NUCLEIC ACIDS

Content Statements:

A1.2.1	DNA as the genetic material of all living organisms
A1.2.2	Components of a nucleotide
A1.2.3	Sugar-phosphate bonding and the sugar-phosphate “backbone” of DNA and RNA
A1.2.4	Bases in each nucleic acid that form the basis of a code
A1.2.5	RNA as a polymer formed by condensation of nucleotide monomers
A1.2.6	DNA as a double helix made of two antiparallel strands of nucleotides with two strands linked by hydrogen bonds between complementary base pairs
A1.2.7	Differences between DNA and RNA
A1.2.8	Role of complementary base pairing in allowing genetic information to be replicated and expressed
A1.2.9	Diversity of possible base sequences and the limitless capacity of DNA for storing information
A1.2.10	Conservation of the genetic code across all life as evidence of universal common ancestry

NUCLEIC ACIDS

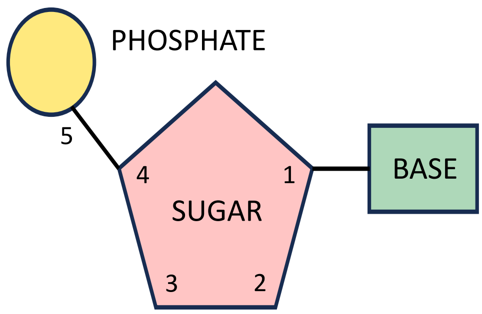
Nucleic acids are organic molecules that act as the genetic material of a cell. Nucleic acids store the coded instructions for the expression of proteins, which determine the characteristics of a cell. These instructions are passed between generations – making the nucleic acids responsible for inheritance within a species.

NUCLEOTIDES

All nucleic acids are composed of monomeric subunits known as **nucleotides**. Each nucleotide is comprised of three components:

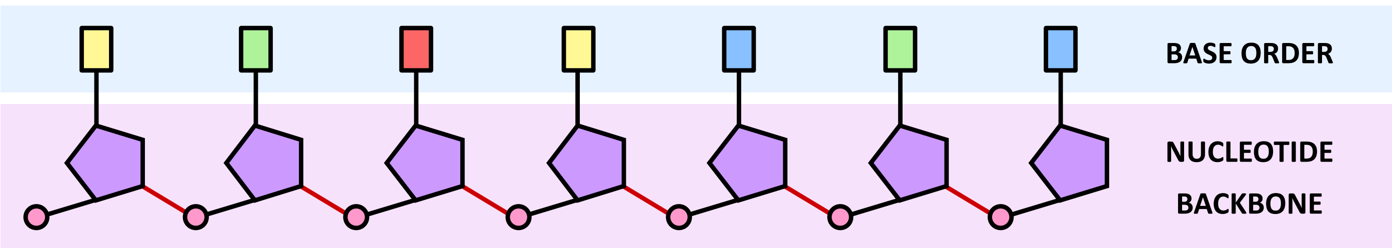
- A pentose sugar (organised into a 5-carbon cyclic structure)
- A nitrogenous base (attached to the sugar at the 1’-carbon)
- A phosphate group (attached to the sugar at the 5’-carbon)

Nucleotides differ according to the nitrogenous base they have



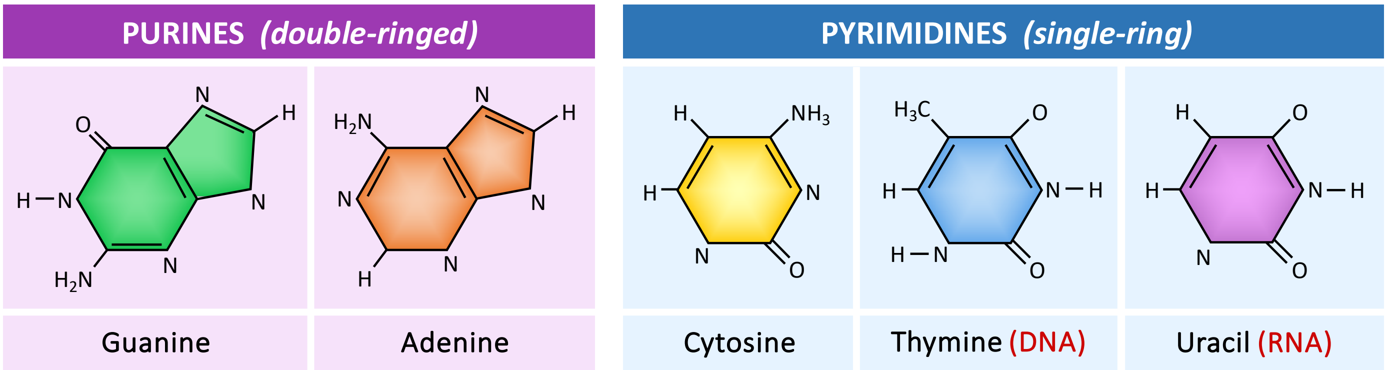
SUGAR-PHOSPHATE BACKBONE

Nucleotides are joined together by **condensation reactions** to form long polynucleotide chains. Nucleotides are connected between the 5’-phosphate and the 3’-position of the sugar. The sugars and phosphates form a backbone, while the bases extend outwards. The order of the base sequence forms the coded instruction.



BASE SEQUENCE

The base sequence of nucleic acids functions as a four-letter code that determines the characteristics of the cell. The nitrogenous bases can be organised into two groups: double-ringed **purine** bases or single-ringed **pyrimidine** bases. Adenine and guanine are purines, while cytosine and thymine (or uracil) are pyrimidines.



DNA VERSUS RNA

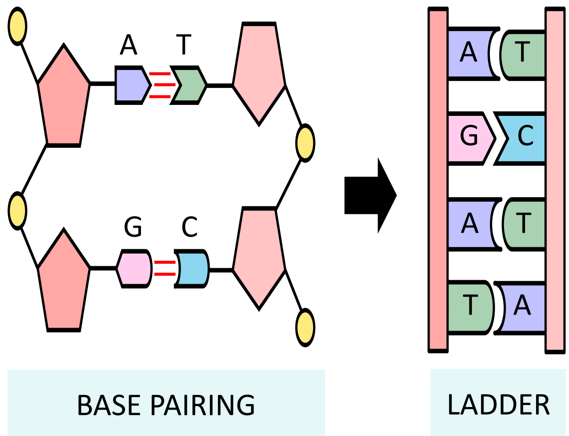
There are two main types of nucleic acids. DNA functions as the master template of the genetic instructions and remains in the nucleus of eukaryotic cells (or in the nucleoid region of prokaryotic cells). RNA functions as a transient copy of the template instructions and is transported to the ribosomes to synthesise proteins.

There are a number of key structural differences between the structures and functions of DNA and RNA:

- In DNA nucleotides the pentose sugar is **deoxyribose**, whereas RNA nucleotides use the sugar **ribose**
- In RNA, the nitrogenous base **thymine** is replaced by **uracil** (i.e. DNA uses T, whereas RNA uses U)
- Whereas DNA is a **double-stranded** molecule, RNA is always a **single-stranded** molecule

DNA STRUCTURE

DNA is composed of double-stranded polynucleotide chains. The two DNA chains are held together by hydrogen bonds that form between the two sets of bases. When they pair the two polynucleotide strands will form a structure like a **ladder** – the backbones are struts and the bases are rungs. In order for the complementary bases to pair, the two DNA strands must be running in opposite directions, and hence the two strands are **antiparallel**. Double-stranded DNA will arrange into the most stable configuration: a **double helix**.



RNA STRUCTURE

RNA is a single-stranded molecule that uses the base uracil (**U**) instead of thymine. It is synthesised from the DNA template and is involved in protein assembly. There are three main types of RNA made by cells:

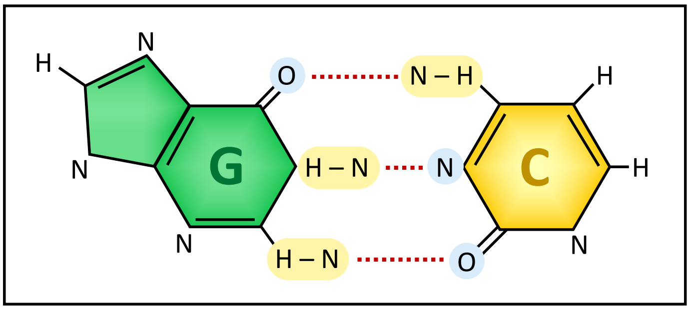
- **Messenger RNA** (**mRNA**): A transcript of a DNA sequence that is translated by ribosomes into protein
- **Transfer RNA** (**tRNA**): Brings amino acids to the ribosome according to the specific mRNA sequence
- **Ribosomal RNA** (**rRNA**): A component of the ribosome that enables it to interact with mRNA and tRNA

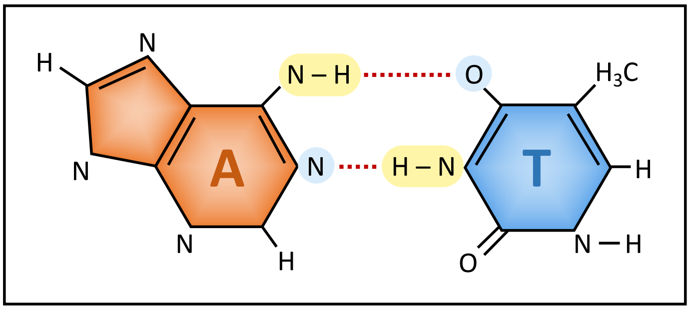
All three types of RNA are required for protein synthesis to occur at the ribosomes. When the protein has been synthesised, the mRNA transcripts are broken down and the nucleotides can be recycled by the cell.

COMPLEMENTARY BASE PAIRING

In order for DNA to form a double stranded structure, be replicated or interact with RNA, the bases must be able to connect in a consistent pattern so as to maintain the DNA sequence. This involves what is known as **complementary base pairing**. A purine must always pair with a pyrimidine in order to maintain an optimal distance between the two molecules that are interacting. The complementary base pairing that occurs is:

- The purine **adenine** (A) always pairs with the pyrimidine **thymine** (T) by forming two hydrogen bonds
- The purine **guanine** (G) always pairs with the pyrimidine **cytosine** (C) by forming three hydrogen bonds
- In an RNA sequence, the base thymine is replaced by **uracil** (U), and so this pairs with adenine instead.





GENETIC CODE

A sequence of DNA that codes for a particular protein is called a **gene**. Because a gene sequence can be of any length and involve any possible combination of bases, the capacity for DNA to store information has no limits. A gene sequence will give rise to a polypeptide sequence because specific base combinations code for particular amino acids. The set of instructions that determines which amino acid is produced by a given combination of bases is called the **genetic code**. The genetic code is conserved across all forms of life – this suggests that all living things share universal common ancestry (all existing life came from a single source).

CHROMOSOMES

Within cells, molecules of DNA are organised into discrete structures called **chromosomes**. The way DNA is packaged and stored within the cell will differ between prokaryotic and eukaryotic cells. In prokaryotic cells (bacteria), the DNA is unpackaged (naked) and forms a single circular chromosome known as a *genophore*. In eukaryotes, DNA is packaged with **histone proteins** to form *nucleosomes*, which allow the chromosomes to adopt a more compact structure known as chromatin. This chromatin will then condense (supercoil) to form linear chromosomes. Additionally, eukaryotic cells are more complex and will consequently possess a larger number of chromosomes (i.e. more than one) than are typically present within most bacterial cells.

PROKARYOTE
DNA is naked
Chromosome is circular
Sequence is more compact (there are usually no introns)
Only one main chromosome plus additional plasmids
DNA stored in the nucleoid

EUKARYOTE
DNA is bound to histones
Chromosomes are linear
Sequence is less compact (genes may contain introns)
Multiple chromosomes (usually organised in pairs)
DNA is stored in the nucleus