Minerals

University Of Fallujah
College Of Medicine

Lecture : (1)

Stage : 2th Stage

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Department: Chemistry and Biochemistry

Date:

❑ Learning Objectives

- Define minerals in the context of human physiology and nutrition.
- State the overarching importance of minerals for the normal growth and maintenance of the body.
- List the physiological processes for which minerals are essential
- **Calcium** :
- Foundational Concepts
- Calcium Sources, Requirement, and Absorption
- Physiological Functions and Blood Calcium
- Hormonal Regulation of Calcium
- Calcium Balance and Associated Disorders

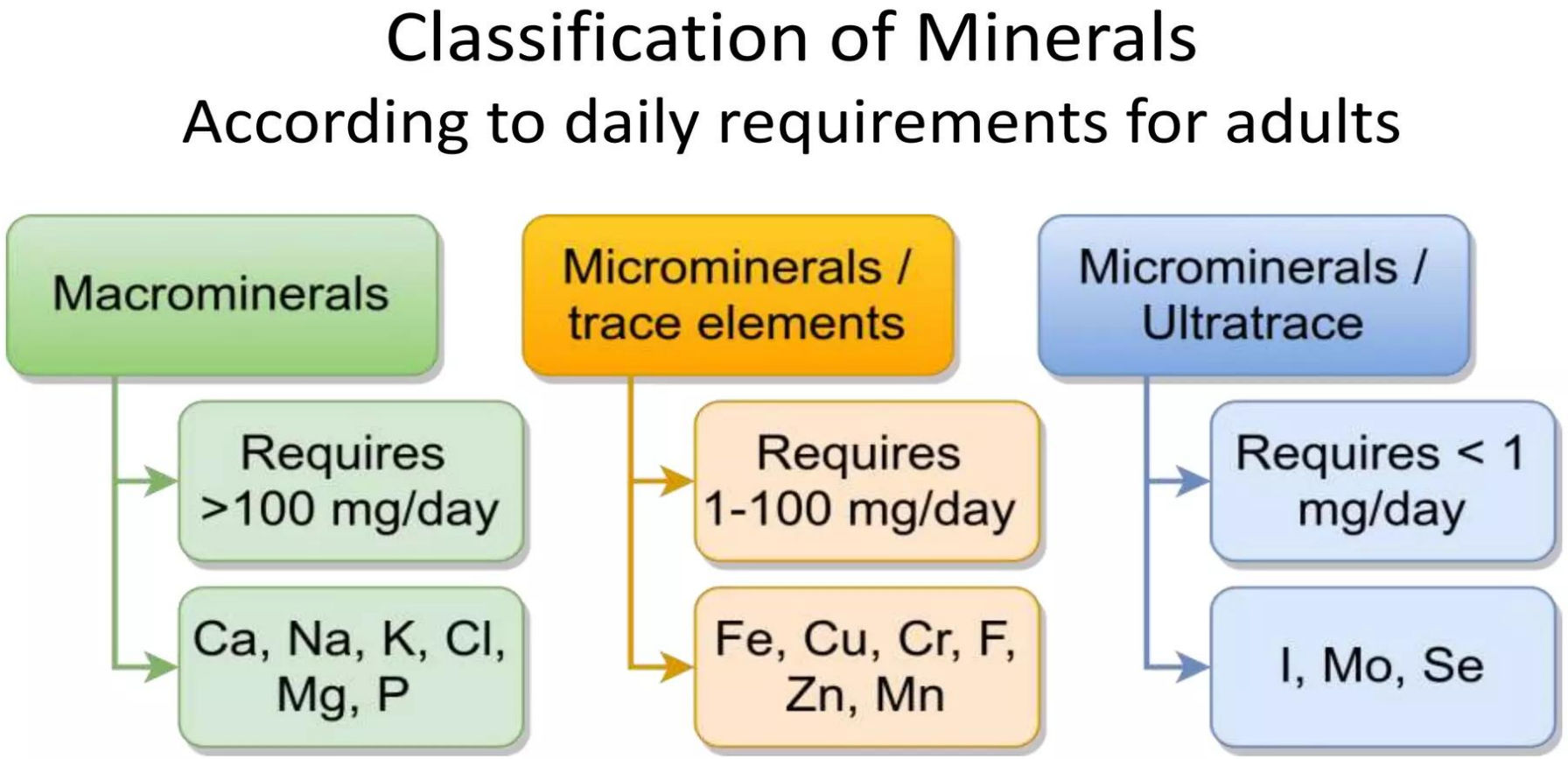
MINERALS METABOLISM

- **MINERALS** : Minerals are essential for the normal growth and maintenance of the body.

- Essential for calcification of bone, blood coagulation, neuromuscular irritability, acid-base equilibrium, fluid balance & osmotic regulation.

- Also, minerals along with vitamins as essential components in enzymes and coenzymes

Minerals classification



MAJOR MINERALS

❑1. CALCIUM (Ca^{+2}):

- Calcium (Ca^{+2}) most abundant mineral in the human body . Total Calcium in the human body is about 1 to 1.5 kg, 99% of which is seen in bone together with phosphate. Small amounts in soft tissue & 1% in extracellular fluid.

- **Sources of Calcium**
- Milk is a good source for calcium. Calcium content of cow's milk is about 100 mg/100 ml. Egg, fish and vegetables are medium sources for calcium. Cereals (wheat, rice) contain only small amount of calcium.

❑ Daily Requirement of Calcium

Daily Calcium Requirements

Life Stage / Condition	Recommended Calcium Intake
Adult	500 mg/day
Child	1200 mg/day
Pregnancy & Lactation	1500 mg/day
Older Adults (50+)	1500 mg/day *plus* Vitamin D (20 µg/day)

Clinical Note: The increased requirement for older adults, combined with Vitamin D, is a key

- **Absorption:**

1. Site of Absorption:

- **Where:** The **first and second part of the duodenum** .
- **Why this is important:** This is where the chyme from the stomach is still acidic, which helps keep calcium soluble and available for absorption.

2. Nature of Absorption :

- **"Against a concentration gradient":** This means calcium is moving from an area of lower concentration to an area of higher concentration (inside the intestinal cell and then into the blood). This is an **active transport** process.
- **"Requires energy":** Because it is active transport, it cannot happen passively; it needs cellular energy (ATP) to pump the calcium ions.

3. Mechanism of Absorption (The "How"):

- **Carrier Protein:** The primary carrier protein in the intestinal cells is called **Calbindin**. The synthesis of this protein is critically dependent on **Vitamin D (Calcitriol)**.
- **Calcium-dependent ATPase:** This is the specific **"pump"** that uses energy (from ATP) to actively transport calcium across the cell membrane into the bloodstream.

❑Factors causing increased absorption.

- Vitamin D: Calcitriol induces the synthesis of the carrier protein) Calbindin (in the intestinal epithelial cells, and so facilitates the absorption of calcium
- Parathyroid hormone :It increases calcium transport from the intestinal cells.
- Acidity :It favors calcium absorption.
- .Amino acids :Lysine and arginine increase calcium absorption

❑Factors causing decreased absorption.

- Phytic acid: Hexaphosphate of inositol is present in cereals. Fermentation and cooking reduce phytate content.
- Oxalates: They are present in some leafy vegetables, which cause formation of insoluble calcium oxalates.
- Malabsorption syndromes: Fatty acid is not absorbed, causing formation of insoluble calcium salt of fatty acid.
- .Phosphate: High phosphate content will cause precipitation as calcium phosphate.

❑Physiologic functions of Calcium :

1.blood coagulation .

2.muscle contraction .

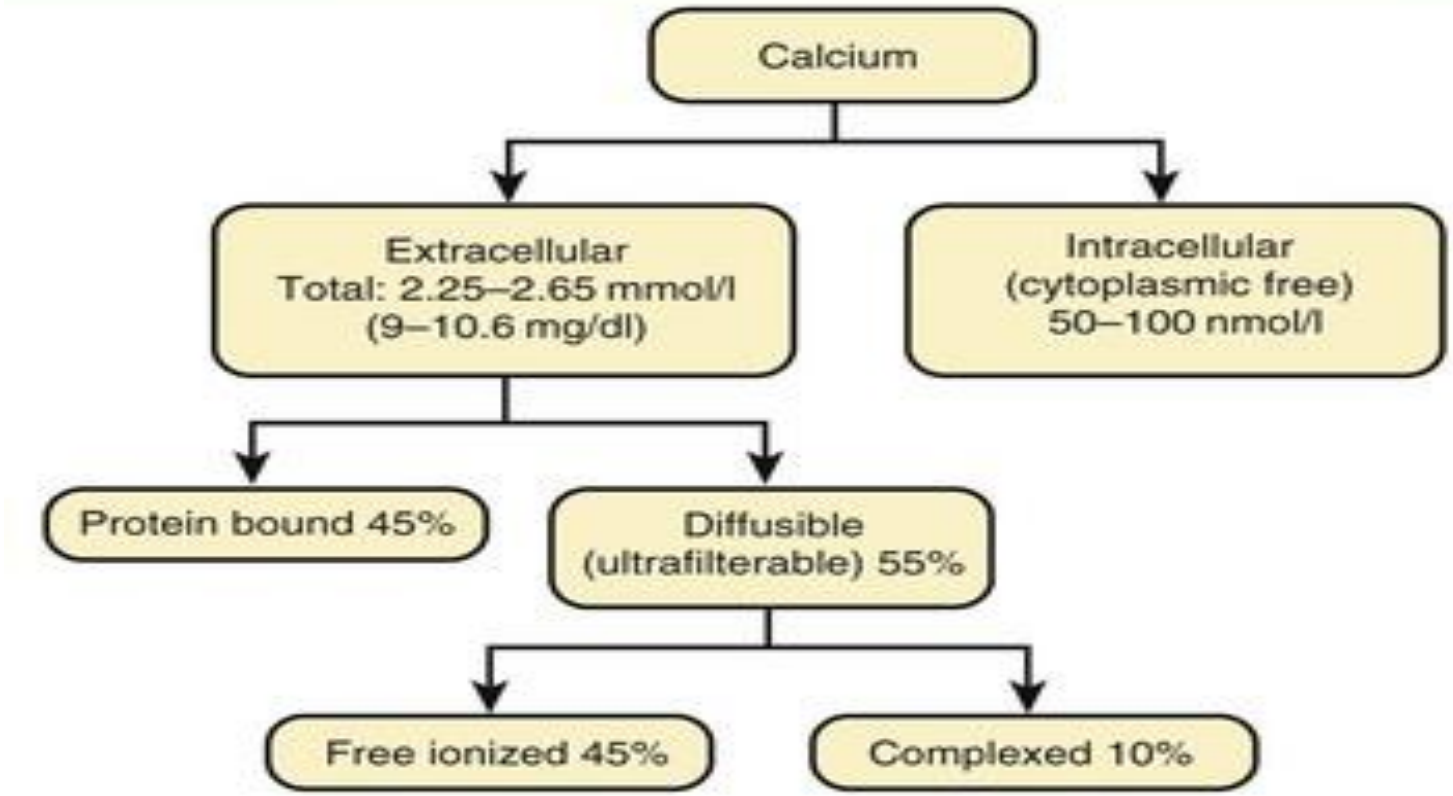
3.neuromuscular transmission .

4.Skeletal growth & mineralization

❑Calcium in blood:

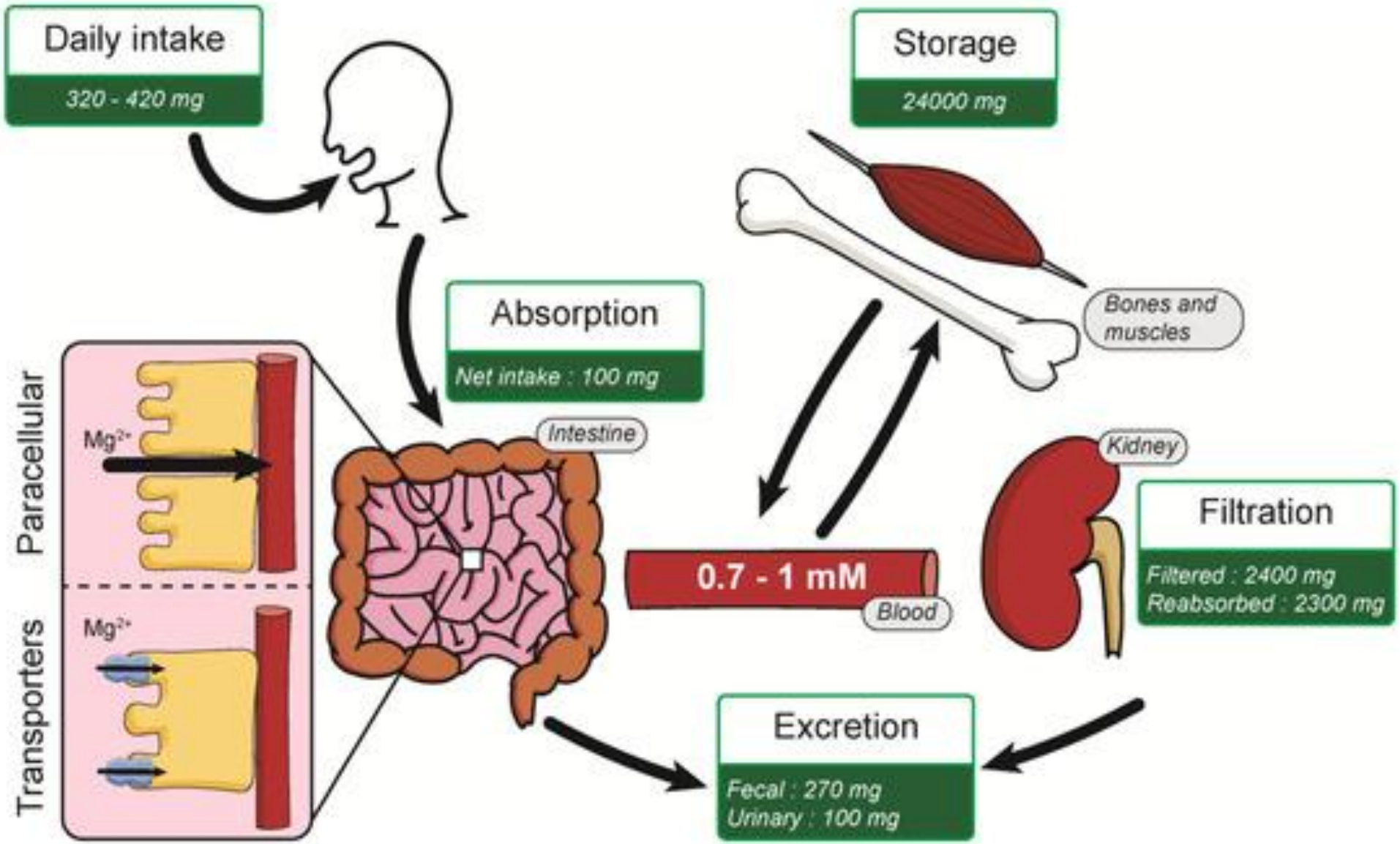
- **99%** of total body calcium in the bone and **1%** in extracellular fluid:
- The 1% can be divided in 3 components :
- 1) 50% ionized .
- 2) 40% bound to protein .
- 3)10% complex w/anions{citrate,phosphate,..

Distribution of Calcium in Extracellular and Intracellular Spaces



❑Calcium Balance

- **Normal** condition Intake = output
- **Negative** calcium balance: Output > intake
- Negative Ca^{2+} balance leads to osteoporosis (weak, porous bones – and 80% of people with osteoporosis are women. Symptoms of osteoporosis include back pain, stooped posture, height loss, and bones that break easily).
- **Positive** calcium balance: Intake > output Occurs during growth
- **Intake, Uptake and Excretion**

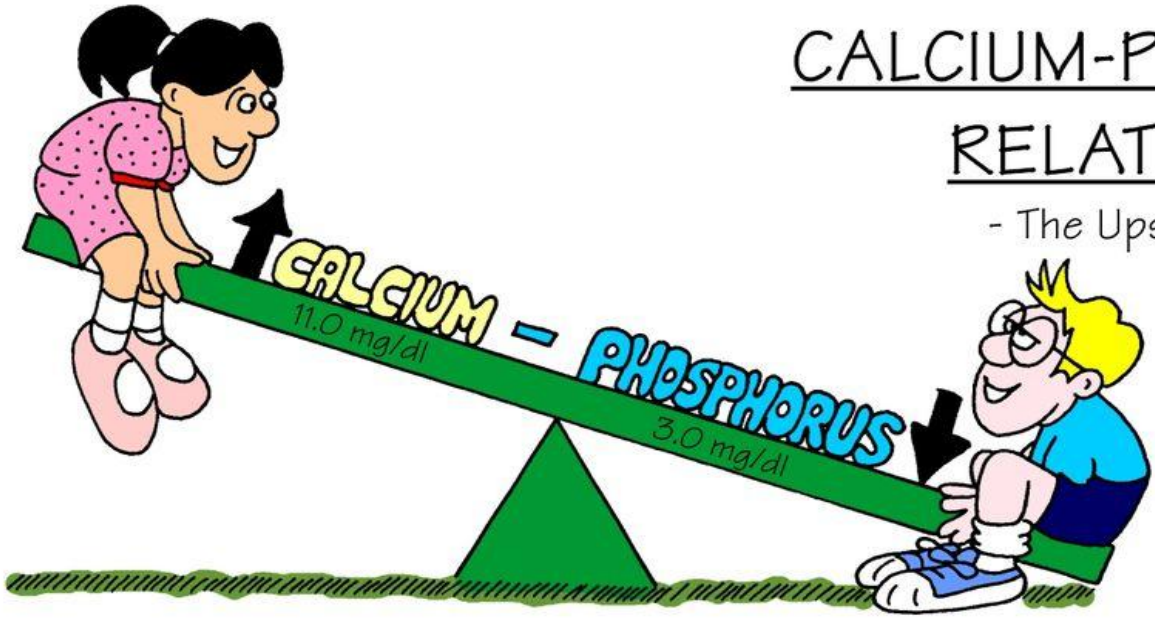

Daily intake
320 - 420 mg
Storage
24000 mg
Absorption
Net intake : 100 mg
Bones and muscles
Intestine
Paracellular
Transporters
Mg2+
Mg2+
0.7 - 1 mM
Blood
Kidney
Filtration
Filtered : 2400 mg
Reabsorbed : 2300 mg
Excretion
Fecal : 270 mg
Urinary : 100 mg

- **Regulation of plasma calcium level :**
- Dependent on the function of 3 main organs (Bone, Kidney, Intestine)with 3 main hormones (Calcitriol, Parathyroid hormone, Calcitonin) in addition of growth hormone, glucocorticoids, estrogens, testosterone & thyroid hormones**.**

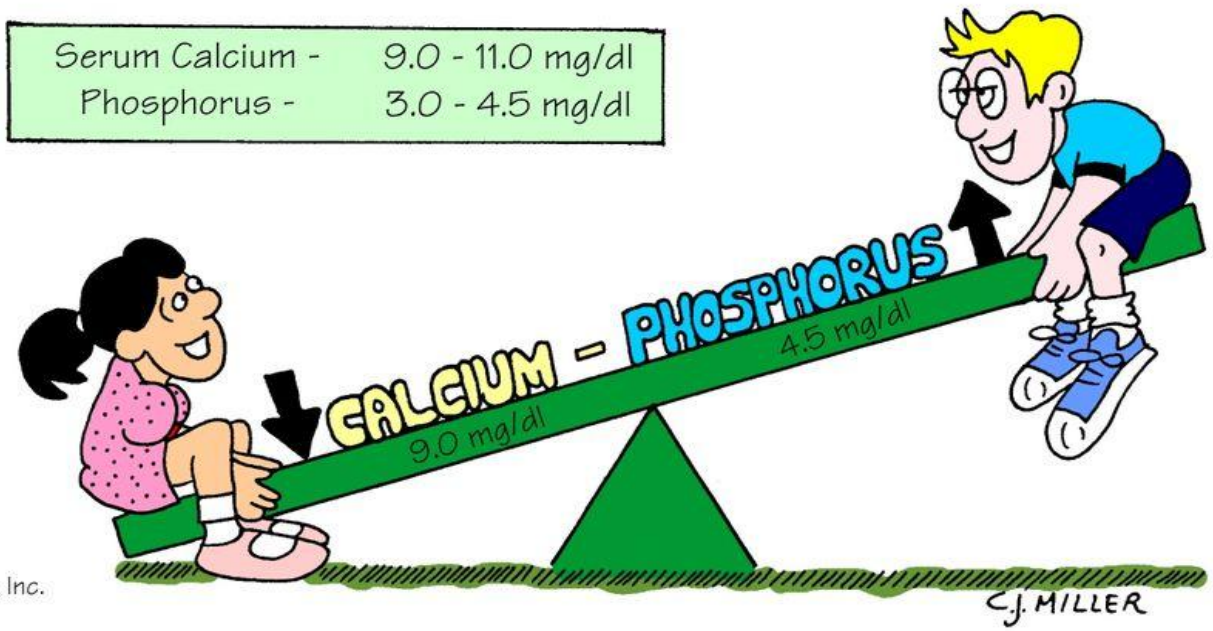
- **Vitamin D** :provide Ca & PO_4 to ECF for bone mineralization
- Deficiency of vit .D in children lead to **Rickets**
- Deficiency of vit .D in adult lead to **Osteomalacia**

CALCIUM-PHOSPHORUS RELATIONSHIP

- The Ups and Down -

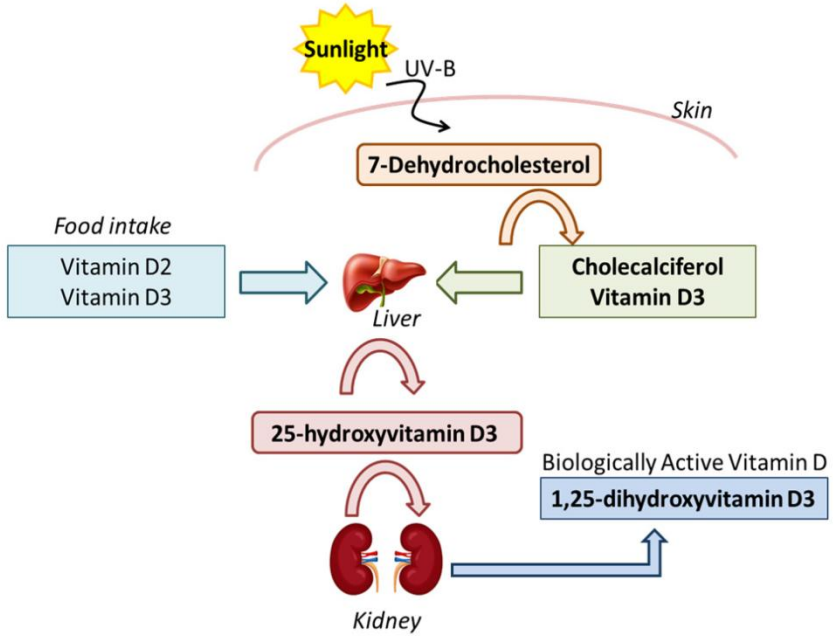


Serum Calcium -	9.0 - 11.0 mg/dl
Phosphorus -	3.0 - 4.5 mg/dl



❑Sources of Vit.D

- 7-dehydrocholestrol (skin) cholecalciferol Vitamin D is produced in the skin by ultraviolet radiation and ingested in the diet.
- Vitamin D itself is inactive, it requires modification to the active metabolite, 1,25-dihydroxy-D.
- The first hydroxylation reaction takes place in the liver yielding 25-hydroxy D. Then 25-hydroxy D is transported to the kidney where the second hydroxylation reaction takes place



Role of calcitriol on bone:

- Stimulates calcium uptake in osteoblasts for bone mineralization (as calcium phosphate)
- Essential for bone formation
- With PTH, increases calcium & phosphate release from bone
- Raises plasma calcium and phosphate levels

Role of calcitriol on kidneys : Calcitriol minimizing the excretion of Ca^{2+} & phosphate by decreasing their excretion & enhancing reabsorption .

Role of calcitriol on intestine:

- Calcitriol increases the intestinal absorption of Ca^{2+} & phosphate . Calcitriol binds with a cytosolic receptor to form a calcitriol-receptor complex . Complex interacts with DNA leading to the synthesis of a specific calcium binding protein . This protein increases calcium uptake by intestine

❑Parathyroid hormone (PTH)

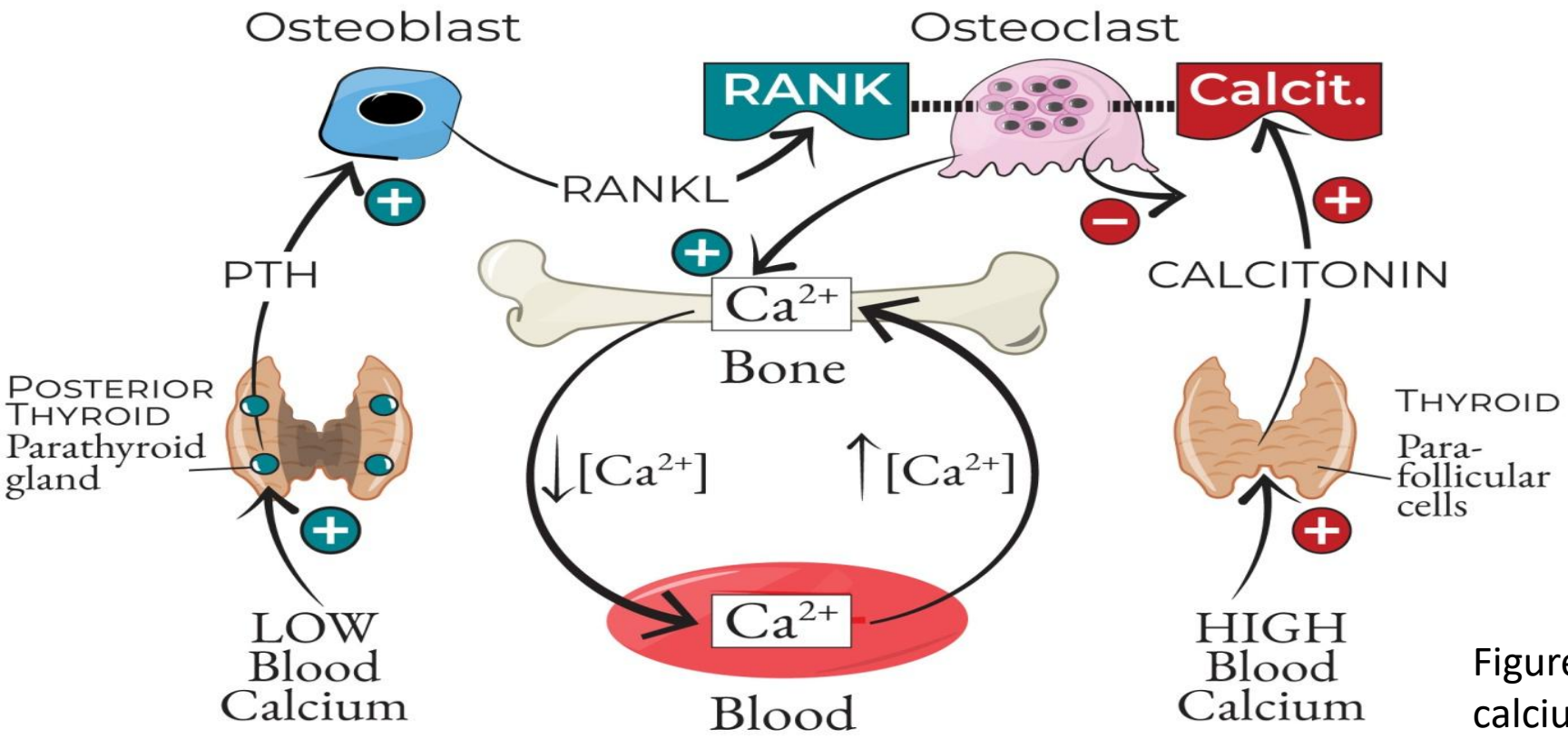
- Major hormone in regulation serum Ca. Parathyroid hormone is secreted by two pairs of parathyroid glands .
- The rate of formation & secretion of PTH are promoted by low Ca^{2+} concentration

❑Mechanism of action of PTH

- **Action on the bone:**
- PTH promotes bone demineralization by activating osteoclasts
- Enzymes like pyrophosphatase & collagenase aid in bone resorption
- Increases blood calcium (Ca^{2+}) levels
- **Action on the kidney :**
- ▪ Increases Ca^{2+} reabsorption in kidney tubules
  ▪ Rapidly raises blood calcium levels
  ▪ Stimulates production of calcitriol (1,25-DHCC)
  ↳ via 1-hydroxylation of 25-hydroxycholecalciferol.

- **Action on the intestine:** It increases the intestinal absorption of Ca^{2+} by promoting the synthesis of calcitriol

Calcium Homeostasis



Serum Calcium Range

$[Ca^{2+}]$ = 8.5 to 10.5 mg/dL

Figure: (Calcium homeostasis) .When serum calcium is low, PTH is stimulated, resulting in increased calcium release from bone and decreased renal calcium excretion. PTH also stimulates increased production of calcitriol, which acts to increase absorption of calcium from intestine

❑Calcitonin

- Calcitonin is a peptide secreted by parafollicular cells of thyroid gland .
- The action of Calcitonin on calcium is antagonistic to that of PTH .
- Calcitonin promotes calcification by increasing the activity of osteoblasts
- Calcitonin decreases bone resorption & increases the excretion of Ca^{2+} into urine
- **Overall effect : decrease serum Ca** .

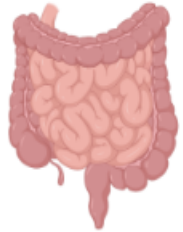
❑Calcitonin, Calcitriol and PTH Act Together

- **Hormonal Regulation of Blood Calcium**
- ↓ Blood Ca^{2+} → ↑ PTH, ↓ Calcitonin → Bone resorption → ↑ Blood Ca^{2+}
- ↑ Blood Ca^{2+} → ↓ PTH, ↑ Calcitonin → Calcium deposition in bone
- Bone serves as the main calcium reservoir

Thyroid gland

Calcitonin

Lowers Ca^{2+} levels in blood



Inhibits Ca^{2+} absorption by the intestines

Inhibits Ca^{2+} reabsorption in the kidney (excreted in the urine)

Promotes deposition of Ca^{2+} into bones (inhibits osteoclasts and stimulates osteoblasts)

❑Disturbance in calcium metabolism:

- **Hypercalcemia** :The serum Ca^{2+} level >11 mg/dl is called as Hypercalcemia

✓**Causes:**

1. Hyperparathyroidism: Decrease in serum phosphate (due to increased renal losses) and increase in ALP activity are found in hyperparathyroidism .
2. Urinary excretion of Ca^{2+} & P resulting in formation of urinary calculi .
3. The determination of ionized Ca^{2+} (elevated to 6-9mg/dl) is useful for the diagnosis of hyperparathyroidism

- **Clinical features of hypercalcemia**
- Neurological symptoms such as depression, confusion, inability to concentrate
- Generalized muscle weakness
- Gastrointestinal problems such as anorexia, abdominal pain, nausea, vomiting & constipation
- Renal feature such as polyuria & polydipsia
- Cardiac arrhythmias.

❑**Hypocalcemia** : Decreased serum Ca^{2+} < 8.8 mg/dl

- **Causes**:
- Hypoproteinaemia: If albumin concentration in serum falls, total calcium is low because the bound fraction is decreased.
- Hypoparathyroidism: The commonest cause is neck surgery, idiopathic or due to magnesium deficiency
- Vitamin D deficiency: May be due to malabsorption or an inadequate diet with little exposure to sunlight leads to bone disorders, osteomalacia & rickets.
- Renal disease: In kidney diseases, the 1, 25 DHCC (calcitriol) is not synthesized due to impaired hydroxylation
- Pseudohypoparathyroidism: PTH is secreted but there is failure of target tissue receptors to respond to the hormone

❑• Clinical features of hypocalcemia:

- Enhanced neuromuscular irritability • Neurologic features such as tingling, tetany, numbness (fingers and toes), muscle cramps
- Cardiovascular signs such as an abnormal ECG
- Cataracts

❑Rickets or osteomalacia :

- **Rickets is a** patients who have vitamin D deficiency or disturbed metabolism of vitamin D are all liable to suffer from the bone disease osteomalacia or, in children, from rickets.
- Symptoms: Bone pain, tenderness, proximal muscle weakness
- Skeletal deformities common in rickets
- Mineralisation of osteoid is defective, with absence of the calcification front. Other causes of rickets or osteomalacia, unrelated to vitamin D deficiency or defects in its metabolism, An inherited defect in the tubular reabsorption of phosphate

* BONE SOFTENING

- FAULTY PROCESS of BONE MINERALIZATION
- DEFICIENT or IMPAIRED METABOLISM of
  - VITAMIN D
  - PHOSPHATE
  - CALCIUM

RICKETS
(in CHILDREN)

OSTEOMALACIA
(in ADULTS)

❑Osteoporosis

- A metabolic bone disease characterized by progressive **demineralization** and loss of bone mass, leading to reduced bone strength and increased fracture risk.
- **Pathophysiology:**
  - After age 40-45, calcium absorption decreases and excretion increases, creating a **net negative calcium balance**.
  - This imbalance accelerates bone demineralization, with clinical osteoporosis typically evident after age 60.
- **Etiological Factors in Aging:**
  - Decreased intestinal absorption of Vitamin D.
  - Reduced levels of sex hormones (estrogens/androgens).

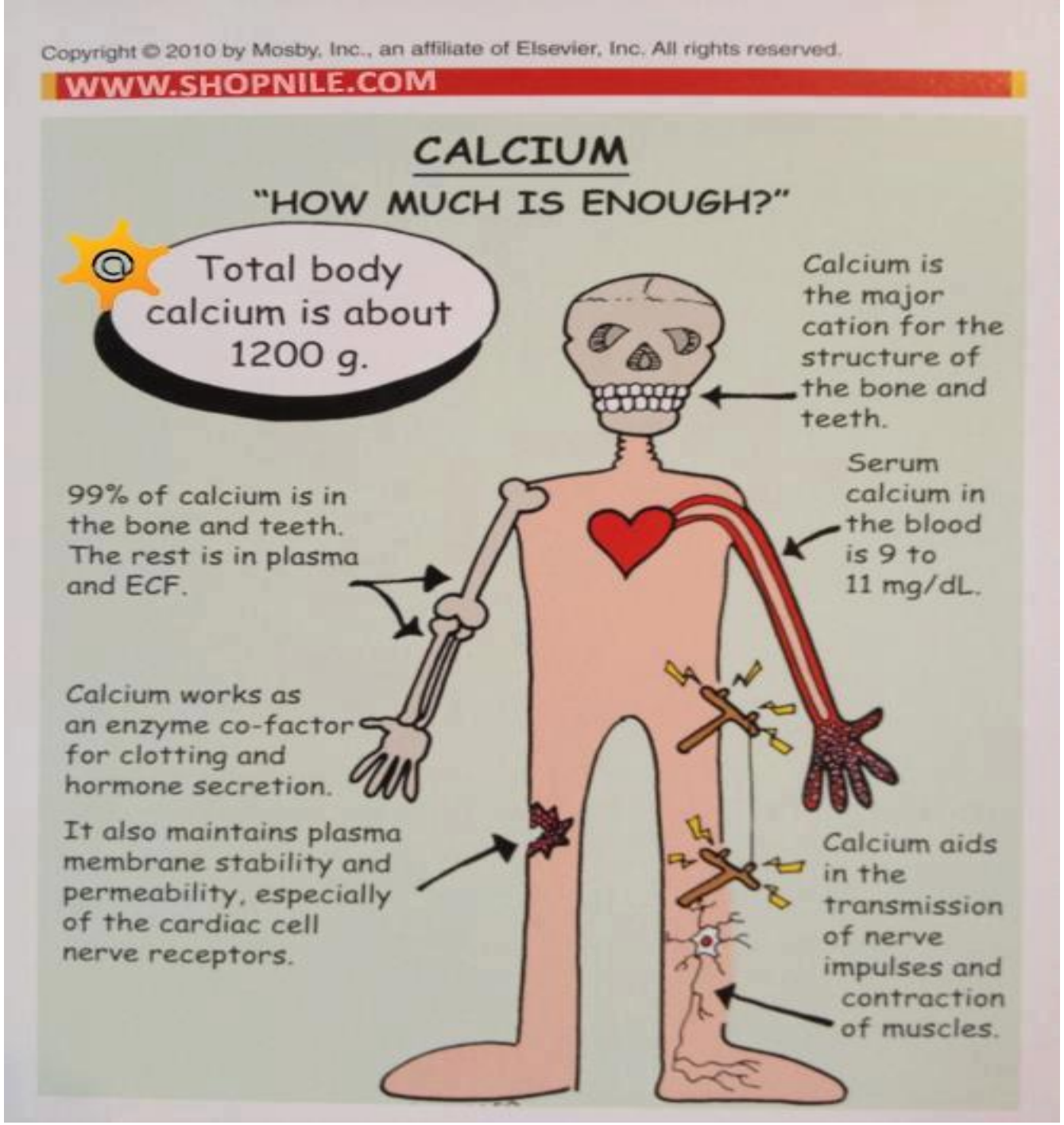
❑ Paget's disease of bone

- Paget's disease is more common in the elderly, possibly being present in about 5 per cent of people over 60 years old.
- There is increased bone turnover and remodelling due to increased osteoclastic and osteoblastic function.

- Diagnosis may needing radiographs and/or bone scanning. Plasma calcium and phosphate concentrations are rarely affected unless ,. Plasma alkaline phosphatase activity is typically very high.

Osteomalacia	Osteoporosis	Differences
Demineralization of the bones	Reduction of the bone mineral density	Definition
Adults	≥ 65 years women	Presence
Weakness of the muscles and fragile bones	Curving of the back and risk for fractures	signs and symptoms
Deficiency in Vitamin D	Deficiency in calcium and phosphorous, drugs, inherited, endocrine disorders, alcohol drinking.	Causes
Injections of Vitamin D	Healthy lifestyle, calcium supplements and naturally calcium-diet	Treatment

Thank you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CALCIUM
"HOW MUCH IS ENOUGH?"
Total body calcium is about 1200 g.
Calcium is the major cation for the structure of the bone and teeth.
Serum calcium in the blood is 9 to 11 mg/dL.
99% of calcium is in the bone and teeth. The rest is in plasma and ECF.
Calcium works as an enzyme co-factor for clotting and hormone secretion.
It also maintains plasma membrane stability and permeability, especially of the cardiac cell nerve receptors.
Calcium aids in the transmission of nerve impulses and contraction of muscles.