1.3. Control of gene expression

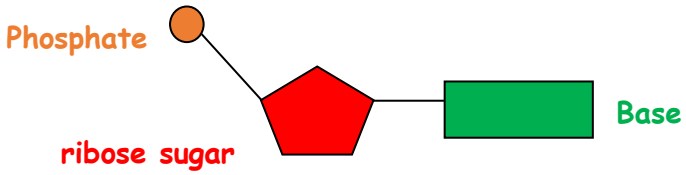
A cell's **genotype** (genetic constitution) is determined by the sequence of the DNA bases in its genes (the genetic code).

A cell's **phenotype** (physical and chemical state) is determined by the proteins that are synthesised when the genes are expressed.

Gene expression is controlled by the regulation of transcription and translation. It is influenced by **environmental factors** acting inside and outside of the cell. Only a fraction of the genes in a cell are expressed.

RNA

Ribonucleic acid (RNA) is a single strand of RNA nucleotides. Each RNA nucleotide is composed of a molecule of **ribose** sugar, a **phosphate** group and an organic **base**. In RNA, the base **uracil**, replaces thymine (found in DNA).



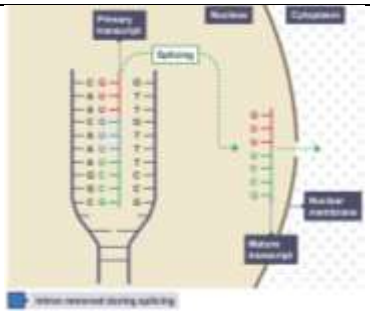
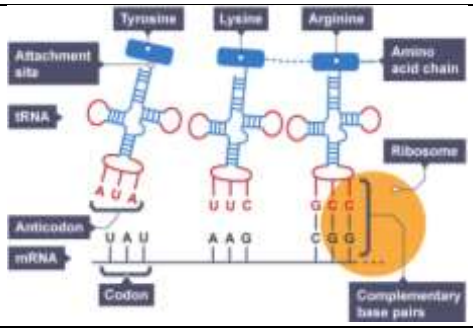
Characteristic	RNA	DNA
number of nucleotide strands present in one molecule	one	two
complementary base partner of adenine	uracil	thymine
sugar present in a nucleotide	ribose	deoxyribose

There are three types of RNA

Messenger RNA (mRNA)	carries a complementary copy of the DNA code from the **nucleus** to **ribosomes** in the cytoplasm.
Transfer RNA (tRNA)	is a type of RNA found in the **cytoplasm**. tRNA folds due to base pairing to form a triplet anticodon site and an attachment site for a specific amino acid. tRNA carries specific amino acids to ribosomes, where they can be assembled to form polypeptide chains.
Ribosomal RNA (rRNA)	rRNA and proteins are **components** of the **ribosome** and therefore they are both essential for protein synthesis to take place in all living cells.

Transcription

- Transcription takes place in the **nucleus** and is the first step in gene expression.
- **RNA polymerase** unwinds and unzips the double helix, of the gene to be expressed, by breaking the hydrogen bonds between the complementary bases.
- RNA polymerase then aligns complementary **free RNA nucleotides** against the exposed DNA nucleotides of the template strand.
- These free RNA nucleotides join together to form a **primary** transcript of mRNA, which is made up of groups of three bases called **codons**.
- Each primary transcript of mRNA has both **introns** (non-coding regions) and **exons** (coding regions). During a process called **RNA splicing** the introns are removed and the exons are spliced together to form a **mature** transcript of mRNA.
- This mature mRNA transcript then passes out of the **nucleus** to the **ribosomes** (found in the cytoplasm) to be translated.

Transcription	Translation
	

Translation

- During this second stage, the mature mRNA transcript binds onto a **ribosome**
- mRNA carries a **start** codon, to begin transcription
- **tRNA molecules** transport a specific amino acid from the cytoplasm to the mRNA on the ribosome
- **mRNA codons** recognise incoming **tRNA anticodons** and match up to form **complementary** base pairs
- Empty tRNA molecules exit the ribosome and collect another specific amino acid
- **Peptide bonds** form between the adjacent amino acids to form the polypeptide chain
- The mRNA carries a **stop** codon, to signal the end of translation, releasing the polypeptide chain
- The polypeptide chain folds into a **three**-dimensional shape to form a protein, which is held together by **peptide** bonds, **hydrogen** bonds and other molecular interactions between amino acids.

Different proteins can be expressed from the one gene, as a result of alternative RNA splicing and post-translational modifications.

Alternative RNA splicing	Post-translational modifications
Different mRNA molecules are produced from the same primary transcript depending on which **exons** are included in the **mature** RNA transcript.	After translation, the polypeptide chain can be changed by **cutting** and **combining** chains or by adding **phosphate** or **carbohydrate** groups to a protein.