



# MACRONUTRIENTS, MICRONUTRIENTS AND WATER

## MACRONUTRIENT STRUCTURE AND FUNCTION

### **FOOD IS COMPOSED OF SOME COMBINATION OF THREE**

macronutrients: carbohydrate, protein, and fat. The term macronutrient simply means that the nutrient is needed in large quantities for normal growth and development. Macronutrients are the body's source of calories, or energy to fuel life processes.

### **CARBOHYDRATES**

Carbohydrates are the body's preferred energy source. Made up of chains of sugar molecules, carbohydrates contain about 4 calories per gram. A monosaccharide is the simplest form of sugar. The three monosaccharides are glucose, fructose, and galactose. Glucose is the predominant sugar in nature and the basic building block of most other carbohydrates. Fructose, or fruit sugar, is the sweetest of the monosaccharides and is found in varying levels in different types of fruits. Galactose joins with glucose to form the disaccharide lactose, the principal sugar found in milk. Other disaccharides include maltose, which is two glucose molecules bound together, and sucrose (table sugar), which is formed by glucose and fructose linked together.

An oligosaccharide is a chain of about three to 10 or fewer simple sugars. A long chain of sugar molecules is referred to as a polysaccharide. Glycogen, an animal carbohydrate found in meat products and seafood, and starch, a plant carbohydrate found in grains and vegetables, are the only polysaccharides that humans can fully digest. Both are long chains of glucose and are complex carbohydrates (versus simple carbohydrates, which are short chains of sugar).

Carbohydrates consumed in the diet that are not immediately used for energy are stored as glycogen. Glycogen is stored in the liver and muscle cells and can be broken down into single glucose molecules to provide a rapid source of energy. The amount of stored glycogen can be increased fivefold with physical training (Mahan & Escott-Stump, 2000). Carbohydrate loading also increases glycogen stores. Because glycogen contains many water molecules, it is large and bulky and therefore unsuitable for long-term energy storage. Thus, if a person continues to consume more carbohydrates than the body can use or store, the body will convert the sugar into fat for long-term storage.

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## PROTEIN



Proteins contain 4 calories per gram and are the building blocks of human and animal structure. Proteins serve innumerable functions in the human body, including the following: formation of the brain, nervous system, blood, muscle, skin and hair; the transport mechanism for iron, vitamins, minerals, fats and oxygen; and the key to acid–base and fluid balance. Proteins form enzymes, which speed up chemical reactions to milliseconds that might otherwise take years. Antibodies that the body makes to fight infection are made from proteins. In situations of energy deprivation, the body can break down proteins for energy.

Proteins are built from amino acids, which are carbohydrates with a nitrogen-containing amino group and, in some cases sulfur, attached. Proteins, or polypeptides, form when amino acids are joined together through peptide bonds. Eight to 10 essential amino acids cannot be made by the body and must be consumed in the diet. A specific food's protein quality is determined by assessing its essential amino-acid composition, digestibility and bioavailability, or the degree to which the amino acids can be used by the body. Generally, animal products contain all of the essential amino acids (called complete proteins), while plant foods do not. One notable exception is soy, which is a plant-based complete protein. Therefore, animal proteins and soy are better sources of quality protein than plants. However, combining complementary incomplete plant proteins that together can provide all of the essential amino acids boosts the protein quality. Excellent combinations include grains-legumes (e.g., rice/beans), grains-dairy (e.g., pasta/cheese), and legumes-seeds (e.g., falafel).

## FATS

The most energy-dense of the macronutrients, fat provides 9 calories per gram. Ounce for ounce, this is 2.25 times more calories than both carbohydrate and protein. Fats serve many critical functions in the human body, including insulation, cell structure, nerve transmission, vitamin absorption, and hormone production. The body stores adipose tissue (fat) as triglyceride. Unsaturated fatty acids contain one or more double bonds between carbon atoms, are typically liquid at room temperature and are fairly unstable, making them susceptible to oxidative damage and a shortened shelf life. Monounsaturated fat contains one double bond between two carbons. Common sources include olive, canola and peanut oils. Polyunsaturated fat contains a double bond between two or more sets of carbons. Sources include corn, safflower, and soybean oils and cold water fish. Essential fatty acids are a type of polyunsaturated fat that must be obtained from the diet. Unlike other fats, the body cannot produce omega-3 (linolenic acid) or omega-6 (linoleic acid) fatty acids. Omega-3 fatty acids come in three forms: alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexanoic acid (DHA). ALA is the type of omega-3 found in plants. It can be converted to EPA and DHA in the body, but the research supporting the benefits of ALA is much less compelling than that for EPA and especially DHA. DHA and EPA omega-3 fatty acids are naturally found in egg yolk and cold-water fish and shellfish like tuna, salmon, mackerel, cod, crab, shrimp and oyster. Overall, omega-3s reduce blood clotting, dilate blood vessels and reduce inflammation. They are important for eye and brain development (and are especially important for a growing fetus in the late stages of pregnancy); act to reduce cholesterol and triglyceride levels; and may help to preserve brain function and reduce the risk of mental illness and attention deficit hyperactivity disorder (ADHD), though more research is needed to confirm these mental health benefits. Notably, most Americans tend not to



get enough omega-3 fatty acids. Though natural food sources are best, people who do not meet this recommendation may benefit from supplementation or from fortified foods. While there is no established Dietary Reference Intake (DRI) for the optimal amount of EPA+DHA intake, some expert panels have recommended an intake between 250 and 500 mg per day. This dosage is likely safe and effective to achieve the benefits of the omega-3s without increased risk of complications such as bleeding. Of note, while many products claim to be fortified with omega-3s, it is important for consumers to read the label. If the omega-3s are mostly ALA (as is the case with the omega-3-fortified bread at Subway®), they are unlikely to be optimally converted to EPA and DHA and likely have fewer of the health benefits. If the added omega-3s are of a negligible amount, it is also unlikely that the added cost of the product is worth the limited benefit.



Omega-6, which is generally consumed in abundance, is an essential fatty acid found in flaxseed, canola, and soybean oils and green leaves. It works opposite to omega-3s in that it seems to contribute to inflammation and blood clotting. The balancing act between omega-6 and omega-3 is essential for maintaining normal circulation and other biological processes. In the past, scientists had hypothesized that reducing consumption of omega-6 fatty acids and increasing consumption of omega-3 fatty acids may lower chronic disease risk, but more recent research has shown that maintaining a high consumption of both omega-3 and omega-6 fatty acids has cardiovascular health benefits (Harris, 2010). The American Heart Association recommends that Americans consume 5 to 10 percent of calories as omega-6 polyunsaturated fatty acids—that is about 12 g/day for women and 17 g/day for men (Harris et al., 2009).

Some fats—notably saturated fats and trans fats—lead to clogging of the arteries, increased risk for heart disease, and myriad other problems. Saturated fatty acids contain no double bonds between carbon atoms, are typically solid at room temperature and are very stable. Foods high in saturated fat include red meat, full-fat dairy products and tropical oils like coconut and palm. Saturated fat increases levels of low-density lipoprotein (LDL) cholesterol, the “bad” cholesterol.

Trans fat, which may be listed as “partially hydrogenated” oil on a food ingredient list, results from a manufacturing effort to make unsaturated fat solid at room temperature in order to prolong its shelf life. The process involves breaking the double bond of the unsaturated fat. The product is a heart-damaging fat that increases LDL cholesterol even more than saturated fat. Due to legislation requiring food manufacturers to include the amount of trans fat on the nutrition label if it is more than 0.5 g per serving, many processed foods that used to be high in trans fat, such as chips, crackers, cakes, peanut butter, and margarine, are now “trans-fat free.” Clients and participants should be advised to check the label and look on the ingredients list for “partially hydrogenated” oil to determine if a food still contains small amounts of trans fat. If so, they should avoid that food.



Cholesterol, a fat-like, waxy, rigid four-ring structure, plays an important role in cell membrane function. It also helps to make bile acids (which are important for fat absorption), metabolize fat-soluble vitamins (A, D, E, and K), and make vitamin D and some hormones such as estrogen and testosterone. Saturated fat, converted to cholesterol in the liver, is the main dietary cause of hypercholesterolemia (high blood levels of cholesterol), though high levels of cholesterol are also found in animal products such as egg yolks, meat, poultry, fish, and dairy products. Cholesterol causes problems when there is too much of it in the bloodstream. For cholesterol to get from the liver to the body’s cells (in



the case of endogenously produced cholesterol), or from the small intestine to the liver and adipose tissue (in the case of exogenously consumed cholesterol) it must be transported through the bloodstream. Because it is fat-soluble, it needs a water-soluble carrier protein to transport it. When the cholesterol combines with this protein en route to the body's cells, it is termed LDL. LDL is susceptible to getting stuck in the bloodstream and clogging the arteries, thus forming a plaque and causing atherosclerosis. High-density lipoprotein (HDL) cholesterol, the “good cholesterol,” removes excess cholesterol from the arteries and carries it back to the liver where it is excreted.

## MICRONUTRIENT REQUIREMENTS AND RECOMMENDATIONS

The World Health Organization (WHO) refers to micronutrients, so called because they are only needed in small amounts, as the “magic wands” that enable the body to produce enzymes, hormones and other substances essential for proper growth and development” (WHO, 2007). When the body is deprived of micronutrients, consequences are severe. But when consumed in just the right amounts, they are key to optimal health and function.

Importantly, though a fitness professional can be a valuable source of nutrition knowledge, when a fitness professional suspects that an individual may have an inadequate or excessive intake of a particular vitamin or mineral, it is important to refer that individual to a registered dietitian for a nutrition assessment or to the individual's primary care physician. Fitness professionals should avoid advising people to consume specific amounts of food or supplement sources of micronutrients.

## VITAMINS

Vitamins are organic, non-caloric micronutrients that are essential for normal physiologic function. Vitamins must be consumed through food with only three exceptions: vitamin K and biotin can also be produced by normal intestinal flora (bacteria that live in the intestines and are critical for normal gastrointestinal function), and vitamin D can be self-produced with sun exposure. No “perfect” food contains all the vitamins in just the right amount; rather, a variety of nutrient-dense foods must be consumed to assure adequate vitamin intakes. Many foods (such as breads and cereals) have been fortified with some nutrients to decrease the risk of vitamin deficiency. And some foods contain inactive vitamins—called provitamins. Fortunately, the human body contains enzymes to convert these inactive vitamins into active vitamins.

Humans need 13 different vitamins, which are divided into two categories: water-soluble vitamins and fat-soluble vitamins. Thiamin, riboflavin, niacin, pantothenic acid, folate, vitamin B6, vitamin B12, biotin, and vitamin C are the water-soluble vitamins. Their solubility in water (which gives them similar absorption and distribution in the body) and their role as cofactors of enzymes involved in metabolism (i.e., without them the enzyme will not work) are common traits. With the exception of vitamins B6 and B12, water-soluble vitamins cannot be stored in the body and are readily excreted in urine. This decreases the risk of toxicity from overconsumption and also makes their regular intake a necessity. Folate (vitamin B9; also known as “folic acid” in its supplement form)—named for its abundance in plant foliage (like green leafy vegetables)—deserves special mention due to its crucial role during pregnancy. Folate is essential for





production of deoxyribonucleic acid (DNA), red and white blood cell formation, neurotransmitter formation and amino-acid metabolism. Deficiency is relatively common, as folate is easily lost during food preparation and cooking and because most people do not eat enough green leafy vegetables. Folate deficiency early in pregnancy can be devastating for a developing fetus, leading to neural tube defects such as spina bifida. Deficiency also causes a megaloblastic anemia, skin lesions, and poor growth. Notably, excessive consumption of folate can mask a vitamin B12 deficiency.

Vitamins A, D, E and K are the fat-soluble vitamins. Often found in fat-containing foods and stored in the liver or adipose tissue until needed, fat-soluble vitamins closely associate with fat. If fat absorption is impaired, so is fat-soluble vitamin absorption. Unlike water-soluble vitamins, fat-soluble vitamins can be stored in the body for extended periods of time and eventually are excreted in feces. This storage capacity increases the risk of toxicity from overconsumption, but also decreases the risk of deficiency.

Choline, called a “quasi-vitamin” because it can be produced in the body but also provides additional benefits through consumption from food, is also important since it plays a crucial role in neurotransmitter and platelet function and may help to prevent Alzheimer’s disease.

## MINERALS

Serving roles as varied as regulating enzyme activity and maintaining acid–base balance to assisting with strength and growth, minerals are critical for human life. Unlike vitamins, many minerals are found in the body as well as in food. The body’s ability to use the minerals is dependent on their bioavailability. Nearly all minerals, with the exception of iron, are absorbed in their free form—that is, in their ionic state unbound to organic molecules and complexes. When bound to a complex, the mineral is considered to not be bioavailable and it will be excreted in feces. Typically, minerals with high bioavailability include sodium, potassium, chloride, iodide, and fluoride. Minerals with low bioavailability include iron, chromium, and manganese. All other minerals, including calcium and magnesium, are of medium bioavailability.

An important consideration when consuming minerals, and particularly when people take mineral supplements, is the possibility of mineral-to-mineral interactions. Minerals can interfere with the absorption of other minerals. For example, zinc absorption may be decreased through iron supplementation. Zinc excesses can decrease copper absorption. Too much calcium limits the absorption of manganese, zinc, and iron. When a mineral is not absorbed properly, deficiency may develop.

Serving a variety of functions in the body, minerals are typically categorized as macrominerals (bulk elements) and microminerals (trace elements). Macrominerals include calcium, phosphorus, magnesium, sulfur, sodium, chloride and potassium. Microminerals include iron, iodine, selenium, zinc, and various other minerals that do not have an established DRI and will not be discussed here.

## WATER

Although it provides no calories and is inorganic in nature, water is as important as the oxygen people breathe. Loss of only 20% of total body water may cause death, while a 10% loss causes severe disorders. In general, adults can survive up to 10 days without water, while children can live up to five days (Mahan & Escott-





Stump, 2000). Water is the single largest component of the human body, comprising about 50 to 70 percent of body weight. That is, approximately 85 to 119 lb of a 170-lb man (39 to 54 kg of a 77-kg man) is water weight. Physiologically, this water has many important functions, including regulating body temperature, protecting vital organs, providing a driving force for nutrient absorption, serving as a medium for all biochemical reactions and maintaining a high blood volume for optimal athletic performance.

Water volume is influenced by a variety of factors, including food and drink intake; sweat, urine, and feces excretion; metabolic production of small amounts of water; and respiratory losses of water that occur with breathing. These factors play an especially important role during exercise when metabolism is increased. The generated body heat is released through sweat, a solution of water and sodium and other electrolytes. If fluid intake is not increased to replenish the fluid lost, the body attempts to compensate by retaining more water and excreting more concentrated urine; the person is said to be dehydrated. Severe dehydration can lead to heat stroke. On the other hand, if someone ingests excessive amounts of fluid to compensate for minimal amounts of water lost in sweat, he or she may become fluid overloaded, or hyponatremic. When the blood's water:sodium ratio is severely elevated, excess water can leak into brain tissue, leading to encephalopathy, or brain swelling.

Diuretics (whether prescribed for diseases such as congestive heart failure or hypertension or consumed as beverages such as coffee) increase the excretion of water and electrolytes by the kidneys. The loss of water leads to decreased blood volume, which can predispose an exerciser to dehydration. A person taking a diuretic should be advised to consume ample fluids before, during, and after exercise, especially in warm, humid environments. ●

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