Vegetables and fruits are not only rich in nutrition, but also rich in color. A carrot, a vegetable well-known for its contribution to maintaining good eye health, for example, has a vibrant orange color. Have you ever wondered why carrots are orange? And why is it that carrots do such a good job at maintaining good eye health? Surprisingly, the answer to both of these questions is the molecule beta-carotene.

Beta-carotene is a strongly colored red-orange pigment abundant in vegetables and fruits, especially in carrots and colorful vegetables. Beta-carotene is only manufactured in plants, not in humans and animals. In plants, beta-carotene absorbs light and energy, and is transferred to the chlorophyll for photosynthesis. The color fruits and vegetables have is due to the light that is not absorbed by the pigments and is reflected back to the environment. This is why carrots and other vegetables and fruits look the way they do - because beta-carotene reflects red orange and yellow light back into the eyes. There are many vegetables and fruits that contain beta-carotene; some of them are onions, broccoli, spinach, apricots, sweet potatoes, cantaloupes, pumpkins, and various herbs. As the name suggests, the name carotene is derived from the vegetable carrot, which in Latin is “carota”. Beta-carotene was named after carrots because the chemical was first discovered via crystallization of carrot roots in 1831. Wachenroder, the scientist who crystallized beta-carotene from carrot roots, came up with the name "carotene."

The chemical formula of beta-carotene is $C_{40}H_{56}$ and its structure was deduced by Paul Karrer in 1930. Beta-carotene is an organic compound and is classified as a hydrocarbon, specifically as a terpenoid. In addition, beta-carotene is a non-polar compound and is lipophilic, which means that it has the ability to dissolve in fats, oils, lipids, and other non-polar solvents. Its molar mass is 536.87g/mol, has a density of 0.94g/cm$^3$, melting point of 180 degrees Celsius, and a boiling point of 633 to 677 degrees Celsius.
Besides enriching vegetables and fruits with their vibrant color, beta-carotene is also important for human health. When humans consume vegetables and fruits, the beta-carotene enters the human body, and then is converted into vitamin A (retinol). The two cyclohexyl rings in the beta-carotene molecule cleave either symmetrically or asymmetrically. The symmetric cleavage is done by the enzyme beta-carotene-15,15'-dioxygenase in the human body. When beta-carotene is cleaved symmetrically, two equivalent retinal molecules are formed. The two retinal molecules further react until they become reinoic acid and retinol, or vitamin A. Vitamin A is crucial for maintaining health in skin, immune system, and eyes. When beta-carotene is cleaved asymmetrically, beta-apocarotenal is formed instead. Asymmetric cleavage significantly decreases the retinoic acid levels.

Not all of beta-carotene is converted into vitamin A. Less than a quarter of the carotene in root vegetables and about half of the carotene in leafy green vegetables is converted into vitamin A. Some unconverted carotene is absorbed into the circulatory system and stored in the fat tissues. The rest of the unabsorbed carotene is excreted in the feces. People suffering from diabetes or liver disease often have difficulty converting beta-carotene to vitamin A. Moreover, strenuous exercises shortly after eating, illnesses, eating alcohol of fried foods, and cold weather all hinder the metabolism of beta-carotene. Also, gastric pH level is also known to change beta-carotene absorption. In 1981 and 1984, a study was conducted by the Boston Nutritional Status Survey, and it was discovered that carotenoid values were lowest for subjects with severe atrophic gastritis, a condition in which little hydrochloric acid is secreted by the stomach. A diet consisting of low amounts of fat and oils also hinder the digestion of beta-carotene. Beta-carotene cannot dissolve in water and need fat and oil for absorption through the intestinal wall. Therefore, intake of fats and oil via foods such as butter, olive, flaxseed, corn, canola, and soy are crucial for proper beta-carotene digestion.
Absorption of beta-carotene can be increased by steaming, juicing, or mashing vegetables. By doing so, the cell membranes are ruptured and as a result carotene becomes more available for absorption. If eaten raw, vegetables and fruits should be chewed well to maximize beta-carotene absorption. Raw vegetables and fruits contain beta-carotene in all-trans configuration and cooked vegetables and fruits contain cis-configuration beta-carotene. The cis isomers are shorter in length, more stable, and more bioavailable. Therefore, it is best to cook vegetables and fruits in order to consume beta-carotene in its most absorbable cis form. The converted beta-carotene is absorbed by the human body in 6 to 7 hours.

![cis and trans beta-carotene](http://www.alternativemed.com/publications/5/6/530.pdf)

Beta-carotene is beneficial to humans in many ways. To begin, beta-carotene helps detoxify pollutants such as pesticides, fertilizer residues, industrial poisons, and toxic drugs. Vitamin A stored in the liver purifies the blood and the purified blood increases resistance to infection and inflammation. Second, beta-carotene increases the immune system's T-cell activity. The T-cell protects the body against a wide range of allergens, bacteria, and viruses. Beta-carotene also strengthens the immune response of the human body and is known to have a profound effect on the thymus gland where immune cells are synthesized. Third, beta-carotene enhances the production of RNA, a nucleic acid that transmits instructions to all cells inside the human body.

Another characteristic of beta-carotene is that it is an antioxidant. An antioxidant inhibits the oxidation of other molecules and protects the body from free radicals. Without antioxidants, free radicals damage cells through oxidation and the damages lead to many different illnesses. Some of the most harmful illnesses caused by free radicals are cancer and heart disease. Therefore, by consuming vegetables and fruits rich in beta-carotene, one can lower the chances of cancer of heart disease. Also, some suggest that beta-carotene help people with the genetic condition erythropoietic protoporphyria. Also, intake of beta-carotene improves osteoarthritis, Alzheimer's disease, and cystic fibrosis. Additionally, beta-carotene helps protect the soft tissue and linings of the digestive tract, kidneys, and bladder, and helps heal stomach ulcers. Beta-carotene also protects the skin from aging, helps with the secretion of gastric juices necessary for proper digestion of proteins, helps build strong teeth and bones, and helps the formation of visual purple - a substance in the eye necessary for proper night vision. Additionally, beta-carotene speeds wound healing, soothes mucus membranes, eases aching joints, eases pain of arthritis, and protects against colon cancer.
Ironically, however, consuming a high dose of artificially created beta-carotene supplements is known to increase cancer and heart disease in smokers. Beta-carotene and smoking is known have harmful synergistic effects. Studies conducted in 1994 and 1996 by the National Cancer Institute indicated that high dosage of beta-carotene supplements significantly increased the risk of lung cancer and heart disease among smokers. Due to the alarming results, the experiment was stopped 21 months prematurely. Out of 18,314 smokers tested, there was a 28 percent increased risk of lung cancer for those who took beta-carotene supplements. However, when consumed as a whole-foods form, beta-carotene is not harmful. In 2004, Cancer Epidemiology Biomarkers and Prevention found that when beta-carotene was taken in whole-foods form, it posed no threat to cancer. Therefore, it is best to take beta-carotene from the natural food, and not from excess supplements.

Although there is a recommended dietary allowance for vitamin A, there is no specific recommended dietary allowance for beta-carotene, the precursor of vitamin A. The suggestion is that beta-carotene should be taken between 15 and 180 milligrams a day. When beta-carotene is taken in regular amounts, it has very few side effects. Excessive consumption of beta-carotene can lead to side effects such as carotenodermia, the orange coloring of the skin. Carotenodermia occurs from the deposition of the carotenoid in the outermost layer of the epidermis. However, this is temporary and relatively harmless because the symptom disappears when intake is reduced.
References

8. http://www.carrotmuseum.co.uk/betacarotene.html