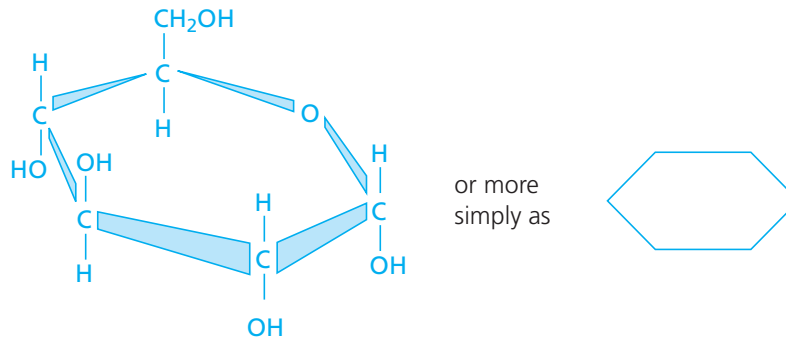


Biological Molecules:

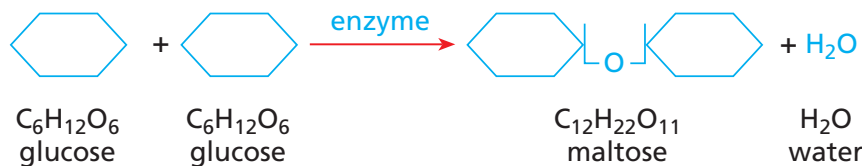
Carbohydrates:

These may be simple, soluble sugars or complex materials like starch and cellulose, but all carbohydrates contain carbon, hydrogen and oxygen only. A commonly occurring simple sugar is **glucose**, which has the chemical formula $C_6H_{12}O_6$.

The glucose molecule is often in the form of a ring, represented as:

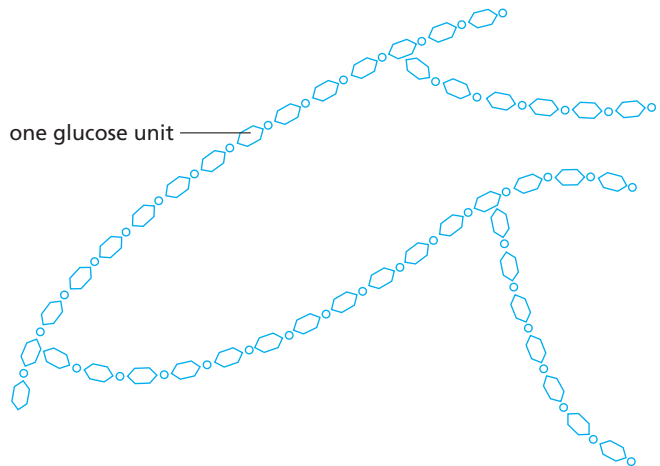


Two molecules of glucose can be combined to form a molecule of maltose $C_{12}H_{22}O_{11}$



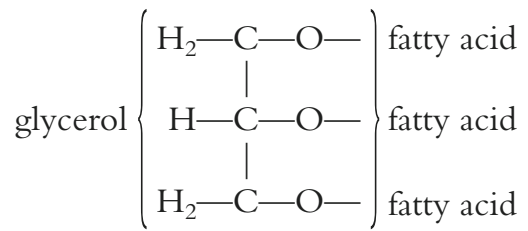
Sugars with a single carbon ring are called **monosaccharides**, e.g. glucose and fructose. Those sugars with two carbon rings in their molecules are called **disaccharides**, e.g. maltose and sucrose. Mono- and disaccharides are readily soluble in water. When many glucose molecules are joined together, the carbohydrate is called a **polysaccharide**.

Glycogen is a polysaccharide that forms a food storage substance in many animal cells. The **starch** molecule is made up of hundreds of glucose molecules joined together to form long chains. Starch is an important storage substance in the plastids of plant cells. Plastids are important organelles in plant cells. They are the sites where molecules like starch are made and stored. One familiar example of a plastid is the chloroplast. **Cellulose** consists of even longer chains of glucose molecules. The chain molecules are grouped together to form microscopic fibers, which are laid down in layers to form the cell wall in plant cells. Polysaccharides are not readily soluble in water.

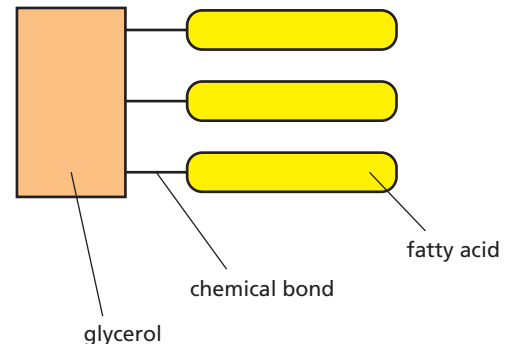


Fats:

Fats are a solid form of a group of molecules called **lipids**. When lipids are liquid they are known as oils. Fats and oils are formed from carbon, hydrogen and oxygen only. A molecule of fat (or oil) is made up of three molecules of an organic acid, called a **fatty acid**, combined with one molecule of **glycerol**.



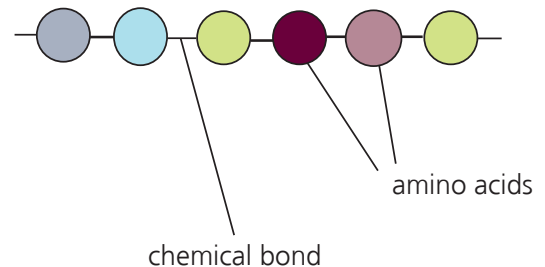
Lipids form part of the cell membrane and the internal membranes of the cell such as the nuclear membrane. Droplets of fat or oil form a source of energy when stored in the cytoplasm.



Proteins:

Some proteins contribute to the structures of the cell, e.g. to the cell membranes, the mitochondria, ribosomes and chromosomes. These proteins are called **structural proteins**.

There is another group of proteins called **enzymes**. Enzymes are present in the membrane systems, in the mitochondria, in special vacuoles and in the fluid part of the cytoplasm. Enzymes control the chemical reactions that keep the cell alive. Although there are many different types of protein, all contain carbon, hydrogen, oxygen and nitrogen, and many contain sulfur. Their molecules are made up of long chains of simpler chemicals called **amino acids**.

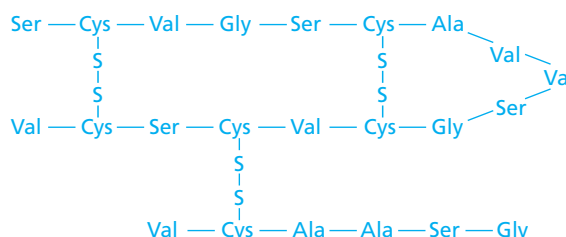


There are about 20 different amino acids in animal proteins, including alanine, leucine, valine, glutamine, cysteine, glycine and lysine. A small protein molecule might be made up from a chain consisting of a hundred or so amino acids, e.g. glycine–valine–valine–cysteine–leucine–glutamine–, etc. Each type of protein has its amino acids arranged in a particular sequence. The chain of amino acids in a protein takes up a particular shape as a result of cross-linkages. Cross linkages form between amino acids that are not neighbors, as shown in the figure. The shape of a protein molecule has a very important effect on its reactions with substances, as explained in Enzymes.

For example, the shape of an enzyme molecule creates an **active site**, which has a complementary shape to the substrate molecule on which it acts. This makes enzymes very specific in their action (they usually only work on one substrate). **Antibodies** are

proteins produced by white blood cells called lymphocytes. Each antibody has a binding site, which can lock onto pathogens such as bacteria. This destroys the pathogen directly, or marks it so that it can be detected by other white blood cells called phagocytes. Each pathogen has **antigens** on its surface that are a particular shape, so specific antibodies with complementary shapes to the antigen are needed.

When a protein is heated to temperatures over 50 °C, the cross-linkages in its molecules break down; the protein molecules lose their shape and will not usually regain it even when cooled. The protein is said to have been **denatured**. Because the shape of the molecules has been altered, the protein will have lost its original properties.



Egg-white is a protein. When it is heated, its molecules change shape and the egg-white goes from a clear, runny liquid to a white solid and cannot be changed back again. The egg-white protein, albumen, has been denatured by heat. Proteins form enzymes and many of the structures in the cell, so if they are denatured the enzymes and the cell structures will stop working and the cell will die. Whole organisms may survive for a time above 50 °C depending on the temperature, the period of exposure and the proportion of the cells that are damaged.

Structure of DNA:

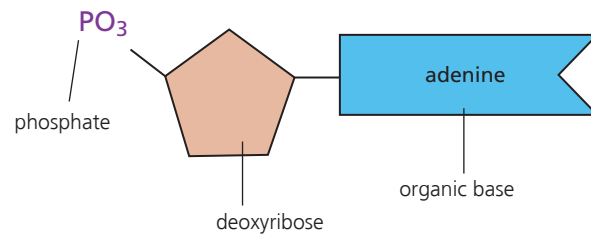
A DNA molecule is made up of long chains of nucleotides, formed into two strands. A **nucleotide** is a 5-carbon sugar molecule joined to a phosphate group (–PO₃) and an organic base (Figure 4.9). In DNA the sugar is deoxyribose and the organic base is either **adenine** (A), **thymine** (T), **cytosine** (C) or **guanine** (G).

Note: for exam purposes, it is only necessary to be able state the letters, *not* the names of these bases.

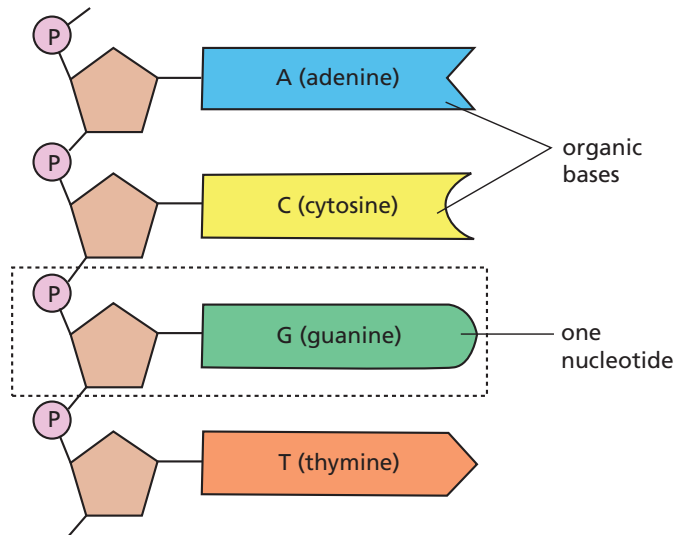
The nucleotides are joined by their phosphate groups to form a long chain, often thousands of nucleotides long. The phosphate and sugar molecules are the same all the way down the chain but the bases may be any one of the four listed above.

The DNA in a chromosome consists of two strands (chains of nucleotides) held together by chemical bonds between the bases. The size of the molecules ensures that A (adenine) always pairs with T (thymine) and C (cytosine) pairs with G (guanine). The double strand is twisted to form a helix (like a twisted rope ladder with the base pairs representing the rungs).

A Nucleotide (Adenosine Monophosphate):



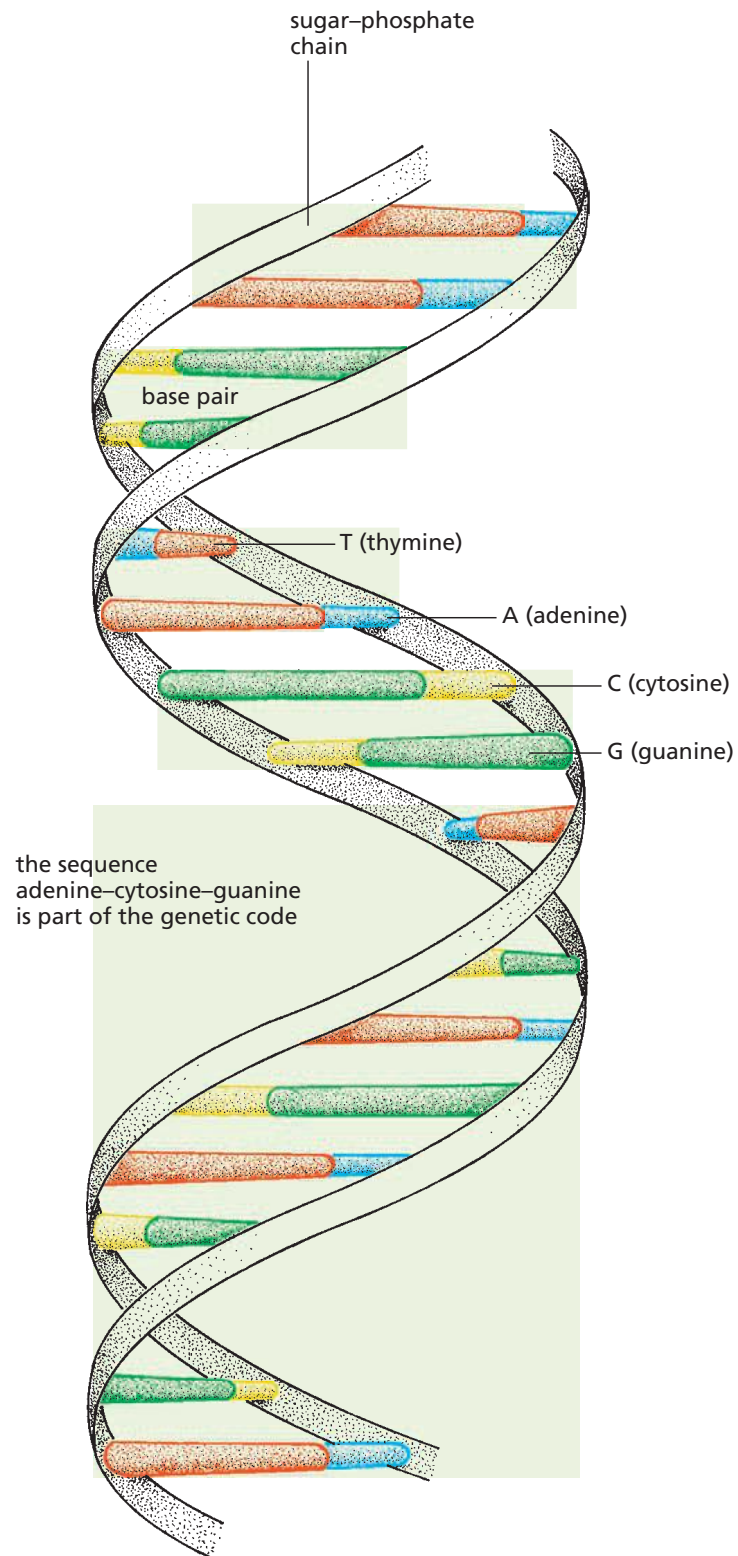
Part of a DNA Molecule with Four Nucleotides:



Model of DNA Structure:



The Drawing Shows Part of a DNA Molecule Schematically:



Water:

Water molecules take part in a great many vital chemical reactions. For example, in green plants, water combines with carbon dioxide to form sugar. In animals, water helps to break down and dissolve food molecules. Blood is made up of cells and a liquid called **plasma**. This plasma is 92% water and acts as a transport medium for many dissolved substances, such as carbon dioxide, urea, digested food and hormones. Blood cells are carried around the body in the plasma.

Water also acts as a transport medium in plants. Water passes up the plant from the roots to the leaves in xylem vessels and carries with it dissolved mineral ions. Phloem vessels transport sugars and amino acids in solution from the leaves to their places of use or storage.

Water plays an important role in excretion in animals. It acts as a powerful solvent for excretory materials, such as nitrogenous molecules like urea, as well as salts, spent hormones and drugs. The water has a diluting effect, reducing the toxicity of the excretory materials.

The physical and chemical properties of water differ from those of most other liquids but make it uniquely effective in supporting living activities. For example, water has a high capacity for heat (high thermal capacity). This means that it can absorb a lot of heat without its temperature rising to levels that damage the proteins in the cytoplasm. However, because water freezes at 0 °C most cells are damaged if their temperature falls below this and ice crystals form in the cytoplasm. (Oddly enough, rapid freezing of cells in liquid nitrogen at below –196 °C does not harm them).

Summary of the Main Nutrients:

Nutrient	Elements present	Examples	Sub-units
carbohydrate	carbon, hydrogen, oxygen	starch, glycogen, cellulose, sucrose	glucose
fat/oil (oils are liquid at room temperature, but fats are solid)	carbon, hydrogen, oxygen (but lower oxygen content than carbohydrates)	vegetable oils, e.g. olive oil animal fats, e.g. cod liver oil waxes	fatty acids and glycerol
protein	carbon, hydrogen, oxygen, nitrogen, sometimes sulfur or phosphorus	enzymes, muscle, haemoglobin, cell membranes	amino acids (about 20 different forms)