

# **Physiology of Digestion and Absorption**

## **Vitamins and Trace Elements**

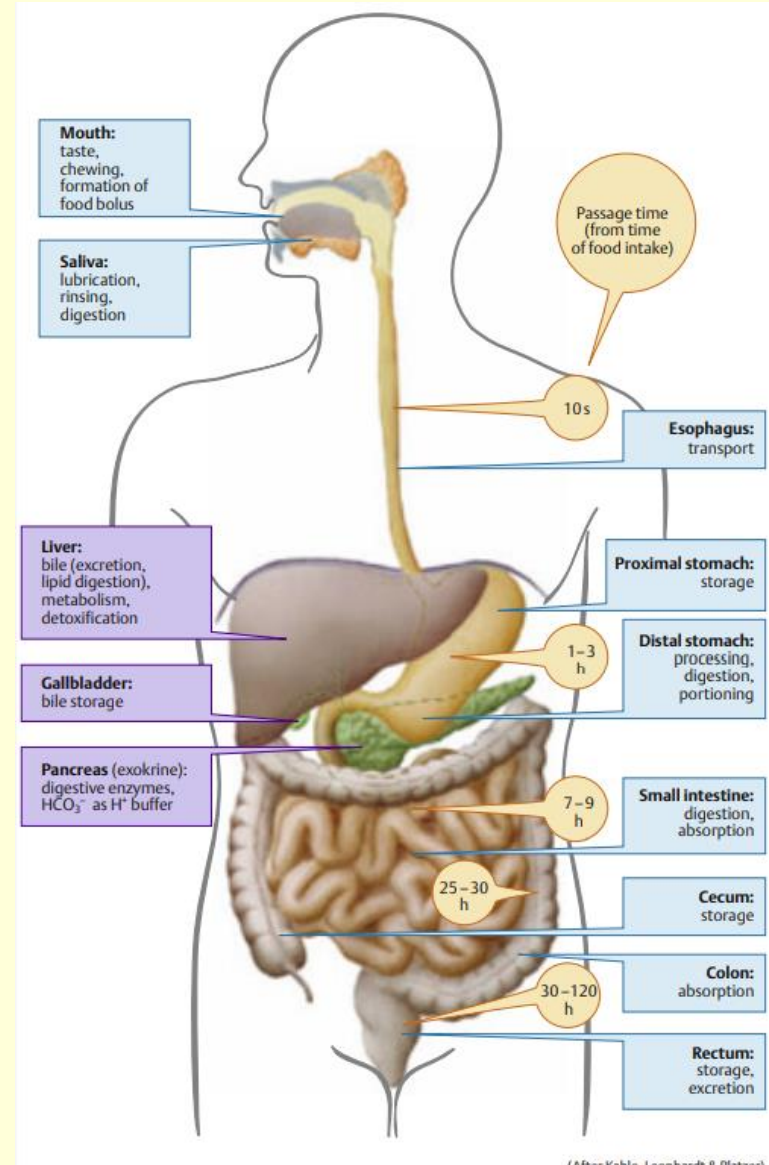
lecture from Physiology and Pathophysiology I

25. 10. 2022

M. Chalupová

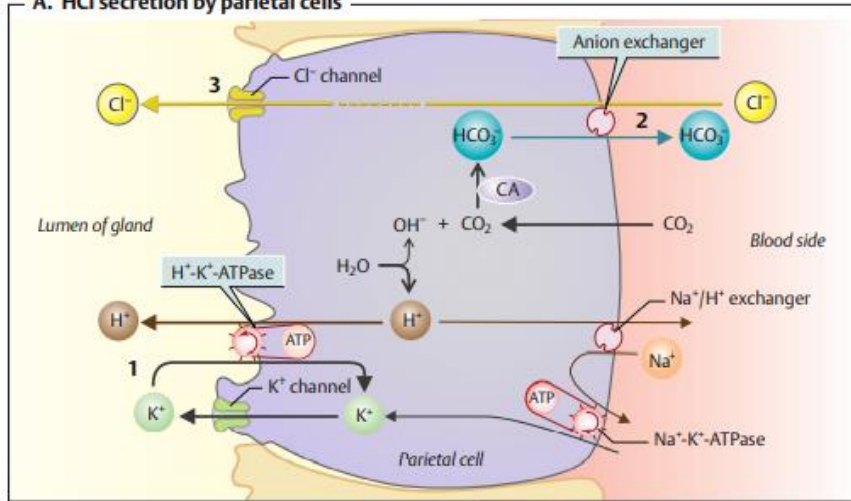
# GIT Functions

- oral cavity
- esophagus
- stomach
  - liver
  - pancreas
- small intestine
- large intestine
  - rectum, anus

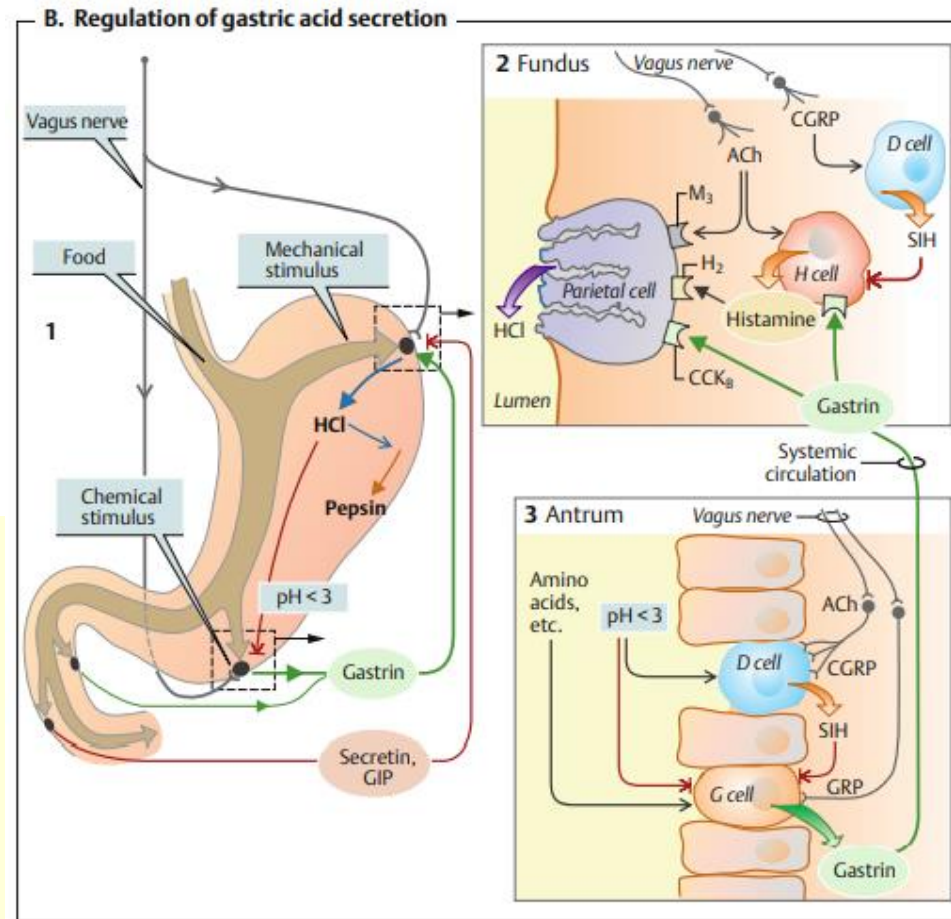


# Gastric Secretion

A. HCl secretion by parietal cells

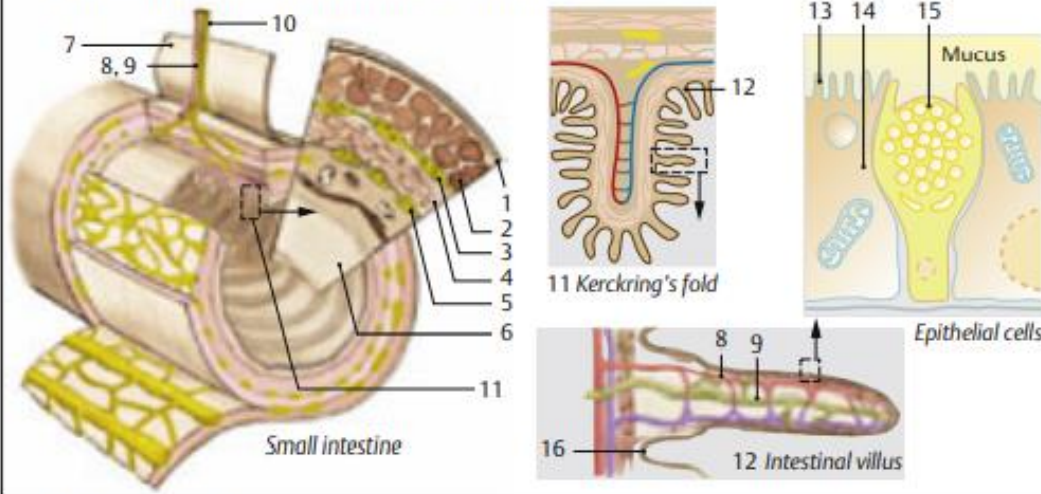


B. Regulation of gastric acid secretion

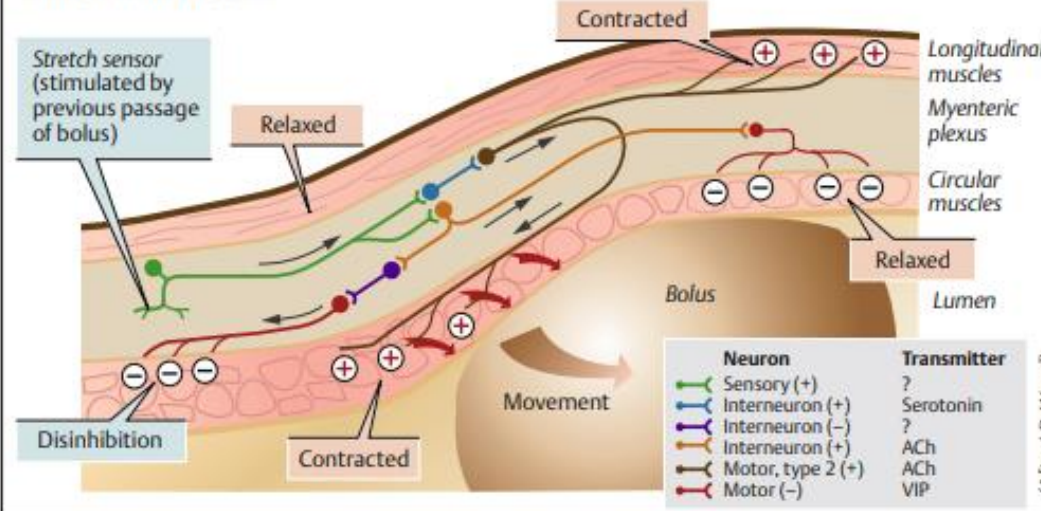


# Small Intestine

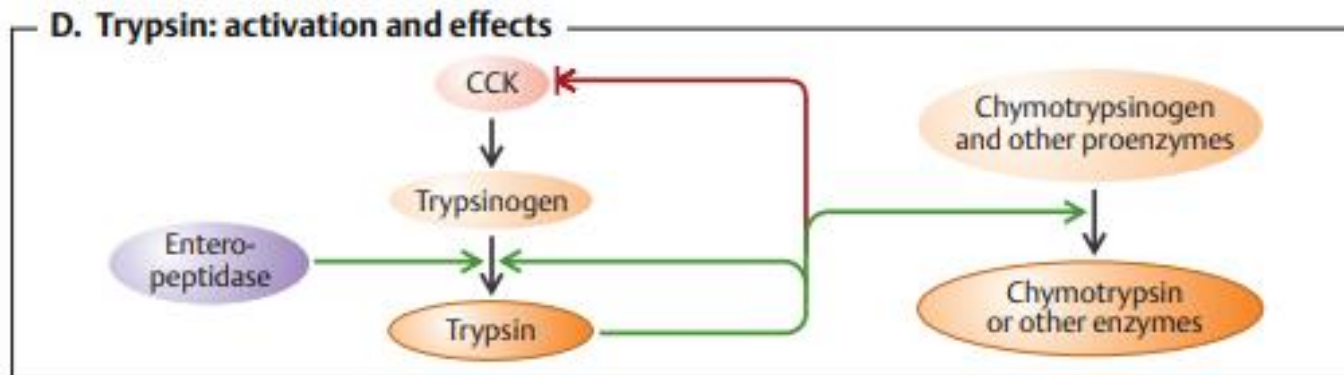
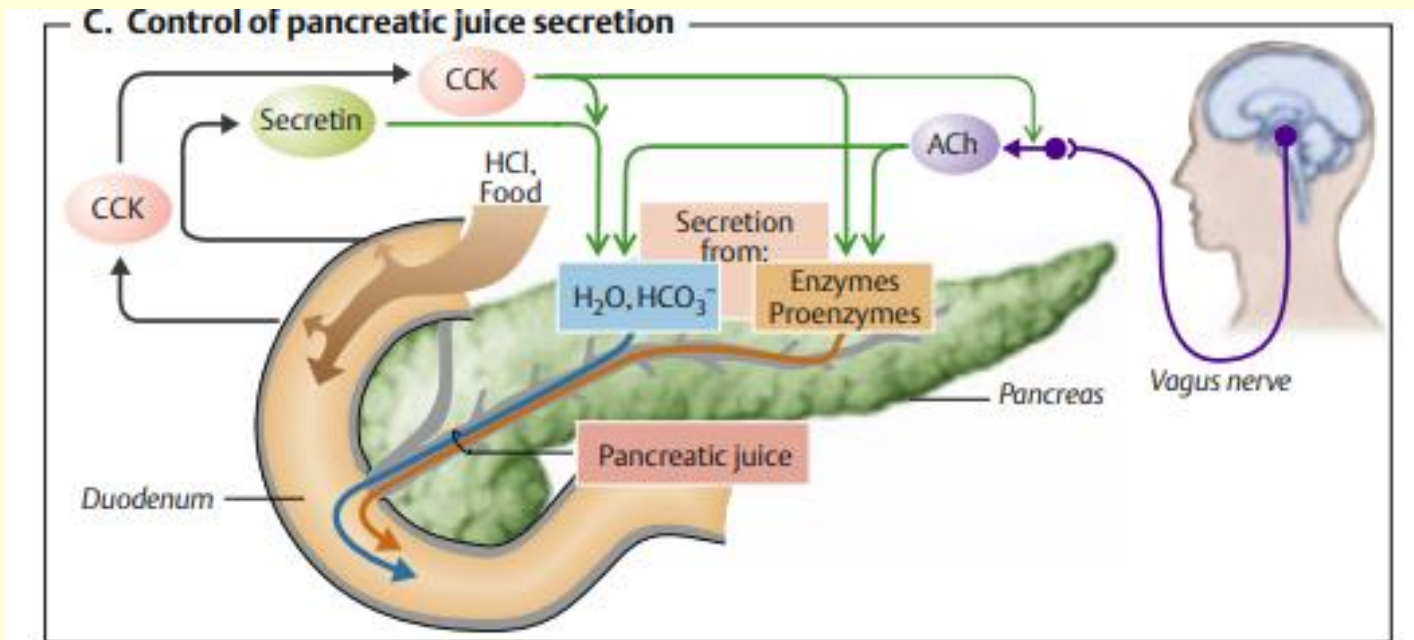
## A. Structure of the small intestine (schematic)



## B. Peristaltic reflex

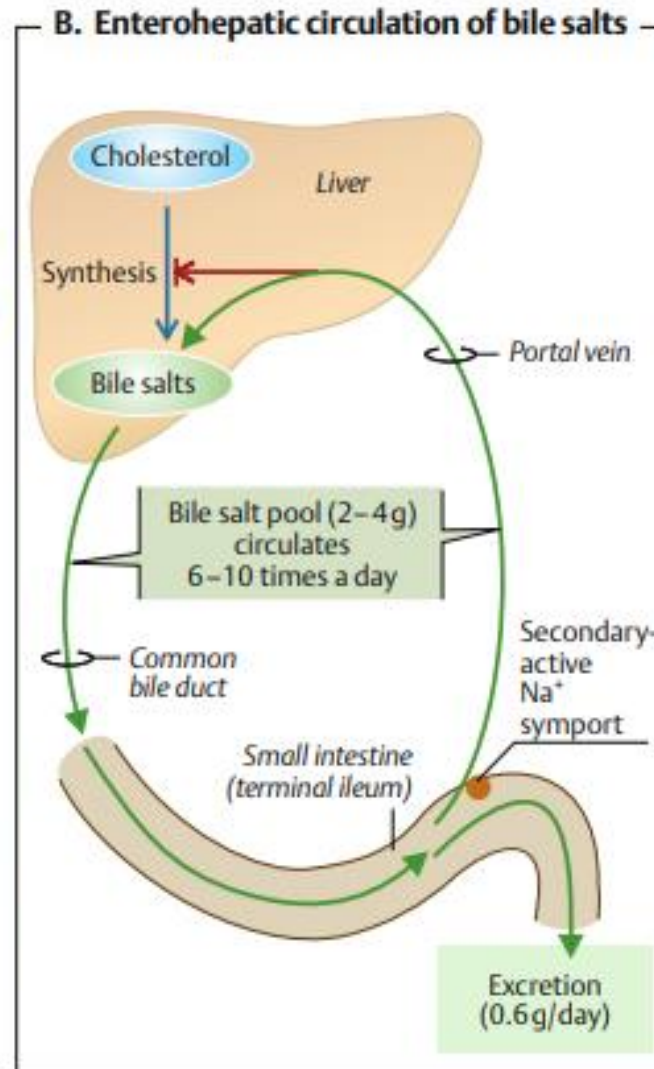
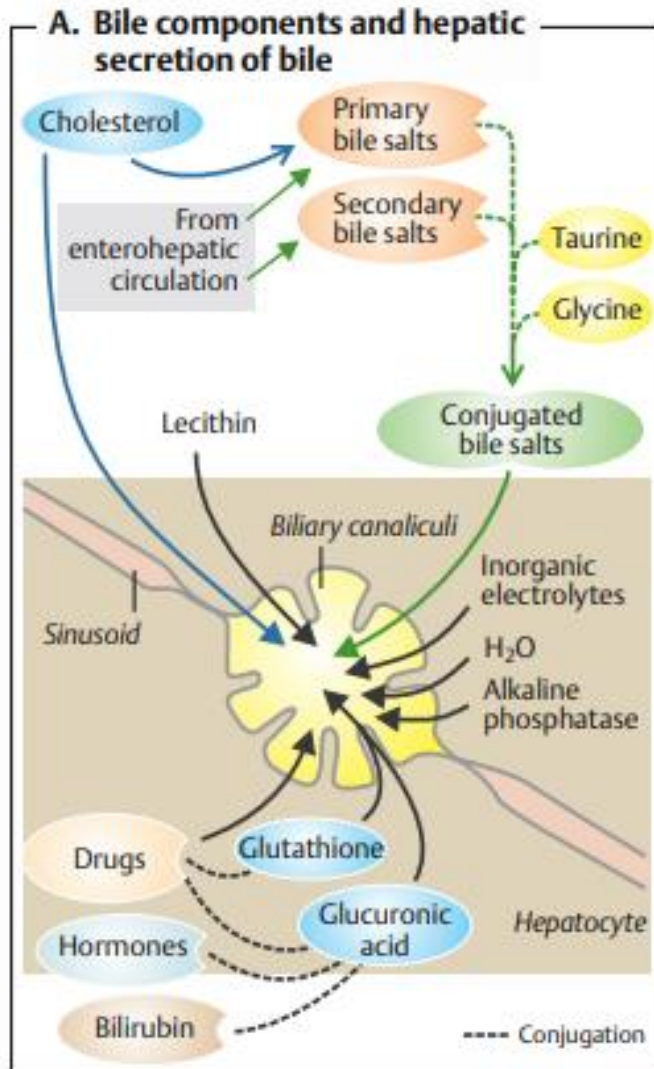


# Pancreas Secretion

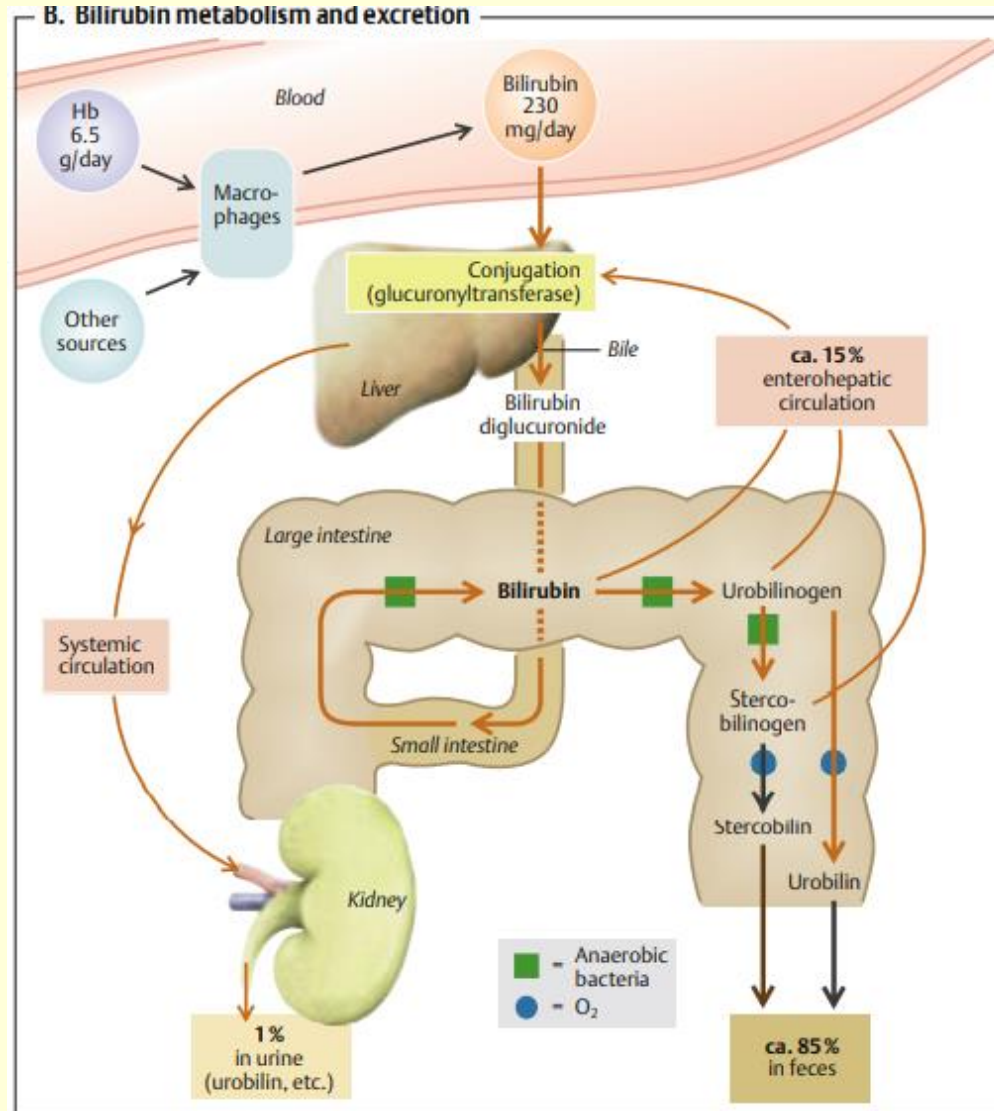




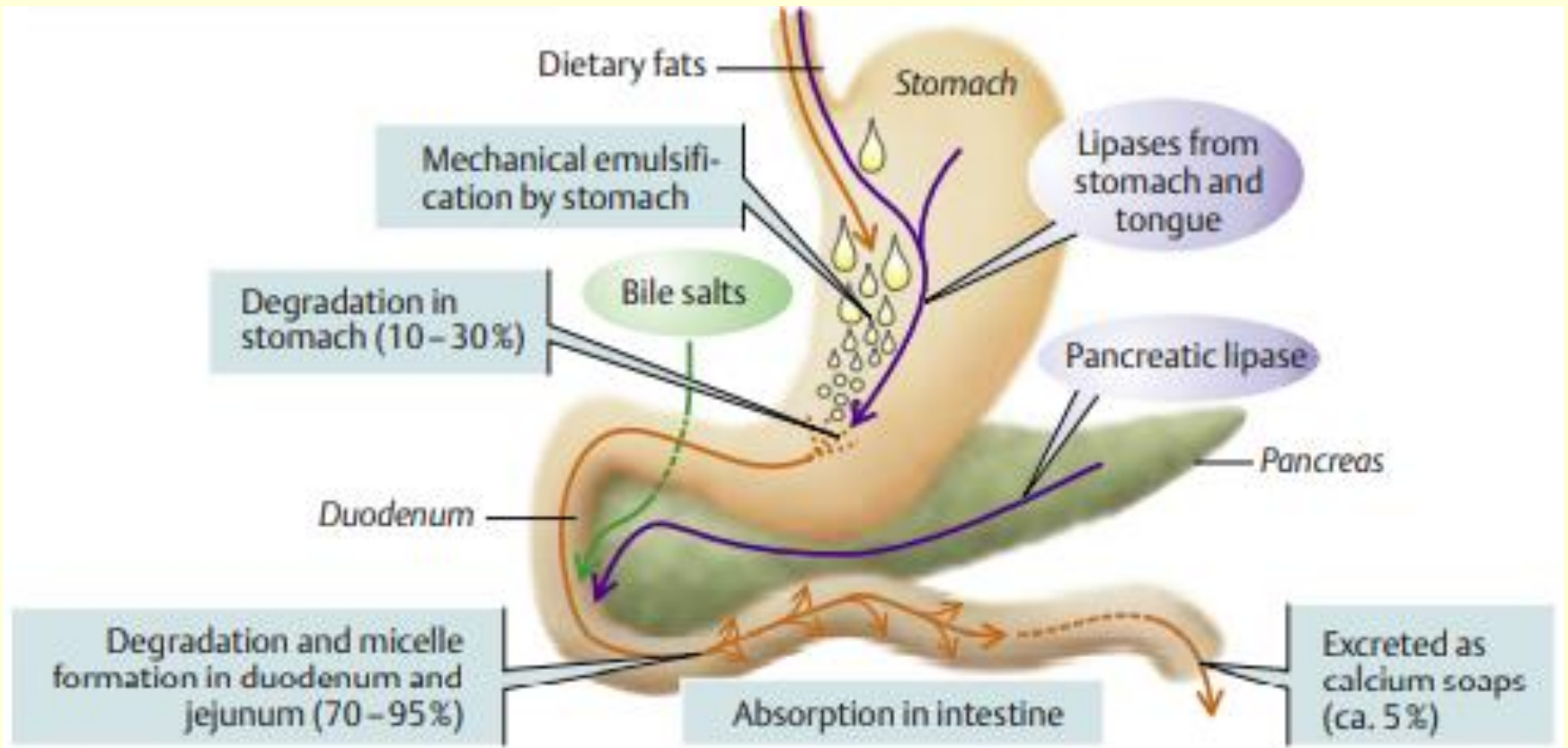
# Liver Secretion – Bile



# Bilirubin – Metabolism and Excretion

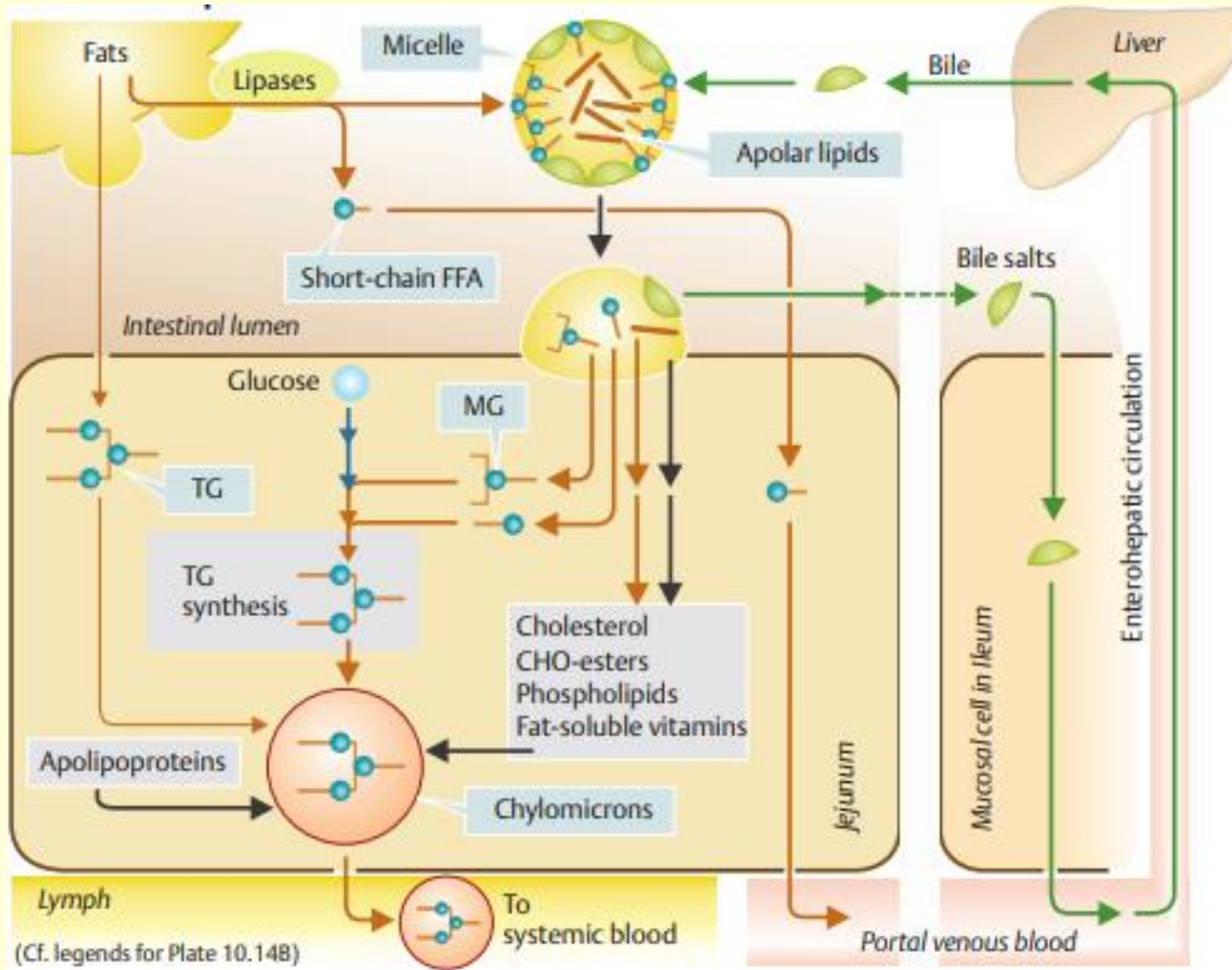


# Lipid Digestion

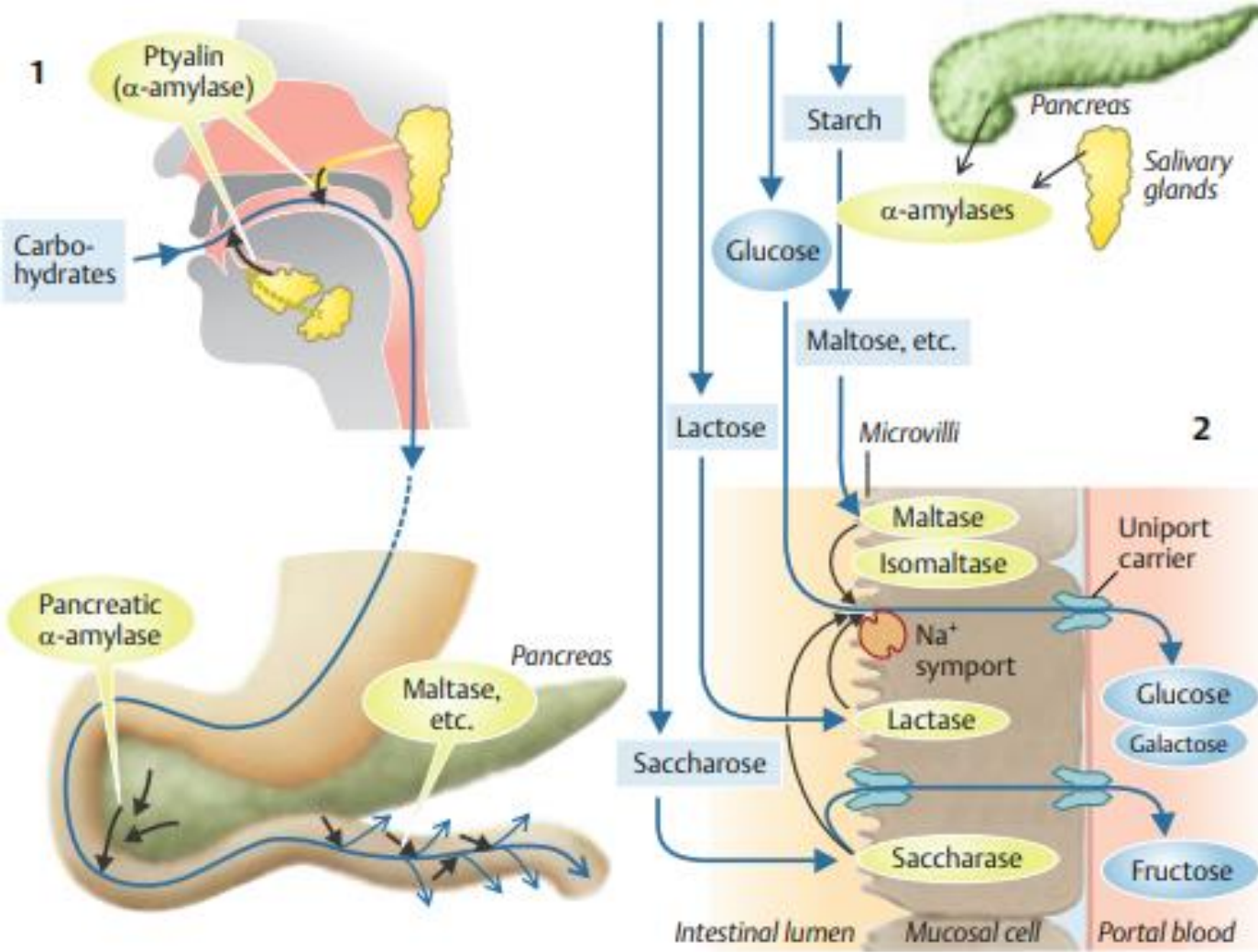




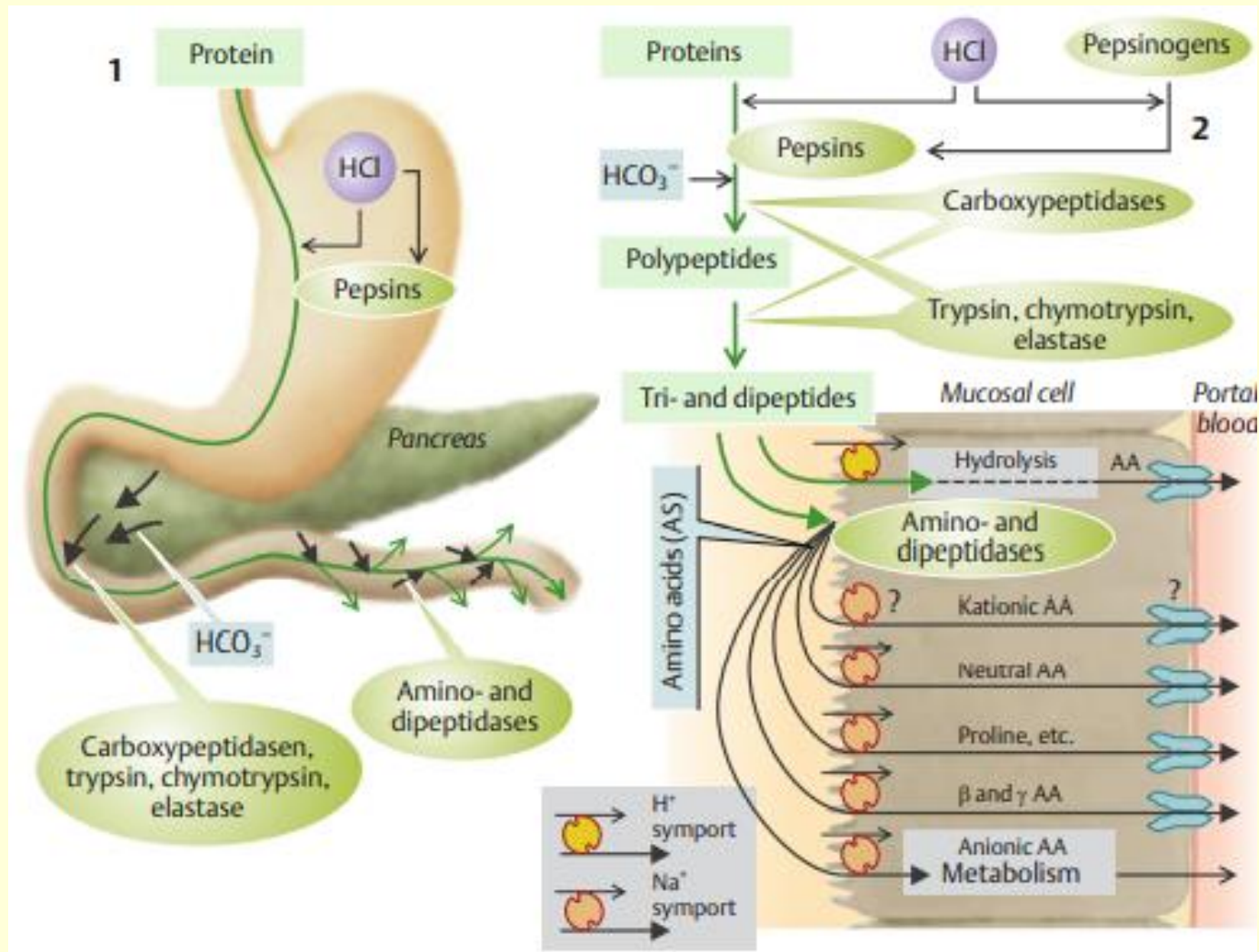
# Lipid Absorption



# Carbohydrate Digestion and Absorption



# Protein Digestion and Absorption



# Vitamins

- essential, non-caloric nutrients needed in small amounts from the diet
- help regulate cell processes and functions
- fat soluble (A, D, E, K)
- water soluble (B vitamins, vitamin C)

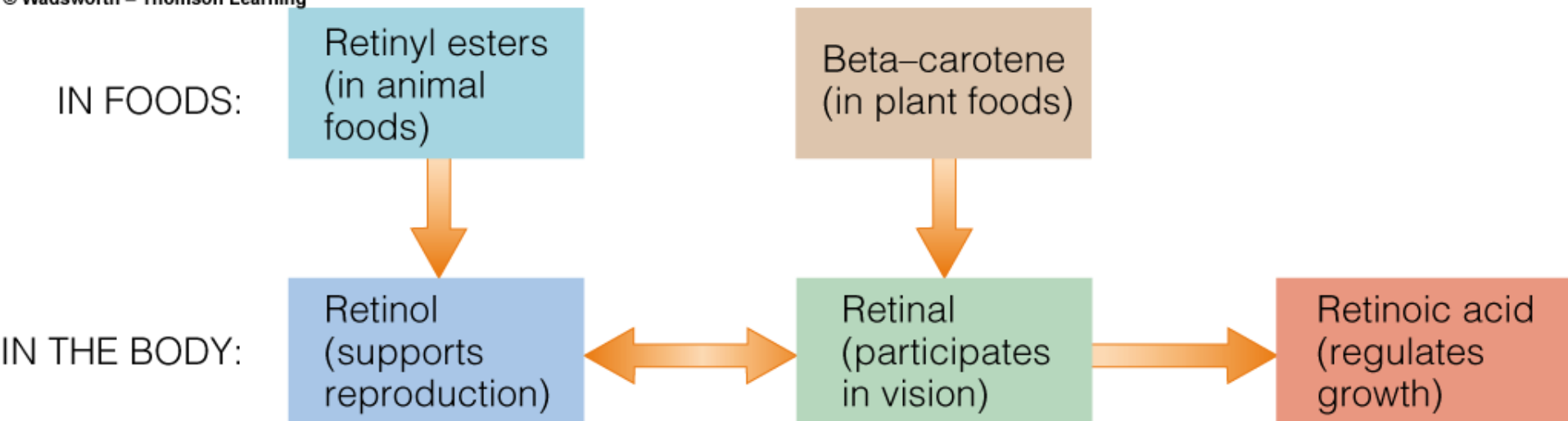
# Fat Soluble Vitamins

- fats and oils of foods
- deficiency of these vitamins is rare though can occur with a fat-free diet over long periods
- excess stored in the liver and body fat
  - possible to build up to a toxic level
  - toxicity is a greater risk if these vitamins are taken as supplements daily



# Vitamin A (retinol)

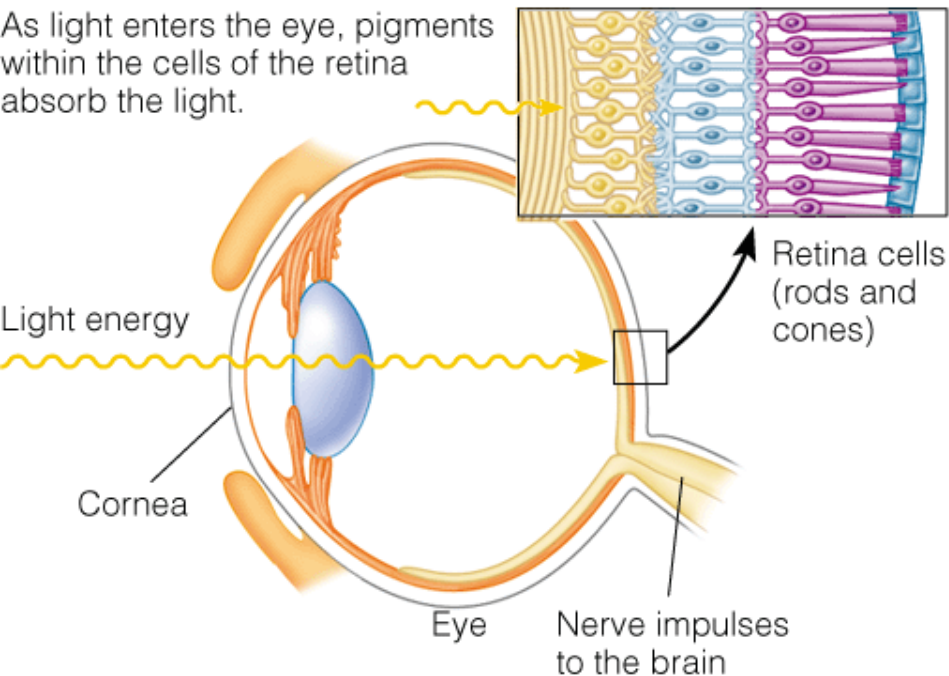
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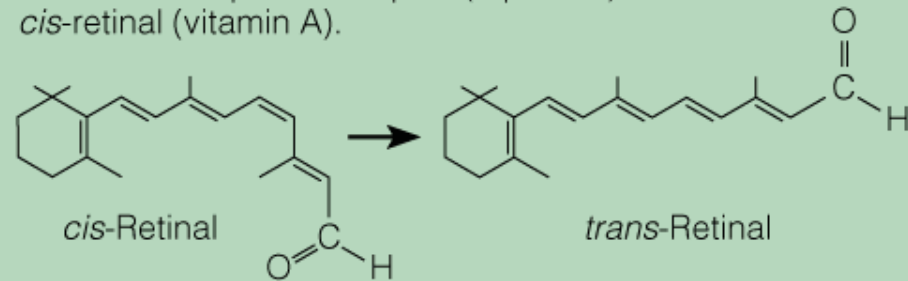
# Vitamin A (retinol)

- beta-carotene is converted into vitamin A
- vitamin A:
  - vision
  - promotes healthy mucous membranes and skin
  - growth and maintenance of bones, teeth, and cell structure
  - immunity
  - reproduction
- RDA: 900 ug for males; 700 ug for females

# Vitamin A in Vision



The cells of the retina contain rhodopsin, a molecule composed of opsin (a protein) and *cis*-retinal (vitamin A).



As rhodopsin absorbs light, retinal changes from *cis* to *trans*, which triggers a nerve impulse that carries visual information to the brain.

# Vitamin A Food Sources

- Foods

- Only animal products

- Liver
- Eggs
- Milk, butter and cheese



- Carotenoids

- Orange/Yellow fruits and vegetables

- Cantaloupes, carrots, sweet potatoes, winter squash

- Leafy green vegetables

- Spinach, broccoli



# Vitamin A Deficiency

- not common in the western world but very common in developing countries
- blindness, keratinization (hardening and thickening of the skin)
- stunted growth, impaired immunity, poor appetite and death



# Toxicity of Vitamin A

- not common unless large amounts of liver eaten
- more common from supplements providing several times the recommended level
  - occurs because vitamin A is stored in the liver and adipose tissue and accumulates
  - toxicity from beta-carotene does not occur because conversion to retinol is inefficient
- excess beta-carotene turns people yellow, but is reversible
- abdominal pain, hair loss, joint pain, stunted growth, bone and muscle soreness, nausea, diarrhea, rashes, enlargement of spleen and liver damage

# Vitamin D

- **1,25-dihydroxycholecalciferol**
  - precursor is the body's own cholesterol
- hormone
- raises blood calcium by acting on the skeleton, kidneys and the digestive tract to release calcium
- cell maturation and immune system stimulation
- RDA: 5 micrograms until age 50
  - 10 micrograms / day until 70; 15 mcg 70+

# Vitamin D Synthesis

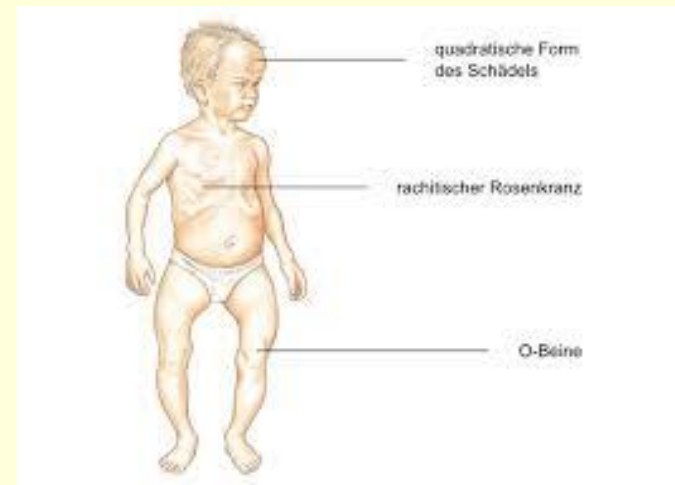
- ultraviolet light shines on a cholesterol compound in human skin, the compound is transformed into a vitamin D precursor and is absorbed directly into the blood
- over 1 1/2 days, the kidneys and liver finish converting the precursor to active vitamin D
- kidney or liver disease may affect this process

# Vitamin D Sources

- significant sources
  - fortified milk, margarine, butter, cereals, and chocolate mixes
  - veal, beef, egg yolks, liver, fatty fish (herring, salmon, sardines) and their oils

# Vitamin D Deficiency

- **children**
  - inadequate calcification, resulting in misshapen bones (bowing of legs)
  - enlargement long bones ends (knees, wrists)
  - deformities of ribs (bowed, with beads or knobs)
  - delayed closing of fontanel, resulting in rapid enlargement of head
  - lax muscles, muscle spasms
- **adults**
  - soft, brittle, deformed bones





# Vitamin D Toxicity

- most toxic of all the vitamins
  - elevated blood calcium
  - calcification of soft tissues (blood vessels, kidneys, heart, lungs, tissues around joints)
  - frequent urination

# Vitamin E (tocopherol)

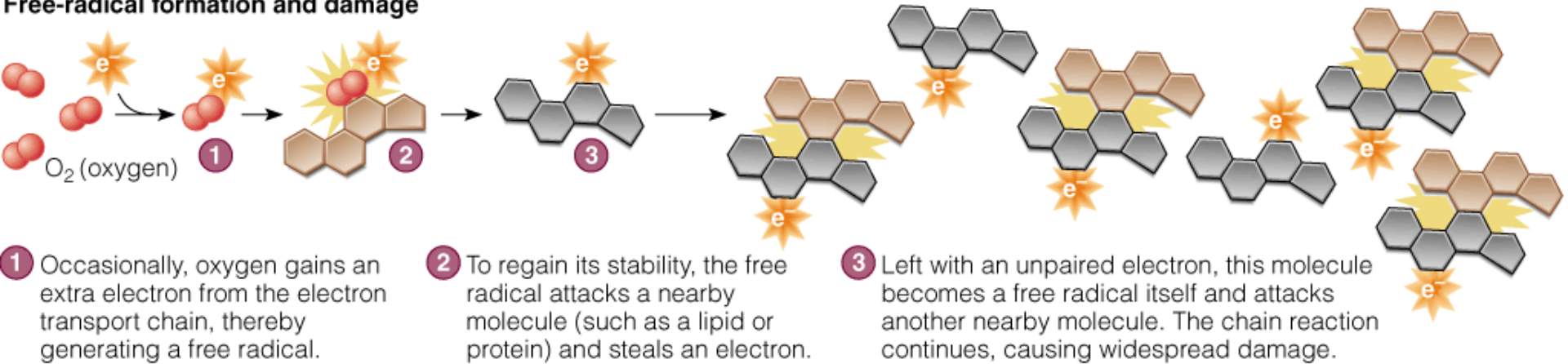
- antioxidant (stabilization of cell membranes, regulation of oxidation)
- red blood cells, neurons
- deficiency and toxicity are rare – hemolysis, nerve damage
- sources: vegetable oils, salad dressings, whole grain cereals, green leafy vegetables, nuts, seeds, peanut butter, egg yolks



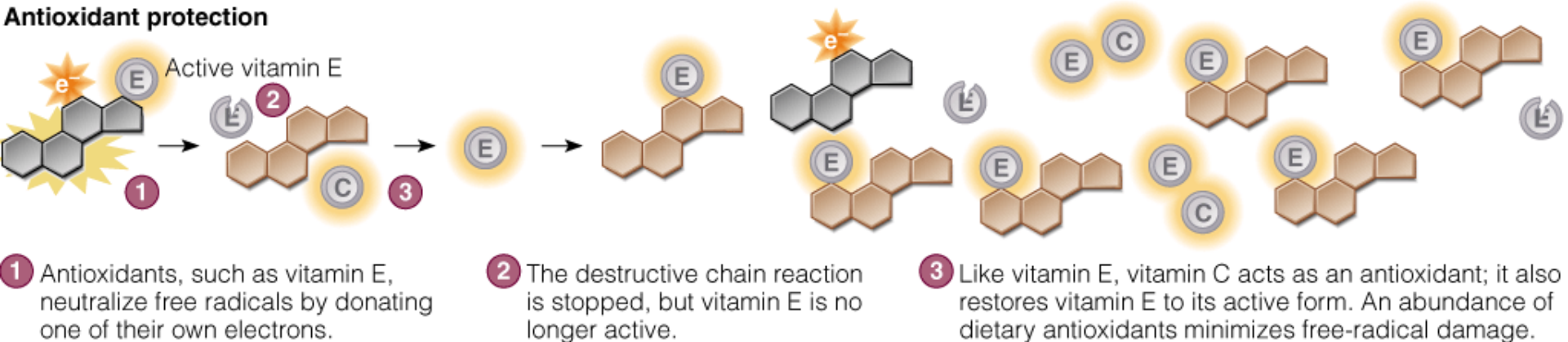
# Vitamin E (tocopherol)

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## Free-radical formation and damage

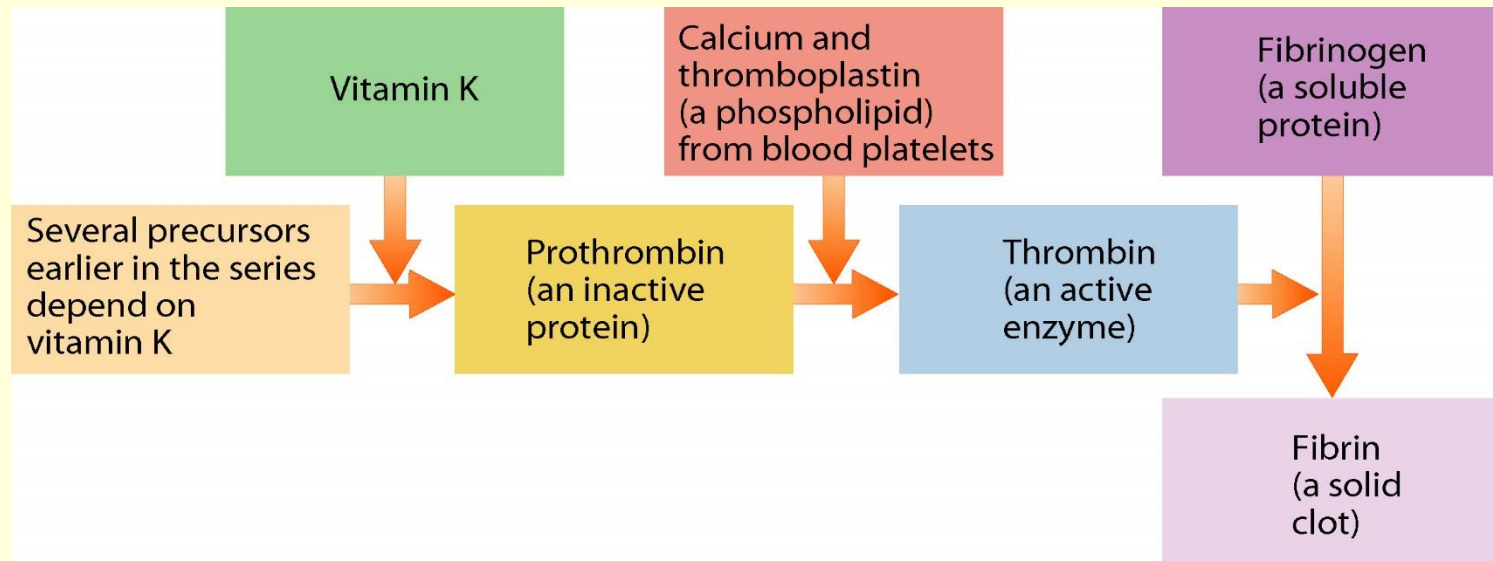


## Antioxidant protection

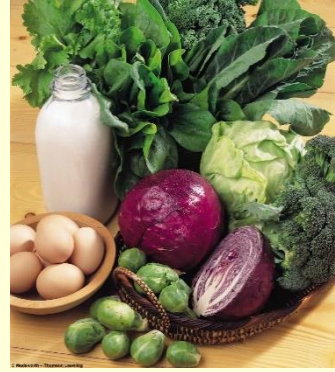


# Vitamin K

- synthesis of blood-clotting proteins and bone proteins that regulate blood calcium



# Vitamin K



- sources:
  - bacterial synthesis in the digestive tract
  - liver
  - leafy green vegetables, cabbage-type vegetables
  - milk
- deficiency symptoms: hemorrhage

# Water-Soluble Vitamins

- **Vitamins Bs and C**
- **B vitamins:**
  - Thiamin (B1)
  - Riboflavin (B2)
  - Niacin (B3)
  - Pyridoxine (B4)
  - Cobalamin (B12)
  - Folic acid
  - Pantothenic acid
  - Biotin

# B vitamins

- act as co-enzymes, involved in energy metabolism
  - **coenzyme** is a small molecule that combines with an enzyme to make it active

## B vitamins

- thiamin, riboflavin, niacin, pantothenic acid and biotin participate in the release of energy from carbohydrates, proteins and lipids
- vitamin B<sub>6</sub> helps the body use amino acids to make protein. Folate and B<sub>12</sub> help cells to replicate



# Vitamin B1 (thiamin)

- helps converting carbohydrates to energy
- deficiency:
  - fatigue, nausea, depression, nerve damage
- sources:
  - pork, beef, liver, peas, seeds, legumes, whole-grain products, and oatmeal

# B2 Vitamin (riboflavin)

- key to metabolism and red blood cells
- deficiency:
  - dry, scaly skin
- sources:
  - milk, yogurt, cheese, whole-grain breads, green leafy vegetables, meat, and eggs

# B3 Vitamin (niacin)

- involved with energy production, skin, nerves and digestive system
- deficiency:
  - rare: diarrhea, dermatitis, dementia and death
- sources:
  - meat, poultry, liver, eggs, brown rice, baked potatoes, fish, milk, and whole-grain foods

# B6 Vitamin (pyridoxine)

- involved in chemical reactions of proteins and amino acids
- deficiency:
  - skin changes, dementia, nervous system disorders and anemia
- sources:
  - lean meats, fish, legumes, green leafy vegetables, raisins, corn, bananas, mangos

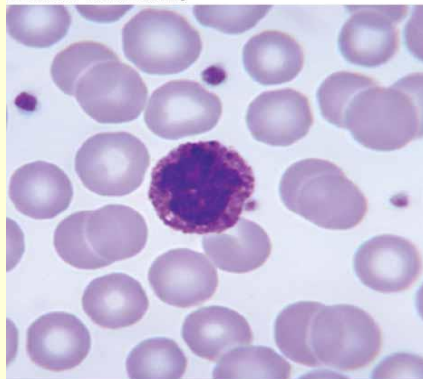
# B12 Vitamin (cobalamin)

- helps red blood cells production
- maintains the myelin sheaths
- helps to break down some fatty acids and amino acids
  
- absorption
  - HCl
  - pepsin
  - intrinsic factor required for activation
  
- sources:
  - only found in animal products (meat, fish, poultry, shellfish, milk, cheese, eggs)

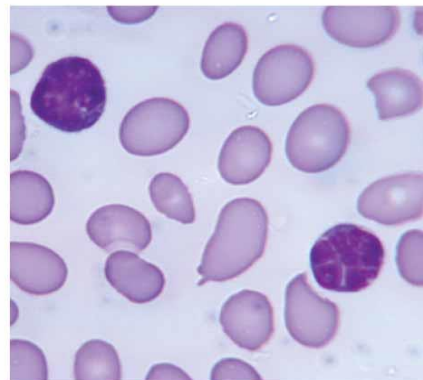
# B12 Vitamin (cobalamin)

- deficiency of folate or B<sub>12</sub> produces **pernicious anemia (macrocytic, large-cell type)** and fatigue, degeneration of peripheral nerves progressing to paralysis
- toxicity symptoms: none reported

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Normal blood cells. The size, shape, and color of the red blood cells show that they are normal.



Blood cells in pernicious anemia (megaloblastic). Megaloblastic blood cells are slightly larger than normal red blood cells, and their shapes are irregular.

# B9 Vitamin (folic acid)

- key role in red blood cell formation and cell division
- activation – vitamin B12
- deficiency:
  - anemia (large-cell type), digestive disorders
  - weakness, mental confusion, fatigue
- sources:
  - leafy, dark green vegetables
  - liver, beans, peas, asparagus, oranges, avocados



# B5 Vitamin (pantothenic acid)

## B7 Vitamin (biotin)

- help with metabolism and formation of some hormones
- deficiencies are rare
- sources:
  - almost any food, plant-based or animal-based

# Vitamin C

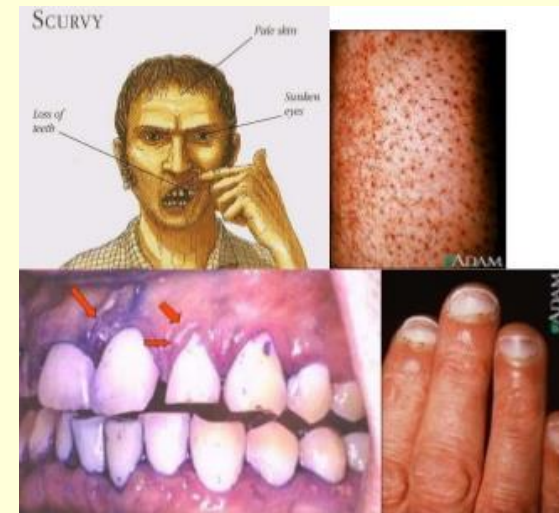
- main functions in the body
  - collagen synthesis
    - Strengthens blood vessel walls, forms scar tissue, provides matrix for bone growth
  - antioxidant
  - thyroxin synthesis
  - amino acid metabolism
  - strengthens immune system
  - helps in absorption of iron

# Vitamin C

- significant sources
  - citrus fruits
  - cabbage-type vegetables, dark green vegetables (such as bell peppers and broccoli)
  - cantaloupe, strawberries
  - lettuce, tomatoes, potatoes
  - papayas, mangoes
- easily destroyed by heat and oxygen

# Vitamin C

- deficiency disease: **scurvy**
- deficiency symptoms
  - anemia (microcellular)
  - atherosclerotic plaques in the vessels
  - pinpoint hemorrhages, bone fragility, joint pain
  - poor wound healing, frequent infections, bleeding gums, loosened teeth
  - muscle pain and atrophy, depression, rough skin, blotchy bruises



# Vitamin C

- toxicity symptoms
  - nausea, abdominal cramps, diarrhea
  - headache, fatigue, insomnia
  - hot flashes, rashes
  - aggravation of gout symptoms, urinary tract problems, kidney stones

# Body Minerals

- **major (macrobiogenic)**
  - carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus
  - sodium, potassium, calcium, chlorine, magnesium, iron
- **microbiogenic and trace**
  - copper, zinc, molybdenum, cobalt, fluorine, iodine
  - selenium, manganese, chromium, arsenic, nickel, silicon, boron, cobalt

# Calcium

- the most abundant mineral in your body
  - 99% is stored in the bones and teeth
- integral part of bone structure (serves as a calcium release place)
- calcium in body fluids regulates transport of ions across cell membranes
- particularly important in nerve transmission and muscle contraction
- role in blood clotting

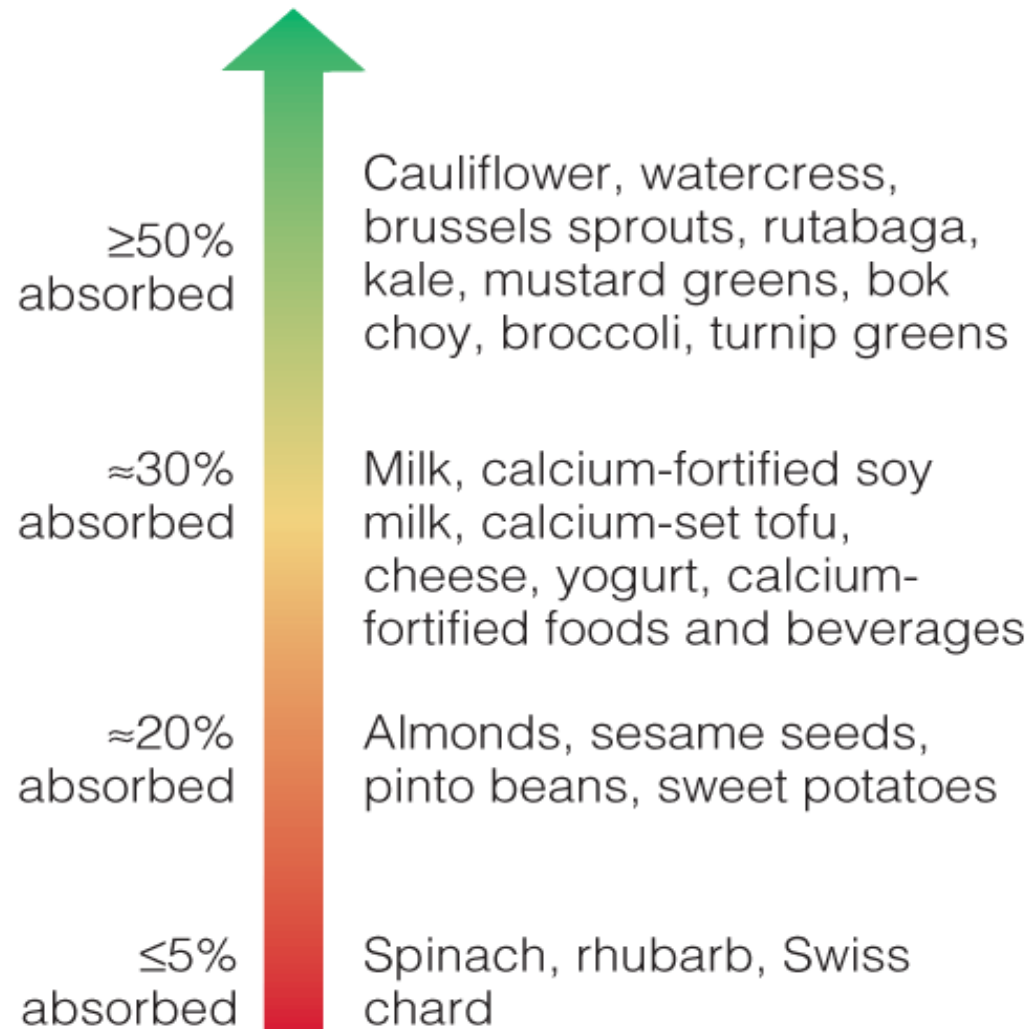


# Calcium

- blood calcium is regulated by hormones sensitive to blood calcium and not by dietary intake
- inadequate intake of calcium in early life results in poor bone mass and can lead to osteoporosis
  
- adolescents: 1300 mg/day
- adults 19 -50, 1000 mg/day
- adults over 51, 1200 mg/day
  
- food sources: milk and dairy products best source, small bones of fish like salmon and sardines, dark green vegetables like broccoli, kale, and spinach

# Calcium

## ■ Bioavailability of Calcium from Selected Foods



# Calcium Absorption

Factors that enhance Ca absorption:

- stomach acid
- vitamin D
- lactose
- growth hormones

Factors that inhibit Ca absorption:

- lack of stomach acid
- vitamin D deficiency
- high phosphorus intake
- high- fiber intake
- phytates (seeds, nuts, grains)
- oxalates (beet greens, rhubarb, spinach)

# Sodium

- the principle cation in the extracellular fluids of the body
- helps to maintain acid-base balance
- essential to muscle contraction and nerve transmission
- 40% of body's sodium thought to be stored on surface of bone crystals where body can easily draw it into blood
- deficiency would be harmful but few diets lack sodium
  
- sodium/water ratio delicately balanced by kidneys
- vomiting, diarrhea, and excessive sweating can deplete sodium

# Sodium

- Deficiency symptoms
  - Muscle cramps, mental apathy, loss of appetite
- Toxicity symptoms
  - Edema, acute hypertension
- Significant source
  - Table salt, soy sauce
  - Moderate amounts in meats, milks, breads, and vegetables
  - Large amounts in processed foods

# Potassium

- principal cation within the body's cell
- chief functions in the body
  - Maintains normal fluid and electrolyte balance
  - Facilitates many reactions
  - Supports cell integrity
  - Assists in nerve impulse transmission and muscle contractions

# Potassium

- deficiency symptoms
  - muscular weakness
  - paralysis
  - confusion
- toxicity symptoms
  - muscular weakness
  - vomiting
  - heart arrest after intravenous application

# Potassium

- significant sources
  - all whole foods
  - meats, milks, fruits, vegetables, grains, legumes





# Magnesium

- chief functions in the body
  - bone mineralization
  - proteosynthesis
  - enzyme activity
  - muscle contraction
  - nerve impulse transmission
  - maintenance of teeth
  - immune system functions

# Magnesium

- **deficiency** symptoms
  - weakness
  - confusion
  - if extreme, convulsions, bizarre muscle movements (especially of eye and face muscles), hallucinations, and difficulty in swallowing
  - in children, growth failure
- **toxicity** occurs in older people abusing magnesium based laxatives, antacids and other medications  
Symptoms severe: diarrhea, acid-base imbalance, kidney impairment, confusion, coma, death

# Magnesium

- significant sources
  - nuts, legumes
  - whole grains
  - dark green vegetables
  - seafood
  - chocolate, cocoa