Molecules

Most important molecules are based on carbon.

Carbon can form bonds with four other elements, and molecules made up from carbon can branch in many different directions.

[OVERHEAD, fig. 3.1A & B, p. 34]

Ways of presenting what these molecules look like can vary quite a bit (e.g., first row of figure).

Double and single bonds can combine (see 1 or 2-Butene, or Benzene)

Arrangement can be as chain, branched or unbranched, in rings, etc.

If only carbon or hydrogen make up the molecule, it's called a “hydrocarbon”

Hydrocarbons are generally non-polar (electrons are more or less equally shared).

Functional groups.

These are groups of atoms that “react”. [OVERHEAD, table 3.2, p. 35].

These groups are all “polar”, that is oxygen or nitrogen tend to pull on electrons.

Because they're polar, they're usually water soluble.

A change in the functional group can mean a big change in function, even if the rest of the molecule is almost identical (Estradiol & Testosterone) [OVERHEAD, fig. 3.2, p. 35].

We'll describe some of these as needed as we go on.

Using these basic building blocks, a large number of complicated biological molecules can be built up.

There are four main classes of molecules important in biology:

Carbohydrates, proteins, lipids (fats), nucleic acids

All of these are composed of simple subunits.

These subunits are called “monomers”. They come together and form longer “chains” called polymers.

Confusingly, these may have separate names for each of the main classes of molecules (e.g., monosaccharides and polysaccharides for carbohydrates, etc.)

With only a few varieties of subunits, a huge variety of different polymers can be made.
For example, proteins (polymers) are made up of subunits (amino acids (monomers)).

There are only 20 different amino acids, and yet over a trillion different kinds of proteins.

By stringing together these 20 amino acids in different ways, we come up with staggering possibilities.

All together, there are only about 40 or 50 monomers that are biologically common (& a few rare one), and make up the vast majority of polymers.

Monomers are linked together by a dehydration reaction.

Dehydrate - “lose water”. So in this reaction, the monomers loose water (an hydroxyl group and an oxygen). [OVERHEAD, fig. 3.3 A & B, p. 36]

Just by doing this, huge molecules can be put together.

Most biological molecules are so large we call them “macromolecules”.

Polymers can be taken apart by hydrolysis (break up water).

This is the reverse of the above. We attach an OH and an H group and so break up a polymer.

Carbohydrates

Includes sugars, starches, and everything in between.

A single carbohydrate monomer is known as a monosaccharide (“Sacchar” is Greek for sugar).

Usually, monosaccharides have molecular formulas that are multiples of CH\text{2}O. Glucose (very important sugar) has C\text{6}H\text{12}O\text{6}.

Generally have hydroxyl functional groups (so sugars are also alcohols)

Also have a carbonyl group (which makes sugars either aldehydes or ketones, depending on the location of the carbonyl group).

Note that Fructose is an “isomer” of glucose. It's got the same chemical formula, but because its carbonyl group is elsewhere, it behaves a little differently. [OVERHEAD, fig. 3.4, p. 37].

Sugars have three to seven carbons.

In solution, these sugars form rings.

Sugars often form the main fuel for organisms (derives from breaking the chemical bonds in sugars).
Disaccharides:

Two monosaccharides put together through a dehydration reaction.

[OVEREAD, fig. 3.5, p. 38]

Two glucose molecules => maltose
Glucose + fructose => sucrose (table sugar)

Polysaccharides [OVERHEAD, fig. 3.7, p. 39]:

Long chains of monosaccharides.

Put together the same way as disaccharides, except now we have many monomers (monosaccharides).

Starch is composed of glucose.

Glycogen - similar to starch (used for short term energy storage in animals).

More branched than starch, but still composed of glucose.

Cellulose

Also made up of glucose, but arranged differently into a single long string.

Animals generally can't digest cellulose, so this is useless (although a good source of fiber (undigestable)).

Modified carbohydrates:

Some carbohydrates can be modified somewhat by using functional groups other than OH.

This can give rise to such important molecules as chitin or glucosamine.

Chitin - hard shell of insects and other arthropods

Glucosamine - helps keep cells together (galactosamine, closely related, is an important part of cartilage).

Lipids

Consist mostly of hydrogen and carbon molecules, with a few oxygens tossed into the mix.

Are hydrophobic (don't like water). This is the reason oil and water don't mix.
Detergents work by attaching both to water and oil.

Fat is a particular kind of lipid composed of two different types of subunits:

Glycerol (hydrogen, carbon, oxygen). A three carbon chain (also an alcohol due to the hydroxyl groups).

Fatty acid (chain of mostly carbon - hydrogen (approximately 15 units), but one carboxyl group)

Fatty acids hook into the glycerol with a dehydration reaction

[OVERHEAD, fig. 3.8, p. 40]

Fats are very good for storing energy (about twice that of sugars or proteins).

Also insulates quite well.

If the carbon chains of the fatty acid subunit have double bonds, the fat becomes “unsaturated”. It doesn't have as much hydrogen as it could.

If it has the maximal possible hydrogens (no double bonds), it's saturated.

Unsaturated fats are liquid at room temperature (generally plant oils are unsaturated).

Saturated fats are solid at room temperature (animal fats).

Also not very healthy - lead to build up of plaque in arteries.

Other lipids:

Used in cell membranes (phospholipids, have phosphorus, and only two fatty acid chains) [OVERHEAD, fig. 3.9A, p. 41]

Have hydrophylllic heads, and hydrophobic tails. By arranging them in two layers, we can make cell membranes:

++++++ hydrophilic layer
------------- hydrophobic layer
------------- hydrophobic layer
++++++ hydrophilic layer

Waxes (one fatty acid chain linked to an alcohol). Very hydrophobic

Steroids

(book discusses some of the problems with steroids)
Proteins

Structural molecules, enzymes, act as signals, in the immune system, etc. Very important (Nucleic acids code for proteins)

Proteins are made up of amino acids. These are combined (through dehydration reactions) to make up proteins.

Bonds between amino acids are called “peptide bonds”

Chains of amino acids are also called “polypeptides”

A protein may have more than one polypeptide.

All amino acids have a “carboxyl” group (hence “acid”), and an amino group [OVERHEAD, fig. 3.11A, p. 42].

The peptide bond forms between a carboxyl group and an amino group [OVERHEAD, fig. 3.11C, p. 43].

Some amino acids are hydrophilic (like water), others hydrophobic (dislike water)

Amino acids differ in what is termed their “R” group [OVERHEAD, fig. 3.11B, p. 42].

All the stuff between the carboxyl and amino groups (except the carbon that ties everything together).

As mentioned, only 20 amino acids give rise to bewildering variety of proteins.

Book mentions alphabet and words/language, not a bad analogy.

As the amino acids are piled on, the polypeptide starts to twist into its finished three dimensional shape [see fig. 3.12, p. 43].

The shape determines its function (that groove in lysozyme must fit into an attachment site of bacteria (lysozyme can destroy bacteria).

Altering the shape of proteins leads to “denaturation”.

When the shape is altered, the protein can't function properly anymore.

E.g., that groove in lysozyme may take on a different shape.

Salt, pH, heat, all can change the shape (denature) of a protein.

High fevers denature many proteins in the body - without proteins, the body can't function.

The final shape of a protein depends on four levels (this is simplified a bit from the book, which is a bit too complicated) [OVERHEAD, fig. 3.13, p. 45]:

Primary structure:

The sequence of amino acids. This determines the rest of the shape of a particular polypeptide (note that a polypeptide is not necessarily a protein).

The sequence of amino acids must be exact, or the overall shape of the polypeptide may not be right.

This sequence is determined genetically (nucleic acids code for this sequence).

A single change in 1 amino acid, can cause a protein to be defective (this can be caused by a single genetic mutation).

Secondary structure:

As this long chain forms, it begins to form more complicated structures. Parts of the chain get close to other parts, and hydrogen bonds can begin to form.

These will hold the different parts of the chain together.

Tertiary structure:

As these different parts come together we get the final 3D structure of the protein.

Quaternary structure:

Proteins composed of more than one polypeptide have quaternary structure.

Often, single polypeptides twist around each other in a specified way, giving rise to the overall structure of the protein.

Nucleic Acids:

We'll learn a lot more about these when we do genetics.

Monomers of nucleic acid are called “nucleotides”.

Each nucleotide has three parts [OVERHEAD, fig. 3.15A, p. 46]:

A phosphate group

A sugar group

A nitrogenous base (five kinds, Adenine (A), Thymine (T), Cytosine (C), Guanine (G), and Uracil (U)).
- DNA uses A, T, G & C
- RNA uses A, U, G, & C

DNA and RNA are the best examples. DNA has deoxyribose as a sugar, RNA uses ribose.

These nucleotides are put together (again, a dehydration reaction) in long chains called nucleic acids (DNA & RNA) [OVERHEAD, fig. 3.15 B & C, p. 46 & 47].

The sequence of nitrogenous bases is what makes nucleic acids work.

- (each set of three bases codes for different amino acids, and so nucleic acids directly control proteins).

- See section 3.15 about Linus Pauling for some details on how we worked out the structure of proteins, and even a little on DNA.