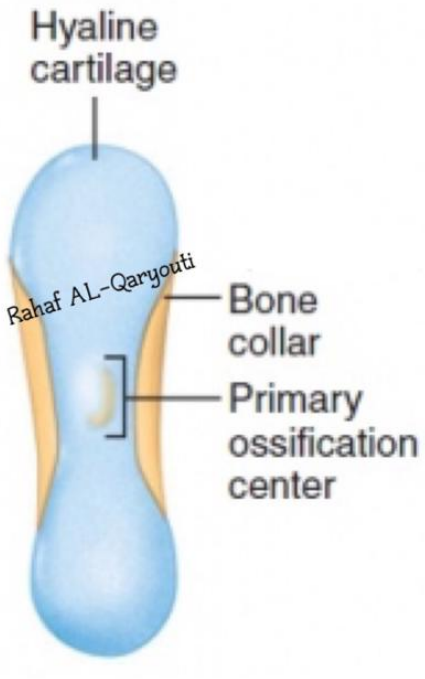
REM : perichondrium is composed of two layers: outer fibrous and inner cellular containing chondrogenic cells

- This perichondrium contains **osteochondrogenic cells** (they have the ability to differentiate into chondroblasts or osteoblasts)
- at the beginning of the 2nd month of fetal development, instead of giving chondrogenic cells, it gives **osteogenic cells**
- The perichondrium surrounding the diaphysis of this long bone will give rise to bone tissue.
- This will form a bony structure surrounding the diaphysis of the long bone and it's called **bone collar**

REM : cartilage is avascular and depends on perichondrium for diffusion of gases and nutrients



- When bone tissue is formed, neither oxygen nor nutrients will reach the cartilage cells at the middle so they will die and degenerate leaving behind spaces and cavities inside the middle of the diaphysis in a process called <u>cavitation of the bone</u>
- Chondrocytes don't die directly, they undergo gradual death
- In the beginning, when oxygen and nutrients are cut off from these cells, they become under stressful conditions (anaerobic condition)
- First reaction of these cells is to increase in size (**<u>hypertrophy)</u>**
- They start to accumulate inside their cytoplasm high amount of glycogen
- When these cells become larger, ECM will thin out.
- Then cells commit suicide, they secrete alkaline phosphatase enzyme which will calcifiy their matrix. By calcification of their ECM, chondroblasts isolate themselves completely from the surroundings, so they eventually die leaving behind cavities and calcified cartilage matrix.
- Blood vessels from outer fibrous periosteum will invade this cavity , it enters this cavity carrying oxygen, nutrients, osteoprogenitor cells (osteoblasts) and osteoclasts
- This blood vessel that comes from periosteum is called ***periosteal bud***

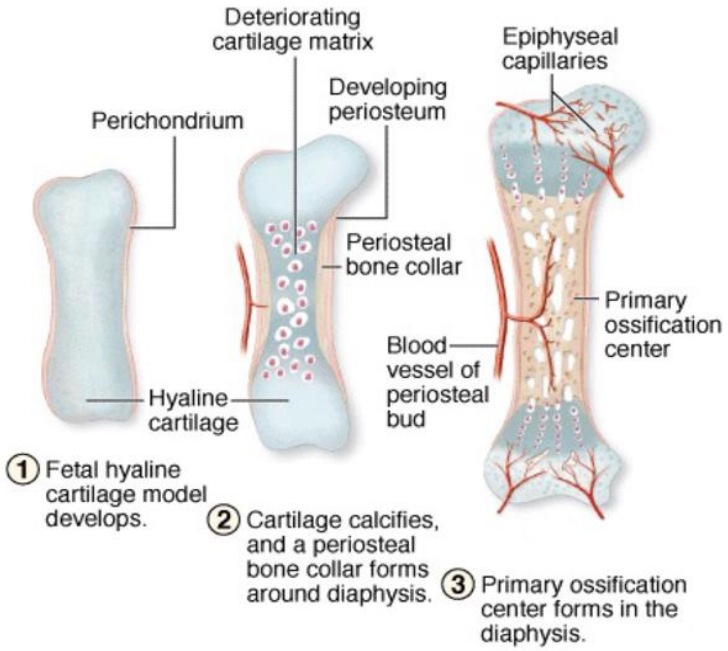


- osteoblasts will find calcified matrix (scaffold) and cavities. They adhere to the remnants calcified cartilage and start the synthesis of bone in the middle of the diaphysis
- This area at the center of the diaphysis is called primary center of ossification where the formation of bone starts
- **Importance of Bone Collar in this Process:**

1) Cuts the oxygen supply to chondroblasts
2) Provides stability during the cavitation process

- Anywhere else , cartilage will continue to grow
- Notice that the membrane is now called periosteum after the formation of bone collar

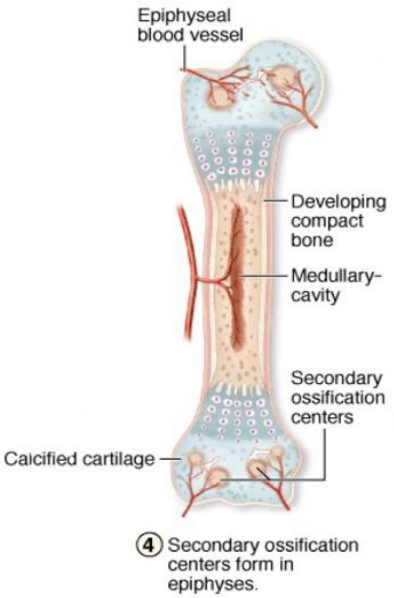
Primary Center of Ossification



REM: the diaphysis of long bone is mainly compact bone and in the center is the medullary canal

- Osteoclasts will resorb the bone in the middle and medullary canal is formed

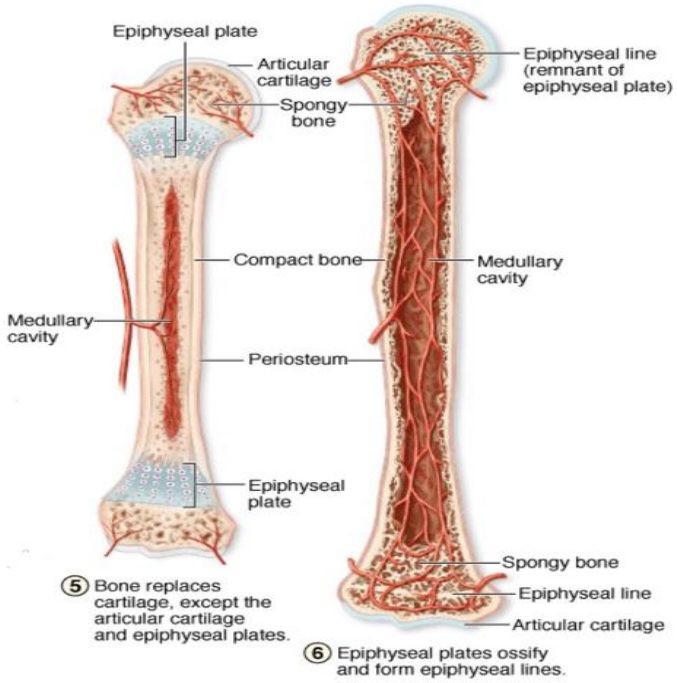
- The bone starts solid and it becomes a hollow structure



- Around the time of birth, another center of ossification will appear at the epiphysis, this is the ***Secondary Ossification Center***
- Not only one center of ossification, as in the proximal end of humerus we find three centers of ossification for head , greater tubercle and lesser tubercle
- Formation of bone in the secondary center of ossification is the same concept as in the primary center and the direction of growth is radially from inward to outward
- All the cartilaginous model is replaced by bone except in two places
    1. Articular cartilage for smooth movement of joints
    2. Epiphysial plate between epiphysis and diaphysis

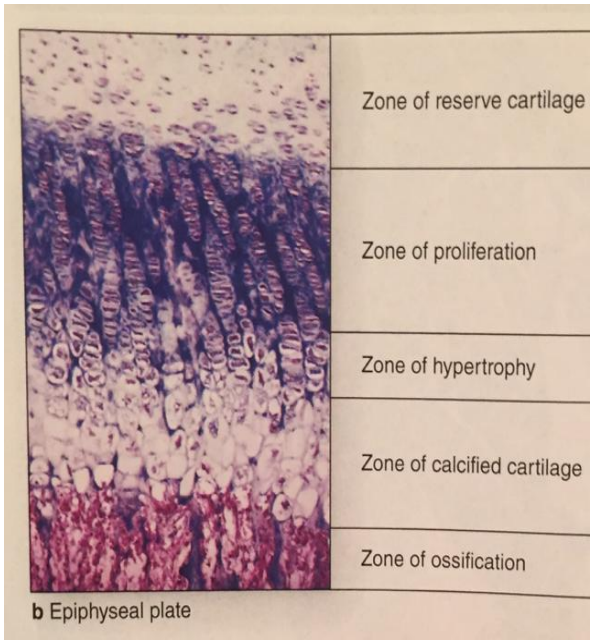
REM : ~As long as this plate is present, you can grow taller

~this plate is composed of hyaline cartilage which undergoes interstitial growth

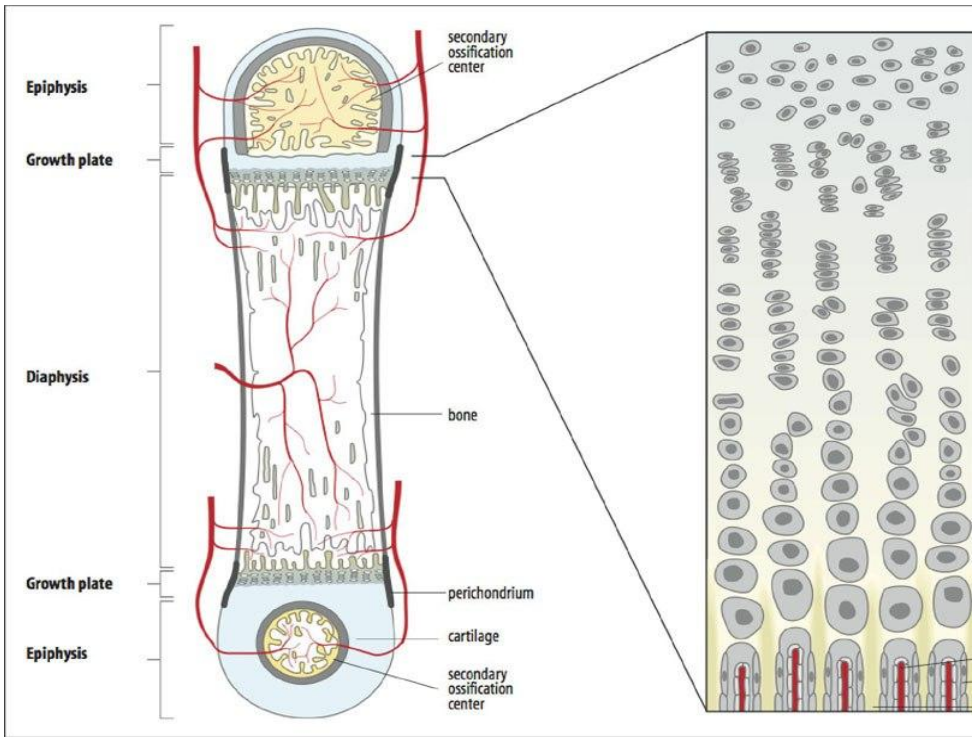


Histology of Epiphysial Plate

- ✓ Divided into five zones



These two zones are considered as one zone



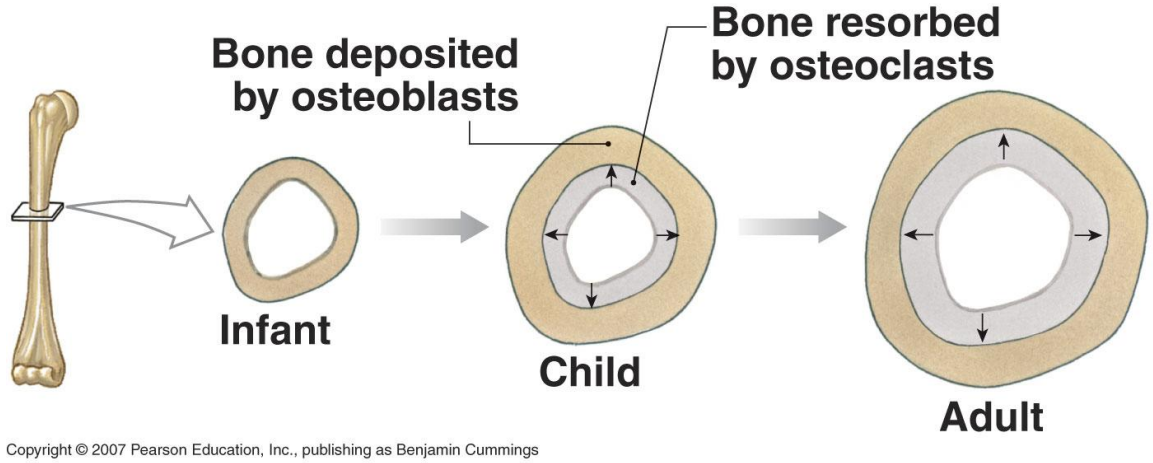
- ✓ At the most proximal, chondroblasts are located within lacunae. It is called *Resting Zone* where cells don't undergo any changes (normal resting cartilage)

REM : Isogenous group of cells secret matrix and become separated from each other---interstitial growth

- ✓ In the next zone, cells undergo mitosis (proliferation), but instead of forming isogenous groups they form columns because these cells are responsible for longitudinal bone growth. This zone is called *Growth/ proliferation Zone*
- ✓ Getting closer to bone collar , cells start to die (less oxygen and nutrients reaching cells)
- ✓ They respond by increasing size so the matrix thins out
- ✓ This zone is called *Hypertrophy Zone*
- ✓ 2nd response is to calcify their matrix by secreting certain enzyme in order to deposit minerals inside the matrix so this zone is called *calcification zone* (we consider hypertrophy and calcification zones as the same zone)
- ✓ Now these cells completely die leaving behind spaces and the calcified matrix of the cartilage. Blood vessels invade these cavities and Osteoblasts adhere to the calcified matrix and start bone synthesis. This zone is called *Zone of Ossification*

#ECM of cartilage is **basophilic** and you can't see cells (calcified matrix) while ECM of bone is **acidophilic** and you can see cells

- Lengthening stops at the end of adolescence (18 in females & 21 in males) when the chondrocytes stop mitosis
- In general, these cells are under the control of growth hormone
- That is the longitudinal growth of bones. Bones also thicken
- Periosteum and endosteum contain osteogenic cells (osteoblasts) and osteoclasts
- Osteoblasts synthesize more bone on periosteum and osteoclasts resorb bone from the endosteum. That means deposition of bone on the outer surface of the bone and at the same time bone resorbtion from inner surface of bone, in order to keep the correct proportions of bone parts
- Note the thickening of bone is accompanied by widening of the marrow canal and cavities
- This is important because if it was only bone deposition, this will cause narrowing of the medullary canal which contains bone marrow



- this would result in less RBCs and WBCs production, which produces anemia and the patient is more prone to infections
- Osteoblastic activity is always accompanied by osteoclastic activity in order to keep the correct proportion between different parts of bone
- This is called ***Bone Remodeling***

Refer to

http://highered.mheducation.com/sites/0072495855/student_view0/chapter6/animation__bone_growth_in_width.html

- Osteoblasts on the periosteum synthesize bone surrounding blood vessels that means forming a groove around the blood vessel then it is transferred into tunnel and then the lining of this tunnel becomes endosteum which contains osteoblasts that will form the osteon of Havarsian's system

Bone Remodeling

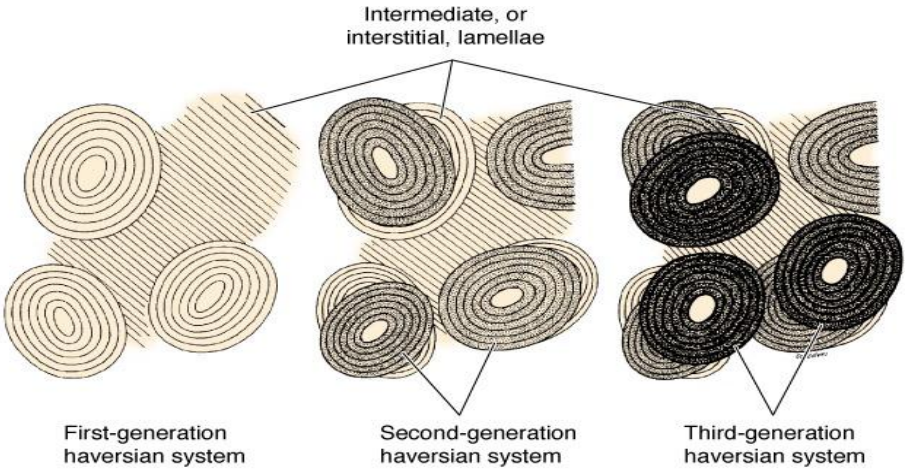
- Bone deposition by osteoblasts and resorption by osteoclasts
- It is important for:
    a. Reshaping of skeleton during growth
    b. Maintaining Ca^{+2} level in the blood
    c. Repairing micro fractures that occur in everyday activities
    ^^ It is not necessarily that all fractures need medical attention

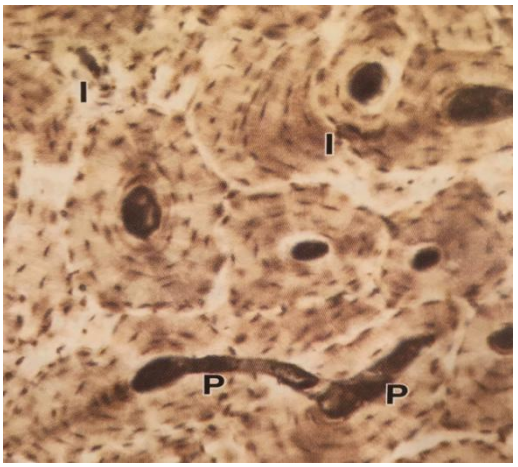
Refer to
http://depts.washington.edu/bonebio/ASBMRed/growth/newlongbone2.swf
http://depts.washington.edu/bonebio/ASBMRed/growth/newBMUbu.swf

When there is a microfracture, the osteoclasts eat up the bone and the osteoblasts synthesize new bone

- Every day stresses can produce mini-fractures of bone so the bone repairs itself
- Growth of bone in length is by the activity of epiphysial plate
- It is not only growth, it is also accompanied by osteoclastic activity in order to reshape bone during growth

- The interstitial lamellae is in between osteons of compact bone
- Remember: the compact bone is composed of osteons, and the bone in between these osteons is called interstitial lamellae and these interstitial lamellae represent the old Haversian systems. Osteoclasts drill through the bone (forming tunnels) , then oseoblasts build bone toward the center of these tunnels





- In histological sections of compact bone, more than one generation of osteons can be seen
- Bone is a dynamic structure due to: osteoblastic activity (building) + osteoclastic activity (cutting)
- 5% of our bone is replaced each week
- In general, spongy bone is recycled faster than compact bone
  ~ Every four years, all your spongy bone is completely recycled and renewed
  ~ Compact bone is renewed after ten years

(osteoblasts, osteoclasts and chondrocytes) :

- Are controlled by many hormones:
    1) Growth hormone >>increases bone deposition
    2) Thyroid
    3) 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

- Any imbalance in these hormones will result in abnormal skeletal growth
- Any excessive production of hormones will result in medical condition
  >over production of growth hormone results in gigantism

  >decline in production of growth hormone results in dwarfism

- 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 result in formation of bony prominences like ridge, tubercle…..
- Principle inside the bone : " what you don't use, you lose "
  >>more exercise means more deposition, the stresses applied to bones during exercise are essential to maintaining bone strength and bone mass

Clinical Application

Osteoporosis

- Osteoporosis causes bones to become weak and brittle — so brittle that a fall or even mild stresses can cause a fracture
- More osteoclast activity resulting in more spaces inside bone
- Is very common in females. Estrogen prevents osteoclastic activity during reproductive time. But after menupause, osteoclasts are more active and more bone resorbtion takes place

#First bone deposited in the body during growth or repair is called <u>primary (woven) bone</u>

- Temporary, replaced by secondary bone.
- Collagen fibres are irregularly arranged (appear woven).
- Lower mineral content.
- Easily penetrated by x-ray.
- Number of osteocytes is relatively high

<u>Secondary Bone Tissue</u> (lamellar/mature)

- Collagen fibers arranged in parallel or concentric lamellae.
- Concentric lamella surround a canal containing vessels and nerves = ***<u>haversian system</u>*** = ***<u>osteon</u>***.
- Osteons are lined with endosteum.
- Osteons are connected together and to the endo-or-periosteum by Volkmann's canal.

<u>Joints</u>

- Places where bones meet or articulate allowing movement of skeleton
- Arthrosis means: joint
- Classification is according to the degree of movement or the type of tissue between the two articulating bones

1) Diarthoses : freely mobile (synovial joints)
2) Synarthroses : with limited or no movement

- Types of synarthroses:

~ Synostosis: is fusion of two bones (bones are joined by bone tissue). Ex. Sutures of the skull

~ Syndesmosis: bones are joined by connective tissue. ex. interosseous membrane between radius and ulna

~ Symphysis: bones are joined by fibrocartilage, ex. pubic symphysis

~ Chondrosis: bones are joined by hyaline cartilage. Ex. growth plate

Recommended link:

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