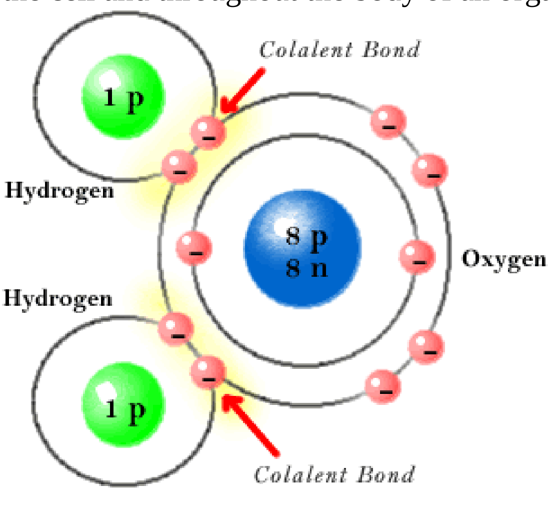
INORGANIC AND ORGANIC COMPOUNDS

INORGANIC compounds are those which generally do not contain *both* Hydrogen and carbon. They may contain hydrogen *or* carbon (or neither), but do not contain both elements. Inorganic compounds are relatively small molecules overall, and may be either covalently or ionically bonded. Covalent examples include water (H_2O) and carbon dioxide (CO_2). Ionic examples include table salt (NaCl, sodium chloride) and chalk ($CaCO_3$, calcium carbonate).

The most important inorganic compound is *water* (H_2O). Most of the mass of living organism consist of water, and all of the chemical reactions responsible for life's processes (biochemistry) take place in water solutions. Water also serves as the transportation medium for compounds around in the cell and throughout the body of an organism.



Bohr Model of H_2O

Water is *polar* molecule, in that the shared electrons are shared unequally, spending more time around the oxygen atom than around the hydrogen atoms. This is because of the stronger electronegativity of the oxygen atom. As a result, the oxygen atom has a partial negative charge, while the hydrogen atoms have a partial negative charge. [Partial charges are shown in the diagram at left by the lowercase Greek letter δ (delta)] This effectively creates positive and negative ends of the water molecule, which allows the formation of hydrogen bonds between water molecules, which in turn gives water many of its unique characteristics that are so essential to life.

The Biological Importance of Water

1. a large constituent of cytoplasm, the "soup" in which cellular process and structures exist
2. non-compressible at pressures found in living tissues, therefore gives structural support and shape to the organism.
3. "universal solvent" – most substances important to life are at least partially soluble in water, which allows them to be transported through the water-based tissues and system of the body.
4. remains liquid in a wide range of moderate temperatures, resisting freezing and boiling- in allows living things to exist a variety of environments.
5. adheres to surfaces, acting as lubricant to reduce friction.
6. cohesive – water molecules attract each other, allowing water to flow in a continuous stream.
7. transparent to visible light

ORGANIC compounds are substances that always contain both hydrogen and carbon, alone or in combination with many other elements. They are formed mostly with covalent bonds, and range in size from methane (CH_4) to huge macromolecules containing millions of atoms each. In general, the organic molecules important in living systems are much larger then the inorganic ones. Organic compounds form the major components of living cells. the major categories of organic molecules important to living things are ***carbohydrates, proteins, lipids***, and ***nucleic acids***.

CARBOHYDRATES contain the elements C, H, and O only, and form the primary source of energy for plants and for animals. The term ***carbohydrate*** means "hydrate of carbon," hydrate means "water". Carbohydrates can be thought of as being made of carbon and water because the ratio of hydrogen to oxygen in carbohydrates is always 2:1, just as it is in water (H_2O). All carbohydrates are ***sugars***, and are classified by the number of carbons in each sugar units in the entire molecule. The major class names have the suffix *–saccharide,* which means "sugar". Sugar units are basically of two types, *pentoses* (5-carbon) and *hexoses* (6-carbon). The suffix *–ose* also indicates "sugar." Sugars can be depicted as straight chains, but usually exist as ringed structures.

Monosacharides: One –unit (monomeric, mono = one, meric = unit) sugars. Also known as "simple sugars." Pentose examples include ribose and deoxyribose. Hexose examples include glucose, fructose, and galactose. Glucose is the single most important molecule used by the living cell for energy production and storage.

Disaccharides: Two-unit (dimeric, *di* = two) sugars. Two simple sugars covalent bonded together, through the reaction known as *dehydration synthesis*. Each reaction eliminates two hydrogen atoms and one oxygen atom from the sugars, producing one molecule of water as a byproduct for each disaccharide formed (*dehydration* = removal of water). The sugars unit can be broken apart again by the reverse reaction, *hydrolysis*, which breaks the bond between the sugars by adding back water (*hydro* = water, *lysis* = split apart). Examples include **maltose** (malt sugar, glucose + glucose), **sucrose** (table sugar, glucose +fructose), and **lactose** (milk sugar, glucose + galactose).

Polysaccharides: multiple-unit (polymeric, *poly* = many) sugars. Formed from many simple sugars by multiple dehydration synthesis reactions, producing one water molecule as byproduct for each sugar unit added to the chain. Large polysaccharides are the form in which living things arrange sugars for short-term storage energy. They are also used as structural components in plants. The most important polysaccharides are starch, glycogen, and cellulose. All three are polymers of glucose.

Starch: Energy storage form for plants. Long chains of glucose with few side chains.

Glycogen: Energy storage form for animals. Many more side chains, allowing many hydrolysis reactions to take place simultaneously, providing much quicker release of energy.

Cellulose: Primary structural component in plants, found in the cell wall. Linkage between glucose units is different, making it harder to break the units apart.

LIPIDS contain the elements C, H, and O, but not in the ratio found in carbohydrates. Lipids include the compounds commonly referred to as fats, oils, and waxes. They are used by plants and animals for long- term storage of energy and are also structural components of the cell membrane.

Triglycerides are lipids from **glycerol** and three **fatty acids**. Fats and oils are triglycerides. Glycerol is a 3-carbon alcohol with three hydroxyl (-OH) groups. Fatty acids are long chains of carbon with hydrogens attached (*hydrocarbons*) and a carboxylic acid (*carboxyl*, -COO) group on one end. Triglycerides are formed by dehydration synthesis, joining the three fatty acids to the glycerol "backbone", and producing three water molecules as byproducts. Triglycerides can be broken back down through hydrolysis and hold more than twice as much energy per gram as carbohydrates. Triglycerides are also sometimes called *neutral fats*, because the molecules are electrically neutral.

Triglycerides can be *saturated* or *unsaturated*, depending on how the fatty acids it contains are structured. When a triglyceride is made of fatty acids having only single bonds between the carbons, then it will have the maximum number of hydrogen atoms attached and is said to be a *saturated* fat (as in *saturated with hydrogen*). If one of the bonds between carbons is a double bond, there will be one less hydrogen attached to each of those two carbons, and the fat is said to be *monounsaturated*. If many carbons have double bonds between them, there will be much fewer types of hydrogen (much less saturation) and the fat is said to be *polyunsaturated.* Oils are less saturated than fats (which are why oils are liquid at room temperature, while fats are solids), and triglycerides are from plants are in general much less saturated than those from animals. However, some plants oils are highly saturated (coconut, palm, and other tropical oils, for example). Saturated fats and oils have been linked to heart disease, and should be eaten in moderation. They should be replaced in human diet by polyunsaturated whenever feasible; however research has indicated that we need some saturated triglycerides in our food to remain healthy.

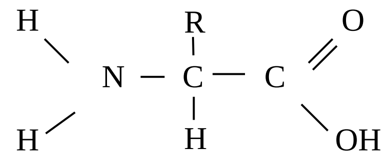
Phospholipids have the same structure as triglycerides, except that one fatty acid on the glycerol backbone is replaced by a *phosphate* group (glycerol + 2 fatty acids + phosphate). Unlike triglycerides, phospholipids are not electrically neutral because the phosphate group has a charge on it. The polar phosphate group repels the non-polar fatty acids groups, bending the molecule into a shape having a polar "head" and non-polar "tails."

Steroids have a very different structure. All have a backbone composed of four fused carbon rings, with various sides groups attached at one end. Cholesterol is a steroid from which many others steroids are derived, including the sex hormones.

Carotenoids are red and yellow pigments classified by some lipids because they are insoluble in water and have an oily consistency. These compounds are found in plants, where they have a role in photosynthesis. They are also believed to beneficial nutrients in the human diet.

PROTEINS contain the elements C, H, O, and N. They are important in the structure of cell walls, are a major component of muscle and connective tissues, help to carry oxygen in the body, and are incorporated into many hormones, enzymes, and antibodies. Proteins are polymers of *amino acids*, all of which have the same structure:

NH_2 = amino group
COOH = carboxyl
R = radical (different for each amino acid)



There are 20 amino acids commonly found in proteins. Humans can manufactured 11 of them (mostly by converting one amino acid into another), but the remaining nine must be obtained in our diet. These nine are referred as the *essential amino acids*.

Proteins are formed by linking amino acids together through dehydration synthesis, forming *peptide bonds*, which of course can be broken again through hydrolysis. Two amino acids linked together are called a *dipeptide*; three, a *tripeptide*; and many amino acids, a *polypeptide*. There are four levels of protein structure:

Primary: The order in which the different amino acids are linked together in the polypeptide

Secondary: the coiling of the polypeptide chain into an *alpha helix*, held by hydrogen bonds

Tertiary : The bending and twisting of the helix in three dimensions, held in place by a combination of covalent, ionic, and hydrogen bonds

Quaternary: The grouping together of several different polypeptide chains whose tertiary structure allows them to "fit together" life pieces of puzzle.

Proteins are polar compounds whose carboxyl and amino groups may become charged, depending on the pH of the surroundings solutions. The shapes of many proteins, especially enzymes, are very important to their function. Drastic changes in temperature or pH can cause an irreversible change in the shape of proteins, disrupting their secondary or higher-levels structures. Such proteins are said to be *denatured*, and can no longer perform their usual functions.

Enzymes are proteins that act as catalysts for biochemical reactions in the cells. Like all catalysts, they affect the rate at which the reactions proceeds by lowering the energy level needed to activate the reactions. This energy level is known as the *activation energy*. The energy is required to break bonds so that new bonds can be formed. A catalyzed reaction proceeds more quickly than an uncatalyzed reactions because the activation energy required is less. Many biochemical reactions cannot occur at all without the present of the proper enzyme. Only a small amount of particular enzyme is needed to catalyze a reaction, because the enzyme molecules themselves are not changed by the reaction and so can be used over and over again. The compound on which an enzyme acts to activate a reaction is called the *substrate.* Enzymes are very specific for particular substrates, because of the three-dimensional shapes of the enzymes and substrates. An enzyme will form a temporary complex with its substrate, fitting together like a key in a lock to activate the reaction. The specific part of the enzyme that joins with the substrate is called the *activate site*. As each reaction is completed, the complex breaks up, releasing the product for use, and freeing the enzyme to form a new complex with another substance molecule, thereby catalyzing the next reaction. As noted earlier, enzymes require a limited range of temperature and pH in order to function properly.

NUCLEIC ACIDS include DNA, and RNA. DNA holds the genetics instructions for all cellular process and structures, passing them on from one generation to the next in the form of *chromosomes*. RNA is used to read the code contained by DNA, and transport it to places in the cell where it will direct cellular functions. Nucleic acids are polymers of *nucleotides*, which in turn are composed of three functional groups: 1) a 5-carbon sugar, 2) a phosphate group, and 3) a nitrogenous base. The sugar in RNA is *ribose*, hence the name *ribonucleic acid* (RNA). The sugar in DNA is *deoxyribose* (*deoxy-* because it has one less oxygen than ribose), hence the name *deoxyribonucleic acid* (DNA). The sugars and phosphate groups form the backbone of the nucleic acids, linking the nucleotides together by bonding the sugar of the nucleotide to the phosphate group of the next, and so on. The nitrogenous bases hang off this chain, which is referred to as a strand of nucleic acid. There are five different nitrogenous bases, classified by their structure:

> *Purines* have a double ring structure of carbon and nitrogen, with hydrogen attached.
> The two purines are called *adenine* and *guanine*
>
> *Pyrimidines* have a single ring of carbon and nitrogen, with hydrogen attached.
> The three pyrimides are *cystosine, thymine* (found only in DNA), and *uracil* (found only in RNA).

RNA has only one strand. DNA has two strands forming a double helix, held together by hydrogen bonds between pairs made of one purine and one pyrimidine (this is called *complementary base pairing*).
In DNA adenine is paired with thymine, but since RNA does not contain any thymine, in RNA adenine is paired with uracil (RNA can pair up with one of the DNA strands during a process called *transcription*: adenine on the DNA strands pairs with uracil on the RNA strand, but thymine on DNA strands will still pair with the adenine on the RNA strand; so uracil can substitute for thymine in pairing with adenine, but uracil and thymine cannot pair with each other). Guanine is *always* paired with cystosine in *both* DNA and RNA.

COMPARISION BETWEEN DNA AND RNA

CHARACTERISTICS	DNA	RNA
FUNCTION	stores genetic code, directs protein synthesis	transport and translate DNA code, assists in protein synthesis
SUGAR	deoxyribose	ribose
BASES	adenune, guanine, cystosine, thymine	adenune, guanine, cystosine, uracil
STRANDS	double	single
HELIX	Yes	no

Another important nucleotide is ATP (*adenosine triphosphate*), which is composed of adenine and ribose (collectively called *adenosine*) attached to the chain of three phosphate groups. The two bonds linking the three phosphates to each other contain a large amount of energy (*high energy bonds*), which makes ATP an efficient, compact transporter of energy through the cell. When energy is needed to supply a reaction, one of the bonds is broken to release that energy, converting ATP to ADP (adenosine *di*phosphate) in the process. ADP is then regenerated back into ATP for reuse.

Vitamins are organic substances required in very small amounts (*micronutrients)* in order for the body to function properly. Human beings cannot manufacture them, so we must obtain them in our diet. There are 13 vitamins presently identified. All have very specific functions, some acting as *coenzymes* (enzymes helpers). Vitamins A, D, E, and K are fat-soluble, which means they stored in the liver and other fatty tissues where they can build up and become toxic if consumed in large enzymes. Water-soluble vitamins act as coenzymes. Excess amounts of these vitamins are excreted in the urine, so they are less likely to build up to toxic levels in the body. They include vitamins C (ascorbic acid), B1 (thiamine), B2 (riboflavin), B3 (niacin), B6 (pyridoxine), B12, pantothenic acid, biotinic acid (biotin), and folic acid (folacin). Vitamin deficiency can cause serious problems.