**The Chemistry of the Cell**

**Elements of Life**

An **element** is one of the basic building blocks of matter; an element cannot be broken down by chemical means. Considering the variety of living and nonliving things in the world, it‘s remarkable that there are only **92 naturally occurring elements**. It is even **more surprising** that over **90%** of the human body is composed of just **four** elements: **C, N, O**, and **H.** Even so, other elements, such as **iron**, are important to our health. **Iron-deficiency anemia** results when the diet doesn‘t contain enough iron for the making of hemoglobin.

When the above mentioned and others chemical elements combined in various ways, all known **biomolecules** could be formed. **B**iomolecules can be classified into **micromolecules** and **macromolecules**.

**Biological Micromolecules**

The **micromolecules** are relatively smaller in size and low molecular weight than one thousand Daltons. The **micromolecules** may occur free in water or can serve as **monomers** join together by bonds to form the **polymers** or the large molecules. The most important micromolecules are **water, minerals, amino acids (**form **protein**s)**, sugar such as glucose**, and nucleotides (form **nucleic acids).** The micromolecules act as **substrates for various reactions** and are also the products of **metabolism**.

Water functions as a **universal solvent** in which almost all polar and ionic substances can dissolve. Most of the cellular **metabolic reactions** carried out with the help of water. **Minerals** form only about 1-3% of a cell‘s composition but they are essential for **cellular activities**.

Minerals like Mg function as **cofactors** in **enzymes**, or they become a component of certain organic compounds, such as: **iron** in **hemoglobin**, **Ca** and **P** in **bones**, and **Mg** in **chlorophyll**. Also, they are essential components of various **biological fluids**.

**Biological Macromolecule (Molecules of life)**

Proteins, carbohydrates, nucleic acids, and lipids are the four major classes of biological **macromolecules**—large molecules necessary for life that are built from smaller organic molecules. Macromolecules are made up of single units known as **monomers** that are joined by **covalent bonds,** with the release of a water molecule, to form larger **polymers**. These types of reactions are known as **dehydration or condensation reactions**. When polymers are broken down into smaller units (monomers), a molecule of water is used for each bond broken by these reactions; such reactions are known as **hydrolysis reactions**. **Dehydration reactions** typically require an **investment of energy** for new bond formation, while **hydrolysis reactions** typically **release energy** by breaking bonds.

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| --- | --- | --- |
| **Macromolecule** | **Monomer** | **Examples** |
| **Proteins** | **Amino acids** | **Enzymes, some hormones** |
| **Lipids** | **Fatty acid and glycerol** | **Butter, oil, cholesterol, beeswax** |
| **Carbohydrates** | **Monosaccharides** | **Glucose, Starch, Glycogen, Cellulose** |
| **Nucleic Acids** | **Nucleotides** | **DNA, RNA** |

* + **Carbohydrates**

Carbohydrates are almost used as an energy source for living organisms, including humans. In some organisms, such as plants and bacteria, carbohydrates have a **structural function**. Carbohydrate molecules all have C, H, and O atoms and the ratio of **H** to O is approximately 2:1.

**Simple Carbohydrates: Monosaccharides**

Monosaccharides (mono=one; saccharide= sugar) consist of only a single sugar molecule and are commonly called simple sugars. A monosaccharide can have a carbon backbone of three to seven carbons. For example, **pentoses** with **5** carbons (Ribose), and **hexoses** with **6** carbons. The most common monosaccharide, and the one that our

bodies use as an immediate source of energy, is the hexose **glucose.**

1. **Disaccharides**

A disaccharide (di= ―two‖; saccharide= ―sugar‖) is made by joining only two monosaccharides together. **Maltose** is a disaccharide formed by a dehydration reaction between two glucose molecules (Figure 2). When our hydrolytic digestive juices break down maltose, the result is two glucose molecules. When **glucose and fructose** join, the disaccharide sucrose forms, **Sucrose (**table sugar). You may also have heard of lactose, a disaccharide found in milk. **Lactose** is glucose combined with galactose.

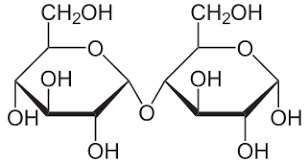


Figure 2: Disaccharide molecules (Maltose)

1. **Complex Carbohydrates: Polysaccharides**

**Starch, glycogen**, and **cellulose** are polysaccharides (poly =many) that contain long chains of glucose subunits. The polysaccharides **starch (**in plants such as wheat, potatoes.**)** and **glycogen (in animals)** are **long polymers** of **glucose** (**several 1000s glucose molecules)**. Both starch and glycogen are used to **store glucose** to meet the **energy needs** of the cell. The polysaccharide **cellulose,** commonly called **fiber**, is found in **plant cell walls**. We are **unable to digest foods** containing cellulose; therefore, cellulose largely passes through our digestive tract as fiber, or **roughage.**

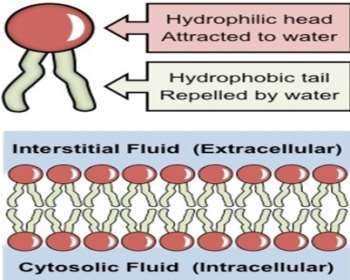
* + **Lipids**

Lipids are diverse in structure and function. They do not dissolve in water due to an absence of **hydrophilic polar groups**. They contain little **O**2 and consist mostly of C and **H** atoms. Lipids contain **more energy per gram** than other biological molecules; therefore**, fats** in animals and **oils** in plants function well as energy storage molecules. Four main groups of lipids are known

* Fatty acids (saturated and unsaturated)
* Glycerides (glycerol-containing **lipids- fats and oils**)
* Nonglyceride **lipids** (sphingolipids, steroids, waxes)
* Complex **lipids** (lipoproteins, glycolipids, phospholipids)

**Steroids** are a large class of lipids that includes the **sex hormones**.

**Phospholipids** are the primary components of the plasma membranes in cells. They form the polar (**hydrophilic**) head of the molecule, and the rest of the molecule becomes the **nonpolar (hydrophobic)** tails. In a water environment, they spontaneously form a **bilayer** (a sort of molecular ―sandwich‖) in which the hydrophilic heads (the sandwich ―bread‖) face outward toward watery solutions, and the tails (the sandwich ―filling‖) form the **hydrophobic interior**.

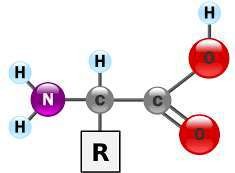


**Phospholipids**

* + **Proteins**

Proteins are macromolecules with **amino acid** subunits. The c**entral carbon atom** in an amino acid bonds to a **hydrogen atom**, an -NH2 (amino group), a -COOH (carboxyl group, an acid), and the R group (figure below).

The covalent bond between two amino acids is called a **peptide bond**. When three or more amino acids are linked by peptide bonds, the resulted chain is called a **polypeptide**.



Proteins are of primary importance in the **structure and function of cells**. Some of their many functions are listed in the below table:

|  |  |  |
| --- | --- | --- |
| **Protein type** | **Examples** | **Functions** |
| **Digestive** | **Enzymes: mylase, lipase, trypsin** | digestion of food into monomeric units |
| **Transport** | **Hemoglobin** | Carry O2 in the blood |
| **Structural** | **Actin, tubulin, keratin** | Construct different structures, like the  cytoskeleton, hair, nails |
| **Hormones** | **Insulin, thyroxine** | Coordinate the activity of different body systems |
| **Defense** | **Immunoglobulins** | Protect the body from foreign pathogens |
| **Contractile** | **Actin, myosin** | Effect muscle contraction |
| **Storage** | **egg white (albumin)** | Provide nourishment in early development of  the embryo |