1 MACROMOLECULES

MACROMOLECULES: ORGANISATION

Macromolecules are large organic molecules containing mainly carbon (C), hydrogen (H), oxygen (O) and nitrogen (N). They serve a variety of functions in living organisms. The four main classes of macromolecules are:

1. Proteins
2. Carbohydrates (or sugars)
3. Lipids (or fats)
4. Nucleic acids (DNA and RNA)

M1: DNA and RNA

Before we address DNA in detail, it is important to gain an overall appreciation of how genetic information is organised. There are three fundamental units (organised in a hierarchical fashion) of genetic information, DNA, genes and chromosomes:

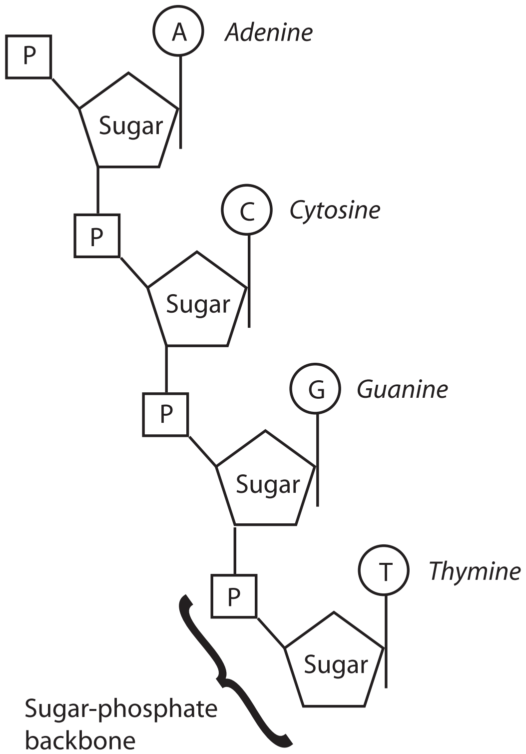
1. DNA – this is the chemical unit of genetic information.
2. Genes – these are the functional units of genetic information. They are formed by specific DNA sequences. Genes determine protein synthesis, physical characteristics of organisms and inheritance from one generation to the next.
3. Chromosomes – these are the structural units of genetic information. Each chromosome is a large discrete double-helix DNA molecule. Chromosomes are the structures you see under the microscope when the cell divides. There are many genes on each chromosome.

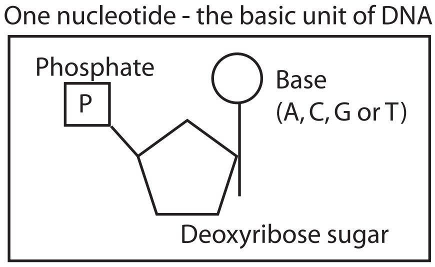
DEOXYRIBONUCLEIC ACID

DNA (deoxyribonucleic acid) is made up of small repeating units called nucleotides, joined together in a chain. Each nucleotide is, in turn, made up of three components:

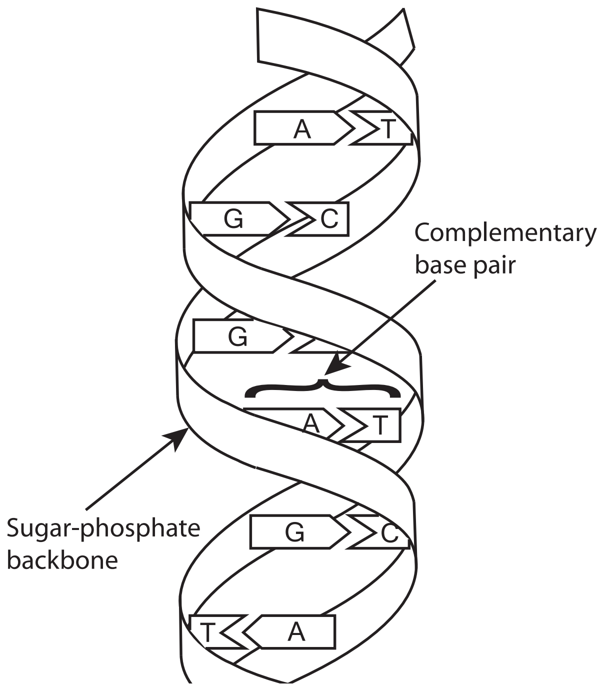
1. Deoxyribose sugar
2. Nitrogenous base – Adenine (A), Thymine (T), Guanine (G) or Cytosine (C)
3. Phosphate group

DNA CHEMICAL STRUCTURE





DNA DOUBLE HELIX



The structure of DNA is often described as a double helix. The double helix is made up of two strands with complementary base pairs, joined together by weak bonds (hydrogen bonds). Adenine can only bind (i.e. is complementary) to Thymine and, similarly, Cytosine can only bind Guanine. The bases are attached to a sugar-phosphate backbone, formed by the sugar and phosphate components of DNA.

RIBONUCLEIC ACID

The other type of nucleic acid is RNA (ribonucleic acid). RNA serves as a temporary store of genetic information prior to it being passed on for protein synthesis. Each unit of RNA, like DNA, is made up of a sugar, a base and a phosphate group. However, there are three key differences between the two:

1. The sugar in RNA is ribose (not deoxyribose as in DNA).
2. The four bases are the same except that Thymine (T) is replaced by Uracil (U).
3. RNA is usually single-stranded (whereas DNA is usually double-stranded).

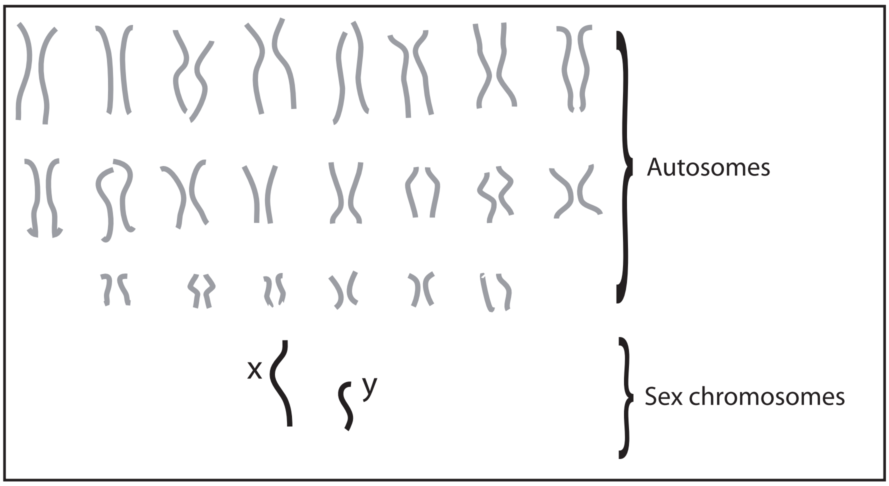
M2: Chromosomes

When a cell is not dividing, DNA is wrapped up with proteins (called histones) to form long thread-like structures called chromatin. When a cell starts to divide, the chromatin condenses to form discrete pairs of short fat structures called chromosomes.

In human cells, there are 23 pairs of chromosomes, 1 of which (called the sex chromosomes) determines sex. Males have the XY sex chromosome pair while females have the XX pair. The other 22 pairs are called autosomes, which determine a variety of other human characteristics.

Chromosomes can be visualised under the microscope during cell division. A picture of a complete set (23 pairs) of chromosomes is called a karyotype.

HUMAN KARYOTYPE (male)



22 pairs of autosomes and 2 sex chromosomes

M3: Genes

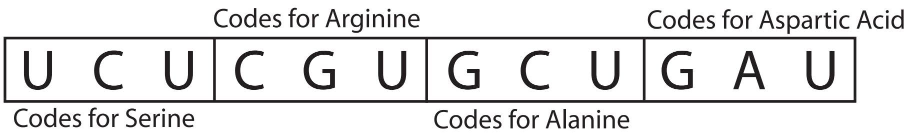
Genes are unique sequences of DNA on the chromosome which code for specific proteins. There are two basic steps involved in protein synthesis:

- In the first step (called transcription), information from DNA is transcribed into messenger RNA (mRNA) in the nucleus.
- This information in mRNA is then passed on, in the second step (called translation), for protein synthesis in the cytoplasm.

MESSENGER RNA

mRNA (single-stranded) contains groups of three consecutive bases called codons. As their name suggests, each codon "codes" for a specific amino acid (amino acids being the building blocks for proteins). Since there are 4 bases to choose from (A, U, C and G) and 3 bases in each codon, there are 64 (= 4^3) possible codons. However, only 20 amino acids are used for protein synthesis, which means that some codons code for the same amino acid. In addition, there are a special group of codons which, instead of coding for an amino acid, provide the signal for the beginning or termination of protein synthesis (called START and STOP codons, respectively).

mRNA STRAND (4 codons shown)



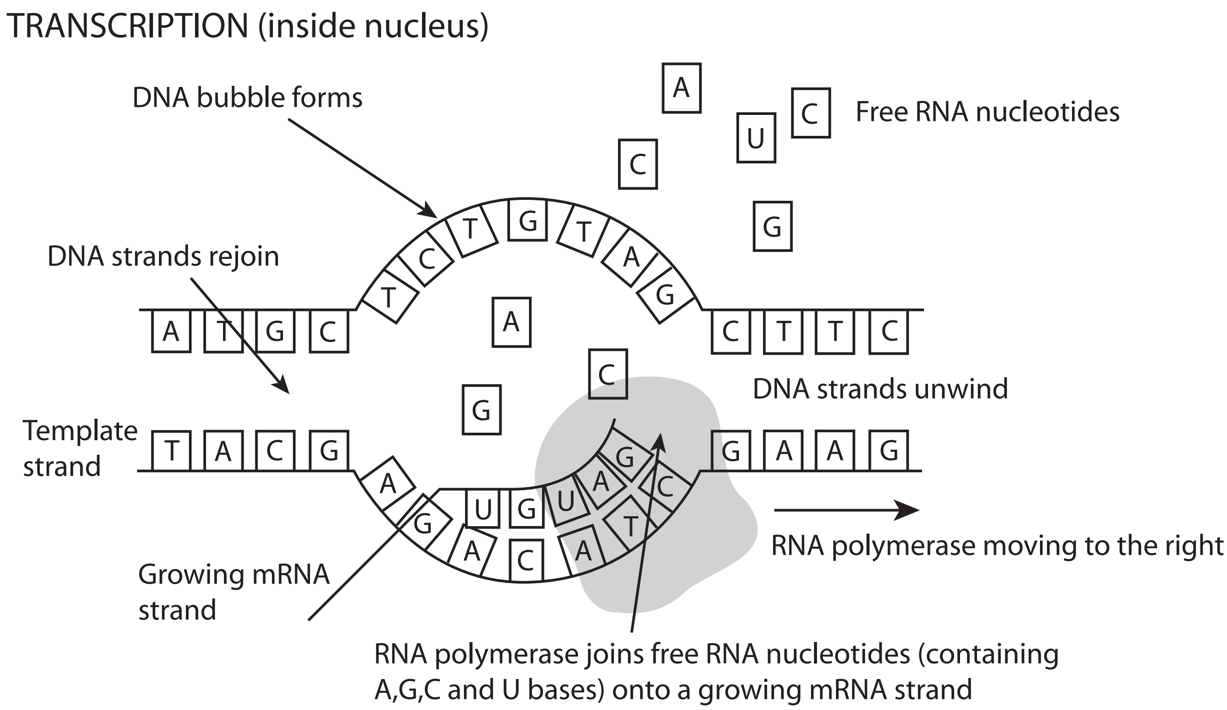
M4: Protein synthesis, transcription and translation

In most organisms, the flow of information from DNA to protein is unidirectional, i.e. DNA → RNA → protein. As previously alluded to, DNA → RNA is called transcription (and takes place in the nucleus), and RNA (mRNA and tRNA) → protein is called translation (and takes place in the cytoplasm).

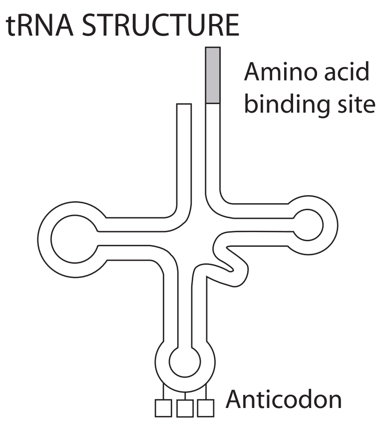
TRANSCRIPTION

The steps involved in transcription are:

1. A segment of DNA is unwound, creating a DNA bubble where the bases are exposed.
2. Free nucleotides floating inside the nucleus bind to bases on the exposed DNA (A to T, U to A, C to G and G to C). An enzyme called RNA polymerase joins these nucleotides together to form a growing mRNA strand.
3. Regions on the mRNA that are not required for amino acid synthesis (called introns) are removed. The exons (the coding regions) are preserved.
4. The mRNA then diffuses out of the nucleus into the cytoplasm through small holes (called nuclear pores). The unwound DNA strands rejoin.



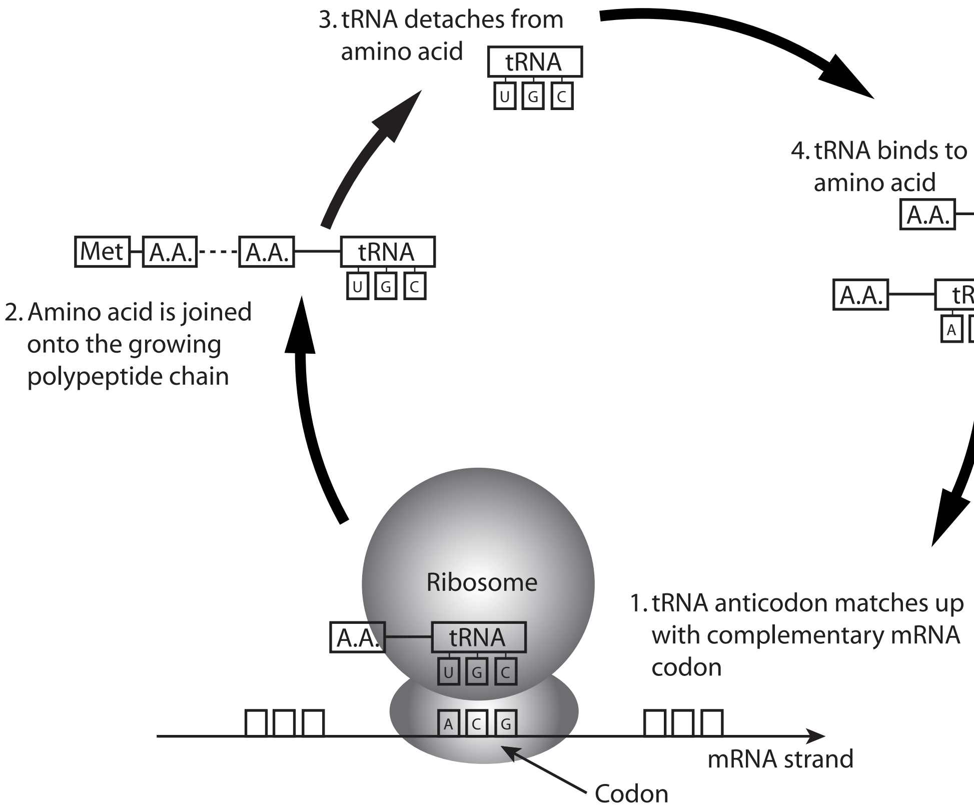
TRANSLATION



The steps involved in translation are:

1. The mRNA molecule binds to a ribosome, which starts to read its codons.
2. An mRNA codon read by the ribosome binds a complementary anticodon (also a group of 3 bases) on a tRNA molecule. tRNA molecules are clover-shaped structures in the cytoplasm with an anticodon at one end and a specific amino acid attached at the other end.
3. As the ribosome moves down the mRNA strand and subsequent codons are read, new amino acids are brought in and offloaded by tRNA.
4. Each new amino acid joins onto the previous one, forming a growing protein. The first amino acid to be translated is always Methionine.

TRANSLATION (inside cytoplasm)



M5: Protein structure

Proteins are made up of large chains of amino acids. There are four levels of protein structure:

1. Primary structure – refers to the primary (peptide) bonds between the individual amino acids.
2. Secondary structure – refers to the coiling or folding (due to secondary interaction forces between amino acids) of sections of a chain of amino acids into either a helix or a sheet.
3. Tertiary structure – refers to the three dimensional shape of an entire polypeptide chain.
4. Quaternary structure – refers to the three dimensional shape of the whole protein, made up of several polypeptides.

4 LEVELS OF PROTEIN STRUCTURE