

What is the role of vitamin A in vision and other functions?

LO 6 Discuss the contribution of vitamin A to vision, cell differentiation, and growth and reproduction.

As early as AD 30, the Roman writer Aulus Cornelius Celsus described in his medical encyclopedia, *De Medicina*, a condition called night blindness and recommended as a cure the consumption of liver. We now know that night blindness is due to a deficiency of vitamin A, a fat-soluble vitamin stored primarily in the liver of animals. When we consume vitamin A, we store 90% in our liver, and the remainder in our adipose tissue, kidneys, and lungs.

There Are Several Forms of Vitamin A



There are three active forms of vitamin A in our body: retinol is the alcohol form, retinal is the aldehyde form, and retinoic acid is the acid form. These three forms are collectively referred to as the *retinoids*. Of the three, retinol has the starring role in maintaining our body's physiologic functions. Remember from the previous section that beta-carotene is a precursor to vitamin A. When we eat foods that contain beta-carotene, it is converted to retinol in the wall of our small intestine.

The unit of expression for vitamin A is Retinol Activity Equivalents. You may still see the expression Retinol Equivalents (RE) or International Units for vitamin A on food labels and dietary supplements.

Vitamin A Is Essential to Sight

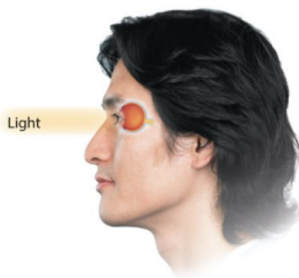
Vitamin A enables our eyes to react to changes in the brightness of light, and to distinguish between various wavelengths of light—in other words, to see different colors. Let's take a closer look at this process.



Watch a 3-minute video of the process of vision from the National Library of Medicine at www.nlm.nih.gov/medlineplus/ency/anatomyvideos/000109.htm

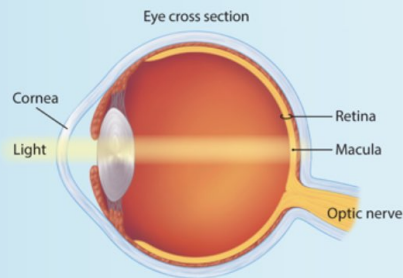
Light enters our eyes through the cornea, travels through the lens, and then hits the retina, which is a delicate membrane lining the back of the inner eyeball (**Focus Figure 8.18**). You might already have guessed how *retinal* got its name: it is found in—and is integral to—the retina. In the retina, retinal combines with a protein called *opsin* to form rhodopsin, a light-sensitive pigment. Rhodopsin is found in the *rod cells*, which are cells that react to dim light and interpret black-and-white images.

Focus Figure 8.18 Vitamin A's Role in Vision

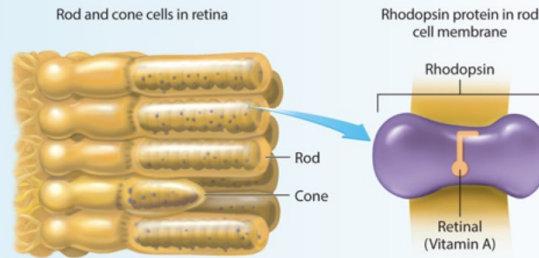


Vitamin A is a component of two light-sensitive proteins, rhodopsin and iodopsin, that are essential for vision. Here we examine rhodopsin's role in vision. Although the breakdown of iodopsin is similar, rhodopsin is more sensitive to light than iodopsin and is more likely to become bleached.

EYE STRUCTURE

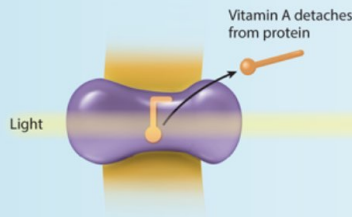


1 After light enters your eye through the cornea, it travels to the back of your eye to the macula, which is located in the retina. The macula allows you to see fine details and things that are straight in front of you.

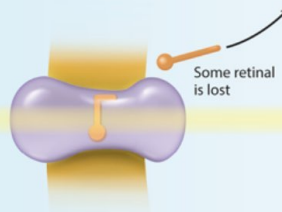


2 Inside the retina are two types of light-absorbing cells, rods and cones. Rods contain the protein rhodopsin, while cones contain the protein iodopsin.

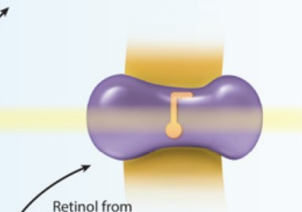
EFFECT OF LIGHT ON RHODOPSIN



1 As rhodopsin absorbs incoming light, the shape of vitamin A is altered, and it detaches from the rhodopsin.



2 This process, called bleaching, causes a cascade of events that transmits visual messages through your optic nerve to your brain. After bleaching, some retinal is lost.



3 Retinol from the blood is converted to retinal to replenish what is lost. The vitamin A returns to its original shape and becomes part of rhodopsin again, regenerating the eye's light-absorbing capabilities. This regeneration can take a few moments.

When light hits the retina, the rod cells go through a *bleaching process*. In this reaction, rhodopsin is split into retinal and opsin, and the rod cells lose their color. The retinal and opsin components also change shape, an event that generates a nerve impulse that travels to the brain, resulting in the perception of a black-and-white image. Most of the retinal is then converted back to its original form and binds with opsin to regenerate rhodopsin, allowing the visual cycle to begin again. However, some of the retinal is lost with each cycle and must be replaced by retinol from the bloodstream. This visual cycle goes on continually, allowing our eyes to adjust to subtle changes in our surroundings or in the level of light.

When levels of vitamin A are deficient, people suffer from night blindness, a condition in which the eyes are unable to adjust to dim light. It can also result in the failure to regain sight quickly after a bright flash of light (Figure 8.19).

Figure 8.19

A deficiency of vitamin A can result in night blindness. This condition results in (a) diminished side vision and overall poor night vision and (b) difficulty in adjusting from bright light to dim light.



(a) Normal night vision



Poor night vision



(b) Normal light adjustment



Slow light adjustment

At the same time we are interpreting black-and-white images, the *cone cells* of the retina, which are only effective in bright light, use retinal to interpret different wavelengths of light as different colors. The pigment involved in color vision, *iodopsin*, experiences similar changes during the color vision cycle as rhodopsin does during the black-and-white vision cycle. As with the rod cells, the cone cells can also be affected by a deficiency of vitamin A, resulting in color blindness.

Vitamin A Supports Cell Differentiation, Reproduction, and Bone Growth

Vitamin A also contributes to cell differentiation, the process by which stem cells mature into highly specialized cells that perform unique functions. It begins when the retinoic acid form of vitamin A interacts with receptor sites on a cell's DNA. This interaction influences gene expression and the type of cells that the stem cells eventually become. Obviously, this process is critical to the development of healthy tissues, organs, and body systems.

For example, vitamin A is necessary for differentiation of epithelial cells such as skin cells and the mucus-producing cells lining the lungs, eyes, bladder, and other organs. The mucus that epithelial cells produce lubricates the tissue and helps us eliminate microbes and irritants (e.g., when we cough up secretions or empty our bladder). When vitamin A levels are insufficient, the epithelial cells fail to differentiate appropriately, and we lose these protective barriers against infectious microbes and irritants. Vitamin A is also critical to the differentiation of specialized immune cells called *T-cells*, which assist in fighting infections. You can therefore see why vitamin A deficiency significantly increases the risk of infectious disease.

Vitamin A is also involved in reproduction. Although its exact role is unclear, it appears necessary for sperm production and for fertilization. It also contributes to healthy bone growth by assisting in breaking down old bone, so that new, longer, and stronger bone can develop. As a result of a vitamin A deficiency, children suffer from stunted growth and wasting.

Some research has indicated that vitamin A may act as an antioxidant by scavenging free radicals and protecting LDLs from oxidation. However, it is unclear if vitamin A makes some minimal contribution to antioxidant function.

Avoid Excessive Intake of Vitamin A

Vitamin A can be obtained from both plant and animal sources. To calculate the total RAE in your diet, you must take into consideration both the amount of retinol and the amount of provitamin A beta-carotene you consume. For example, because 12 µg of beta-carotene yields 1 µg of RAE, if a person consumes 400 µg retinol and 1,200 µg of beta-carotene, the total RAE is equal to $400\text{ }\mu\text{g} + (1,200\text{ }\mu\text{g} \div 12)$, or 500 µg RAE.

Recommended Intakes and Food Sources of Vitamin A

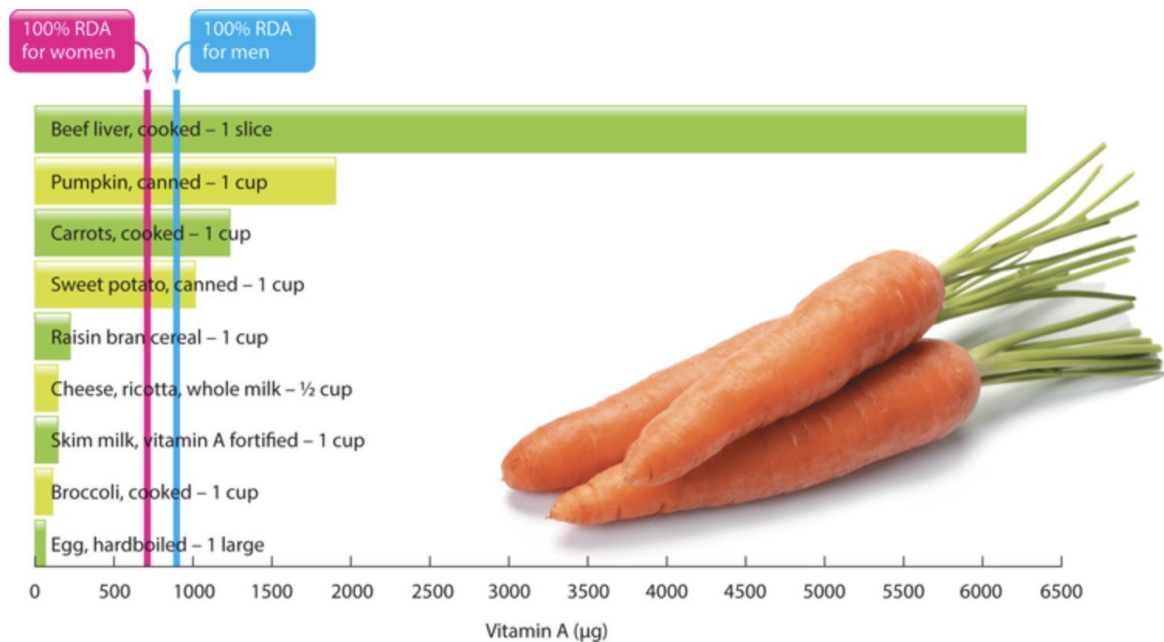
Vitamin A toxicity can occur readily because it is a fat-soluble vitamin, so it is important to consume only the amount recommended for your gender and age range (see [Table 8.1](#)). The UL is 3,000 µg per day of preformed vitamin A in women (including those pregnant and lactating) and men.

The most abundant natural sources of dietary preformed vitamin A are animal foods, such as beef liver, chicken liver, eggs, and whole-fat dairy products. Vitamin A is also found in fortified reduced-fat milks, margarine, and some breakfast cereals ([Figure 8.20](#)).

Figure 8.20

Common food sources of vitamin A. The RDA for vitamin A is 900 µg/day for men and 700 µg/day for women.

Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2015. USDA Nutrient Database for Standard Reference, Release 28.



Other good sources of vitamin A are foods high in beta-carotene and other carotenoids that can be converted to vitamin A. Carrots, spinach, mango, cantaloupe, and tomato juice are examples.



Vitamin A Toxicity and Deficiency

Vitamin A is highly toxic, and toxicity symptoms develop after consuming only three to four times the RDA. Toxicity rarely results from food sources, but vitamin A supplementation is known to have caused severe illness and even death. In pregnant women, it can cause serious birth defects and spontaneous abortion. Other toxicity symptoms include fatigue, loss of appetite, blurred vision, hair loss, skin disorders, diarrhea, and damage to the liver and nervous system. If caught in time, many of these symptoms are reversible once vitamin A supplementation is stopped. However, permanent damage can occur to the liver, eyes, and other organs. Because liver contains such a high amount of vitamin A, children and pregnant women should not consume liver on a daily or weekly basis.

Although not common among people of developed nations, vitamin A deficiency is a severe public health concern in developing nations. According to the World Health Organization, approximately 250 million preschool children worldwide suffer from vitamin A deficiency,²² which can result in irreversible blindness. This occurs because lack of vitamin A causes the epithelial cells of the cornea (the transparent membrane covering the front of the eye) to lose their ability to produce mucus, causing drying, hardening, and an increased risk for damage and infection.

Vitamin A deficiency can also lead to follicular *hyperkeratosis*, a condition in which a protein called keratin clogs hair follicles, and the skin becomes dry, thick, rough, and bumpy. Other deficiency symptoms include impaired immunity, increased risk for illness and infections, reproductive system disorders, and failure of normal growth. Individuals who are at risk for vitamin A deficiency include newborn or premature infants (due to low liver stores of vitamin A), and people with poor diets. Any condition that results in fat malabsorption can also lead to vitamin A deficiency.

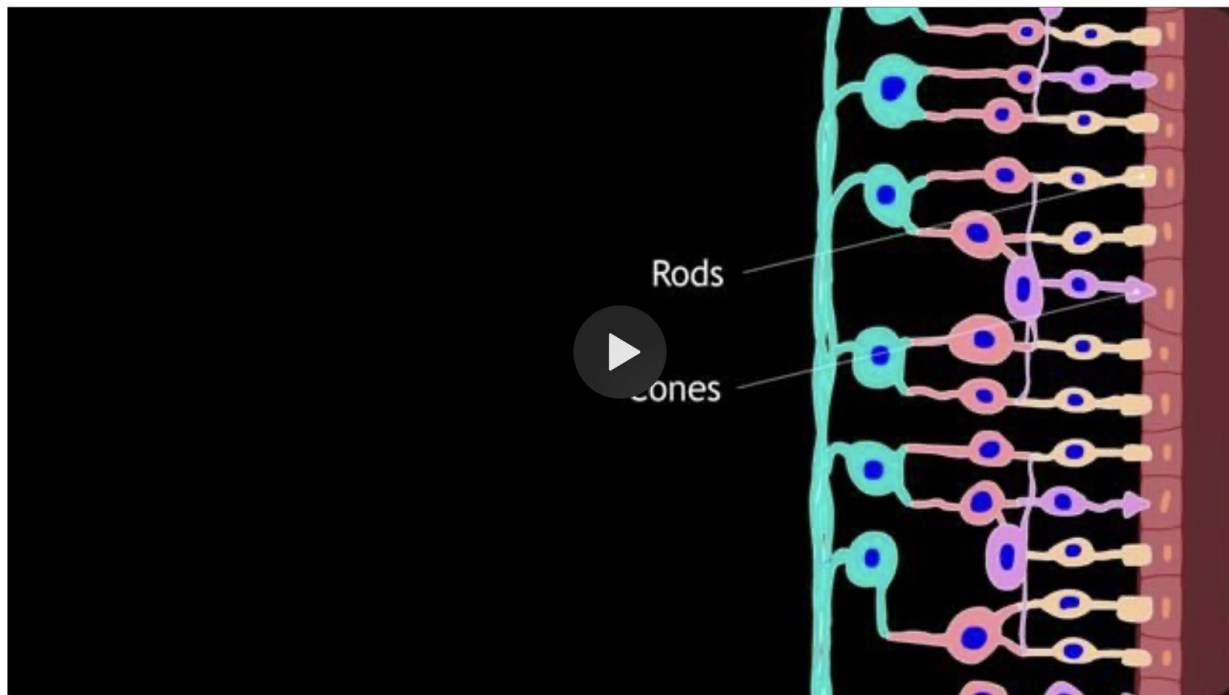
Vitamin A Derivatives Are Effective in Treating Acne

Acne is a skin disorder affecting approximately 50 million Americans.²³ The characteristic lesions form when an oily substance called sebum accumulates in hair follicles, typically on the face and upper torso. The deposits can become infected, resulting in painful cysts that sometimes leave scars.

Vitamin A is commonly identified on the Internet as an effective treatment for acne. However, there are no well-conducted studies linking vitamin A intake or status directly with acne, and vitamin A supplements are not recommended in acne treatment. In contrast, synthetic derivatives of vitamin A are effective treatments. These drugs, which are classified as retinoids, work by affecting the body's rate of replacement of skin cells. Retinoids are available by prescription and over-the-counter (OTC).

Prescription retinoids include Retin-A (or tretinoin) and isotretinoin. Retin-A is a cream applied to the skin. It may cause skin redness, irritation, and worsening of acne in the initial weeks of use, as well as increased sensitivity to the sun. Retin-A is absorbed from the skin into body tissues, and its use during pregnancy is not recommended. Isotretinoin is taken orally. It also typically causes a temporary worsening of acne in the initial weeks of use, as well as dry lips, dry skin, and increased risk of sunburn. Because of the high risk for severe birth defects associated with its use, isotretinoin is prescribed in women only as part of a special procedure, including pregnancy testing and mandatory use of effective contraceptives. The drug is also associated with a variety of other complications, from vision disorders to inflammatory bowel disease. In 2009, lawsuits stemming from complications of the drug caused one pharmaceutical company to remove their version of the drug (called Accutane) from the U.S. market.

In 2016, the U.S. Food and Drug Administration (FDA) approved an OTC topical retinoid called Differin Gel 0.1% (adapalene) for treatment of acne. It is the only OTC retinoid approved for acne. Although there is inadequate research on Differin Gel in pregnant women, absorption of the drug is limited, and there is no evidence that its use causes birth defects.²³



Recap

Vitamin A is critical for maintaining our vision. It is also necessary for cell differentiation, reproduction, and growth. The role of vitamin A as an antioxidant is still under investigation. Animal liver, dairy products, and eggs are good animal sources of vitamin A; fruits and vegetables are high in beta-carotene, a pro-vitamin for vitamin A. Supplementation can be dangerous because toxicity is reached at levels of only three to four times the RDA. Toxicity can cause birth defects, spontaneous abortion, organ damage, and other disorders. Deficiency symptoms include night blindness, hyperkeratosis, impaired immune function, and growth failure. Vitamin A supplements are not effective in treating acne; however, a class of retinoid medications can provide effective treatment.