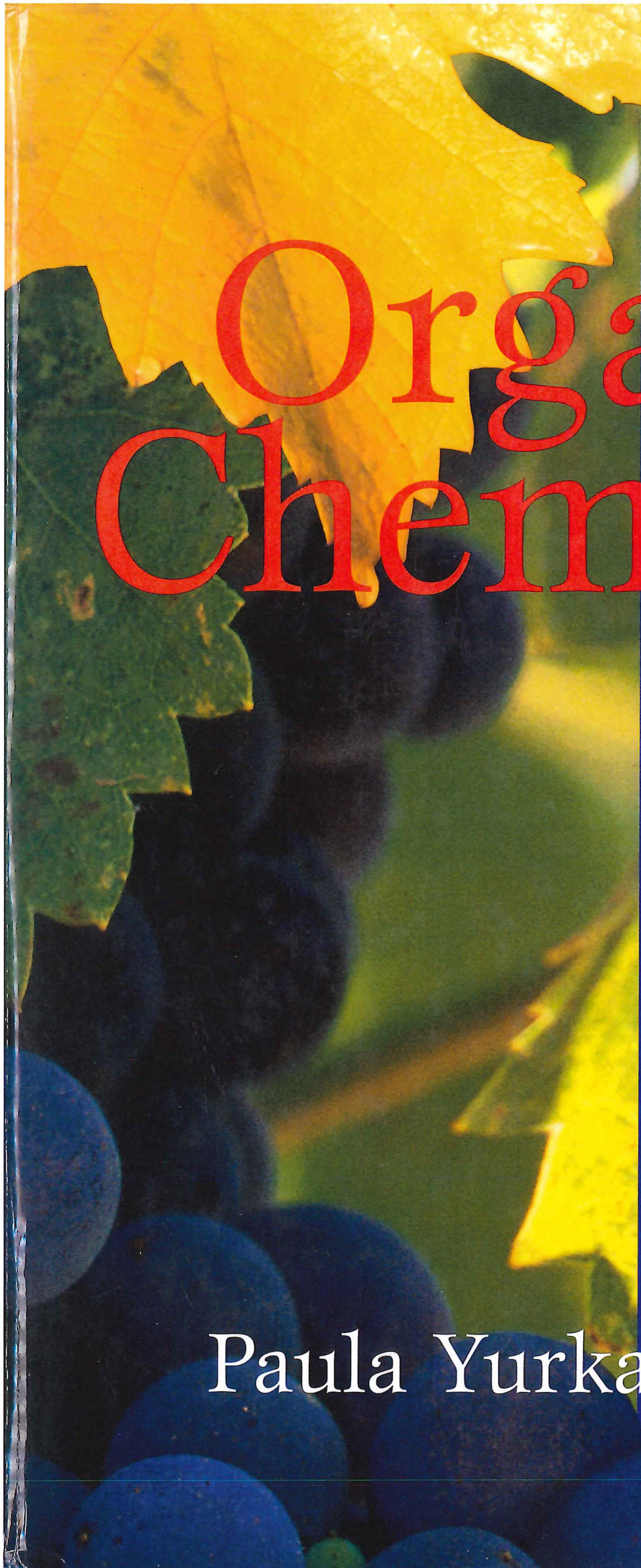
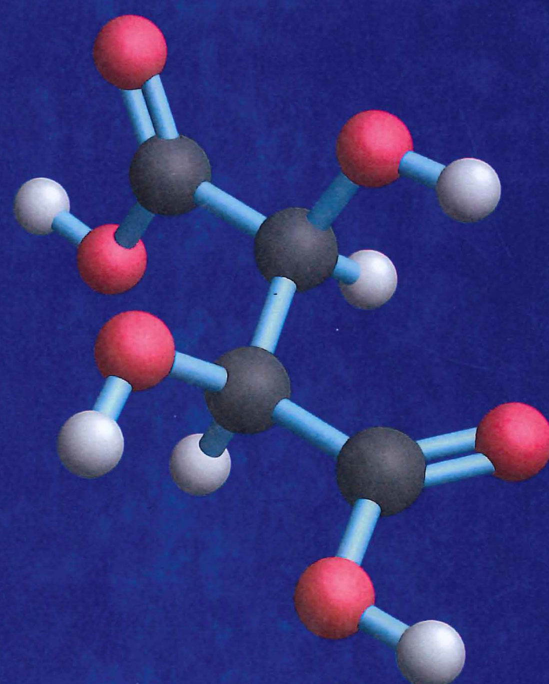
SECOND EDITION

Organic Chemistry





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ORGANIC CHEMISTRY

SECOND EDITION

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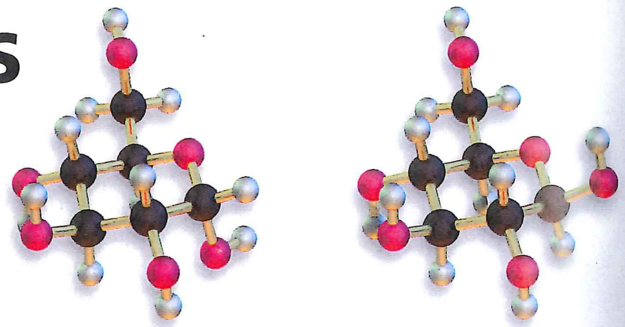
19

CARBOHYDRATES

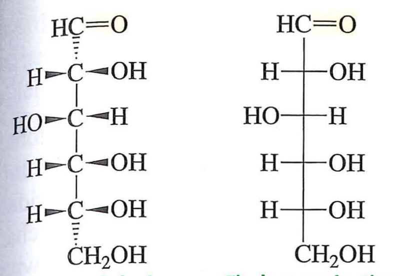


α-D-glucose, β-D-glucose

Carbohydrates are the first group of bioorganic compounds we will study. **Bioorganic compounds** are organic compounds that are found in biological systems. The structures of most bioorganic compounds are more complicated than the structures of many of the organic compounds you are used to seeing, but do not let the complicated-looking structures fool you into thinking their chemistry is equally complicated. Bioorganic compounds follow the same principles of structure and reactivity as the organic molecules we have discussed so far. One reason bioorganic compounds have complicated structures is because the compounds must be able to recognize each other, and much of their structure is for this purpose—a concept known as **molecular recognition.**

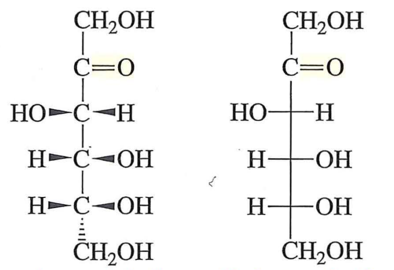
Carbohydrates are the most abundant class of compounds in the biological world, making up more than 50% of the dry weight of Earth's biomass. Carbohydrates are important constituents of all living organisms, and have a variety of different functions. Some are important structural components of cells, and some act as recognition sites on cell surfaces. Others serve as a major source of metabolic energy. For example, the leaves, stems, and roots of plants contain carbohydrates that plants use both for their own metabolic needs and for the metabolic needs of the animals that eat them.

The first carbohydrates investigated had molecular formulas that made them appear to be hydrates of carbon, $C_n(H_2O)_n$; hence the name. Later structural studies revealed that these compounds were not hydrates because they did not contain intact water molecules. However, the term "carbohydrate" persisted. It now refers either to polyhydroxy aldehydes such as D-glucose and polyhydroxy ketones such as D-fructose, or to compounds such as sucrose that can be hydrolyzed to polyhydroxy aldehydes or polyhydroxy ketones. The chemical structures of carbohydrates are commonly represented by wedge-and-dash structures or by Fischer projections. Notice that both D-glucose and D-fructose have molecular formulas $[C_6(H_2O)_6]$ that make them appear to be hydrates of carbon.



wedge-and-dash structure | Fischer projection

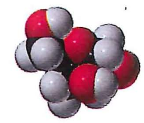
D-glucose
a polyhydroxy aldehyde



wedge-and-dash structure | Fischer projection

D-fructose
a polyhydroxy ketone

D-glucose



D-fructose

The most abundant carbohydrate is D-glucose. Cells of organisms oxidize D-glucose in the first of a series of processes that provide energy to the cells. When animals have more D-glucose than they need for energy, they convert the excess D-glucose into a polymer called glycogen. When an animal needs energy, glycogen is broken down into individual D-glucose molecules. Plants convert excess D-glucose into a polymer known as starch. Cellulose is another polymer of D-glucose. It is the major structural component of plants. Chitin, a carbohydrate similar to cellulose, makes up the exoskeletons of crustaceans, insects and other arthropods, and the structural material of fungi.

Animals obtain glucose by eating plants or by eating food containing glucose. Plants obtain glucose by a process known as **photosynthesis.** During photosynthesis, plants take up water through their roots and use carbon dioxide from the air to synthesize glucose and oxygen. Because photosynthesis is the opposite of the process used by organisms to obtain energy, plants require energy to carry out the process of photosynthesis. They acquire this energy from sunlight. Chlorophyll molecules in green plants capture the light energy used in photosynthesis. Notice that photosynthesis uses the CO_2 that animals exhale as waste and generates the O_2 that animals inhale. Nearly all the oxygen in Earth's atmosphere has been released by photosynthetic processes.

$$\underset{\text{glucose}}{C_6H_{12}O_6} + 6\,O_2 \xrightleftharpoons[\text{photosynthesis}]{\text{oxidation}} 6\,CO_2 + 6\,H_2O + \text{energy}$$

19.1 CLASSIFICATION OF CARBOHYDRATES

The terms "carbohydrate," "saccharide," and "sugar" are often used interchangeably. Saccharide comes from the word for "sugar" in several early languages (*sarkara* in Sanskrit, *sakcharon* in Greek, and *saccharum* in Latin).

There are two classes of carbohydrates—simple carbohydrates and complex carbohydrates. **Simple carbohydrates** are **monosaccharides** (single sugars). **Complex carbohydrates** contain two or more sugar subunits linked together: **disaccharides** have two linked sugar subunits; **oligosaccharides** have three to ten sugar subunits (*oligos* is Greek for "few"); and **polysaccharides** have more than ten sugar subunits linked together. Disaccharides, oligosaccharides, and polysaccharides can be broken down to monosaccharide subunits by hydrolysis.

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