Water Soluble Vitamins

Objectives:

• Understand what a vitamin is

• Learn the 9 water soluble vitamins and their food sources
  • Vitamin B1 (Thiamin)
  • Vitamin B2 (Riboflavin)
  • Vitamin B3 (Niacin)
  • Pantothenic Acid
  • Biotin
  • Vitamin C (Ascorbic acid)
  • Folic acid
  • Vitamin B12 (Cobalamin)
  • Vitamin B6

• For each vitamin understand its sources; how it is digested and absorbed, transported and stored; its major functions and mechanisms of action; its interaction with other nutrients; how it is metabolized and excreted; signs of deficiency and toxicity
Water-soluble vitamins

Vitamin C (ascorbic acid)

Energy releasing
1. Thiamin (B₁)
2. Riboflavin (B₂)
3. Niacin (B₃)
4. Pantothenic acid
5. Biotin
6. Vitamin B₆

B-complex vitamins

Hematopoietic
1. Folic acid
2. Vitamin B₁₂
3. Vitamin B₆
4. Pantothenic acid

Other
1. Vitamin B₆
2. Thiamin (B₁)
3. Folic acid
4. Vitamin B₁₂
5. Niacin (B₃)
- Primates are one of the few mammals that are unable to synthesize vitamin C.
Common foods with high Vitamin C content

- Asparagus
- Oranges
- Cauliflower
- Green peppers
- Lemons
- Kale
- Strawberries
Absorption:

- Undergoes oxidation prior to absorption
- Co-transport across intestinal membrane (sodium dependent); carrier mediate transport from intestinal cell into blood
- Saturable transport
- Absorption inhibited by pectin and zinc; interferes with iron and copper
- May be destroyed before absorption by high iron concentrations in diet

Transported by blood to tissues with ascorbate transporters; stored in non-fatty tissues

- Adrenal gland, pituitary gland, lens of the eye
- Liver, spleen heart, kidneys, lungs, pancreas, leukocytes
Major Functions of Ascorbic Acid

- Collagen synthesis
- Tyrosine synthesis and catabolism – epinephrine, norepinephrine, serotonin, dopamine
- Maturation of glial cells in developing nervous system
- Iron absorption and storage
- Bile acid formation/cholesterol degradation
- Vasodilation and anticlotting (via activation of NO release)
- Aids in prevention of cancers of oral cavity and pancreas
- General antioxidant
- Pro-oxidant (not necessarily good)
- Common cold??????
- Immune function???????
Collagen Synthesis

- Collagen is a structural protein in almost all connective tissues, including bone, cartilage, skin, tendons.
- Composed of a triple helix of helical proteins.
- Vitamin C is necessary for the helical proteins to crosslink posttranslationally.
- Indirectly used because Fe$^{2+}$ is a cofactor for the enzyme prolyl hydroxylase, and ascorbate is needed to recycle the iron from the Fe$^{3+}$ to the Fe$^{2+}$ state.
Scurvy
Involved in neurotransmitter synthesis

- Cu1+-dependent monooxygenases
  - Norepinephrine (shown)
  - Bombesin
  - Calcitonin
  - CCK
  - Gastrin
  - Oxytocin
  - Vasopressin

*Vitamin C may function in tetrahydrobiopterin regeneration.*
Could taking vitamin pills reduce the risk of getting an infection?

Dr Linus Pauling’s Unified Theory of Cardiovascular Disease

Summary of Evidence From Randomized Controlled Trials

Routine Vitamin Supplementation to Prevent Cancer
RDA: 90 mg for males, 75 mg for females; smokers should take in 35 mg additional

Toxicity: not likely; GI problems, increased risk of kidney stones for some, iron toxicity for some
Toxicity (max dose without adverse effects 2g/day)

- GI problems including abdominal pain and diarrhea
- Increased risk of kidney stones in susceptible populations
- Increased risk of iron toxicity in susceptible populations
- Can interfere with clinical lab tests including glucose in urine, fecal occult blood, and urine blood.
Vitamin B1 - Thiamin

**Found in:** meat, legumes, and whole, fortified, or enriched grain products, cereals and breads. Yeast and wheat germ.

Exists in a non-phosphorylated form in plant sources, but in a phosphorylated form (thiamin pyrophosphate or TPP) in meats.

**Absorption:**

- Intestinal phosphatases hydrolyze the phosphates prior to absorption.
- Can be absorbed either actively, or move through membrane passively depending on concentration of vitamin present.
- Transport into blood is energy dependent and requires sodium co-transport. Inhibited by ethanol.
Transport:

- Free form on albumin (10%) or inside RBCs as thiamin monophosphate (TMP; 90%)
- Active transport into tissues - skeletal muscle, liver, heart, kidney and brain

*Diaphosphate addition occurs here to form the active coenzyme thiamin diphosphate (TDP).
Functions:
• As a coenzyme in energy transformation reactions
• Synthesis of pentose sugars and NADPH as a coenzyme
• Maintenance of membrane and nerve conduction (not as a coenzyme)
Energy Transformation Reactions

- Pyruvate dehydrogenase complex
- A keto dehydrogenase complex
- Transketolase
Pyruvate dehydrogenase complex

Thiamin pyrophosphate in green
Beriberi

Early symptoms
- Loss of appetite
- Tingling hands and legs
- Numbness, aches, pains,
- Weakness and wasting of leg muscles
- Difficulty in walking

Infantile beriberi
Babies can get beriberi if breast-fed by a vitamin B₁ deficient woman.
Symptoms:
- Fretful
- Vomiting
- Weight loss
- Swelling
- Convulsions

Toxicity?? Problems at 100X dose
Riboflavin (B2)

Found In: milk and milk products, eggs, meat and legumes

Freed by HCl in stomach, absorbed by a saturable, energy requiring carrier in the duodenum.

Phosphorylated to form FMN, enters portal system. Transported by a variety of proteins.

Tissues take it up via carrier mediated processes - not brain!
Regulated by ACTH, aldosterone, and thyroid hormone
Flavin mononucleotide \[\rightarrow\] FAD synthetase \[\rightarrow\] Flavin adenine dinucleotide (FAD)

\[\text{ATP} \rightarrow \text{PP}_i\]
Functions:

• Electron transport chain (see below) or as intermediate electron carriers
  • In succinate dehydrogenase
  • In fatty acyl dehydrogenase (beta oxidation)
  • In metabolism of drugs or toxins
• As a coenzyme for: xanthine oxidase, aldehyde oxidase, pyridoxine phosphate oxidase, glutathione reductase
• Synthesis of folate
• Monoamine oxidase metabolism - neurotransmitters
• Prevention of cataracts
• Treatment of migraine headaches
Breakdown and Excretion:

• Bacteria can break it down, then its metabolites are excreted in the urine
• If not bound to proteins, it is filtered by the kidney and excreted in the urine
• Tissue metabolites including several biproducts are excreted in urine
• Increased urine concentrations can be visualized in the urine (light yellow to fluorescent yellow or orange/yellow)
Nutrient Interactions:
• Other B-complex vitamins
• Iron

Drug Interactions
• Antipsychotic medications, chlorpromazine, and tricyclic antidepressants
• Antimalarial drugs (quinacrine)
• Chemotherapy agents (adriamycin)
• Anti-convulsant drug (phenobarbitol)
Deficiency

• Ariboflavinosis
  • Cheliosis, angular stomatitis, magenta tongue, seborrheic dermatitis, vascularization of the cornea
  • Normochromic normocytic anemia
• Preeclampsia
Toxicity : none known
Niacin (B3); nicotinamide, nicotinic acid

Sources:

• Fish (tuna and halibut), beef, chicken, turkey, pork (nicotinamide).

• Enriched cereals and breads, whole grains, seeds, and legumes (bound to carbs as niacytin; bound to peptides as nyacinogen).

• Coffee and tea!!!

• Synthesized in liver from tryptophan
Absorption: stomach and small intestine; cotransport using sodium; saturable system at low concentrations, passive at high concentrations

In plasma as nicotinamide bound primarily to plasma proteins, then into tissues via passive diffusion

Functions: 200 enzymes require NAD or NADP as a coenzyme; act as hydrogen donors or acceptors
(a) \[ \text{NAD}^+ + H + 2e \rightleftharpoons \text{NADH} \]

(b) \[ \text{NAD}^+ + R\text{C}R' \rightleftharpoons \text{NADH} + R\text{C}R' + H^+ \]
Breakdown and Excretion:

- Degraded by glucohydrolase into nicotinamide and ADP-ribose
- Released nicotinamide is oxidized in the liver into a variety of products; excreted in urine

Deficiency: Pellagra

- Dermatitis
- Dementia
- Diarrhea
- Death
Toxicity (> 35 mg/day):

• Used to treat high cholesterol but often results in several unpleasant side effects including:
  • Flushing
  • Heartburn, nausea, vomiting
  • Liver injury, jaundice, hepatitis, liver failure
  • Hyperuricemia and gout
  • Glucose intolerance
Pantothenic Acid (pantothenate; B5)

**Sources:** virtually all foods; high in meats, egg yolk, potatoes, mushrooms, legumes and whole grain cereals, royal jelly from bees

Found in both free and bound forms - 85% occurs bound as a part of coenzyme A (CoA)

**Absorption:** CoA is hydrolysed to pantothenate; passive absorption in the jejunum, but at low concentrations shares a multivitamin transporter with biotin and lipoic acid.
Differential uptake by different tissues
Functions:

• A part of coenzyme A
  • Acetylates sugars, proteins, fatty acid metabolites
  • Oxidative decarboxylation of pyruvate
  • Synthesis of cholesterol, bile salts, ketones, fatty acids, steroid hormones
• A part of 4’-phosphopantetheine
  • Prosthetic group for acyl carrier protein (ACP) in fatty acid synthesis
• Wound healing
• Cholesterol metabolism; pantethine

Excretion - primarily urine

Toxicity - rare; tingling hands and feet

Nutrient and Drug Interactions:
• Oral contraceptives containing both estrogen and progesterone
The phases of cutaneous wound healing

a Injury

b Coagulation

c Early inflammation (24 h)

d Late inflammation (48 h)

e Proliferation (72 h)

f Remodelling (weeks to months)
Biotin (B7)

Sources: liver, soybeans, egg yolk, cereals, legumes, nuts; found combined to lysine (biocytin) or other proteins; intestinal bacteria can synthesize biotin.

Fig. 9-22, p. 295
Absorption:

- Protein portion digested off by peptidases or biotinidase
- 100% absorption in the jejunum and ileum
- Passive diffusion into enterocytes; carrier mediated into plasma; cotransport with sodium into tissues
- Stored in small quantities in muscle, liver, and brain
Functions:

- **Coenzyme for carboxylases; move a carboxyl group from one compound to another**

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Role</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyruvate carboxylase</td>
<td>Converts pyruvate to oxaloacetate</td>
<td>Replenishes oxaloacetate for Krebs cycle. Necessary for gluconeogenesis</td>
</tr>
<tr>
<td>Acetyl CoA carboxylase</td>
<td>Forms malonyl CoA from acetate</td>
<td>Commits acetate units to fatty acid synthesis</td>
</tr>
<tr>
<td>Propionyl CoA carboxylase</td>
<td>Converts propionyl CoA to methylmalonyl CoA</td>
<td>Provides mechanism for metabolism of some amino acids and odd-numbered–chain fatty acids.</td>
</tr>
<tr>
<td>β-methylcrotonyl CoA carboxylase</td>
<td>Converts β-methylcrotonyl CoA to β-methylglutaconyl CoA</td>
<td>Allows catabolism of leucine and certain isoprenoid compounds</td>
</tr>
</tbody>
</table>

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Fig. 9-26, p. 298

Pyruvate carboxylase

Pyruvate $\xrightarrow{\text{Mg}^{2+}}$ Oxaloacetate

Biotin
Activated carbon dioxide

Long, flexible chain

Amide link

Lysine residue of carboxylase

Biotin

Rest of carboxylase

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Fig. 9-24, p. 297
• DNA maintenance/cell cycle
• Gene expression
  • ↑ Insulin, insulin receptor, glucokinase
  • ↓ PEP carboxykinase
Excretion: broken down (not ring structure) into several metabolites; excreted in urine

Toxicity: none known
Deficiency: rare

- Lethargy, depression, hallucinations, muscle pain, parathesia, anorexia, nausea, alopecia, dermatitis
- May occur during pregnancy
- May occur with excessive consumption of alcohol
- Is known as a teratogen in mammals
Folic Acid (folacin; folate; pteropolyglutamate)

- Pteridine: (2-NH₂-4-OH-6-CH₃ pterin)
- PABA: (para-aminobenzoic acid)
- Glutamic acid

- Pteroic acid

- Folic acid (pteroylmonoglutamic acid or pteroylglutamate)
Sources: mushrooms, green leafy vegies, legumes, citrus fruits, and liver; raw foods have more than cooked

Absorption: brush border enzymes cut off the glutamates (requires Zinc; inhibited by alcohol, legumes, lentils, cabbage and oranges); transporter is pH and sodium dependent; mostly in jejunum; efficiency estimated to be about 50%
Conversion of folate in the enterocyte

Found in the portal circulation

Monoglutamate forms found in the systemic blood; bound to plasma proteins

Taken up by tissues that have folate receptors (liver, kidney, hematopoietic cells)
Functions:
- Coenzyme - accepts one-carbon groups then donates them in synthetic reactions (histidine, serine, glycine, methionine)
  - Plays a role in reducing blood homosysteine levels

\[
\begin{align*}
5\text{-formimino THF} & \quad \text{―HC=NH―} \\
5,10\text{-methenyl THF} & \quad \text{―CH―} \\
5,10\text{-methylene THF} & \quad \text{―CH}_2\text{―} \\
5\text{-methyl THF} & \quad \text{―CH}_3
\end{align*}
\]
Dementia
Colon cancer
Neural tube defects
Genesis of RBC

Deficiency: Megaloblastic, Macrocytic Anemia

- Proerythroblast
- Basophilic erythroblasts
- Polychromatophil erythroblast
- Orthochromatotic erythroblast
- Reticulocyte
- Erythrocytes

Microcytic, hypochromic anemia

Megaloblastic anemia

Fig. 9-34, p. 308
Interaction with other nutrients: vitamin B12 needed and *visa versa*; oversupply of one can mask a deficiency of the other

Excretion: in urine and in feces; some intact, some in metabolite forms
Also excreted as a part of bile, however it is reabsorbed

Toxicity: rare; in reported cases you can have insomnia, irritability and GI distress
Cobalamin (B12; corrinoids - 5'-deoxyadenosylcobalamin and methylcobalamin)

**Sources:** all naturally occurring B12 is made by microorganisms; we get ours from animals that have B12 from microorganisms

Meat, meat products, poultry, fish, shellfish, and eggs (yolk), milk and milk products, tobacco!!!!!
Absorption: receptor mediated endocytosis;

Binds to TCI, II or III in blood

Tissue uptake is receptor dependent

B12 can be stored for relatively long periods of time (liver, muscle, bone, kidneys, heart, brain, and spleen.)
Functions: Coenzyme in two reactions

- Conversion of homocysteine to methionine; “methyl-folate trap”

![Diagram showing the conversion of homocysteine to methionine and back through the methyl-folate trap mechanism.](image)
- Coenzyme in production of Krebs cycle intermediates from some amino acids, and odd chain fatty acids
  - Deficiency causes build-up of methylmalonyl CoA which is useful in diagnosis of B12 deficiency
Deficiency: megaloblastic, macrocytic anemia;
symptoms include: pallor, fatigue, sortness of breath, palpitations, insomnia, tingling and numbness in extremities, abnormal gait, loss of concentration, memory loss, and possibly dementia.

Anemia can be corrected with large doses of folate, but the neuropathies cannot.

Associated with risk factors for coronary heart disease via homocysteine production

Most deficiencies associated with:
• malabsorption (long term vegetarians; vegetarian children and infants; changes in intrinsic factor production;
• GI diseases such as sprue;
• prolonged use of H blockers and proton pump inhibitors

Excretion: not extensively degraded prior to excretion; almost all excreted in bile

Toxicity: none known
Vitamin B6 (pyridoxine, pyridoxal, pyridoxamine and their phosphate derivatives)

Sources: Pyridoxine in plant sources; pyridoxal phosphate and pyridoxamine phosphate primarily in animal products

Overall found in meats, whole-grain products, vegies, bananas, and nuts, also fortified cereals; processing influences availability
**Absorption:** dephosphorylation by alkaline phosphatase in the brush border; absorption in the jejunum by passive diffusion; overall efficiency about 75%

Dephosphorylated forms move into blood and taken up by the liver where it is converted by pyridoxal phosphate. This requires riboflavin.

Pyridoxial phosphate is bound to albumin for circulation in the systemic blood.

Tissues only take up unphosphorylated forms (alkaline phosphatase in plasma), they are then rephosphorylated intracellularly.

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**Pyridoxine or pyridoxamine phosphate** → **FMN-dependent oxidase** → **Pyridoxal phosphate**

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Enzymes

A  Kinase (ATP dependent)
B  PMP and PNP oxidase* (FMN dependent)
C  Phosphatase

*Oxidase is found mainly in the liver and enterocytes.
Functions:

**Coenzyme** (>100 reactions) most in amino acid metabolism
- Transamination
- Decarboxylation

Initial step in glycogen metabolism
- *Glycogen phosphorylase*
Deficiency: relatively rare

Symptoms include: sleepiness, fatigue, cheilosis, glossitis, stomatitis, and neurological problems; alteration of magnesium and calcium metabolism; impairs niacin synthesis; inhibits homocysteine metabolism

Toxicity: sensory and peripheral neuropathy (100 mg/day); High doses used for hyperhomocysteinemia, carpal tunnel syndrome, premenstrual syndrome, depression, muscular fatigue, and autism.

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.
**Question:** Is vitamin B6 effective in preventing or curing a hangover?
**Answer:** No. While many people believe that B6 cures the after-effects of drinking, this has not been scientifically proven.

**Question:** Can vitamin B6 relieve the symptoms of pre-menstrual syndrome (PMS)?
**Answer:** Studies have shown vitamin B6 to be effective in alleviating some symptoms of "PMS" in some women, such as breast tenderness, headaches, tension, irritability, and bloating. A general dosage range of 50-100mg/day is recommended and considered safe.

**Question:** Can vitamin B6 supplements help in the management of diabetes?
**Answer:** Some studies have shown B6 supplementation reduces the painful neuropathy experienced by some diabetics. More research is needed in this area.

**Question:** Can you protect yourself from mosquito bite by taking large amounts of vitamin B1?
**Answer:** Perhaps. Vitamin B1 has a distinct smell. Taken in large doses, it emits an odour through the pores and is said to keep mosquitoes away. Some people find it effective, but it is safer to rely on insect repellents, especially in countries where malaria is a problem. According to the CDC (Center for Disease Control): "Vitamin B and 'ultrasonic' devices are NOT (emphasis theirs) effective in preventing mosquito bites"

**Question:** Is vitamin B6 effective in treating carpal tunnel syndrome (CTS)?
**Answer:** Researchers have discovered that 100-200 mg/day for three months effectively relieves the symptoms of "CTS" for many people. Because high doses of B6 can cause neurological complications in some individuals, such treatment should be supervised by a physician.
<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Discovery</th>
<th>Main Coenzymes</th>
<th>Biochemical or Physiological Function</th>
<th>Deficiency Syndrome or Symptoms</th>
<th>Good Food Sources</th>
<th>RDA* or Alt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin (vitamin B₁)</td>
<td>Casimir Funk (1912)</td>
<td>Thiamin diphosphate (TDP) or thiamin pyrophosphate (TPP)</td>
<td>Oxidative decarboxylation of α-keto acids and 2-keto sugars</td>
<td>Beriberi, muscle weakness, anorexia, tachycardia, enlarged heart, edema</td>
<td>Yeast, pork, sunflower seeds, legumes</td>
<td>1.1 mg* 1.2 mg</td>
</tr>
<tr>
<td>Riboflavin (vitamin B₂)</td>
<td>Kuhn, Szent-György, and Wagner-Jaunergy (1933)</td>
<td>Flavin adenine dinucleotide (FAD); flavin mononucleotide (FMN)</td>
<td>Electron (hydrogen) transfer reactions</td>
<td>Ariboflavinosis, cheilosis, glossitis, hyperemia and edema of pharyngeal and oral mucous membranes, angular stomatitis, photophobia</td>
<td>Beef liver, braunschweiger sausage, steak, mushrooms, ricotta cheese, nonfat milk, oysters</td>
<td>1.1 mg* 1.3 mg</td>
</tr>
<tr>
<td>Niacin (vitamin B₃) (nicotinic acid, nicotinamide)</td>
<td>Elvehjem et al. (1937)</td>
<td>Nicotinamide adenine dinucleotide (NAD); nicotinamide adenine dinucleotide phosphate (NADP)</td>
<td>Electron (hydrogen) transfer reactions</td>
<td>Pellagra, diarrhea, dermatitis, mental confusion, or dementia</td>
<td>Tuna, beef liver, chicken breast, beef, halibut, mushrooms</td>
<td>14 mg* 16 mg</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>R. J. Williams (1933)</td>
<td>Coenzyme A (CoA)</td>
<td>Acyl transfer reactions</td>
<td>Deficiency very rare; numbness and tingling of hands and feet, vomiting, fatigue</td>
<td>Widespread in foods; exceptionally high amounts in egg yolk, liver, kidney, yeast</td>
<td>5 mg*</td>
</tr>
<tr>
<td>Biotin</td>
<td>Szent-György (1940)</td>
<td>N-carboxybiotinyl lysine</td>
<td>CO₂ transfer/carboxylation reactions</td>
<td>Deficiency very rare, anorexia, nausea, glossitis, depression, dry scaly dermatitis</td>
<td>Synthesized by microflora of digestive tract; yeast, liver, kidney</td>
<td>30 μg*</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Vitamin B&lt;sub&gt;6&lt;/sub&gt; (pyridoxine, pyridoxal, pyridoxamine)</th>
<th>Szent-György, Kuhn (1938)</th>
<th>Pyridoxal phosphate (PLP)</th>
<th>Transamination and decarboxylation reactions</th>
<th>Dermatitis, glossitis, convulsions</th>
<th>Steak, navy beans, potato, salmon, banana, whole grains</th>
<th>1.3 mg*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folic acid (folacin)</td>
<td>Mitchell et al. (1941)</td>
<td>Derivatives of tetrahydrofolic acid: 5,10-methylidyne THF, 10-formyl THF, 5-formimino THF, 5,10-methylene THF, 5-methyl THF</td>
<td>One-carbon transfer reactions</td>
<td><em>Megaloblastic anemia</em>, diarrhea, fatigue, depression, confusion</td>
<td>Brewer’s yeast, spinach, asparagus, turnip greens, lima beans, beef liver</td>
<td>400 μg*</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt; (cobalamin)</td>
<td>Riches, Folkers, et al. (1948)</td>
<td>Methyl cobalamin, adenosyl cobalamin (cobalamides)</td>
<td>Methylation of homocysteine to methionine; conversion of methylmalonyl CoA to succinyl CoA</td>
<td><em>Megaloblastic anemia</em>, degeneration of peripheral nerves, skin hypersensitivity, glossitis</td>
<td>Meat, fish, shellfish, poultry, milk</td>
<td>2.4 μg*</td>
</tr>
<tr>
<td>Ascorbic acid (vitamin C)</td>
<td>Szent-György‡ (1928)</td>
<td>None</td>
<td>Antioxidant, cofactor of hydroxylating enzymes involved in synthesis of collagen, carnitine, norepinephrine</td>
<td><em>Scurvy</em>, loss of appetite, fatigue, retarded wound healing, bleeding gums, spontaneous rupture of capillaries</td>
<td>Papaya, orange juice, cantaloupe, broccoli, brussels sprouts, green peppers, grapefruit juice, strawberries</td>
<td>75 mg*</td>
</tr>
</tbody>
</table>

*Adults age 19 to 50 years, females and males respectively.
†Adequate intake.
‡Szent-György and King are considered to be codiscoverers of vitamin C.
Chapter 6 - Lipids
Be able to describe the lipids of major biological importance - fatty acids, triglycerides, phospholipids, and sterols - what is their basic structure and function?
Additionally, what are the essential fatty acids? Why are they essential?
What type of fat is an eicosanoid and why are they important?
What is a trans fat? A saturated fat? An unsaturated fat?
Which are good for you, which not?
How are lipids digested and absorbed by the GI tract? What role does the endoplasmic reticulum in the intestinal cells play? Which fats are absorbed into the blood? Which are absorbed into the lymph?
How are lipids transported in the blood when they initially leave the intestine? Where do these lipids end up?
What determines how lipids are packaged into various types of lipoproteins? What are apoproteins and what is their function? You should understand the basic composition of the four major types of lipoproteins (chylomicrons, VLDLs, LDLs, and HDLs) and the function of each. Which are most related to heart disease and why? How is a fatty streak on an artery developed and what role does fat play?
• Understand how lipid metabolism is regulated via LCAT and LDL receptors, and how diet and pharmaceutical aids target this regulation.
• What role do the liver and adipose tissue play in fat metabolism?
• Learn how the major lipids are metabolized via β-oxidation, how ketones are formed, and how we regulate the manufacture and breakdown of cholesterol.
• Why is brown fat thermogenic? How does it form yellow fat?
Chapter 7 Protein

- Review the basic structure of proteins and their component amino acids. Be aware of the different chemical classes of amino acids and where you would find them in a folded protein.
- Be able to name some functional "classes" of proteins (e.g., Enzymes). What other roles do they play?
- What are the essential amino acids? Why are they essential and where can we get them in our diet?
- How are proteins digested and absorbed into the blood? How do other tissues and organs get the amino acids out of the blood?
- What are plasma proteins and why are they important? Be able to give an example of a plasma protein.
- Learn how amino acids can be used in
  - The synthesis of new proteins for growth, or replacement of cellular proteins
  - Production of important non-protein nitrogen containing molecules (glutathione, carnitine, creatine, choline, purines and pyrimidines)
  - Oxidation as an energy source
  - Synthesis of glucose, ketones or fatty acids
  - Understand how the liver and muscle handle amino acid metabolism, and how excess nitrogen from proteins is disposed of. What is gout and how is it related to BUN?
Chapter 9 Water Soluble Vitamins
Be able to name the 9 water soluble vitamins and their food sources. How are the water soluble vitamins grouped, and why? Which are most closely related?

Vitamin B1 (Thiamin) -
Vitamin B2 (Riboflavin)
Vitamin B3 (Niacin)
Pantothenic Acid
Biotin
Vitamin C (Ascorbic acid)
Folic acid
Vitamin B12 (Cobalamin)
Vitamin B6

For each of these vitamins shown above, be able to describe how it is digested and absorbed, transported and stored; its major functions and mechanisms of action; its interaction with other nutrients; how it is metabolized and excreted; signs of deficiency and toxicity.