Vitamins & Minerals Associated with Metabolism & Blood Health
Metabolism

• B-complex vitamins are especially important for energy metabolism

  • thiamin (B₁)        folate
  • riboflavin (B₂)     vitamin B₁₂
  • niacin               pantothenic acid
  • vitamin B₆           biotin
Metabolic Process

- **Conversion to pyruvate or Acetyl CoA**
- **Energy Harnessing of Oxidative Phosphorylation** (Electron transport chain)
- **Energy Harnessing of Citric Acid (Krebs) Cycle**
Krebs & Electron Transport
Coenzymes in metabolism

(a) Vitamin and Coenzyme Connections

(b) Protein, Carbohydrate, and Fat Metabolism

Energy to perform all body functions
Thiamin (vitamin B₁)

• **As a Coenzyme:**
  - Thiamin pyrophosphate (TPP) required for carbohydrate metabolism *(pyruvate → Acetyl CoA)*
  - Some fatty acids metabolism
  - Component of nerve cell membrane

• **Sources** = Any whole food: root veggies, fruits, pork, whole grains

• **Beriberi** - deficiency of thiamin resulting in muscle wasting and nerve damage
Riboflavin (vitamin B$_2$)

- **As coenzymes:**
  - electron shuttling of ATP production pathway (FAD & FMN)
- **As antioxidant:**
  - Part of antioxidant enzyme (*glutathione peroxidase*; removes H$_2$O$_2$ from body)
- **Sources** = Milk, yogurt, organ meat
- **Ariboflavinosis** – riboflavin deficiency; sore throat, swollen mucous membranes
Riboflavin ($B_2$)
Riboflavin coenzyme (FAD)

During the TCA cycle, compounds release hydrogens, and the riboflavin coenzyme FAD picks up two of them. As it accepts two hydrogens, FAD becomes FADH₂.

FADH₂ 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 FADH₂ becomes FAD again. For every FADH₂ that passes through the electron transport chain, 2 ATP are generated.
Figure J-1: The Roles of FMN and FAD

The Complex I protein of the Electron Transport Chain is composed of an FMN group and a variety of other proteins. NADH, an electron carrier, binds to Complex I and transfers its electrons to FMN. FADH$_2$, another electron carrier, transfers its electrons to Complex II. Once FADH$_2$ transfers its electrons, it is converted back to FAD and used again as an electron carrier in metabolic processes.
Niacin

- Niacin = Nicotinamide and nicotinic acid
- As Coenzyme NAD & NADP:
  - Electron shuttlers in carbohydrate and fatty acid metabolism
- Sources: All meats, enriched bread products
- Toxicity can result from supplements
- Deficiency: Pellagra – severe niacin deficiency
Biotin

• **As coenzyme:** involved in
  - gluconeogenesis, fatty acid synthesis, ATP production, & perhaps gene expression
• Biotin content has been determined for very few foods
• **Deficiencies:** hair thinning, loss of hair color, red rash on face
Biotin
Biotin as coenzyme

THE Coenzyme in Acetyl CoA
Vitamin B₆ (pyridoxine)

- Group of 6 related compounds
- Part of a coenzyme for over 100 enzymes in amino acid metabolism including transamination
  - Metabolism of carbs & homocysteine (AA), hemoglobin synthesis
Vitamin B\textsubscript{6} Sources

- meat
- fish
- poultry
- starchy vegetables
- enriched cereals
Folate

- DNA synthesis, amino acid metabolism
- Critical for cell division of very early embryos (Spina bifida)
  - Attempting-to-conceive women should monitor intake carefully

- Tox*icity can mask vitamin B_{12} deficiency, which can also damage nervous system (myelin sheath)
Folate

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

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

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B₁₂ activates folate

Activates itself in the process

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

To activate folate, vitamin B₁₂ removes and keeps the methyl group, which activates vitamin B₁₂.

Both the folate coenzyme and the vitamin B₁₂ coenzyme are now active and available for DNA synthesis.
Folate Sources

Green fruits and leafy greens; nuts & beans; ready-to-eat cereals, enriched bread products
Vitamin B₁₂ (some cobalamins)

• As coenzymes:
  - In blood cell formation
• Required for nerve functioning
  - Maintains myelin sheath of nerve fibers
• Required for homocysteine (AA) breakdown
  - High levels associated with vascular disease
• Sources: only from bacteria in/on animal-based foods
• Deficiency results in anemia, low energy, fatigue, shortness of breath & leads to pernicious anemia
Homocysteine (AA) breakdown

![Diagram of Homocysteine Metabolism]

Source: J Clin Hypertens © 2004 Le Jacq Communications, Inc.
Vitamin $B_{12}$

- Deficiency of folate or $B_{12}$ produces pernicious anemia

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

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

- Needed to construct coenzyme A:
  - Component of Acetyl CoA
  - TCA cycle
- Required for building new fatty acids
- Good sources: chicken, beef, egg yolk, potatoes, oat cereals, tomato products
Pantothenic Acid
Iodine

- Critical for synthesis of thyroxine (thyroid hormones)
  - Regulate body temperature, BMR & development
- Good sources: saltwater fish, shrimp, iodized salt, milk and dairy products
  - (marine animals concentrate iodine)
Excesses & Deficiencies

- **Excess iodine**
  - Blocks *synthesis* of thyroid hormones
  - Thyroid tries to make *more* hormones
  - Results in *goiter* - enlarged thyroid

- **Iodine deficiency**
  - Results in hypothyroidism and goiter
  - *Cretinism* - mental retardation from iodine deficiency during embryonic development
Nutrients & Blood function

• Blood is composed of $\text{H}_2\text{O}$, antibodies, proteins, cells with specific functions (clotting, immune response, etc.)

• Functions
  - Transport of oxygen and nutrients (example?) to cells
  - Removal of wastes (examples?) from tissues
Components of Blood

- **Erythrocytes** - red blood cells (RBC) for transporting $O_2$ through the body
- **Leukocytes** - white blood cells (WBC) of the immune system (T & B)
- **Platelets** - cell fragments that assist in blood clotting (thrombocytes)
- **Plasma** - the fluid portion of the blood ($H_2O$ & proteins)
Whole blood

Components separated by centrifuge

55% plasma (fluid portion of blood)

Less than 1% platelets and white blood cells (leukocytes)

45% red blood cells (erythrocytes)
Vitamin K

• Recall: Fat-soluble; stored in liver
• Both a bacterial byproduct & a plant form of vitamin K
  - All animal products & some in your SI
  - Increase its bioavailability by cooking in fats
• Functions of vitamin K (primarily a coenzyme)
  - Modification of blood coagulation proteins; Synthesis of prothrombin & procoagulant proteins
  - Bone metabolism - osteoblasts require it for $Ca^{2+}$ deposition (osteocalcin)
Underingestion

• Inability to form blood clots
  - Those with fat absorption issues are at risk (cystic fibrosis, Crohn's disease)
  - Newborns are given Vitamin K injections because they lack intestinal bacteria necessary to make it

• Slow rates of bone deposition
Iron

• Vital component of hemoglobin, which carries $O_2$ in erythrocytes (RBC); ~ 2/3 of our iron is located here

• Vital component of myoglobin which binds $O_2$ in muscle cells

• A coenzyme involved in metabolism of carbs, fats, and proteins
  - Part of cytochrome enzymes that shuttle electrons during ATP production
Iron storage & absorption

• Iron can be stored as **ferritin** or **homosiderin**
  - Storage in the liver, bone marrow (why here?), intestinal mucosa, and spleen
• How much do we absorb?:
  - Body absorbs iron from the diet **only** when we need it
  - Those with LOW stomach acid secretions absorb **less**
• Two types of iron in foods
  - **Heme iron** - in animal based foods; more absorbable
  - **Non-heme iron** - not easily absorbed. Addition of Vitamin C can help
DRI

• **Recommended intake**
  - Varies based on age and gender
  - 8 mg/day for adult men
  - 27 mg/day for pregnant women

• **Sources**
  - Meat, poultry, fish, clams, oysters, *enriched cereals and breads*
Sources of Iron

- Clams, canned—3 oz.
- Kellogg's Product 19 cereal—1 cup
- Turkey giblets, cooked—1 cup
- Soybeans, boiled—1 cup
- Pork & beans, canned—1 cup
- Tomato paste—1 cup
- Lentils, boiled—1 cup
- Spinach, cooked—1 cup
- Chili con carne with beans—1 cup
- Beef, chuck roast, cooked—3 oz.
Too much?

• Iron overdose is one of the most common cause of poisoning deaths in children (in U.S.)
• Toxicity symptoms: nausea, vomiting, diarrhea, dizziness, confusion
• Delayed treatment can result in severe damage to the heart, CNS, liver, kidneys
Too little?

• Iron deficiency is the most common nutrient deficiency in the world

• High risk groups include infants, young children, preadolescent girls, premenopausal women, and pregnant women

• Three stages of iron deficiency

• Major cause of anemia
Anemia

- **Anemia** *(without blood)*; = any condition of low hemoglobin levels

- Many types and causes of anemia:
  - Iron-deficiency anemia
  - Pernicious anemia
  - Macrocytic anemia
Stages of deficiency

**Stage 1 iron deficiency**
- Decreased iron stores
- Reduced ferritin level
- Reduced production of heme
- No physical symptoms

**Stage 2 iron deficiency**
- Decreased iron transport
- Reduced transferrin
- Reduced production of heme
- Physical symptoms include reduced work capacity

**Stage 3 iron deficiency**
- Iron deficiency anemia
- Production of normal red blood cells decreases
- Reduced production of heme
- Inadequate hemoglobin to transport oxygen
- Symptoms include pale skin, fatigue, reduced work performance, impaired immune and cognitive functions
Major Issues

- Iron, folate, and B vitamin deficiencies
  - Anemia
  - Neural tube defects
  - Homocysteine breakdown
Importance of Folate

• A woman’s need for folate dramatically increases during pregnancy
  – Folate is required for cell division and proper formation of the neural tube
    • Neural tube develops into brain and spinal cord

• Increased need develops very early, usually before she knows she is pregnant

• All women of childbearing age should consume an extra 400 µg/day of folate
Macrocytic anemia

- Caused by severe folate deficiency
  - Results in enlarged erythrocytes carrying insufficient hemoglobin
    - Retarded DNA replication rate coupled with normal RNA & protein synthesis & retention of nucleus
  - Shows common symptoms of anemia including weakness, fatigue, difficulty concentrating, irritability, headache, shortness of breath
Pernicious anemia

2 causes

1. Occurs after the loss of parietal cells of the stomach
   - Produce intrinsic factor, which allows absorption of vitamin $B_{12}$
     • Primary cause of $B_{12}$ deficiency

2. Occurs in people who consume very little vitamin $B_{12}$ in their diet
   • Symptoms: pale skin, reduced energy, fatigue, neurological symptoms
Vascular Disease

• **Folate** and **vitamin B\textsubscript{12}** are required for breakdown of **homocysteine** (AA)
  - Low intakes allow increased level of homocysteine

• High homocysteine levels associated with greater risk of cardiovascular and cerebrovascular disease
  - *Perhaps* by inappropriate activation of clotting proteins OR increased plaque formation
Chromium

• Assists insulin in transporting glucose from the blood into cells
• Good sources: mushrooms, prunes, dark chocolate, nuts, whole grains
• Chromium deficiency inhibits glucose absorption; can elevate blood lipid levels