3.1.3 Macromolecules

Simpler organic molecules often associate to form larger molecules. A **macromolecule** is a giant molecule made from many repeating units. Molecules built like this are known as **polymers**. The individual units are known as **monomers**. The units are joined by a chemical process known as **condensation**, which means removal of water. They can be broken down again by the opposite process, **hydrolysis**, or addition of water. There are three important types of macromolecule in biology, namely **polysaccharides**, **proteins** and **nucleic acids** and their constituent monomers are **monosaccharides**, **amino acids** and **nucleotides** respectively.

Macromolecules account for over 90% of the dry mass of cells. Polysaccharides tend to be used for food storage or structural purposes, whereas nucleic acids and proteins can be regarded as 'informational' molecules. This means that the *sequence* of subunits is important in proteins and nucleic acids and is much more variable than in polysaccharides, where only one or two different subunits are normally used. The reasons for this will become clear later. In the rest of this chapter, we shall be studying the three classes of macromolecules and their subunits in detail. Lipids, which are generally much smaller molecules, will also be studied since they are made from simple organic molecules (fig 3.4).

3.2 Carbohydrates

Carbohydrates are substances which contain the elements carbon, hydrogen and oxygen and have the general formula $C_x(H_2O)_y$, where x and y are variable numbers; their name (hydrate of carbon) is derived from the fact that hydrogen and oxygen are present in the same proportions as in water, namely two hydrogen atoms to one oxygen atom. In addition, they have the following properties:

- all are aldehydes or ketones,
- all contain several hydroxyl groups.

Their chemistry is determined by these groups. For example, aldehydes are very easily oxidised and hence are powerful reducing agents. The structures of these groups are shown in table 3.2.

Carbohydrates are divided into three main classes, monosaccharides, disaccharides and polysaccharides, as shown in fig 3.7.

3.2.1 Monosaccharides

Monosaccharides are single sugar units. Their general formula is $(CH_2O)_n$ and some of their properties are shown in fig 3.7. They are classified according to the number of carbon atoms as trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C). Of these, pentoses and hexoses are the most common.

Table 3.4 Chief functions of monosaccharides.

Trioses $C_3H_6O_3$ e.g. glyceraldehyde, dihydroxyacetone
Intermediates in respiration (see glycolysis), photosynthesis (see dark reactions) and other branches of carbohydrate metabolism

Pentoses $C_5H_{10}O_5$ e.g. ribose, deoxyribose, ribulose

- Synthesis of nucleic acids; ribose is a constituent of RNA, deoxyribose of DNA
- Synthesis of some coenzymes, e.g. ribose is used in the synthesis of NAD and NADP
- Synthesis of ATP requires ribose
- Ribulose bisphosphate is the CO_2 acceptor in photosynthesis and is made from the 5C sugar ribulose

Hexoses $C_6H_{12}O_6$ e.g. glucose, fructose, galactose

- Source of energy when oxidised in respiration; glucose is the most common respiratory substrate and the most common monosaccharide
- Synthesis of disaccharides; two monosaccharide units can link together to form a disaccharide
- Synthesis of polysaccharides; glucose is particularly important in this role

Aldoses and ketoses

In monosaccharides, all the carbon atoms except one have a hydroxyl group attached. The remaining carbon atom is either part of an aldehyde group, in which case the monosaccharide is called an **aldose** or **aldo sugar**, or is part of a keto group, when it is called a **ketose** or **keto sugar**. Thus all monosaccharides are aldoses or ketoses. The two simplest monosaccharides are the trioses glyceraldehyde and dihydroxyacetone. Glyceraldehyde has an aldehyde group and dihydroxyacetone has a keto group (fig 3.8). In general, aldoses, such as ribose and glucose, are more common than ketoses, such as ribulose and fructose.

CARBOHYDRATES

	'SUGARS'		POLYSACCHARIDES
Physical properties	Small molecules Sweet Readily soluble in water Crystalline Name always ends in -ose e.g. glucose, sucrose		Macromolecules Not sweet Insoluble or slightly soluble in water Non-crystalline
	MONOSACCHARIDES 'Simple sugars'	DISACCHARIDES	
Synthesis		Made by joining two monosaccharides	Made by joining many monosaccharides
Diagrammatic representation of structure	monosaccharide	glycosidic bonds	Molecules sometimes branched
General formula	$(CH_2O)_n$ where $n = 3$ to 9	Usually $C_{12}H_{22}O_{11}$ (two hexoses)	$C_x(H_2O)_y$
Chemical properties	All reducing sugars	Some reducing, some non-reducing sugars (see section 3.2.2)	Non-reducing