

## Vitamins - 1

At this point in our survey of nutrition and the human body, we will turn our attention to the **vitamins** and **minerals**. All vitamins and minerals are essential nutrients, but they differ from proteins, lipids and carbohydrates because they are **not energy-yielding** nutrients. Some are required structural substances; most have metabolic functions. In addition, relative to proteins, carbohydrates and lipids, the amounts required are very small, essential as they are. Vitamins are small organic molecules; minerals are inorganic ions.

We shall discuss vitamins first, then minerals, but because they are so often linked, there will be some common elements in this section.

The average drug store in the United States has at least one aisle of vitamin/mineral products, and increasingly, shelves of "natural supplements":

- Some are pills or capsules.
- Some are liquids.
- Some are chewable. (Some are even marketed as chewing gum.)
- In addition many products, especially breakfast cereals, are advertised as much for their vitamin/mineral content as for any other benefit they may provide.

To reiterate:

- Vitamins are **essential** (that our bodies can not manufacture\* vitamins).
- Vitamins are **small organic** (carbon-containing) molecules. Vitamins are **required in small quantities** (relative to protein, lipids and carbohydrate).
  - \* Vitamin D can be manufactured from cholesterol-type precursors in the skin, in the presence of sunlight.
  - \* Vitamin A can be synthesized from carotenes in the diet.
  - \* Niacin can be synthesized from tryptophan (an amino acid).

Insufficient intake of some vitamins causes dreadful and sometimes fatal diseases, such as scurvy (Vitamin C), pellagra (Niacin), beriberi (Thiamin), rickets (Vitamin D), pernicious anemia ( $B_{12}$ ), and blindness (Vitamin A). Too much of many of the vitamins also have serious health consequences.

Vitamins also differ to some extent from our major nutrients because how much we absorb and can use in our body of a certain vitamin at any given time is related to its **bioavailability**. Vitamins are not digested, but they may not be available for absorption in some forms.

Bioavailability depends on a number of factors including:

- Efficiency of digestion and absorption -- transit time is important
- Foods consumed at the same time
- Food preparation method -- processing and cooking affect some vitamins and many minerals)
- Source of vitamin or mineral -- naturally in the food or as a synthetic formulation or additive to food

## Vitamins - 2

As we look at vitamins in our diets, we will address:

- What the vitamins are
- What vitamins do in the body
- Some specific vitamin deficiency and toxicity symptoms
- Dietary sources for vitamins
- Other stuff

Unfortunately, most of this is specific information, and it's not easy. There are 13 recognized vitamins, and each has a list for function, deficiency, toxicity and dietary sources. We want to do more than just "catalog" information, but try to put vitamins (and minerals) into the overall picture of how we function. If time allows, we can also look at the value of vitamin supplements in the diet, megavitamin doses and vitamin health theory, plus some of the non-vitamins that are advertised.

At any rate, we can start with the question **"What are the vitamins?"**

Vitamins came to the forefront of nutrition in the early 20<sup>th</sup> century when certain diseases were associated with insufficient intake of certain substances that were found in foods. These needed substances were called vitamins, more or less because they were "vital to life".

Initially, as these substances were identified they were assigned letters of the alphabet. Subsequently, a host of vitamins associated with metabolism were identified, and the "B" vitamins were given numerical subscripts. Today we as often refer to vitamins, and in particular, the B vitamins by their chemical identifications. By the way, it is incorrect to say "vitamin B". There is no single "vitamin B".

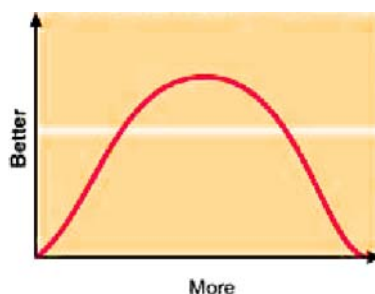
Vitamins are also divided into two broad groups depending on if they are soluble in water or in fat/ether/alcohols. Dividing vitamins by solubility is convenient for learning what the vitamins are, and for some general chemical behavioral differences caused by their hydrophobic or hydrophilic nature.

## Vitamins - 3

### Vitamin Classification and Characteristics Based on Solubility

Characteristic	Water Soluble	Fat Soluble
<b>Number</b>	9	4
<b>Absorption and Transport</b>	Directly into Capillaries	Lymph to Blood
<b>Storage</b>	Most In circulation B <sub>12</sub> in liver (4 years)	Adipose Tissue
<b>Handling of Excess</b>	Mostly excreted	Some excreted
<b>Toxicity*</b>	Rarely toxic; safe upper levels set	A and D can accumulate to toxic levels
<b>How Excreted</b>	Urine	Bile
<b>Requirements</b>	Mostly daily	Weekly/monthly
<b>Precursors</b>	Niacin from tryptophan	A from carotene D from cholesterol
<b>Name</b>	Thiamin (B <sub>1</sub> ) Riboflavin (B <sub>2</sub> ) Niacin (B <sub>3</sub> ) Biotin Pantothenic acid Pyridoxine (B <sub>6</sub> ) Folate (Folic Acid) Cobalamin (B <sub>12</sub> ) C (Ascorbic Acid)	A D E K

\*A note on toxicity: The dietary reference intakes are established from studies that determine upper safe levels for the majority of people. For most, intake above that level confers no benefit, and at some point increasing the amount consumed is harmful. Effects of vitamin toxicity will be discussed with the individual vitamins.



From the list of vitamins we can see that some of the "behavior" is related to whether they are fat or water soluble. Because vitamins are organic molecules, they are susceptible to degradation and oxidation. Many are heat sensitive.

Vitamin discussions often refer to the loss of vitamins in foods during preparation and/or storage of foods. Before we start our discussion of specific vitamins, let's digress a little and look at how food preparation and processing affects vitamins (as well as some minerals).

## **Food Preparation and Storage Impact on Vitamins**

### **Heat Exposure**

Food preparation and preservation methods that use high temperatures for long periods affect heat-sensitive vitamins. Canning is an excellent way to protect foods from bacteria and fungi, but the time and temperature used are important. A short time at high temperature retains more vitamins. **Thiamin, riboflavin** and **vitamin C** are destroyed by heat. Acid helps prevent vitamin degradation.

### **Cold Exposure**

Most foods are best kept at cooler temperatures to minimize spoilage. Freezing is an excellent preservation method with minimal nutrient loss, if foods are kept at 0° F. Some **vitamin C** is lost by exposure to air while preparing foods for freezing and **pantothenic acid**, a B vitamin, is destroyed by freezing.

Some plant foods, however, cannot be frozen because tissue damage results from freezing. When thawed, damaged tissues are, shall one say, "slimed".

### **Light Exposure**

**Riboflavin** is destroyed by light, including UV light. Milk stored in clear glass jars in the grocery will lose some of its riboflavin.

### **Air Exposure**

Some vitamins, notably **vitamin C**, are destroyed by exposure to air. Chopping or slicing foods exposes more surfaces to air, increasing nutrient loss. All cut foods and juices should be kept in sealed containers.

### **Drying Foods**

Drying can preserve many foods with minimal losses. Fruits are often dried. Some **vitamin C** is lost in drying from exposure. Sulfur dioxide used to preserve dried fruits may destroy thiamin, but protects vitamin C.

### **Extrusion Processing**

Extrusion processing is common with cereals and snack foods. Extruded foods are heated, ground up, mixed into a slurry and then squeezed through molds to obtain the desired shape and often dried. There may be significant nutrient losses, though some restored by enrichment. Many such products are also fortified with additional nutrients.

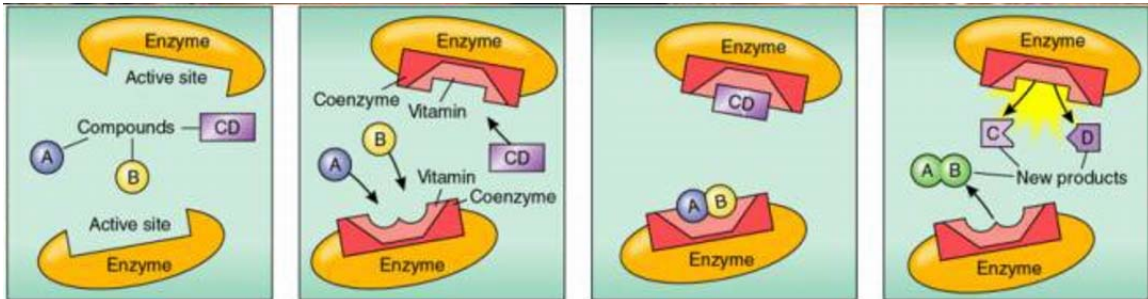
### **Water Used in Food Preparation**

Water soluble vitamins and minerals are leached by preparation in water. Some minerals (and to a lesser extent, vitamins) can still be useful if you use the water that they've leached into. Variables involve volume of water, time in water and how the food is cut.

We can now turn to our discussion of what vitamins do.

### The Water-Soluble Vitamins (All the B's and Vitamin C)

Most water-soluble vitamins need to be consumed daily, or nearly so. They are readily carried in the blood plasma, and excess amounts are routinely excreted in urine. Many of the B vitamins function in metabolism as **coenzymes**, small organic molecules that help enzymes do their job. They are particularly important in the process of cell respiration.



If any of the B-complex vitamins are lacking in the diet, some metabolic pathways will be affected, or even halted. Most B-complex deficiencies involve more than one vitamin, and symptoms frequently overlap. Deficiency symptoms show first in areas of rapid cell division, such as the skin and the linings of the digestive tract, and notably the tongue. Non-visible tissues are probably affected as much, but it's more difficult to verify the symptoms. There are also unique things that each of these B-complex vitamins does, with other symptoms.

To accurately assess deficiencies you must have a clinical diagnostic test. Symptoms are not sufficient in most cases to make an accurate diagnosis!

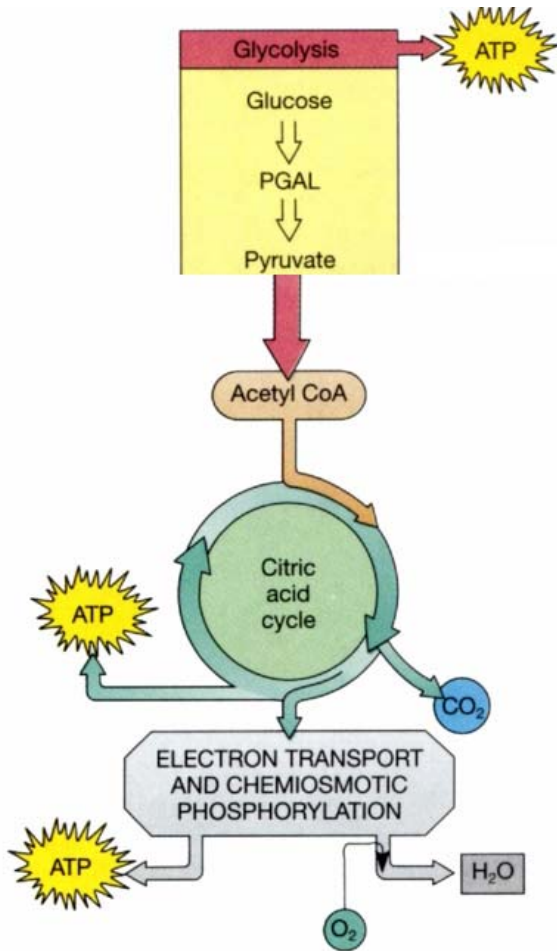
### B Vitamins and Metabolism

One of the most important metabolic pathways in all cells is **cell respiration**, the process by which all cells oxidize fuel molecules to obtain energy to do work. In cell respiration, glucose is oxidized to form ATP, the molecule that provides the immediate energy for any energy-consuming process in cells. Vitamins, themselves, are not fuel molecules, but act as critical **coenzymes** in these processes. It makes sense, at this time, to look at how these vitamins fit into the picture. Cell respiration is discussed thoroughly in our section on metabolism.

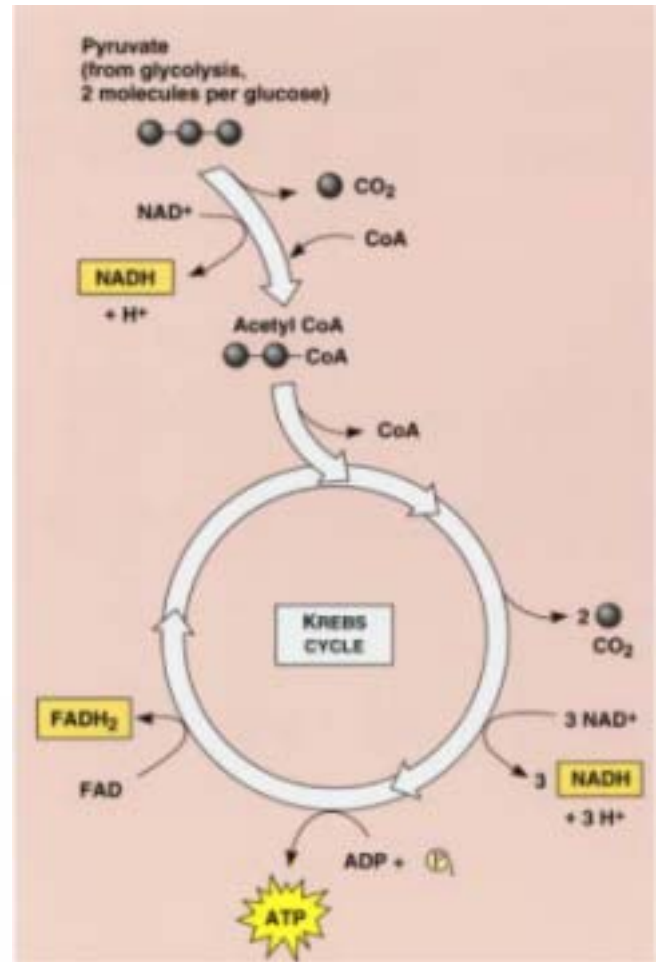
**Aerobic cell respiration** involves three stages:

- **Glycolysis**, an anaerobic stage that converts glucose to a 3-carbon molecule, pyruvate
- **Krebs cycle** (or TCA cycle or Citric acid cycle) the oxidizes pyruvate transferring electrons and hydrogen to electron carrier molecules (many of which are coenzymes derived from B vitamins)
- **Electron transfer**, in which the energy of the electrons is used to synthesize **ATP**

## Vitamins - 6



Overview of Cell Respiration



Krebs Cycle

- **NAD**, made from **Niacin**, is needed to remove hydrogen (and its electrons) from the glucose molecule and from the acids in the Krebs cycle.
- **Thiamin** is a component of the coenzyme TPP) needed to convert pyruvate to acetyl to enter the Krebs cycle
- **Biotin** is also needed to convert pyruvate to acetyl
- **Coenzyme -A**, made from **Pantothenic acid**, is needed to carry acetyl into the Krebs cycle and to carry inorganic phosphate into the Krebs cycle
- **FAD**, made from **Riboflavin**, is another energy carrying coenzyme needed to remove hydrogen and electrons in the Krebs cycle
- **NADH** and **FADH<sub>2</sub>** transfer their electrons and hydrogens in the electron transport system to provide energy to synthesize **ATP** by the process of chemiosmosis.

When fuel molecules other than glucose are metabolized, they enter the cell respiration pathway either as acetyl, as intermediates of the Krebs cycle, or rarely in intermediates of glycolysis. **Folate**, **Biotin**, **B<sub>12</sub>** and **B<sub>6</sub>** are involved in the inter-conversion of nutrients to provide fuel molecules that can enter the cell respiration pathway.

Now to "tackle" the vitamins – one by one!

## Thiamin (B<sub>1</sub>)

### Functions

- Thiamin forms the coenzyme TPP (thiamin pyrophosphate)
- TPP is necessary to convert pyruvate to acetyl during cell respiration and in the Krebs cycle to convert  $\alpha$ -ketoglutaric acid to succinyl.
- Thiamin is essential for nerve cell transmission. It forms a part of nerve cell membrane sodium channels

### Recommended Amount

- 0.5 mg/1000 calories consumed (1 - 1.5 mg/day)

### Deficiency

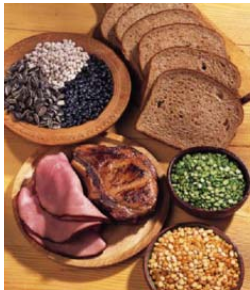
A prolonged deficiency of thiamin can cause **beriberi** ("I can't, I can't"). Thiamin deficiency can cause damage to the cardiovascular and nervous systems, with effects worse with children. Muscle weakness and edema are common symptoms. Apathy and impaired mental function result from thiamin deficiency.

Diets that rely on empty calories (sugars, fats, alcohol) are most likely to be deficient in thiamin. Diets rich in processed grains that are not enriched can also be deficient in thiamin. In the United States processed wheat flour must be, by law, enriched with thiamin.

### Toxicity

Toxicity can be induced with megadoses of supplements, but not with normal food consumption. Toxic levels of thiamin cause nerve hypersensitivity.

### Food Sources



Most people who have nutritious diets with adequate calories will get sufficient thiamin. Best sources are:

- Whole and enriched grains
- Legumes
- Pork and liver
- Nuts and seeds

### Special Considerations with Thiamin

- Thiamin oxidizes at high temperatures
- Thiamin is destroyed by baking soda and sulfites (color preservatives)
- Folate promotes absorption of thiamin
- Antacids can inhibit thiamin absorption

## Riboflavin (B<sub>2</sub>)

### Functions

- Riboflavin is a component of the coenzyme FAD. FAD is an important electron transfer (oxidation-reduction) molecule in cell respiration.
- Riboflavin also facilitates hydrogen transfer in amino acid and fatty acid degradation.
- Riboflavin activates Folate.

### Recommended Amount

- 1mg/1000 calories consumed (1.2 - 1.7 mg/day)
- Children need proportionally more than adults for growth

### Deficiency

Riboflavin deficiency is rare. Insufficient riboflavin may cause inflammation of the membranes lining the digestive tract and the eyes. The tongue may be reddish to purple. Skin may get rough and scaly and be sensitive to light. Some people experience depression or altered personality. **Ariboflavinosis** is the deficiency disease.

### Toxicity

Riboflavin toxicity is not known. Excesses are readily (and visibly) excreted.

### Food Sources



Most people who have nutritious diets with adequate calories will get sufficient riboflavin. Best sources are:

- Dairy Products
- Meats, especially liver
- Mollusks
- Dark Leafy Vegetables
- **Enriched** grains

### Special Considerations

- Riboflavin is a distinctive yellow-gold crystalline substance
- Riboflavin is sensitive to UV light (50 - 80% of riboflavin can be lost in 6 hours)
- Riboflavin is also sensitive to higher levels of radiation, such as the irradiation used to protect some foods and to add vitamin D to milk.

## Niacin (B<sub>3</sub>)

### Forms

Niacin comes in two forms: **Nicotinic acid** from plants and **nicotinamide** (niacinamide) from animals. Nicotinic acid is readily converted to nicotinamide in the body. Niacin can also be synthesized from excess tryptophan in the diet (see later).

### Functions

- Niacin is a component of the coenzyme, NAD, the high energy hydrogen carrier in cell respiration (NAD).
- Niacin is also needed for DNA synthesis and to repair DNA

### Recommended Amount

- 15 - 20 mg/day

### Deficiency

Niacin deficiency causes pellagra, dermatitis. Skin becomes flaky and darkened on areas of the skin exposed to light. Diarrhea, vomiting and abdominal pain are also symptoms of pellagra. The tongue appears smooth and orange. Blurred vision, apathy, depression and mental deterioration accompany the disease. Pellagra may also cause liver damage.

### Toxicity

- Taking about 100 mg of niacin can induce the "niacin flush".
- Excess niacin can cause liver damage, vision problems and intestinal disorders. (It's not uncommon for toxicity symptoms to be similar to deficiency symptoms for many vitamins.)

### Food Sources



- Organ meats and meats, poultry and fish in general
- Whole and **enriched** grains
- Legumes are high in tryptophan so can provide some niacin
- Milk and eggs are potential sources, because they are high in tryptophan
- Smaller amounts of niacin are found in dark leafy greens

**Special Considerations for Niacin**

- Niacin can be synthesized from the amino acid, tryptophan, if tryptophan is in excess. About 1% of protein consumed is tryptophan. For each 600 excess milligrams of tryptophan in the diet, 10 milligrams of niacin can be made. A typical older woman needs about 40 grams of protein per day. About .4 grams of that would be tryptophan. Eating twice as much protein as recommended could provide enough excess tryptophan to make 6.6 mg of niacin. Vitamin B<sub>6</sub> is needed for the conversion.
- Medicinal doses of niacin are used rarely to treat arteriosclerosis. Taking niacin medicinally should be only under medical supervision. These excess doses may elevate HDL and lower LDL and cholesterol.
- Niacin is a relatively stable molecule and easily absorbed.

## **Biotin**

### **Forms**

Biotin from plant sources is free and water-soluble; biotin is complexed in animal sources and fat-soluble.

### **Functions**

- Biotin functions in carbon fixation and removal of CO<sub>2</sub> especially in the Krebs cycle
- Biotin is also involved with carbon transfer in metabolic intermediates, oxidation of fatty acids and carbohydrates, and in glycogen synthesis.

### **Recommended Amount**

- 0.3 µg/day

### **Deficiency**

Biotin deficiency is unknown but can be induced in laboratories causing rashes, hair loss, and neurological impairment.

### **Toxicity**

Toxicity symptoms are unknown for biotin.

### **Food Sources**

Biotin is in all whole foods and can be synthesized by intestinal bacteria, although the amount absorbed is unknown. Some especially good sources are:

- Legumes
- Whole Grains
- Meats

### **Special Considerations**

- Antibiotics that destroy intestinal bacteria may affect short term biotin levels, and you may result in short term deficiencies, but not enough to worry about. The most common medications that may do this are sulfa drugs and tetracyclines.
- **Raw** egg white contains avidin, a protein that binds biotin. Consuming 24 raw egg whites **daily** can result in biotin deficiency. Proteins are denatured by heat, so there is no problem with cooked eggs.

## **Pantothenic Acid**

### **Functions**

- Pantothenic acid is a component of Coenzyme A, a critical coenzyme of cell respiration. Coenzyme A carries acetyl and inorganic phosphate ( $P_i$ ) into the Krebs cycle.
- Pantothenic acid is needed for lipid synthesis, including the steroid hormones, synthesis of some neurotransmitters and hemoglobin synthesis. Over 100 chemical reactions have been identified that involve pantothenic acid.

### **Recommended Amount**

- About 5 mg/day

### **Deficiency**

Natural deficiencies of pantothenic acid are not known because it is so common in foods. When deficiency is induced, burning and itchy feet, fatigue and nausea are symptoms.

### **Toxicity**

Meagadoses of pantothenic acid (20 grams or more) may cause diarrhea.

### **Food Sources**

Pantothenic acid is plentiful in fresh whole foods. Some better sources are:

- Meats and Fish
- Whole grains
- Fresh vegetables, especially from the Solanaceae

### **Special Considerations**

- Processing grains causes significant (50% or more) loss of pantothenic acid. It is not one of the mandatory enrichment vitamins.
- Pantothenic acid is easily destroyed by heat and freezing

## **Vitamin B<sub>6</sub> (Pyridoxine)**

### **Forms**

Vitamin B<sub>6</sub> occurs in three forms, **pyridoxal**, **pyridoxine** and **pyridoxamine**. They are all converted to the coenzyme, **PLP** (pyridoxal phosphate), which is involved in amino acid conversion and metabolism.

### **Functions**

Vitamin B<sub>6</sub> is a vital coenzyme used for:

- Non-essential amino acid rearrangement
  - Antibody production in the immune system
  - Deamination of amino acids
  - Synthesis of the heme portion of hemoglobin
  - Synthesis of niacin from tryptophan
  - Synthesis of serotonin from tryptophan
  - Nucleic acid (DNA and RNA) synthesis
  - Lecithin synthesis
  - Glycogen conversion to glucose
- Vitamin B<sub>6</sub> also affects steroid hormone function.

### **Recommended Amount**

- About 1.3 mg /day.

### **Deficiency**

Insufficient vitamin B<sub>6</sub> affects neurotransmitters related to tryptophan synthesis. Early symptoms include depression and confusion. Insomnia and lack of muscle coordination are additional consequences of B<sub>6</sub> deficiency.

### **Toxicity**

Vitamin B<sub>6</sub> toxicity is well documented. Chronic megadoses of more than 2 grams/day cause nerve damage. Symptoms of B<sub>6</sub> toxicity include tingling sensations and numbness, especially in the face, and poor muscle coordination. Although some take megadoses of B<sub>6</sub> for PMS and some for carpal tunnel syndrome, it is not recommended, since B<sub>6</sub>-induced nerve damage is permanent.

### Food Sources for Vitamin B<sub>6</sub>



No foods are superior sources of B<sub>6</sub>, but many vegetables, when ranked by nutrient density, are good sources. Other food sources include:

- Meats
- Some fruits, such as bananas are good B<sub>6</sub> sources.
- B<sub>6</sub> is readily available in fortified foods, too.

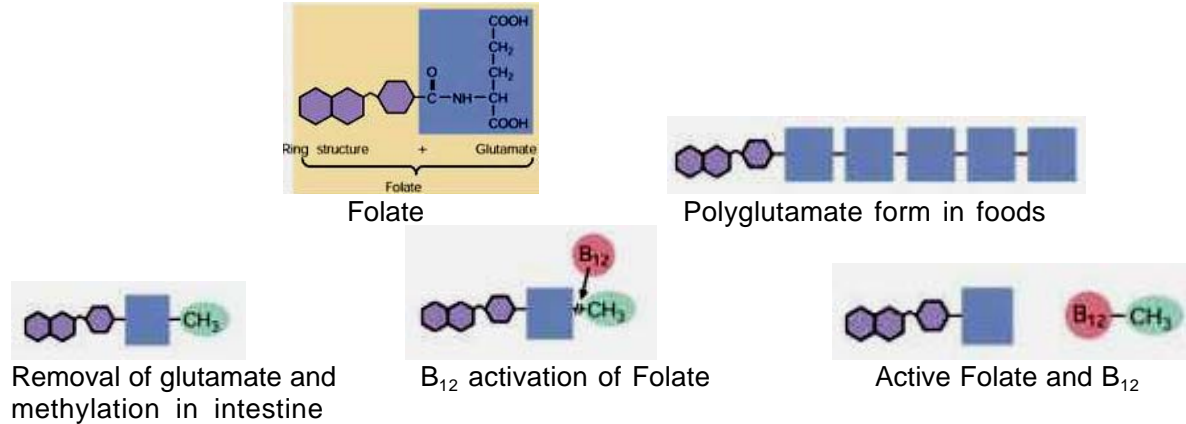
### Special Considerations

- Vitamin B<sub>6</sub> is stored in muscle tissue.
- Alcohol deactivates the coenzyme PLP, effectively removing vitamin B<sub>6</sub>.
- The drug, INH, used to treat tuberculosis (one of the few) destroys vitamin B<sub>6</sub>.
- High doses of estrogen stimulate the breakdown tryptophan, which requires B<sub>6</sub> to synthesize.
- B<sub>6</sub> is destroyed by heat and by processing of foods.

## Folate (Folic Acid or Folacin) (Pteroylglutamic acid)

### Forms

Folate is found in plant foods where it is bound with the amino acid glutamate, forming polyglutamates. However, intestinal enzymes must remove the glutamates and attach a methyl group (CH<sub>3</sub>) to folate for optimum absorption. In order to convert folate to the cellular active form, vitamin B<sub>12</sub> is needed to remove the methyl group. Interestingly, the methyl group is needed to activate vitamin B<sub>12</sub>, so that folate and vitamin B<sub>12</sub> are interconnected in how we need and use them.



### Functions

- Folate is a component of the coenzyme **THF** (tetrahydrofolate) that transfers 1-carbon molecular fragments during metabolism. This is especially important in cell respiration, DNA synthesis and the formation of the coenzyme derived from vitamin B<sub>12</sub>.
- Folate is needed for red blood cell synthesis (along with B<sub>12</sub>).
- Folate is needed for both DNA and RNA synthesis and DNA repair.
- Folate reduces the risk of neural tube defects in embryonic development.
- Folate breaks down excess homocysteine, an amino acid implicated in cardiovascular disease.
- Folate may also lower the risk of peripheral arterial disease (which results in reduced circulation to the legs and feet, often associated with symptoms of pain and sores that heal poorly).

### Recommended Amount

- The folate in supplements or fortified foods is readily absorbed; it does not need to be converted by intestinal enzymes. It is estimated that about 50% of the naturally occurring folate is absorbed.
- 400 µg/day of folate is recommended for women of child-bearing age. 4 milligrams of folate/day is recommended for women at risk of bearing a child with neural tube defects.
- Folate intake should **not** exceed 1 mg/day. (It very rarely does; most of us get about half the recommended amount.)

### Storage

Folate can be stored in the liver for 4 - 5 months, and can be recycled from the intestine since excess folate is excreted with bile.

### Folate Deficiency

- A deficiency of folate results in megaloblastic anemia, a failure of the red blood cells to mature.
- Since folate is needed for DNA synthesis, deficiencies lower the rate of cell repair and replacement. Cells of the digestive tract are affected first with folate deficiency.
- Folate deficiency can cause heart arrhythmia.

### Toxicity

Folate megadoses can mask B<sub>12</sub> deficiency. Chronic deficiency of B<sub>12</sub> can result in permanent nerve damage, so that folate intake and B<sub>12</sub> intake need to be matched.

### Food Sources



Fresh foods are better sources of folate than prepared foods, and folate is especially abundant in **legumes**. Other good sources of folate include:

- Fresh leafy vegetables
- Citrus fruits (because vitamin C protects folate)
- Yeast
- Liver
- Enriched grain products

### Special Considerations

- Folate may reduce the risk of pancreatic cancer in smokers and breast cancer in women who drink alcohol.
- The folate recommendation is based on its role in reducing the risk of neural tube defects in embryonic development.
- As stated, folate breaks down excess homocysteine, an amino acid implicated in cardiovascular disease.
- Folate, more than any other vitamin, is affected by drugs, both over-the-counter and prescription drugs.
  - Aspirin and antacids both interfere with folate.
  - Many chemotherapy drugs affect folate by blocking the coenzyme attachment site on the enzymes with which it works.
  - Alcohol interferes with folate function.
  - Oral contraceptives interfere with folate function.
- Heat and oxidation can destroy folate.
- Smoking may interfere with folate function.
- Absorption of folate is increased by Vitamin C, B<sub>12</sub> and niacin.

## **Cobalamin (B<sub>12</sub>)**

### **Functions**

- Vitamin B<sub>12</sub> does most of its work in conjunction with folate. Both are needed for DNA and RNA synthesis, maturation of red blood cells and regeneration of some amino acids.
- In addition, vitamin B<sub>12</sub> is needed for:
  - Maintenance of myelin sheath of nerve cells
  - Bone cell metabolism
  - Glucose uptake by cells of the brain

### **Recommended Amount**

- 2 - 3 µg/day; older people 6 – 15 µg/day
- The B<sub>12</sub> intrinsic factor, a mucoprotein produced in the stomach that binds to B<sub>12</sub>, is needed for absorption. Older people absorb B<sub>12</sub> less well.

### **Storage**

- Once conjugated to the intrinsic factor, vitamin B<sub>12</sub> can be stored in the liver for several years.
- In addition, B<sub>12</sub> can be recycled for several years. It is excreted in bile from the liver, but can be reabsorbed in the intestine.
- Adults with stores of vitamin B<sub>12</sub> can have diets with no B<sub>12</sub> and exhibit no deficiencies. This is not so for children, who have not had time to build the reserves.

### **Deficiency**

Vitamin B<sub>12</sub> deficiency is more often caused by the inability to absorb vitamin B<sub>12</sub> than failure to consume adequate amounts. Some people cannot manufacture the intrinsic factor so vitamin B<sub>12</sub> does not get absorbed. Older people often produce less B<sub>12</sub> intrinsic factor so absorb less. A second factor is insufficient HCl in the stomach to release B<sub>12</sub> from foods so that it can bind to the intrinsic factor in the stomach.

- A deficiency of B<sub>12</sub>, in association with folate deficiency causes pernicious (or megaloblastic) anemia. As discussed with folate, the red blood cells cannot mature and become enlarged. Cell division must be preceded by DNA synthesis, and folate and B<sub>12</sub> are required for DNA synthesis. Other symptoms of pernicious anemia include rapid deterioration of body systems and hyperpigmentation and yellowing of skin.
- Chronic deficiency causes nerve degeneration and paralysis that may be permanent.
- Strict vegetarians (vegans), especially children, may be candidates for B<sub>12</sub> deficiency since B<sub>12</sub> is found in animal foods but not in plants.

### **Toxicity**

Vitamin B<sub>12</sub> toxicity is unknown. The liver excretes excess amounts in bile.

### **Food Sources of B<sub>12</sub>**

B<sub>12</sub> is abundant in muscle tissues. Good sources are:

- Liver
- All meats
- Dairy products
- Eggs
- B<sub>12</sub> fortified "nutritional" yeast or other foods fortified with B<sub>12</sub>. Some plant foods are advertised as containing natural B<sub>12</sub> from fermentation, but the form of B<sub>12</sub> in these foods is not active B<sub>12</sub> and poorly available.

Plants do not produce vitamin B<sub>12</sub>.

### **Special Considerations**

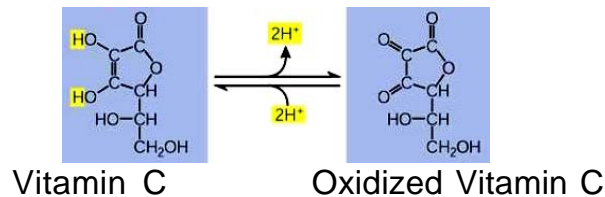
Vitamin B<sub>12</sub> is inactivated by microwave cooking methods, so cooking meats and dairy products in the microwave is not recommended to protect vitamin B<sub>12</sub>.

## Vitamin C (Ascorbic acid)

### Functions

Vitamin C has two primary functions, **antioxidant** and **coenzyme**. (Technically cofactors are inorganic ions that facilitate enzyme function; coenzymes are organic molecules that do the same thing.)

- As an **antioxidant**, vitamin C protects substances from oxidation by free radicals, molecules that need electrons for stability and oxidize "almost anything" to get the electrons. Free radicals can damage cells and tissues with their activity. Free radicals are produced in all cells and tissues as by-products of and/or intermediates of many cellular activities.
- Antioxidants, as a group, are substances that are easily oxidized (that is donate their electrons to the free radicals), and sacrifice themselves to protect other molecules from oxidation. Vitamin C is an important antioxidant for water-soluble substances.
- Vitamin C is especially important for **iron absorption** because it protects iron from oxidation. Reduced iron is absorbable; oxidized iron is not.
- Vitamin C promotes folate absorption.



- **Structurally**, vitamin C is needed for the formation of **collagen**, an important structural protein in all connective tissue, which includes blood vessel linings, and in bone and tooth structure. Two amino acids, proline and lysine, need iron to convert them to the form needed in collagen and vitamin C is needed to protect the iron.
- Vitamin C is needed to synthesize a number of other proteins, such as thyroxine and norepinephrine, and the neurotransmitter, serotonin.
- Vitamin C is released by the adrenal glands during stress, and when the body has physical stresses (from wounds, infections, poisonings, etc.), the need for vitamin C increases. What vitamin C is doing relative to physical stress isn't known.

### Recommended Amount

- The current recommendation for vitamin C is 75 mg/day for women and 90 mg/day for men. Smokers need about 35 mg/day more.
- Body tissues are saturated with vitamin C at about 100 mg/day.
- No level has been set for the antioxidant properties of vitamin C, but vitamin C levels beyond tissue saturation are excreted readily by the kidney.
- More than 3000 mg/day (3 grams) can be toxic.

### Storage

Vitamin C can be stored in liver and the aqueous humor of eye. We can have as much as a two-month supply in these tissue.

### **Vitamin C Deficiency**

Prolonged vitamin C deficiency causes scurvy, long famous as a disease (often lethal) of sailors during the era of sailing ships. Most symptoms of scurvy are related to its role in collagen formation, particularly in blood vessels. The following list is progressive for scurvy. Symptoms appear within about one month of vitamin C deficiency.

- Gums and soft tissues are inflamed and bleed.
- Pinpoint hemorrhages occur in skin and near hair follicles.
- Bruising is common.
- Wounds can't heal because collagen scar tissue isn't synthesized.
- Skin becomes dry and scaly.
- Plaque formation occurs promoting arteriosclerosis (not visible).
- Bones soften, become painful, break easily and are malformed in infants.
- Muscles degenerate.
- Teeth loosen and fall out.
- Anemia and infections are common.
- Victims become depressed and sometimes hysterical (understandably so).
- Death may occur from sudden bleeding.

Many symptoms of scurvy can be reversed within 5 days

### **Toxicity**

Although excess vitamin C is readily excreted, so many people take megadoses that toxic symptoms can, and do, occur. The most common symptoms of vitamin C toxicity are nausea and diarrhea. In addition:

- Excess excretion of vitamin C with frequent urination can obscure symptoms of diabetes.
- Vitamin C is an anticoagulant antagonist and can interfere with anti-clotting medications.
- We can be conditioned to excess vitamin C so much so that if we stop taking large doses the body will enter into short-term deficiency symptoms. Newborn infants can exhibit scurvy symptoms if the mother took large doses while pregnant. Milk contains virtually no vitamin C.
- There are medical conditions for which levels of vitamin C are critical:
  - Kidney disease
    - Vitamin C promotes uric acid formation characteristic of kidney stones
  - Hemolytic anemia
  - Gout
  - Intolerance to reducing agents (An antioxidant is a reducing agent)
  - Iron overload – Vitamin C promotes iron absorption and free iron in body tissues.

## Vitamin C Food Sources



A number of fruits and vegetables contain good amounts of vitamin C. The best sources based on calories are:

- Solanaceous vegies
- Cruciferous vegies
- Citrus fruits
- Liver is about the only animal source of vitamin C
- Some individual fruits are excellent sources, such as:
  - Papaya
  - Cranberries
  - Cantaloupe
  - Strawberries
  - Kiwi
- Many juice drinks are fortified with C
- Vitamin C is **not** found in grains or seeds
- Vitamin C is just as readily absorbed in supplement form as it is in fresh whole foods.

## Special Considerations

- Ascorbic acid is not stable!
- Vitamin C can be chelated by heavy metals, such as lead, mercury or cadmium
- Vitamin C may harm tooth enamel, especially when chewed. (It's an acid)
- Vitamin C is used as a food additive to minimize oxidation and spoilage of some foods.
- **Vitamin C and Colds**  
A comprehensive study of a number of clinical trials testing the efficacy of vitamin C for colds showed that there is a minimal decrease in the duration of colds when high doses of vitamin C are taken. Unfortunately, the studies also show that those who thought they were taking vitamin C but were actually taking placebos also reported their colds to be of shorter duration.
- **Vitamin C and Cancer**  
Vitamin C is a strong antioxidant. It may destroy potentially harmful oxidizing agents. There is some population evidence that individuals who consume foods high in vitamin C have a reduced risk of cancer. Studies do not show that it is the vitamin C in the foods that confers this reduced risk. Foods high in vitamin C are foods rich in a number of phytochemicals, any or some of which might be responsible for the effects.

## The Fat-Soluble Vitamins

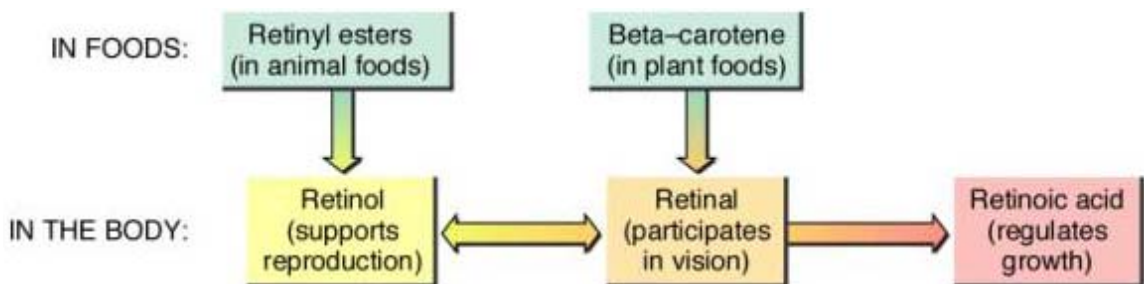
The fat-soluble vitamins (**A**, **D**, **E**, and **K**) are often found in the fats and oils of foods we eat, and require bile for absorption. They are not readily excreted, and tend to be stored in fatty tissues of the body. As long as we consume adequate quantities of these vitamins in general, we can go for periods with little intake, drawing on the stored supplies. Unfortunately, this storing capacity can also be responsible for the accumulation of toxic quantities of these vitamins, notably A and D.

Deficiencies can show up when the diet chronically lacks foods that contain these vitamins, or when there is a problem with the digestion and absorption of fats. Some substances ingested that attract fats, and which are not digestible, may result in the excretion of fat-soluble vitamins. Apart from these common features, the vitamins have very different "jobs" to do. Let's now look at the individual fat-soluble vitamins.

## Vitamin A

### Forms

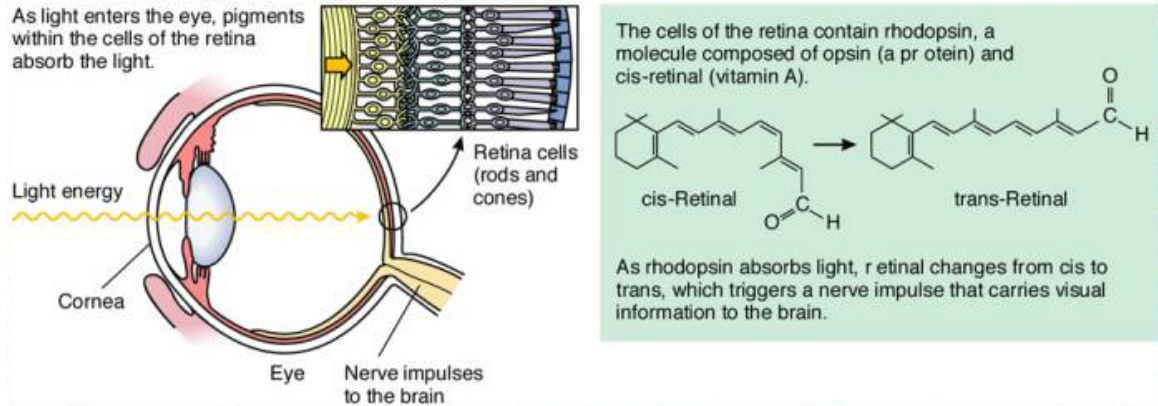
Vitamin A is found in three forms: **retinol**, **retinal**, or **retinoic acid**, collectively called **retinoids**. Each has different functions. Animal foods contain **retinyl esters** that are converted to **retinol** in the intestine. Retinol can be converted to the other forms of vitamin A. In addition, vitamin A can be synthesized from  $\beta$ -carotene, found in plants. Vitamin A is bound to a protein in the liver for circulation throughout the body.



### Functions

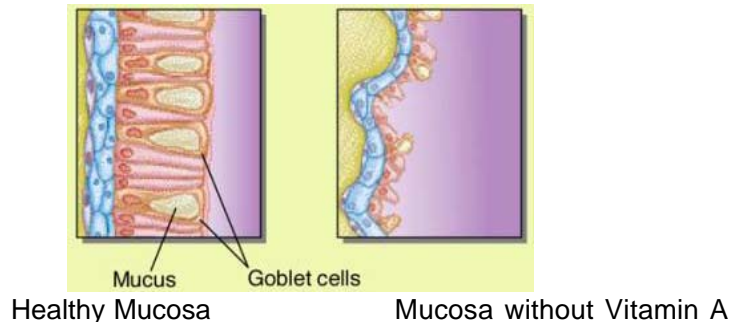
- Vitamin A (retinal) is a structural component of the visual pigments:
  - **Rhodopsin**
    - The pigment of the rods that detects light
    - There are about 100 million rods in the eye
  - **Iodopsin**
    - The pigment of the cones that detects color vision
    - There are about 6 - 7 million cones in the eye

Rods and cones undergo a cis-trans conformational change when struck by light energy. This change in form triggers the nerves that transmit "vision" to the brain.



A leading cause of blindness in malnourished children is vitamin A deficiency. Blindness is not reversible.

- Vitamin A is a component of the mucus layers of epithelial tissues, including skin and mucosa. There are about 75 square yards of mucosa in the body that protect and lubricate. The protein, keratin, is produced in the absence of mucus. In contrast to mucus, keratin inhibits transfer of substances across membranes.



- Vitamin A promotes cell differentiation and protein synthesis, so it is needed for all growth activities, including fetal growth.
- Vitamin A is needed for proper bone growth. It controls the degradation of enzymes when new bone growth is needed, especially in long bones.
- Vitamin A is needed for proper immune system response. The severity of measles infections is correlated to vitamin A sufficiency in the diet.
- Vitamin A functions in maintaining the stability of the myelin sheath of nerve cells.
- $\beta$ -carotene is an antioxidant independent of its role as a vitamin A precursor.

### Recommended Amount

The recommended amount of vitamin A is given in retinol equivalents (or retinol activity equivalents) in  $\mu\text{g}$ .  $12 \mu\text{g}$  of  $\beta$ -carotene =  $1 \mu\text{g}$  of retinol.

- Adults need  $700 \mu\text{g}$  for women and  $900 \mu\text{g}$  for men.

### Storage

- Vitamin A can be stored in liver for a year or so in adults.

### **Vitamin A Deficiency:**

Inadequate vitamin A intake is pretty common among poor everywhere in the world! As mentioned, vitamin A deficiency is a cause of blindness in third world nations. In the United States, vitamin A deficiency is more often a result of poor food choices. Because vitamin A is needed for proper functioning of the immune system, infectious diseases are more serious when vitamin A intake is low.

The most conspicuous deficiencies are those of vision and skin. The effects on mucosa are just as serious, but not visible. Symptoms of vitamin A deficiency include:

- Vision
  - Night blindness
  - Xerosis (drying of the eye) followed by softening, scarring and thickening of the cornea, which can cause blindness (keratomalacia)
- Skin
  - Skin bumps cause by keratinization of hair follicles
- Mucosa problems
  - Diarrhea
  - Decreased nutrient absorption
  - Keratinization of the membranes
  - Increased respiratory and urogenital infections
- Bones and teeth
  - Reduced bone growth
  - Cracked, poor enamel

### **Vitamin A Toxicity:**

Toxicity can occur when free vitamin A circulates and attacks cells and tissues. Vitamin A needs to bond to a protein in the liver, and if too much vitamin A is consumed, inadequate binding protein is available. Zinc is also required for vitamin A bonding, and for converting vitamin A to the visual pigments. Excess carotene does not cause tissue damage.

Toxic effects can result from as little as 5 times the recommended intake of active Vitamin A per day for a period of about 2 months. More commonly, the level needed to induce toxicity is 10 - 15 times the daily recommendation. Very high megadoses can cause birth defects.

Some of the toxic effects of excess vitamin A are:

- Severe to total hair loss
- Overactive osteoblasts resulting in abnormal and painful bone growth
- Dry, scaly, brittle skin and nails
- Fatty and jaundiced liver
- Fatigue, irritability, and headaches
- Excess carotene can cause hyperkaratonemia (yellowing of skin), because carotene is stored in the subcutaneous fatty layers.

## Food Sources for Vitamin A



Carotene Sources of vitamin A include:

- Dark green leafy vegies
- Yellow, orange or scarlet vegies

Vitamin A (retinoid) sources from animals include:

- Liver (may get overdose)
- Milk fat products, including butter
- Eggs
- Low fat milk is usually fortified with vitamin A.

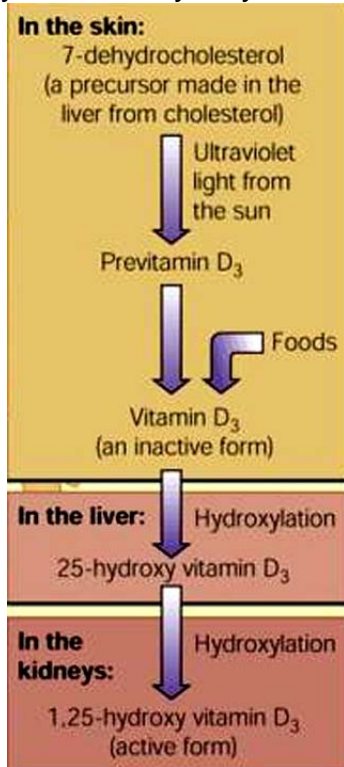
Unfortunately, foods that are high in carotenes are often foods we don't care for, and we too often don't get adequate vitamin A in our diets.

## Special Considerations

- "Fast Food" is notoriously low in vitamin A
- Eating excessive amounts of liver can cause toxicity symptoms. A serving of liver contains three times the daily recommended amount of vitamin A. It's rare for anyone to eat excessive amounts of liver.
- Birth defects can result when women take megadose supplements. The acne medication, accutane, which is derived from vitamin A, is prohibited for women of child-bearing age unless they are on effective contraceptives because of the associated risk for birth defects.
- Retin-A, a topical ointment or cream, smoothes skin wrinkles in some people and is also an acne treatment. It is skin irritant, however, and chronic use is discouraged.
- Some synthetic retinoids have shown promise in treating abnormal cell growths and tumors. It may be that sufficient vitamin A is essential for healthy mucosa. The respiratory tract and digestive tract are exposed to many carcinogens. Our mucus layers are part of our defense.
- $\beta$ -carotene, as an antioxidant, has shown promise in decreasing some cancer risks, but has been correlated with an increase cancer risk for smokers.

## Vitamin D

Vitamin D is a conditionally essential nutrient. We can synthesize vitamin D in our skin cells from the cholesterol precursor, **dehydroxycholesterol**, if we have exposure to adequate UV light. The vitamin then needs modifying in both the liver and the kidney to become the active form of vitamin D. Adequate exposure to sunlight becomes problematic for older people and for those who live in latitudes above 40°. In addition, with the known risks of skin cancers with sun exposure, relying on solar synthesis of vitamin D is risky. On the positive side, vitamin toxicity is unlikely if you are relying on solar synthesis.



## Functions

Vitamin D's functions are those of a hormone. In contrast to our hormones, we don't always synthesize adequate vitamin D. If we had a nutrient category for essential, or conditionally essential hormones, we could put vitamin D in it. Vitamin D has the following regulatory properties:

- Vitamin D is essential for bone mineralization. It works with the hormones calcitonin (a form of vitamin D) and parathormone, the minerals calcium, phosphorus and magnesium, as well as with vitamins A, C and K to ensure proper bone growth and maintenance.
- Vitamin D maintains proper blood calcium levels
  - Vitamin D promotes calcium absorption from intestine. It stimulates the synthesis of the protein that binds calcium for absorption,
  - Vitamin D promotes reabsorption of calcium from the kidney.
  - Vitamin D promotes removal of calcium from bone to retain blood levels as needed.
- Mineral levels in other tissues may also be regulated by vitamin D.

### **Recommended Amount**

- For those under 50, the recommended amount is 5  $\mu\text{g}/\text{day}$ . 10  $\mu\text{g}/\text{day}$  is recommended for 50 – 70, and 15  $\mu\text{g}/\text{day}$  for people over 70. Milk is fortified with 10  $\mu\text{g}/\text{quart}$ . This is the same as 400 IU.

### **Storage**

Vitamin D is stored in adipose tissue.

### **Deficiency Problems**

When levels of vitamin D are low, the protein needed to bind calcium in the intestine is not produced so calcium is not absorbed. Therefore, vitamin D deficiency results in a calcium deficiency. Most symptoms relate to the absence of calcium.

- The deficiency disease **rickets** affects children. Inadequate calcium causes bones, especially weight-bearing bones, to be weak and malformed
- Osteomalacia, a softening of bones in adults is a symptom of vitamin D deficiency. Bowed legs are common in both rickets and osteomalacia.
- Osteoporosis results when bones have too little calcium and become brittle. Bones of people with osteoporosis fracture easily.
- Deafness from damage to the middle ear bones is possible.
- Vitamin D deficiency can also promote muscle spasms.

### **Toxicity Problems**

Vitamin D toxicity symptoms can appear with chronic intake of just 4 – 5 times the recommended levels. Toxicity can also appear when stores of vitamin D are excessive. Toxicity is usually associated with taking supplements of vitamin D.

- Excess vitamin D promotes excess calcium levels in the blood. The excess calcium precipitates and can form deposits in arterial linings aggravating plaque formation. This is a risk factor in cardiovascular disease.
- Calcium precipitates in the kidney form kidney stones.
- The high level of calcium can also produce blood electrolyte imbalance.

### **Food Sources of Vitamin D**

Few foods contain vitamin D. Most people get their vitamin D from fortified milk. Natural vitamin D is found in:

- Egg yolks
- Liver
- Fish Oils

### **Special Considerations of Vitamin D**

It is important to get adequate amounts of both calcium and vitamin D for both to do the "jobs" they have to do. And it's not just for bone health. Recent studies showed that people who had adequate levels of both calcium and vitamin D had a lower risk of developing **pre-cancerous colon polyps**.

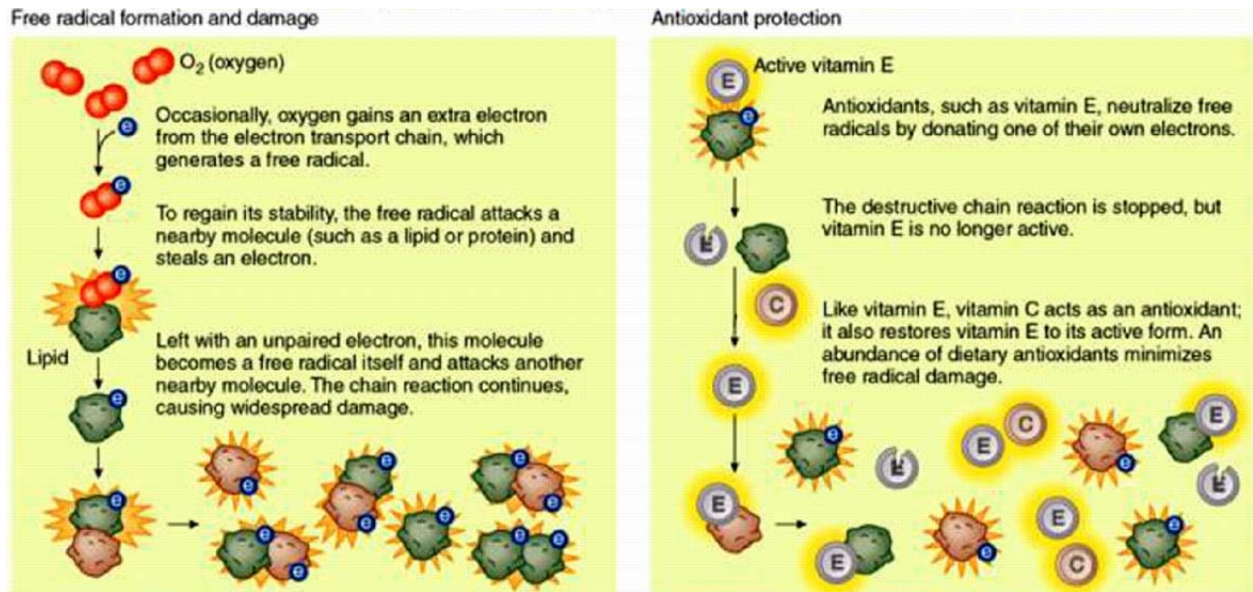
## Vitamin E

### Form

Vitamin E is tocopherol, a ring-shaped alcohol with a long hydrocarbon side chain, with four isomer forms.  **$\alpha$ -tocopherol** is the biologically active isomer.

### Functions

- Vitamin E is the body's primary antioxidant. Its major job is protecting the polyunsaturated fatty acids in cell membranes from oxidation.
- Vitamin E protects vitamin A from oxidation.
- Vitamin E protects lung tissues from free radicals inhaled, including pollutants such as ozone.
- Vitamin E protects the stability of red blood cells and cells of the immune system.
- Vitamin E appears to enhance immune system response, including reducing respiratory infection severity.
- Vitamin E may also protect LDLs from oxidation. Oxidized LDLs are more likely to deposit materials in blood vessels forming plaques.
- By providing stability to membranes, vitamin E may help reduce cancer risks.



### Recommended Amount

- Adults need about 15 mg/day, more if the diet is high in polyunsaturated fats.
- Some researchers are suggesting we should supplement our diets with up to 400 mg/day of vitamin E for its anti-oxidant protective properties. This is controversial since some studies show no benefit from such high doses. Its potential protective role is an area of active research.

### Storage

Vitamin E is stored indefinitely in adipose tissue.

### **Deficiency Problems with Vitamin E**

- Vitamin E deficiencies do not exist except with diseases that affect absorption of fats.
- Pancreas and gall bladder problems may affect vitamin E absorption.
- Those with cystic fibrosis have problems with vitamin E absorption.
- Vitamin E deficiency is extremely rare in those whose diets are very low in fat for long periods.
- Symptoms of deficiency include ruptured red blood cells from loss of membrane integrity, called **hemolytic anemia**. It sometimes happens in premature infants who do not have a store of vitamin E.
- Neuromuscular damage and damage to the retina of the eye occur with prolonged vitamin E deficiency, but vitamin E supplements do not help those with neuromuscular diseases unrelated to deficiency.

### **Toxicity Problems**

- Vitamin E is a vitamin K antagonist, and effects may be seen with very large doses. Levels of 1000 mg/day do not induce symptoms, however.
- High doses of vitamin E increase the action of anti-clotting (blood-thinning) drugs, and caution should be taken.

### **Food Sources**

- Vitamin E is plentiful in vegetable oils. Many have 10 mg/teaspoon.
- Seeds and nuts are also good sources of vitamin E.
- Small amounts of vitamin E are in many vegetables.

### **Special Considerations**

- Vitamin E is easily oxidized. (That's its job.) Heat and processing destroy vitamin E. Oils used in frying lose vitamin E.
- Most supplements are mixed tocopherols, so the level of active vitamin E is less than the amount of vitamin E listed in the supplement.
- Vitamin E containing creams may improve skin quality, but this is based on anecdotal evidence. If vitamin E is skin healthy, plain vegetable oil contains more vitamin E than the creams and is much less expensive!
- Vitamin E supplements may help one type of leg cramps caused by restricted blood flow to the legs.

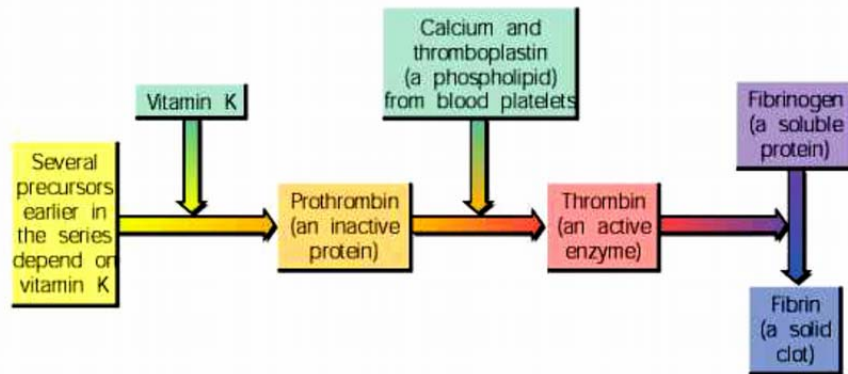
## Vitamin K

### Forms

Vitamin K is found in plants and in bacteria. The form in plants is **phylloquinone**, and in bacteria, **menaquinone**. A synthetic form of vitamin K is menadione.

### Functions

- Vitamin K is a critical blood clotting factor needed to convert prothrombin to thrombin.



- Vitamin K also works with Vitamin D in maintaining bone structure.

### Recommended Amount

- Adults need between 90 (women) – 120 (men)  $\mu\text{g}/\text{day}$  of Vitamin K. Men need more because they usually have a larger mass and more blood.
- Bacteria in intestine may synthesize about half our requirement.

### Storage

- Vitamin K is stored in the liver.

### Deficiency Problem

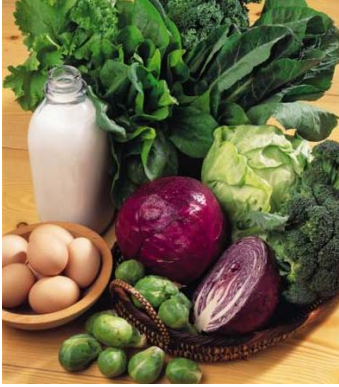
- Blood will not clot in the absence of vitamin K. (That's pretty serious.)
- Short term deficiencies can occur if/when you have(are):
  - poor fat absorption
  - taking antibiotics
  - serious diarrhea
  - taking sulfa drugs
  - taking anticoagulant medications that are Vitamin K antagonists

### Toxicity Problems

Toxicity can occur when taking synthetic Vitamin K supplements. The symptoms are more severe in infants and in pregnant women, and include:

- Jaundice (hyperbilirubinemia)
- Hemolysis (destruction of red blood cells)
- Brain damage from the bilirubin pigments

### Food Sources of Vitamin K



- Cruciferous vegetables
- Other dark green leafy vegetables
- Liver
- Milk (some)
- Eggs (some)

### Special Considerations

Newborn infants are often given a vitamin K supplement to establish a reserve.

### **The "Vitamins" That Aren't Vitamins**

Recall that a vitamin is an essential nutrient, one that cannot be synthesized by body tissues, or not synthesized in adequate amounts from precursors. The exceptions are vitamin D, which can be synthesized from cholesterol precursors in the skin with adequate UV light so long as the liver and kidney can provide maturation factors, and niacin that can be synthesized from surplus tryptophan in the diet. Vitamin A can be synthesized from carotene in the diet. There are a number of substances needed by cells and tissues that are readily synthesized in our bodies. We have no need to take these as supplements. There are some other substances, not needed by the body, that are sometimes claimed to be vitamins that are beneficial to health. This section will discuss some of these substances.

### **Choline**

Choline is the phosphate group from lecithin, the phospholipid that is found in all unprocessed foods. Choline can also be manufactured from the amino acid methionine so it is not essential. However, if the diet lacks choline, (meaning lacks sufficient whole foods) we do not synthesize sufficient amounts, so for some, choline is considered a conditional requirement. Choline is a component of acetylcholine, a neurotransmitter.

Overdoses of choline can cause:

- dizziness and nausea
- heart malfunction
- diarrhea

### **Inositol**

Inositol is another component of phospholipids, but no known requirement for it has been established. We consume about 1 gm/day in foods we eat.

### **Carnitine**

Carnitine is found in muscle and liver tissue, and these tissues synthesize all that is needed. Elevated levels of carnitine are believed, by some, to delay the onset of heart pain during exercise. Healthy muscle tissue generally has higher levels of carnitine, but that does not mean that carnitine promotes healthy muscle development.

There are a host of non-vitamins that have no identified function in humans that include:

- **Bioflavonoids (Vitamin P or hesperidin)** May inhibit cataract formation in diabetics, by inhibiting the enzyme that promotes the cataract formation.
- **PABA (Para-aminobenzoic Acid)** Neutralizes sulfa drugs and does prevent sunburn when used topically.
- **Lipoic Acid** May stimulate some cancers.

- **Ubiquinone (Coenzyme Q)** Quinones are fat-soluble electron carriers in cell respiration, functioning in electron transport along with the cytochromes. All cells contain them and there is no reason to think we do not manufacture all that we require.
- **Laetrile (B<sub>17</sub>)** Laetrile is a cyanogenic glucoside found naturally in the seeds of plants of the Rose family. It is claimed to be a cancer cure but there is no evidence to support such claims and some people have died from the cyanide concentration in laetrile. It has been largely discredited.
- **Pangamic Acid (B<sub>15</sub>)** is another apricot pit derivative claimed to cure almost everything. Like laetrile, no benefits have been demonstrated and it may be mutagenic.