Chapter 10 – The Water-Soluble Vitamins: B Vitamins and Vitamin C

Learning Objectives

1. Explain how the vitamins differ from the energy nutrients.
2. Describe some general differences between fat-soluble and water-soluble vitamins.
3. List the B vitamins that are involved in energy metabolism, protein metabolism, and cell division.
4. For thiamin, riboflavin, niacin, biotin, pantothenic acid, vitamin B₆, folate, vitamin B₁₂, and vitamin C, list:
   - Its chief function in the body.
   - Its characteristic deficiency symptoms.
   - Its significant food sources.
5. Describe the relationship of tryptophan to niacin.
6. Describe the relationship between folate and vitamin B₁₂.
7. List the risks are associated with high doses of niacin, vitamin B₆, and vitamin C.

Lecture Outline

I. The Vitamins-An Overview

Vitamins differ from carbohydrate, fat and protein in structure, function and food contents. Vitamins are similar to the energy-yielding nutrients in that they are vital to life, organic, and available from foods.

A. Bioavailability is the rate and extent that a nutrient is absorbed and used.
   1. Water-soluble vitamins are absorbed directly into the blood and travel freely.
   2. Fat-soluble vitamins are absorbed first into the lymph, then the blood. Many require protein carriers.

B. Precursors, also known as provitamins, are consumed in an inactive form and become active vitamins in the body.

C. The organic nature of vitamins means they can be destroyed in cooking and storage. There are methods used to minimize nutrient losses.
   1. Refrigerate fruits and vegetables.
   2. Store cut fruits and vegetables in airtight wrappers or closed containers and refrigerate.
   3. Use a microwave, steam, or simmer in small amounts of water. Save cooking water for other uses.
   4. Avoid high temperatures and long cooking times.

D. Solubility and Storage
   1. Water-soluble vitamins (B Vitamins and Vitamin C)
      a) Circulate freely
b) Excreted in urine

2. Fat-soluble vitamins (Vitamins A, D, K, and E)
   a) Stored in cells associated with fat
   b) Less readily excreted

E. Toxicity
   1. Water-soluble vitamins can reach toxic levels with supplement use.
   2. Fat-soluble vitamins are likely to reach toxic levels with supplement use.
   3. DRI has established Tolerable Upper Intake Levels for niacin, Vitamin B₆, folate, choline, and Vitamin C.

F. Vitamin Requirements
   1. Water-soluble vitamins are needed in frequent doses.
   2. Fat-soluble vitamins are needed in periodic doses.

II. The B Vitamins—As Individuals
    The B Vitamins are very active in the body. Several of the B Vitamins form part of the coenzymes that assist enzymes in the release of energy. Other B Vitamins participate in metabolism and cell multiplication. Recommendations for the B-Vitamins come from RDA’s, AI’s, and Tolerable Upper Level Intakes. There are deficiencies, toxicities and food sources that are unique for each vitamin.

A. Thiamin
   1. Thiamin Chief Functions
      a) *Thiamin pyrophosphate* TPP is the coenzyme form.
      b) Energy metabolism
   2. Thiamin Recommendations
      a) RDA Men: 1.2 mg/day
      b) RDA Women: 1.1 mg/day
   3. Thiamin Deficiency and Toxicity
      a) Deficiency Symptoms
         (1) Enlarged heart and possible cardiac failure
         (2) Muscular weakness
         (3) Apathy, poor short-term memory, confusion, and irritability
         (4) Anorexia and weight loss
      b) Deficiency disease is beriberi.
      c) Deficiency disease in alcohol abusers is Wernicke-Korsakoff syndrome.
      d) No reported toxicities
   4. Thiamin Food Sources
      a) Whole-grain, fortified or enriched grain products
      b) Moderate amounts in all foods
      c) Pork
5. Other Information  
   a) Also called Vitamin B₁  
   b) Easily destroyed by heat, steaming and microwaving are cooking methods that conserve thiamin. Thiamin leaches into water with boiling or blanching.

B. Riboflavin  
1. Riboflavin Chief Functions  
   a) Flavin mononucleotide FMN and flavin adenine dinucleotide FAD are the coenzyme forms.  
   b) Energy metabolism  
2. Riboflavin Recommendations  
   a) RDA Men: 1.3 mg/day  
   b) RDA Women: 1.1 mg/day  
3. Riboflavin Deficiency and Toxicity  
   a) Deficiency Symptoms  
      (1) Inflamed eyelids, sensitivity to light, and reddening of the cornea  
      (2) Sore throat and cracks and redness at the corners of the mouth  
      (3) Painful, smooth and purplish tongue  
      (4) Skin lesions covered with greasy scales  
   b) Deficiency disease is arboflavinosis  
   c) No reported toxicities  
4. Riboflavin Food Source  
   a) Milk products – yogurt and cheese  
   b) Enriched, fortified and whole-grains  
   c) Liver  
5. Other information  
   a) Also called Vitamin B₂  
   b) Easily destroyed by ultraviolet light and irradiation  
   c) Not destroyed by cooking.

C. Niacin  
1. Niacin Chief Functions  
   a) Nicotinamide adenine dinucleotide NAD, and NADP, the phosphate form of NAD, are the coenzyme forms.  
   b) Energy metabolism  
2. Niacin Recommendations  
   a) Niacin equivalents (NE) – 60 mg of dietary tryptophan can be used to make 1 mg niacin  
   b) RDA Men: 16 NE/day  
   c) RDA Women: 14 NE/day  
   d) Upper level of 35mg/day for adults.
3. Niacin Deficiency
   a) Deficiency Symptoms
      (1) Diarrhea, abdominal pain, and vomiting
      (2) Inflamed, swollen, smooth and bright red tongue
      (3) Depression, apathy, fatigue, loss of memory, and headache
      (4) Rash when exposed to sunlight
   b) Deficiency disease is pellegra
4. Niacin Toxicity
   a) Toxicity Symptoms
      (1) Painful flush, hives and rash
      (2) Excessive sweating
      (3) Blurred vision
      (4) Liver damage
      (5) Impaired glucose tolerance
   b) Niacin flush dilates the capillaries and may be painful
   c) Upper level of 35 mg/day for adults
5. Niacin Food Sources
   a) Milk
   b) Eggs, meat, poultry and fish
   c) Whole-grain and enriched breads and cereals
   d) Nuts and all protein containing foods
6. Other Information
   a) Also called nicotinic acid, nicotinamide, niacinamide, and Vitamin B$_3$
   b) The amino acid tryptophan is the precursor.
   c) The vitamin can be lost from foods when it leaches into water.
   d) Resistant to heat.

D. Biotin
1. Biotin Chief Functions
   a) Part of a coenzyme used in energy metabolism
   b) Fat synthesis
   c) Amino acid metabolism
   d) Glycogen synthesis
2. Biotin Recommendations
   a) AI Adults: 30µg/day
3. Biotin Deficiency and Toxicity
   a) Deficiency Symptoms
      (1) Depression, lethargy, and hallucinations
      (2) Numb or tingling sensation in the arms and legs
(3) Red, scaly rash around the eyes, nose and mouth
(4) Hair loss
b) Deficiencies are rare
c) Biotin can be bound with an egg-white protein called avidin.
d) No reported toxicities
e) Biotin can also be synthesized by intestinal bacteria.

4. Biotin Food Sources
a) Widespread in foods
b) Organ meats, egg yolks and fish
c) Soybeans
d) Whole-grains

E. Pantothenic Acid
1. Pantothenic Acid Chief Functions
   a) Part of Coenzyme A
   b) Energy metabolism
2. Pantothenic Acid Recommendations (2006 Adequate Intake)
   a) AI Adults: 5 mg/day
3. Pantothenic Acid Deficiency and Toxicity
   a) Deficiency Symptoms- Deficiency is rare.
      (1) Vomiting, nausea, and stomach cramps
      (2) Insomnia and fatigue
      (3) Depression, irritability, restlessness, and apathy
      (4) Hypoglycemia and increased sensitivity to insulin
   b) No reported toxicities
4. Pantothenic Acid Food Sources
   a) Widespread in foods
   b) Chicken, beef, liver, and egg yolk.
   c) Potatoes, tomatoes, and broccoli
   d) Whole grains and oats.
   e) Can be destroyed by freezing, canning, and refining.

F. Vitamin B₆
1. Vitamin B₆ Chief Functions
   a) Pyridoxal phosphate PLP and pyridoxamine phosphate PMP are the coenzyme forms.
   b) Amino acid metabolism
   c) Fatty acid metabolism
   d) Helps to convert tryptophan to niacin and serotonin
e) Helps to make red blood cells

2. Vitamin B₆ Recommendations
   a) RDA Adults 19-50 years: 1.3 mg/day

3. Vitamin B₆ Deficiency
   a) Deficiency Symptoms
      (1) Scaly dermatitis
      (2) Anemia – small cell type
      (3) Depression, confusion, and convulsions
   b) Isoniazid INH drug used for tuberculosis acts as an antagonist.

4. Vitamin B₆ Toxicity
   a) Toxicity Symptoms
      (1) Depression, fatigue, irritability, and headaches
      (2) Nerve damage causing numbness and muscle weakness leading to inability to walk
      (3) Convulsions
      (4) Skin lesions
   b) Upper level for adults: 100 mg/day

5. Vitamin B₆ Food Sources
   a) Meats, fish poultry and liver
   b) Legumes and soy products
   c) Noncitrus fruits
   d) Fortified cereals
   e) Potatoes and other starchy vegetables

6. Other Information
   a) Also called pyridoxine, pyridoxal, pyridoxamine
   b) Easily destroyed by heat
   c) Vitamin B₆ is ineffective in curing carpal tunnel syndrome and sleep disorders

G. Folate

1. Folate Chief Functions
   a) Tetrahydrofolate THF and dihydrofolate DHF are the coenzyme forms.
   b) DNA synthesis and new cell formation

2. Folate Recommendations
   a) RDA Adults: 400 µg/day
   b) Dietary Folate Equivalents DFE is a calculation that accounts for the bioavailability differences between folate from foods and folate from supplements.
   c) There are higher recommendations for pregnant women.

3. Folate and Neural Tube Defects
a) Women of childbearing age should eat folate-rich foods, folate-fortified foods and take folate supplements containing .4 mg folate daily.

b) Pregnant women should take folate supplements.

4. Folate and Heart Disease
   a) High levels of homocysteine and low levels of folate increase risk of heart disease
   b) Folate breaks down Homocysteine.

5. Folate may help to prevent cancer but may also promote cancer growth once cancer has developed.

6. Folate Deficiency
   a) Deficiency Symptoms
      (1) Macrocytic anemia, also called megaloblastic anemia – large cell type
      (2) Smooth, red tongue
      (3) Mental confusion, weakness, fatigue, irritability and headaches
      (4) Shortness of breath
      (5) Elevated homocysteine levels
   b) Most vulnerable of all the vitamins to interactions with medications
      (1) Anticancer drugs
      (2) Antacids and aspirin
      (3) Oral contraceptives

7. Folate Toxicity Symptoms
   a) Masks Vitamin B\textsubscript{12} deficiency symptoms
   b) Upper level for adults: 1000 µg/day

8. Folate Food Sources
   a) Fortified grains
   b) Leafy green vegetables
   c) Legumes and seeds
   d) Liver

9. Other Information
   a) Also called folic acid, folacin, pteroylglutamic acid PGA
   b) Easily destroyed by heat and oxygen

H. Vitamin B\textsubscript{12}
1. Vitamin B\textsubscript{12} Chief Functions
   a) Methylcobalamine and deoxyadenosylcobalamin are the coenzyme forms.
   b) New cell synthesis
   c) Maintains nerve cells
   d) Reforms folate coenzyme
   e) Helps to break down some fatty acids and amino acids

2. Vitamin B\textsubscript{12} Recommendations (2006 RDA)
   a) RDA Adults: 2.4 µg/day
3. Vitamin B\textsubscript{12} Deficiency and Toxicity
   a) Deficiency Symptoms
      (1) Anemia – large cell type
      (2) Fatigue and depression
      (3) Degeneration of peripheral nerves progressing to paralysis
      (4) Sore tongue, loss of appetite and constipation.
   b) Deficiency disease is called \textbf{pernicious anemia}
   c) \textit{Atrophic gastritis} in older adults destroys stomach cells which diminishes intrinsic factor and hydrochloric acid production
   d) No known toxicities
4. Vitamin B\textsubscript{12} Food Sources
   a) Meat, fish, poultry, and shellfish
   b) Milk, cheese and eggs
   c) Fortified cereals
5. Other Information
   a) Binds with \textit{intrinsic factor} in the small intestine for absorption
   b) Also called cobalamin
   c) Easily destroyed by microwave cooking
I. Vitamin likr compounds
1. Choline
   a) Choline Chief Functions
      (1) Synthesis of acetylcholine, a neurotransmitter
      (2) Synthesis of lecithin, a phospholipid
   b) Choline Recommendations
      (1) AI Men: 550 mg/day
      (2) AI Women: 425 mg/day
   c) Choline Deficiency and Toxicity
      (1) Deficiency symptom is liver damage
      (2) Toxicity Symptoms
         (a) Body odor and sweating
         (b) Salivation
         (c) Reduced growth rate
         (d) Low blood pressure
         (e) Liver damage
      (3) Upper level for adults: 3500 mg/day
   d) Choline Food Sources
      (1) Milk
      (2) Liver
(3) Eggs
(4) Peanuts

2. **Inositol** and **Carnitine**
   a) Inositol is made from glucose and part of the cell membrane structure.
   b) Carnitine is made from lysine and transports long-chain fatty acids to be oxidized.

3. Non-vitamins are substances needed by other forms of life but not human beings. They can be potentially dangerous when used by humans.

III. The B Vitamins—In Concert

The B Vitamins are interdependent. The presence of one may affect the absorption, metabolism and excretion of another. A deficiency of one may affect the functioning or deficiency of another. A variety of foods from each food group will provide an adequate supply of all the B Vitamins.

A. B Vitamin Roles
   1. Coenzymes involved directly or indirectly with energy metabolism
   2. Facilitate energy-releasing reactions
   3. Build new cells to deliver oxygen and nutrients for energy reactions

B. B Vitamin Deficiencies
   1. Deficiencies rarely occur singly except beriberi and pellagra.
   2. Can be primary or secondary causes
   3. **Glossitis** and **cheilosis** are two symptoms common to B vitamin deficiencies.
   4. Symptoms that individuals experience are not necessarily related to a vitamin deficiency.

C. B Vitamin toxicities can occur with supplements.

D. B Vitamin Food Sources
   1. Grain group provides thiamin, riboflavin, niacin and folate.
   2. Fruits and vegetables provide folate.
   3. Meat group provides thiamin, niacin, Vitamin B₆ and Vitamin B₁₂.
   4. Milk group provides riboflavin and Vitamin B₁₂.

IV. **Vitamin C** (antiscorbutic factor is the original name for Vitamin C)

Vitamin C differs from the B Vitamins in that it serves as a cofactor to facilitate the action of an enzyme. It also serves as an antioxidant.

A. Vitamin C Roles
   1. **Antioxidant**
      a) Defends against free radicals
      b) Protects tissues from oxidative stress
   2. Cofactor in Collagen Formation”
      a) Collagen is used for bones and teeth, scar tissue, and artery walls
b) Works with iron to form hydroxiproline which is needed in collagen formation

3. Cofactor in Other Reactions
   a) Hydroxylation of carnitine
   b) Converts tryptophan to neurotransmitters
   c) Makes hormones

4. Stress - Vitamin C needs increase during body stress, i.e. infections, burns, extremely high or low temperatures, heavy metal intakes, certain medications, and smoking
   a) In the prevention and treatment of the common cold
   b) Some relief of symptoms
   c) Vitamin C deactivates histamine like an antihistamine

5. Disease prevention is still being researched.

6. Role in disease prevention is still being researched.

B. Vitamin C Recommendations

RDA Men: 90 mg/day
1. RDA Women: 75 mg/day
2. Smokers: +35 mg/day

C. Vitamin C Deficiency
1. Deficiency disease is called scurvy
2. Deficiency Symptoms
   a) Anemia – small cell type
   b) Atherosclerotic plaques and pinpoint hemorrhages
   c) Bone fragility and joint pain
   d) Poor wound healing and frequent infections
   e) Bleeding gums and loosened teeth
   f) Muscle degeneration and pain, hysteria, and depression
   g) Rough skin and blotchy bruises

D. Vitamin C Toxicity
1. Toxicity Symptoms
   a) Nausea, abdominal cramps, diarrhea, headache, fatigue and insomnia
   b) Hot flashes and rashes
   c) Interference with medical tests creating a false positive or a false negative
   d) Aggravation of gout symptoms, urinary tract infections, and kidney stones
2. Upper level for adults: 2000 mg/day

E. Vitamin C Food Sources
1. Citrus fruits, cantaloupe, strawberries, papayas and mangoes
2. Cabbage and cabbage-type vegetables, dark green vegetables like green peppers and broccoli, lettuce, tomatoes and potatoes

F. Other Information
1. Also called ascorbic acid
Easily destroyed by heat and oxygen

V. Highlight: Vitamin and Mineral **Supplements**
Many people take dietary supplements for dietary and health insurance. Some take multinutrient pills daily. Others take large doses of single nutrients. A valid nutrition assessment by professionals determines the need for supplements. Self-prescribed supplementation is not advised. There are many arguments for and against supplements.

A. Arguments for Supplements
1. Correct Overt Deficiencies
2. Improve Nutrition Status
3. Reduce Disease Risks
4. Support Increased Nutrient Needs
5. Improve the Body’s Defense
6. Who Needs Supplements?
   a) People with nutritional deficiencies
   b) People with low energy intake – less than 1200 kcalories per day
   c) Vegans and those with atrophic gastritis need Vitamin $B_{12}$
   d) People with lactose intolerance, milk allergies, or inadequate intake of dairy foods
   e) People in certain stages of the life cycle
      (1) Infants need iron and fluoride
      (2) Women of childbearing age need folate
      (3) Pregnant women need iron
      (4) Elderly need Vitamin $B_{12}$ and D
      (5) Those with limited sun exposure and poor milk intake need vitamin D
   f) People with diseases, infections, injuries, and those who have had surgery that affects nutrient digestion, absorption or metabolism
   g) People taking medications that interfere with the body’s use of specific nutrients

B. Arguments against Supplements
1. Toxicity
2. Life-Threatening Misinformation
3. Unknown Needs
4. False Sense of Security
5. Other Invalid Reasons
   a) Belief that food supply and soil contain inadequate nutrients
   b) Belief that supplements provide energy
   c) Belief that supplements enhance athletic performance or lean body mass without physical work or faster than work alone
   d) Belief that supplements will help a person cope with stress
   e) Belief that supplements can prevent, treat or cure conditions
6. Bioavailability and Antagonistic Actions
   a. Micronutrients from supplements compete for absorption e.g. zinc, iron, calcium, magnesium.
   b. Some can interfere with each other’s metabolism e.g. beta-carotene, Vitamin E.

C. Selection of Supplements
1. What form do you want?
2. What vitamins and minerals do you need?
   a) Do not exceed Tolerable Upper Intake Levels.
   b) Be careful about greater than 10 mg of iron.
3. Are there misleading claims?
   a) Ignore organic or natural claims.
   b) Avoid products that make high potency claims.
   c) Watch fake preparations.
   e) Be aware of preparations that contain alcohol.
   f) Be aware of the latest nutrition buzzwords.
   g) Internet information is not closely regulated.
4. What about the Cost? – Local or store brands may be just as good as nationally advertised brands.

D. Regulation of Supplements
1. Nutritional labeling for supplements is required.
2. Labels may make nutrient claims according to specified criteria.
3. Labels may claim that lack of a nutrient can cause a deficiency disease and include the prevalence of that disease.
4. Labels may make health claims that are supported by significant scientific agreement.
5. Labels may claim to diagnose, treat, cure, or relieve common complaints but not make claims about specific diseases.
6. Labels may make structure-function claims if accompanied by Food And Drug Administration FDA disclaimer.
   a) Role a nutrient plays in the body
   b) How the nutrient performs its function
   c) How consuming the nutrient is associated with general well-being