A Cellular World
PH709 The Biology of Public Health

PH709 A Cellular World

The Building Blocks of Life

This is a video segment (3:36) from Discovery Channel. It's a very basic introduction to cells, but may be of interest to students with little background in the sciences.

Learning Objectives

After successfully completing this section, the student will be able to:

- List and distinguish the major organic molecules (sugars and starches; amino acids and proteins, nucleotides and nucleic acids; fatty acids, phospholipids, trigylcerides, and cholesterol) and explain how polymers provide for increasingly complex molecules.
- Distinguish between covalent and ionic chemical bonds.
- Explain what is meant by a "polar" compound.
- Explain how the amphipathic nature of molecules enables the self-assembly of macromolecular structures such as the cell membrane.
- Describe the composition of the cell membrane.
- List the functions of protein molecules in cells. Define what is meant by "protein binding sites".
- Describe the three mechanisms by which proteins enable transport of substances across cell membranes.
- List and distinguish the hierarchy of organization within organisms (atoms -> molecules -> organelles -> cells -> tissues -> organs -> organ systems)

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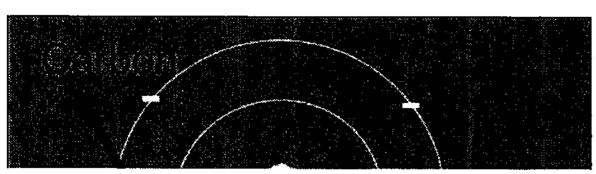
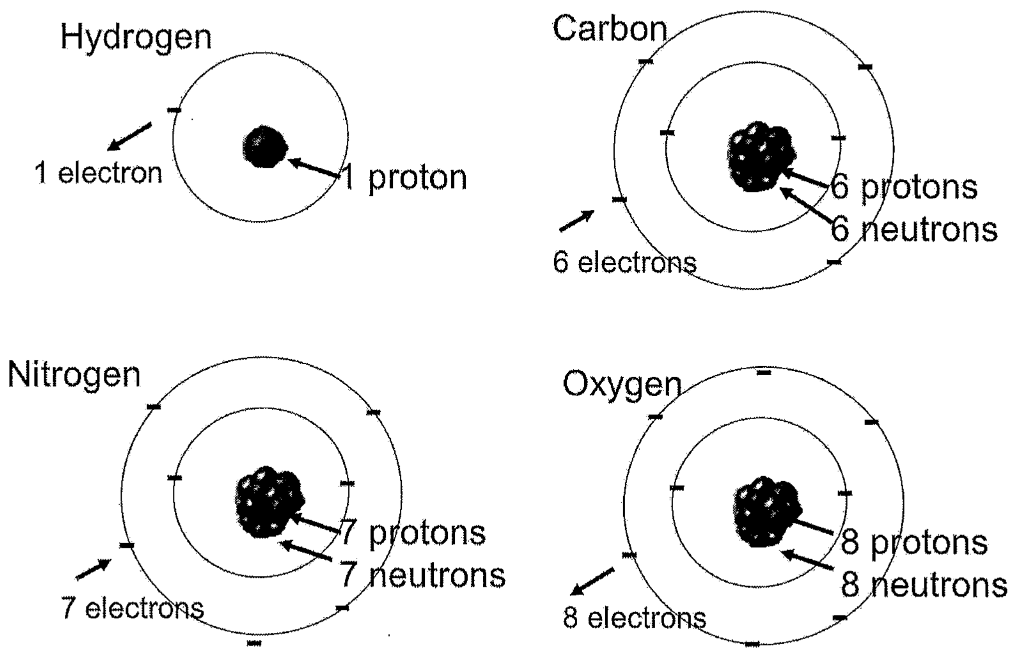
Chemical Elements: Atoms

All matter, whether it is living or not, is composed of chemical



elements;
these are fundamental chemicals in the sense that they are what they are - they can't be changed into another element. Each element is distinguished by the number of protons, neutrons, and electrons that it possess. For example, carbon's atomic number is 6, and has an atomic mass of about 12, because it has 6 positively charged protons and 6 non-charged neutrons. The 6 charged electrons contribute very little to the atomic mass. There are 92 naturally-occurring elements on earth. The array of elements and their subatomic structure are summarized by the periodic table of the elements, shown to the right.

In living organisms the most abundant elements are **carbon, hydrogen, and oxygen**. These three elements along with nitrogen, phosphorus, and a handful of other elements account for the vast majority of living matter. An atom is one single unit of a chemical element. Some of these elements that are abundant in organic molecules are shown below.

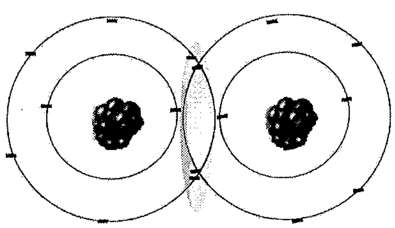


Molecules

Atoms can combine with other atoms by forming chemical bonds.

Covalent Bonds

A covalent bond is one in which one or more pairs of electrons are shared by two atoms. The illustration to the right shows two atoms of oxygen that are covalently bonded by the sharing of two pairs of electrons as illustrated in the shaded area.



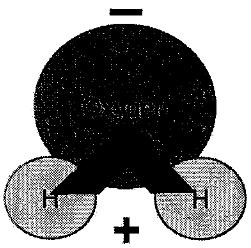
Oxygen gas (O_2)

O=O

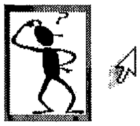
A double covalent bond (sharing 2 pairs of electrons)

The figure below shows a series of molecules formed by covalent binding. Mouse over each molecule to see a brief description.

Water is a Polar Molecule



Note also that the sharing of electrons is not always equal. For example, in a water molecule, the negatively charged electrons spend more time in the vicinity of the heavier oxygen atom. The net result is that the water molecule has one end that is more negative relative to the other end. Water is therefore a "polar" molecule. We will see that this polarity has important implications for many biological phenomena including cell structure. You may have heard the expression "*like dissolves like*." What this means is that polar molecules dissolve well in polar fluids like water. Sugars (e.g., glucose) and salts are polar molecules, and they dissolve in water, because the positive and negative parts of the two types of molecules can distribute themselves comfortably among one another.

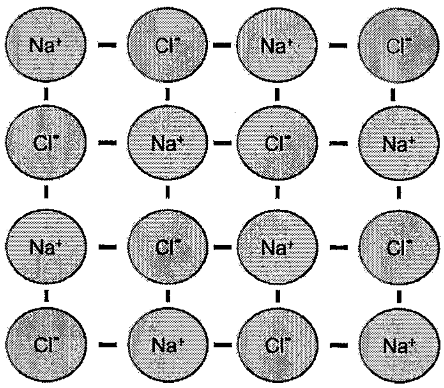


Test Yourself

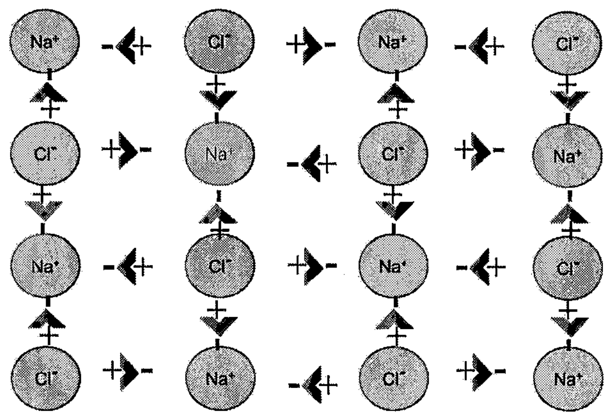
Ionic Bonds

Sodium has a single electron in its outermost orbital shell, and it is thermodynamically more stable if it gives up this electron. This loss of a negative electron results in a positively charged sodium ion, abbreviated Na^+. Chlorine, on the other hand, has seven electrons in its outermost orbital shell, and it is more thermodynamically stable if it acquires an extra electron to complete the outer orbital shell. This results in a negatively charged chloride ion, abbreviated Na+. The positively charged sodium ions and the negatively charged chloride ions attract each other and result in the formation of an ionic bond. In the absence of water, sodium and chloride form a crystal lattice because of the attraction of negative and positive ions.

Crystal Lattice of NaCl (table salt)



However, if sodium chloride crystals are placed in water, the polar water molecules will "hydrate" the sodium and chloride atoms because the water molecules are polar. In the illustration below the darker blue V-shaped figures represent water molecules, which are polar. The positive ends of the water molecules are attracted to the negatively charged chloride ions, while the negative pole of the water molecule is attracted to the positive sodium ions. As a result, the ions are hydrated and the crystal lattice dissolves into the aqueous solution. This is exactly what happens when you add crystalline table salt to a glass of water.



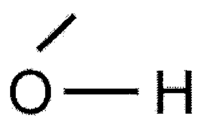
The video below provides an animated explanation of how salts like NaCl dissolve in water.

More Complex Biological Molecules

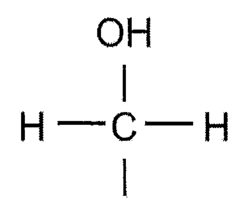
Carbohydrates

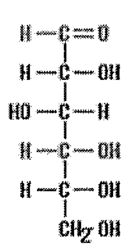
Sugar Molecules

The stuff of life is amazingly diverse and complex, but it is all based on combinations of simple biological molecules. Biological molecules are often made from chains & rings of carbon. These molecular structures can be represented by "stick drawings" that show the component atoms (e.g., C, H, N, O for carbon, hydrogen, nitrogen, and oxygen respectively) and show the bonds between them as dashes. A single dash (-) represents a single bond, and a double dash (=) represents a double bond.

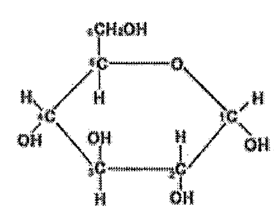


Note that some common "groups" are depicted without showing the bonds between them. For example, the hydroxyl group (-OH) in the sugar molecule below is an oxygen bonded to a hydrogen, as show more explicitly to the left. The "CH_2OH" group at the bottom of the glucose molecule shown below is a shorthand notation for the structure shown more explicitly to the right.



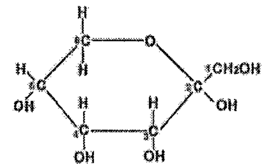


For example, a molecule of the sugar glucose consists of 6 carbon atoms bonded together as a chain with additional atoms of oxygen and hydrogen. This short chain forms a ring in aqueous solutions, e.g., in body fluids, as shown to the right.



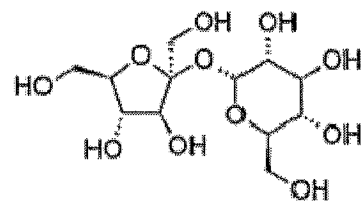
D-glucose

Fructose is another sugar, which also has 6 carbons, 12 hydrogens, and 6 oxygen atoms. However, the arrangement of the atoms is different, and this makes it much sweeter than glucose and also affects its ability to combine with other molecules.



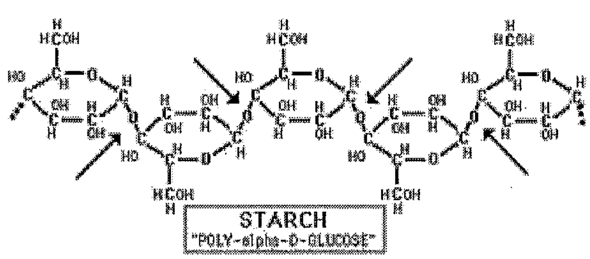
fructose

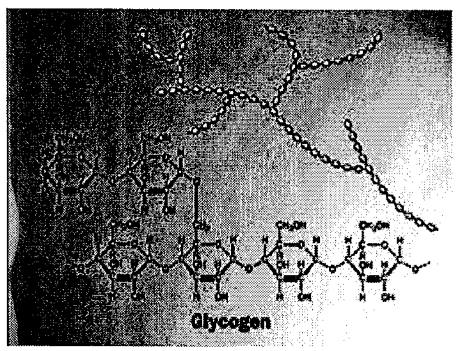
Another important theme is that single units of biological molecules (monomers) can join to form increasingly complex molecules (polymers). For example, two monosaccharide sugars can also become bound together chemically to form a disaccharide. Sucrose is the disaccharide in common sugar that we buy at the grocery store. The structure of sucrose is shown at the right.



Polysaccharides: Starch, Glycogen, and Cellulose

Glucose and fructose are examples of monosaccharides, meaning they consist of a single sugar unit, while sucrose is an example of a disaccharide. However, sugar units can be bonded or linked together to form polysaccharides, which consist of many sugars linked together to form extensive chains of sugars. Plants store energy as starch, which consists of very long chains of glucose linked together. Animals store energy as glycogen, which consists of more highly branched chains of glucose. Collectively, sugars, starch, and glycogen are know as carbohydrates, and they are an important source of cellular energy.





Cellulose is yet another polysaccharide formed from glucose. Cellulose is composed of unbranched, parallel chains of glucose. A key feature is that the chains bond to one another to form strong fibers that serve a structural purpose. Humans do not have the enzymes necessary to break the bonds in cellulose, and any cellulose we ingest passes through our digestive systems. It is a major component of what we refer to as dietary "fiber."

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