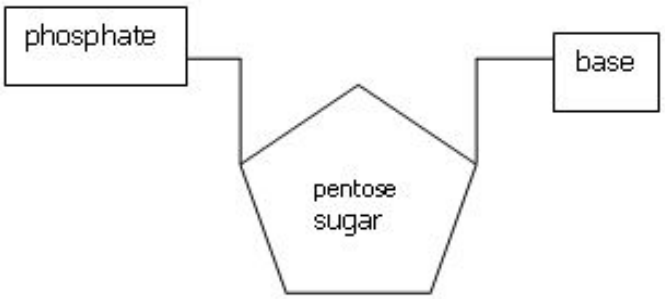
CAIE Biology A-level

Topic 6: Nucleic acids and protein synthesis

Notes

DNA and Protein Synthesis



Both **DNA** and **RNA** carry information. DNA holds genetic information, whereas RNA then transfers this genetic information from DNA to **ribosomes** made of RNA and proteins. Both deoxyribonucleic and ribonucleic acid are **polymers of nucleotides**.

Nucleotides consist of **pentose** which is a 5 carbon sugar, a nitrogen containing **organic base** and a **phosphate group**:

- The components of a **DNA** nucleotide are **deoxyribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or thymine**. Adenine and guanine both have double ring structure and are classified as **purine** bases.

- The components of an **RNA** nucleotide are **ribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or uracil**. Thymine, uracil and cytosine all have single ring structure and are classified as **pyrimidines**.

- Nucleotides join together by **phosphodiester bonds** formed in **condensation reactions**.

DNA structure

- A **double helix** composed of two polynucleotides joined together by hydrogen **bonds** between complementary bases.
- In DNA the 2 strands lie **antiparallel** and complementary base pairing takes place between the **5' to 3'** strand and the **3' to 5'** strand
- A purine always joins to a pyrimidine base
- Depending on the bases a different number of hydrogen bonds are formed.
    - **Adenine and Thymine** join together by **2** hydrogen bonds
    - **Cytosine and guanine** join together by **3** hydrogen bonds.
- Nucleotides are joined together by phosphodiester bonds.

RNA structure

- **RNA is a relatively short polynucleotide chain.**
- An RNA nucleotide consists of **ribose** instead of deoxyribose, a **phosphate group and one of the organic bases adenine, cytosine, guanine and uracil** (instead of thymine).

DNA replication

The **semi-conservative replication** of DNA ensures genetic continuity between generations of cells meaning that genetic information is passed on from one generation from the next. DNA replication occurs during the S phase of the cell cycle.

The steps of semi-conservative replication of DNA are as following:

- The **double helix unwinds** and the **hydrogen bonds between the complementary bases break** using **DNA helicase** thus separating the two strands of DNA
- One of the strands is used as the **template** and **complementary base pairing occurs** between the template strand and **free nucleotides**
- Adjacent nucleotides are joined by **phosphodiester bonds** formed in condensation reactions using **DNA polymerase**

DNA polymerase only works in the **5' to 3' direction.** This means that DNA polymerase is only able to add nucleotides **starting from the 3' end of the new strand.**

- **The leading strand** is replicated **continuously** in the **3' to 5' direction.**
- The second strand which is called the **lagging strand** is replicated **discontinuously** in the **5' to 3' direction.** This means it is replicated in short sections forming **Okazaki fragments.**
- The Okazaki fragments are joined together with **DNA ligase.**

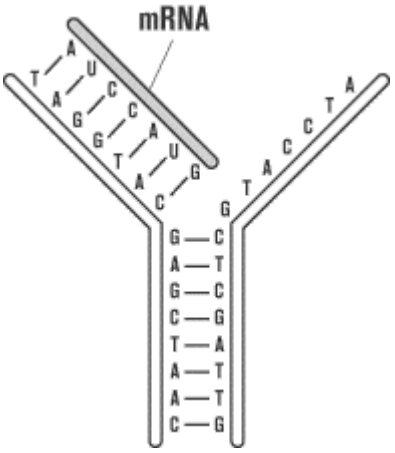
Protein synthesis

Proteins are **polypeptide chains**, coded for by a gene.

- The genetic code is **universal** and the sequence of bases determines which protein the gene is coding for.
- The **triplet code** is the sequence of 3 nucleotides which code for either an **amino acid, start codon or stop codon.**

There are two stages of **protein synthesis: transcription and translation. Transcription** which occurs in the nucleus and involves **DNA and mRNA** and **translation** which involves **mRNA, tRNA and ribosomes**. During transcription, DNA strand is transcribed into mRNA and translation is the process during which the amino acids are assembled together to form a polypeptide chain/protein.

Transcription:
During transcription, a molecule of mRNA is made in the nucleus:



- The **hydrogen bonds** between the complementary bases break and the **DNA uncoils,** separating the two strands - this is done by **DNA helicase**
- One of the DNA strands is used as a **template** to make the mRNA molecule, this is called the **template or transcribed strand**
- **Free nucleotides** bind to the exposed bases via **complementary base pairing** until a stop codon is reached.
- Adjacent nucleotides are joined by phosphodiester bonds, forming a molecule of mRNA - this is done by **RNA polymerase**
- mRNA detaches from DNA then moves out of the nucleus through a **pore** and attaches to a **ribosome** in the cytoplasm which is the site of next stage of protein synthesis called **translation**

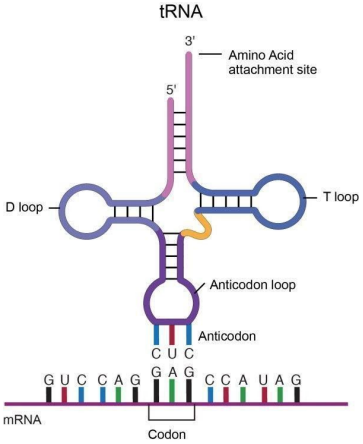
In eukaryotic cells, the RNA molecule formed from transcription is called the **primary transcript.** This is then modified by;

- Removal of non-coding sequences called **introns**
- Joining together coding sequences called **exons**
- This forms **mRNA**

Translation:

During translation amino acids join together to form a polypeptide chain:

- **mRNA** attaches to a subunit of a ribosome at the start codon. **Transfer RNA** is a type of RNA. It has an anticodon on one end and an amino acid bonded to the other, which it carries to the ribosome.
- The **anticodon of the tRNA** binds itself to the first codon on the mRNA by **complementary base pairing**
- Another tRNA molecule binds to the second codon of the mRNA. The amino acids attached to the tRNA molecules join by a **peptide bond** and then **tRNA molecules detach** themselves from the amino acids, leaving them behind
- This process is repeated thus leading to the formation of a **polypeptide chain** until a **stop codon** is reached on mRNA and ends the process of protein synthesis



Gene mutations

A gene mutation occurs when the **base sequence of DNA is altered**. If the DNA sequence is altered, this change is replicated in the mRNA chain and thus can result in an **altered polypeptide chain**. Gene mutations are caused by **mutagenic agents** such as chemicals and ionising radiation.

Mutations are a result of:

- **Substitution** - when 1 or more nucleotides are substituted by another in the DNA strand
- **Insertion** - when 1 or more nucleotides are inserted into the DNA strand
- **Deletion** - when 1 or more nucleotides are deleted in the DNA strand

Effects of mutations:

- **Nonsense** - a mutation resulting in a stop codon hence no polypeptide chain will be formed
- **Missense** - a mutation resulting in a different amino acid being coded for hence changing the polypeptide chain
- **Silent** - a mutation resulting in a different codon however it still codes for the same amino acid meaning the polypeptide chain produced is the same