Physiology Team

MEDICAL COLLAGE 433

# Physiology of Bone

Color Index

Red = Important

Purple = Addition

Orange = Explanation

@PhysiologyTeam

Pht433@gmail.com

Contact us: pht433@gmail.com

# Objectives :

1) Define bone & differentiate between types of bone (cortical & trabecular)

2) Appreciate differences between both types of bone in function.

3) State $Ca^{++}$ concentration and its forms in the ECF ; its relation to PO

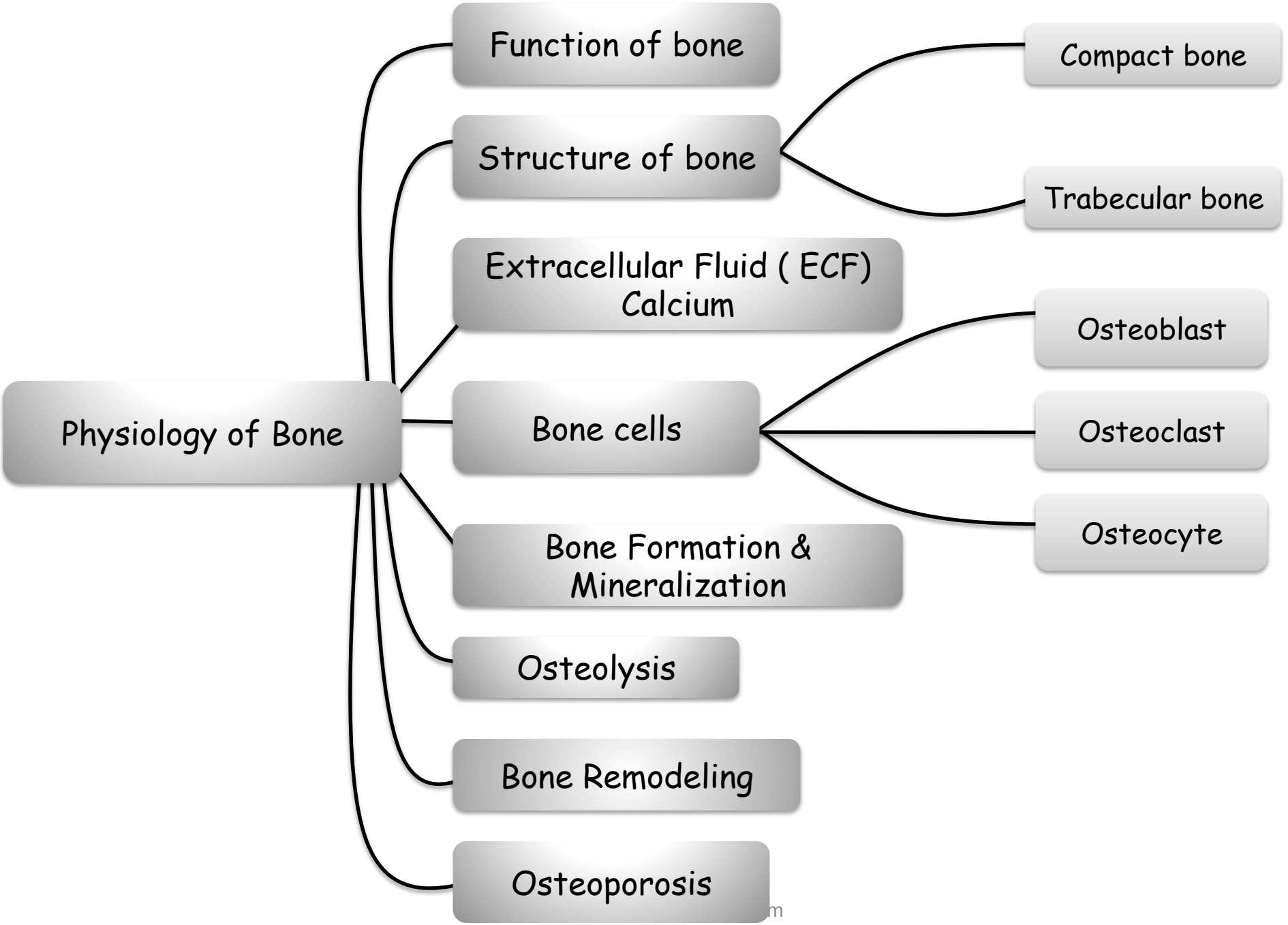
Differentiate between the types of bone cells & appreciate their functions.

5) Describe bone formation & remodelling.

6) Understand what is osteoporosis.

7) Appreciate the effects of different hormones on bone.

Contact us: pht433@gmail.com

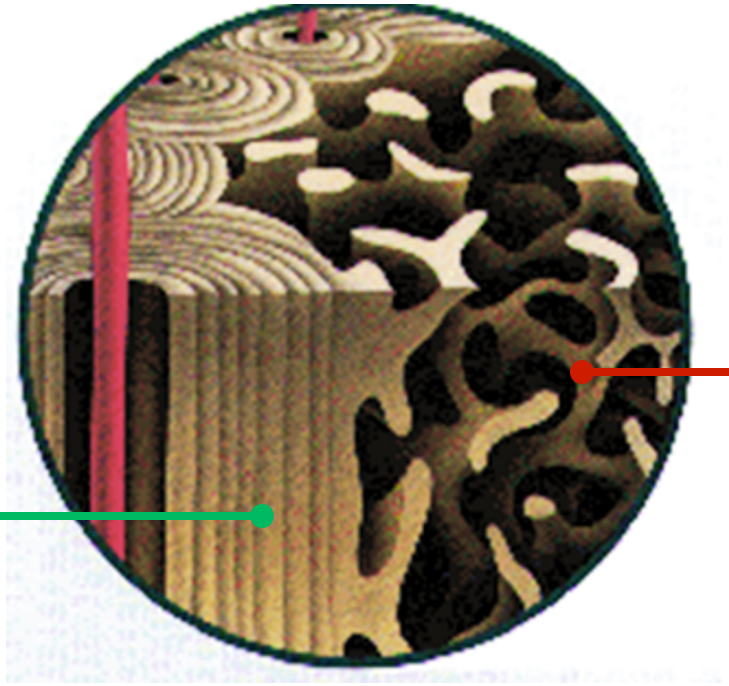

Physiology of Bone
Function of bone
Structure of bone
Compact bone
Trabecular bone
Extracellular Fluid ( ECF) Calcium
Bone cells
Osteoblast
Osteoclast
Osteocyte
Bone Formation & Mineralization
Osteolysis
Bone Remodeling
Osteoporosis

# Function of the Bone :

- Protects vital organs(cranium and thoracic cavity)
- Provides support for soft tissues
- Reservoir for Calcium & Phosphate to maintain constant conc. Of them in body fluid
- Allows & facilitates movement
- Contains bone marrow for blood cells synthsis.

# Structure of Bone:

1. • **Organic** matrix made of **collagen (mainly)** , called osteoid , makes 30% of bone and calcified material .
2. • **Inorganic** ( mineral ) bone component , called hydroxyapatite , made of $CaPO_4$ crystals , that constitutes the remaining 70% of bone .



# Types of Bones :

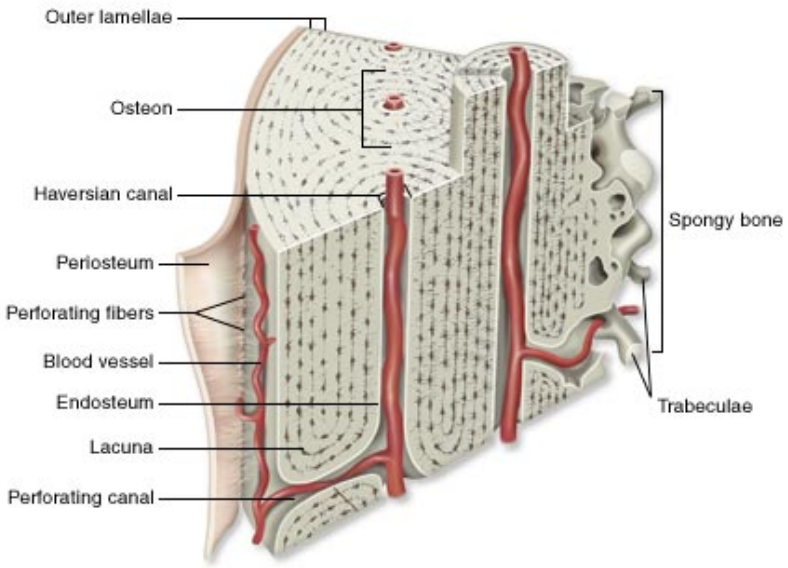
## Cortical (Compact) bone

- Also called **compact** bone
- Forms a **protective** outer shell of bone
- Represent **80 %** of total body bone mass
- Has a **slow** turnover rate
- Has **high** resistance to bending and torsion
- Constitutes the dense concentric layers of long bones
- In outer layer surround trabecular bone at ends of long bones(**to protective**)

**Turnover means the ability to exchange calcium between bones and bloods**

Contact us: pht433@gmail.com

osteons system are found only in compact bone




The Cortical bone composed of overlapping circular structures (formations) called Haversian Systems or Osteons

Each osteon has a central canal called Osteonic Canal or Haversian Canal

The Osteonic Canal contain blood vessels (capillaries, arterioles, venules), nerves and lymphatics

Between Haversian systems are concentric layers of mineralized bone called interstitial lamellae

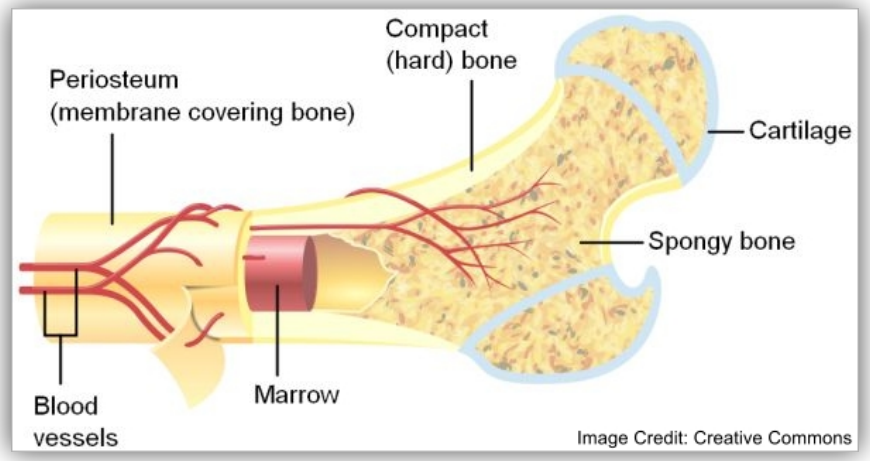
Contact us: pht433@gmail.com

# Trabecular Bone

- Present in the interior of skull,ribs,vertebre,pelvis and (in long bones present only in epiphyseal and metaphysal regions & has spongy appearance .
- it has **5 times greater surface area than cortical bone**
- Represent **20%** of total bone mass
- Because of its **large** surface, it has **faster** turnover rate than cortical bone
- it is more important than cortical bone in terms of calcium turnover
- Help bone to maintain shape despite compressive forces.

## Trabecular Bone Compared to cortical bone

- It is less dense
- more elastic
- Greater surface area
- has high calcium turnover rate




**The center of the bone contains red, yellow marrow, bone cells and other tissues.**

Contact us: pht433@gmail.com

# Extracellular Fluid (ECF) Calcium

- $Ca^{++}$ level in plasma is 8.5-10 mg/dL (mean 9.4 mg/dl)
- It exists in three fractions:

1) Ionized calcium → 50% of total ECF calcium, diffusible through capillary membrane **(Only biologically active)**
2) Protein-bound calcium → 40% of total ECF calcium(non diffusible through capillary membrane)

- Most of this is bound to **albumin** and, Much less is bound to **globulins**.

3) Calcium bound to serum constituents The remaining 10% of plasma calcium bound to citrate & phosphate(not ionized –diffusible)

## Binding of calcium to albumin is pH-dependent

Alkalosis increases calcium binding to protein → thereby **decreases ionized calcium level**.

Calcium is tightly regulated with Phosphorous in the body.

$PO_4$ plasma concentration is 3.0-4.5 mg/dL

# Phosphate (PO4)

- 85% of PO4 in bone
- 15% in cells
- less than 1% in ECF In forms as H2P04 , HPO4

$Ca^{++}$ X $PO_4$ = constant ( solubility product)

If anyone increase it should precipitate in bone.

Contact us: pht433@gmail.com

**99%** of the Calcium of bone in from of :

- hydroxyapatite crystal)
- phosphate salts
  - CaPo4
  - hydroxide

**70% of Bone is formed of calcium**

**about 0.1% in ECF**

**1% of our body Ca is in cells organelles**

## Bone growth

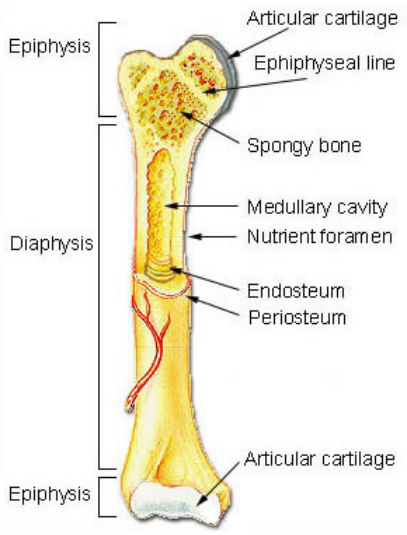
**Calcium salts in bone provide structural integrity of the skeleton**

Growth occurs at **epiphyseal** → Linearplates

Growth occurs at **periosteum** →width

During growth, bone mass increases and bone formation exceeds resorption.

- ✓ At adult → **equal** rates of formation and resorption to maintain bone mass.
- ✓ 10% of total adult bone mass turns over each year during remodeling process
- ✓ At about 30 years old → rate of resorption begins to **exceed** يتجاوز formation and bone mass slowly decreases.



# Bone Cells

There are three types of bone cells:

## (1) Osteoblast:

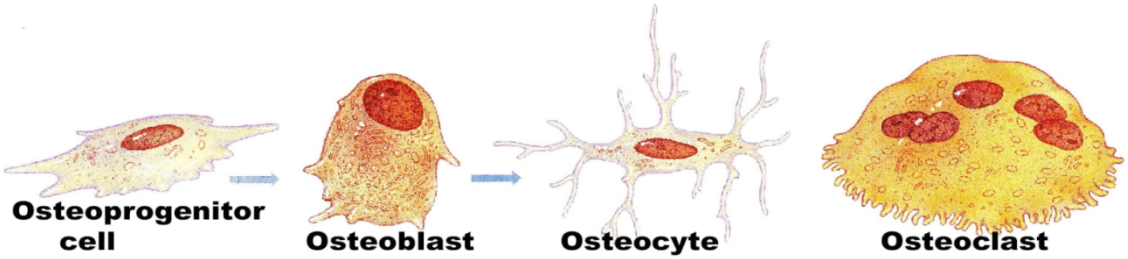
- "Bone-forming" cell, present on outer surface of bone and bone cavities.
- secretes osteoid (bone matrix , mainly collagen) on which $Ca^{++}$ and $PO_4$ are precipitated.
- it is stimulated by anabolic steroids.

## (2) Osteoclast:

- Large phagocytic multinucleated.
- "Bone-reabsorbing" (removing) cell.
- its increased activity stimulated by **parathyroid hormone**
- Osteoclasts secrete enzymes that dissolve the matrix of old bone tissue and acids that dissolve bone salts

## (3) Osteocyte:

- Mature bone cell derived from osteoblasts, it is enclosed in bone matrix.
- Transfers of calcium from canaliculi to the ECF.
- Interior osteocytes remain connected to surface cells (osteoblasts) via syncytial cell processes



# CANALICULI

- Fluid contaning channels called the canaliculi.
- Interior osteocytes remain connected to surface cells ( osteoclasts) via syncytial cell processes.
- Osteocytes transfer calcium from large surface area of the interior of canaliculi to the ECF.

# Bone formation & Mineralization

- First osteoblasts synthesize bone matrix (osteoid, mainly collagen) → which will then be mineralized by deposition of Calcium Phosphate on it.
- This mineralization(deposition and precipitation of calcium and phosphate on the osteoid collagen fibers forming hydroxyaptite crystals over a period of weeks or months, dependent on Vitamin D.
- Alkaline phosphatase and osteocalcin play roles in bone formation, their plasma levels are indicators"المؤشرات" of osteoblast activity.

# Osteocytic Resorption (Osteolysis)

- Calcium exraction (demineralization).
- Removal of the osteoid matrix.

Cells responsible for resorption are "Osteoclasts".

Bone reabsorption is stimulated by Parathyroid hormone (PTH), which stimulates formation of "mature Osteoclasts" that leads to release of calcium from "bone into the ECF".

# Control of bone Resorption ارتشاف

| | Osteocytic osteolysis | Osteoclasitc resorption |
|---|---|---|
| **Rate of affect** | rapid and transient effect (In minute) | slow and sustained mechanism(days or weeks) |
| **Cell responsible** | osteocytes | osteoclasts |
| **Bone mass** | Does not decrease bone mass | diminishes bone mass |
| **Calcium and PO4** | reduce calcium & Po4 | not diminishes calcium & Po |
| **Function** | 1) Removes calcium from recently formed crystals<br><br>2) digest mineralized bone & transfere calcium & Po4 from canaliculi to ECF | 1) acidify area of bone to dissolve hydroxyapatite by Hcl then lysosomes & acid proteases (digest collagen)<br>2) Destroy matrix of old bone |

# Bone Remodeling

This refers to the continuous processes of bone absorption (by Osteoclasts) and then its deposition (by Osteoblasts). This results in a 10% turnover of the adult bone mass per year.

1. • Endocrine signals to rest Osteoblasts, Paracrine signals to generate Osteoclasts
2. • Osteoclasts digest and resorb area of mineralized bone.
3. • Local macrophages clean up debris
4. • Osteoblasts are recruited to site and deposit new matrix which will be mineralized.
5. • New bone replaces previously resorbed bone.

## Bone Remodeling affected by

1. Mechanical stress on bone stimulates formation of stronger bone.
2. Parathyroid hormone (PTH) and 1,25 Dihydroxycholecalciferol (active Vit D3) stimulate formation of mature osteoclasts and stimulate their activity.
3. Calcitonin inhibits activity of osteoclasts

Contact us: pht433@gmail.com

# Hormonal control of Calcium

## 1-Parathyroid hormone (PTH)

- increase plasma Ca++ levels when it drops and decrease plasma phosphate levels
- Act on the bones to stimulate Ca absorption by activating osteoclasts.
- Act on kidney to stimulate Ca++ reabsorption, and inhibit reabsorption of phosphate and indirectly by activation of 25-(oh)-D into 1,25-$(OH)_2$-D
- On intestine to stimulate Ca++ reabsorption

## 1,25-dihydroxycholicalcefirol(active Vitamin D)

- **(**cholicalcefirol = Vitamin D3**)**
- In skin: Cholesterol → Vit D3(cholecalciferol)
- In liver: Vit D3→ 25 hydroxycholecalciferol
- In kidney :Parathormone (PTH) 25 hydroxycholecalciferol → 1,25 dihydroxycholecalciferol (active form)

three organs that function in Ca+ +homeostasis

- bone,
- kidney
- intestine

## Calcitonin

- From parafollicular cells of the thyroid gland (C cells).
- decrease plasma Ca ++ levels
- increases osteoblastic activity
- decrease formation of new osteoclasts
- Stimulated by a rise in plasma Ca++ levels

Contact us: pht433@gmail.com

# Osteoporosis(هشاشة العظام)

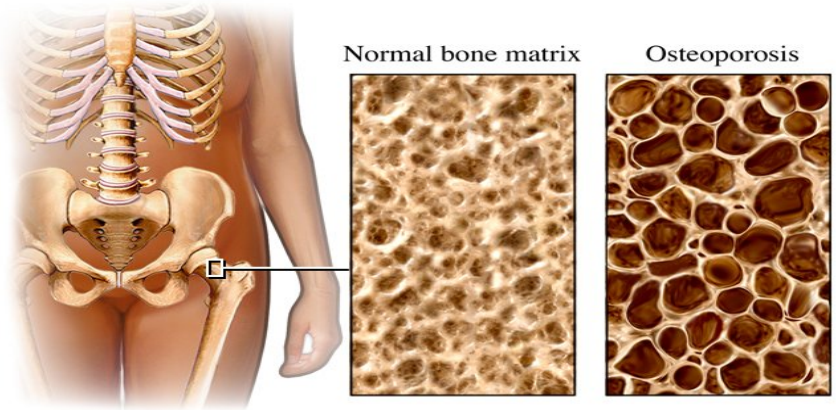
Men have more total bone mass than women. During childhood, bone formation exceeds resorption, and the total bone mass peaks at 25-35 years of age.

Thereafter, because of **falling levels of the anabolic steroids** **(**oestrogen & progesterone which stimulate osteoblasts**)**, we get Osteoporosis, which means, reduced bone density and mass.

This leads to increased susceptibility to fracture. Osteoporosis occurs earlier in life for women than men (Especially women around menopause) but, eventually both genders succumb to it.

Note That :

Osteoporosis is increased by: Smoking , soft drinks , alcohol , and is reduced by physical activity and high calcium in the diet. Osteoclastic bone resorption is: slow process that reduces bone-mass.



# Summary :

**-Types of bones**: (Compact) bone Represent **80 %** of total body bone mass and Trabecular(spongy) Bone Represent **20%** of total bone mass

**-Extracellular Fluid (ECF) Calcium**:1)Ionized calcium**,** 2)Protein-bound calcium ,3)The remaining 10% of plasma calcium bound to citrate & phosphate

-Calcium is tightly regulated with Phosphorous in the body.

-**There are three types of bone cells:** Osteoblast, Osteoclast, osteocyte

-**Bone Remodeling(ECF) Calcium:**This refers to the continuous processes of bone absorption (by Osteoclasts) and then its deposition (by Osteoblasts). This results in a 10% turnover of the adult bone mass per year.

-**Hormonal control of Calcium:**1) 1,25-dihydroxycholicalcefirol 2)Calcitonin 3)Parathyroid hormone (PTH)

**-Osteoporosis** which means, reduced bone density and mass -bone becomes weak & ca++ is lost from skeleton -Earlier in life for women than men

Contact us: pht433@gmail.com


**Introduction to Bone Biology**

http://www.youtube.com/watch?v=inqWoakkiTc

**Osteoblasts and Osteoclasts**

http://www.youtube.com/watch?v=78RBpWSOl08

**Bone remodeling and modeling**

http://www.youtube.com/watch?v=0dV1Bwe2v6c

Contact us: pht433@gmail.com

# Multiple Choice Questions

Q1: The falling level of anabolic steroids indicate

A) High osteoblast , and osteoporosis
B) Low osteoblast, and osteoporosis
C) Normal osteoblast , no osteoporosis

Q2: Which one of the following is biologically active?

A) Protein bound calcium
B) Ionized calcium
C) The remaining plasma calcium
D) All of them

Q3: Which one of the following is stimulated by the parathyroid glands?

A) Osteocyte
B) Osteoblast
C) Osteoclast
D) None of them

Q4: Which of the following inhibits the osteoclast?

A) Parathyroid gland
B) Active vitamin D
C) Calcitonin
D) Myocin

Q5: Which one of the following is a feature of Compact Bone?

A) High turnover rate
B) Low resistance to bending and torsion
C) Less dense
D) Composed of overlapping circular structure

Q6: Osteoporosis decreased by :

A) Smoking
B) Soft drinks
C) Physical activity
D) Alcohol

Q7: Which of the following will increase turnover of trabecula?

A) Its surface area
B) Its mass
C) Its bone marrow
D) None of these

1-B 2-B 3-C 4-C 5-D 6-C 7-A

Contact us: pht433@gmail.com