Chemistry:

(I am not a chemist, this is only a brief overview).

In order to understand much about biology, we need to know some basic chemistry

Structure of molecules (important to almost all aspects of biology (food, DNA, structure of organisms, function of organisms, etc.).

Function of ions (nervous system, respiratory system, etc.)

Elements:

Can not be broken down further by using chemistry (can use techniques from physics, though).

Examples are oxygen, hydrogen, nitrogen, sulfur, sodium, iron, etc.

Water, carbon dioxide, salt are NOT elements (they are composed of more than one element).

About 25 elements make up the necessities for life (all the ones above are on the list).

Nitrogen, oxygen, carbon & hydrogen make up 96% of the elements needed for life.

Most of the others in the list that are present in percentages higher than 0.01% are important as ions (except sulfur).

The rest of the elements are considered to be "trace" elements.

"Trace" elements are important in specific functions. For example:

Iodine is needed by the thyroid to make hormones (for growth and metabolism). Iodine deficiency causes enlargement of the thyroid (goiter).

Iron is an important component of hemoglobin (the molecule in red blood cells that delivers oxygen to your body).

Some of these are added as food supplements:

Iodine in "iodized" salt

Iron/zinc/copper in fortified cereals

Molecules

Made up of two or more elements.

Elements can combine in various way to make molecules

These may have totally different properties from those of elements.

Some can become very complicated (DNA, hemoglobin, etc.)

Example: Salt is made up of sodium and chlorine. Sodium is a metal, and can be somewhat unstable if exposed to water. Chlorine is a poisonous gas (used in WW I).

Sodium and Chlorine combine to form Sodium chloride (= salt).

Obviously has totally different properties from sodium or chlorine.

We need to discuss how elements can combine. But first we need to know more about the structure of atoms.

Atoms:

Each atom is composed of protons, neutrons & electrons

Protons determine the “atomic number”of an element.

Have mass and a (+) electric charge

Neutrons

Have mass and a neutral charge (no charge)

Electrons

Have almost no mass (1/2000 that of a proton), and a (-) electric charge

An atom's mass is essentially the sum of its protons and neutrons (electrons contribute very little).

Structure of atoms:

Protons and neutrons exist in the atoms nucleus (the central part of the atom)

Electrons exist in a large cloud surrounding the nucleus (at a considerably distance from the nucleus).

Depending on the number of electrons, they exist in a number of different shells surrounding the nucleus (more below).

Differences in elements are due primarily to the number of protons.

The number of protons for each element gives each element its unique properties. Elements have a unique atomic number (see any periodic table).

Atoms can be held together by different types of bonds (which form compounds):

Covalent bonds

Atoms want a specific number of electrons in their outer shell.

The first shell has a capacity of 2, the second 8, the third 8, etc. (take a chemistry course for details).

As mentioned, atoms strive to have the correct number of electrons in the outer shell.

Atoms can share electrons in their outer shell. For example:

Hydrogen has one electron in its outer shell (1 proton, 1 electron)

Thus, two hydrogens can each share their electron. This generates a covalent single bond.

Oxygen has 6 electrons in it's outer shell, but a capacity for 8. Thus it can share two electrons with another oxygen atom.

This forms a double bond (covalent).

Triple bonds are also possible (e.g, nitrogen, N_2)

(Quadruple bonds and higher exist, but are rare).

Methane, water are other examples.

Ionic bonds

In this case, an electron actually moves from one atom to another.

Sodium has one electron in its outer shell, Chlorine has 7.

Chlorine wants one electron. Sodium can get rid of its electron since it only has one.

Sodium “gives” its electron to chlorine.

But now, sodium has a (+) charge and chlorine a (-) charge.

Opposite charges attract, so Sodium attaches to chlorine, forming sodium chloride (= salt). Note that charged atoms are called ions.

In solution, these “ions” can separate, and they are very important biologically.

Hydrogen bonds

Water is a polar molecule.

Although hydrogen and oxygen share electrons, oxygen has a stronger attraction for electrons than does hydrogen.

This causes oxygen to be slightly negative (electrons are (-))

Hydrogen is slightly (+).

Opposite charges attract, so water molecules (molecule = more than one atom in some type of bond) attach to each other using these weak hydrogen bonds.

This causes water molecules to stick together, and is responsible for many properties like surface tension.

Overfilling a spoon (won't work with detergent in the water).

Properties of water:

Temperature - water resists temperature changes due to hydrogen bonds. This gives it a higher boiling point.

Evaporative cooling - water molecules with the most energy (heat) leave, leaving cooler ones behind. This carries heat from your body.

Ice is less dense than water. This is again due to hydrogen bonds.

As water cools, the hydrogen bonds force water molecules into a specific pattern

This pattern is such that a specific volume holds less water molecules than in the liquid state, so water is denser than ice. Ice floats.

Incredibly important for life - if ice didn't float, organisms in the bottom of ponds, lakes & rivers would freeze. Instead, ice insulates the liquid water below (from the air above).

Water is a good solvent.

Due to differing charges on the molecule, water will dissolve a lot of stuff.

Salt dissolves because all the negative parts (oxygen) are attracted to positive parts (Sodium), and vice versa.

Many molecules with some kind of charge will dissolve in water (not just ions).

pH

Let's keep this simple.

Certain compounds (acids) contribute Hydrogen (which is (+)) to water, others (bases) contribute hydroxide (OH, which is (-)) to water.

Both of these are ions:

- excess H (or insufficient OH) --> acidic

- excess OH (or insufficient H)--> basic

- 0 is extremely acidic, 14 is extremely basic (scale actually goes beyond 0 or 14).

A one step increase in pH => a 10 fold increase in the number of H ions (i.e., pH is a logarithmic scale).

Biological fluids usually have buffers - substances that can absorb excess H or OH ions, thus preventing pH changes.

This is very important. Blood is at a pH of 7.4 (small changes can cause death).

Strong acids or bases can be extremely dangerous

Hydroflouric acid can dissolve glass.

Acid precipitation:

Better known as acid rain

Destroys monuments,

Much more importantly, it destroys habitat (turns lakes, streams, ponds acidic).

This kills many aquatic organisms that live in water.

Also destroys soils (leaches important nutrients), which leads to destruction of forests.

Finally, chemical reactions.

The way in which molecules, compounds, elements are changed into other molecules, elements or compounds.

For example, to get water, we need to combine hydrogen and oxygen

$2 H_2 + O_2 \text{ --> } 2 H_2O$

Two hydrogen molecules (4 total atoms) and one molecule of oxygen (2 total atoms) combine to give 2 molecules of water.

Notice that the number of atoms on one side of the equation is identical to the number on the other side.

Incidentally, this reaction releases a lot of energy (one reason we're investigating "hydrogen" cars. Hydrogen is very flammable (in the presence of oxygen)).

Chemical reactions can be much more complicated - for example, one beta cartene molecule (together with oxygen and hydrogen) give rise to 2 vitamin A molecules.