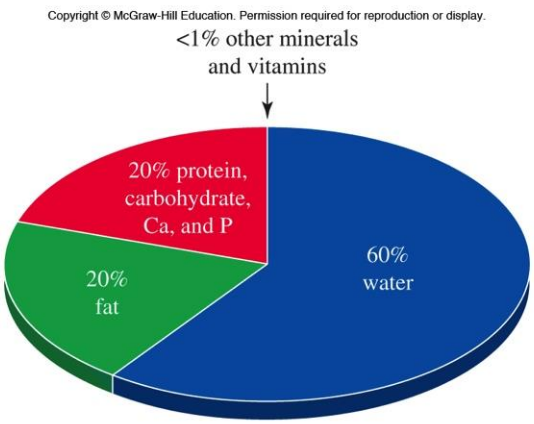
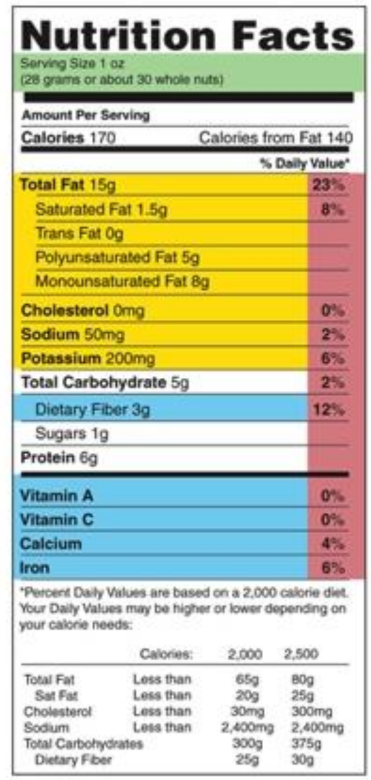
Macronutrients: Fat, Carbohydrate, and Protein

Human bodies are approximately 60% water. Water, however, cannot be burned as a fuel in the body. We need food as an energy source to power muscles, to send nerve impulses, and to transport molecules and ions in our bodies. In addition, food serves as the raw material for bodies, including new bone, blood cells, enzymes, and hair. Food also supplies nutrients essential for metabolism, the complex set of chemical processes that are essential in maintaining life.





Think about the foods you ate yesterday. Did they come to you with minimal or no processing, such as an apple, a baked potato, or a juicy pork chop? Or did you obtain these same foods as apple sauce, French fries, or sliced smoked bacon? The latter are processed foods, foods that have been altered from their natural state by techniques such as canning, cooking, freezing and adding chemicals such as thickeners or preservatives.

Processed foods in the United States must list nutritional information on their labels. These labels, such as the one shown above, include a list of the **macronutrients (fat, carbohydrate and protein)**, minerals and vitamins. Macronutrients provide essentially all of the energy and most of the raw material for your body. Sodium and potassium ions are present in much lower amounts, but these ions are essential for the proper electrolyte balance in the body. Several other minerals and many vitamins are listed in terms of the percent of recommended daily requirements supplied by a single serving of the product. All these substances, whether naturally occurring or added during processing, are chemicals. In fact, all foods are chemicals, even those claiming to be organic or “natural”.

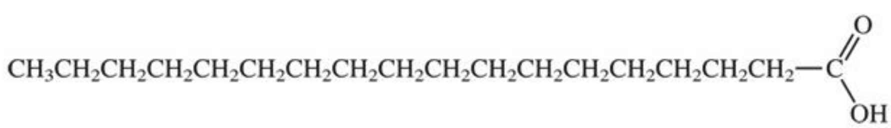
Fats and Oils

From your experiences with ice cream, butter and cheese, you probably know that **fats** can help impart a desirable flavor and texture to food. More generally, fats are greasy, slippery and low-melting solids that are not soluble in water. When melted, they float on the top of broth or soup. Sour cream, frosting, and most pastries are loaded with fats. Most fats are of animal origin, although meats vary in their fat content. You may also know about **oils**, such as those obtained from corn and other vegetables. You may have seen peanut oil forming a layer on top of your peanut butter. You may enjoy eating bread dipped in olive oil. Or you may prepare a loaf of bread using canola oil as the shortening. Many oils are of plant origin. Oils exhibit many of the properties of animal-based fats; but unlike fats, they are liquids at room temperature. Another commonality between fats and oils is that they are both **triglycerides**, molecules that contain three ester functional groups. They are formed from a chemical reaction between **fatty acids** and glycerol (an alcohol). Fats are triglycerides that are solid at room temperature, whereas oils are triglycerides that are liquid at room temperature.

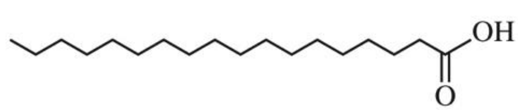
People tend to be preoccupied with dietary fat, as fats pack more Calories than any other nutrients. But fats are far more than just a fuel. Fats enhance our enjoyment of food, improve "mouth feel", and intensify certain flavors. Almost every dessert tastes better with a bit of whipped cream! Fats also are essential for life. They provide insulation that retains body heat and helps to cushion internal organs. Triglycerides and other lipids, including cholesterol, are the primary components of cell membranes and nerve sheaths and our brains are rich in lipids.

In the paragraphs above, we introduced several new terms. Let's get to know these terms, starting with **fatty acids** using stearic acid as an example. Stearic acid has a chemical formula of $C_{17}H_{35}COOH$. The figure below shows several different representations of stearic acid.

Condensed structure formula: **$CH_3(CH_2)_{16}COOH$**



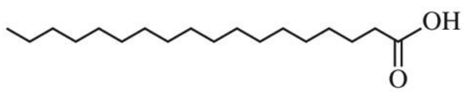
Semi-condensed structure formula



Line-angle drawing

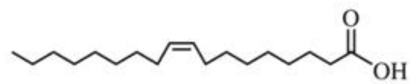
Like all fatty acids, the stearic acid molecule has two important characteristics. One is a long hydrocarbon chain with an even number of carbon atoms, typically 12 to 24 (including the C in the –COOH group). This hydrocarbon chain gives fats and oils their characteristic greasiness. The other important feature of fatty acid is the carboxylic acid group, –COOH, at the end of the hydrocarbon chain. The carboxylic acid group accounts for the "acid" in the name fatty acid.

When reading the nutritional information on food labels, you most likely will see the following listed under "total fat": **saturated fat**, **monounsaturated fat**, **polyunsaturated fat** and ***trans* fat**. What are the differences between these different types of fats? Let's find out. A fatty acid is **saturated** if the hydrocarbon chain contains only single bonds between the carbon atoms. In a saturated hydrocarbon chain, the C atoms contain the maximum number of H atoms that can be accommodated and therefore is saturated in hydrogen. This is the case with stearic acid. In contrast, fatty acids are **unsaturated** if they contain one or more C=C double bonds. Unsaturated fatty acids can be either monounsaturated or polyunsaturated. The difference is how many double bonds per fatty acid molecule. For example, oleic acid, with only one C=C double bond per molecule, is classified as **monounsaturated**. In contrast, linoleic acid (two C=C double bonds per molecule), and linolenic acid (three C=C double bonds per molecule) are both examples of **polyunsaturated** fatty acids.



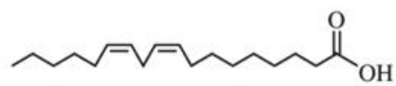
Stearic acid, a **saturated** fatty acid

$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$



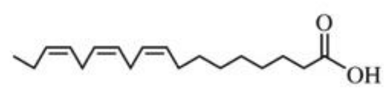
oleic acid, a **monounsaturated** fatty acid

$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$

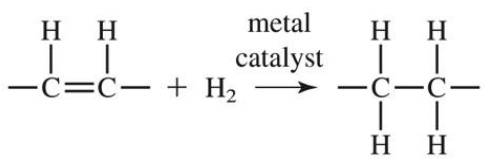


linoleic acid, a **polyunsaturated** fatty acid

$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$



linolenic acid, a **polyunsaturated** fatty acid

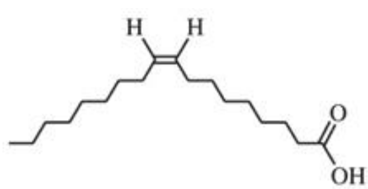


Hydrogenation of oil to increase degree of saturation

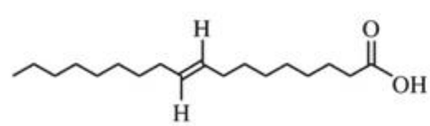
Hydrogenation is a process in which H_2 gas adds to a C=C double bond in the presence of a metal catalyst and converts it to a C−C single bond. This is commonly done to increase the shelf-life of food items containing oil. Hydrogenation also makes the oil more margarine-like, semisolid and spreadable. However, hydrogenation also generates a type of fat that isn't found in nature: ***trans* fat**.

To understand what *trans* fat is, we need to take a closer look at the arrangement of the H atoms attached to the C=C double bonds in unsaturated fatty acids. Two types of unsaturated fatty acids, *cis*- and *trans* fatty acid, exist depending on the arrangement of the H atoms.

- If the H atoms are on the *same* side of the C=C double bond, we call this arrangement *cis*.
- If the H atoms are on the *opposite* side of the C=C double bond, we call this arrangement *trans*.



oleic acid, a *cis* fatty acid



elaidic acid, a *trans* fatty acid

Fats containing one or more *trans* fatty acids are called ***trans*-fat**. Studies show that *trans* fats are similar in properties to saturated fats and raise the level of triglycerides and "bad" cholesterol in the blood. This is because *trans* fats more closely resemble the shape of saturated fats and behave in a similar way.

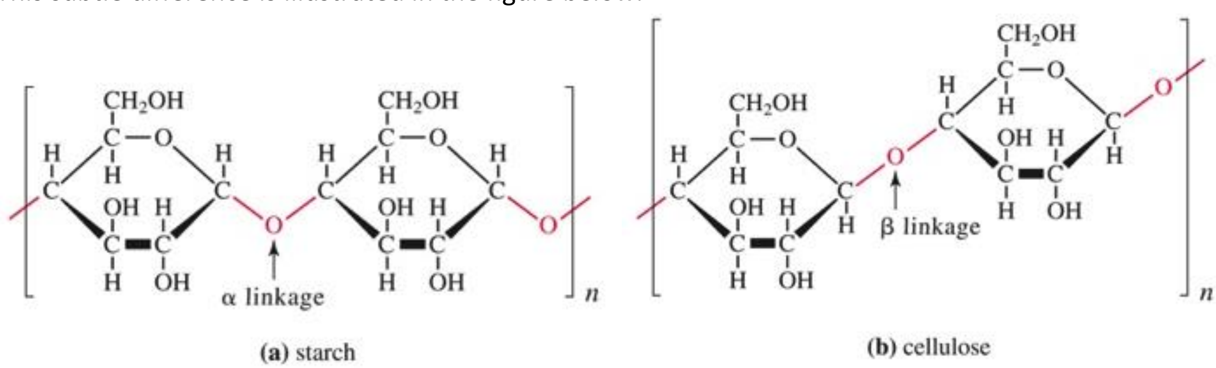
Carbohydrates: Sweet and Starchy

Carbohydrates are compounds that contain carbon, hydrogen and oxygen with H and O atoms found in the same 2:1 ratio as in H_2O. This composition gives rise to the name carbohydrate, which implies "carbon plus water". However, the H and O atoms in the carbohydrates are not in the form of H_2O molecules.

Sugars are the sweet-tasting members of the carbohydrate family. Examples that you may recognize include glucose and fructose, both naturally occurring in fruits, vegetables and honey. In addition, glucose and fructose are components of high fructose corn syrup. Starch, a polymer of glucose, is another carbohydrate. It is found in nearly all types of grains, potatoes, and rice. Although pleasing to our taste buds, starch lacks a sweet taste and takes a bit longer to digest than sugars. Whether sweet or starchy, carbohydrates have the job of providing energy to the cells in our body.

Fructose and glucose are both examples of a **monosaccharide**, that is, a single sugar. Sucrose (table sugar) is a **disaccharide**, a "double sugar" formed by joining two monosaccharide units. In forming a sucrose molecule, a glucose and a fructose unit are connected by a C-O-C linkage created when an –H atom and an –OH group are split off to form a water molecule.

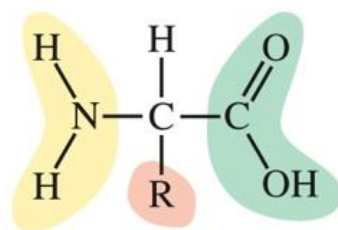
Monosaccharides also can link to form much bigger molecules. **Polysaccharides** are condensation polymers made up of thousands of monosaccharide units. As the name implies, these macromolecules consist of "many sugar units". Familiar polysaccharides include starch and cellulose. Our bodies can digest starch by breaking it down into glucose; in contrast, we cannot digest cellulose. Consequently, we depend on starchy foods such as potatoes or pasta rather than devouring grass. The difference in digestibility stems from a subtle difference in how the glucose monomers are connected to form starch and cellulose. This subtle difference is illustrated in the figure below.



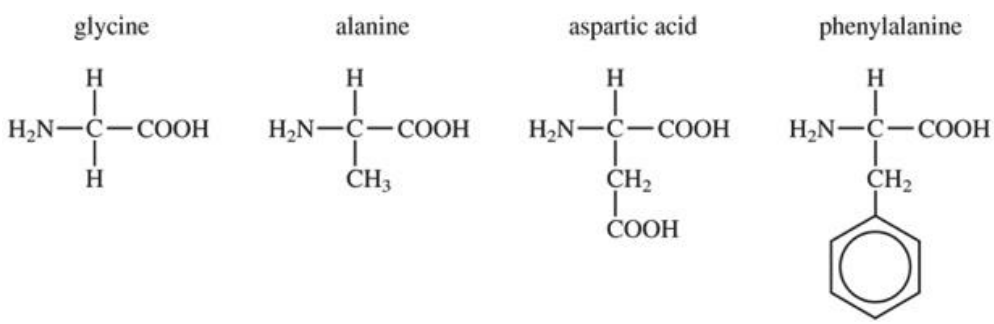
Proteins

Proteins are an essential part of every living cell. They are major components in hair, skin, and muscle. They also transport oxygen, nutrients, and minerals through the bloodstream. Many of the hormones that act as chemical messengers are proteins, as are most of the enzymes that catalyze the chemistry of life.

A **protein** is a biological polymer. A protein is either a polyamide or **polypeptide**, that is, a polymer built from **amino acid** monomers. The great majority of proteins are made from various combinations of the 20 different naturally occurring amino acids. Molecules of amino acids share a common structure. Four chemical species are attached to a carbon atom: a carboxylic acid group (−COOH, highlighted in green), an amine group (−NH_2, highlighted in yellow), a hydrogen atom, and a side chain designated as R (highlighted in orange), as shown in the figure below.



Generic structure for an amino acid



Examples of amino acids with different side chains

Normally, the body does not store a reserve supply of protein, so foods containing protein must be eaten regularly. As the principal source of nitrogen for the body, proteins are constantly being broken down and reconstructed. Of the 20 natural amino acids that make up our proteins, we can synthesize 11 in our bodies from simpler molecules. We must obtain the other 9 from the foods we eat. Listed in the table below are the nine **essential amino acids**.

Table 11.5 The Essential Amino Acids

histidine	lysine	threonine
isoleucine	methionine	tryptophan
leucine	phenylalanine	valine

The essential amino acids are found in both animal sources and plant sources. The 2nd link below is for plant-based sources for these essential amino acids. The 1st link includes some brief information about sources of essential amino acids from meat, fish, eggs, dairy products and plants.

http://www.livestrong.com/article/538851-nutritional-sources-of-essential-amino-acids/

http://www.onegreenplanet.org/natural-health/need-protein-amino-acids-found-abundantly-in-plants/

Vitamins and Minerals: the other essentials

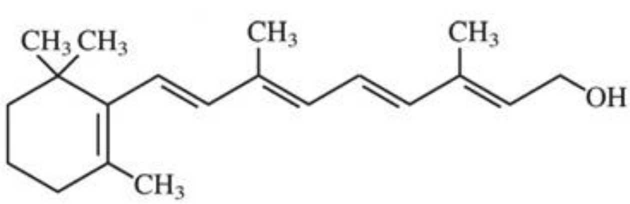
Vitamins and minerals are micronutrients, substances that are needed only in miniscule amounts but still are essential to life. Nearly everyone in the United States knows that vitamins and minerals are important, but a thriving multimillion-dollar supplement industry reminds any who forget. Many processed foods that are high in sugars and fats lack essential micronutrients.

Only relatively recently have we come to understand the role of vitamins and minerals in our diet. Over the ages, humans learned that they became ill if certain foods were lacking. Systematic studies began early in the 20th century with the discovery of "Vitamin B_1 (thiamine)". The particular designation, B_1, was the label on the test tube in which the sample was collected. The general term "vitamin" was chosen because the compound, which is vital for life, contains the amine group. The final "e" disappeared with the discovery that not all vitamins are amines.

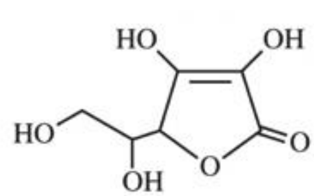
Vitamins are organic compounds with a wide range of physiological functions. Although only small amounts are needed in the diet, vitamins are essential for good health, proper metabolism, and preventing disease. In general, vitamins are not sources of energy for the body although some help break down macronutrients.

Vitamins can be classified on the basis of being water- or fat-soluble. The solubility of vitamins has significant implications for health. Because of their fat-solubility, vitamins A, D, E and K are stored in cells rich in lipids, where they are available on biological demand. If ingested in excess, fat-soluble vitamins can build up to a toxic level. For example, high doses of vitamin A can result in both troublesome symptoms such as fatigue and headache and in more serious ones such as blurred vision and liver damage.

In contrast, water-soluble vitamins are excreted in the urine rather than stored in the body. As a result, you need to eat foods containing these vitamins frequently. Although water-soluble vitamins can accumulate to toxic levels when taken in large doses, such cases are rare. For most people, a balanced diet provides the necessary water-soluble vitamins, making vitamin supplements unnecessary. The one exception seems to be vitamin D, which is synthesized in the skin by using the energy of sunlight, rather than ingested. Recent research on vitamin D has led more physicians to check vitamin D blood levels as part of an annual physical exam and to use the results to determine whether taking a supplement is necessary.



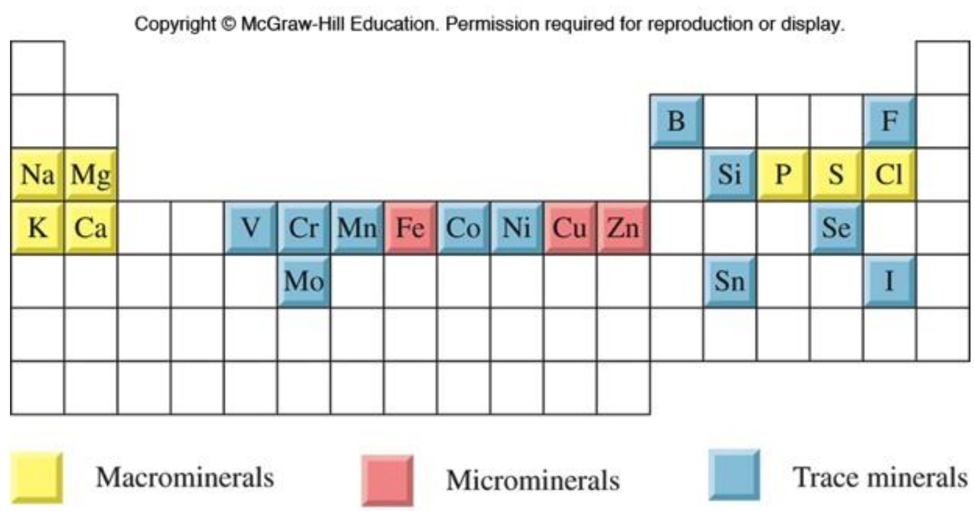
vitamin A, a lipid-soluble vitamin



vitamin C, a water-soluble vitamin

<u>Minerals</u> are ions or ionic compounds that, like vitamins, have a wide range of physiological functions. You may be familiar with minerals such as sodium and calcium, but actually the list is much longer. Depending on how much of them you need, minerals are classified as either macro, micro, or trace.

- **Macrominerals**: Calcium (Ca), Phosphorus (P), Chlorine (Cl), Potassium (K), Sulphur (S), Sodium (Na) and Magnesium (Mg)
  These elements are necessary for life but not nearly as abundant in our bodies as Oxygen (O), Carbon (C), Hydrogen (H) and Nitrogen (N). You need to ingest macrominerals daily, typically in the range of 1 to 2 g.
- **Microminerals**: Iron (Fe), Copper (Cu) and Zinc (Zn)
  The body requires lesser amounts of these. You may recognize iron as a component of hemoglobin, a protein in the blood that carries oxygen.
- **Trace minerals**: Iodine (I), Florine (F), Selenium (Se), Vanadium (V), Chromium (Cr), Manganese (Mn), Cobalt (Co), Nickel (Ni), Molybdenum (Mo), Boron (B), Silicon (Si) and Tin (Sn)
  These usually are measured in microgram quantities. Although the total amount of trace elements in the body is tiny, their small quantity belies the importance they have in good health.



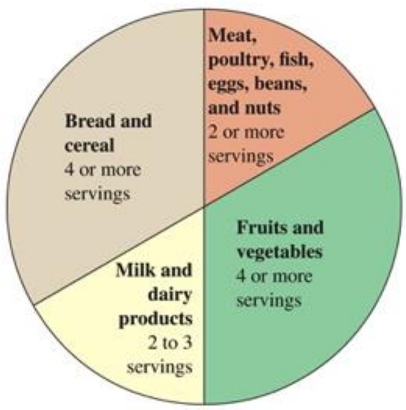
Periodic table indicating dietary minerals necessary for human

Dietary advice: Quality *Vs* Quantity

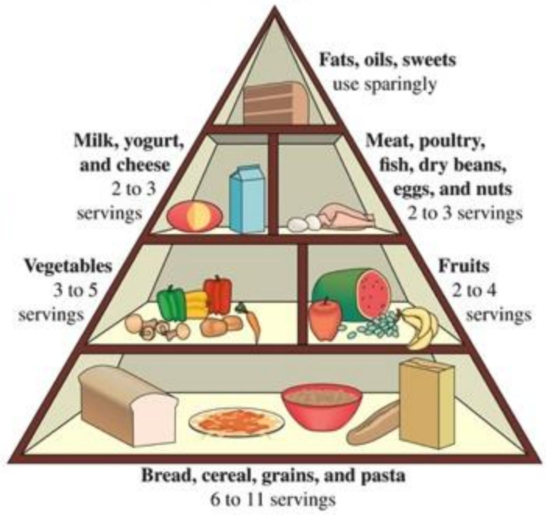
Which foods should you eat less of… and which ones more? One day the experts say one thing; the next day they seem to say the opposite. With so much information available, you may be confused or feel overwhelmed.

Indeed, dietary advice is changing. If you are a young adult, you may have parents or grandparents who remember “The Basic Four” and “The Food Pyramid”. Take a trip back in time with the following figure, courtesy of the U.S. Department of Agriculture. Both emphasize the concept of a daily serving.

1958
The Basic Four

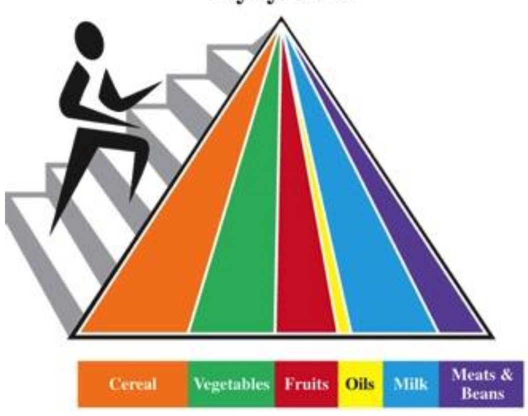


1991
The Food Pyramid



In 2005, the U.S. Department of Agriculture introduced a new pyramid, “Steps to a Healthier You”. It turned the 1991 pyramid sideways, added stairs, and named it MyPyramid. In 2011, MyPlate was launched as a more straightforward way to help people remember what to put on their plates. The message was simple: at least half of your meal should be fruits and vegetables. The research of nutritional scientists supports this recommendation.

2005
MyPyramid



2011
MyPlate