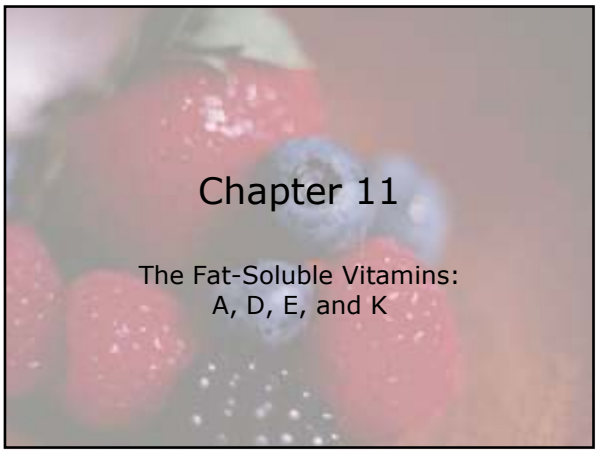
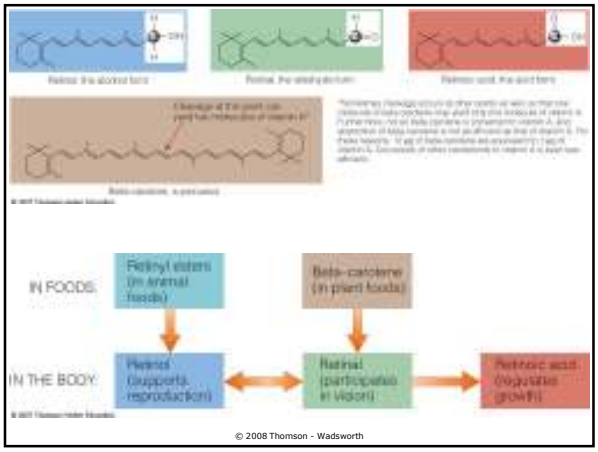


Chapter 11

The Fat-Soluble Vitamins: A, D, E, and K

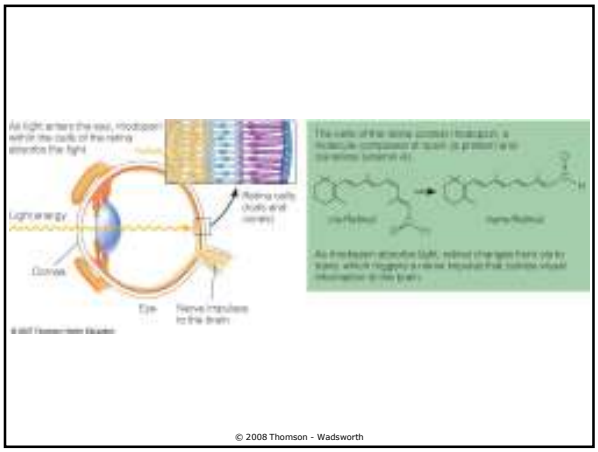
Vitamin A and Beta-Carotene

- 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 deficiency is a major health problem in the world.
- Toxicity is often associated with abuse of supplements.
- Plant foods provide carotenoids, such as beta-carotene, some of which have vitamin A activity.
- Animal foods provide compounds that are easily converted to retinol.
- Retinol binding protein (RBP) allows vitamin A to be transported throughout the body.



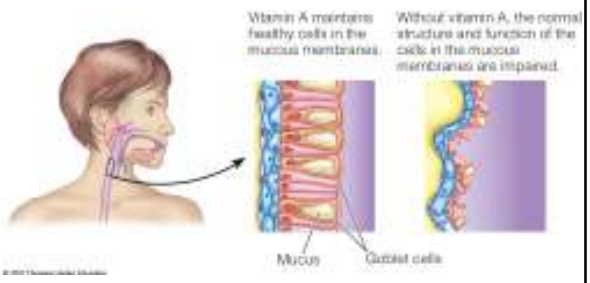
Vitamin A and Beta-Carotene

- 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 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 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 and Beta-Carotene

- Vitamin A Deficiency
  - ✓Blindness
    - Xerophthalmia is blindness due to vitamin A deficiency.
    - 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

In vitamin A deficiency, the epithelial cells secrete the protein keratin in a process known as *keratinization*. (Keratinization doesn't occur in the GI tract, but mucus-producing cells dwindle and mucus production declines.) The extreme of this condition is *hyperkeratinization* or *hyperkeratosis*. When keratin accumulates around hair follicles, the condition is known as *follicular hyperkeratosis*.

Vitamin A and Beta-Carotene

- 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.

The hand on the right shows the skin discoloration that occurs when blood levels of beta-carotene rise in response to a low-kcalorie diet that features carrots, pumpkins, and orange juice. (The hand on the left belongs to someone else and is shown here for comparison.)

Vitamin A and Beta-Carotene

- Vitamin A Toxicity
  - ✓Birth Defects
    - Teratogenic risk is possible, resulting in abnormal fetal development and birth defects.
    - Vitamin A supplements are not recommended the first trimester of pregnancy.
  - ✓Not for Acne
    - Massive doses for teens are not effective on acne.
    - Accutane is made from vitamin A, but is chemically different. It is toxic during growth and can cause birth defects.
    - Retin-A fights acne, the wrinkles of aging, and other skin disorders.

Vitamin A and Beta-Carotene

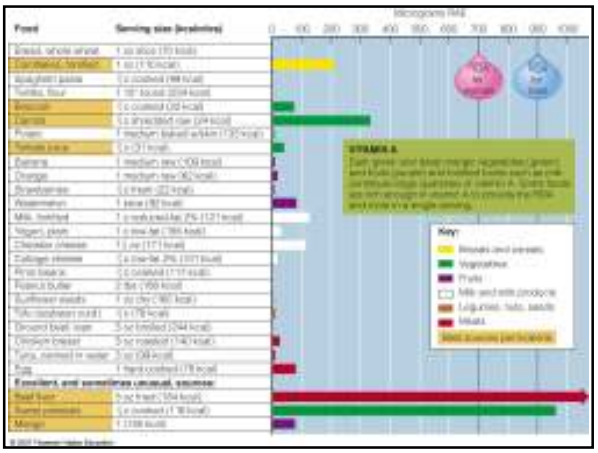
- Vitamin A Toxicity
  - ✓Toxicity disease is called hypervitaminosis A
  - ✓Chronic toxicity symptoms include liver abnormalities.
  - ✓Acute toxicity symptoms include blurred vision, nausea, vomiting, vertigo, headaches, and pressure in the skull.
  - ✓Upper level for adults: 3000 µg/day

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

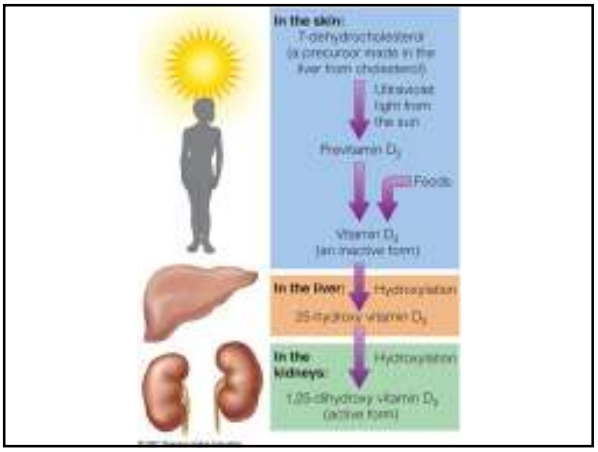
Vitamin A and Beta-Carotene

- 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.
  - ✓ Vitamin A is poor in fast foods and foods with the xanthophyll pigments (beets, corn).
  - ✓ Liver is rich in vitamin A.



Vitamin D

- Also known as calciferol, 1,25-dihydroxy vitamin D (calcitriol), vitamin D_3 or cholecalciferol, vitamin D_2 or ergocalciferol
- Vitamin D is a nonessential nutrient that acts like a hormone in the body.
- The body can make vitamin D with help from sunlight.
- The plant version of vitamin D is called vitamin D_2 or ergocalciferol.
- The animal version of vitamin D is called vitamin D_3 or cholecalciferol.
- Once the vitamin enters the body it must become activated.
- Activation occurs through the action of the liver and the kidneys.



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

Vitamin D

- Roles in the Body
  - ✓Vitamin D in Other Roles
    - Immune system
    - Brain and nervous system
    - Pancreas, skin, muscles, cartilage, and reproductive organs

Vitamin D

- Vitamin D Deficiency
  - ✓Factors that contribute to deficiency
    - Dark skin
    - Breastfeeding without supplementation
    - Lack of sunlight
    - Use of nonfortified milk

Vitamin D

- Vitamin D Deficiency
  - ✓Rickets
    - Affects mainly children worldwide
    - Deficiency symptoms
      - Inadequate calcification of bones
      - Growth retardation
      - Misshapen bones including bowing of the legs
      - Enlargement of the ends of long bones
      - Deformities of ribs, rachitic rosary of rickets
      - Delayed closing of fontanel thus rapid enlargement of the head
      - Lax muscles (resulting in a protruding abdomen) and muscle spasms

Bowed legs. In rickets, the poorly formed long bones of the legs bend outward as weight-bearing activities such as walking begin.

Beaded ribs. In rickets, a series of "beads" develop where the cartilages and bones attach.

Vitamin D

- Vitamin D Deficiency
  - ✓Osteomalacia
    - Affects adults
    - Soft, flexible, brittle, and deformed bones
    - Progressive weakness
    - Pain in pelvis, lower back, and legs

Vitamin D

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

Vitamin D

- Vitamin D Toxicity
  - ✓More likely to be toxic 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

- Vitamin D Toxicity
  - ✓High blood calcium is called hypercalcemia and is often associated with vitamin D excess
  - ✓Upper level for adults: 50 µg/day
  - ✓Toxicity disease is called hypervitaminosis D

Vitamin D

- 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

- 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
    - Vegans may need fortification or supplements if they do not have adequate sun exposure.

Vitamin D

- Vitamin D Recommendations
  - ✓Vitamin D from the Sun
    - Synthesized in the body from cholesterol
    - SPF of 8 or above prevents the synthesis of vitamin D from sunlight.
    - Can be obtained from tanning beds depending on type of UV radiation.

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

- 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

- 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

- 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.
- Vitamin K 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.

Vitamin K

- 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

- Vitamin K Toxicity
  - ✓Uncommon
  - ✓No known toxicities
  - ✓High doses can decrease the effectiveness of anticlotting medications.

Vitamin K

- 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

The Fat-Soluble Vitamins--In Summary

- The function of fat-soluble vitamins depends on the presence of other fat-soluble vitamins.
- There are many interactions of fat-soluble vitamins with minerals.
- It is important to eat a wide variety of foods every day.

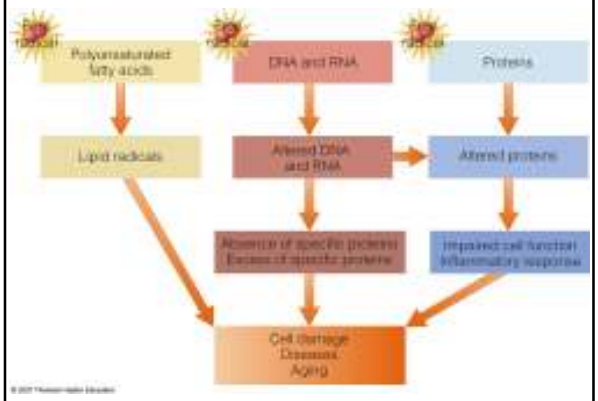
Antioxidant Nutrients in Disease Prevention

Antioxidant Nutrients in Disease Prevention

- Oxidants are compounds in the body that oxidize other compounds.
- Antioxidants have a role in preventing oxidation, and thus assist in the prevention of chronic disease.
- Researchers and medical experts are still clarifying the roles of these nutrients in relationship to health and disease.

Free Radicals and Disease

- Produced by normal body processes and environmental factors such as ultraviolet light, air pollution and tobacco smoke
- Free radicals are highly unstable due to unpaired electrons and are often damaging.
- Antioxidants stabilize free radicals and protect against oxidative stress.
- Cognitive performance, aging, cancer, arthritis, cataracts and heart disease may be protected with antioxidants.



Defending against Free Radicals

- Limiting free radical formation
- Destroying free radicals or their precursors
- Stimulating antioxidant enzyme activity
- Repairing oxidative damage
- Stimulating repair enzyme activity

Defending against Cancer

- Antioxidants may protect DNA.
- Fruits and vegetables have antioxidants such as vitamin C and beta-carotene.

Defending against Heart Disease

- Fruits and vegetables strengthen antioxidant defenses against LDL oxidation.
- Vitamin E defends against LDL oxidation, inflammations, arterial injuries and blood clotting.
- Vitamin C may protect against LDL oxidation, raises HDL, lowers total cholesterol and improves blood pressure.

Food, Supplements, or Both?

- Food and diet
  - ✓Reduce saturated or trans-fat
  - ✓Select foods rich in omega-3 fatty acids.
  - ✓Fruits and vegetables offer antioxidants among other vitamins and minerals.
  - ✓High in whole grains and low in refined grains
  - ✓Exercise, control weight and eliminate smoking to prevent disease.

Food, Supplements, or Both?

- Supplements
  - ✓Not enough data to confirm benefits of supplements only
  - ✓Contents of supplements are limiting
  - ✓Still need research to define optimum and dangerous levels with supplements
  - ✓At high levels, supplements may act as prooxidants.

Food, Supplements, or Both?

- High-antioxidant foods
  - ✓**Fruits** – pomegranates, berries and citrus
  - ✓**Vegetables** – kale, spinach and Brussels sprouts
  - ✓**Grains** – millet and oats
  - ✓**Legumes** – pinto beans and soybeans
  - ✓**Nuts** - walnuts