Introduction to macromolecules

Types of large biological molecules. Monomers, polymers, dehydration synthesis, and hydrolysis.

Introduction

Think back to what you ate for lunch. Did any of your lunch items have a “Nutrition Facts” label on the back of them? If so, and if you had a look at the food's protein, carbohydrate, or fat content, you may already be familiar with several types of large biological molecules we’ll discuss here. If you’re wondering what something as weird-sounding as a “large biological molecule” is doing in your food, the answer is that it’s providing you with the building blocks you need to maintain your body – because your body is also made of large biological molecules!
Just as you can be thought of as an assortment of atoms or a walking, talking bag of water, you can also be viewed as a collection of four major types of large biological molecules: carbohydrates (such as sugars), lipids (such as fats), proteins, and nucleic acids (such as DNA and RNA). That’s not to say that these are the only molecules in your body, but rather, that your most important large molecules can be divided into these groups. Together, the four groups of large biological molecules make up the majority of the dry weight of a cell. (Water, a small molecule, makes up the majority of the wet weight).

Large biological molecules perform a wide range of jobs in an organism. Some carbohydrates store fuel for future energy needs, and some lipids are key structural components of cell membranes. Nucleic acids store and transfer hereditary information, much of which provides instructions for making proteins. Proteins themselves have perhaps the broadest range of functions: some provide structural support, but many are like little machines that carry out specific jobs in a cell, such as catalyzing metabolic reactions or receiving and transmitting signals.

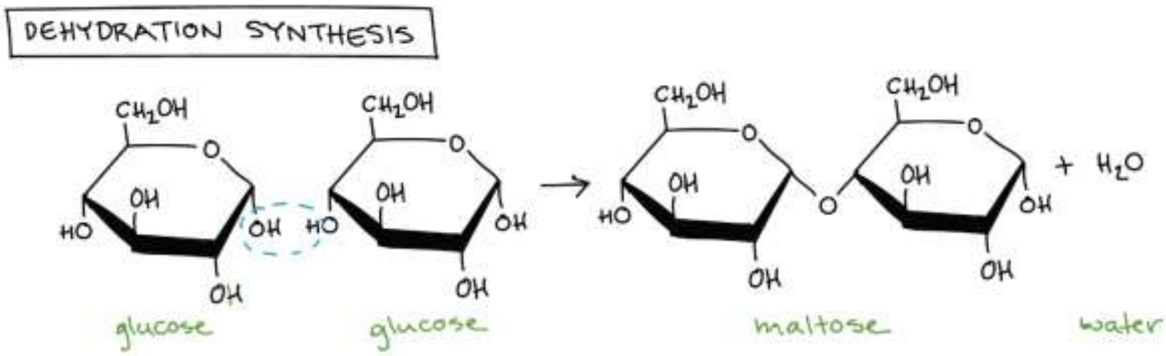
We’ll look in greater detail at carbohydrates, lipids, nucleic acids, and proteins a few articles down the road. Here, we’ll look a bit more at the key chemical reactions that build up and break down these molecules.

Monomers and polymers

Most large biological molecules are **polymers**, long chains made up of repeating molecular subunits, or building blocks, called **monomers**. If you think of a monomer as being like a bead, then you can think of a polymer as being like a necklace, a series of beads strung together. Carbohydrates, nucleic acids, and proteins are often found as long polymers in nature. Because of their polymeric nature and their large (sometimes huge!) size, they are classified as **macromolecules**, big (*macro*-) molecules made through the joining of smaller subunits. Lipids are not usually polymers and are smaller than the other three, so they are not considered macromolecules by some sources[1,2]. However, many other sources use the term “macromolecule” more loosely, as a general name for the four types of large biological molecules[3,4]. This is just a naming difference, so don’t get too hung up on it. Just remember that lipids are one of the four main types of large biological molecules, but that they don’t generally form polymers.

Dehydration synthesis

How do you build polymers from monomers? Large biological molecules often assemble via **dehydration synthesis** reactions, in which one monomer forms a covalent bond to another monomer (or growing chain of monomers), releasing a water molecule in the process. You can remember what happens by the name of the reaction: dehydration, for the loss of the water molecule, and synthesis, for the formation of a new bond.



Dehydration synthesis reaction between two molecules of glucose, forming a molecule of maltose with the release of a water molecule.

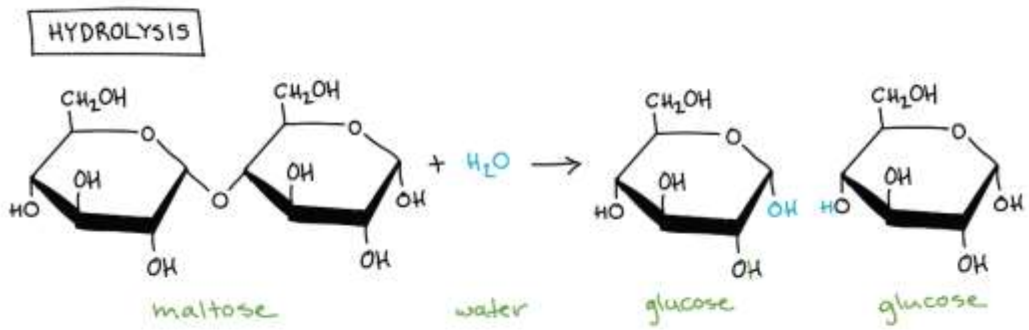
In the dehydration synthesis reaction above, two molecules of the sugar glucose (monomers) combine to form a single molecule of the sugar maltose. One of the glucose molecules loses an H, the other loses an OH group, and a water molecule is released as a new covalent bond forms between the two glucose molecules. As additional monomers join by the same process, the chain can get longer and longer and form a polymer.

Even though polymers are made out repeating monomer units, there is lots of room for variety in their shape and composition. Carbohydrates, nucleic acids, and proteins can all contain multiple different types of monomers, and their composition and sequence is important to their function. For instance, there are four types of nucleotide monomers in your DNA, as well as twenty types of amino acid monomers commonly found in the proteins of your body. Even a single type of monomer may form different polymers with different properties. For example, starch, glycogen, and cellulose are all carbohydrates made up of glucose monomers, but they have different bonding and branching patterns.

Hydrolysis

How do polymers turn back into monomers (for instance, when the body needs to recycle one molecule to build a different one)? Polymers are broken down into monomers via **hydrolysis** reactions, in which a bond is broken, or lysed, by addition of a water molecule.

During a hydrolysis reaction, a molecule composed of multiple subunits is split in two: one of the new molecules gains a hydrogen atom, while the other gains a hydroxyl (-OH) group, both of which are donated by water. This is the reverse of a dehydration synthesis reaction, and it releases a monomer that can be used in building a new polymer. For example, in the hydrolysis reaction below, a water molecule splits maltose to release two glucose monomers. This reaction is the reverse of the dehydration synthesis reaction shown above.



Hydrolysis of maltose, in which a molecule of maltose combines with a molecule of water, resulting in the formation of two glucose monomers.

Dehydration synthesis reactions build molecules up and generally require energy, while hydrolysis reactions break molecules down and generally release energy. Carbohydrates, proteins, and nucleic acids are built up and broken down via these types of reactions, although the monomers involved are different in each case. (In a cell, nucleic acids actually aren't polymerized via dehydration synthesis; we'll examine how they're assembled in the article on nucleic acids. Dehydration synthesis reactions are also involved in the assembly of certain types of lipids, even though the lipids are not polymers[3].

In the body, enzymes catalyze, or speed up, both the dehydration synthesis and hydrolysis reactions. Enzymes involved in breaking bonds are often given names that end with *-ase*: for instance, the maltase enzyme breaks down maltose, lipases break down lipids, and peptidases break down proteins (also known as polypeptides, as we'll see in the article on proteins). As food travels through your digestive system – in fact, from the moment it hits your saliva – it is being worked over by enzymes like these. The enzymes break down large biological molecules, releasing the smaller building blocks that can be readily absorbed and used by the body.