Editing file

Physiology of Bone

- Red : important
- Black : in male / female slides
- Pink : in female slides only
- Blue : in male slides only
- Green : notes
- Gray : extra

Objective

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

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

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

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

5- Define osteoporosis and state its causes.

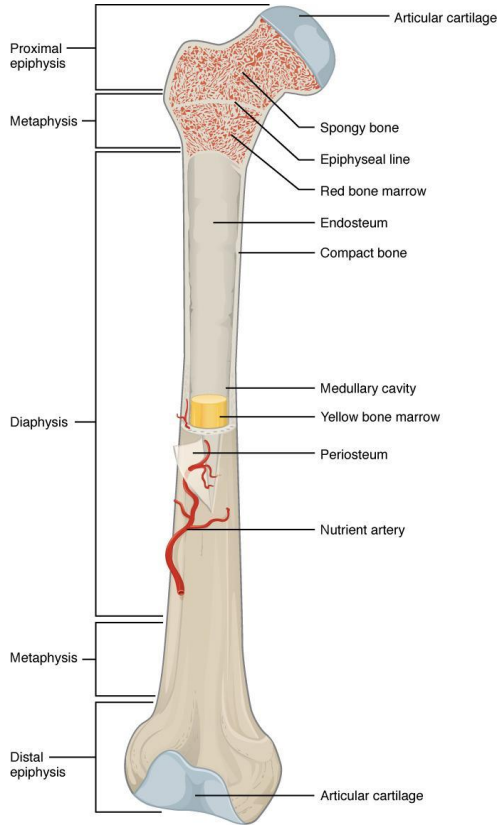
6- Discuss the effect of different hormones on bone physiology.

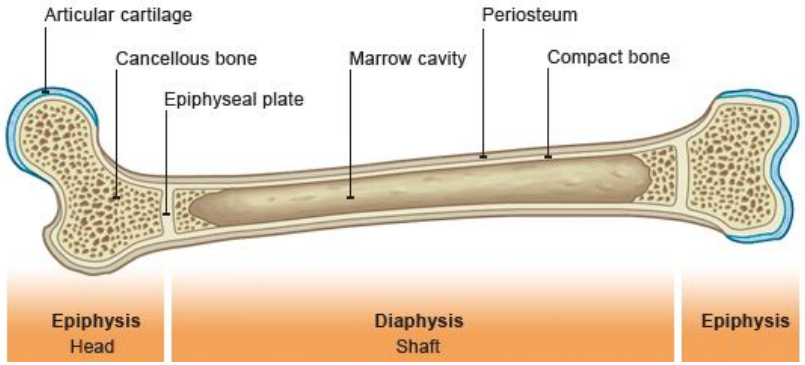
Physiology of Bone

- Bone = special Connective Tissue
- Vascularized
- Total Blood Flow 200-400 mL/min in adult

Structure (Overview)	Notes
Epiphyses	The end of each long bone, Proximal and Distal
Metaphysis	
Epiphyseal plate	• separates epiphysis from the shaft of the bone • Actively proliferating cartilage (Causes Linear growth)
Shaft	

Linear Growth:
Occur when epiphysis is separated from shaft
Epiphyseal closure ⟶ Epiphysis and shaft unite ⟶ Growth stops





Function & Types of bone

Types and structure of bone	
1. Compact (cortical bone) 80% ; the outer layer of most bones.	2. Trabecular (Spongy bone) 20% ; inside the cortical bone
More Bone tissue & less space	Less dense
Resistant to bending	More elastic
Haversian systems (Haversian Canal)	Great Surface Area
Concentric layers of mineralized bone called interstitial	More turnover rate (calcium)
Osteons (Osteonic Canals)	made up of spicules or plates.
Contain blood vessels, nerves, and lymphatics	Nutrients diffuse from bone extracellular fluid (ECF) into the trabeculae
the bone cells lie in lacunae. They receive nutrients by way of canaliculi from haversian canals vessels.	

Center of bone: Red bone marrow, yellow bone marrow, bone cells, and others

Functions of bone

- Calcium Ca++ & Phosphate PO4- Homeostasis
- Store Calcium & Phosohate
- Protect Vital Organs
- Locomotion and support against gravity
- Contain bone marrow (blood cell formation)

Composition of Compact bone

Matrix

(30%) is organic Matrix composed of

Collagen fibers (90-95%):

1. Extend primarily along tensional force
2. Provide tensile strength

Ground Substance (5-10%)

ECF and Proteoglycans

(Chondroitin sulphate and Hyaluronic acid)

(70%) is inorganic

Bone salt (70% of Matrix):

They make the bone hard tissue

1. Crystalline salt of Ca++ & PO4 (Hydroxyapatite)

* Hydroxyapatite الكالسيوم و الفوسفات يرتبطون مع بعض و يكونون الـ

Ca/P ratio = 1.3-2

2. Mg+ , Na+ ,K+, Carbonate Ions (HCO3)

Note: New bone has more organic matrix in relation to salts.

Bone cells

Osteoblasts

- Bone forming cells
- Secrete Collagen to form matrix
- Regulate Ca and PO4 concentration (secretes substance that neutralize pyrophosphate)

Osteocytes

- Osteoblasts with calcified matrix surrounding them
- send processes into the canaliculi that ramify throughout the bone.

Osteoclasts

- Multinuclear cells
- Erode and resorb bone
- Phagocytose bone → digesting it in their cytoplasm

Mechanism of Bone Calcification

Osteoblasts secrete
1. collagen (Monomer)
2. Ground sub. (Proteoglycan)

→ Collagen —polymerize to→ Collagen fibers →

Tissue: Osteoid
Cartilage-like material
differing from cartilage in that calcium salts readily precipitate in it.

→ *Osteoblasts* become entrapped in the osteoid and are called *Osteocytes* →

After the osteoid is formed, Ca salts begin to precipitate on the collagen fibers forming the *hydroxyapatite crystals*

Tensile and compressional strength of Bone

Tensile: resistance to breaking (through pulling)
Compressional: Withstand loads

Those 3 factors provide extreme tensile and compressional strength:

1. Collagen fibers (like in tendons) provide Tensile strength
2. Calcium Salts provide compressional strength
3. properties plus the degree of bondage between the collagen fibers and the crystals provide a bony structure that has both extreme tensile strength and compressional strength.

How osteoblasts enhance calcification in bones ?
They secrete substance that inhibit Pyrophosphate

Note: hydroxyapatite crystals fail to be formed in normal tissues except in bone despite the high levels of Ca & P ions due to the presence of an inhibitor of precipitation called *pyrophosphate*.

Calcium in body:

Calcium in body:

1.5 % of total body weight (1100 – 1300 g)

99 % of Calcium in skeleton

Plasma calcium

Found in female slides only

Plasma calcium level: (9 -11 mg/dl) average :9.4 mg/dl

59% (diffusible)= Ionized + Complexed

41% (non diffusible)= protein bound

كالسيوم مرتبط مع شيء اخر

بما انه بروتين بوند فما راح يدخل للخلايا، يبقى بالبلازما

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

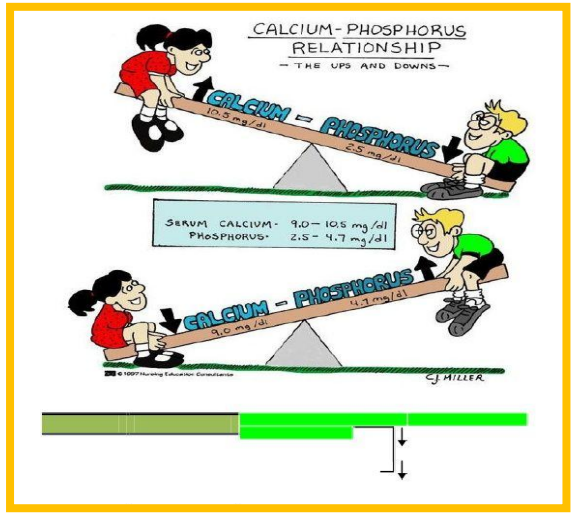
	Calcium	Phosphorus
Total Body Content	1,300 g	600 g
Relative Tissue Distribution (% of total body content)		
Bones and teeth	99%	86%
Extracellular fluid	0.1%	0.08%
Intracellular fluid	1.0%	14%

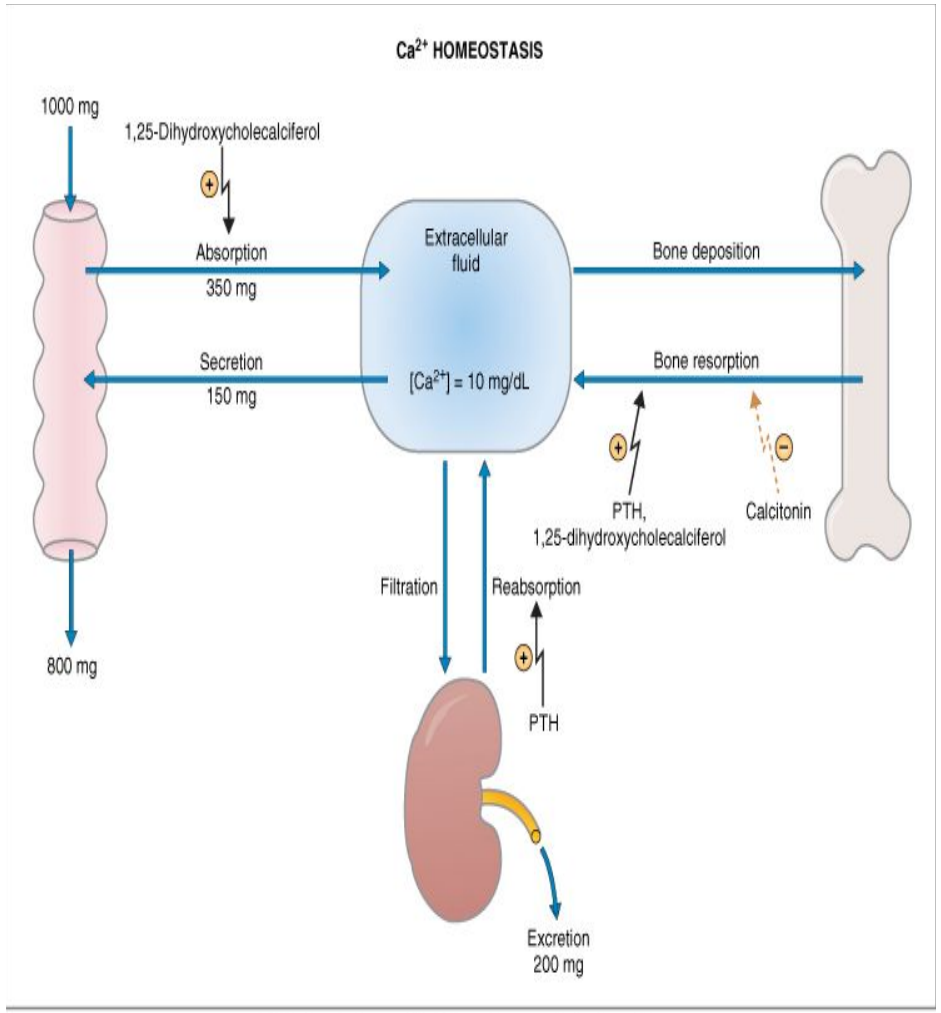
- دائمًا الكالسيوم و الفوسفات مرتبطين ببعض و علاقتهم عكسية اذا زاد مثلا الكالسيوم يقل الفوسفات و العكس

Serum calcium and Phosphate

شرح للصورة :

- اتفقنا سابقًا ان علاقة الكالسيوم بالفوسفات عكسية، و دايما احنا في جهة ان الكالسيوم اكثر و الفوسفات اقل.
- بكل بساطة لو زاد الكالسيوم في الجسم ممكن يروح للكلية و يطلع برا الجسم او من الأمعاء يطلع او يروح للعظام و تخزنه فيه في غرفة طوارئ (شرح اكثر السلايد القادم)
- لو قل الكالسيوم راح يتعوض النقص من العظام من خلال الكالسيوم الغير مرتبط بالفوسفات (شرح اكثر في السلايد القادم) و يروح للكلية يزود الـ reapsorption of ca





Calcium exchange – Bone & ECF

- The bone contains a type of exchangeable calcium that is always in equilibrium with the Ca++ ions in the ECF
- This calcium is a form of readily mobilizable salt such as dicalcium phosphate (CaHPO4) 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.

The table is important*

Exchangeable Calcium	
Concentration	0.4 – 1% of total calcium
Example	CaHPO4 & Calcium salts
Function	Found in equilibrium with Calcium ions
Importance	Buffer: Keeping Calcium level constant in ECF

شرح أكثر :

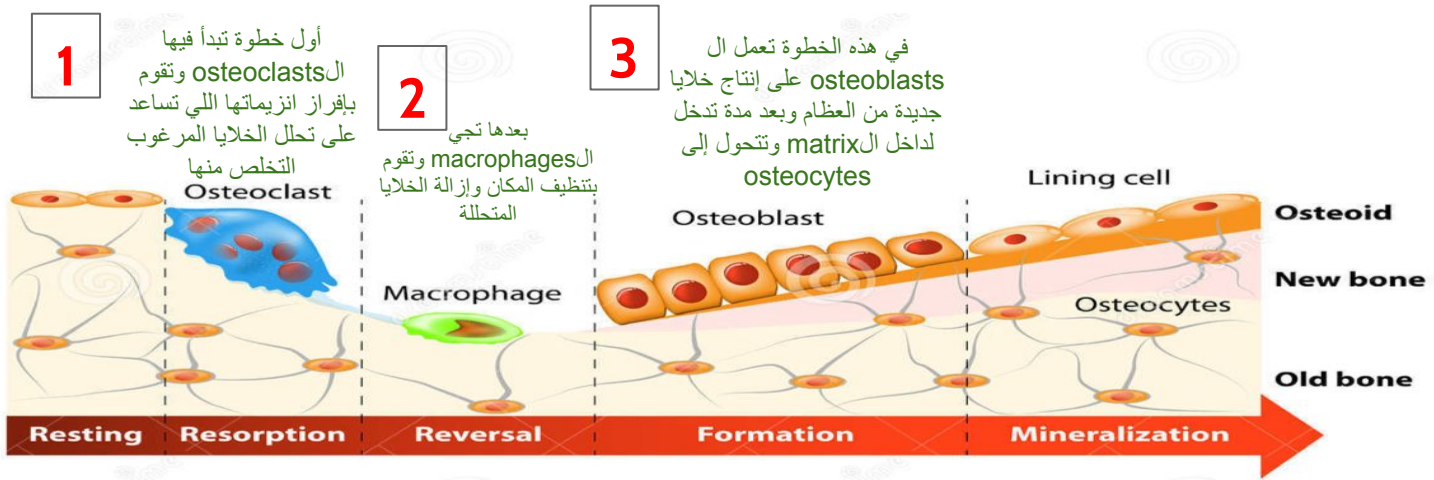
فيه كمية قليلة من الكالسيوم 0.4 – 1%غير مرتبط مع الفوسفات موجودة في مكان بالعظم زي غرفة طوارئ، لو قل الكالسيوم في البلازما يطلع من هذي الغرفة بسرعة و يعوض النقص، و لو زاد الكالسيوم في البلازما يدخل للغرفة هذي و يستخدم لاحقا اذا قل الكالسيوم في البلازما، لو طول ما استخدم لتعويض النقص ينتقل لمرحلة انه يرتبط مع الفوسفات و يكون الـ Hydroxyapatite

Bone remodeling

Bone is continually deposited by osteoblasts, and absorbed where osteoclasts are active.

Osteoblasts Deposition

Found in on outer surfaces and 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
Renewal rate for Compact bone – 4% per year
Renewal rate for Trabecular bone – 20% per year



Osteoclasts Resorption

Large phagocytic and Multinucleated
Normally active (<1% of bone surfaces of an adult)
The osteoclasts secrete two types of substances: 1) proteolytic enzymes from the lysosomes 2) several acids from the mitochondria and secretory vesicles. • The enzymes dissolve the organic matrix, and the acids cause solution of the bone salts.
Phagocytose small particles of matrix and salt crystals, dissolute them, then release to blood

Note:
- Osteoblasts build bone
- Osteoclasts destroy bone

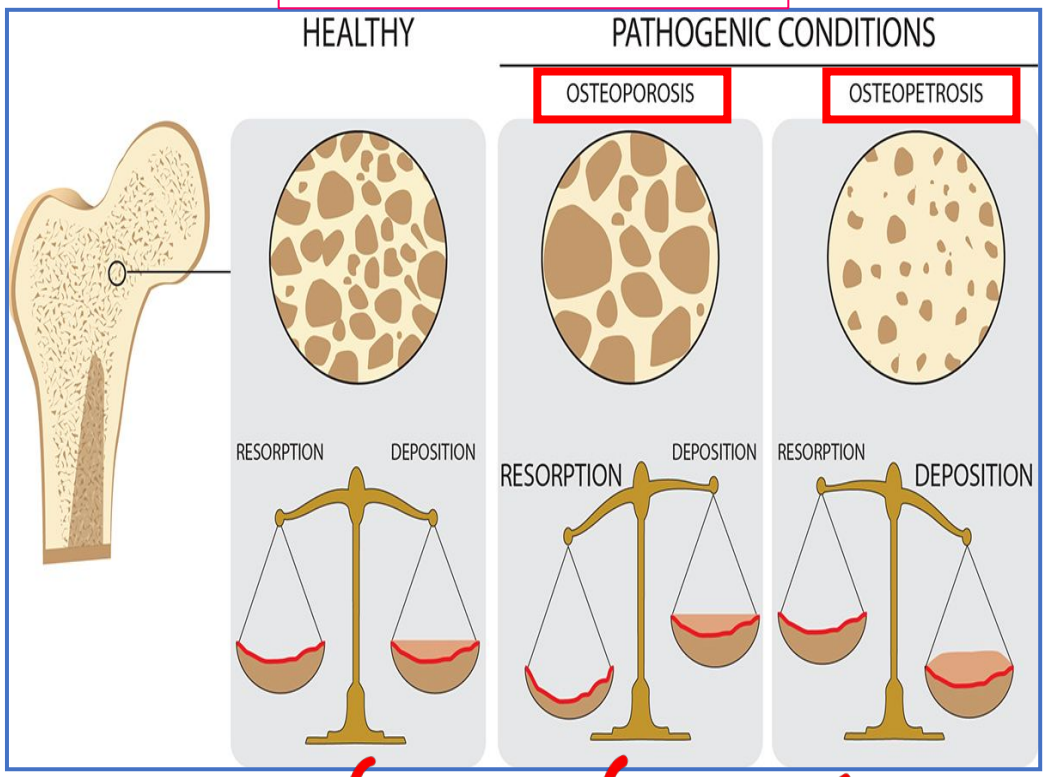
Cont...

Value of continual bone remodeling:

1. **Bone adjusts its strength** in proportion to the degree of **bone stress** and it thicken when subjected to heavy loads.
2. Rearrange **shape due to proper support** of mechanical forces.
3. **Old bone** becomes weak & brittle – **new organic matrix** is needed to maintain the normal toughness of bone .
4. More remodeling happens in children bone (their bone is stronger and less brittle)

أقل هشاشة و أقوى لأنها تو ها جديدة

Found in girls slides only



Resorption = deposition = Healthy

Resorption > deposition = osteoporosis هشاشة

Resorption < deposition = osteopetrosis

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

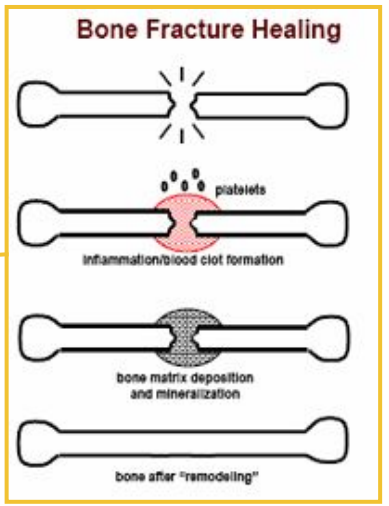
Stress effect on Bone deposition
Deposition is proportional to load on bone that it must carry
Physical stress **stimulate** Osteoblasts deposition and calcification
Stress can also affect the shape of bone under certain circumstances. (e.g. Healing of fractures may start angulated in children then become straight).
Example: Athletes bones become heavier than non athletes
Also, the bone of the leg in the cast becomes thin and up to 30 % decalcified within a few weeks.

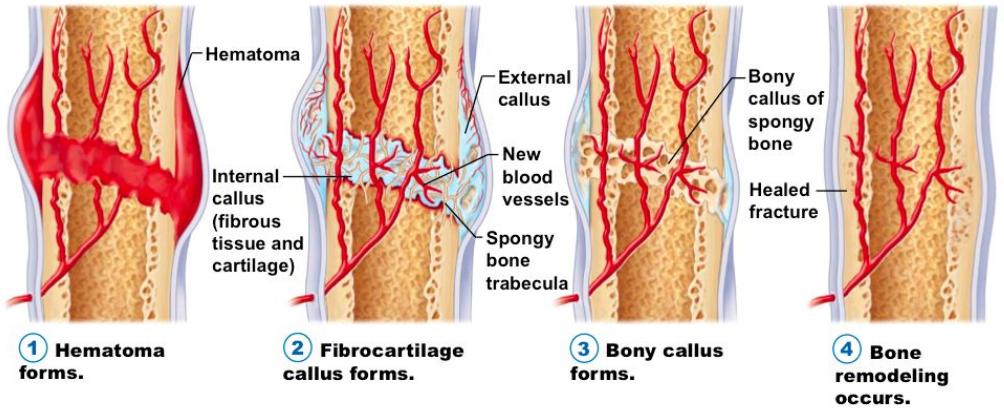
شرح لآخر نقطتين :
إن العظم كل ما كان تحت ضغط أكثر (مثل التمارين الرياضية ورفع الأثقال) بيحتاج nutrients أكثر وبالتالي بيصير وزنها أثقل وأقوى وكلما خف الضغط (مثل إذا كانت اليد عليها جبس) فيقل حاجتها للnutrients وبالتالي بيقل وزنها

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

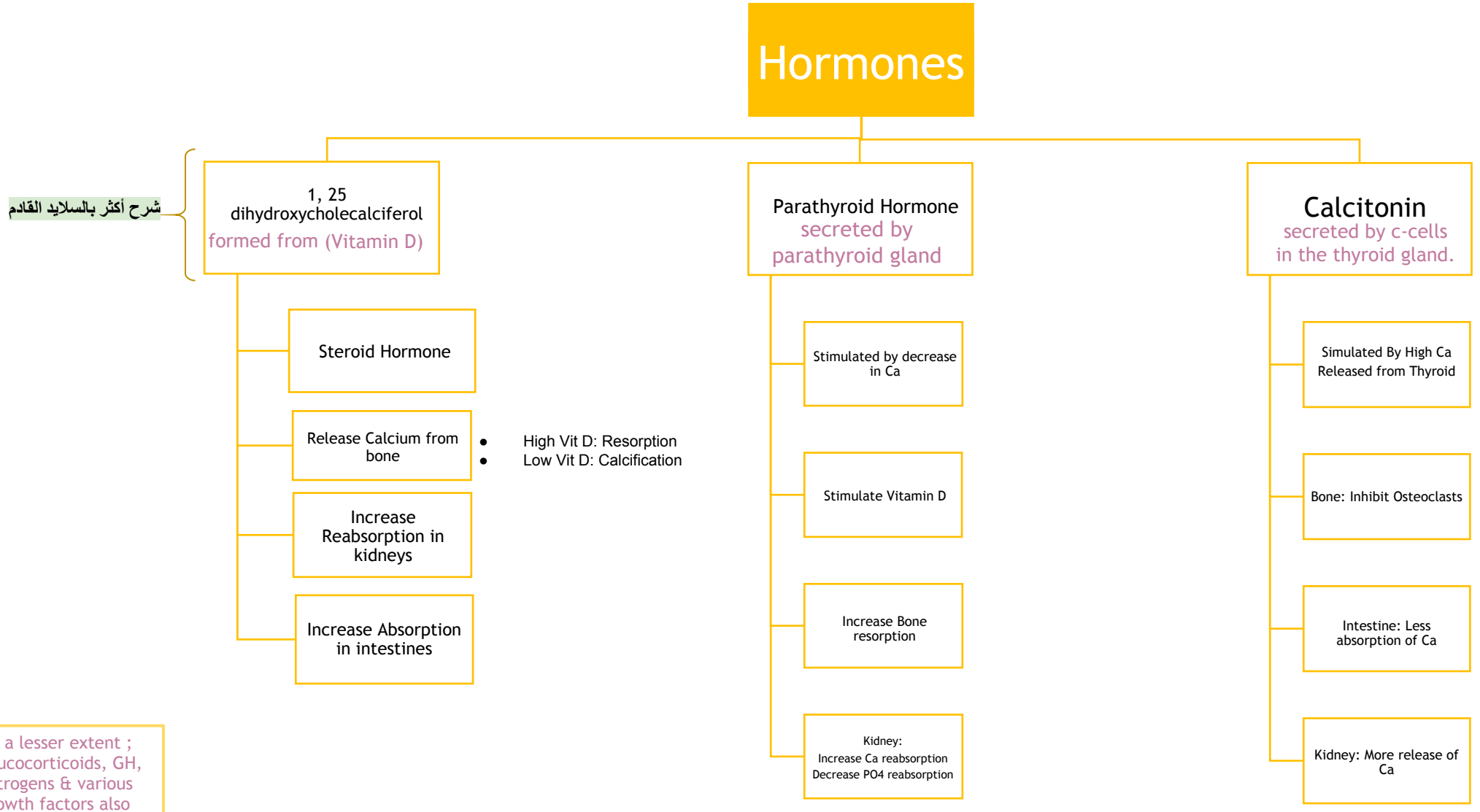
Repair of a fracture by Osteoblasts
Fracture of a bone activates:
1. Periosteal Osteoblasts
2. Intraosseous Osteoblasts
Osteoprogenitor cells which are bone stem cells in the surface tissue lining bone, called the "bone membrane” form large number of new Osteoblasts
Shortly a large bulge of osteoblastic tissue and new organic bone matrix, develops between the two broken ends of the bone followed shortly by the deposition of calcium salts. This is called a callus.

شرح إضافي:
بما ان بعملية الريبير راح يتكون كثير ماتريكس و اوستيوبلاست فما راح يكون مرتب ولا بحجم العظم و هنا يجي دور الـ osteoclast انها تشيل الأجزاء الزائدة و تخليه على حجم العظم الطبيعي





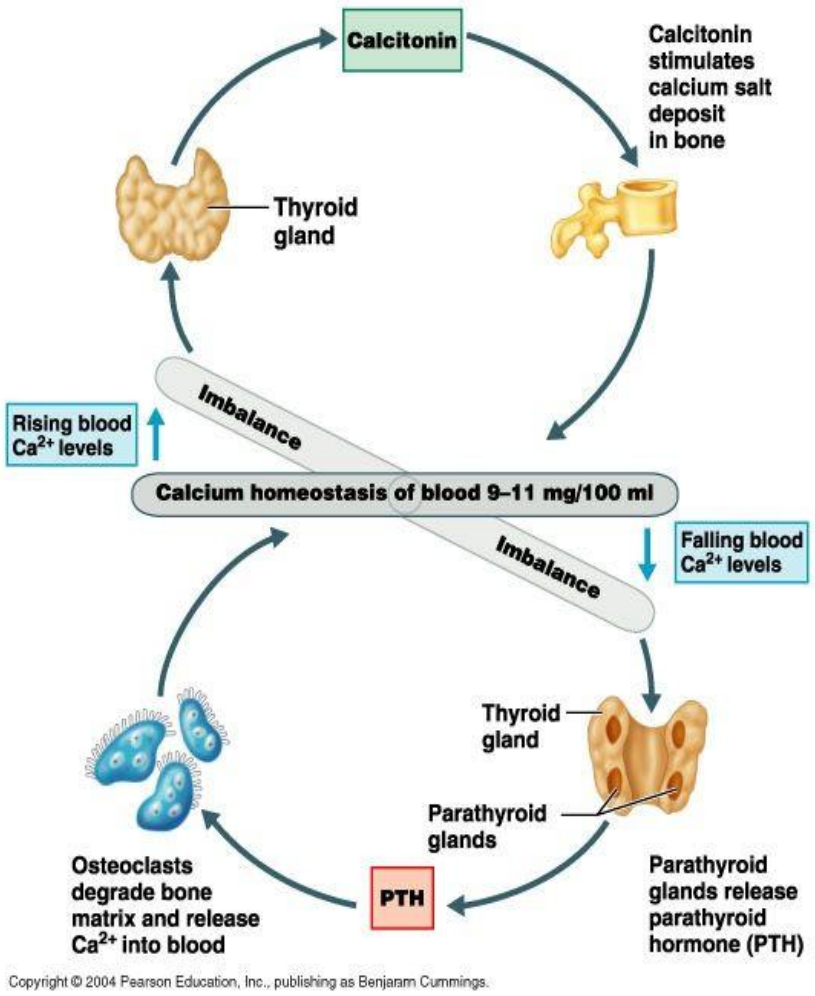
Hormones and Calcium Regulation



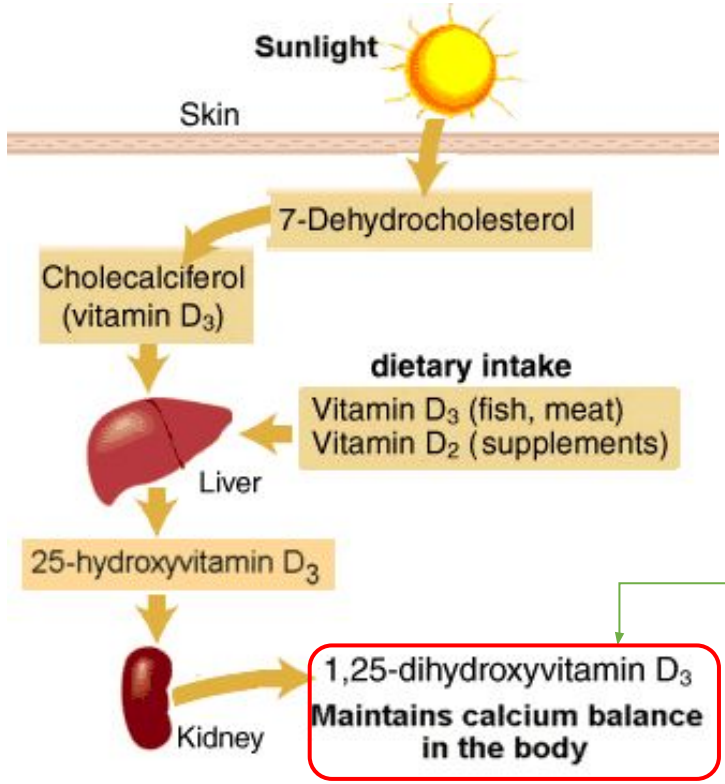
- To a lesser extent ; Glucocorticoids, GH, estrogens & various growth factors also affect Calcium Metabolism.

Hormones and Calcium Regulation- cont..

★ لفهم الية عمل الهرمونات في السلايد السابق



Vitamin D



لما يصير اكتيف يقدر يساعد PTH و يشتغل على العظام او الأمعاء او الكلية عشان يشجع إعادة امتصاص الكالسيوم و يعيد التوازن

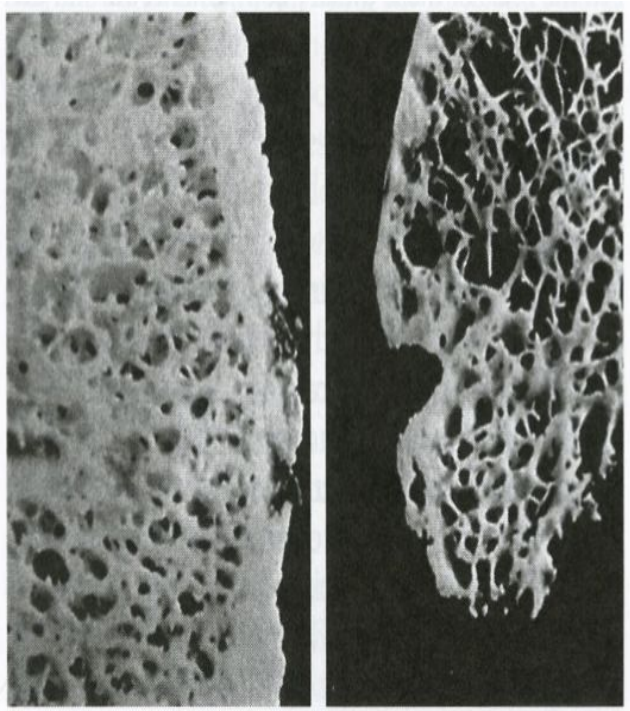
Osteoporosis

- Definition: reduced bone density and mass, Matrix and mineral are both lost
- Caused by decreased Osteoblastic activity or increase Osteoclastic Activity

Causes
Lack of Physical Stress
Malnutrition
Lack of Vitamin C
Old Age
Postmenopausal lack of Estrogen
Cushing's syndrome (excessive cortisol secretions)

Complications
Increase incidence of fracture
Example: distal forearm (Colle's fracture), vertebral body, and hip
Because of high content of trabecular bone (which is more active metabolically) that's lost rapidly
Fracture of **vertebra** with kyphosis produces "widow's hump" (Curvature) in old women with osteoporosis
Fracture of **hip** with 12-20% mortality rate, and half of those who survive require prolonged expensive care.
Management: Moderate exercise & Calcium intake

Osteoporosis



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

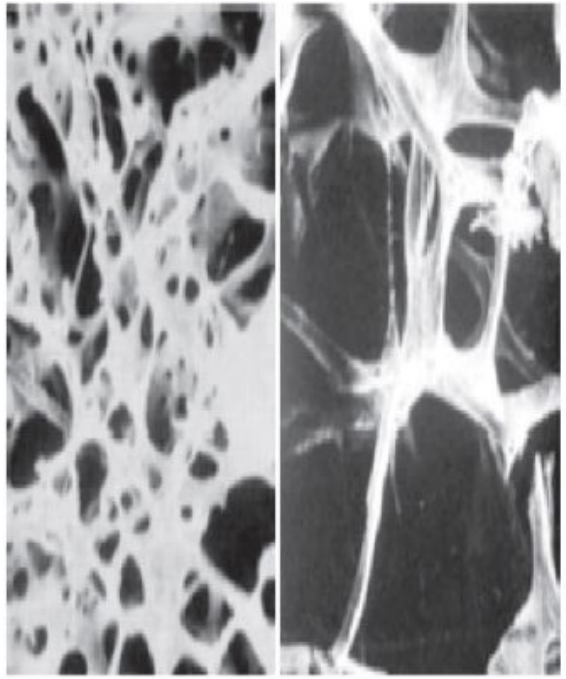


FIGURE 21–11 Normal trabecular bone (left) compared with trabecular bone from a patient with osteoporosis (right). The loss of mass in osteoporosis leaves bones more susceptible to breakage.

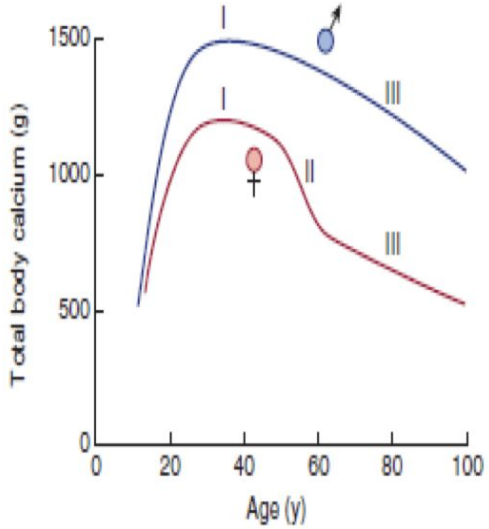


FIGURE 21–12 Total body calcium, an index of bone mass, at various ages in men and women. Note the rapid increase to young adult levels (phase I) followed by the steady loss of bone with advancing age in both sexes (phase III) and the superimposed rapid loss in women after menopause (phase II). (Reproduced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

Quiz

SAQ

Q1- List 3 regularity ca hormones .

Q2- What helps in regulating Calcium level in ECF ?

Answers

SAQ1-

1, 25 dihydroxycholecalciferol , PTH, calcitonin

SAQ2- exchangeable calcium

1) if Resorption more than deposition =		2) PTH Stimulated by decrease in	
A.	osteoporosis	A.	PO4
B.	Healthy bone	B.	Ca
C.	osteopetrosis	C.	Blood count
D.	None	D.	Vit C
3) Normal tissues (other than bones) has:		**4) Collagen fibers provide:**	
A.	Calcifications area	A.	Tensile strength
B.	Pyrophosphate inhibitor	B.	compressional strength
C.	Pyrophosphate	C.	resistance to breaking (through pulling)
D.	exchangeable calcium	D.	Both A and C

Answers key: 1) A 2)B 3)C 4)D

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Thank you

@physiology438

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