We inherit our DNA from our parents – we inherit 23 pairs of chromosomes that contain millions of genes. These genes code for our characteristics and all the proteins necessary for our body to function.

On successful completion of this topic you will:

- understand the chemical principles that apply to the structures of biological building block molecules (LO1)
- understand the structures of biological macromolecules and the relationships to biological functions (LO2).

To achieve a Pass in this unit you need to show that you can:

- explain the principal properties and classification of nucleosides and nucleotides (1.3)
- explain the principal properties and classification of fatty acids (1.4)
- outline briefly the roles of the nucleic acids in protein biosynthesis with reference to the structural differences between DNA and different types of RNA (2.4)
- explain the structural features and properties of phospholipids that enable them to form membranes (2.5).
Before you start
If you find some parts of this unit challenging, remember you are working at a higher level than you may be used to. In this unit it is important that you fully understand the following themes and topics before you begin:
• structure and function of biological molecules
• enzyme structure and function
• aerobic respiration.

If you need to check your understanding of proteins, carbohydrates, lipids and nucleic acids, Unit 2 Module 1 of OCR AS Biology (P. Kennedy and F. Sochacki, 2008), offers a good introduction to the topic.

If you need to check your understanding of aerobic respiration and the stages of glycolysis, link reaction, the Krebs cycle and the electron transport chain, you may find Unit 1 Module 4 of OCR A2 Biology (S. Hocking, 2008) useful.

Deoxyribonucleic acid (DNA)
A nucleotide is a monomer made from a sugar, a phosphate group and a base. The nucleosides are the bases that form part of the nucleotide.

Figure 1.6.1 shows the basic structure of a nucleotide and Figure 1.6.2 shows the structures of different types of nucleosides known as pyrimidines and purines.

Deoxyribonucleic acid (DNA) is a large molecule made from a chain of nucleotides bonded together, a condensation reaction between the phosphate group of one nucleotide and the sugar of another producing ester bonds. This produces a long sugar-phosphate backbone and the attached bases protrude into the centre of the structure – this is called a polynucleotide.

DNA consists of two long polymers that run in opposite directions to each other and are therefore anti-parallel, one backbone being 3’ (three prime) and the other 5’ (five prime) (the direction of the 3rd and 5th carbon on the sugar molecule is known as three prime or five prime).

Inside the sugar phosphate backbone are bases. It is the sequence of these bases along the backbone that codes for our characteristics. Purines pair with pyrimidines – adenine (A) and guanine (G) are both purines, thymine (T) and cytosine (C) are pyrimidines.

In DNA, A pairs with T and they are held together by two hydrogen bonds and C pairs with G, held together by three hydrogen bonds. As these bases bond together the DNA molecule starts to form a double-stranded helix. As the DNA strand grows larger, the double helix twists 360°.

Key term
Double helix: The structure formed by double-stranded molecules of nucleic acids.
Ribonucleic acid (RNA)

Ribonucleic acid (RNA) is usually single stranded and smaller than DNA, consisting of just hundreds of nucleotides rather than thousands (like DNA). RNA contains the base uracil in place of thymine and therefore is a different macromolecule from DNA. RNA is less stable and only has a short-term function. It exists in three forms:

- messenger RNA (mRNA): a small molecule that is made inside the nucleus by copying a template DNA strand. Once it is constructed it moves outside the nucleus to the ribosomes where protein synthesis takes place. Figure 1.6.4 shows the structure of a single strand of mRNA synthesised inside the nucleus.
- ribosomal RNA (rRNA): found in ribosomes
- transfer RNA (tRNA): transfers amino acids to the ribosomes where protein synthesis is taking place, i.e. where polypeptides are built. Figure 1.6.5 shows the structure of tRNA including the specific amino acid.
Protein synthesis

Genes are a length of DNA that code for particular proteins. The sequence of the bases on the DNA code for a specific sequence of amino acids that join together with peptide bonds to make specific proteins. The DNA inside the nucleus cannot leave, so the sequence of bases in a particular gene must be copied for protein synthesis to occur.

Transcription

Transcription is the first stage of protein synthesis – the length of DNA unzips, breaking the hydrogen bonds between the complementary bases. This exposes the bases, so that free RNA nucleotides can bind to the complementary bases on the template DNA strand.

The reaction is catalysed by the enzyme RNA polymerase. G binds with C and U binds with A and this makes a strand of mRNA, which is complementary to the original DNA sequence. The mRNA strand is released from the DNA; it passes out of the nucleus, through pores in the nuclear envelope and to the ribosomes.

Translation

Translation is the second stage of protein synthesis. During this stage the amino acids assemble to make a polypeptide. The succession of the amino acids depends on the sequence of the codons on the mRNA strand. tRNA molecules are uniquely shaped into a hairpin structure, so that there are three exposed bases at one end where amino acids bind, and at the other end is the anticodon.
Each anticodon binds with a complementary **codon** on the mRNA strand. As each tRNA molecule arrives at the ribosome, peptide bonds are formed between the adjacent amino acids until a stop codon is reached (UAA, UAC, UGA), producing a polypeptide.

### Activity

The RNA polymerase enzyme moves along a DNA sequence reading TATTGGGCTTATACAGGC.

1. What would the sequence of the mRNA be?
2. How many amino acids are assembled in this sequence?

### Portfolio activity (2.4)

You can generate evidence for your portfolio by:
- producing a table of differences between DNA and RNA
- describing the roles of each in protein synthesis.

### Checklist

In this topic you should now be familiar with the following ideas about nucleotides:
- a nucleotide is a monomer made from a sugar, a phosphate group and a base
- nucleoside bases found on nucleotides are adenine, thymine, cytosine, guanine
- pyrimidines are cytosine and thymine
- purines are adenine and guanine
- DNA is a polynucleotide
- the DNA structure is described as a double helix
- RNA is a single-stranded molecule
- mRNA is messenger RNA that carries the genetic code from the nucleus to the ribosome
- rRNA is ribosomal RNA found in ribosomes during protein synthesis
- tRNA is transfer RNA that assembles specific amino acids according to the triplet codon
- genes are lengths of DNA
- protein synthesis is the production of proteins according to the DNA code
- transcription is the process of copying the original DNA code
- translation is the process of amino acid assembly.

## 2 Lipids

Lipids have many functions, which include energy source, energy storage, biological membranes, insulation and hormones. There are many types of lipid, including triglycerides, phospholipids and cholesterol. Triglycerides are made from a glycerol molecule and fatty acids – the fatty acid molecules differ depending on the molecule. The fatty acids are composed of an acid group at one end and a hydrocarbon chain of between 2–20 carbons in length.
Saturated and unsaturated

Too much saturated fat is considered to be bad for human health. Saturated fats are saturated with hydrogen atoms whereas unsaturated fats contain double bonds so have fewer hydrogens.

If a single double bond is present between two carbons this produces a monounsaturated fatty acid. If two or more double bonds are present it produces a polyunsaturated fatty acid. The presence of the C=C bond changes the shape of the hydrocarbon chains. This makes the substance more fluid so they are usually found as oils.

Figure 1.6.6 shows the structural difference between saturated and unsaturated fats. Notice the presence of a double bond (and therefore fewer hydrogen atoms) on the unsaturated fat molecule.

Triglycerides

Animals store energy in the form of triglycerides; these are made from one glycerol molecule bonded to three fatty acid tails.

Triglycerides are described as hydrophobic lipids because they are insoluble in water – the hydrogen bonds cannot form with water and therefore the two do not combine.

Phospholipids

A phospholipid also consists of one glycerol molecule but it differs from a triglyceride molecule because only two ester bonds form, allowing two fatty acid tails to bond. The third fatty acid tail does not bond; instead a phosphate group is covalently bonded to the third –OH group of the glycerol molecule.

The phosphate head is polar but the fatty acid tails are non-polar. When placed in water they arrange themselves so that the tails are pointing inwards and their phosphate heads point outwards.

The water solubility of the head enables the molecules to form membranes in double layers called bilayers. Bilayers consist of proteins and other biological molecules. Membranes are very fluid, constantly moving.

Scientists Singer and Nicholson introduced the Fluid Mosaic model to describe the structure of biological membranes. The correct ratio of saturated to unsaturated fatty acids keeps the membrane fluid at any temperature necessary. The presence of cholesterol lowers the requirement for unsaturated fatty acids and helps maintain fluidity of biological membranes at body temperature.
Cholesterol

Cholesterol is a lipid but it is structurally different from those discussed previously. It is made from four carbon-based rings and it is also smaller than other lipids.

Cholesterol provides strength and fluidity to biological membranes, placed between hydrocarbon chains of phospholipids.

See the Case study for a real life example of cholesterol in the human body.

Figure 1.6.8: Structure of cholesterol.

Checklist

In this topic you should now be familiar with the following ideas about lipids:

- lipids are fats and oils
- lipids have many functions in living organisms
- lipids are found in fats, oils and membranes
- saturated fats have the full allocation of hydrogen atoms and are therefore said to be saturated with them
- unsaturated fats contain C=C and have less hydrogen atoms
- phospholipids contain only two fatty acid tails, a phosphate head and one glycerol molecule
- phospholipids make biological membranes in bilayers because of the hydrophilic and hydrophobic properties
- cholesterol is present in membranes to give strength and fluidity.

Further reading


Take it further

There are several suitable books or websites that show you the Fluid Mosaic model. Try this website:
http://telstar.ote.cmu.edu/biology/MembranePage/index2.html

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