VITAMINS (class exercise)

- Name of vitamin
- Source
- Physiological function
- Deficiency (disease)

LECTURE 2: VITAMINS

- Classification
- Sources
- Chemistry, Physiological and Biochemical functions
- Deficiency symptoms and Related Disorders

VITAMINS

- Vitamins are chemical compounds organic in nature that occur in minute quantities in the diet
- Not synthesised by humans
- Supplied in the diet as Provitamins
- Play catalytic roles

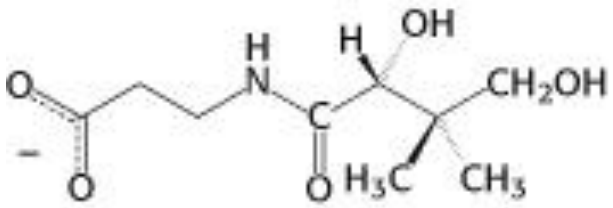
Classification of Vitamins

1. Solubility
   i. Water Soluble
   ii. Fat soluble
   iii. Not soluble – Biotin
2. Nomenclature – order of discovery (alphabetic order)

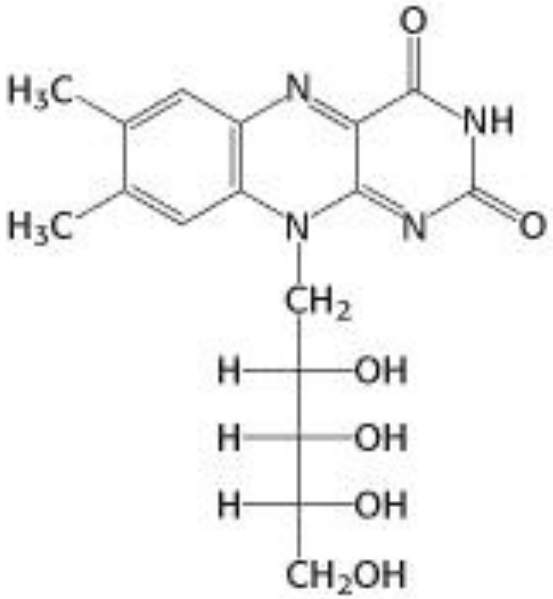
Fat Soluble vs Water soluble Vitamins

	Fat Soluble	Water Soluble
Absorption	Into lymphatic system (fat/bile)	Directly into blood stream
Storage	For future use	Note stored
Effect of Overdose	Toxic	Can be excreted
Stability	Less fragile	Easily destroyed on heating

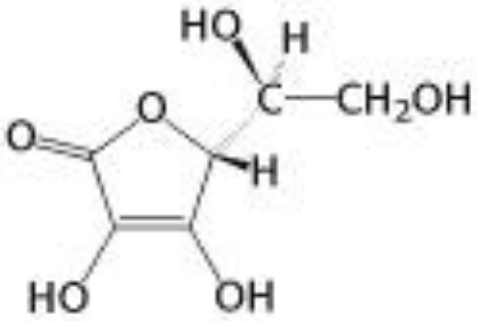
Water Soluble Vitamins



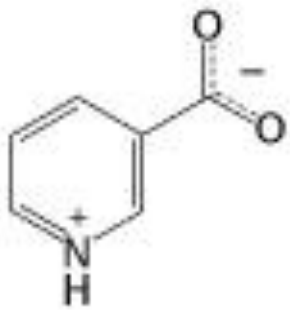
Vitamin B_5
(Pantothenate)



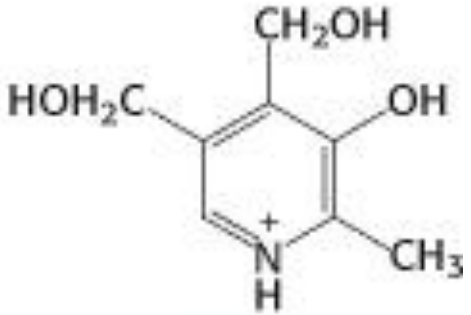
Vitamin B_2
(Riboflavin)



Vitamin C
(Ascorbic acid)



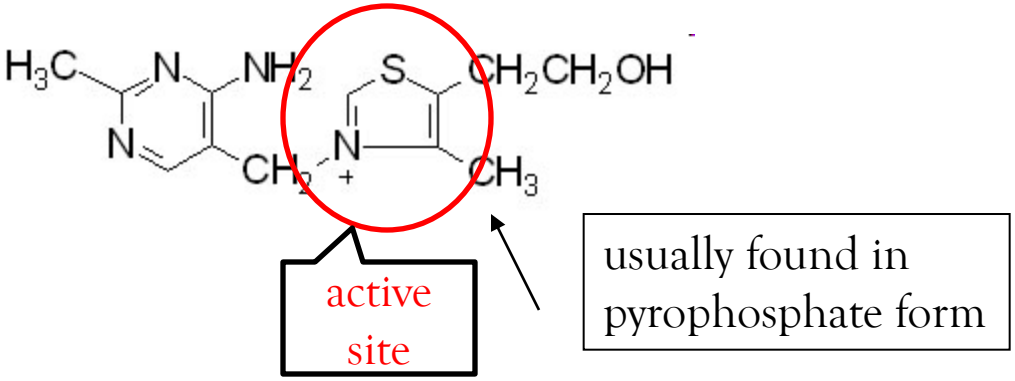
Vitamin B_3
(Niacin)

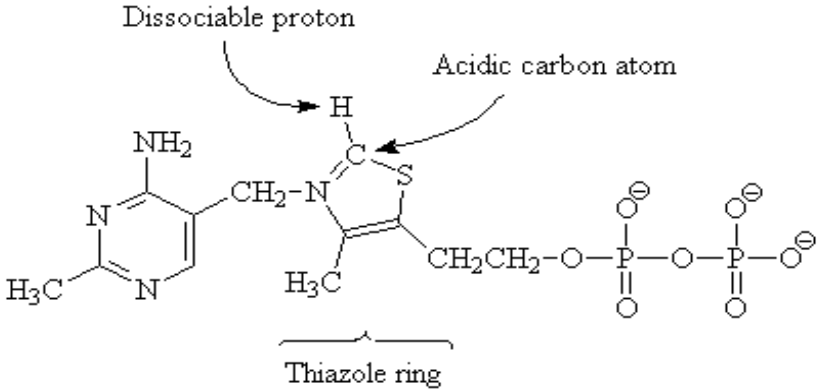


Vitamin B_6
(Pyridoxine)

Thiamine (B_1)

- Thiamine - a thiazole ring joined to a substituted pyrimidine by a methylene bridge





THIAMINE PYROPHOSPHATE (TPP)

- ❖TPP is the active form
- ❖Easily destroyed by heat

Thiamine pyrophosphate

TPP is the active form

Functions:

- Energy metabolism
  - required for the normal metabolism of -CHO.
    - catalyzes decarboxylations of α-keto acids e.g.
      - pyruvic acid → acetaldehyde in glycolysis
      - pyruvic acid → acetyl-CoA
  - formation and cleavage of α -hydroxyketones
- Supports nervous system
- Daily requirements
  - men: 1.2 mg/day
  - women: 1.1 mg/day

Thiamine Sources

- Occur in both plant & animal sources

Animal:

- Pork, milk Liver, eggs, rumen

Plants:

- Whole/enriched grains
  - Esp seed coats & embryos; eg. wheat germ
- fresh green forage
- yeast

Deficiency symptoms of Thiamine

1. Beriberi

- Anorexia: loss of appetite
- severe nervous disorders
- General &muscular weakness
- tissue wasting & edema
- Dyspepsia (indigestion)
- Needle –like feeling under the skin

- **Three types of beriberi**
  - Dry beriberi- adults
  - Wet beriberi – youth
  - Infantile beriberi- infants

Deficiency symptoms of Thiamine

2. Warnicke-Korsakoff Syndrome

- Korsakoff's psychosis –
  - confused state- characterized by
  - confabulation
  - memory loss of recent events /non-impairment of past events
- Wernicke encephalopathy-
  - Neurological charcterised by
  - Nystagmus (involuntary spasmodic movement of eye ball
  - Ocular palsy

Chronic peripheral neuritis

- Neurological problems eg. confusion and ataxia
- Thiamine deficiency due to alcoholism
- TPP is required to metabolize energy
- Alcohol contains calories which must be metabolized but no thiamine,
- Leads to neurological problems

Risky groups

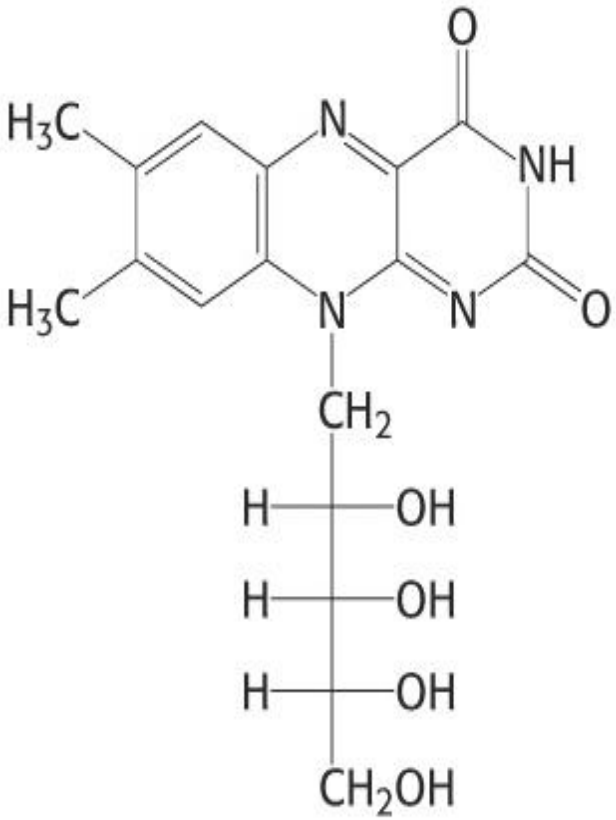
- Chronic alcoholics
- Population dependent on polished rice
- People who consume raw sea fish
- Rice & sea raw fish contain active thiaminase-enzyme destroys the vitamin

Vitamin B_2

Riboflavin

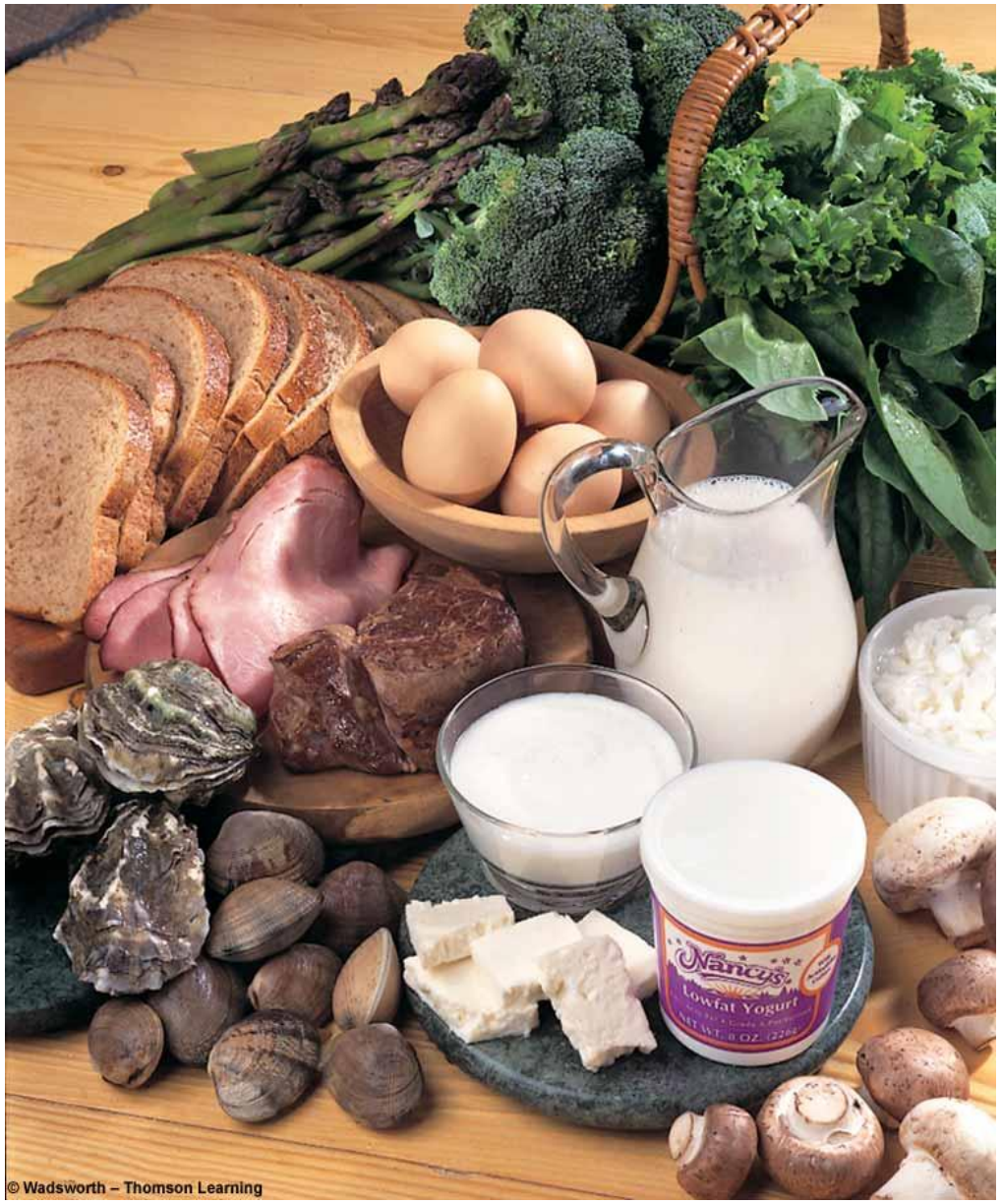
Also known as vitamin B_2

- Contain ribitol & isoalloxazine (flavin) ring
- Coenzyme (Active form)
  - Flavin mononucleotide (FMN)
  - Flavin adenine dinucleotide (FAD)
- FMN &FAD not true nucleotides
  - Names are traditional and they persist!



Vitamin B_2 (Riboflavin)

Riboflavin Sources



Widely present in plants & animal sources

Animals:

- Milk & dairy products- yogurt, cheese, liver, meat, kidney, eggs

Plants:

- Enriched /whole grains- wheat bran
- Yeast
- Fresh vegetables
- Rumen synthesis

Functions of Riboflavin

Energy metabolism:

- part of FMN (Flavin Mononucleotide)
- FAD (Flavin Adenine Dinucleotide)

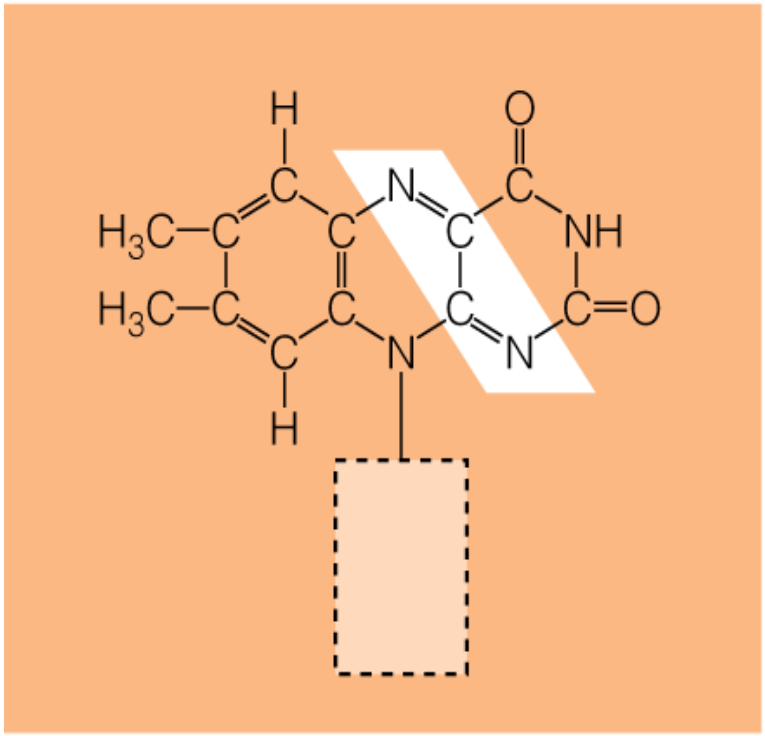
- Important coenzymes in energy metabolism
- catalyzes dehydrogenation rxns
- Important in the metabolism of a.a, fats & -CHO.

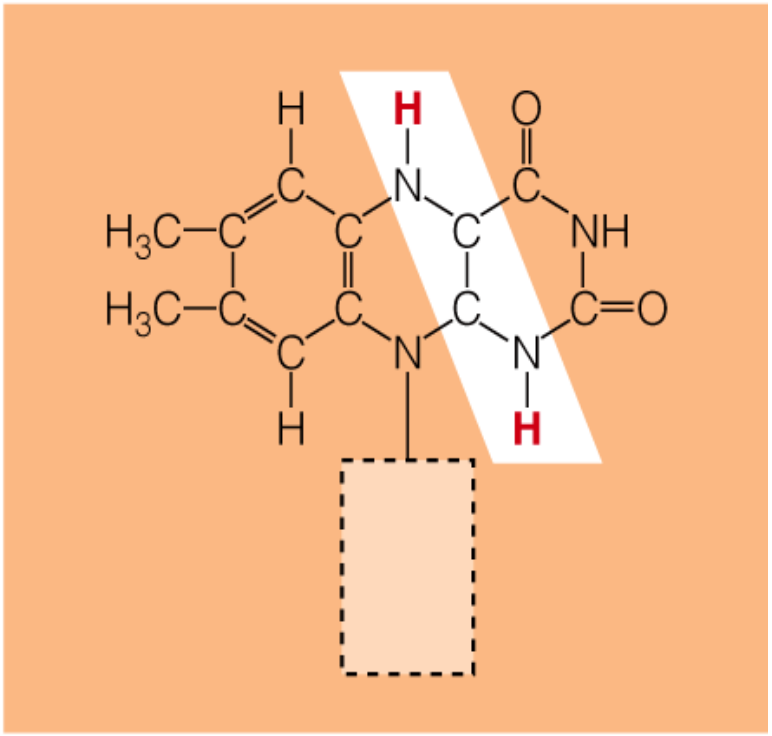
Promotes healthy skin & vision

Necessary for normal embryo development,

- Easily destroyed by ultraviolet light & irradiation
- Daily requirements
  - ❖ Men: 1.3 mg/day
  - ❖ Women: 1.1 mg/day

Riboflavin in redox reactions





FAD

$FADH_2$

During the TCA cycle, compounds release hydrogens, and the riboflavin coenzyme FAD picks up two of them. As it accepts two hydrogens, FAD becomes $FADH_2$.

$FADH_2$ carries the hydrogens to the electron transport chain. At the end of the electron transport chain, the hydrogens are accepted by oxygen, creating water, and $FADH_2$ becomes FAD again. For every $FADH_2$ that passes through the electron transport chain, 2 ATP are generated.

Vitamin B_2 : Deficiency symptoms:

Riboflavinosis (never fatal) characterised by

- Cheilosis- swelling and fissuring of lips
- Angular stomatitis- lessions at the margin of the mouth
- Painful desquamation of the tongue
    - (dry and atrophic) magenta tongue
- Scaly dermatitis
- Eye problems lead*in*g to
    - corneal vascularisation
    - inflammation with cloudiness of cornea
    - photophobia
    - cataract
- Skin disorders

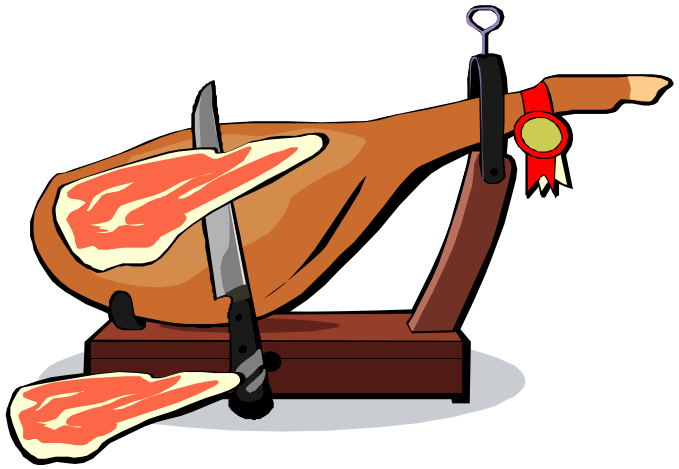
Vitamin B_3

Niacin (B_3)

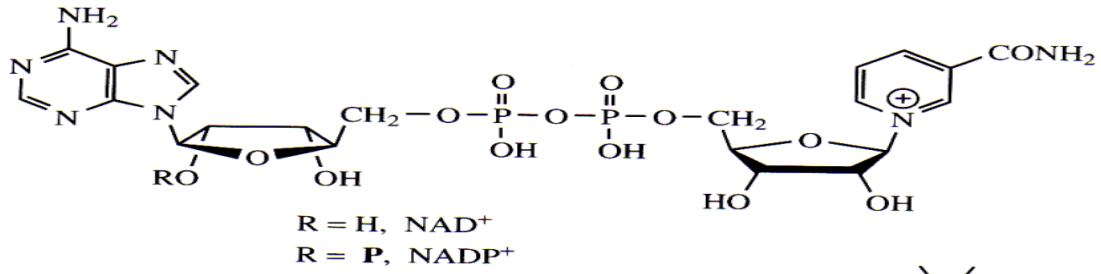
Other names

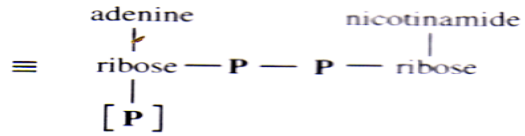
- ❖ Nicotinic acid
- ❖ Nicotinamide
- ❖ Niacinamide

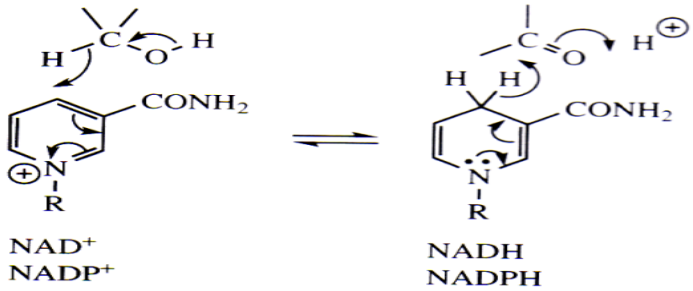
- Precursor: dietary **tryptophan**



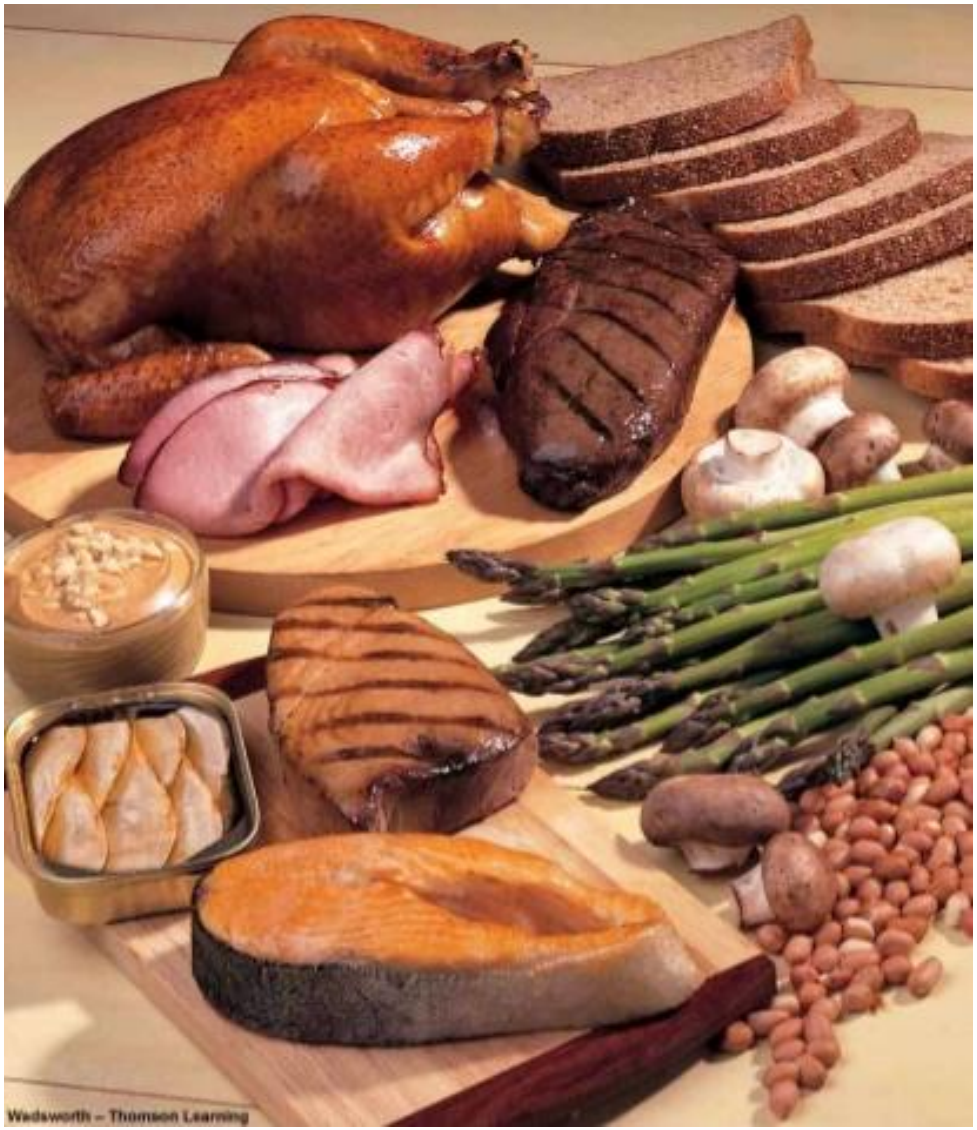
Dehydrogenases: NAD⁺ and NADP⁺







Niacin Sources



- Both plant & animal sources
- Animal:
  - protein foods
    - Milk
    - eggs
    - meat
    - fish, poultry
- Plants
  - legumes
  - Enriched/whole grains
  - Nuts
  - Yeast

Functions of Niacin

- Energy metabolism:
  - Part of coenzymes NAD & NADP
    - catalyzes **redox** rxns of alcohols/carbonyl groups
    - Degradation of l-Trp → niacin

- General metabolism,
  - healthy skin,
  - nervous & digestive system

Niacin Deficiency

Pellagra characterized by 3Ds

- ❖diarrhea
- ❖dermatitis
- ❖ dementia
- ❖oral lesions

Toxicity symptoms

- ❖Painful flush,
- ❖hives
- ❖ rash (“niacin flush”)
- ❖Excessive sweating
- ❖Blurred vision
- ❖Liver damage, impaired glucose tolerance

RDA

Men: 16 mg NE/day

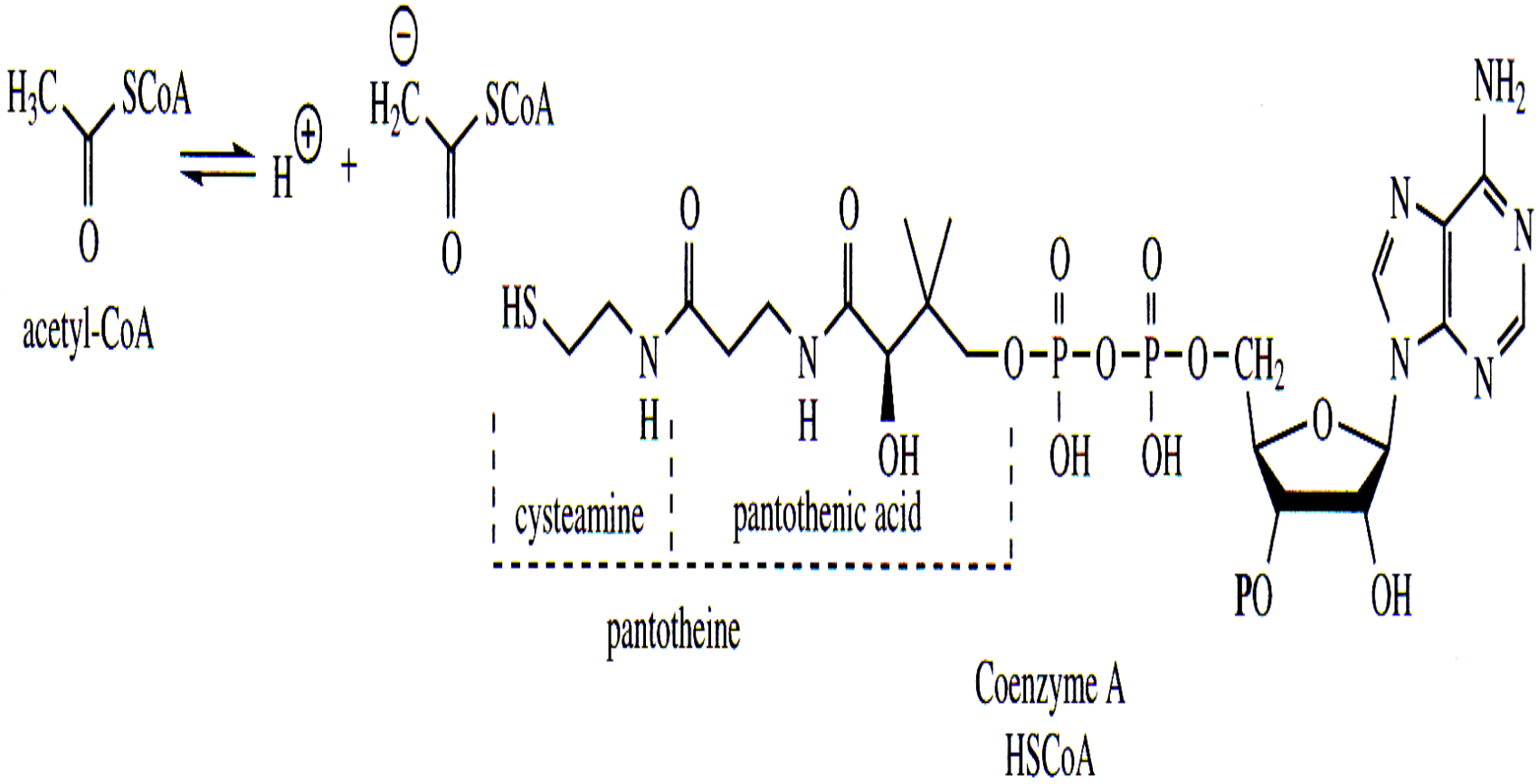
Women: 14 mg NE/day

Upper level for adults: 35 mg/day

Vitamin B_5

Pantothenic acid

- Also known as vitamin B_5
- Part of Coenzyme A



Functions of Pantothenic Acid

- Part of coenzyme A,
  - used in energy metabolism

- Easily destroyed by food processing

- 1998 adequate intake (AI)
  - Adults: 5 mg/day

Sources of Pantothenic Acid

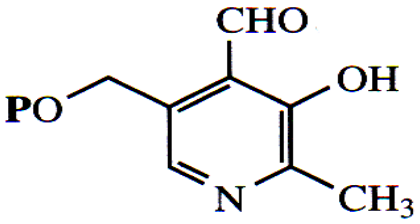
- Widespread in foods- plants & animals
- Plants
  - Broccoli
  - Whole grains
  - Mushrooms
  - Avacado
- Animals
  - Organ meats
  - yeast
  - liver

Functions of Pantothenic acid

- Synthesis of fatty acids (acetate pathway),
- Synthesis of some peptides, isoprenoids phenylpropanoids
- Metabolism of fat, carbs and protein
- Vitamins B_3, B_5, B_6 and biotin are thought to promote healthy hair and prevent hair loss
- Deficiency is rare

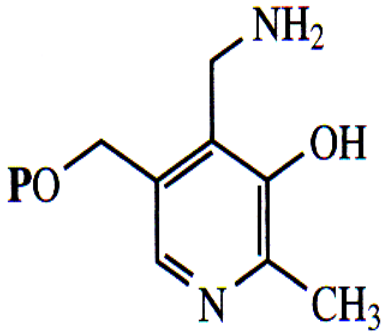
Vitamin B_6

Vitamin B_6



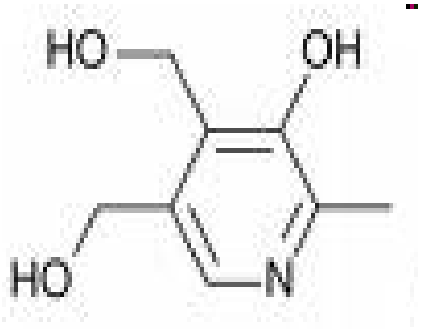
pyridoxal P
(PLP)

- Other names
  - Pyridoxine
  - Pyridoxal
  - Pyridoxamine



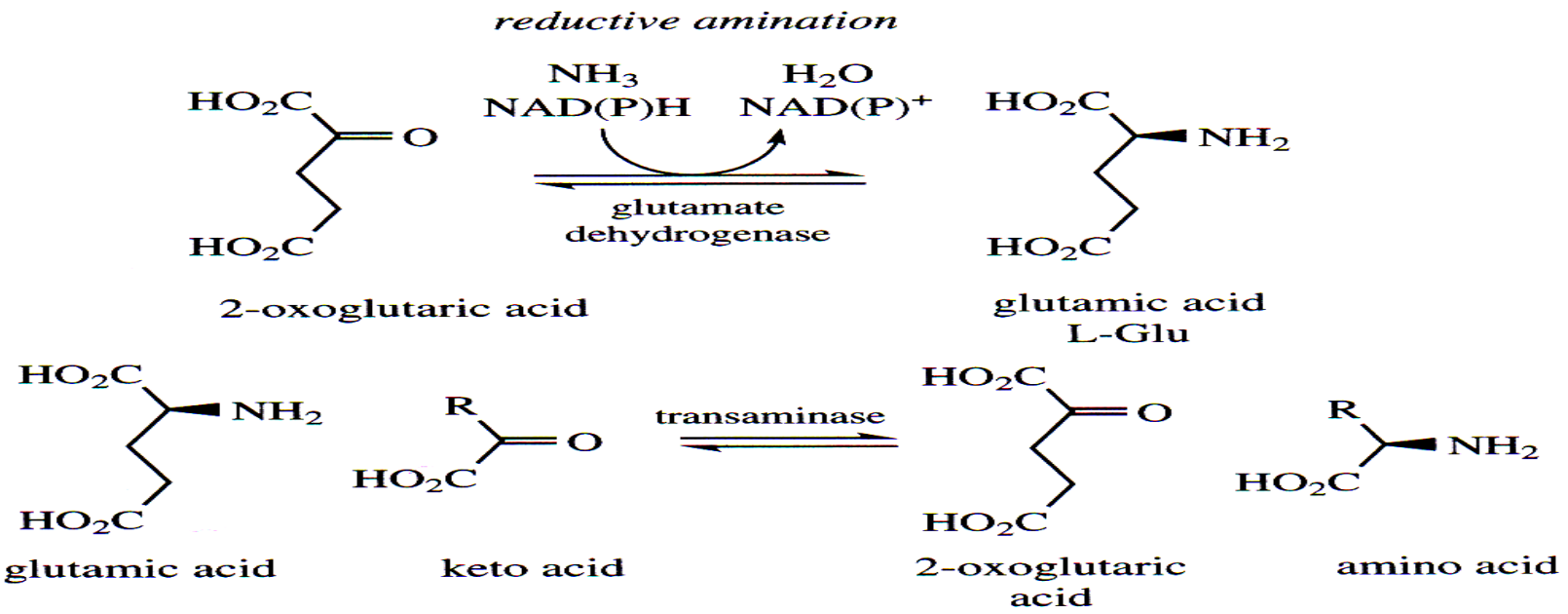
pyridoxamine P

- Coenzyme PLP, PNP or PMP
- Adults (19-50 years): 1.3 mg/day
- Upper level for adults: 100 mg/day



Function of vitamin B6

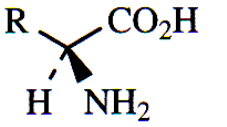
Amination reactions: Gain of N by a molecule
Reductive amination: N comes from ammonia
Transamination: NH_2 group is transferred from an a.a

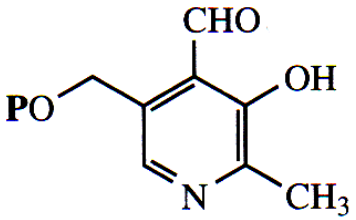


Product of Krebs cycle

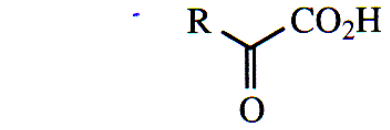
Loss of N:

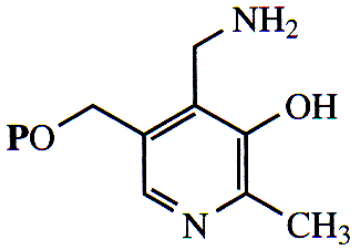
Deamination of an amino acid by Vitamin B_6 involves imine formation and hydrolysis





pyridoxal P (PLP)



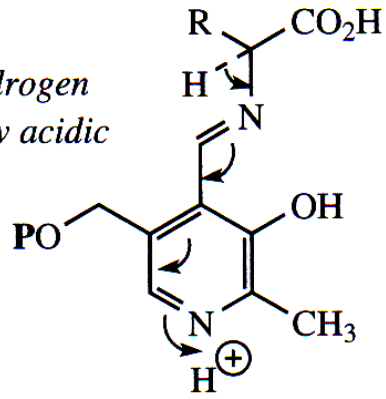


pyridoxamine P

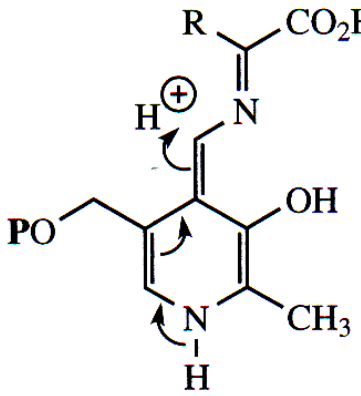
formation of imine from aldehyde and amino acid

hydrolysis of imine to keto acid and amine

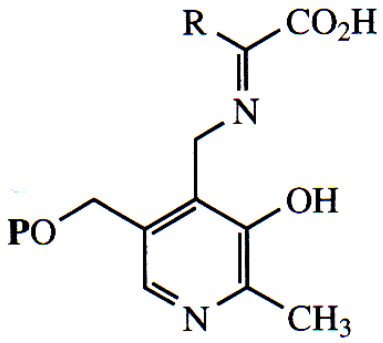
α-hydrogen is now acidic



aldimine



restoring aromaticity



ketimine

Sources of vitamin B_6

- Animal:
  - Meat,
  - Fish eg salmon,
  - Poultry,
  - Liver
- Plants :
  - nuts, cereals
  - bananas, Potatoes,
  - legumes
  - Non-citrus fruits
  - Fortified cereal
  - Soy products

Chief functions of Vit B_6 in the body

- Energy metabolism:
  - Amino acid and fatty acid metabolism :
  - Part of coenzymes pyridoxal phosphate
  - Catalyzes transaminations & decarboxylations of amino acids
  - PLP is important in f.a and aa metabolism

- Convert tryptophan to niacin and to serotonin
- Helps to make red blood cells
- In plants, used in biosynthesis of phenylpropanoids from amino acids

Deficiency symptoms of Vitamin B_6

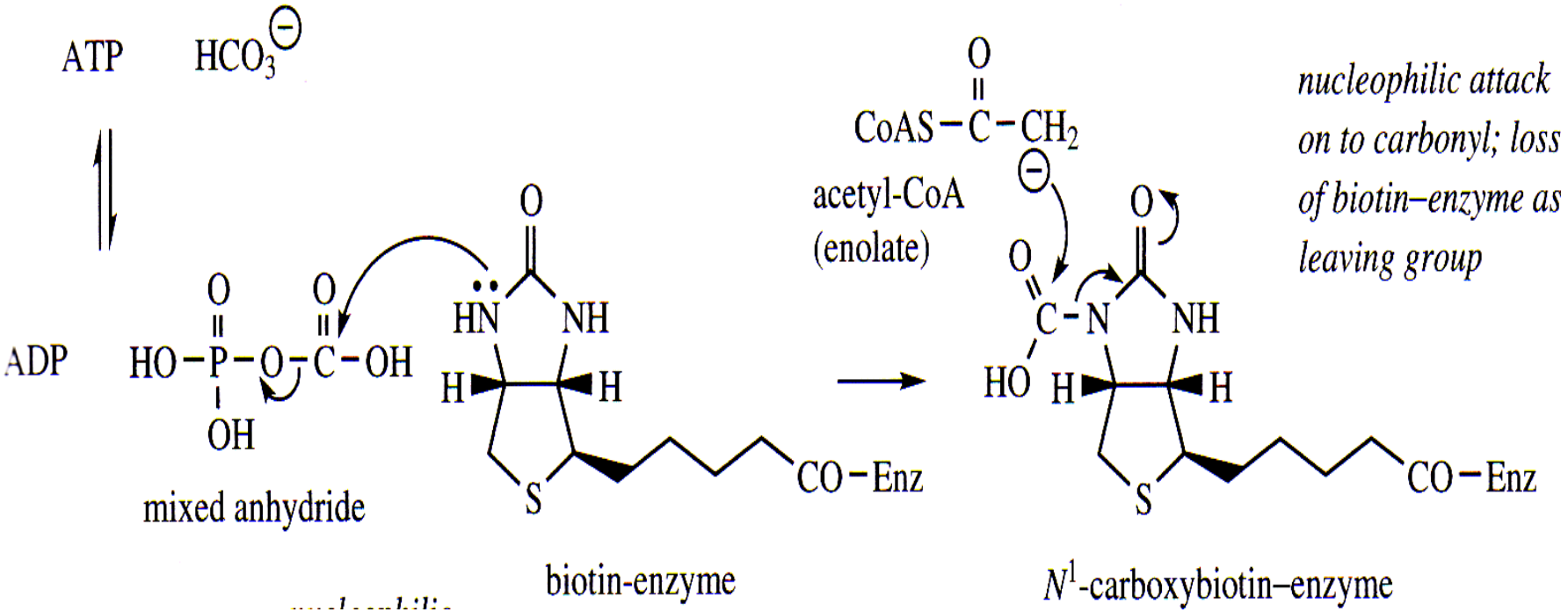
- Scaly dermatitis
- Anemia (small-cell type)
- Depression, confusion, abnormal brain wave pattern, convulsions
- Nervous disorders, skin rash, muscle weakness,

- Vit B_6 can be lost through cooking, deficiency usually caused by poor absorption

Vitamin B_7

Biotin (B_7)

Biotin (Vitamin H): functions as a carboxyl group carrier
Ex: transforms acetyl-CoA to malonyl-CoA (acetate pathway)
Deficiency is rare, but could lead to dermatitis and hair loss ☹



- 1998 adequate intake (AI)
  Adults: 30 μg/day

Biotin Sources

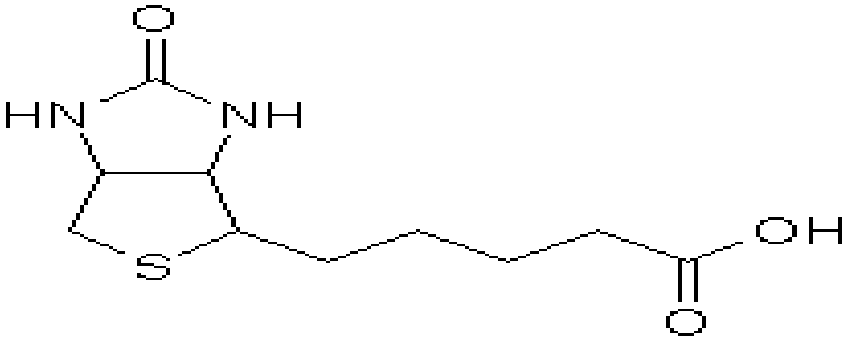
- Animal sources
  - Organ meats, fish
  - Egg yolks, liver, kidney, milk
- Plant sources- Soybeans, Whole grains, yeast, cereals
- Also produced by intestinal microflora

- **Chief functions in the body - part of a coenzyme used in energy metabolism, fat synthesis, amino acid metabolism, and glycogen synthesis**

Biotin "chemistry on a tether"

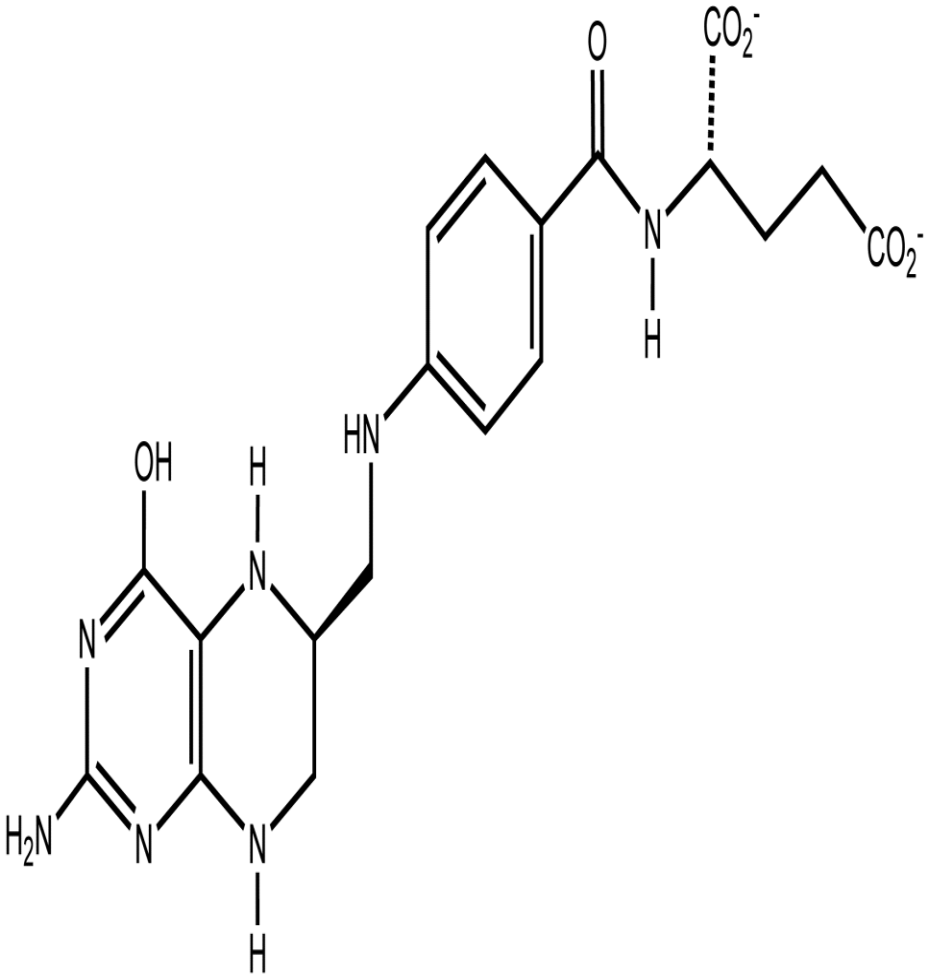
- Mobile carboxyl group carrier
- Bound covalently to a lysine
- The biotin-lysine conjugate is called biocytin
- The biotin ring system is thus tethered to the protein by a long, flexible chain

- Whenever you see a carboxylation that requires ATP and CO2 or HCO3-, think biotin!
- Activation by ATP involves formation of carbonyl phosphate (aka carboxyl phosphate)
- Carboxyl group is transferred to biotin to form N-carboxy-biotin
- The "tether" allows the carboxyl group to be shuttled from the carboxylase subunit to the transcarboxylase subunit of ACC-carboxylase



Vitamin B_9

Folate (B_9)



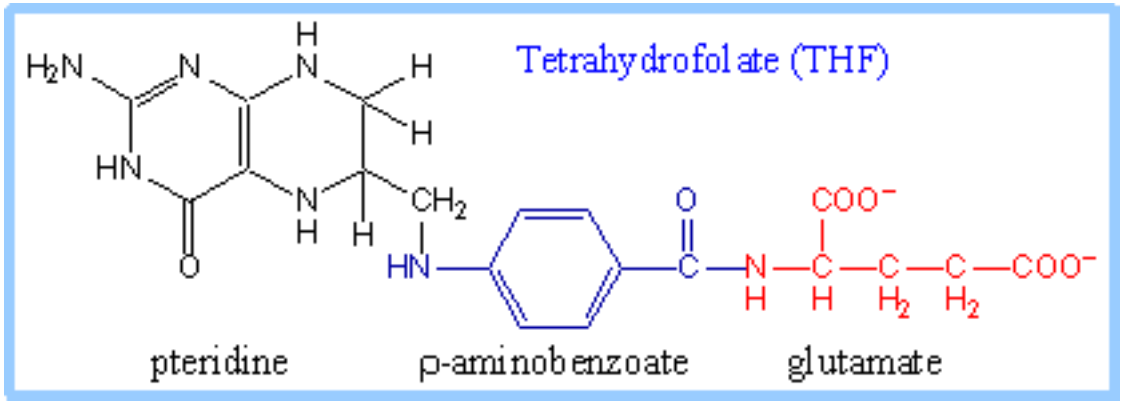
- Other names
  - Folic acid
  - Folacin
  - Pteroylglutamic acid (PGA)
- 1998 RDA
  - Adults: 400 μg/day
- Upper level for adults: 1000 μg/day

Folate Sources

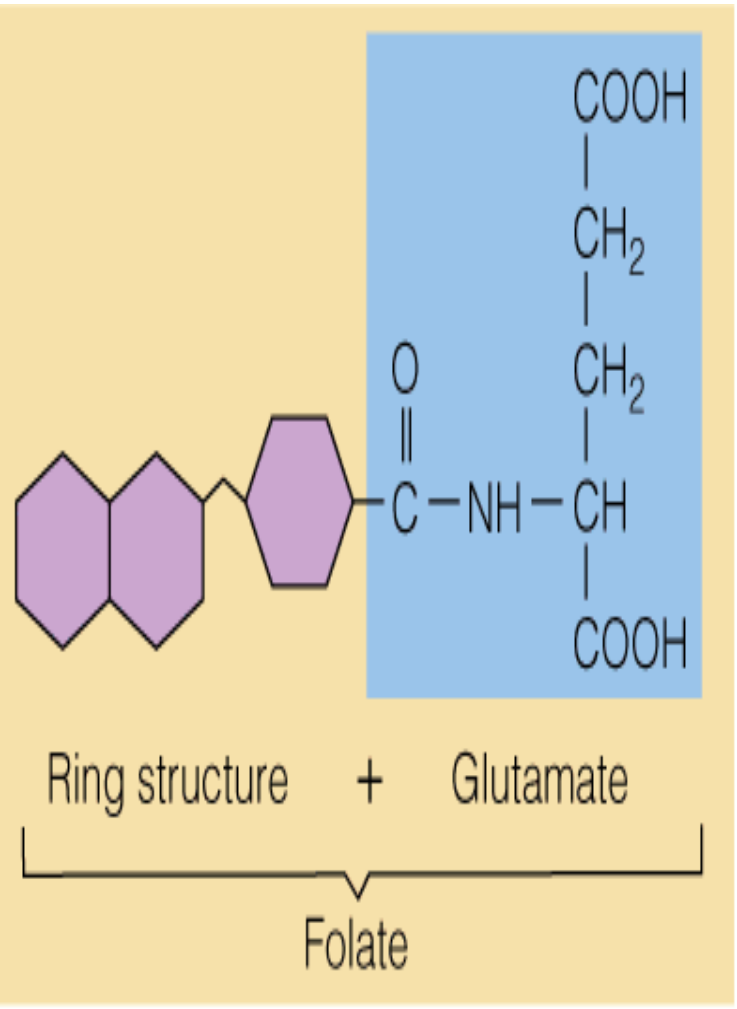
- Plant sources
  - Whole & Fortified grains
  - Leafy green vegetables
  - Legumes
  - Seeds
  - Yeast
  - some fruits
- Animal sources
  - Liver,

Folic Acid

- Folates are donors of 1-C units for all oxidation levels of carbon except that of CO_2
- Active form is tetrahydrofolate (THF)
- THF is formed by two successive reductions of folate by dihydrofolate reductase

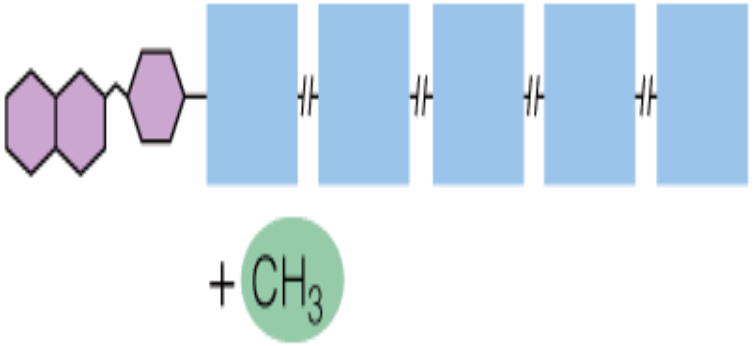


Folate

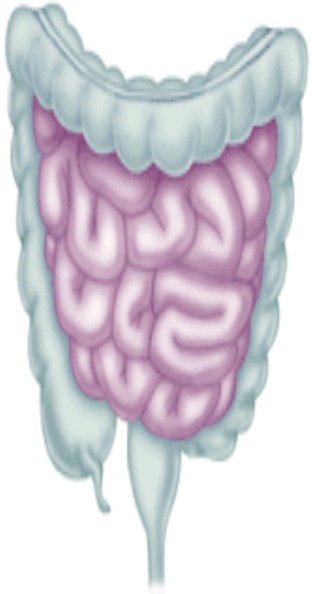


In foods, folate naturally occurs as polyglutamate. (Folate occurs as mono-glutamate in fortified foods and supplements.)

Spinach

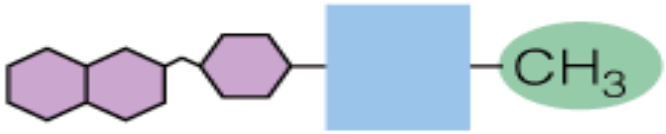


In the intestine, digestion breaks glutamates off . . . and adds a methyl group. Folate is absorbed and delivered to cells.

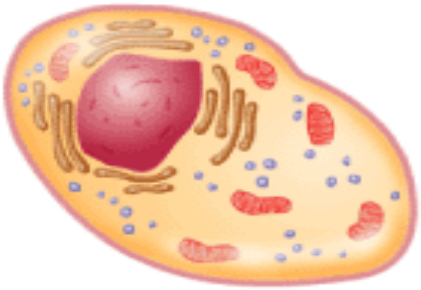


Intestine

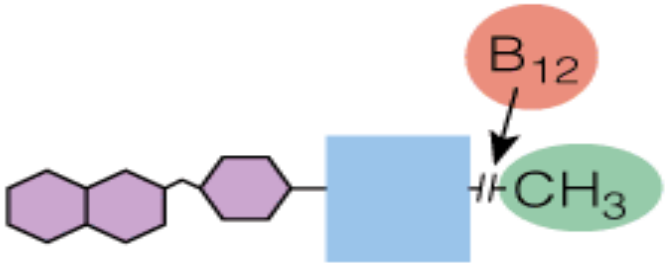
Folate



In the cells, folate is trapped in its inactive form.



Cell



To activate folate, vitamin B_{12} removes and keeps the methyl group, which activates vitamin B_{12}.

Both the folate coenzyme and the vitamin B_{12} coenzyme are now active and available for DNA synthesis.

DNA

Folate

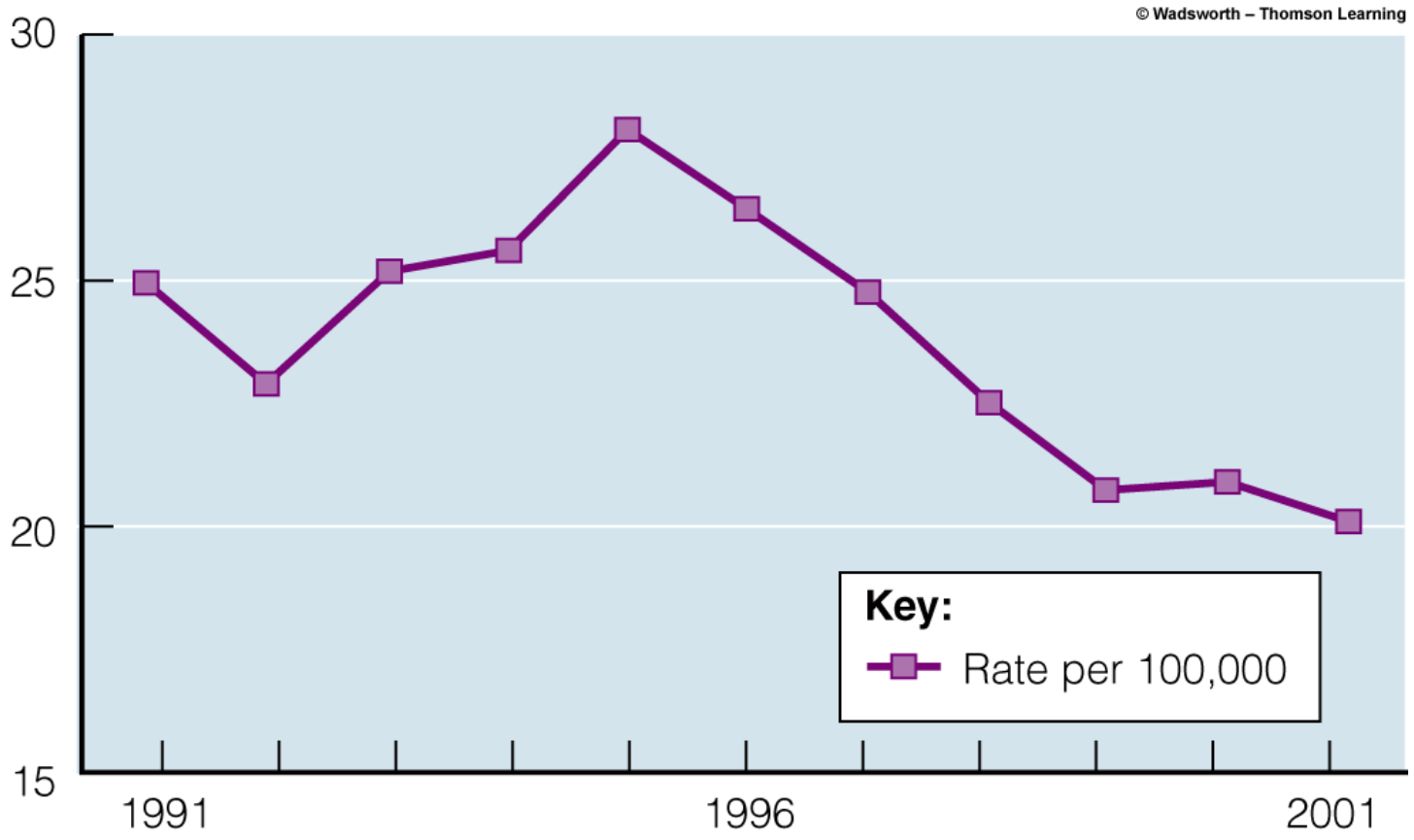
- Chief functions in the body
- Part of coenzymes
  - Tetrahydrofolate (THF)
  - Dihydrofolate (DHF)
  - used in DNA synthesis
  - DNA important in new cell formation
- THF important in one-C metabolism
  - Acts as a carrier of methyl, methylene or formyl groups
- Involved in amino acid &nucleotide metabolism,
- Involved in red blood cell formation

Folacin Deficiency

- Anemia,
- Neural tube defects in a fetus,
- Cardiovascular problems in adults
- **Neural Tube Defects**
  - Malformation of the central nervous system that forms very early in the pregnancy (often even before woman realizes she is pregnant
- Spina bifida- spine develops outside of the body
- Anencephaly- entire brain and skull above the ears is missing
- Folate intake linked to reduced CVD, colon cancer in women and depression in men

Folate Supplementation

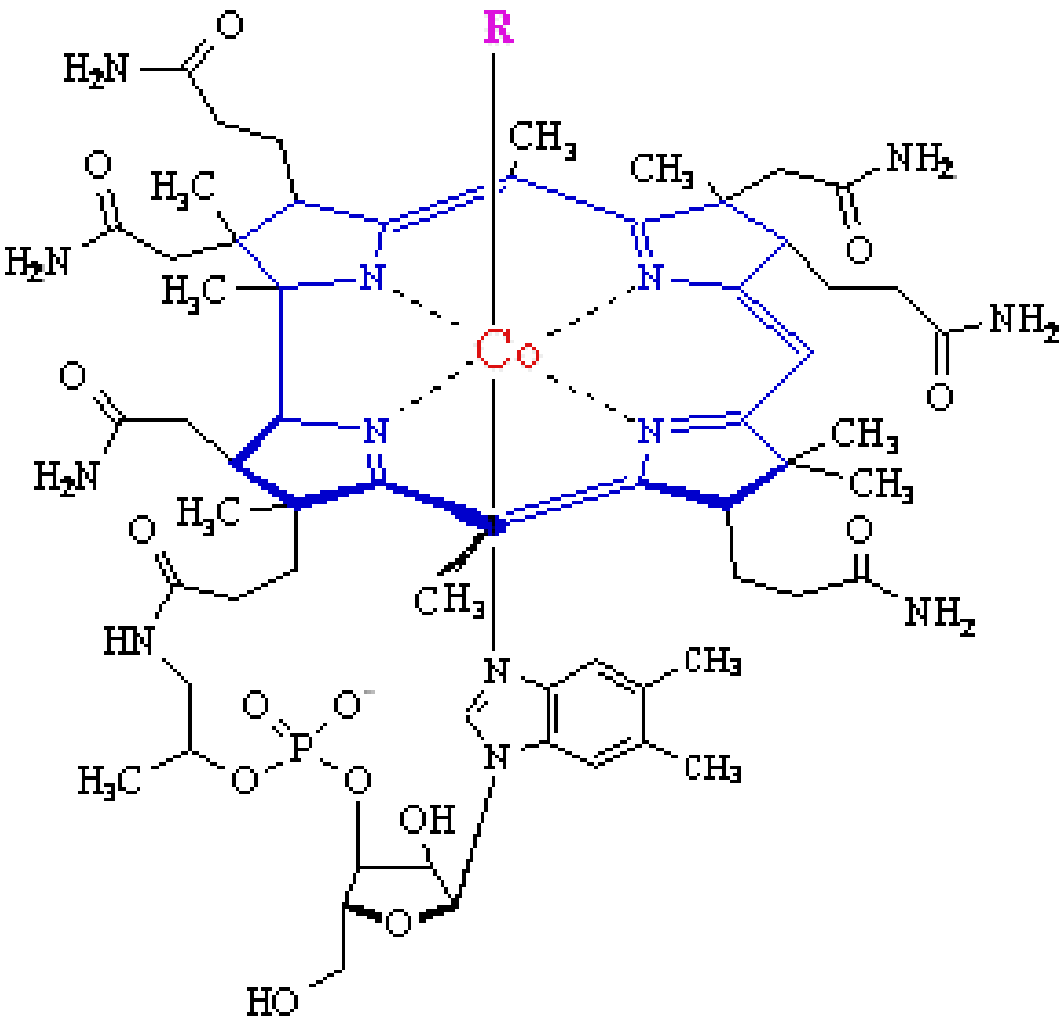
- Decrease in neural tube defects with supplementation of cereals



Vitamin B_{12}

Vitamin B_{12}

R groups vary:
CN, OH, H_2O, NO_2, Me

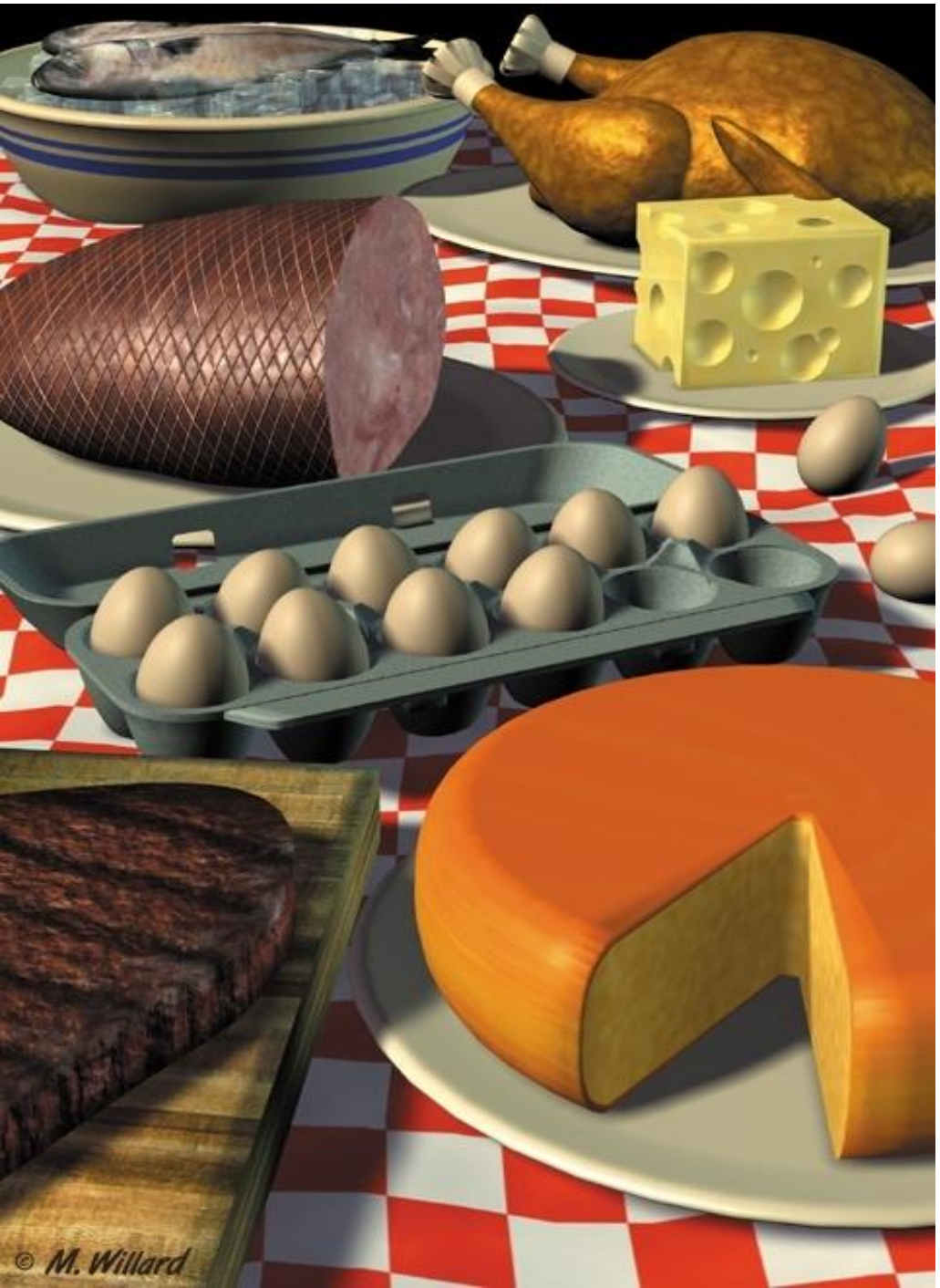


Other names: cobalamin (and related forms)

- Contains Co(III) coordinated to a corrin ring
- (R = CN is cyanocobalamin, most common form)

1998 RDA

Adults: 2.4 μg/day



Vitamin B_{12} Sources

- Animal products
  - Meat, poultry fish, shellfish, Eggs
  - Milk, cheese ,
  - dairy products
- Fortified cereals
- Microbial in origin; intestinal flora contribute towards human dietary needs.
- Stored in the liver

Chief functions of B_{12} in the body

- New cell synthesis:
  - Part of coenzymes for new cell synthesis
  - methylcobalamin
  - deoxyadenosylcobalamin
- Methylations reactions
  - one-C metabolism (methylations) reactions
  - Conversion of of homocysteine to methionine
- Biosynthesisof DNA, amino acids, fatty acids,
  - Needed to maintain RBC, genes
  - Helps to maintain nerve cells
  - Reforms folate coenzyme
  - Helps to break down some f.a & amino acids
- Activates Folate

Vitamin B_{12}

- Absorption of Vitamin B_{12} requires
  - HCl
  - Pepsin
  - Intrinsic factor
- Poor absorption is thought to be a complication of aging
- Easily destroyed by microwave cooking

Vitamin B_{12} Deficiency

- Pernicious Anemia
  - Common in strict vegetarians – obtained only from animal sources

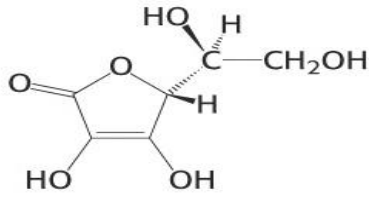
- "Intrinsic factor" needed for B_{12} absorption
- secreted by the parietal cells in lining of gastric mucosa
- Toxicity: none reported

Vitamin C

Ascorbic Acid

Vitamin C

- A vitamin in some animals
  - Most plants and animals make ascorbic acid - for them it is not a vitamin
  - Only a few vertebrates - man, primates, guinea pigs, fruit-eating bats and some fish (rainbow trout, carp and Coho salmon) cannot make it!
- Vitamin C is a reasonably strong reducing agent
- It functions as an electron carrier (describe how)

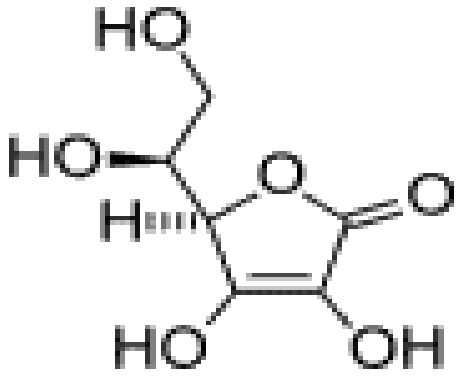


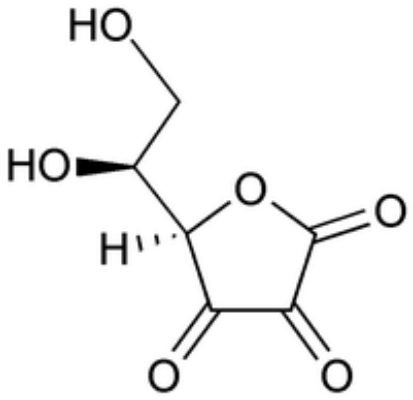
Vitamin C (Ascorbic acid)

- Hydroxylations of proline and lysine (collagen)
- Metabolism of Tyr in brain
- Fe mobilization from spleen
- May prevent the toxic effects of some metals
- Ameliorates allergic responses
- Can stimulate the immune system

Vitamin C (Ascorbic acid)

- Antioxidant, strong reducing agent
- Collagen synthesis, tissue repair, bones & teeth, immune system, iron absorption
- Cannot be made by human body though animals can biosynthesize from glucose
- Found in citrus fruits, cruciferous veggies, tomatoes, dark green leafy, berries, mangos, melons
- Degraded by cooking
- **Deficiency causes**
  - scurvy,
  - anemia,
  - depression,
  - infection,
  - tooth/gum problems,
  - muscle deterioration,
  - fragile bones,
  - poor wound healing



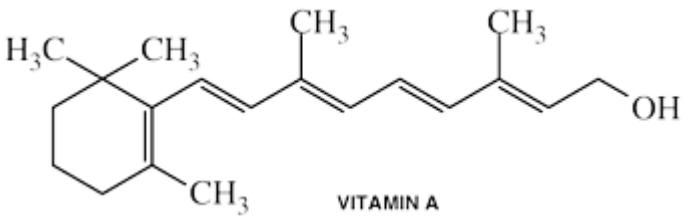


L-dehydroascorbic acid

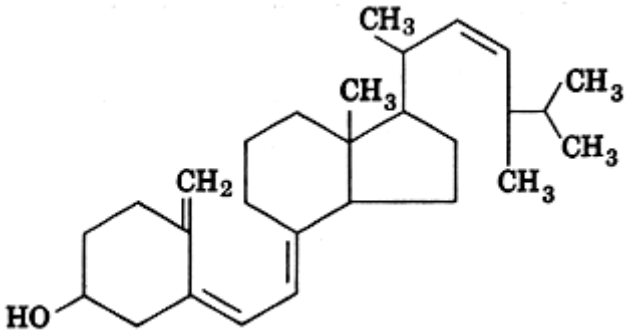
A look at

Fat soluble Vitamins

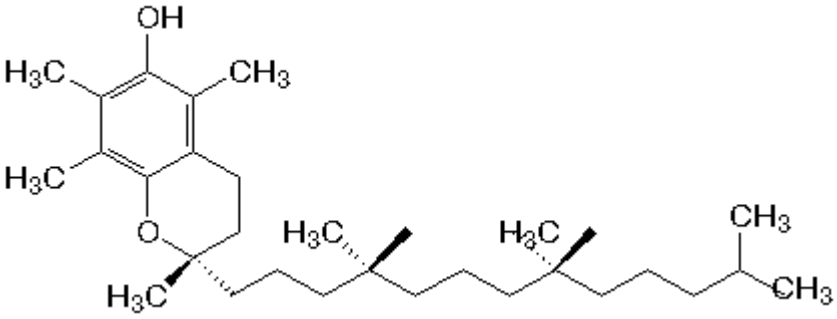
Fat soluble Vitamins



Retinol: Vitamin A

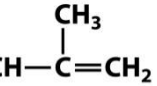


Calciferol: Vitamin D

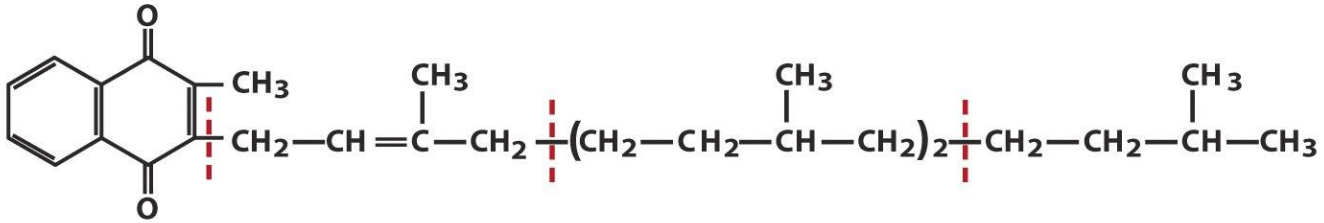


α-tocopherol: Vitamin E

Building bock



Isoprene



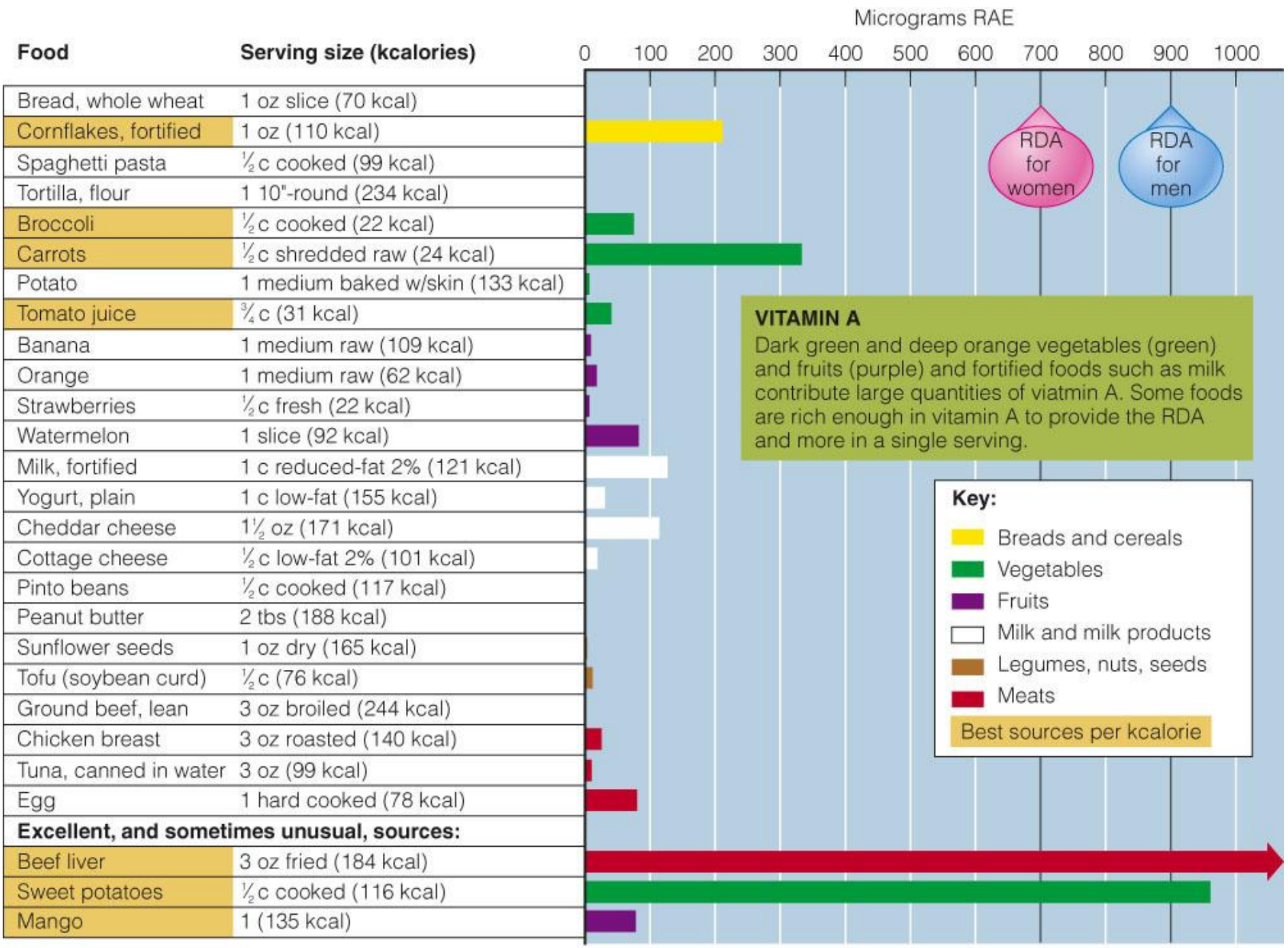
Phylloquinone: Vitamin K

Vitamin A

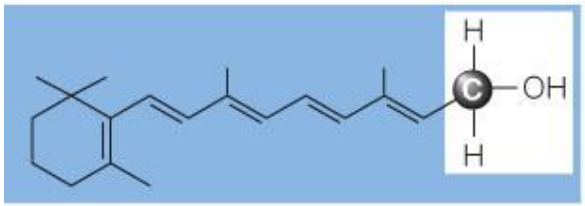
- Also known as retinol, retinal, retinoic acid
- Vitamin A is found in the body in compounds known as retinoids: retinol, retinal, and retinoic acid.
- **These have functional roles in vision, healthy epithelial cells, and growth.**

Vitamin A and Beta-Carotene

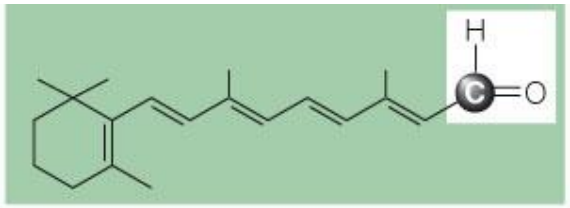
- **Vitamin A in Foods**
  - Retinol is found in fortified milk, cheese, cream, butter, fortified margarine, and eggs.
  - Beta-carotene
    - Spinach and other dark green leafy vegetables (chlorophyll pigment masks the color)
    - Deep orange fruits like apricots and cantaloupe
    - Deep orange vegetables like squash, carrots, sweet potatoes, and pumpkin
    - White foods are typically low in beta-carotene.
  - Liver is rich in vitamin A.



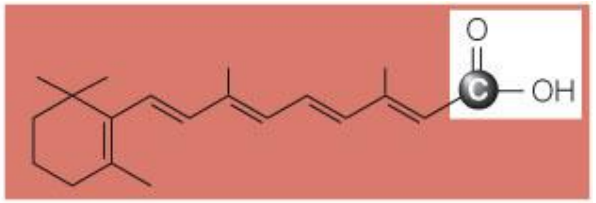
Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk, fortified	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Beef liver	3 oz fried (184 kcal)
Sweet potatoes	½ c cooked (116 kcal)
Mango	1 (135 kcal)



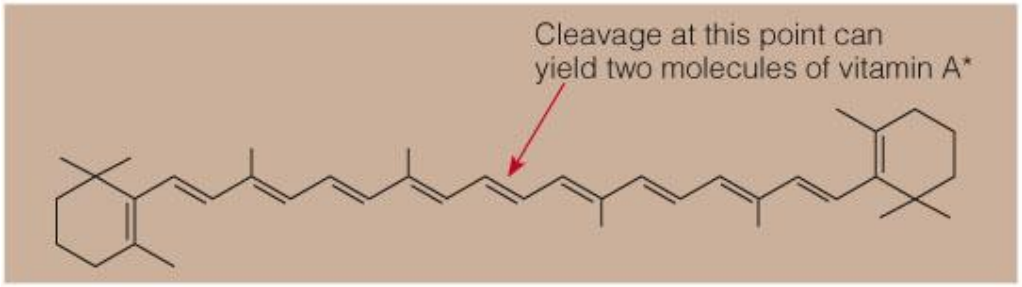
Retinol, the alcohol form



Retinal, the aldehyde form

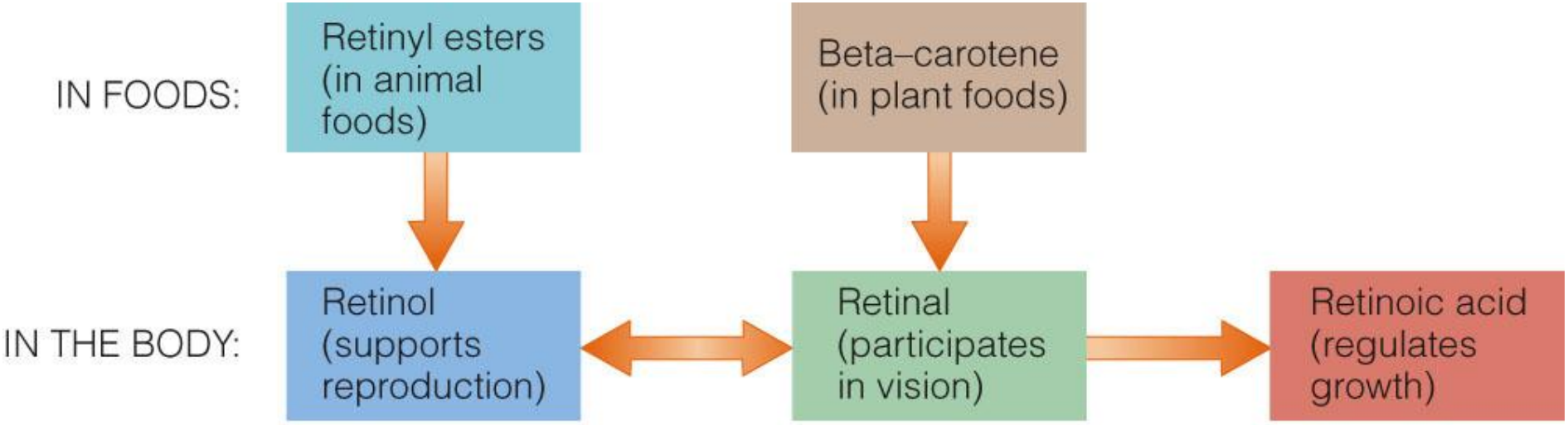


Retinoic acid, the acid form



Beta-carotene, a precursor

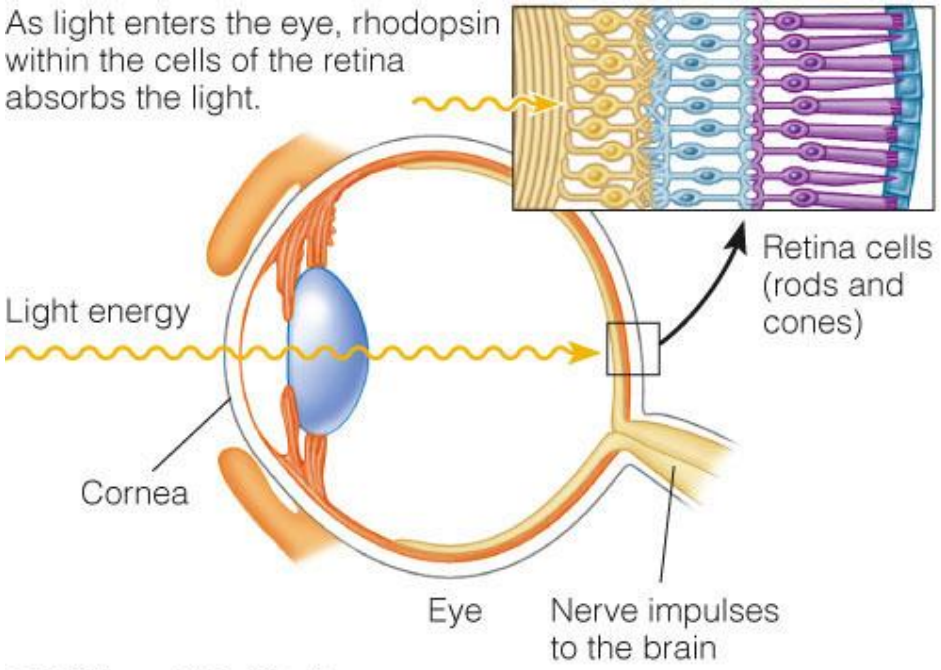
*Sometimes cleavage occurs at other points as well, so that one molecule of beta-carotene may yield only one molecule of vitamin A. Furthermore, not all beta-carotene is converted to vitamin A, and absorption of beta-carotene is not as efficient as that of vitamin A. For these reasons, 12 µg of beta-carotene are equivalent to 1 µg of vitamin A. Conversion of other carotenoids to vitamin A is even less efficient.



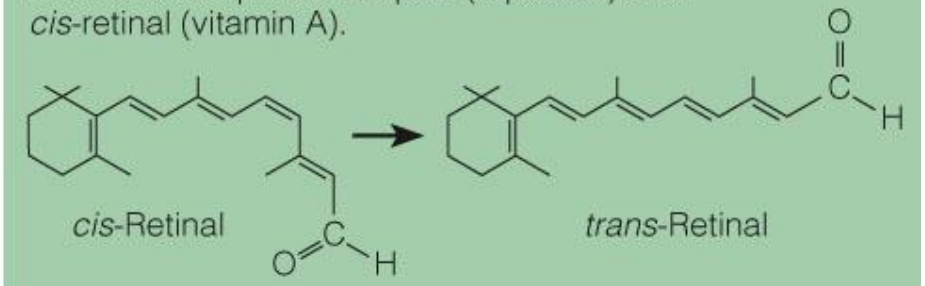
Vitamin A and Beta-Carotene

- Roles in the Body
  - **Vitamin A in Vision**
    - Helps to maintain the cornea
    - Conversion of light energy into nerve impulses at the retina
    - Rhodopsin is a light-sensitive pigment of the retina that contains a protein called opsin

Vitamin A in Vision



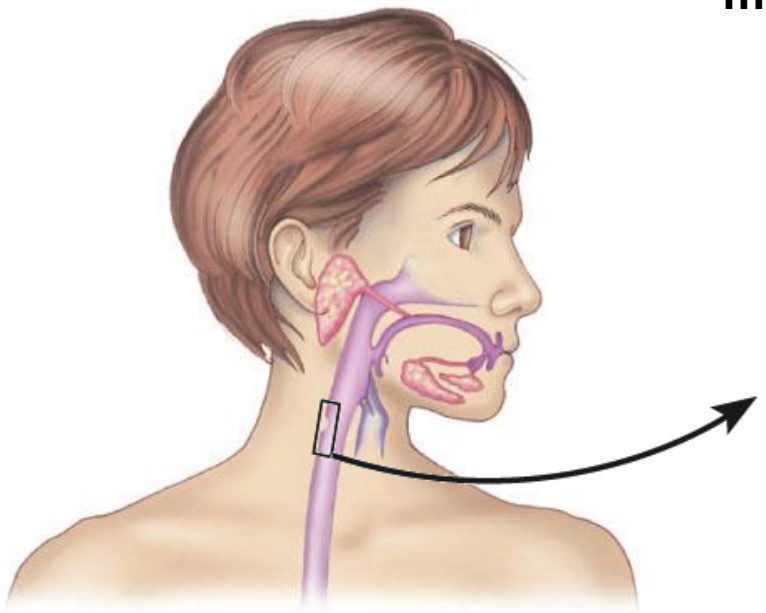
The cells of the retina contain rhodopsin, a molecule composed of opsin (a protein) and *cis*-retinal (vitamin A).



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

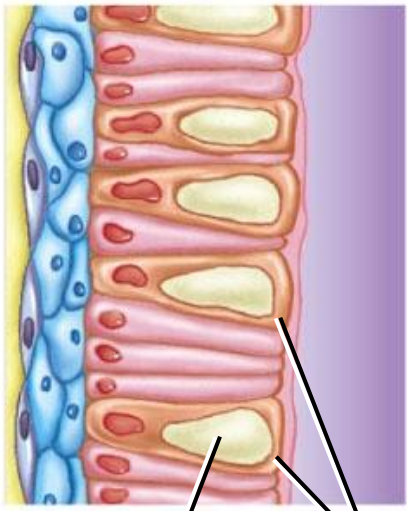
Vitamin A and Beta-Carotene

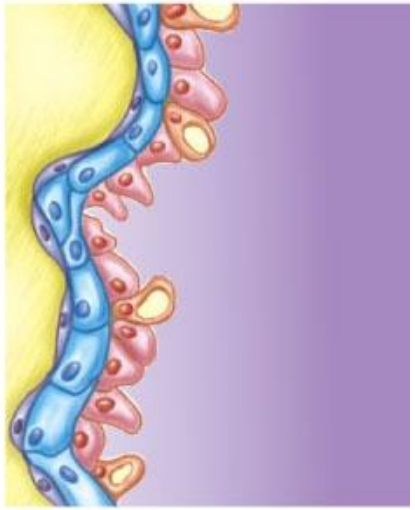
- Roles in the Body
  - **Vitamin A in Protein Synthesis and Cell Differentiation**
    - Through cell differentiation, vitamin A allows cells to perform specific functions
    - Epithelial cells
      - Epithelial tissues on the outside of the body form the skin
      - Epithelial tissues on the inside of the body form the mucous membranes



Vitamin A maintains healthy cells in the mucous membranes.

Without vitamin A, the normal structure and function of the cells in the mucous membranes are impaired.





Mucus

Goblet cells

Fig. 11-4, p. 372

Vitamin A and Beta-Carotene

- Roles in the Body
  - **Vitamin A in Reproduction and Growth**
    - Sperm development in men
    - Normal fetal development in women
    - Growth in children
    - Remodeling of the bone involves osteclasts, osteoblasts, and lysosomes
      - Osteoclasts are cells that destroy bone growth.
      - Osteoblasts are cells that build bones.
      - Lysosomes are sacs of degradative enzymes that destroy bones

Vitamin A and Beta-Carotene

- Roles in the Body
  - **Beta-Carotene as an Antioxidant**
    - Beta-carotene helps protect the body from diseases, including cancer.

Vitamin A and Beta-Carotene

- **Vitamin A Deficiency**
  - **Because vitamin A is stored in the body, it would take a year or more to develop a deficiency in the presence of inadequate intake**
  - **Infectious Diseases**
    - Impaired immunity correlates with vitamin A deficiency in children
    - The goals of worldwide health organizations include vitamin A supplementation
  - **Night Blindness**
    - First detectable sign of vitamin A deficiency
    - Inability to see in dim light or inability to recover sight after a flash of bright light

Vitamin A Deficiency

- **Blindness**
  - **Xerophthalmia**
  - Xerosis is the first stage where the cornea becomes dry and hard.
  - Keratomalacia is the softening of the cornea

- **Keratinization**
  - Epithelial cells secrete a protein called keratin—the hard, inflexible protein of hair and nails.
  - Changes in epithelial cells results in keratinization, rough, dry and scaly skin

- Deficiency disease is called hypovitaminosis A

Vitamin A Toxicity

- **Can occur with concentrated amounts of the preformed vitamin A from animal foods, fortified foods, or supplements.**

- Consuming excessive amounts of beta-carotene from supplements can be harmful.

- Bone Defects
  - Increased activity of osteoclasts causes weakened bones and contributes to osteoporosis and fractures.

- Also, birth defects

Vitamin A Toxicity…

- Toxicity is called **hypervitaminosis A**
- Chronic toxicity symptoms include liver abnormalities.
- Acute toxicity symptoms include blurred vision, nausea, vomiting, vertigo, headaches, and pressure in the skull.
- Upper level for adults: 3000 µg/day

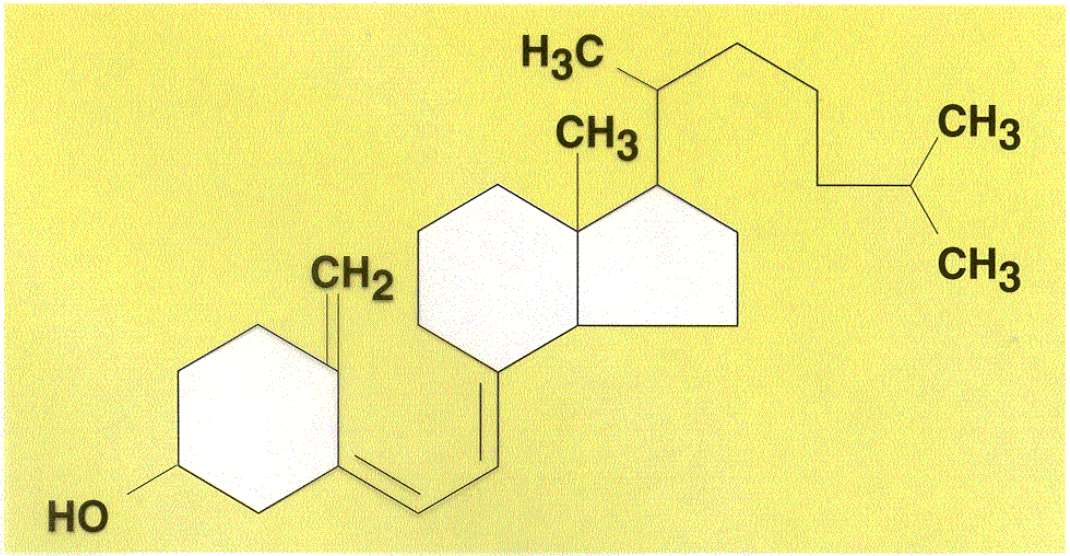
Vitamin A and Beta-Carotene

- Vitamin A Recommendations (2001 RDA)
  - Expressed as **retinal activity equivalents** (RAE) because sources include all forms of retinoids and beta-carotene
  - RDA men: 900 µg RAE/day
  - RDA women: 700 µg RAE/day

Vitamin D

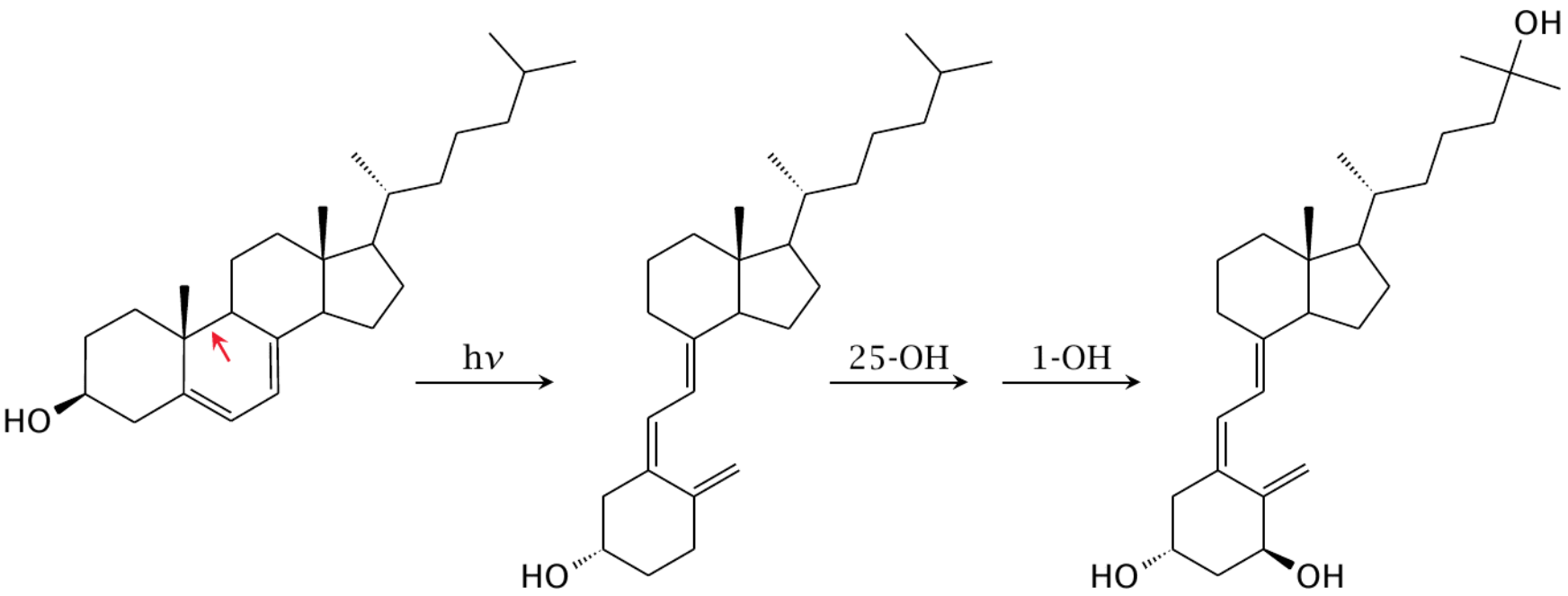
- Vitamin D is a nonessential nutrient that **acts like a hormone** in the body

- The body can make vitamin D with help from sunlight



Vitamin D_3

UV-dependent synthesis of cholecalciferol



7-Dehydrocholesterol Cholecalciferol 1,25-Dihydroxycholecalciferol

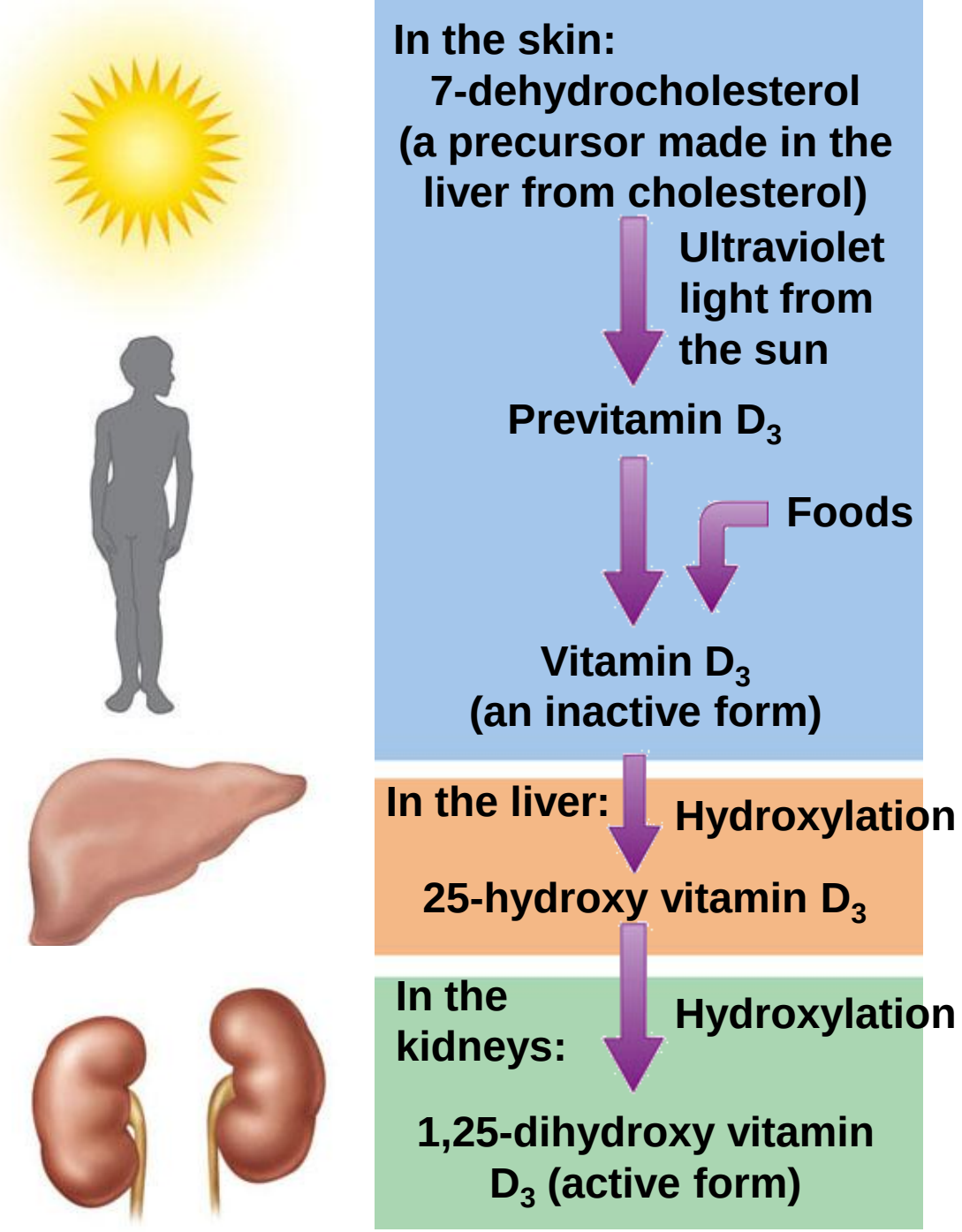

In the skin:
7-dehydrocholesterol
(a precursor made in the liver from cholesterol)
Ultraviolet light from the sun
Previtamin D_3
Foods
Vitamin D_3
(an inactive form)
In the liver:
Hydroxylation
25-hydroxy vitamin D_3
In the kidneys:
Hydroxylation
1,25-dihydroxy vitamin D_3 (active form)

Fig. 11-9, p. 377

Vitamin D

- Roles in the Body
  - **Vitamin D in Bone Growth**
    - Helps to maintain blood levels of calcium and phosphorus
    - Works in combination with other nutrients and hormones
      - Vitamin A, vitamin C, vitamin K
      - Parathormone and calcitonin
      - Collagen
      - Calcium, phosphorus, magnesium, and fluoride

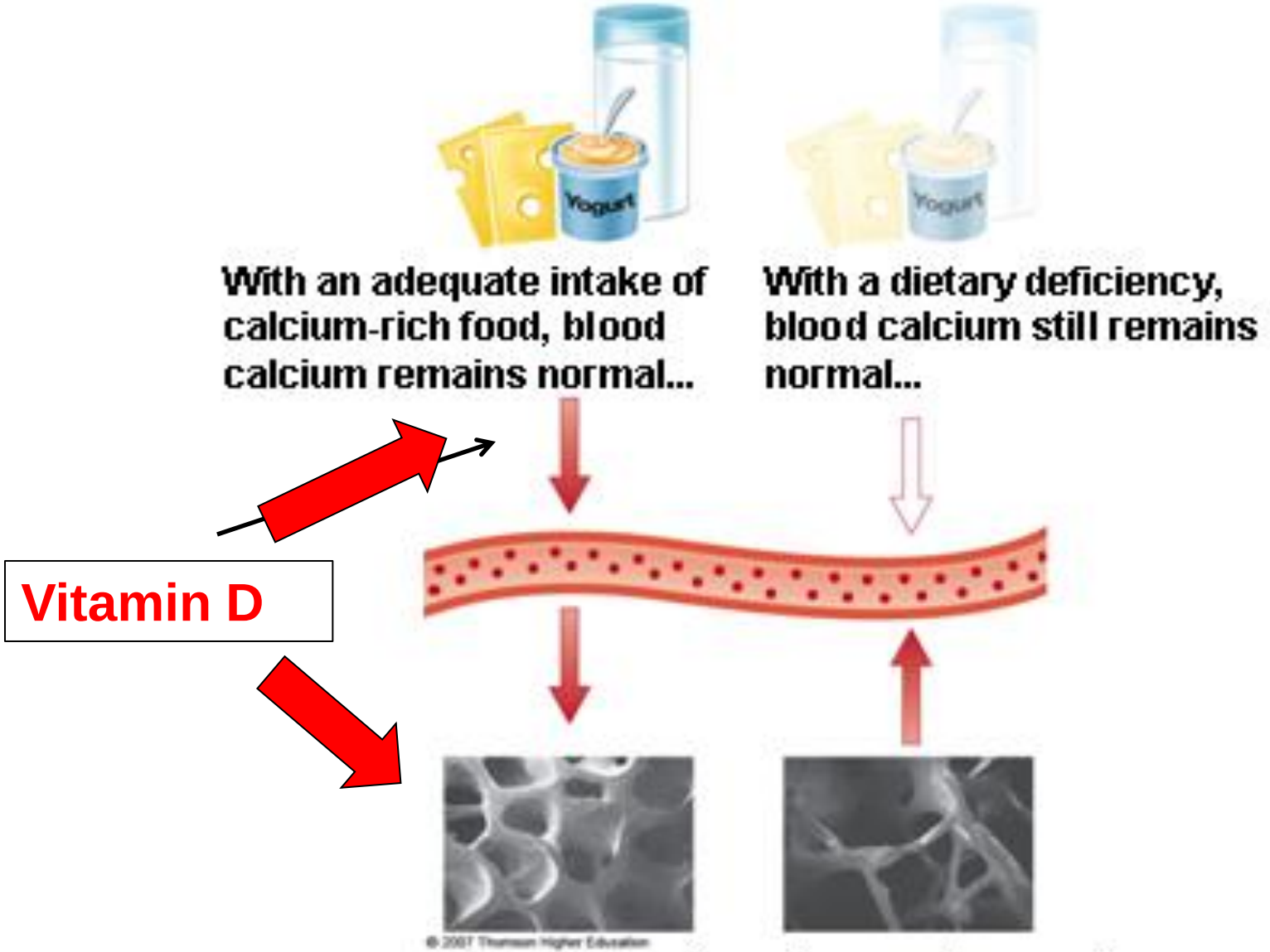

With an adequate intake of calcium-rich food, blood calcium remains normal...
With a dietary deficiency, blood calcium still remains normal...
Vitamin D
...and bones deposit calcium. The result is strong, dense bones.
...because bones give up calcium to the blood. The result is weak, osteoporotic bones.

Fig. 12-13, p. 41

Vitamin D in other roles

- Immune system
- Brain and nervous system
- Pancreas, skin, muscles, cartilage, and reproductive organs

Vitamin D Deficiency

Factors that contribute to deficiency

- Dark skin
- Breastfeeding without supplementation
- **Lack of sunlight**
- Use of nonfortified milk

Vitamin D Deficiency…

- **Rickets**
  - **Affects mainly children worldwide**
  - Deficiency symptoms
    - Inadequate calcification of bones
    - Growth retardation
    - Misshapen bones- bowing of the legs
    - Enlargement of the ends of long bones
    - Deformities of ribs,
    - Lax muscles (resulting in a protruding abdomen) and muscle spasms

Vitamin D Deficiency…

- **Osteomalacia**
  - Affects adults
  - Soft, flexible, brittle, deformed bones
  - Progressive weakness
  - Pain in pelvis, lower back, and legs

Vitamin D Deficiency…

- **Osteoporosis**
  - Loss of calcium from the bones due to inadequate synthesis of vitamin D
  - Results in a reduced bone density

- The Elderly
  - Deficiency due to inadequate production and activation of vitamin D, a decreased consumption of milk, and little time in the sun.
  - There is an increased risk for bone loss and fractures

Vitamin D Toxicity

- More likely compared to other vitamins
- Vitamin D from sunlight and food is not likely to cause toxicity
- High-dose supplements may cause toxicity
- Toxicity symptoms
  - Elevated blood calcium
  - Calcification of soft tissues (blood vessels, kidneys, heart, lungs, and tissues around joints)
  - Frequent urination

Vitamin D Recommendations (1997 Adequate Intake) and Sources

- AI 5 µg/day for adults 19-50 years old
- AI 10 µg/day for adults 51-70 years old
- AI 15 µg/day for adults if older than 70 years of age

Vitamin D Recommendations

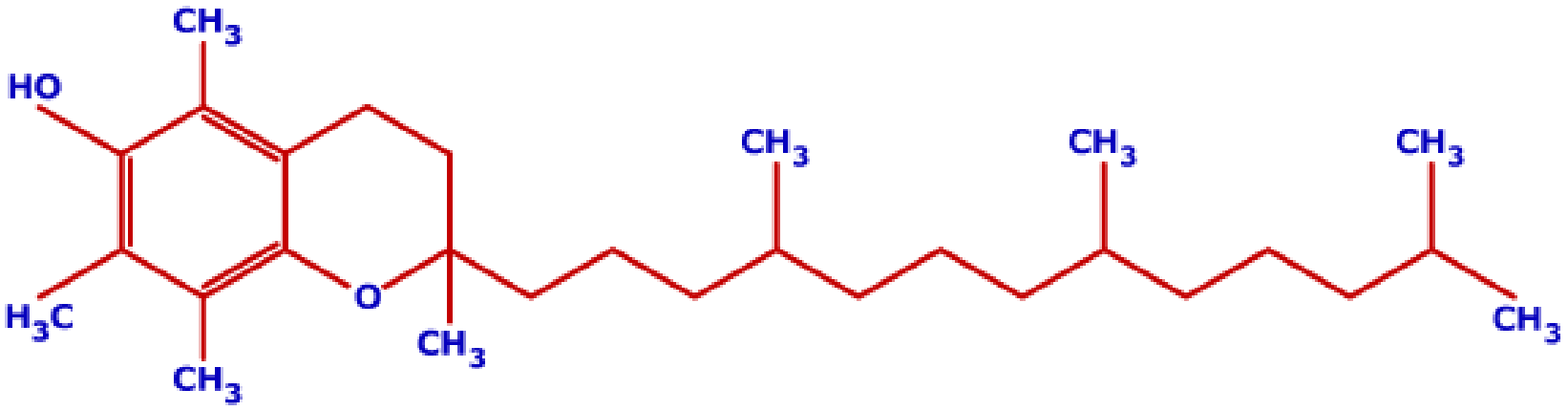
- **Vitamin D in Foods**
  - Fortified milk, butter, and margarine
  - Cereals
  - Chocolate mixes
  - Veal, beef, egg yolks, liver, fatty fish and their oils (Cod liver oil)
  - Vegans may need fortification or supplements if they do not have adequate sun exposure.

Vitamin D Recommendations

- Vitamin D from the Sun
  - Synthesized in the body from cholesterol
  - Can be obtained from tanning beds depending on type of UV radiation.


Rickets Belt
50°
50°
40°
40°
30°
30°
New York
Chicago
Salt Lake City
San Francisco
Denver
St. Louis
Washington, D.C.
Indianapolis
© 2007 Thomson Higher Education

Vitamin E



Tocopherol

Vitamin E

- There are four different tocopherol compounds, but only the alpha-tocopherol has vitamin E activity in human beings.
- Vitamin E as an **Antioxidant**
  - **Stops the chain reaction of free radicals**
  - **Protection of polyunsaturated fatty acids and vitamin A**
  - **Protects the oxidation of LDLs**

Vitamin E Deficiency

- **Primary deficiency due to inadequate intake is rare**

- **Erythrocyte hemolysis**
  - **Occurs in premature infants**
  - **Hemolytic anemia can be treated with vitamin E**

Vitamin E

- Vitamin E Deficiency - Symptoms
  - Loss of muscle coordination and reflexes
  - Impaired vision and speech
  - Nerve damage
  - Erythrocyte hemolysis (breaking open of red blood cells)
- Supplements do not prevent or cure muscular dystrophy
- Fibrocystic breast disease responds to vitamin E treatment
- Intermittent claudication responds to vitamin E treatment

Vitamin E

- Vitamin E Toxicity
  - Rare and the least toxic of the fat-soluble vitamins
  - Upper level for adults: 1000 mg/day
  - May augment the effects of anticlotting medication

- Vitamin E Recommendations (2000 RDA)
  - RDA adults: 15 mg/day

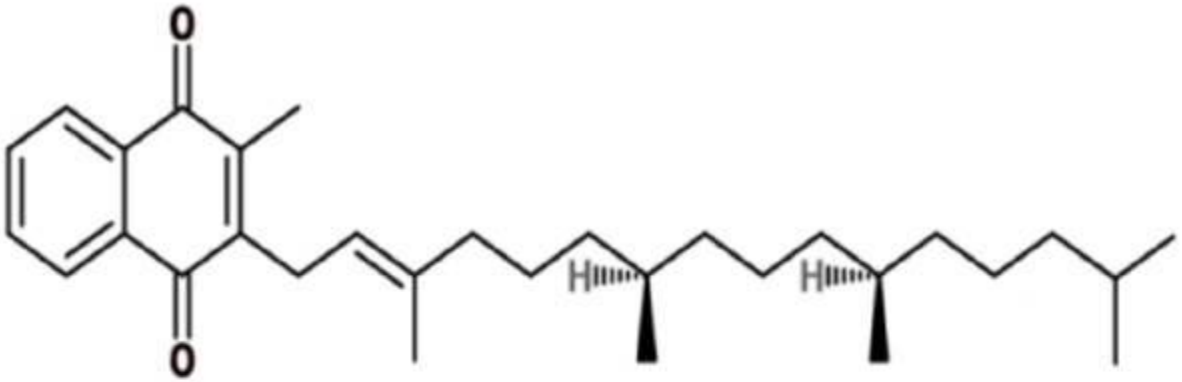
Vitamin E in Foods

- Polyunsaturated plant oils such as margarine, salad dressings, and shortenings
- Leafy green vegetables
- Wheat germ
- Whole grains
- Liver and egg yolks
- Nuts and seeds

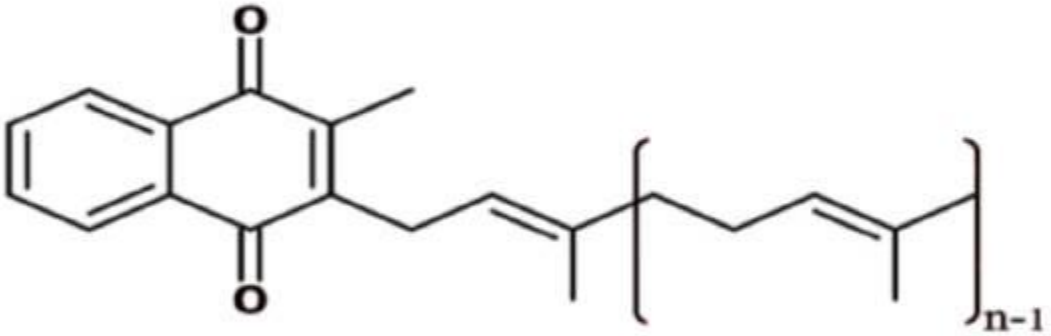
Easily destroyed by heat and oxygen

Vitamin K

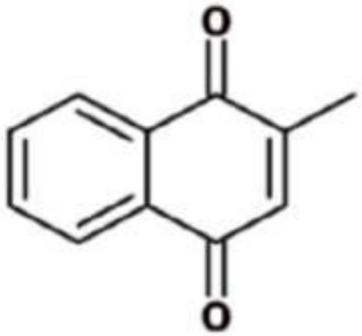
Vitamin K1
(phylloquinone)



Vitamin K2
(menaquinone)



Vitamin K3
(menadione)



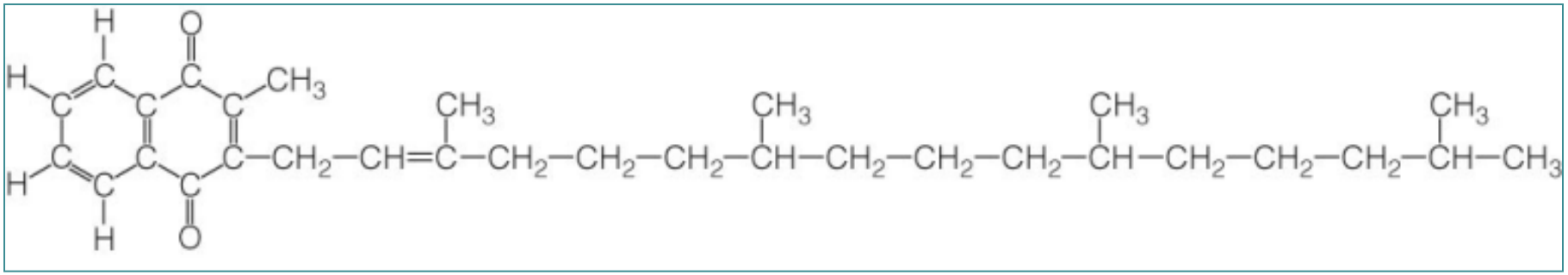
Vitamin K

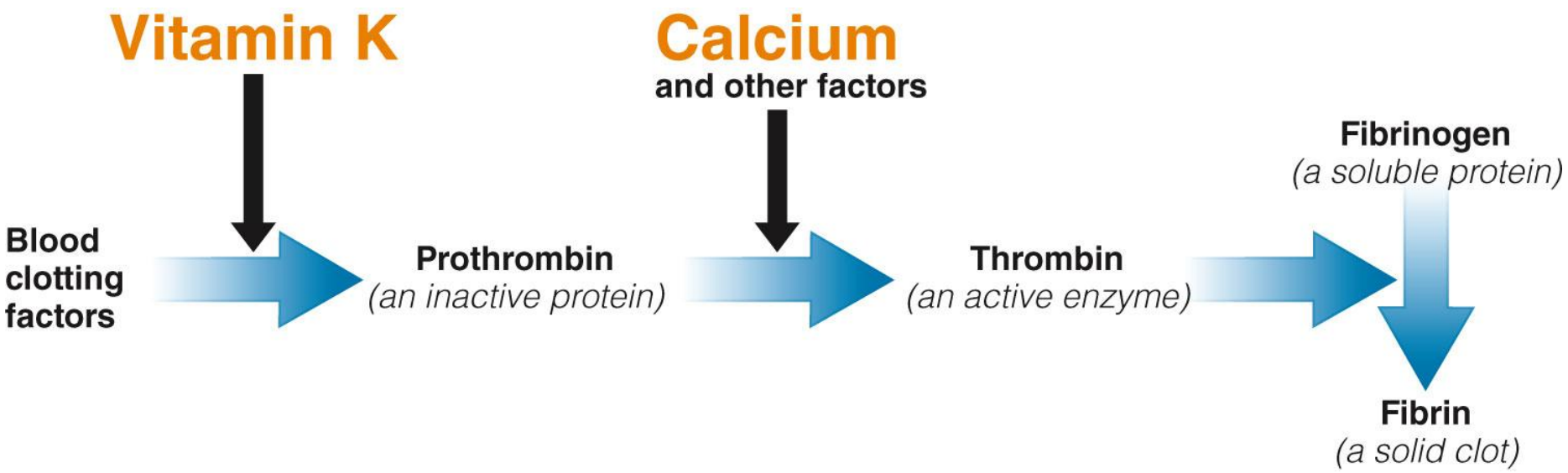
- Also known as phylloquinone, menaquinone, menadione, and naphthoquinone
- Vitamin K is unique in that half of human needs are met through the action of intestinal bacteria
- **Vitamin K is essential in blood clotting.**
- Deficiency can cause uncontrolled bleeding.
- Deficiencies can occur in newborn infants and people taking antibiotics

Vitamin K

- Roles in the Body
  - Synthesis of blood-clotting proteins
  - Synthesis of bone proteins that regulate blood calcium
  - Without vitamin K, a hemorrhagic disease may develop
  - Hemophilia is a hereditary disorder and is not cured with vitamin K

Role of Vit K in fibrin (blood clot) formation





Vitamin K Deficiency

- Symptoms include hemorrhaging
- Secondary deficiencies may occur with use of antibiotics
- Newborn infants receive a single dose of vitamin K at birth because of a sterile intestinal tract

Vitamin K Toxicity

- Uncommon
- No known toxicities
- High doses can decrease the effectiveness of anticlotting medications

- Vitamin K Recommendations (2001 AI) and Sources

  - AI men: 120 µg/day
  - AI women: 90 µg/day
  - **Vitamin K Sources**
    - Bacterial synthesis in the digestive tract
    - Significant Food Sources
      - Liver
      - Leafy green vegetables and cabbage-type vegetables
      - Milk

VITAMIN & MINERAL DEFICIENCY

A devastating force threatens the lives of billions

A Global Summary

- Iodine deficiency lowers the intellectual capacity of nations by as much as 10-15 percentage points
- Iron deficiency impairs the mental development of 40-60% of the developing world's children
- Vitamin A deficiency impairs the immune systems of 40% of the developing world's children

A Global Summary

Every Year:

- **Iodine** deficiency causes 18 million babies to be born with mental impairment
- **Iron** deficiency causes the unnecessary deaths of 60,000 women
- **Folate** deficiency causes approximately 200,000 preventable birth defects
- Nations unnecessarily lose more than 2% of their gross national products

Solutions

1. Fortification
2. Supplementation
3. Education
4. Disease control

- Combined, these methods have brought vitamin and mineral deficiency under control in developed countries.
- It is time now to deploy these solutions for the benefit of developing nations.

Solutions…

- Fortification
  - Adding essential vitamins and minerals to foods that are regularly consumed by a significant proportion of the population (such as flour, salt, sugar, oil and margarine)
  - The cost can be as low as a few cents per person per year

Solutions…

- Supplementation
  - Reaching out to vulnerable groups (particularly children and women of childbearing age) with vitamin and mineral supplements in the form of tablets, capsules and syrups
  - The cost can be as low as a few cents per person per year

Solutions…

- Education and food based approaches
  - Informing communities about the kinds of foods that can increase the intake and absorption of vitamins and minerals

Solutions…

- Disease control
  - Controlling diseases like malaria, measles, diarrhoea, and parasitic infections can also help the body to absorb and retain essential vitamins and minerals

A decade of progress

- Prevalence of iodine deficiency halved
  - Close to 70% of the world's households have access to iodized salt
- Severe vitamin A deficiency largely controlled
  - Close to 70% of the developing world's children receive vitamin A supplements
- Fortification movement gaining momentum
  - 40 countries now have food fortification programs
- Recognition of the **VM** Deficiency problem is growing

Next lecture

Coenzymes and **Cofactors**