SUMMING-UP

1 The function of DNA

- At the beginning of the twentieth century, biologists observed that, during cell division and the production of gametes, chromosomes separate and are distributed in the daughter cells such that each cell possesses the same number. These observations, in agreement with Mendel's theories, led to the **chromosome theory of inheritance**.
- Subsequent research led Frederick Griffith to discover a substance, which he called the **transformation factor**, capable of transforming non-virulent bacteria into virulent bacteria. Avery's experiments showed that this factor was **DNA**, or deoxyribonucleic acid.

2 The chemical structure of DNA

- DNA is a polymer of **nucleotides**. A nucleotide consists of a phosphate group, deoxyribose (a sugar with 5 carbon atoms) and a nitrogenous base. Alternating phosphate groups and sugars form the skeleton of the polymer; nitrogenous bases protrude from the chain.
- The nitrogenous bases may be of four types: **cytosine**, and **thymine** (belonging to the class of pyrimidines), adenine and guanine (belonging to the purines).
- The DNA molecule has a **double helix** shape, in which two anti-parallel strands are joined between the bases by hydrogen bonds and wrap about themselves. The bases pair up according to the complementarity rule (A-T and C-G).

3 DNA replication

- DNA replication occurs through the action of several enzymes: the strands are separated and each acts as a template for the synthesis of a new strand (**semiconservative** replication).
- The enzyme responsible for the synthesis of the strands is **DNA polymerase**, which requires a fuse consisting of a short fragment of RNA (known as a **primer**). The DNA polymerase is able to synthesise only in the direction 3'-5' of the template strand, thus leading to one strand for which the synthesis is rather fast and the other for which it is slower. The DNA polymerase is also able to control and correct the newly synthesised strand.

4 The organisation of DNA in chromosomes

- DNA molecules enter the small volume of the nucleus of a eukaryotic cell due to a specific organisation. The molecules are wrapped around proteins, **histones**, forming **nucleosomes**. These are further compressed and packed to form chromosomes. Each chromosome is made up of a DNA molecule; their number varies depending on the species.
- On the slow DNA strand replication cannot proceed to its conculsion. On each DNA molecule, therefore, there are terminal fragments devoid of information, the **telomeres**, which become shorter with each replication.

5 From the gene to the protein

- The **central dogma of biology** states that the information in cells is transferred only in one direction, from DNA to proteins, i.e. from genes to phenotype. This flow takes place in stages, facilitated by RNA that acts as an intermediary.
- The first stage, in which DNA acts as a template to synthesise a molecule of RNA, is called **transcription**, and occurs in the cell nucleus. The second step is called **translation** and occurs in the cytoplasm, in particular in the **ribosomes**. During this stage the RNA is used to synthesise the proteins.
- The only exception to the dogma is in the case of **retroviruses** (or RNA virus), but these are not considered as living things.

6 Structure and function of RNA

- **RNA** (or ribonucleic acid) is chemically very similar to DNA, but with three differences: the sugar is ribose, the nitrogenous base uracil replaces thymine and the nucleotide strand is single.
- Three types of RNA are involved in protein synthesis: messenger RNA (**mRNA**) transports the gene sequences from the nucleus to the cytoplasm; ribosomal RNA (**rRNA**) forms the ribosomes; and transfer RNA (**tRNA**) translates the language of the bases into that of amino acids.
- tRNA has a specific three-dimensional shape that allows it to transport amino acids to the ribosomes and pair with the mRNAs through a triplet of bases, called the **anticodon**.

SUMMING-UP

7 Transcription of RNA

- RNA is transcribed by **RNA polymerase** from DNA, following the rule of complementarity of the bases.
- The transcript begins at a sequence of DNA called the promoter and ends at a different base sequence, called the terminator.
- The synthesised RNA molecule, called the **primary transcript**, usually undergoes some modification before being used in protein synthesis.

8 The genetic code

- The translation of proteins from sequences of bases proceeds according to the **genetic code**, consisting of 64 triplets of bases called **codons**, which encode for 20 amino acids. In addition, the code includes three stop codons that mark the end of protein synthesis.
- The genetic code is **universal**: the same for all living beings. Some exceptions are known but only among the **protists** and in independent genetic systems, such as mitochondria and chloroplasts. The code is **degenerate** as different **codons** can specify the same amino acid.

9 Protein synthesis

- **Protein synthesis** occurs in ribosomes with the translation process. The start of translation occurs with the recognition of the AUG codon by the tRNA that indicates the amino acid methionine and the start of synthesis.
- The next phase is called elongation and occurs through a shift of the ribosome along the messenger RNA molecule. A new tRNA reaches the ribosome and pairs with the next mRNA codon. The two neighbouring amino acids bind together with the formation of a **peptide bond**. Then a tRNA moves away to permit the entry of the next one.
- The synthesis ends when there is a stop codon on the mRNA, and this causes the entry into the ribosome of a protein, called **releasing factor,** that interrupts the synthesis.

10 Structure and function of proteins

- **Proteins** are biological molecules that perform many functions within cells and organisms in the body: there are proteins with enzymatic functions, others with structural functions, transportation, defence, etc.
- Proteins possess a structure with different levels of organisation and complex **folding** that affects its functionality. This folding depends on the primary structure, i.e. on the protein's sequence of amino acids and determines different types of secondary and tertiary structure. Proteins that are formed by the union of many polypeptide chains also have a quaternary structure.