Nucleic acids

Nucleic acids are the most important of all biomolecules. They are linear polymers (chains) of **nucleotides**. Each nucleotide consists of three components: a **nitrogenous base** (**purine** or **pyrimidine**), a **pentose sugar**, and a **phosphate group** (Figure 5.1).

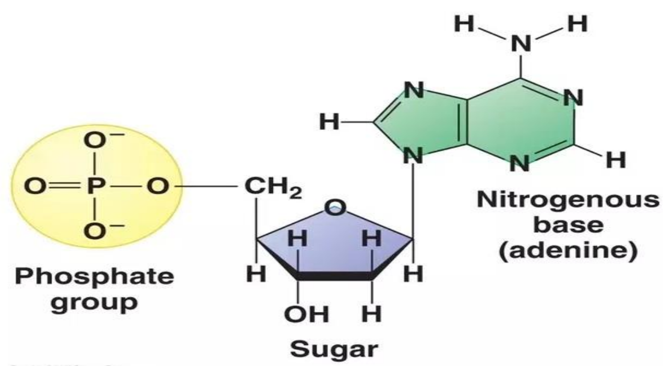


Figure 5.1: The components of nucleotide.

The structure consisting of a nitrogenous base plus sugar is termed a **nucleoside**. If the sugar is a **ribose**, the polymer is **RNA** (ribonucleic acid); if the sugar is a **deoxyribose**, the polymer is **DNA** (deoxyribonucleic acid). The nitrogenous base found in the two nucleic acid types are different: **adenine**, **cytosine**, and **guanine** are found in both RNA and DNA, while **thymine** occurs in DNA and **uracil** occurs in RNA (Figure 5.2).

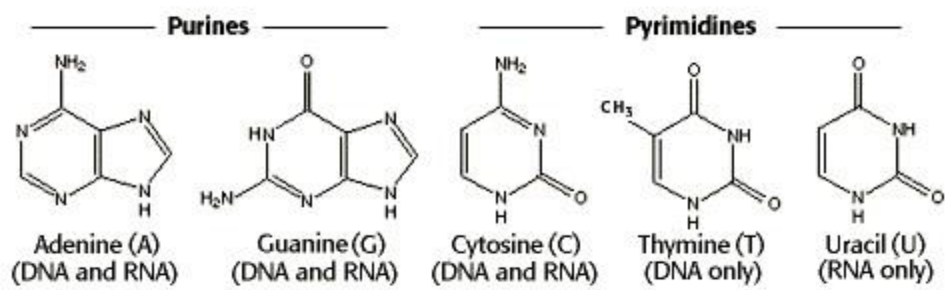


Figure 5.2: purine and pyrimidine

Deoxyribonucleic acid (DNA)

Is a thread-like chain of nucleotides carrying the genetic instructions used in the growth, development, functioning and reproduction of all known living organisms and many viruses.

Molecular structure of DNA was first identified by James **Watson** and Francis **Crick** in 1953. DNA molecules consist of two strands (polynucleotides) coiled around each other to form a double helix. The two DNA strands are composed of nucleotides. Each nucleotide is composed of one of four nitrogen-containing nucleobases (cytosine [**C**], guanine [**G**], adenine [**A**] or thymine [**T**]), a sugar called deoxyribose, and a phosphate group.

The nucleotides are joined together by a **condensation reaction** between the phosphate group of one and the sugar group of another. The bond between the two nucleotides is called a **phosphodiester bond**. Many nucleotides joined together in this way make a repeating Sugar-Phosphate 'backbone' out of which the nitrogenous bases project. The nitrogenous bases of the two separate polynucleotide strands are bound together, according to base pairing rules (A with T and C with G), with hydrogen bonds to make double-stranded DNA. The two strands of DNA run in opposite directions to each other and are thus antiparallel (Figure 5.3).

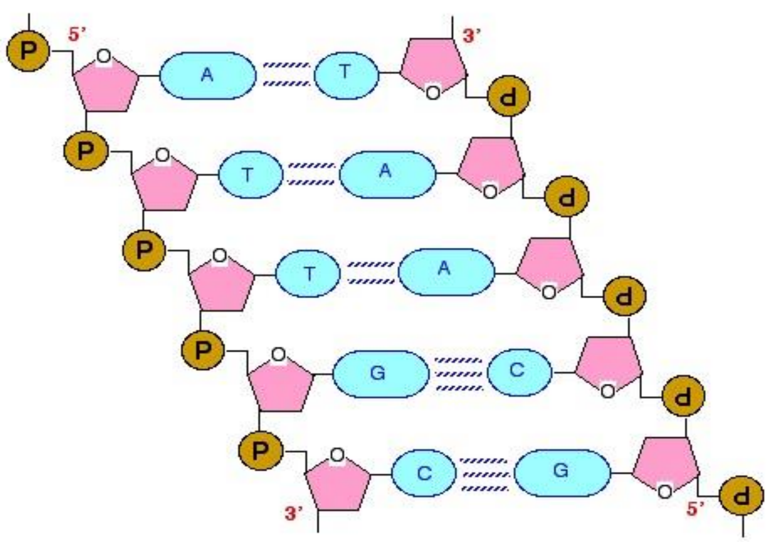


Figure 5.3: The DNA molecule.

Base pairing

In a DNA double helix, each type of nucleobase on one strand bonds with just one type of nucleobase on the other strand. This is called complementary base pairing. Here, purines form hydrogen bonds to pyrimidines, with **adenine bonding only to thymine in two hydrogen bonds**, and **cytosine bonding only to guanine in three hydrogen bonds**. This arrangement of two nucleotides binding together across the double helix is called a **Watson-Crick base pair**. DNA with high GC-content is more stable than DNA with low GC-content.

Biological functions

The set of chromosomes in a cell makes up its **genome**; the human genome has approximately 3 billion base pairs of DNA arranged into 46 chromosomes. The information carried by DNA is held in the sequence of pieces of DNA called **genes**. In **transcription**, when a cell uses the information in a gene, the DNA sequence is copied into a complementary RNA sequence. Usually, this RNA copy is then used to make a matching protein sequence in a process called **translation.** A cell copy its genetic information in a process called DNA **replication**.

Ribonucleic acid (RNA)

RNA is a polymeric molecule essential in various biological roles. RNA and DNA are nucleic acids, and, along with lipids, proteins and carbohydrates, constitute the four major macromolecules essential for all known forms of life. Like DNA, RNA is assembled as a chain of nucleotides, but unlike DNA it is more often found in nature as a **single-strand** folded onto itself, rather than a paired double-strand. Many viruses encode their genetic information using an RNA genome.

Cellular organisms use messenger RNA (**mRNA**) to convey genetic information (using the nitrogenous bases guanine, uracil, adenine, and cytosine, denoted by the letters G, U, A, and C) that directs synthesis of specific proteins, this process uses transfer RNA (**tRNA**) molecules to deliver amino acids to the ribosome, where ribosomal RNA (**rRNA**) then links amino acids together to form proteins.

Types of RNA

1-Messenger RNA (mRNA) is carries information from DNA to the ribosome, the sites of protein synthesis (translation) in the cell. The coding sequence of the mRNA determines the amino acid sequence in the protein that is produced (Figure 5.4).

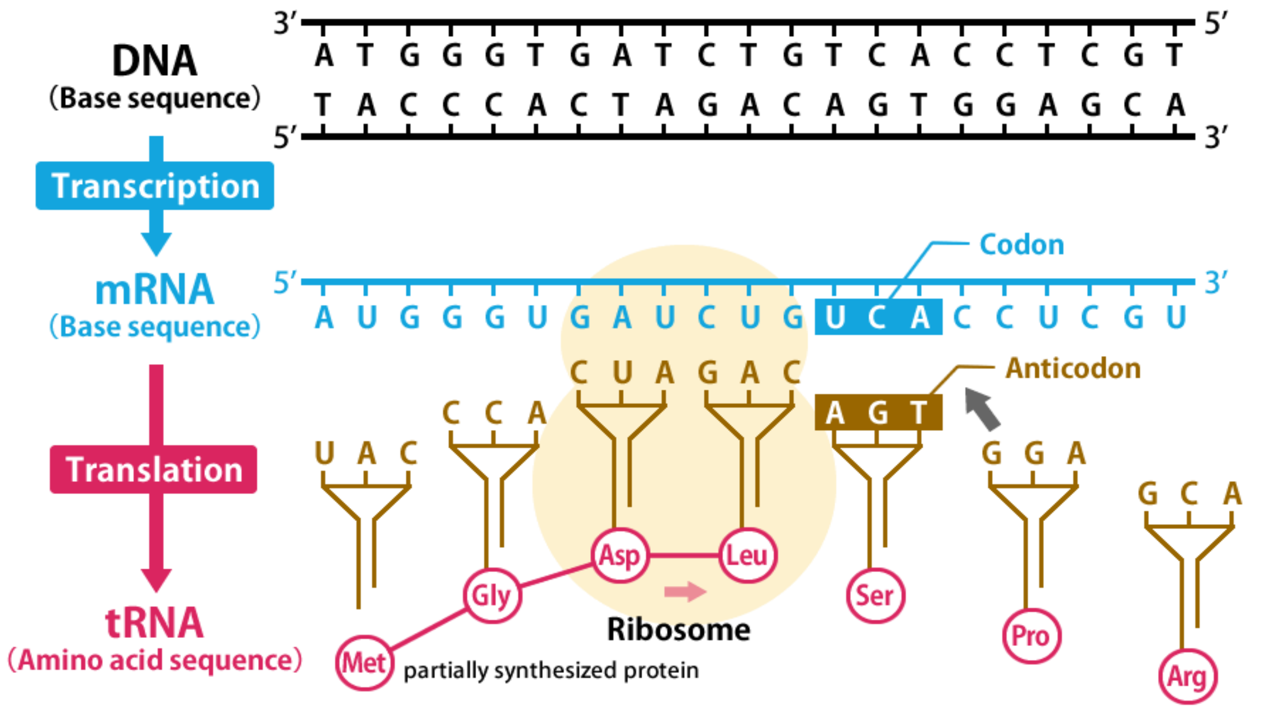


Figure 5.4: Protein synthesis.

2- Transfer RNA (tRNA) is a small RNA chain of about 80 nucleotides that transfers a specific amino acid to a growing polypeptide chain at the ribosomal site of protein synthesis during translation. It has sites for amino acid attachment and an anticodon region for codon recognition that binds to a specific sequence on the messenger RNA chain through hydrogen bonding.

3- Ribosomal RNA (rRNA) is the catalytic component of the ribosomes. In the cytoplasm, ribosomal RNA and protein combine to form a nucleoprotein called a ribosome. The ribosome binds mRNA and carries out protein synthesis. Several ribosomes may be attached to a single mRNA at any time.

Enzyme

Enzymes accelerate chemical reactions. The molecules upon which enzymes may act are called **substrates** and the enzyme converts the substrates into different molecules known as products. Almost all metabolic processes in the cell need enzyme catalysis in order to occur at rates fast enough to sustain life. The study of enzymes is called **enzymology**.

Most enzymes are **proteins**, although a few are catalytic **RNA** molecules. The latter are called **ribozymes**. Enzymes' specificity comes from their unique structures. An enzyme's activity decreases outside its optimal temperature and pH.

Some enzymes require no chemical groups for activity other than their amino acid residues. Others require an additional chemical component called a **cofactor**, either one or more inorganic ions, such as Fe^{2+}, Mg^{2+}, Mn^{2+}, or Zn^{2+}, or a complex organic or metalloorganic molecule called a **coenzyme,** such as biocytin, coenzyme A, flavin adenine dinucleotide, and nicotinamide adenine dinucleotide. Some enzymes require both a coenzyme and one or more metal ions for activity. A coenzyme or metal ion that is very tightly or even covalently bound to the enzyme protein is called a **prosthetic group.** A complete, catalytically active enzyme together with its bound coenzyme and/or metal ions is called a **holoenzyme.** The protein part of such an enzyme is called the **apoenzyme** or **apoprotein.**

Naming and classification

Except some of enzymes such as pepsin, rennin, and trypsin, most enzyme names end in "**ase**". The International Union of Biochemistry (I.U.B.) initiated standards of enzyme nomenclature which recommend that enzyme names indicate both the substrate acted upon and the type of reaction catalyzed. Different enzymes that catalyze the same chemical reaction are called **isozymes**.

The mechanism of enzymatic action

1- Substrate binding: Enzymes must bind their substrates before they can catalyse any chemical reaction.

- **Lock and key model:** both the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another. This is often referred to as "the lock and key" model. This early model explains enzyme specificity.

- **Induced fit model:** enzymes are rather flexible structures, the active site is continuously reshaped by interactions with the substrate as the substrate interacts with the enzyme. The substrate molecule also changes shape slightly as it enters the active site.

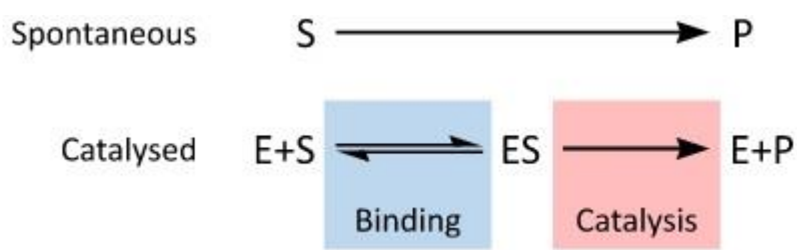
2- Catalysis: Enzymes can accelerate reactions.

3- Dynamics: Enzymes are not rigid, they have complex internal dynamic motions. These motions give rise to a conformational ensemble of slightly different structures that interconvert with one another at equilibrium.

4- Allosteric modulation: Allosteric sites are pockets on the enzyme, distinct from the active site, that bind to molecules.

Enzyme kinetics

Enzyme kinetics is the investigation of how enzymes bind substrates and turn them into products. In 1913 Leonor Michaelis and Maud Leonora Menten proposed a theory of enzyme kinetics, which is referred to as **Michaelis–Menten kinetics**, the substrate binds reversibly to the enzyme, forming the enzyme-substrate complex, the enzyme then catalyzes releases the product.



Biological function of enzymes

- Signal transduction and cell regulation.
- ATPases in the cell membrane are ion pumps involved in active transport.
- Viruses contain enzymes for infecting cells.
- An important function of enzymes is in the digestive systems of animals.