Chapter 3 – Molecules of Cells

Compounds containing carbon are called **organic compounds**
Molecules such as methane that are only composed of carbon and hydrogen are called **hydrocarbons**

The chain of C atoms in organic molecules like these is called a **carbon skeleton (backbone)**
Carbon skeletons can be unbranched (butane) or branched (isobutane)
Carbon skeletons may also include double bonds (1-butene or 2-butene)

Compounds have the same molecular formula but differ in the position of their double bond are called **isomers**

Functional Groups

The unique properties of an organic compound depend not only on its carbon skeleton (with hydrogens), but also on certain groups of atoms that are attached (=covalently bonded) to the skeleton
These assemblages of atoms are called **functional groups**

A. Hydroxyl Group

Consists of a H atom bonded to an oxygen (O) atom, e.g. (- O - H)

B. Carbonyl Group

Is a carbon atom (C) linked by a double bond to an oxygen (O) atom
If the carbon atom of the carbonyl group is at the end of the carbon skeleton, the compound is called an ***aldehyde***
Compounds whose carbonyl groups are within a carbon chain are called ***ketones***

C. Carboxyl Group

Consists of an oxygen atom double bonded to a carbon atom that is also bonded to a hydroxyl group
Compounds containing a carboxyl group are called ***carboxyllic acids***

D. Amino Group

Is composed of a N atom bonded to 2 H atoms
Organic compounds with an amino group are called ***amines***

Making Large Molecules from a Small Set of Small Molecules

On a relative molecular scale, many of life's organic molecules are gigantic and are called **macromolecules**
Cells make most of these large molecules (macromolecules) by joining smaller organic molecules into chains called **polymers** (Gr., "many parts")
The units that serve as the building blocks of polymers are called **monomers**

Synthesis and Hydrolysis

Cells link monomers together to form polymers in a process called **dehydration synthesis**
But, cells not only make monomers, they have to break them down in the process of **hydrolysis** ("to break with water")
In hydrolysis, bonds are broken between monomers by adding water to them

The Types of Organic Molecules

1. Carbohydrates

The name **carbohydrate** refers to a class of molecules that range from small sugar molecules to long polymers of sugar monomers
So carbohydrates are formed from "sugar" monomers

A. Monosaccharides (simple sugars)

Monosaccharides generally have molecular formulas that are some multiple of CH_2O

e.g., glucose - $C_6H_{12}O_6$

Its molecular structure has the 2 trademarks of a sugar:

1. A number of hydroxyl groups (-OH)

2. A carbonyl group (-C=O)

The molecular formula for fructose is also $C_6H_{12}O_6$
Thus, glucose and fructose are **isomers**; they differ only in the arrangement of their atoms

These minor differences give the isomers different properties, such as the ability to interact with other molecules
Also, the differences make fructose sweeter than glucose

Fructose and glucose, are 6-carbon sugars - hexoses
Other monosaccharides have from 3-7 C atoms
The 5 carbon sugars called **pentoses** and the 6-carbon sugars (**hexoses**) are among the most common

In aqueous solutions many monosaccharides form rings
In aqueous solutions the molecules bend and the ends interact with one another --unstable
In so doing, they form a closed ring -- stable and unreactive

B. Disaccharides

Cells construct **disaccharides,** or double sugars from 2 monosaccharides by dehydration synthesis
Sucrose forms from 2 monomers: glucose and fructose

C. Polysaccharides

Polysaccharides are polymers of a few hundred to a few thousand monosaccharides linked together by dehydration synthesis

Starch - a storage polysaccharide in plant roots and other tissues
Animals store excess sugar in the form of the polysaccharide **glycogen**
Polysaccharides such as **cellulose** serve as building material for structures that protect and support whole organisms

2. Lipids

Lipids are diverse compounds that consist mainly of C and H atoms linked by nonpolar covalent bonds
Since they are mostly nonpolar, lipid molecules do not interact well with water molecules which are polar
Because lipids do not mix with water, they are said to be **hydrophobic** (water fearing)

Fats and Oils

Fat and oil are large lipids made from 2 kinds of similar molecules: **glycerol** and **fatty acids**

A fat molecule consists of 3 fatty acids hooked to a glycerol molecule - **triglyceride**

Saturated and Unsaturated Fats

Fats in which every C atom of the carbon skeleton (except the carboxyl carbon) carries 2 H atoms (the maximum number of hydrogens) are said to be **saturated fats**

Fatty acids and fats with double bonds are said to be **unsaturated fats** - meaning that they have less than the maximum number of hydrogens

Diets that are rich in saturated fats may contribute to cardiovascular disease by promoting a condition known as **atherosclerosis**
In this condition, lipid-containing deposits (plaques) build up on the inside surfaces of blood vessels, reducing blood flow

Other Examples of Lipids

Phospholipids

They are a major component of cell membranes
They are structurally similar to fats except they contain a phosphate group and only 2 fatty acid chains

Waxes

They consist of one fatty acid linked to an alcohol
They are much more hydrophobic than fats, and this characteristic makes waxes effective natural coatings for fruits and animals such as insects

Steroids

They are lipids whose carbon skeleton is bent to form fused rings
All steroids have the same ring pattern: three, 6-sided rings and one, 5-sided ring
Cholesterol is a common substance in animal cell membranes, and animal cells also use it as a starting material for making other steroids, including male and female sex hormones

Anabolic steroids are synthetic variants of the male hormone testosterone
Mimic the effects of steroid hormones

3. Proteins

A **protein** is a biological polymer constructed from amino acid monomers

There are 7 major classes of proteins

1. Structural proteins
2. Contractile proteins
3. Storage proteins
4. Defense proteins
5. Transport proteins
6. Signal proteins
7. Enzymes

An **enzyme** is a protein that serves as a chemical **catalyst** - an agent that changes the rate of chemical reaction without being changed into a different molecule in the process

Amino acids

Amino acids all have an amino group and a carboxyl group
Both of these functional groups are covalently bonded to a central C atom (alpha C)
Also bonded to this C is an H atom and a chemical group called the "R" group

The structure of the R group determines the specific properties of each of the **20** aa in proteins

Peptide Bonds

Amino acids are linked together by dehydration synthesis
A carboxyl group of one amino acid must be positioned to the amino group of another amino acid
A water molecule is then removed as the carboxyl group carbon atom bonds to the amino group nitrogen
The resulting covalent linkage is called a **peptide bond**

When 2 amino acids are linked together this way the product of the reaction is a **dipeptide**
Additional amino acids can be added by the same process to form a chain of amino acids - **polypeptide**

Levels of Organization in Protein Structure

1. Primary Structure
The sequence of amino acids forming its polypeptide chains

2. Secondary Structure
The polypeptide chain coils or folds into regular patterns called **secondary structure**
Coiling of a polypeptide chain results in a secondary structure called an **alpha helix**
Folding leads to a structure called **pleated sheets**

3. Tertiary Structure
Tertiary structure refers to the overall 3-dimensional shape of a polypeptide
Most tertiary structures are described as being *globular*

4. Quaternary Structure
This structure is produced by the bonding interactions of 2 or more globular proteins

Nucleic Acids

There are 2 types: **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**

The monomers that make up nucleic acids are **nucleotides**

Each nucleotide monomer has 3 parts:

1. A 5 carbon sugar: DNA has the sugar deoxyribose; RNA has the sugar ribose

2. Linked to one end of the sugar is a functional group called a **phosphate group**

3. Linked to the other end of the sugar is one of a number of chemical units that contain nitrogen called **nitrogenous bases**
DNA has the nitrogenous bases adenine (A), thyamine (T), cytosine (C), and guanine (G)
RNA has A, G, C, and uracil (U) instead of T

A nucleic acid polymer - a polynucleotide - forms from its monomers by dehydration synthesis
The phosphate group of one nucleotide bonds to the sugar of the next nucleotide

RNA is a single polynucleotide strand
DNA is a double stranded molecule; more specifically it's a **double helix,** in which 2 polynucleotides wrap around each other