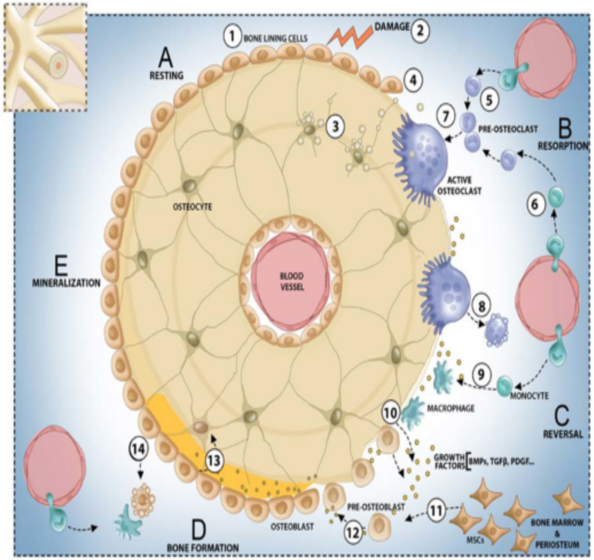


Physiology of Bone

Dr. Aida Korish, PhD

Physiology Department, KSU

Objectives

By the end of the lecture you will be able to:

1- Define bone and differentiate cortical & trabecular bone (sites and function of each).

2- Identify the bone cells and the function of each.

3- Define bone remodelling and explain the mechanism of bone formation.

4-State the normal levels of ca++ in the ECF and its relation to PO4.

5- Interpret the importance of the exchangeable calcium.

6- Discuss the effect of different hormones on calcium homeostasis.

7- Define osteoporosis and state its causes.

Dr.Aida Korish akorish@ksu.edu.sa

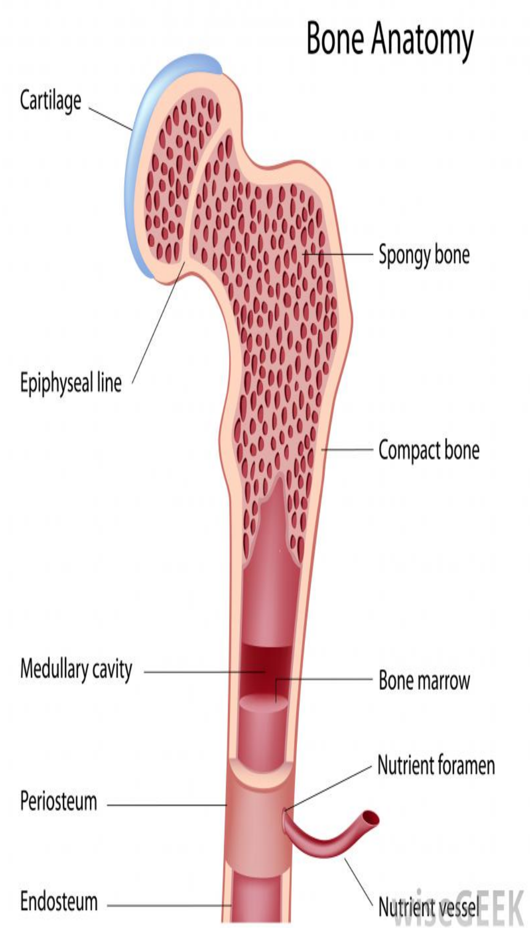
Physiology of Bone

Bone is a special form of connective tissue.

It is well vascularized with total blood flow of 200–400 mL/min in adult humans.

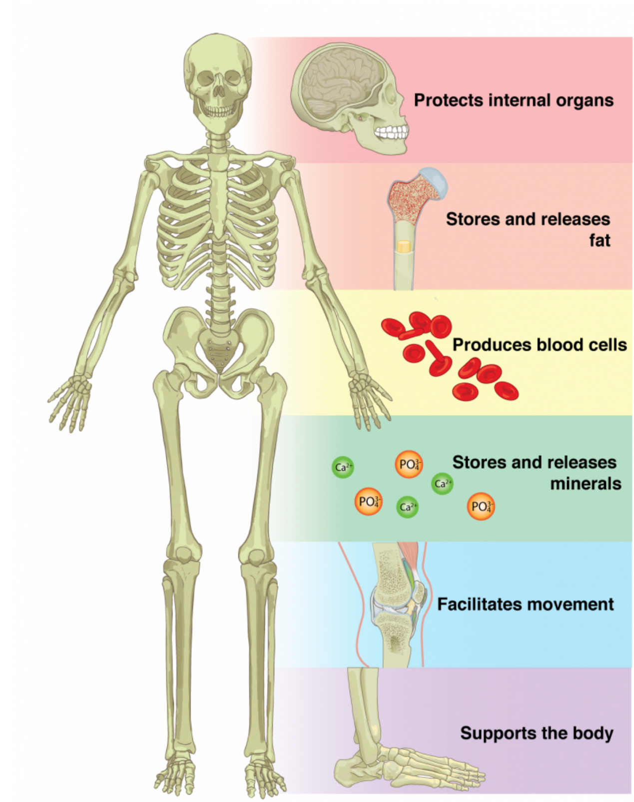
The ends of each long bone **(epiphyses)** are separated from the shaft of the bone by a plate of actively proliferating cartilage, the **epiphyseal plate.**

Linear bone growth can occur as long as the epiphyses are separated from the shaft of the bone, but such growth ceases after the epiphyses unite with the shaft **(epiphyseal closure)** at puberty.

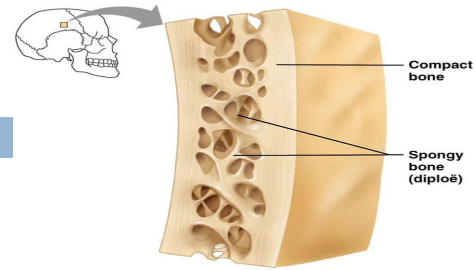


Functions of bone

- Is involved in the overall Ca^{++} and PO_4^{-} homeostasis.
- Protects the vital organs.
- Permits locomotion and support against gravity.
- Contains the bone marrow (blood cells formation).

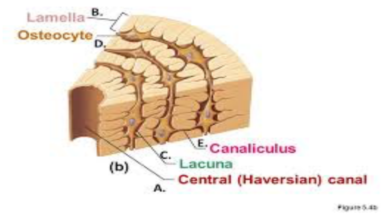


Types and structure of bone

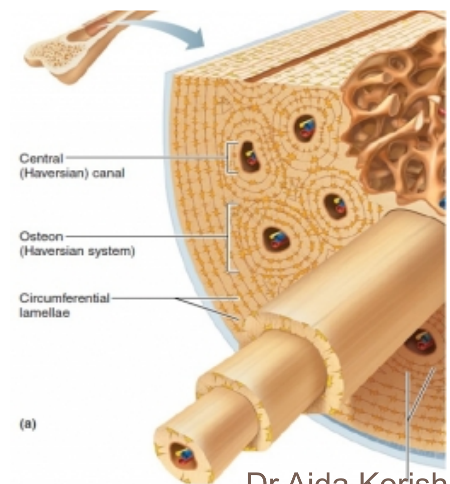


Compact or **cortical bone:** in the outer layer of most bones is (80%) of the bones in the body.

Trabecular or **spongy bone** inside the cortical bone, is 20% of the body bone.



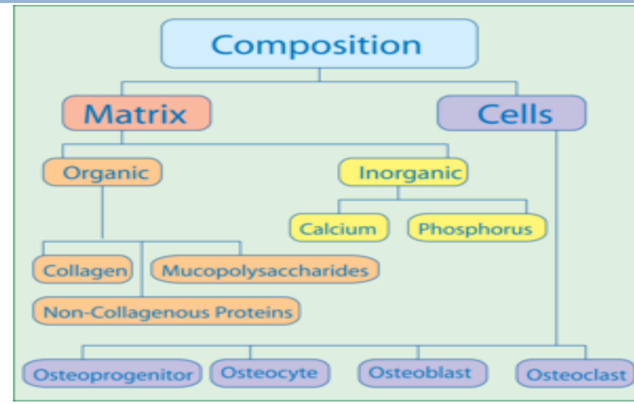
- In compact bone, the bone cells lie in lacunae. They receive nutrients by way of canaliculi from **haversian canals** vessels.
- Collagen is arranged in concentric layers, around the haversian canals forming cylinders called **osteons** or **haversian systems.**
- Trabecular bone is made up of spicules or plates. Nutrients diffuse from bone extracellular



Dr.Aida Korish
akorish@ksu.edu.sa

Composition of Compact Bone

A- Matrix



(30%) is organic Matrix : composed of

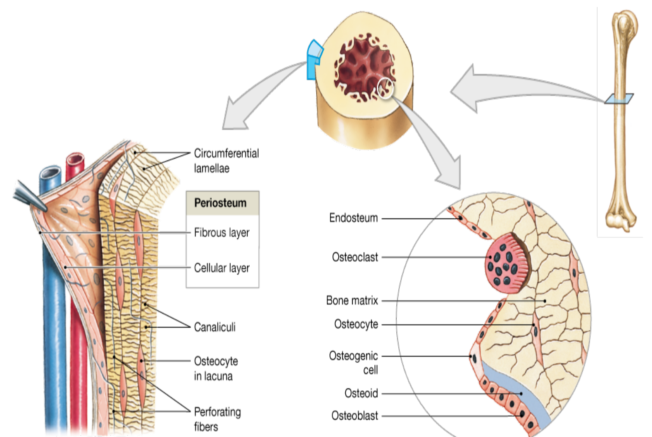
a-Collagen fibers 90-95%: extend primarily along the lines of tensional force and give bone its powerful tensile strength.

b- Ground substance 5-10%:of ECF and proteoglycans (chondrotin sulphate &hayluronic acid)

(70%) is inorganic matrix (bone salts) :

- **Crystalline salts of Ca++ & PO4 (Hydroxyapatite) the Ca/P ratio is 1.3-2).**
- **Mg+, Na+, K+, Carbonate ions are also present.**

NB: newly formed bone have a considerably higher percentage of organic matrix in relation to salts.



a The periosteum contains outer (fibrous) and inner (cellular) layers. Collagen fibers of the periosteum are continuous with those of the bone, adjacent joint capsules, and attached tendons and ligaments.

b The endosteum is an incomplete cellular layer containing osteoblasts, osteogenic cells, and osteoclasts.

B- Bone cells

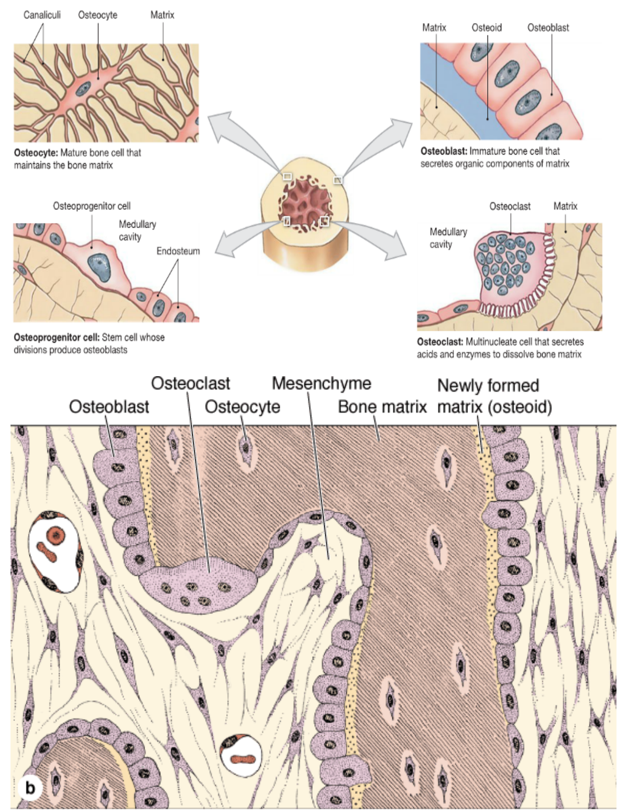
Osteoblasts are the bone forming cells that secrete collagen forming a matrix around themselves which then calcifies.

Osteoblasts regulate Ca and Phosphate concentration in bone fluid.

When the osteoblasts got surrounded by osteoid, they are called **Osteocytes** and send processes into the canaliculi that ramify throughout the bone.

Osteoclasts are multinuclear cells that erode and resorb previously formed bone. They phagocytose bone, digesting it in their cytoplasm.

Figure 6–3 Types of Bone Cells.



Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition:* http://www.accessmedicine.com

Mechanism of Bone Calcification.

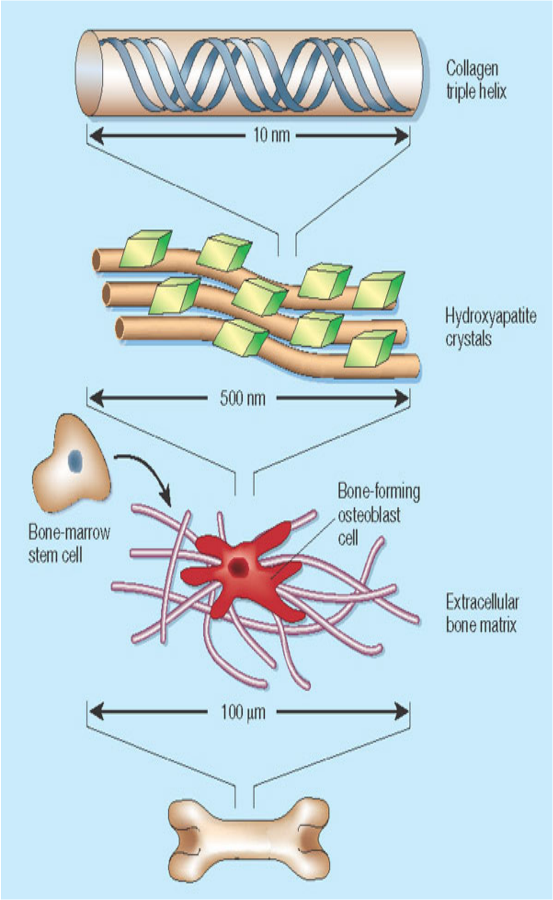
Osteoblasts secrete *collagen* (monomers) and *ground substance* (proteoglycans).

The collagen monomers polymerize to collagen fibers.

The resultant tissue becomes ***osteoid***, a cartilage-like material differing from cartilage in that calcium salts readily precipitate in it.

Osteoblasts become entrapped in the osteoid and are now called ***osteocytes***.

After the osteoid is formed, calcium salts begin to precipitate on the collagen fibers



Cont.. Mechanism of Bone calcification

- The mechanism that causes calcium salts to be deposited in the osteoid is not fully understood,
- The regulation of this process depend to a great extent on pyrophosphate, which inhibits hydroxyapatite crystallization and calcification of the bone.
- The level of pyrophosphate, in turn, is regulated by the **Tissue nonspecifc alkaline phosphatase (TNAP),** which breaks down pyrophosphate, TNAP is secreted by the osteoblasts into the osteoid to neutralize the pyrophosphate, and once the pyrophosphate has been neutralized, the natural affinity of the collagen fibers for calcium salts causes the hydroxyapatite crystallization.

Precipitation of Calcium in Nonosseous Tissues Under Abnormal Conditions.

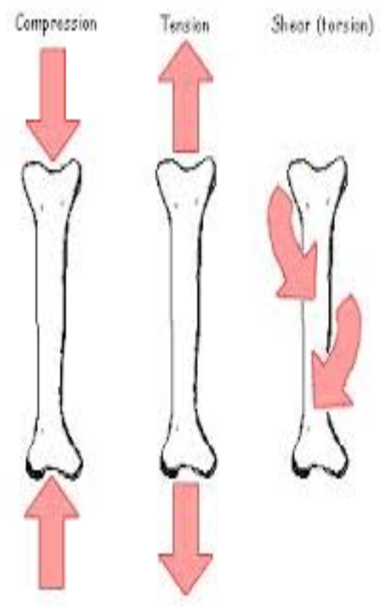
- Hydroxyapetite or Calcium salts do not precipitate in plasma, ECF or normal tissues (EXCEPT bone) despite the high levels of Ca & P ions due to the presence of the inhibitor factor called ***pyrophosphate.***
- under abnormal conditions, they can precipitate e.g
- In arterial walls in arteriosclerosis and cause the arteries to become bonelike tubes.
- In degenerating tissues or in old blood clots.

in these instances, pyrophosphate disappear from the tissues, thereby allowing precipitation.

Tensile and Compressional Strength of Bone

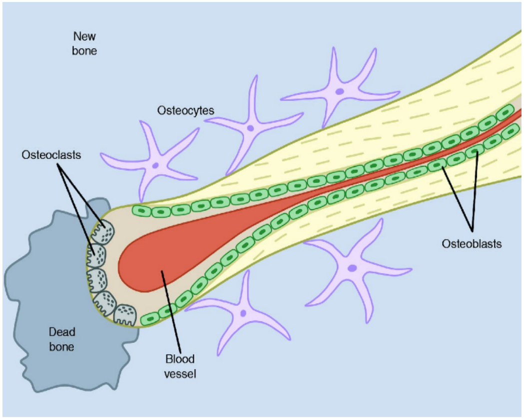
The collagen fibers of bone, like those of tendons, have great tensile strength, whereas the calcium salts have great compressional strength.

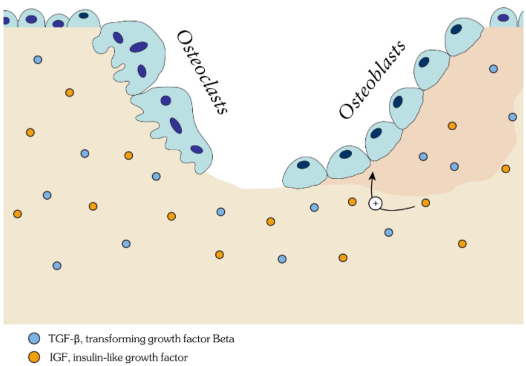
These combined properties plus the degree of bondage between the collagen fibers and the crystals provide a bony structure that has both extreme tensile strength and extreme compressional strength.



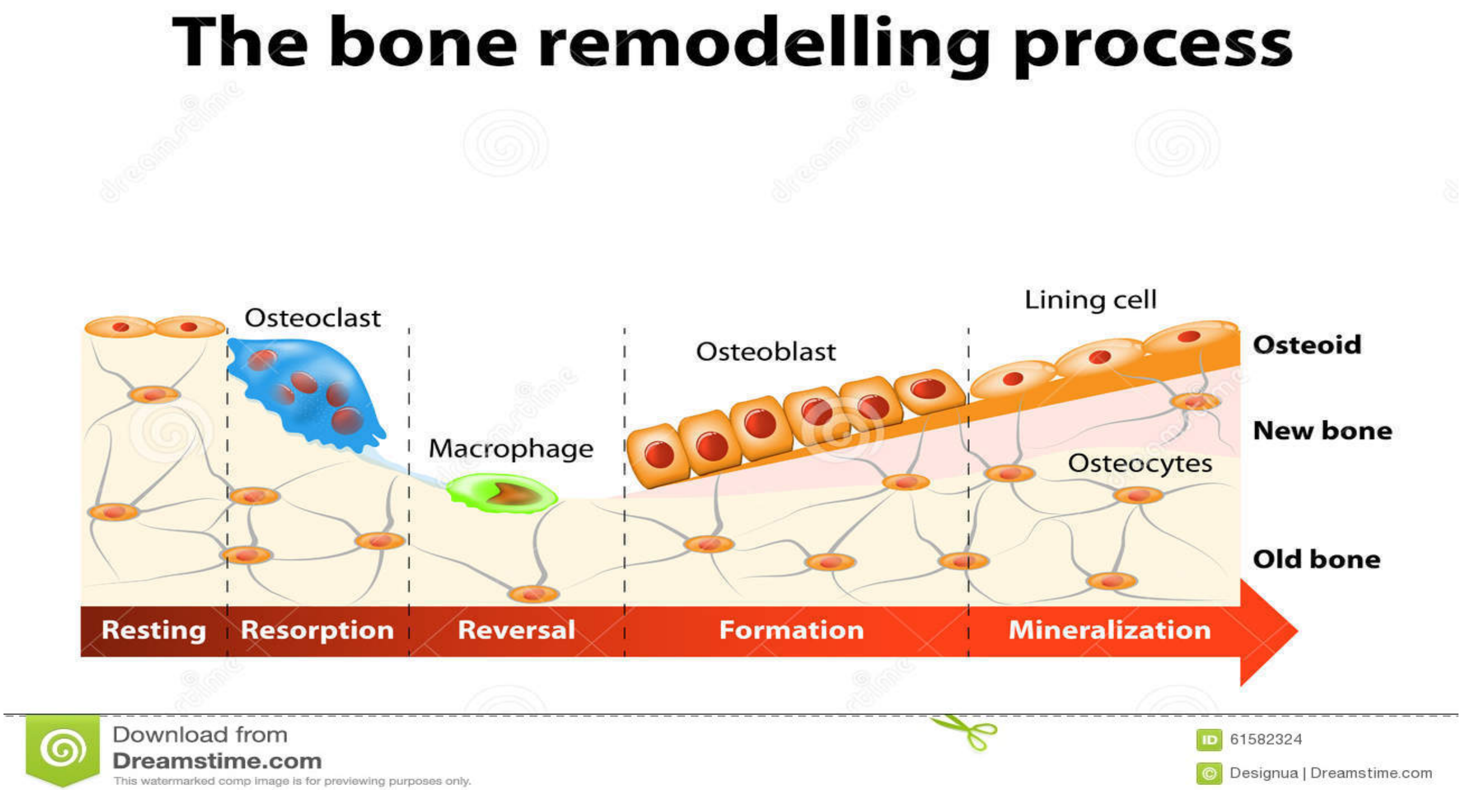
Deposition and Absorption of Bone
Remodeling of Bone

- Bone is continually deposited by ***osteoblasts***, and absorbed where *osteoclasts* are active.
- Osteoblasts are found on the outer surfaces of the bones and in the bone cavities.
- A small amount of osteoblastic activity occurs on about 4% of all bone surfaces at any given time in an adult), so that at least some new bone is being formed constantly.
- The renewal rate is about 4% per year for compact bone and 20% per year for trabecular bone.





Bone remodeling



Cont.….Bone resorption

0

Osteoclasts are large phagocytic multinucleated cells

They are normally active on less than 1% of the bone surfaces of an adult.

The osteoclasts secrete two types of substances:

proteolytic enzymes from the lysosomes

several acids from the mitochondria and secretory vesicles.

The enzymes dissolve the organic matrix, and the acids cause solution of the bone salts.

The osteoclastic cells also phagocytose minute particles of bone matrix and crystals, dissolute them and release the products into the blood.

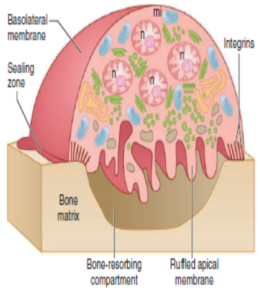
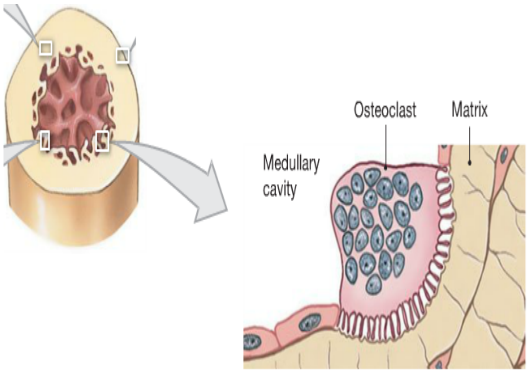


FIGURE 21–10 **Osteoclast resorbing bone.** The edges of the cell are tightly sealed to bone, permitting secretion of acid from the ruffled apical membrane and consequent erosion of the bone underneath the cell. Note the multiple nuclei (n) and mitochondria (mi). (Used with permission of R. Baron.)



Osteoclast: Multinucleate cell that secretes acids and enzymes to dissolve bone matrix

Importance of Continual Bone Remodeling

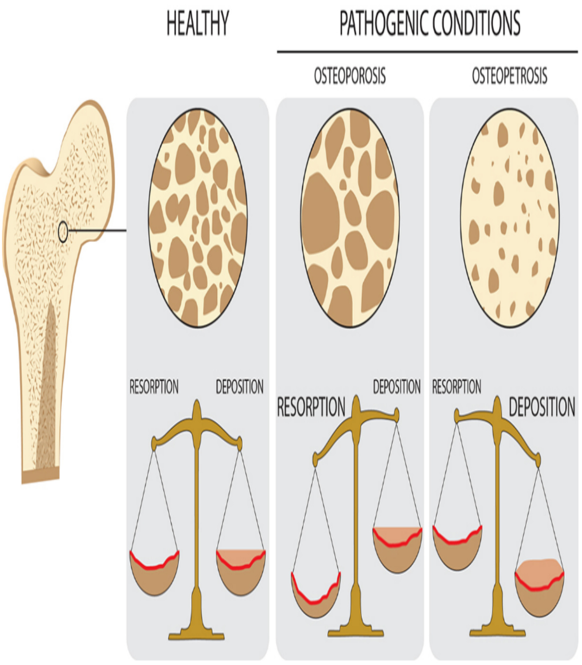
0

1- **Bone adjusts its strength** in proportion to the degree of **bone stress** and it thicken when subjected to heavy loads.

2- **The shape of the bone** can be rearranged **for proper support** of mechanical forces.

3- Because **old bone** becomes relatively brittle and weak, new organic matrix is needed **to maintain the normal toughness** of bone .

The **bones of children are less brittle** due to more remodeling in the children.



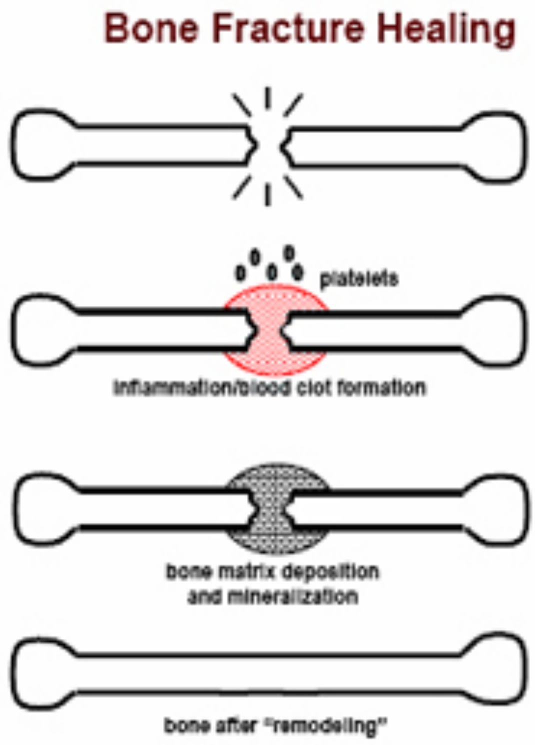
Control of the Rate of Bone Deposition by Bone “Stress”

- Bone is **deposited** in proportion to the **load** that it must carry.
- Continual **physical stress** stimulates osteoblastic **deposition** and **calcification** of bone.
- The bones of **athletes** become considerably **heavier** than those of non athletes. Also, the bone of the leg in the cast becomes thin and up to 30 % decalcified within a few weeks.
- **Bone stress** also determines the **shape of bones** under certain circumstances. (e.g. Healing of fractures may start angulated in children then become straight).

Dr.Aida Korish akorish@ksu.edu.sa

Repair of a Fracture Activates Osteoblasts

- **Fracture** of a bone activates all the periosteal and intraosseous **osteoblasts** involved in the break.
- Large numbers of new osteoblasts are formed from ***osteoprogenitor cells***, which are bone stem cells in the surface tissue lining bone, called the "bone membrane.
- Shortly a large bulge of osteoblastic tissue and new organic bone matrix, develops between the two broken bone ends followed shortly by the deposition of calcium salts. This is called a ***callus***.



Calcium Exchange Between Bone and ECF

- The bone contains a type of *exchangeable* calcium that is always in equilibrium with the Ca^{++} ions in the ECF
- It normally amounts to about (0.4-1%) of the total bone calcium.
- This calcium is a form of readily mobilizable salt such as dicalcium phosphate ($CaHPO_4$) and other amorphous calcium salts.
- The importance of exchangeable calcium is that it provides a rapid *buffering* mechanism to keep the Ca^{++} ions concentration in ECF from rising to excessive levels or falling to very low levels under transient conditions of excess or decreased availability of calcium.

Body Calcium levels

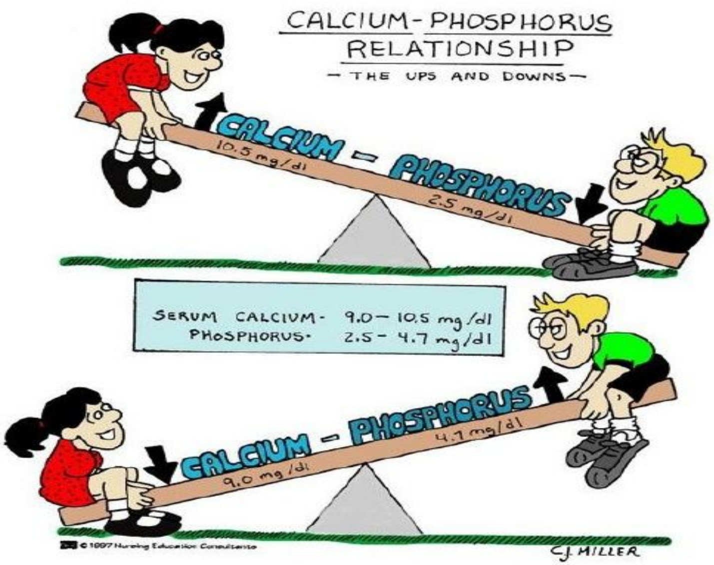
1.5% of body weight is Calcium,
about 1100 -1300 g.
99% is in the skeleton
Plasma calcium level: (9 -11 mg/dl) average 9.4 mg/dl

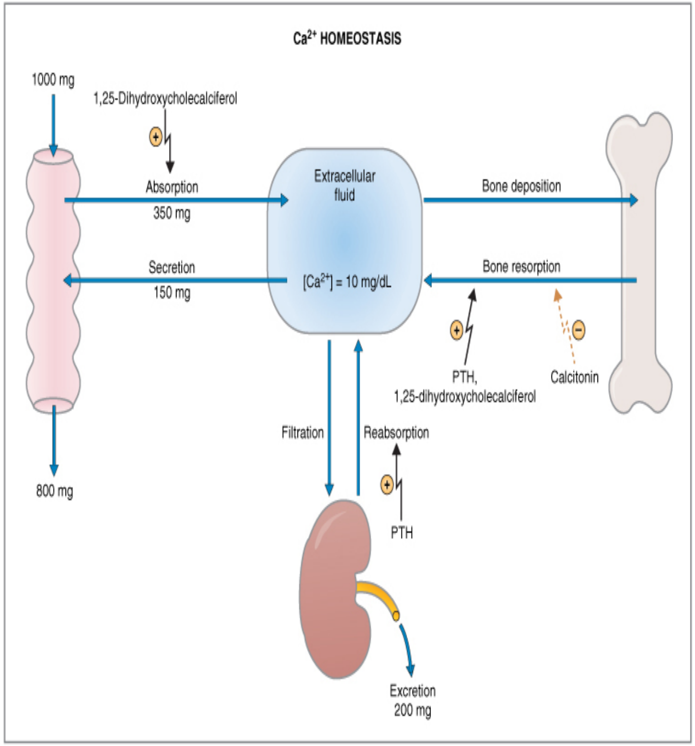
TABLE 36.1 Body Content and Tissue Distribution of Calcium and Phosphorus in a Healthy Adult

	Calcium	Phosphorus
Total Body Content	1,300 g	600 g
Relative Tissue Distribution (% of total body content)		
Bones and teeth	99%	86%
Extracellular fluid	0.1%	0.08%
Intracellular fluid	1.0%	14%

Dr.Aida Korish akorish@ksu.edu.sa

Serum calcium and Phosphate





© Elsevier. Costanzo: Physiology 3E www.studentconsult.com

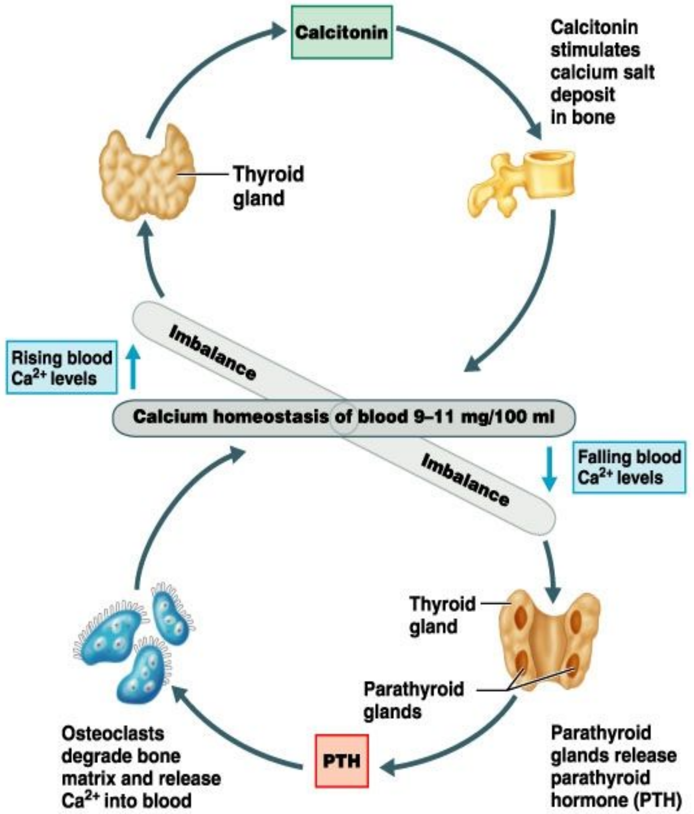
Add to My Slides Go to My Slides

Figure 9-34 **Ca^{2+} homeostasis in an adult eating 1000 mg/day of elemental Ca^{2+}.** Hormonal effects on Ca^{2+} absorption from the gastrointestinal tract, bone remodeling and Ca^{2+} reabsorption in the kidney are shown. PTH, Parathyroid hormone.

Hormonal Control of Calcium Metabolism & Physiology of Bone

Three major hormones are concerned :

- *1, 25 dihydroxycholecalciferol*: a steroid hormone formed from Vitamin D.
- *Parathyroid hormone (PTH)*: secreted by parathyroid gland
- *Calcitonin:* secreted by c-cells in the thyroid gland.
- To a lesser extent ; Glucocorticoids, GH, estrogens & various growth factors also



Osteoporosis

In persons with osteoporosis the osteoblastic activity in the bone is usually less than normal, and consequently the rate of bone osteoid deposition is depressed.

It results from diminished organic bone matrix rather than from poor bone calcification.

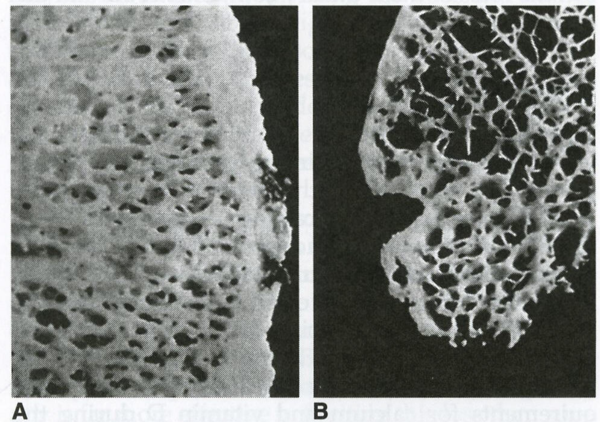
Due to :

Lack of physical stress

Malnutrition, lack of vitamin C

Old age, postmenopausal lack of estrogen.

Cushing's syndrome.



● Difference between normal bone **(A)** and osteoporotic bone **(B)**.

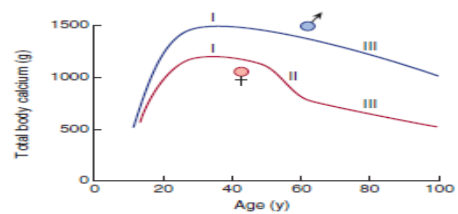


FIGURE 21–12 Total body calcium, an index of bone mass, at various ages in men and women. Note the rapid increase to young adult levels (phase I) followed by the steady loss of bone with advancing age in both sexes (phase III) and the superimposed rapid loss in women after menopause (phase II). (Reproduced with permission from Evans TG, Williams TF (eds): Oxford *Textbook of Geriatric Medicine*. Oxford University Press; 1992.)


THANK YOU
FOR LISTENING