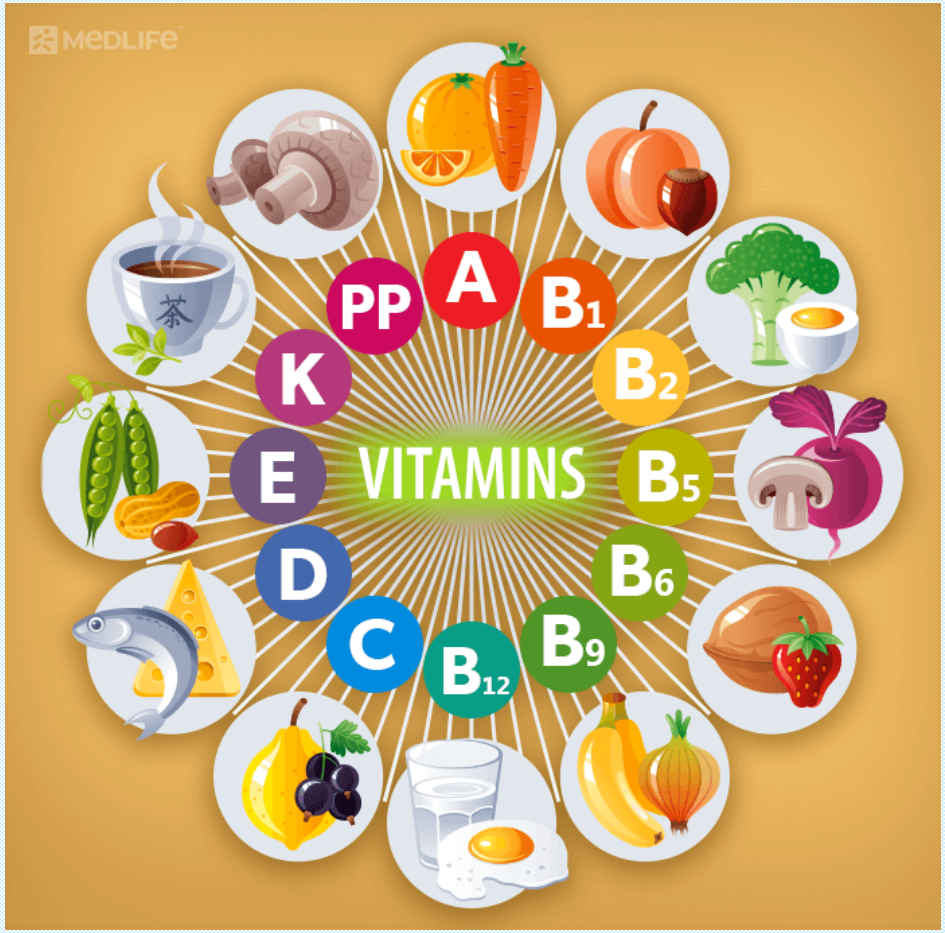
VITAMINS



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What are vitamins ?

- **A group of substances that are needed for normal cell function, growth, and development**.
- Nutrients that our body does not make on its own. Thus we must obtain them from the foods we eat, or via vitamin supplements.
  - ✓ Inadequate supply results in deficiency diseases.
  - ✓ Deficiency diseases are usually corrected by administration of missing vitamin.
- There are 13 essential vitamins:

- ✓ **Vitamin A**
- ✓ **Vitamin C**
- ✓ **Vitamin D**
- ✓ **Vitamin E**
- ✓ **Vitamin K**

- ✓ **Vitamin B1 (thiamine)**
- ✓ **Vitamin B2 (riboflavin)**
- ✓ **Vitamin B3 (niacin)**
- ✓ **Vitamin B6 (pyridoxine)**
- ✓ **Vitamin B12 (cyanocobalamin)**
- ✓ **Pantothenic acid (B5)**
- ✓ **Biotin (B7)**
- ✓ **Folate (folic acid or B9)**

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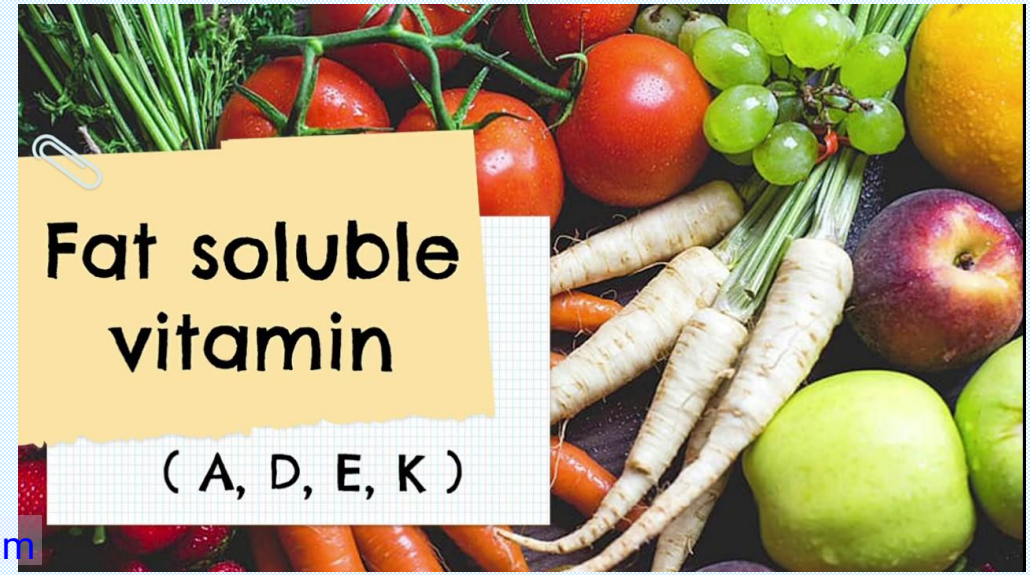
Vitamins are grouped into two categories

1. Fat-soluble vitamins

- The four fat-soluble vitamins are vitamins A, D, E, and K.
- Absorbed more easily by the body in the presence of dietary fat.
- Absorption requires bile salts:
  - impaired secretion of bile → deficiency develops.
- Stored in the body's liver, fatty tissue, and muscles.



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Vitamins are grouped into two categories

2. Water-soluble vitamins

- The nine water-soluble vitamins are vitamin **C** and all the **B** vitamins.
- not stored in the body.
- Any leftover or excess amounts of these leave the body through the urine.
- They have to be consumed on a regular basis to prevent shortages or deficiencies in the body.
  - The exception to this is vitamin B12, which can be stored in the liver for many years.

- ✓ **Vitamin B1 (thiamine)**
- ✓ **Vitamin B2 (riboflavin)**
- ✓ **Vitamin B3 (niacin)**
- ✓ **Vitamin B6 (pyridoxine)**
- ✓ **Vitamin B12 (cyanocobalamin)**
- ✓ **Pantothenic acid (B5)**
- ✓ **Biotin (B7)**
- ✓ **Folate (folic acid or B9)**

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What are Supplements?

- synthetic or natural substances which can be purchased as pills, tablets, capsules, wafers, powders, or liquids.

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Provitamins

- Do not exert vitamin activity as such.
- Active only after chemical transformation into other compound.
- Known as previtamins, provitamins or precursor of vitamin.
  - e.g. β-carotene forms vitamin A in the body

PRECURSOR	PROVITAMIN
Alpha-carotene Beta-carotene Cryptoxanthin	Pro-vitamin A
Panthenol	Pro-vitamin B5
Menadione	Pro-vitamin K
Ergosterol	Pro-vitamin D2

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Fat-soluble Vitamins

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Vitamin A (Retinol)

- **Three forms:**
  - **Retinol** (oxidized) → **retinal** (oxidized) → **retinoic acid**

- **Food sources:**
  - Preformed vitamin (animal sources)
    - ✓ Fish liver oil, fish, liver, eggs, milk, and butter.
  - Provitamin (plant sources)

carotene (pigmented fruits & vegetables - yellow) → vit A (body)

- ✓ Carrots, green leafy vegetables & fruits (spinach, pumpkin, sweet potatoes, papaya, tomatoes)
- ✓ Dried fruits (concentrated source)

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Vitamin A (Retinol)

- **Functions:**

- Retinol
  - ✓ Growth factor
  - ✓ For normal growth and reproduction
- Retinal
  - ✓ For vision
  - ✓ Retina photoreceptors (Rods) contain rhodopsin: opsin + retinal
- Retinoic acid
  - ✓ Formation of glycoproteins → epithelial cells

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Vitamin A (Retinol)

- **Deficiency:**

Epithelium

- Vit A is essential for normal structure and function of epithelial tissues (cornea, respiratory, urinary, and digestive tracts)
- Absence of vitamin A in epithelium …

Normal epithelium → dry keratinized epithelium …

susceptible to infections

Growth

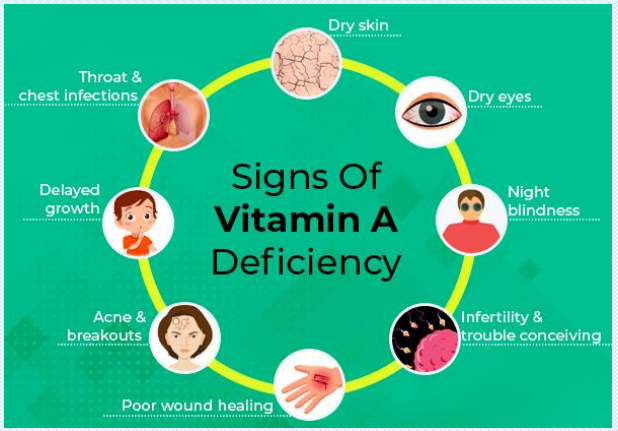
Deficiency → Growth retardation:

skeleton & soft tissues (collagenous)

Eye & Vision

Bitot's spots, Xerosis, Dry eyes,

Keratomalacia, Night blindness.



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Vitamin A (Retinol)

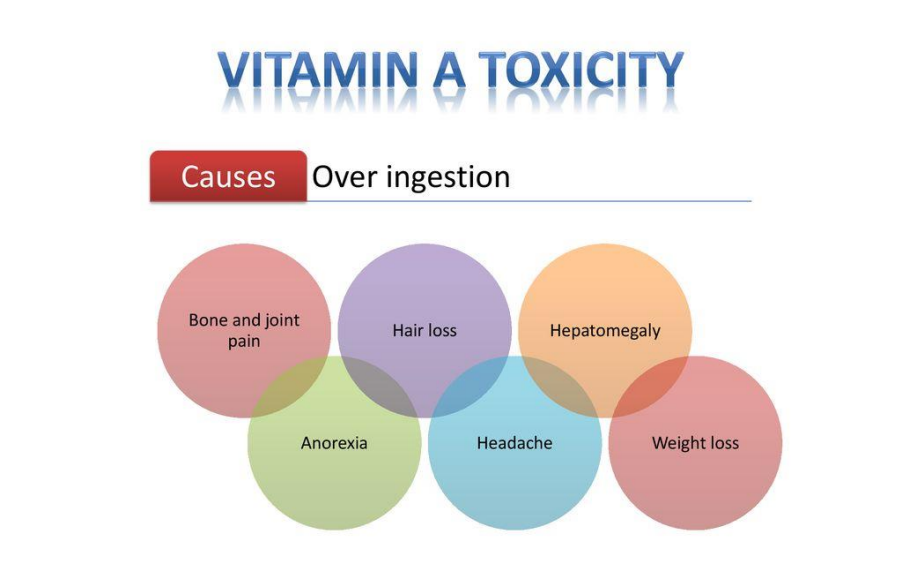
- **Requirements:**

Children: 2,000-5,000 IU

Adults: 5,000 IU

Pregnancy: 6,000 IU

Lactation: 8,000 IU



- **Toxicity:**

➢ Hypervitaminosis A:

>50,000 IU daily over prolonged period

➢ Symptoms:

Anorexia, hyperirritability, skin drying, loss of hair, bone and joint pain, bone fragility, headache, liver & spleen enlargement.

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Vitamin D (Cholecalciferol)

- **Two forms:**
  - Vit D_2 (ergo**calciferol**): plant
  - Vit D_3 (chole**calciferol**): animal

- **Food sources:**
  - Cod or fish liver oil, fish, egg yolk and liver.

  - Sunlight synthesis of Vit D_3 in skin.
    - ✓ Formed in the skin from 7-dehydrocholesterol in a photochemical reaction driven by UV.

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Vitamin D (Cholecalciferol)

- **Functions:**
  - Active form: 1,25-dihydroxycholecalciferol
    (1,25-dihydroxyvitamin D_3)
  - Converted in body
- <u>Metabolism of Ca</u>
  - ✓ Intestine: increase Ca absorption
  - ✓ Kidney: reabsorption of Ca, P
  - ✓ Bone: mobilization of Ca
- <u>Calcification of bones</u>
  - ✓ Calcium and phosphate reabsorption and deposit in bones.
  - ✓ Deposition of crystalline → Stronger bones.

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Vitamin D (Cholecalciferol)

- **Deficiency:**

1. Rickets

- Disease of **infancy** and early childhood
- Faulty deposition of calcium phosphate → abnormal bones

2. Osteomalacia (Softening of bones)

- Disease of **adulthood**
- Poor diet, low intake of milk, malabsorption of Ca, limited sun exposure, repeated pregnancy and prolonged lactation.

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Vitamin D (Cholecalciferol)

- **Requirements:**

Adults: 100 IU

Newborn, Pregnancy, Lactation: 400IU

- **Toxicity:**

➢ Hypervitaminosis D:

- Daily doses >1000-3000 IU

➢ Symptoms:

- Nausea, diarrhea, weight loss, polyuria & nocturia.

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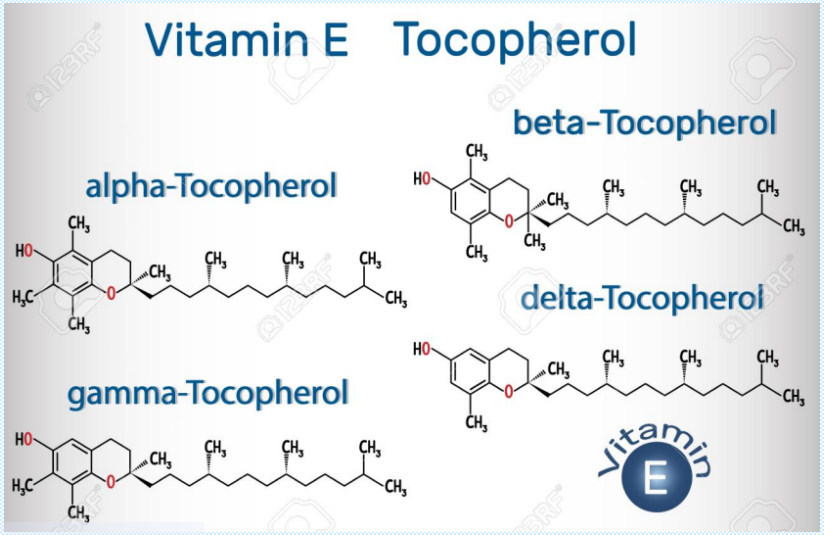
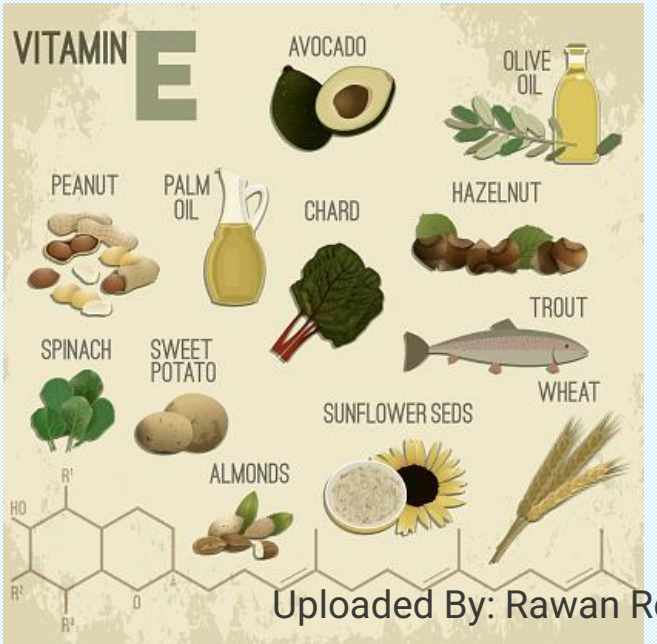
Vitamin E

- Group of closely related lipids called tocopherols.
- Contain a substituted aromatic ring and a long isoprenoid side chain.
- α-tocopherol is the most active.
- **Food sources:**
- Seed oil & lipids of green leafy plants.
- Liver, muscles meat & eggs.





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Vitamin E

- **Functions:**
  - Antioxidant:
    - ✓ Protect unsaturated fatty acids from oxidation
    - ✓ Prevent oxidative damage to membrane lipids
  - Antisterility (fertility) - deficiency of vit E leads to:
    - ✓ In women: fetus resorption
    - ✓ In men: spermatogenic tissue atrophy & permanent sterility
- **Requirements:**
  - Adults: 100 IU
  - Easily supplied by diet
- **Deficiency:**
  - Very rare (not seen)
  - Symptom: fragile erythrocytes

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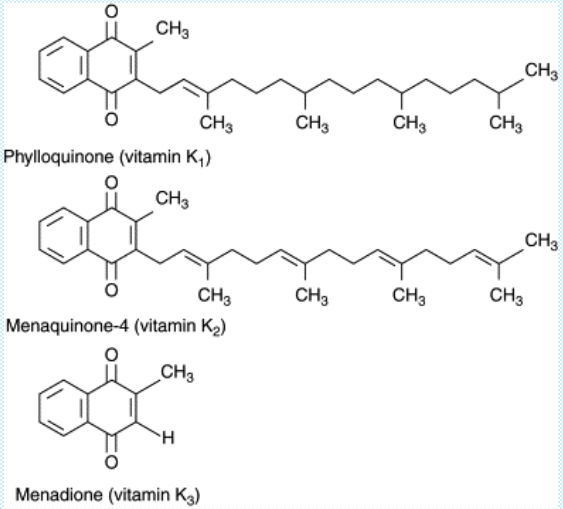
Vitamin K

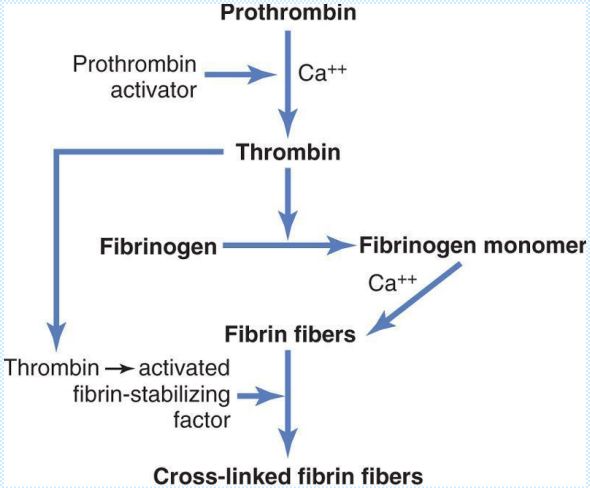
- Three compounds with vit K activity: K_1, K_2 & K_3.



- **Food sources:**
- Green leafy vegetables

Vitamin K

- Anti-hemorrhagic factor.
  - Vitamin K deficiency slows blood clotting, which can be fatal.
- **Function:**
  - Catalyze the synthesis of prothrombin by the liver.
    - Undergoes a cycle of oxidation and reduction during the formation of active prothrombin.
  - Essential for the synthesis of other coagulation factors.
- **Vitamin K deficiency:**
- Very uncommon (in humans)
- May occur:
  - ✓ Following antibiotic therapy
  - ✓ In biliary obstruction
  - ✓ Administration of antagonist
  - → Clotting time is increased.
- Hemorrhagic disease of the newborn (fatal disorder).



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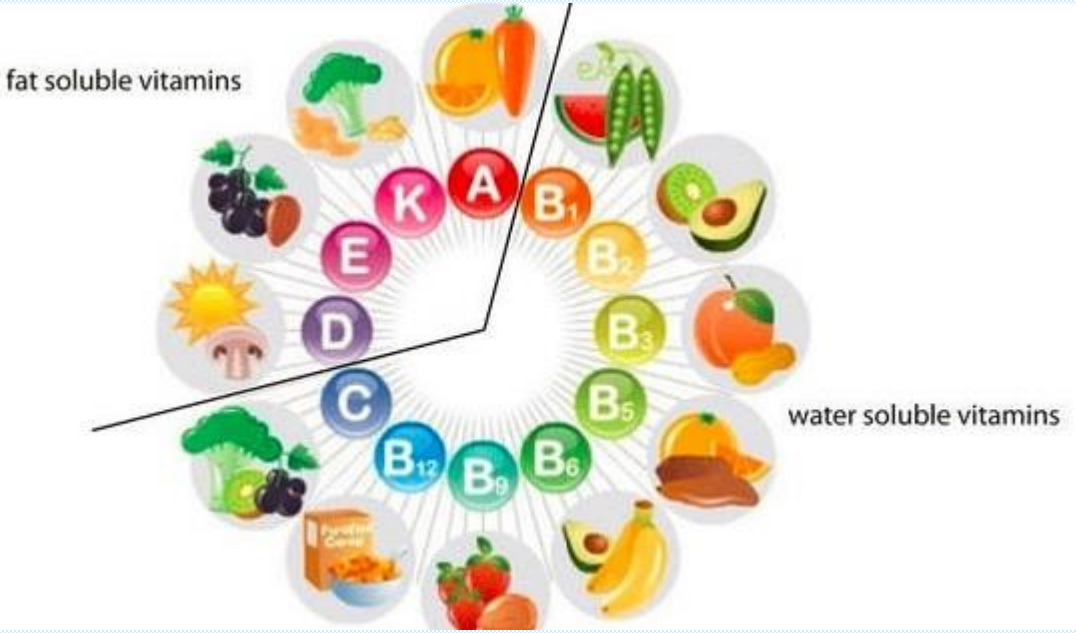
Water-soluble Vitamins



Vitamin C

- Ascorbic acid.
- Antioxidant: Strong reducing agent.

- **Food sources:**
- Green veggies, citrus fruits, tomatoes.
- Easily destroyed by cooking (oxidized by air)

- **Functions:**
- Formation of intercellular substance:
  - ✓ Cartilage, dentin, bone & **collagen**.
- Fe absorption:
  - ✓ Vit C helps in Fe absorption from the gut & utilization.
    - Fe absorption in ferrous state

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Vitamin C

- **Requirements:**
  - Infants: 20 mg/day
  - Adults & children: 40 mg/day
  - Pregnancy: > 40 mg/day
  - Lactation: 80 mg/day

- **Deficiency:**
  - Scurvy:
    - Hemorrhages, loosening of teeth, poor wound heeling, & easy fracturability of bones.
- **Toxicity:**
  - diarrhea, dry mouth & renal stone formation.

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The B Vitamins

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B Complex Vitamins

- Water soluble.
- Similar distribution in food.
- Deficiency occur simultaneously rather than singly.
- **Functions**
- ✓ Most form **coenzymes** in energy metabolism reactions.
- ✓ Deficiency is manifested in tissue of high growth and metabolism.

  e.g. skin, mucus epithelium, digestive glands and bone marrow

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Vitamin B_1

- Thiamine
- The Coenzyme form of vit B1 is thiamine pyrophosphate (TPP)
  - TPP requires Mg^{2+} as activator

- **Food sources:**
- All plant & animal tissues (small amounts).
- Most abundant sources: unrefined cereal grain, beans, nuts, meat.
  - Heat labile & water soluble.

- **Functions**:
- TPP is a coenzyme in carbohydrate metabolism:
  - Oxidative decarboxylation of pyruvate & α-ketoglutarate (PDH & TCA).
  - Transketolation (pentose phosphate pathway).

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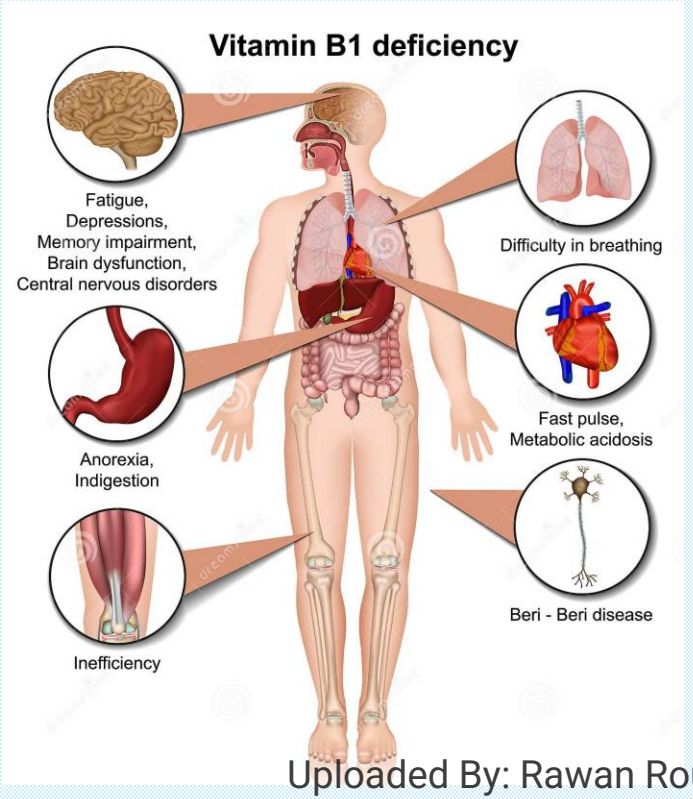
Vitamin B_1

- **Deficiency:**

Accumulation of lactic and pyruvic acids in plasma and pentose sugars in RBCs.

- Beriberi: affects Cardiovascular & nervous systems.
  - Loss of appetite, growth failure, weakness & progressive decline in weight.
- Peripheral neuritis.

- **Requirement:**
- 1-1.5 mg daily according to:
  carbohydrate intake & muscular activity.



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Vitamin B_2

- Riboflavin
  - has orange yellow crystals
  - gives yellow green fluorescence

- **Food sources:**
- Green Leafy veggies & flesh of mammals.
  - ✓ Heart, liver, kidney, milk & eggs.

- **Functions:**
- Forms two coenzymes for <u>flavin linked dehydrogenases</u>
  - Participate in oxidation reduction reactions (H and e transfer).

1. FMN (flavin mono nucleotide)
2. FAD (flavin adenine dinucleotide)

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Vitamin B_2

- **Requirements:**
  - 1-1.5 mg daily, depends upon protein intake.

- **Deficiency:**
  - Cheilosis: transverse fissures at corners of mouth, scaly lips.
  - Glossitis: inflammation of tongue, purple tongue
  - Seborrhic dermatitis.
  - Ocular manifestations.

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Vitamin B_3

- Niacin (nicotinic acid)

- **Food sources:**
- Yeast, meat, fish, liver, poultry, grain products.

- **Functions:**
- Constituent of two coenzymes:

1. Nicotinamide adenine dinucleotide (NAD) → catabolism
2. Nicotinamide adenine dinucleotide phosphate (NADP) → anabolism

- NAD & NADP:
- function as H transfer agents in Redox reaction.
- are part of Nicotinamide nucleotide linked dehydrogenases

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Vitamin B_3

- **Requirements:**
- 20 mg daily
- Influenced by protein intake:
  - 60 mg Trp produce 1 mg niacin

- **Deficiency:**
- Pellagra (rough skin)
  - 3Ds: Dermatitis, diarrhea and dementia (impairment of mental functions)

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Vitamin B_5

- Pantothenic acid
- **Food sources:**
- Found everywhere
- Yeast, polished rice, wheat germs, cereals, legumes & eggs.
- Synthesized by normal flora.
- **Functions:**
- Forms **coenzyme A** (metabolism)
- e.g. acetyl CoA, succinyl CoA, malonyl CoA.
- **Requirements:**
- 20 mg daily
- **Deficiency:**
- Unknown in man.

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Vitamin B_6

- Three compounds: Pyridoxal, pyridoxine, pyridoxamine
- Interconvertible biologically & equally effective.
- Active form is pyridoxal-5-phosphate (**PLP**)
- **Food sources:**
  - Found in plant & animal tissues.
  - Yeast, polished rice, wheat, corn & liver.
  - Synthesized by normal flora.
- **Functions:**
  - **PLP** is a coenzyme in amino acid metabolism
  - ✓ Decarboxylation
  - ✓ Transamination
- **Requirements:**
  - 2 mg daily
- **Deficiency:**
  - Uncommon
  - Impaired growth (brain metabolism, oxalate metabolism, heme synthesis)

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Vitamin B_7

- Biotin
- Carries an activated **CO_2** group.
- **Functions:**
  - Catalyze carboxylation reactions:
  - e.g. acetyl CoA → malonyl CoA
    Pyruvate → oxaloacetate
- **Food sources:**
  - Widely distributed.
  - Egg yolk, kidney, liver, tomatoes, yeast, corn & soya.
- **Requirements:**
  - 100-200 mg daily
- **Deficiency:**
  - Consumption of raw eggs in large quantities cause biotin deficiency.
  - because of avidin binding and lack of intestinal absorption.

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Vitamin B_9

- Folic acid
- for growth and reproduction of cells.
- **Functions:** Folic acid coenzymes
  - Synthesis of purines, pyrimidines, DNA and choline.
  - Metabolism of some amino acids.
- **Food sources:**
  - Widely distributed.
  - Egg yolk, kidney, liver, tomatoes, yeast, corn & soya.
- **Requirements:**
  - Adults: 400 µg daily
  - doubled during pregnancy
- **Deficiency:**
  - Adults: anemia
  - Pregnancy: leads to neural tubes defect in the fetus

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Vitamin B_{12}

- Cyano**cobal**amin
- The only vitamin which contains a metal (Co)
- **Functions:** B_{12} coenzymes catalyze:
  - Intramolecular hydrogen transfer
  - Intermolecular methyl transfer
- **Food sources:**
  - Confined to **animal** food.
  - Richest sources: kidney, liver.
  - Usual sources: meat, fish, eggs, milk.
- **Requirements:**
  - Adults: 1 µg daily
  - Pregnancy & lactation: 1.5 µg daily
- **Deficiency:**

1. Pure vegetarians (vegans)
2. Infants (breast feeding mother – deficient intake of animal protein)
3. Man inadequate intestinal absorption

  - leads to pernicious anemia, peripheral sensory disturbances, hyperactive reflexes, ataxia and paralysis.

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Minerals

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Minerals

- **Inorganic matter**
  - Amount < 5%

- **Essential minerals:**
  - Na, K, Ca, Mg, P, S, Fe, I, Mn, Mo, Zn, F, Cr, Ni, Si, Se, Sn, V.

- **Functions:**
  - Structural (Ca, P)
  - Membrane and transport (Na, K)
  - Enzyme prosthetic groups (Co, Zn, Cu, Mo, Fe)
  - Regulatory role/ role in hormone action (Ca, I, Mn, Mg)

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Minerals

- **Amounts in body varies:**
  - ✓ Kg (Ca)
  - ✓ g (Cl)
  - ✓ mg (Cu)
  - ✓ µg (Co)

- **Requirement**:

1. **Macro**elements
2. **Micro**elements

1. Macroelements

- Minerals required in relatively larger amounts in diet:
  - >100 mg/day
- Seven principle macroelements

1. **Ca**
2. **Mg**
3. **Na**
4. **K**
5. **P**
6. **S**
7. **Cl**

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Sodium (Na)

- About 100 g is present in the body.
- Average Na in plasma: 330 mg/100 ml = 143 mM
- **Functions**:
  - Regulation of acid base balance
  - Maintenance of osmotic pressure of body
  - Preservation of normal irritability of muscles
  - Preservation of normal permeability of cells
- **Regulation:**
- Mediated by the adrenal corticosteroid:
  - aldosterone: Increases Na reabsorption in kidneys.
    - Addison's disease → **Hypo**natremia
    - Cushing's disease → **Hyper**natremia → edema

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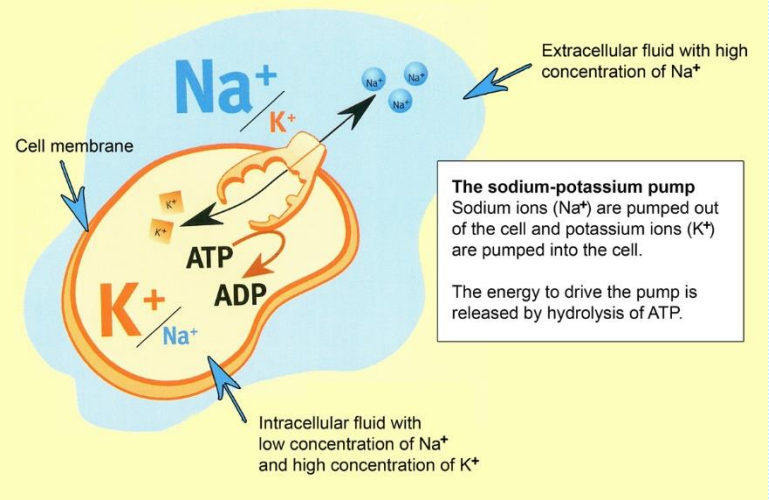
Potassium (K)

- Amount in body 250 g
- 90% intracellular, 10% extracellular.
- **Functions**:
- Intracellular:
  - acid base balance
  - Osmotic pressure & water retention.
- Extracellular:
  - Muscle activity (Cardiac muscle)
- **Regulation:**
- Hyperkalemia caused by:
  - Addison's disease, renal failure, advanced dehydration, & shock
- Hypokalemia caused by:
  - malnutrition, GI losses, metabolic alkalosis, & Cushing's syndrome.



Chlorine (Cl)

- Intracellular & extracellular.
- Plasma: 365 mg/100 ml (103 mM);
- In cells: 190 mg/100 ml (53 mM)

- **Functions**:
  - acid base balance
  - osmotic pressure
  - water balance

- **Regulation:**
- Abnormalities of Na metabolism are generally accompanied by abnormalities in Cl metabolism.
  - e.g. Addison's disease, diarrhea, sweating, vomiting and renal failure.

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Calcium (Ca)

- Amount in body 1.5 Kg (largest for any cation).
  - 99% in bones and teeth
  - 1% in body fluids

- **Functions**:
  - Bone structure
  - Blood coagulation
  - Signal transduction
  - Muscle contraction
  - Enzymatic activity
  - Excitability of cells

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Calcium (Ca)

Absorption:

- Vit D promotes absorption of Ca from the intestine.
- Ca is well absorbed at the Normal pH of the intestine.

- Impaired absorption in the presence of:
  - More alkaline pH (intestine)
  - Oxalate present in food
  - Excess phosphate
  - Fatty acid: impaired fat absorption → produce F.A.
  - Phytic acid present in cereals

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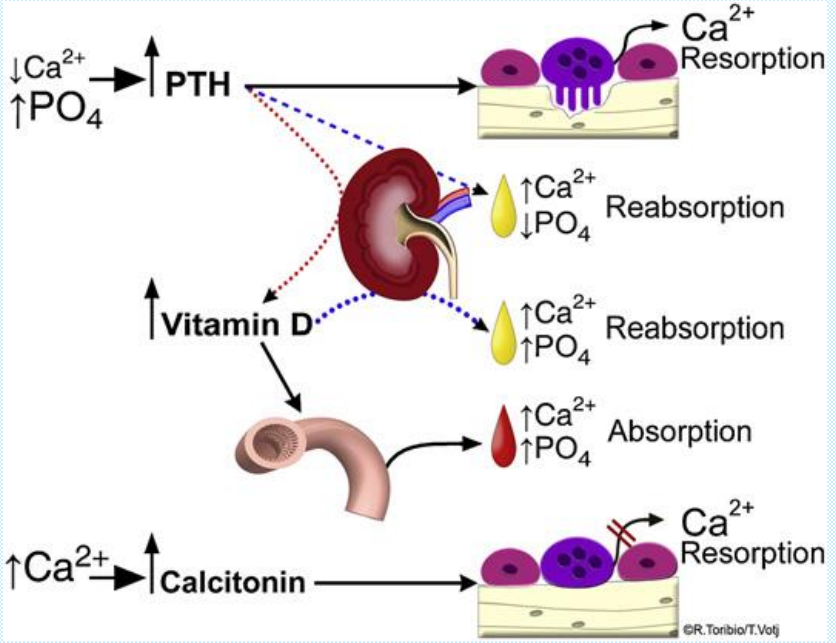
Calcium (Ca)

Metabolism:

- All Ca is present in plasma - two forms :
  1. Diffusible
     - 50-60%
     - ionized Ca, Ca phosphate, Ca citrate
  2. Non-diffusible
     - 40-50%
     - Protein bound



- **PTH** increases serum Ca
- **Calcitonin** decreases serum Ca

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Calcium (Ca)

Regulation - Blood Ca in health & disease:

- **Ca**: 9-11.5 mg%
- **P**: children = 4-6 mg%, adult = 3-4.5 mg%
- **Ca** X **P** product is important for ossification
  - Normal children > 50
  - Normal adults 30-40

- **Disease conditions:**

1. Hypercalcemia result in:
   - hyperparathyroidism
   - multiple myeloma
   - cancer
2. Hypocalcemia result in:
   - Hypoparathyroidism, tetany, rickets, steatorrhea, nephrotic syndrome, chronic renal failure, pregnancy.

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Phosphorus (P)

- Amount in body 400-700 g
- 80% is combined with Ca in bones and teeth
- Present in all foods
- **Functions**:
  - Formation of bones and teeth
  - Formation of high energy phosphates (creatine phosphate)
  - Formation of nucleoproteins
  - Formation of phospholipids (membrane)
  - Influence acid base balance (Na_2HPO_4 & NaH_2PO_4)
- **Regulation**:

Hyperphosphatemia - found in:

Hypoparathyroidism (excessive reabsorption of phosphate)

Renal failure

Hypophosphatemia - found in:

Rickets and osteomalacia

Hyperparthyroidism

Fanconi syndrome

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Magnesium (Mg)

- Amount in body 20-28 g
- 53% is in bones as Mg phosphate
- Widespread in plant & animal tissues

- **Functions**:
  - Part of bone tissue (structural function)
  - Cofactor in several metabolic reactions:
    - Mg binds to substrate → complex
      enzyme interacts with complex.
      e.g. kinase + Mg ATP
    - Important role in:
      glycolysis, TCA, gluconeogenesis, metabolism of lipid, amino acid & nucleic acid.
    - Important in energy metabolism (Mg ATP).

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2. Microelements

- Required in relatively minute amounts
  - <100 mg/day

Subdivided into 3 groups:

1. Essential trace elements

- **Fe**, **Cu**, **I**, **Zn**, **F**, **Cr**, Mn, Co, Mo, Se
- Dietary essential for enzymatic reactions in living cells

2. Possibly essential trace element

- Ni, Sn, V, Cd, Si, Ba, Sr
- Some metabolic activity

3. Non essential trace elements

- Al, B, Pb, Hg, F, As

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Iron (Fe)

Amount in body: 4-6 g

- ➢ >50% is present in heme (Hb, myoglobin, cytochrome ..)
- ➢ Non-heme proteins (ferritin, hemosiderin, & transferrin)

- Fe Metabolism has closed system:

✓ Regulated by absorption (not excretion, unlike other minerals)

Functions

- Respiration
  - ✓ Transport and delivery of oxygen
    - ➢ Blood: Hb, Muscle: Myoglobin
- Heme in cytochromes
  - ✓ Transport of hydrogen and electrons in ETC
  - ✓ Detoxification in liver microsome
- Peroxidase & catalase: oxidation reduction rxn
  degradation of peroxide molecules

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Iron (Fe)

What causes Loss of iron from the body?

- Blood loss
  - Normal (menstruation, delivery)
  - Pathological (hemorrhage, intestinal worms)
- Lactation
  - ~180 mg Fe is lost from a 6-month lactating mother

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Iron (Fe)

Pathology

Deficiency

- Iron deficiency anemia
- Can delay normal infant motor and mental function
- Can increase the risk for small preterm babies
- Can cause fatigue and inability to do work
- Can affect mental function and memory

Excess (Fe overload)

- Repeated mismatched blood transfusions or hemolytic anemia
- Hemochromatosis:
  - Inherited disease
  - Patients absorb much greater percent of food iron
  - Deposited in skin, pancreas and liver → bronzed skin, diabetes mellitus, & cirrhosis.

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Iodine (I)

Function

- Formation of thyroid hormones (T3, T4)
  - *Thermogenesis and oxygen consumption*
    - Levels of thyroid hormones are related to basal metabolic rate
- *Metabolic effects of T3 & T4*
  - Increases intestinal absorption & utilization of glucose
  - Alters metabolism of proteins, lipids, electrolytes & water.

Deficiency

- *Goiter* (enlargement of thyroid gland)
  - If soil and water are low in iodine
  - Treatment with iodized salt
- *Cretinism*
  - Originates in fetal life or early infancy
  - Stunting physical growth and decreased mental development

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Copper (Cu)

Amount in body

- 50-120 mg
- Transported in plasma bound to **ceruloplasmin**

Functions

- Constituent of several enzymes (oxidases) & proteins.
  - Role in Fe storage and transport
  - ➢ **Ceruloplasmin** oxidizes Fe^{+2} → Fe^{+3} to be incorporated in transferrin.
  - **xylyl oxidase**: formation of crosslinks between collagen/elastin fibers.

Deficiency

- Uncommon
  - If occurred develop anemia

Wilson's disease

- Genetic disease of Cu metabolism
- Excessive absorption of Cu → deposition in liver, kidney and brain causing cirrhosis, kidney damage and neurological problems.

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Zinc (Zn)

Amount in body

- 2 g

Functions

- Constituent of many metalloenzymes
  - Alcohol dehydrogenase
  - Alkaline phosphatase
  - DNA polymerase
  - RNA polymerase
- Growth and wound healing

Zn deficiency

- Growth failure
- Poor wound healing
- hypogonadism

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Fluorine (F)

Functions

- Prevention of dental caries
- Maintenance of normal skeleton
- Deposited in bone as calcium fluorapatite
- Essential for growth and development
- Mottling of enamel
  - spotted tooth enamel caused by drinking water containing excessive fluorides

Fluorosis

- Toxic manifestation of excess fluoride in drinking water
  - Dental fluorosis (discolored teeth)
  - Skeletal fluorosis (knock knee and bow legs)

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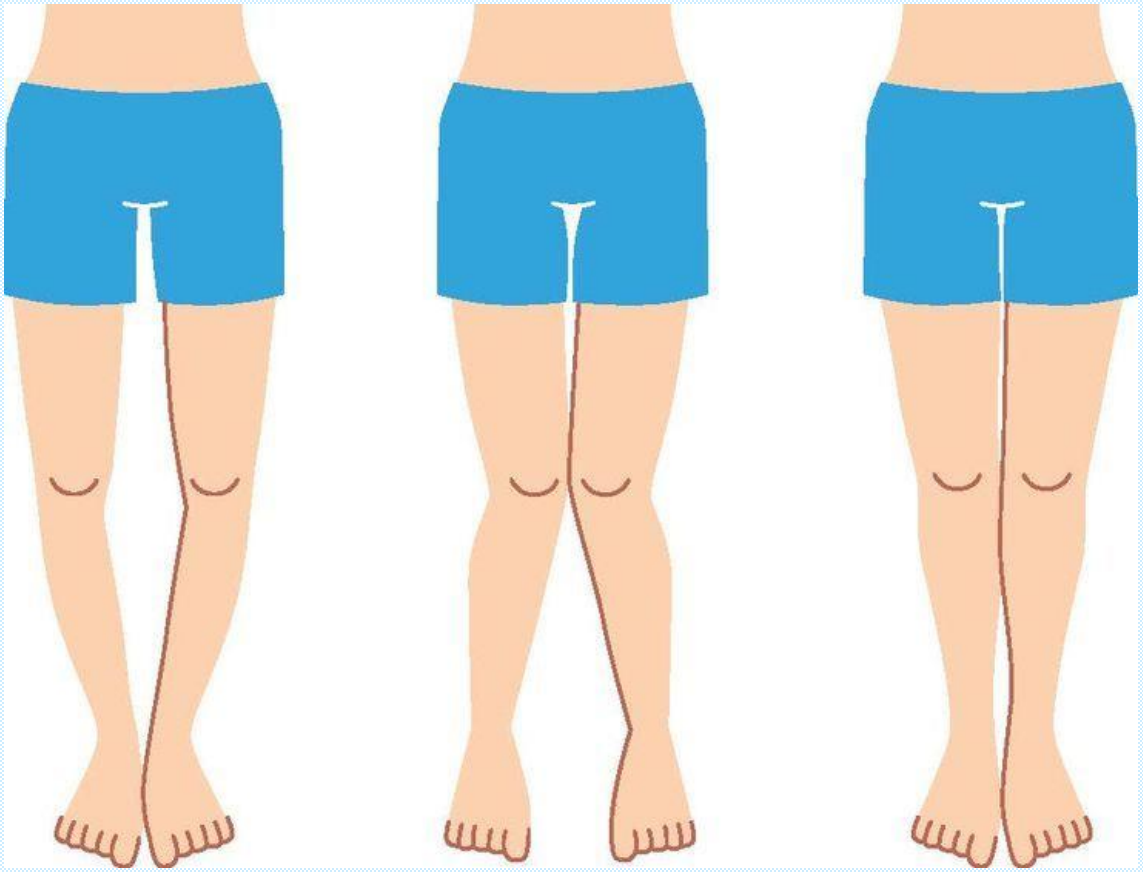
Fluorine (F)



bow legs knock knee Normal

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Chromium (Cr)

- Occurs in multiple valence states (diet)
- Most Cr in food is Cr^{+3}
- Cr^{+6} is poorly absorbed
- Rapidly uptaken by bones
- Also accumulate in spleen, kidney and liver

Function

- Essential for insulin action
  - Cr^{+3} is converted in the liver to an organic compound (glucose tolerance factor) which enhances insulin function in glucose uptake
  - Helps insulin bind to its receptors
- Lowers blood cholesterol

Deficiency

- In old age it is possible to have poor absorption
  - Supplementation in diet improves glucose tolerance
- Growth reduction in experimental animals

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Table 5.4: Summary of functions, dietary sources and deficiency symptoms of various minerals

Minerals	*Functions*	*Dietary sources*	*Deficiency symptoms*
Macroelements			
Sodium	Plasma volume, nerve and muscles function; extracellular cation	Common salt	Deficiency unknown, excess leads to hypertension in susceptible individuals
Potassium	Nerve and muscles function, intracellular cation	Fruits, nuts	Muscular weakness, mental confusion, excess leads to cardiac arrest
Chloride	Fluid and electrolyte balance	Common salt	Primary deficiency unknown; secondary deficiency due to diarrhoea, vomiting
Calcium	Constituent of bone and teeth; muscles and nerve function	Dairy products, beans, leafy vegetables	Parathesias, muscular excitability, cramps, bone fracture
Phosphorous	Constituent of bone and teeth, phosphoproteins	Dairy products	Deficiency is rare, secondary hypophosphatemia leads to skeletal deformities
Magnesium	Constituent of bone and teeth, enzyme cofactor	Green leafy vegetables	Neuromuscular excitability, cramps, parathesias
Microelements			
Iron	Components of heme, iron sulphur protein	Red meat, liver, eggs	Anemia; excess leads to hemochromatosis
Iodine	Component of thyroid hormones	Iodized salt, sea food enzymes	Goiter
Copper	Component of oxidases enzymes	Liver	Anemia
Zinc	Enzyme cofactor	Meat, liver, eggs	Hypogonadism, impairment in growth, wound healing, sense of taste and smell
Fluorine	Normal and strong bones and teeth	Sea food, tea and drinking water	Dental caries; excess leads to fluorosis
Chromium	Cofactor for insulin	Brewer's yeast, spices	Glucose intolerance

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