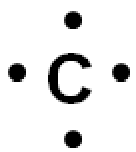
Carbon

Organic chemistry *involves the study of carbon-containing compounds associated with life.*

General Description of Organic Molecules

Carbon atoms form the backbone of many of the molecules that make up biological systems on Earth. These molecules, called *biomolecules*, are made up of carbon bonded with other elements, such as hydrogen, nitrogen, and oxygen.

Carbon atoms have four electrons in their outer shells, and all four are available for bonding. Carbon can share these electrons in single bonds with up to four other atoms to form very stable structures.



Alternatively, carbon can form multiple bonds with up to two other atoms by sharing two or more electrons with another atom. Carbon can also form a combination of double and single bonds, to a maximum of eight shared electrons by each carbon atom.

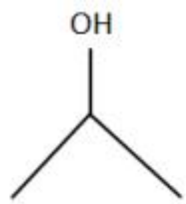
Structure and Shape of Organic Molecules

Carbon can also readily form bonds with other carbon atoms to form long, complex molecules. These complex molecules can be long chains, ring-shaped molecules, or a combination of the two. The backbones of carbon molecules can be of any size and may contain from one carbon atom to thousands of carbon atoms.

When chemists refer to organic molecules, they generally use structural formulas. A diagram of the molecule is often more helpful than the name. Because of the high percentage of carbon and hydrogen in organic molecules, the molecules are drawn without labeling them. Carbon atoms are located where lines intersect, unless otherwise noted, and the 4 bonds around each carbon are understood to be completed by the appropriate number of hydrogens.

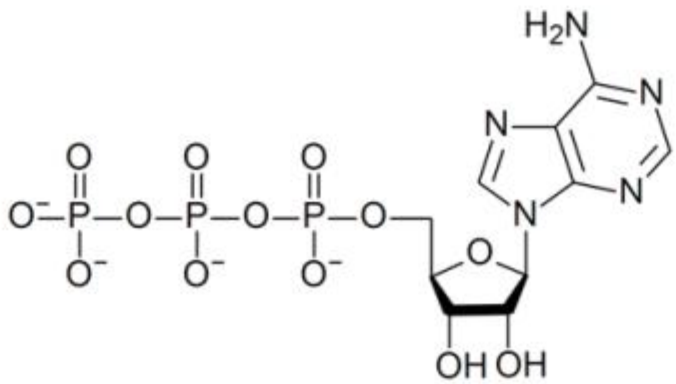
Below are examples of some common carbon-containing compounds.

Octane (C_8H_{18})



Isopropyl alcohol
(C_3H_7OH)

Benzene (C_6H_6)



Adenosine Triphosphate (ATP)

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Complex Organic Molecules

*A group of atoms that is held together by covalent bonds is known as a molecule. When bonding occurs between two or more carbon atoms, the group is known as an **organic molecule**.*

Biological Molecules

Biological molecules are composed of small repeating subunits that bond together to form larger units. The subunits, or **building blocks**, are called *monomers*. *Polymers* are the complex molecules formed from the repeating subunits.

There are four basic classes of complex organic molecules, or *macromolecules*, that compose cells: **carbohydrates**, **proteins**, **lipids**, and **nucleic acids**. Each of the major classes of biological molecules is associated with different properties and functions within cells and whole organisms. Below is a table that compares the basic properties of the four biological macromolecules.

	Carbohydrates	Lipids	Proteins	Nucleic Acids
Building Blocks (monomers)	• monosaccharides (glucose, fructose, ribose, etc.)	• glycerol • fatty acids	• amino acids (20 different amino acids)	• nucleotides (adenine, cytosine, guanine, thymine, uracil)
Function(s) in cells	• energy storage • structural support (plant cell walls)	• energy storage • insulation • protective covering • lubrication	• muscle contraction • oxygen transport • immune responses • chemical reactions	• information storage
Elements Present	• carbon • hydrogen • oxygen	• carbon • hydrogen • oxygen	• carbon • hydrogen • oxygen • nitrogen • sulfur (some)	• carbon • hydrogen • oxygen • nitrogen • phosphorus
Water Soluble	• yes	• no	• many	• yes
Examples	• sugars • starches (glycogen & cellulose)	• fats • oils • waxes	• enzymes • hemoglobin • muscle fibers	• RNA • DNA

Carbohydrates

Carbohydrates are organic macromolecules that are made up of carbon, hydrogen, and oxygen atoms. These atoms are combined in a ratio of:

1 carbon atom : 2 hydrogen atoms : 1 oxygen atom

The presence of multiple carbon-hydrogen bonds within carbohydrates makes them an excellent source of energy. (The energy is released when these bonds are broken.)

Carbohydrates may be simple or complex. The building blocks of carbohydrates are the simple sugars known as **monosaccharides**. Sugars such as glucose, fructose, and ribose are all examples of monosaccharides.

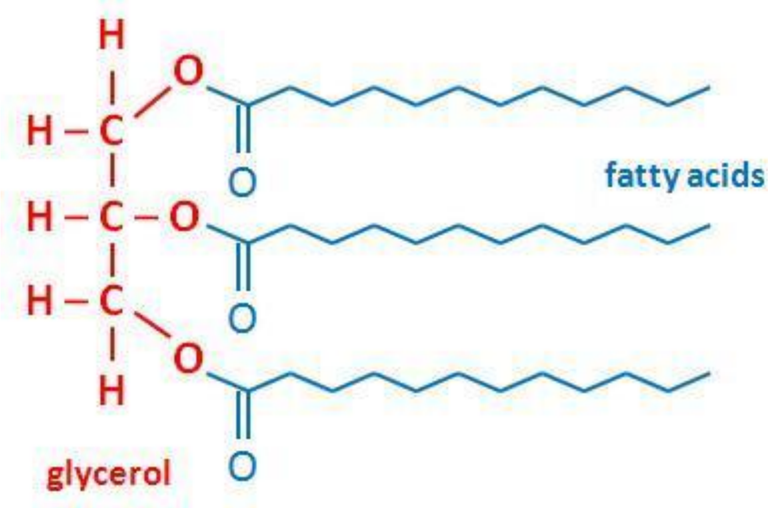
Monosaccharides can be combined to form more complex carbohydrates known as **polysaccharides**. Glycogen, starch, and cellulose are all examples of polysaccharides. These compounds are typically used for long term energy storage or as structural molecules. Cellulose, for example, is a major component found in the cell walls of plants.

Dietary fiber is a special class of carbohydrates that cannot be digested by the human body. Cellulose is one example of a carbohydrate that acts as fiber. Dietary fiber is an important part of a healthy diet because it is essential for proper digestion. Humans can get fiber by eating many different kinds of plants, such as whole grains, legumes, prunes, and potatoes.

Lipids

Lipids are organic macromolecules that are insoluble in water. This is why lipids are often found in biological membranes and other waterproof coverings (e.g. plasma membrane, intracellular membranes of organelles). These lipids play a vital role in regulating which substances can or cannot enter the cell.

The most important lipids, however, are fats. Triglycerides are a type of fat that contain one **glycerol** molecule and three **fatty acids**.

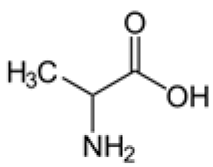


Fatty acids are long chains of CH_2 units joined together. The fatty acids in **saturated fats** do not contain any double bonds between the CH_2 units whereas the fatty acids in **unsaturated fats** contain some carbon-carbon double bonds. Saturated fats are found in butter, cheese, chocolate, beef, and coconut oil. Unsaturated fats are found in olives and olive oil, peanuts and peanut oil, fish, and mayonnaise.

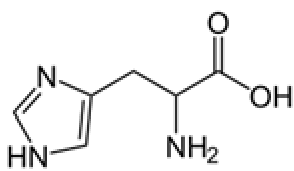
Fats are important because they are a major source of energy. Since they contain even more carbon-hydrogen bonds than carbohydrates, fatty tissue has the ability to store energy for extended periods of time

Proteins

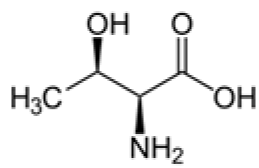
Proteins are organic macromolecules that are composed of **amino acid** monomers. There are 20 essential amino acids that are used by all living things to construct proteins. These amino acids are made up of the elements carbon, hydrogen, oxygen, and nitrogen. Some of the amino acids also contain sulfur. Three of the amino acids are shown below.



Alanine



Histidine



Threonine

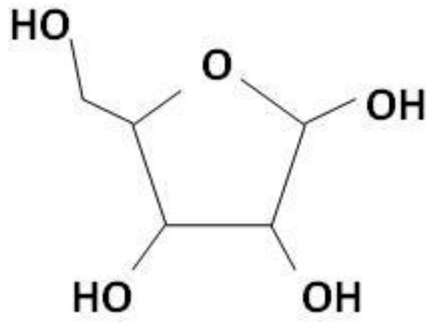
Proteins differ from each other due to the number and arrangement of their component amino acids. Proteins also take on unique shapes as determined by their amino acid sequences.

Water is the most abundant molecule in the body, but proteins are the second most abundant type of molecule. Proteins assist with muscular contractions and serve many structural roles. For example, cartilage and tendons are made of a protein known as collagen, and a protein known as keratin is found in hair, nails, feathers, hooves, and some animal shells. Proteins are also involved in cell signaling, cell transport, immune responses, and the cell cycle. Other proteins known as enzymes can also help speed up cellular reactions.

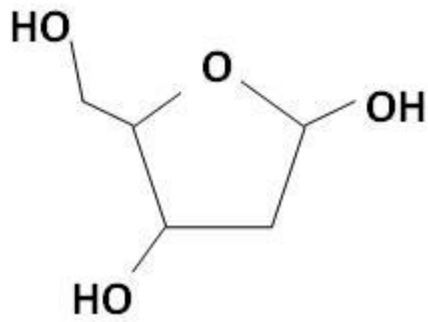
Nucleic Acids

Nucleic acids are formed from **nucleotide** monomers. Nucleotides are chemical compounds that are primarily comprised of the elements carbon, hydrogen, oxygen, nitrogen, and phosphorus. They consist of a **five-carbon sugar**, a **nitrogenous base**, and one or more **phosphate groups**.

There are two main types of nucleic acids - **ribonucleic acids (RNA)** and **deoxyribonucleic acids (DNA)**. These nucleic acids are different because their five-carbon sugars are different. RNA contains **ribose**, and DNA contains **deoxyribose**.



RIBOSE



DEOXYRIBOSE

DNA and RNA also have different functions. DNA stores genetic information and encodes the sequences of all the cell's proteins. RNA is involved in the direct production of the proteins.

Nucleic acids are also different because the sequence of nitrogenous bases that they contain are different. There are five nitrogenous bases found in nucleic acids. **Adenine** (A), **cytosine** (C), and **guanine** (G) are found in both DNA and RNA. **Thymine** (T) is only found in DNA, and **uracil** (U) is only found in RNA.

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Importance & Properties of Water

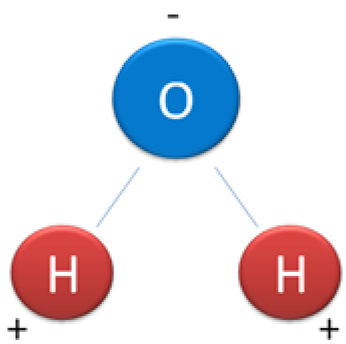
Water has many unique properties that make it essential for life on Earth.

Molecular Shape and Properties

A water molecule is composed of two hydrogen atoms and one oxygen atom (H_2O). The oxygen end of the molecule carries a negative charge and the hydrogen end of the molecule carries a positive charge. This causes water molecules to be attracted to other water molecules (*cohesion*). These charges also cause water to be attracted to other materials that carry an electrical charge (*adhesion*).

Water is a polar molecule.

The **bent shape** of the water molecule gives a partial negative charge around the oxygen area, and a partial positive charge around the hydrogen atoms. With both partial positive and negative charges being present on the molecule, both positive and negative charges are attracted to it.



The polar nature of water allows it to dissolve many different substances.

Due to its molecular structure, water is a **polar substance**. Therefore, it can dissolve many ionic substances, such as salt, and polar substances, such as sugar. As a result of the solvent properties of water, the liquid always contains dissolved materials, particularly ionic substances.

Water is known as the ***universal solvent*** because it dissolves such a large number of substances. More substances are soluble in water than in any other liquid. Water's ability to dissolve so many substances is due to its polar nature.

Surface Tension

Another consequence of the structure of water is that liquid water exhibits surface tension. **Surface tension** is a force acting on the surface of a liquid that tends to make the surface curved. You perhaps have seen surface tension in action when water beads up on a car engine hood that has recently been waxed. Another example is the curved surface of water when it fills a glass to the very top.

Density

Another interesting property of water is that ***solid water (ice) is less dense than liquid water***.

Solid water is less dense than liquid water. This is why ice floats in water.

Most other substances do not exhibit this property. When water freezes and becomes a solid, it expands and becomes less dense with an increase in volume. This happens because solid water forms a crystalline structure internally. One visible result of this is that solid ice floats in liquid water.

Water and Life

Water is the most abundant molecule found in living organisms. Without water, life as we know it would not be possible. Most plants and animals are made up of more than 60% water by mass. Mammals (including humans) are composed of approximately 70% water by mass. Two-thirds of this water is present inside the cells of the animal's body. The other one-third is located outside of the cells in such things as blood plasma.

Almost all the chemical reactions in life processes occur in solutions of water. Cell processes such as cellular respiration, diffusion, osmosis, and the production of ATP would all be impossible without the presence of water. Water is not only known as the universal solvent, is it also known as the ***solvent of life***. Water is necessary for dissolving organic wastes, as well as essential nutrients that plants and animals need to live.

Humans use water in more tangible ways as well. People use water in agriculture to grow foods; people also use water to generate electricity in hydroelectric dams.


Humans use water for drinking, agricultural uses, and industrial uses. Electricity is vitally important to modern societies, and water is used in many of the processes that generate electricity, such as in hydroelectric dams.