

Carbohydrates

Slide 2 When you hear the word carbohydrate, you may initially think of breads, pastas, or the PowerBar® you had before your last workout. While it is true that these foods contain carbohydrates, they contain only a fraction of the types of molecules that are classified as carbohydrates. Carbohydrates, in fact, are a diverse group of organic molecules found in all living organisms. Carbohydrates can play a number of important roles for organisms, including:

- 1) providing an energy source or store,
- 2) providing a source of carbon skeletons useful for making other types of molecules,
- 3) receiving chemical signals
- 4) giving structural support to cells and organisms.

Slide 3 Carbohydrates are composed primarily of carbon, hydrogen, and oxygen, as one would expect from their name, and can range in size from molecular weights of 100 Daltons or less to hundreds of thousands of Daltons. Carbohydrates are considered to be macromolecules because they often form polymers of repeating subunits, or monomers.

The simplest form of a carbohydrate is called a monosaccharide, meaning “single sugar.” Many biologically important monosaccharides have either five or six carbon atoms. Glucose and fructose, for example, contain six carbon atoms. Ribose and deoxyribose, found in RNA and DNA, respectively, have five carbons. You might note that monosaccharides often follow the general formula of $C_nH_{2n}O_n$, and so have their carbon, hydrogen, and oxygen atoms in the ratio of 1:2:1. For example, glucose has the molecular formula $C_6H_{12}O_6$.

Slide 4 Monosaccharides, while carbohydrates themselves, are also the repeating subunits, or monomers, for larger carbohydrates. Monosaccharides may be linked together covalently during a condensation reaction, just like amino acids are linked together by condensation reactions to form polypeptides, and just as nucleotides are linked to form nucleic acids. The bond that forms between monosaccharides is called a glycosidic linkage.

When two monosaccharides are covalently linked together through a condensation reaction, they form a disaccharide. Sucrose, the carbohydrate that is transported through plant vascular tissue, is a disaccharide composed of fructose and glucose.

Slide 5 When several monosaccharides (3-20 or so) are covalently linked together through condensation reactions, they form an oligosaccharide. Oligosaccharides are often found associated with membranes, where they may bind chemical signals from the cell's environment or from other cells. Your blood type, for instance, is determined by oligosaccharides bound to the cell membranes of your red blood cells.

Slide 6 When many monosaccharides are linked together by glycosidic linkages, they form what is called a polysaccharide. Polysaccharides, of course, are the largest carbohydrates, and play diverse and important roles for organisms.

In some cases, polysaccharides consist of linearly connected, unbranched chains of monosaccharides. Cellulose, which is found in the cell walls of plants and protists, consists of linear chains of covalently linked glucose molecules. Cellulose is the most abundant organic compound on earth.

Starch and glycogen, the storage compounds found in plants and animals, respectively, are also made up of many covalently linked glucose molecules. However, the glucose molecules of starch and glycogen may be linked covalently in two ways (technically these linkages involve the first and fourth carbon or the first and sixth carbon of the glucose molecules). As a result, these polysaccharides are branched.

Slide 7 It is worthwhile here to consider the monosaccharide glucose specifically, as glucose is utilized in the metabolic pathways of the vast majority of organisms, and is an integral component of many other types of molecules, as we will see shortly. Glucose most often is found in a ring form, although a small portion of the time it converts to a linear molecule. When it is in the ring form, glucose interconverts between two forms, or isomers – α -glucose and β -glucose. The difference between these two molecules concerns the orientation of the hydrogen and hydroxyl groups on the number one carbon. Because of this difference in orientation, slightly different glycosidic linkages result when molecules of glucose are covalently bound together, depending on whether the glucose molecules are α - or β -glucose. Further, different molecules will also result from this bonding. For example, when an α -glucose is covalently linked to a β -glucose, an α -1,4 glycosidic linkage results, forming the disaccharide maltose. Alternatively, if two β -glucose molecules are linked together, a β -1,4 glycosidic linkage results, forming the disaccharide cellobiose.

On a similar note, the polysaccharides cellulose, starch, and glycogen are all composed of glucose monomers. Each of these molecules, however, has a different shape. In part, this shape is determined by whether each molecule consists of α - or β -glucose monomers, and so α - or β -glycosidic linkages.

It is not important here to memorize the names or structures of maltose and cellobiose. Rather, be aware that the alpha and beta forms of glucose can affect the higher structure of di-, oligo-, and polysaccharides.

Slide 8 Lastly, in many cases sugars are chemically modified by adding other molecular entities. Perhaps most simply, oxygen may be added to the number six carbon of a monosaccharide to form a carboxyl group. The result? What was previously a carbohydrate is now an acid. Other groups may be added to carbohydrates, as well, most notably phosphates, amino groups, and N-acetyl groups. Take for example chitin, which

makes up insect and crustacean exoskeletons, and is also found in the cell walls of fungi. Chitin consists of covalently linked molecules of glucosamine, which are glucose molecules that carry an amino group on their number two carbons. In the case of chitin, glucosamine is further modified by adding an acetyl group to the amino group, resulting in each monosaccharide carrying an N-acetyl group.