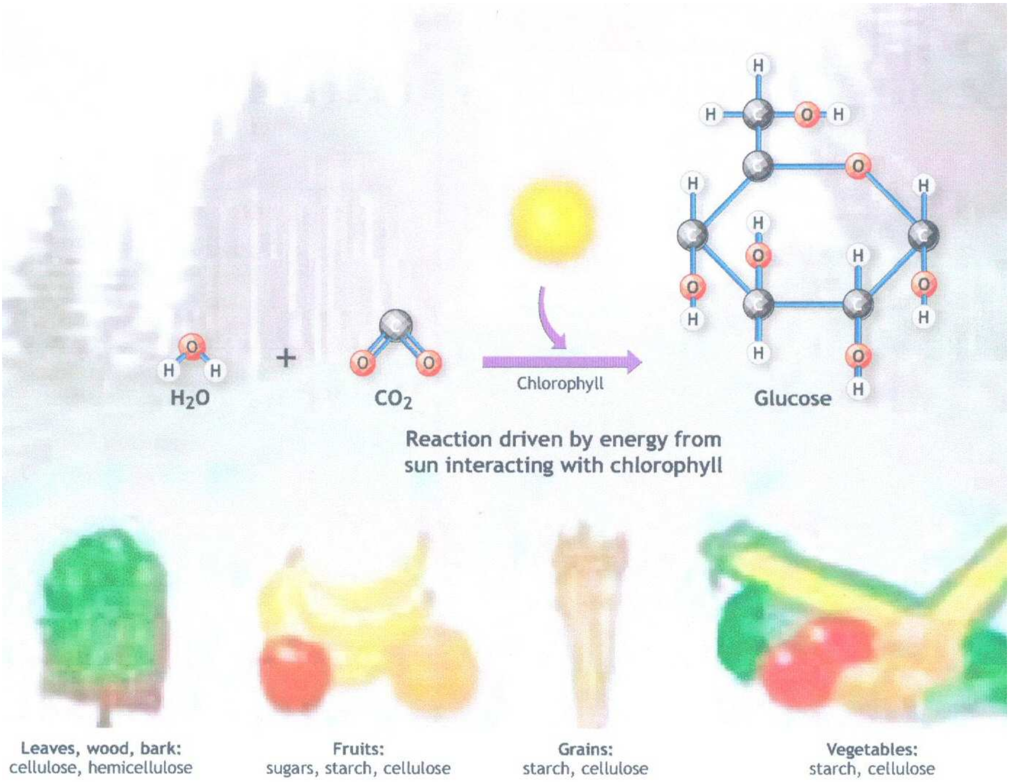
Section 1b

The Composition Of Carbohydrates

Atoms of carbon, hydrogen, and oxygen combine to form a carbohydrate (sugar) molecule in the general formula (CH2O)n, where n ranges from 3 to 7 carbon atoms with hydrogen and oxygen atoms attached by single bonds. Except for lactose and a small amount of glycogen, plants provide the carbohydrate source in the human diet. The following figure illustrates the most typical sugar, glucose, along with other carbohydrates formed in photosynthesis. Glucose consists of 6 carbon, 12 hydrogen, and 6 oxygen atoms, with the chemical formula C6H12O6. Each carbon atom has four bonding sites that can link to other atoms, including carbons. Carbon bonds not linked to other carbons are “free” to hold hydrogen (with only one bond site), oxygen (with two bond sites), or an oxygen–hydrogen combination (OH) termed a hydroxyl. Fructose and galactose, two other simple sugars with the same chemical formula as glucose, have a slightly different C-H-O linkage. The alteration in atomic arrangement makes fructose, galactose, and glucose different substances with distinct biochemical characteristics.



Three-dimensional ring structure of the simple sugar glucose molecule formed during photosynthesis when energy from sunlight interacts with water, carbon dioxide, and the green pigment chlorophyll.

Kinds And Sources Of Carbohydrates

Carbohydrates generally classify as monosaccharides, oligosaccharides, and polysaccharides. The number of simple sugars linked within each of these molecules distinguishes each carbohydrate form.

Monosaccharides

The monosaccharide represents the basic unit of carbohydrates. More than 200 monosaccharides exist in nature, categorized by the number of carbon atoms in their ring. The Greek name for this number ending with "ose" identifies them as sugars. For example, trioses are monosaccharides with three carbons; tetroses have four carbons; pentoses, five; hexoses, six; and heptoses, seven. Hexose sugars include the nutritionally important monosaccharides glucose, fructose, and galactose. Glucose, also called dextrose or blood sugar, forms naturally in food or in the body through digestion of more complex carbohydrates. Gluconeogenesis also synthesizes glucose, primarily in the liver, from the carbon residues of other compounds (generally amino acids, but also glycerol, pyruvate, and lactate). After absorption by the small intestine, glucose either (1) becomes available as an energy source for cellular metabolism, (2) forms glycogen for storage in the liver and muscles, or (3) is converted to triglyceride for later use as energy.

Fructose (fruit sugar or levulose), the sweetest simple sugar, occurs in large amounts in fruits and honey. Some fructose goes directly from the digestive tract into the blood, but all eventually becomes glucose in the liver.76 Galactose does not exist freely in nature; rather, it combines with glucose to form milk sugar in the mammary glands of lactating animals. The body converts galactose to glucose for use in energy metabolism.

Oligosaccharides

Oligosaccharides form when 2 to 10 monosaccharides bond chemically. The major oligosaccharides, the disaccharides or double sugars,

Disaccharides all contain glucose. Three principal disaccharides exist.

• Sucrose (glucose plus fructose), the most common dietary disaccharide, contributes up to 25% of the total caloric intake in the United States. It occurs naturally in most foods that contain carbohydrates, especially beet and cane sugar, brown sugar, sorghum, maple syrup, and honey.

• Lactose (glucose plus galactose), the only sugar not found in plants, exists in natural form only in milk as milk sugar.

• Maltose (glucose plus glucose) occurs in beer, breakfast cereals, and germinating seeds.

Polysaccharides

The term polysaccharide describes the linkage of three to thousands of sugar molecules. Polysaccharides form during the chemical process of dehydration synthesis. These large chains of linked monosaccharides come from either plant or animal sources. The designations plant and animal denote these two polysaccharide subclassifications.

Plant Polysaccharides

Starch and fiber are the common forms of plant polysaccharides.

Starch, the storage form of carbohydrate in plants, is the most familiar form of plant polysaccharide. It occurs in seeds, corn, and various grains of bread, cereal, pasta, and pastries. Large amounts also exist in peas, beans, potatoes, and roots, in which starch serves as an energy store for future use by plants. Starch exists in two forms: (1) amylose, a long straight chain of glucose units twisted into a helical coil, and (2) amy-lopectin, a highly branched monosaccharide linkage. The relative proportion of each form of starch in a particular plant species determines the specific characteristics of the starch, including its “digestibility.” Starches with a relatively large amount of amylopectin digest and absorb rapidly, whereas starches with high amylose content have a slower rate of chemical breakdown (hydrolysis).

Plant starch still represents the most important dietary source of carbohydrate in the American diet, accounting for approximately 50% of total carbohydrate intake. Daily starch intake, however, has decreased about 30% since the turn of the twentieth century, while simple-sugar consumption has correspondingly increased from 30% to about 50% of total carbohydrate intake. The term complex carbohydrate describes dietary starch.

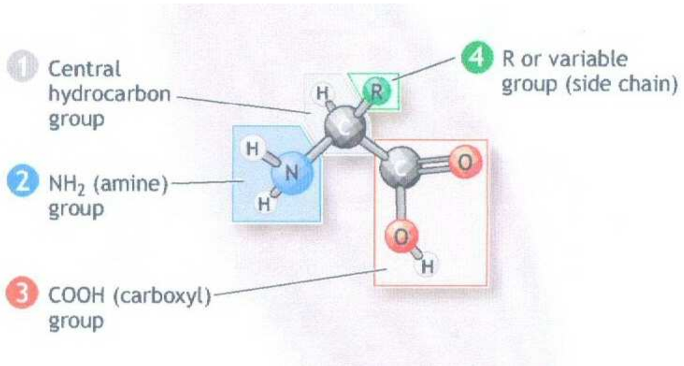
Fiber, classified as a nonstarch, structural polysaccharide, includes cellulose, the most abundant organic molecule on earth. Fibrous materials resist chemical breakdown by human digestive enzymes, although a portion ferments by action of intestinal bacteria and ultimately participates in metabolic reactions following intestinal absorption. Fibers occur exclusively in plants; they make up the structure of leaves, stems, roots, seeds, and fruit coverings. Fibers differ widely in physical and chemical characteristics and physiologic action. Cell walls contain different kinds of fibers (cellulose, hemicellulose, pectin, and the noncarbohydrate lignin); mucilage and gums occur within the plant cell itself.

The composition of Proteins

The body of an average-sized adult contains between 10 and 12 kg of protein, with the largest quantity (6 to 8 kg) located within the skeletal muscle mass. Additionally, approximately 210 g of amino acids exist in free form, largely as glutamine, a key amino acid with functions that include serving as fuel for immune system cells. Humans typically ingest about 10 to 15% of their total calories as protein. During digestion, protein hydrolyzes to its amino acid constituents for absorption by the small intestine. The protein content of most adults remains remarkably stable, and no amino acid “reserves” exist in the body. Amino acids not used for the synthesis of protein or other compounds (e.g., hormones) or for energy metabolism provide substrate for gluconeogenesis or convert to triglyceride for storage in adipocytes.

Structurally, proteins resemble carbohydrates and lipids because they contain carbon, oxygen, and hydrogen atoms. Protein molecules also contain about 16% nitrogen, along with sulfur and occasionally phosphorus, cobalt, and iron. Just as glycogen forms from many simple glucose subunits linked together, the protein molecule polymerizes from its amino acid “building-block” constituents in endlessly complex arrays. Peptide bonds link amino acids in chains that take on diverse forms and chemical combinations; two joined amino acids produce a dipeptide, and linking three amino acids produces a tripeptide, and so on. Generally, a polypeptide chain contains 50 to more than 1000 amino acids. Combination of more than 50 amino acids forms a protein of which humans can synthesize about 80,000 different kinds. Single cells contain thousands of different protein molecules; some have a linear configuration, some are folded into complex shapes having three-dimensional properties. In total, approximately 50,000 different protein-containing compounds exist in the body. The biochemical functions and properties of each protein depend on the sequence of specific amino acids as discussed more fully in the final chapter, “On the Horizon.”

The 20 different amino acids required by the body each have a positively charged amine group at one end and a negatively charged organic acid group at the other end. The amine group has two hydrogen atoms attached to nitrogen (NH2), whereas the organic acid group (technically termed a carboxylic acid group) contains one carbon atom, two oxygen atoms, and one hydrogen atom (COOH). The remainder of the amino acid, referred to as the R group or side chain, takes on a variety of forms. The R group’s specific structure dictates the amino acid’s particular characteristics. The next figure shows the four common features that constitute the general structure of all amino acids. The potential for combining the 20 amino acids produces an almost infinite number of possible proteins, depending on their amino acid combinations. For example, linking just three different amino acids could generate 203, or 8000, different proteins.[1 2 3 4]



[1] http://www.sci.sdsu.edu/class/bio202/TFrey/CH2O_Proteins.html

[2] http://en.wikipedia.org/wiki/Carbohydrate

[3] http://en.wikipedia.org/wiki/Protein_structure

[4] http://www.cristina.prof.ufsc.br/v2/digestorio/mcardle_carbohydrates_lipids_proteins_chp1_connection.pdf