MINERALS

- *Minerals are inorganic elements*

- **CLASSIFICATION**
- **Minerals are classified as principal elements and trace elements**
- **PRINCIPAL ELEMEMTS**
- **The principal elements are required in amounts greater than 100 mg / day**

- **Principal elements are**
- Calcium
- Phosphorus
- Magnesium
- Sodium
- Potassium
- Chloride
- Sulphur

- ESSENTIAL TRACE ELEMENTS
- Iron , copper , iodine , manganese , zinc , molybdenium , cobalt , florine , selenium ,and chromium

- POSSIBLY ESSENTIAL ELEMENTS
- Nickel , vanadium , cadmium , barium
- NON ESSENTIAL TRACE ELEMEMTS
- Aluminum , lead , mercury , boron ,silver ,bismuth .

CALCIUM

LEARNING OBJECTIVES

- Daily intake
- Functions
- Role in formation of cellular matrix of bone
- Diseases

Calcium

Calcium is the most abundant among the minerals in the body. The total content of calcium in an adult man 1 to 1.5kg. 99% of it is present in the bones and teeth and small fraction (1%) of the calcium, found outside the skeletal tissue, perform a wide variety of fucnctions.

Biochemical functions

1. **Development of bone and teeth:** Ca^{+2} along with phosphate is required for the formation of (hydroxyapatite) and physical strength of skeletal tissue. Bone is regarded as a mineralized connective tissue. Bone which are in a dynamic state serve as reservoir of Ca^{+2}
2. **Muscle contraction:** Ca^{+2} interacts with troponin C to trigger muscle contraction. Ca^{+2} also activates ATPase, increases the interaction between actin and myosin .

Biochemical functions

3. **Blood coagulation:** several reactions in the cascade of blood clotting process are are dependent on Ca^{+2}
4. **Nerve transmission:** Ca^{+2} is necessary for the transmission of nerve impulse.
5. **Membrane integirty and permeability:** Ca^{+2} influences the membrane structure and transport of water and several ions across it
6. **Activation of enzymes:** Ca^{+2} is needed for the direct activation of enzymes such as lipase (pancreatic), ATPase and succinate dehydrogenase

Biochemical functions

7. Calmodulin mediated action of Ca^{+2}: Calmodulin (mol. Wt. 17,000) is a Ca^{+2} binding regulatory protein.ca-calmodulin complex activates certain enzymes e.g adenylate cyclase, Ca^{+2} dependent protein kinases.

8. Calcium as intracellular messenger: certain hormones exert their action through the mediation of Ca^{+2}(instead of cAMP). Calcium is regarded as a second messenger for such hormonal action e.g. epinephrine in liver glycogenolysis. Ca^{+2} serves as a third messenger for some hormones e.g. antidiuretic hormone (ADH) acts through cAMP, and then Ca^{+2}

9. Release of hormones: The release of certain hormones (insulin, PTH,calcitonin) from the endocrine glands is facilitated by Ca^{+2}

Biochemical functions

10. Secretory processes: Ca^{+2} regulates microfilament and microtubule mediated processes such as endocytosis and exocytosis and cell motility.

Sources / Absorption

Best sources ------ Milk and milk products

Good sources ---------- Beans, leafy vegatables,fish, cabbage, egg yolk.

Absorption: The absorption of Ca^{+2} mostly occurs in the duodenum by an energy dependent active process.

Dietary requirments

Adult men and women ---------- 800 mg/day

Woman during

Pregnancy, laction

and post-menopause ---------- 1.5g/day

Children (1-18 yrs) ---------- 0.8-1.2 g/day

Factors promoting Ca absorption

1. Vitamin D (through its active from calcitriol) induces the synthesis of Ca^{+2} binding protein in the intestinal epithelial and promotes Ca absorption.
2. Parathyroid hormone enhances Ca absorption through the increase synthesis of calcitriol.
3. Acidity (low pH) is more favourable for Ca absorption
4. Lactose promotes Ca^{+2} uptake by intestinal cells.
5. The amino acids lysine and arginine facilitate Ca absorption.

Factors inhibiting Ca absorption

1. Phytates and oxalates form insoluble salts and interfere with Ca absorption
2. High content of dietary phosphate results in the formation of insoluble Ca^{+2} phosphate and prevents Ca uptake. The dietary ratio of Ca and P----- between 1 : 2 and 2 : 1-----is ideal for optimum Ca absorption by intestinal cells
3. Alkaline condition (high pH) is un-favourable for Ca absorption
4. High content of dietary fiber interferes with Ca absorption.

Plasma calcium

Most of Ca^{+2} is present in the plasma since the blood cells content very little of it. The normal concentration of plasma or serum Ca is 9-11 mg/dl (4.5-5.5 mEq/l).

Factors regulating plasma Ca LEVEL:

The hormones ------ Calcitriol, parathyroid hormone (PTH) and calcitonin are the major factors that regulate the plasma calcium.

Role of PTH

- Stimulates renal reabsorption of calcium
- Inhibits renal reabsorption of phosphate
- Stimulates bone resorption
- Inhibits bone formation and mineralization
- Stimulates synthesis of calcitriol

Net effect of PTH
→

↑ serum calcium
↓ serum phosphate

- **MECHANISM OF ACTION OF PTH**
- Parathyroid harmone binds to a membrane receptor protein on the target cells and activates adenylate cyclase to liberate cAMP .
- Which then increases intracellular calcium that promotes phosphorylation of proteins which brings about biological actions .
- Parathyroid harmone exerts it,s action on three tissues
- Bone , kidneys and intestine .

- **ACTION ON BONE**
- Parathyroid harmone causes demineralization of bone carried by osteoclasts .
- Parathyroid harmone stimulates increased activity of pyrophosphatase and collagenase enzymes ,which results in bone resorption .

- **ACTION ON KIDNEYS**
- Parathyroid harmone increases the calcium reabsorption by kidney tubules resulting in increase in blood calcium level .
- Parathyroid harmone promotes the production of calcitriol in the kidney by stimulating 1-hydroxylation of 25-hydroxycholecalciferol .
- **ACTION ON INTESTINE**
- Action is indirect ,increases absorption by promoting synthesis of calcitriol .

Regulation of PTH

Low serum [Ca^{+2}] → Increased PTH secretion

High serum [Ca^{+2}] → Decreased PTH secretion

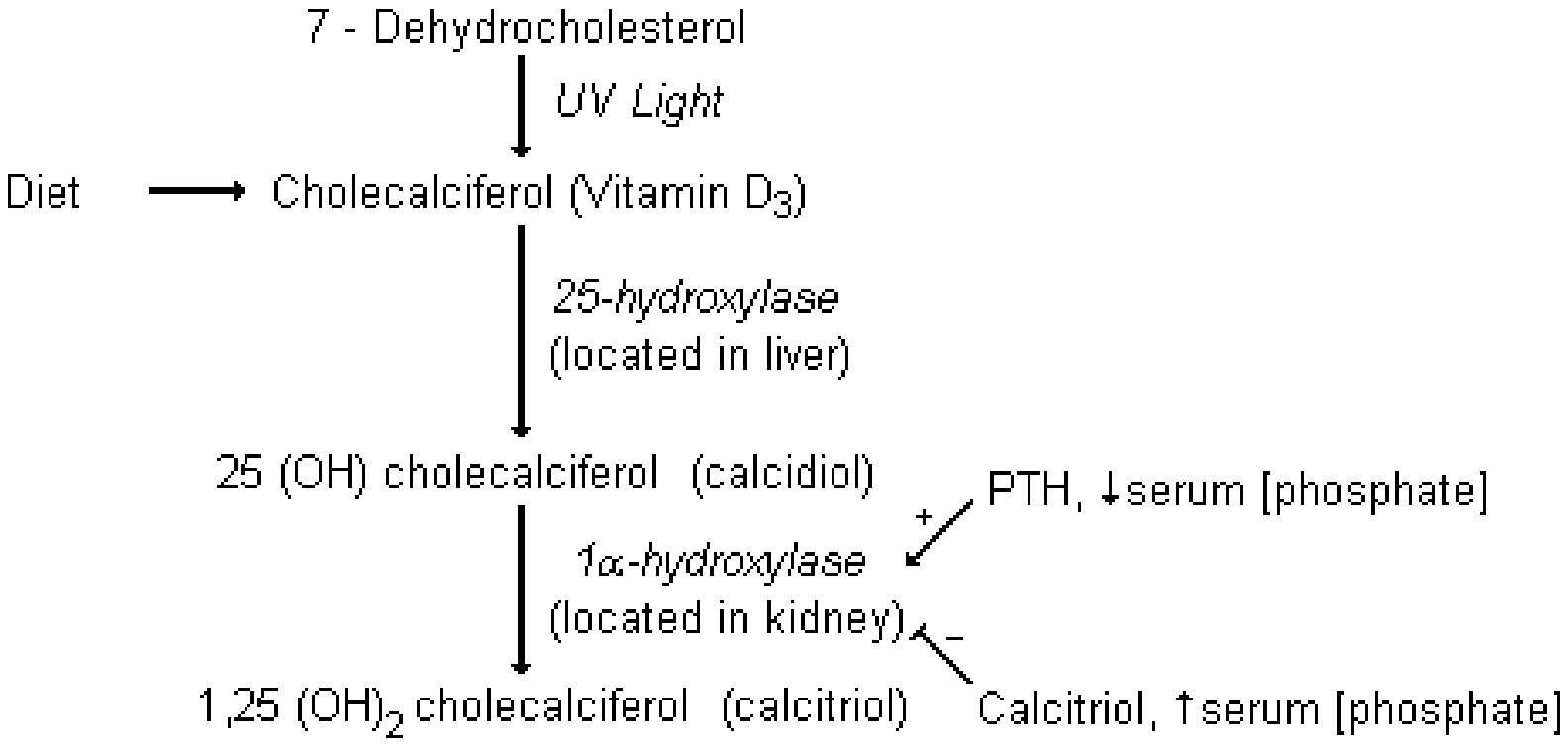
Role of Calcitriol

- Stimulates GI absorption of both calcium and phosphate
- Stimulates renal reabsorption of both calcium and phosphate
- Stimulates calcium uptake by osteoblasts of bone and promotes calcification

Net effect of calcitriol →

↑ serum calcium
↑ serum phosphate

Regulation of Calcitriol



Calcitonin

Calcitonin is peptide containing 32 amino acids. It is secreted by parafollicular cells of thyroid gland. The action of CT on calcium metabolism is antagonistic to that of PTH. Calcitonin promotes calcification by increasing the activity of osteoblasts.

Importance of Ca : P ratio: The ratio of plasma Ca : P is important for calcification of bones. The product of Ca x P (in mg/dl) in children is around 50 and in adults around 40. This product is less then 30 in Rickets.

Disease states
Hypercalcemia

Elevation in serum Ca level (normal 9-11mg/dl) is hypercalcemia. Hypercalcemia is associated with hyperparathyroidism caused by increased activity of parathyroid glands. Decreased in serum phosphate (due to increased renal losses) and increase in alkaline phosphate activity are also found in hyperparathyroidism. Elevation in the urinary excretion of Ca and P, often resulting in the formation of urinary calculi, is also observed in these patients.

Disease states Hypercalcemia

- The symptoms of hypercalcemia include lethargy, muscle weakness, loss of appetite, constipation , nausea, increased myocardial contractility and susceptibility to fractures.

Hypocalcemia

Hypocalcemia is characterized by a fall in the serum Ca to below 7 mg/dl, causing tetany. The symptoms of tetany include neuromuscular irritability, and convulsions.

Cause : The main cause of hypocalcemia due to hypoparathyroidism. This may happen after an accidental or surgical removal of parathyroid or due to an autoimmune disease.

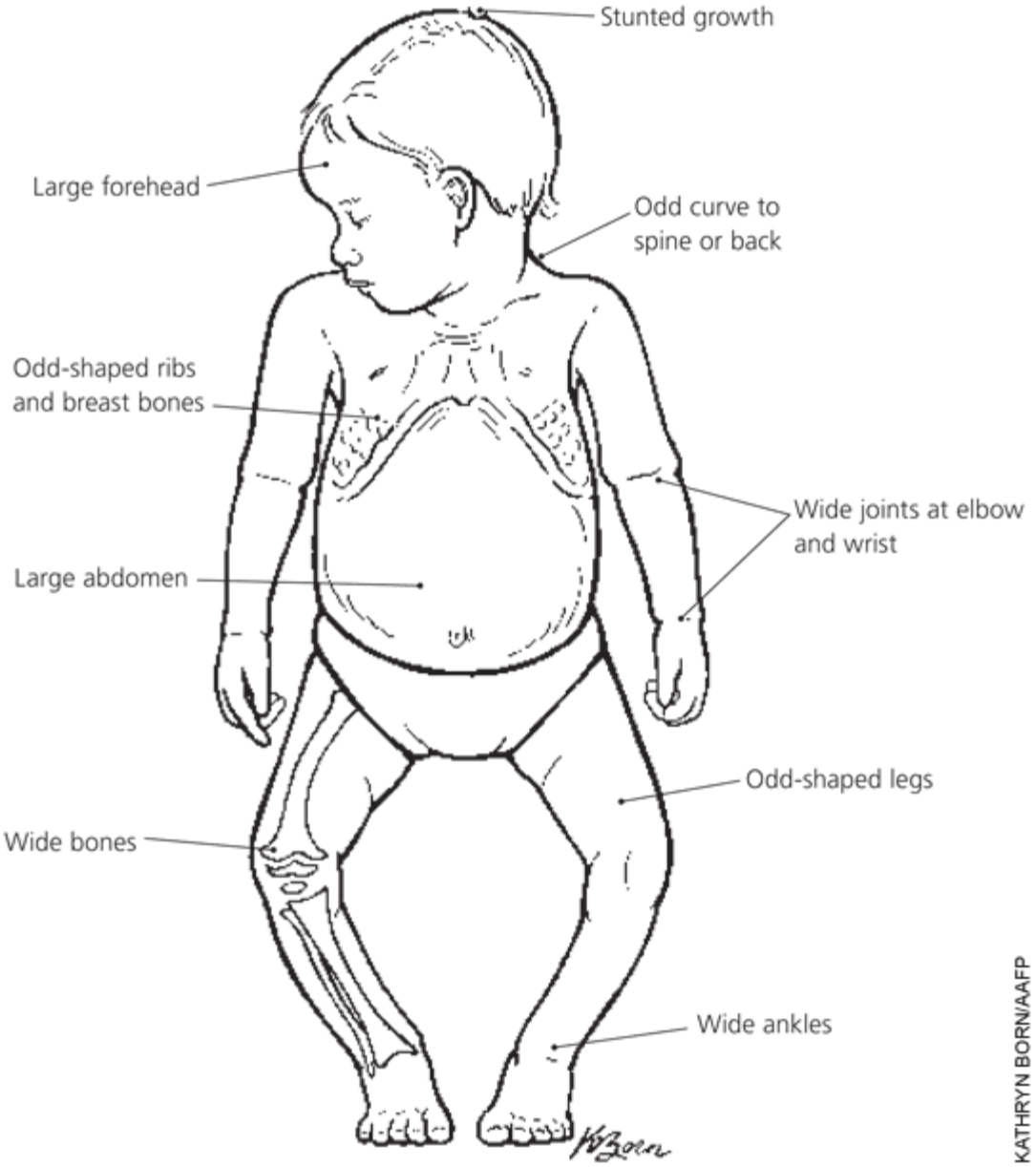
Hypocalcemia

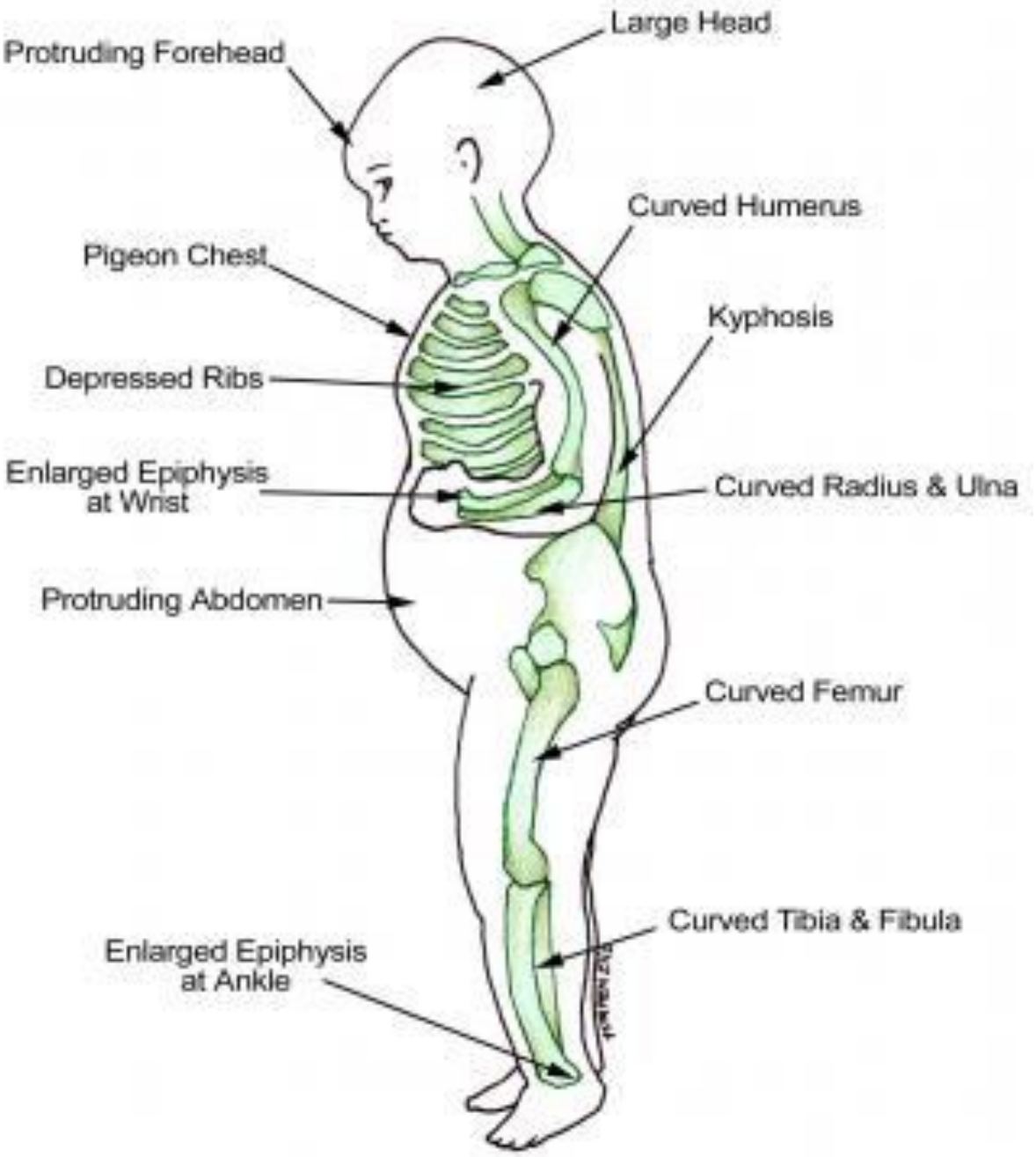
Treatment: supplementation of oral calcium with vitamin D is commonly employed. In severe causes of hypocalcemia Calcium gluconate is intravenously administered

- TETANY
- Main manifestation is carpopedal spasm .laryngeal ,and stridor .
- Chvostek,s sign tapping over facial nerve causes facial contraction will be positive .
- Trousseu,s sign inflation of Bp cuff for 3 mints causes carpopedal spasm .

Rickets

Rickets is a disorder of defective calcification of bones. This may be due to a low level of vitamin D in the body or due to a dietary deficiency of Ca and P ---- or both. The concentration of serum Ca and P may be low or normal. An increase in the activity of alkaline phosphate is a characteristic feature of rickets.


Stunted growth
Large forehead
Odd curve to spine or back
Odd-shaped ribs and breast bones
Wide joints at elbow and wrist
Large abdomen
Odd-shaped legs
Wide bones
Wide ankles
KATHRYN BORN/AAFP


Protruding Forehead
Large Head
Curved Humerus
Pigeon Chest
Kyphosis
Depressed Ribs
Enlarged Epiphysis at Wrist
Curved Radius & Ulna
Protruding Abdomen
Curved Femur
Curved Tibia & Fibula
Enlarged Epiphysis at Ankle

- Rickets is a vit D and calcium deficiency in growing children and is characterized by continuous formation of collagen matrix of bone but incomplete mineralization , resulting in soft pliable bones.
- Rickets can be nutritional or renal .
- SIGN AND SYMPTOMS
- Incomplete mineralization of bone
- Bossing of head
- Increased osteoblastic activity ,increase alkaline phosphatase.

- Cartilage cells at the end of long bones continue to proliferate
- Bow legs tibia bends forwards and femur outwards
- Spine shows kyphosis and scolosis
- Harrison Sulcus a transverse grove appears corresponding with the insertion of diaphragm on either side of thorax
- Pigeon Chest sternum protrudes forward
- Delayed closure of fontanella .

OSTEOPOROSIS

- Osteoporosis is one of the most prevalent disease of aging.
- The disease occurs when the bone mineral density becomes so low that the skeleton is unable to sustain ordinary strains, a condition marked by the occurrence of fractures

Bone section through hip

Normal Bone

Bone with Osteoporosis

OSTEOPOROSIS

Dietary Factors

- Excessive dietary fiber may interfere with calcium absorption
- Excessive animal protein consumption may lead to increased urinary calcium excretion
- High sodium intakes, especially in association with low calcium intakes, can result in increased urinary calcium excretion
- Caffeine can reduce calcium absorption and increase excretion rates.
- High phosphorus intake, in association with low calcium intake may increase bone loss

- **OCCURRENCE**
- AGE above 60 yrs both males and females but more females especially post menopausal females

- **ETIOLOGY**
- **Decrease vit D**
- **Decrease sex harmones**

PREVENTION of OSTEOPOROSIS

- Increase intake of bone-building nutrients
- Reduce consumption of alcohol, tobacco, caffeine, sodium, and animal protein
- Engage in regular weight-bearing exercise

Treatment

Estrogen administration along with calcium supplementation (in combination with vitamin D) to postmenopausal women reduces the risk of fractures. Higher dietary intake of Ca (about 1.5 g/day) is recommended for elderly people

MINERALS
PHOSPHORUS

PHOSPHORUS

Sources

RDA

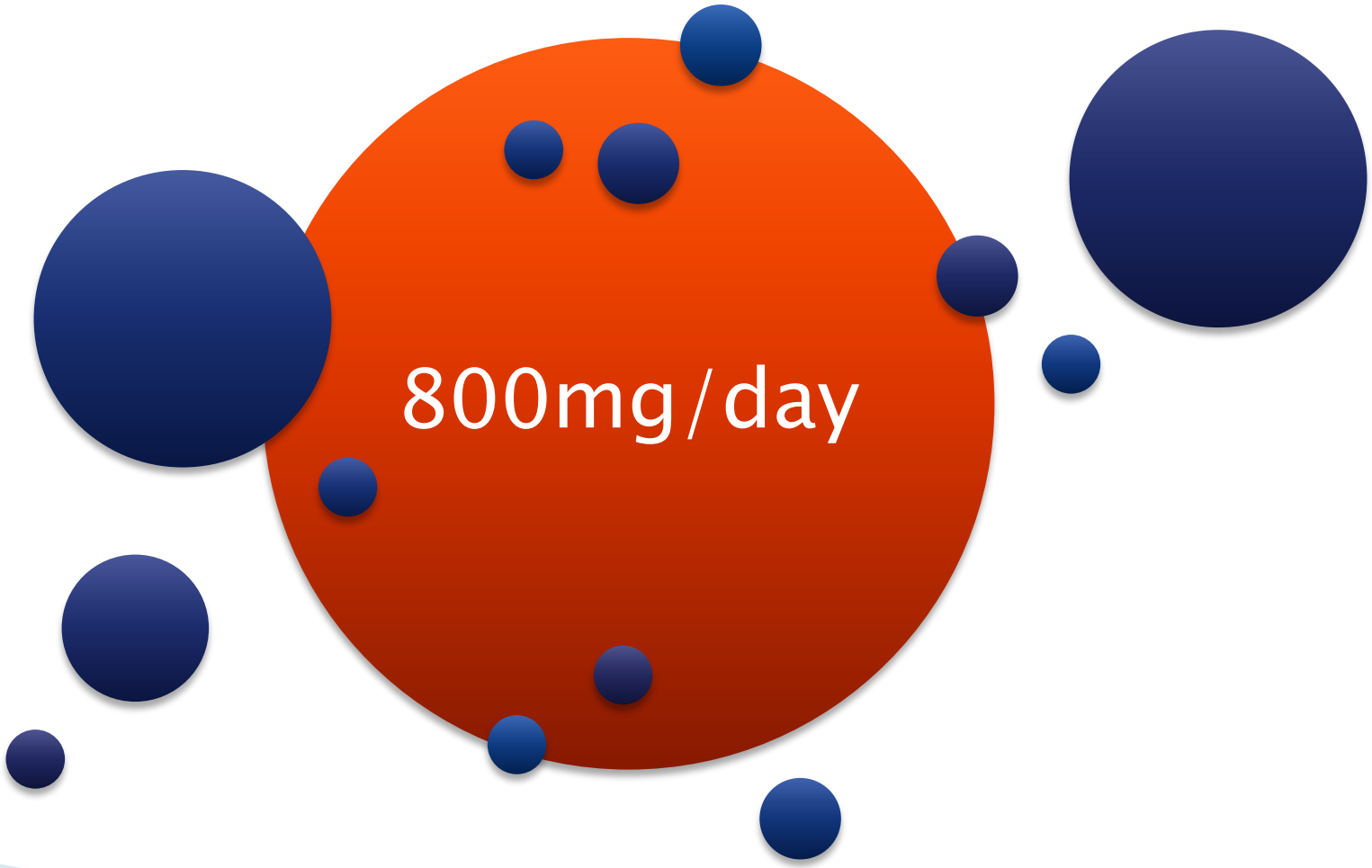
Metabolism

Functions

Disorders

PHOSPHORUS – SOURCES

PHOSPHORUS – RDA



PHOSPHORUS-METABOLISM

Absorption

Factors affecting absorption

Excretion

PHOSPHORUS-ABSORPTION

Efficiency

70% absorbed

FACTORS AFFECTING PHOSPHORUS ABSORPTION

Phosphorus absorption increased by

- Bile salts
  Acidity
  PTH and vitamin D
  Calcium

Phosphorus absorption decreased by

- High Ca: P ratio
  Phytates
  Alkalinity
  Magnesium and aluminium

PHOSPHORUS–EXCRETION

Urine

2/3 of ingested phosphate

0.6gm/day

Stool

Due to non-absorption

0.2 – 0.5 gm/day

Factors affecting renal excretion

↑ PTH

PHOSPHORUS

FUNCTIONS

- Formation of bone and teeth
- Production of high energy compounds
- DNA and RNA synthesis
- Synthesis of coenzymes
- Synthesis of phosphoproteins and phospholipids
- Activation of enzymes by phosphorylation
- Acid base balance

POSPHORUS – DISTRIBUTION

Human body contain about 840gm to 1kg of phosphorus

- 80% present in bone and teeth
- 20% in other tissue

Plasma phosphorus : 3 – 4mg/100ml

PLASMA PHOSPHORUS

ADULT	3 –4mg/dl
CHILDREN	5 – 6mg/dl

REGULATION OF PLASMA PHOSPHORUS

3
HORMONES

$1,25(OH)_2D_3$

PTH

Calcitonin

REGULATION OF PLASMA PHOSPHORUS

$1,25(OH)_2D_3$

Increases plasma phosphorus

Increases absorption from intestine

Increases the mobilization from bone

Increases the renal reabsorption

REGULATION OF PLASMA PHOSPHORUS

PTH

Decreases plasma phosphorus

Decreases the renal reabsorption

REGULATION OF PLASMA PHOSPHORUS

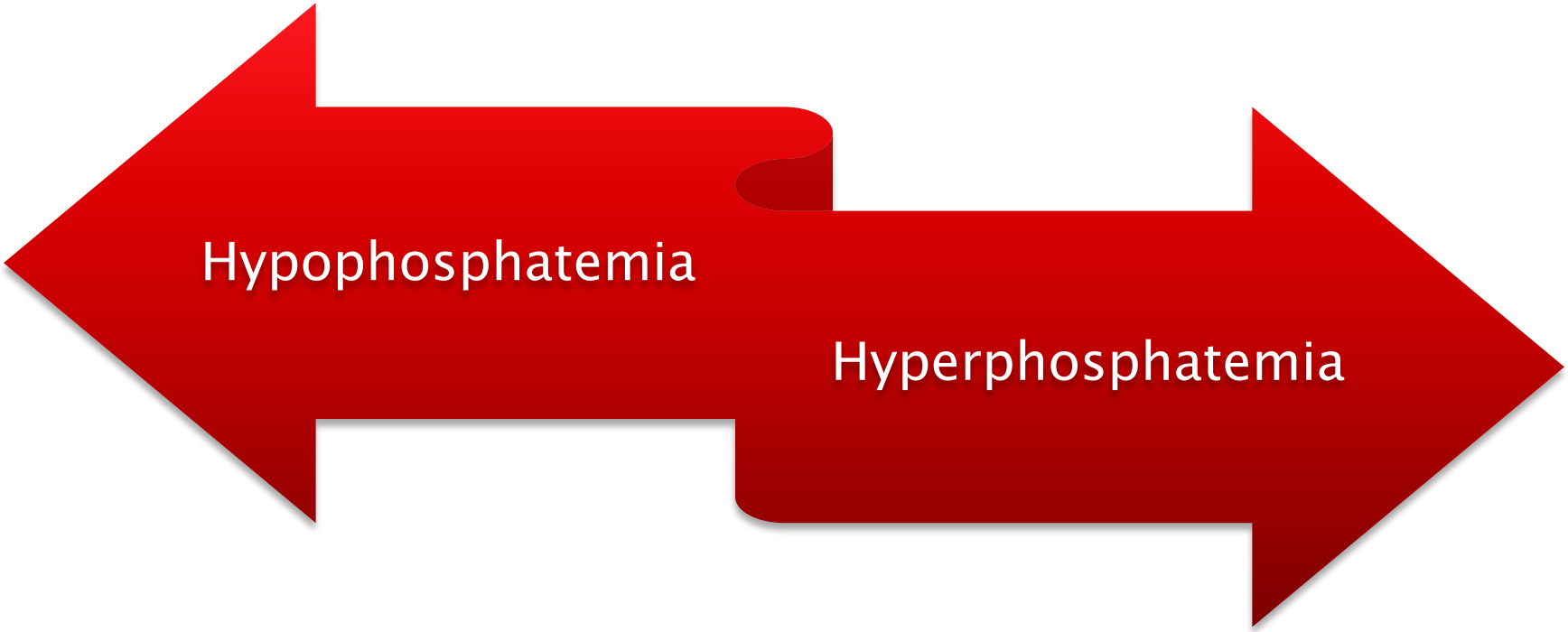
Calcitonin

Decreases plasma phosphorus

Inhibits bone resorption

Decreases the renal reabsorption

DISORDERS OF PHOSPHORUS METABOLISM



HYPOPHOSPHATEMIA

HYPOPHOSPHATEMIA – CAUSES

- Decreased intake
- Decreased absorption
- Increased loss

HYPOPHOSPHATEMIA – TREATMENT

Management of underlying disease

Administration of phosphate

- **Causes 0f hypophosphatemia**
- 1 Decreased absorption of phosphate
- 2 Increased urinary excretion of phosphate
- 3 Hypercalcemia
- 4 Drugs
- Antacids
- Diuretics
- Salicylate intoication

HYPERPHOSPHATEMIA

HYPERPHOSPHATEMIA

CAUSES

- Increased intestinal absorption
- Decreased renal excretion
- Extracellular shift of phosphorus
- Hemolysis

HYPERPHOSPHATEMIA FEATURES

Features of underlying diseases

Soft tissue calcification

- DISEASES
- Serum phosphate level is increased in hypoparathyroidism and decreased in hyperthyroidism
- In severe renal diseases serum phosphate is increased causes acidosis
- Vit D deficiency rickets is characterized by decrease serum phosphate
- Renal rickets is associated with low serum phosphate and . increase alkaline phosohatase activity

MAGNESIUM

The eighth most abundant element in the earth's crust

MAGNESIUM

- The adult body contain about 20 g of magnesium
- About 70% of which is found in bones in combination with calcium and phosphorus.
- The remaining 30% occurs in the soft tissue and body fluids.

MAGNESIUM

Biochemical functions:

- Magnesium is required for the formation of bone and teeth.
- Mg^{+2} serves as a cofactor for several enzymes requiring ATP e.g hexokinase, glucokinase, phosphofructokinase, adenylate cyclase.
- Mg^{+2} is necessary for proper neuro muscular function. Low Mg^{+2} levels lead to neuromuscular irritability.

Can it be synthesized by the human body or must it come from other sources

- Magnesium is a mineral, so therefore just like calcium, magnesium must be absorbed through dietary intake.

Food Sources

- Green vegetables.
- Legumes(beans and peas)
- Nuts and seeds
- Meat , Milk, & fruits.
- Unrefined grains
- Tap water (varies according to the water supply)

Daily Requirement (RDA)

- Adult man ---------- 350mg/day
- Adult woman ---------- 300mg/day

Absorption

- Magnesium is absorbed by the intestinal cells through a specific carrier system.
- About 50% dietary Mg is normally absorbed
- consumption of large amount of calcium phosphate and alcohol diminishes Mg absorption.
- PTH increases Mg absorption

Serum Mg

- Normal serum concentration of Mg is 2—3 mg/dl. It is present in ionized form (60%),
- In combination with other ions (10%).
- Bound to proteins (30%)

Deficiency/Disease Treatment

- Hypomagnesemia, resulting in low blood calcium levels, muscle cramps,spasms or seizures, nausea, weakness, irritability and confusion
- Chronic diseases such as heart disease, high blood pressure, osteoporosis and type 2 diabetes
- Early signs of magnesium deficiency include loss of appetite, nausea,vomiting,fatigue,and weakness

Fun Facts

- “HARD” water contains more magnesium than “Soft” water
- Craving chocolate? Take some magnesium to help take the cravings away

POTASSIUM

Potassium

Potassium is the principal intracellular cation. It is equally important in the extracellular fluid for specific function

Biochemical functions

- κ+ maintains intracellular osmotic pressure
- It is required for the regulation of acid base balance and water balance in the cells.
- The enzyme pyruvate kinase (of glyocolsis) is dependent κ+ for optimal activity.
- K+ is required for the transmission of nerve impulse.
- Adequate intracellular concentration K+ is necessary for proper biosynthesis of proteins by ribosomes.
- Extracellular K+ influences cardiac muscle activity.

Dietary requirments

About 3-4 g/day

Sources

Banana , orange, pineapple, potato, beans, chicken, and liver. Tender coconut water is a rich source of potassium.

Absorption: The absorption of K+ form GIT tract is very efficient (90%) and very little is lost through feces.

Plasma potassium/ Excretion

The plasma (serum) concentration of K+ is 3.4–5.0 mEq/l.

Excretion: K+ is mainly excreted through urine the maintenance of body acid–base balance influences K+ excretion.

Disease States

Hypokalemia: Decrease in the concentration of serum K+ is observed due to overactivity of adrenal cortex (cushing's syndrome) prolonged cortisone therapy I/V administration of K+ free fluids treatment of diabetic coma with insulin prolonged diarrhea and vomiting.

The symptoms of hypokalemia includes irritability, muscular weakness, tachycardia, cardiomegaly and cardiac arrest.

Disease States

Hyperkalemia: Increase in the concentration of serum K+ is observed in renal failure, adrenocortical insufficiency (Addison's disease) diabetic coma, servere dehydration I/V administration of fluids with excessive potassium salts.

The manifestation of hyperkalemia include depression of central nervous system, mental confusion, numbness, bradycardia.

SODIUM

- Sodium is the chief cation of the extra cellular
- Fluid
- BIOCHEMICAL FUNCTIONS
- 1 Regulates acid base balance of the body
- 2 Maintains osmotic pressure and fluid balance of the body
- 3 Is necessary for normal muscle irritability and cell permeability
- 4 Is necessary for maintaining heart beat
- 5 Is necessary for intestinal absorption of
- Glucose galactose and amino acids

- DAILY REQUIREMENT
- 5-10g/day
- SOURCES
- Common salt
- Bread whole grain
- Leafy vegetables
- PLASMA SODIUM
- Normal concentration of plasma sodium is
- 135_145mEq/l

- EXCRETION

- kidney is the major route of excretion from the body
- Most of the filtered sodium by the glomeruli is reabsorbed by the renal tubules
- DISEASES
- HYPONATREMIA
- Serum sodium level falls below normal
- Hyponatremia may occur in vomiting diarrhea
- Chronic renal diseases adrenocortical insufficiency Addison disease

HYPERNATREMIA

- Increased sodium level
- SYMPTOMS
- Increased blood volume and blood pressure
- Hyperactivity of adrenal cortex (cushing syndrome)

- prolong Administration of cortisone ACTH
- Loss of water from the body
- Rapid administration of sodium salts
- Pregnancy steroid and placental harmones

- Edema causes sodium retention along with
- Water
- In patients of hypertention and congestive
- Heart failure low sodium (salt) is advised