Nucleotides

Both **DNA** and **RNA** are made up of **monomers** called **nucleotides**

Each nucleotide contains a **phosphate group**, a **nitrogen-containing** organic base, and a **pentose** (5-carbon) sugar: either **ribose** (RNA) of **deoxyribose** (DNA)

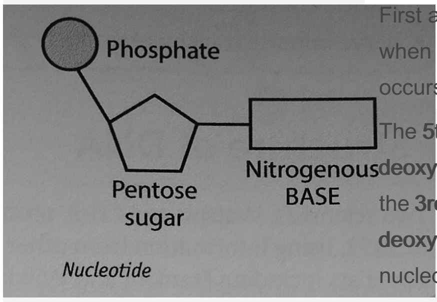
There are 2 groups of organic bases: **Pyrimidines** (single ring) and **purines** (double ring)

For **nitrogenous bases** found in DNA:

- Guanine (Purine)
- Cytosine (pyrimidine)
- Adenine (purine)
- Thymine (pyrimidine)

In **RNA** the pyrimidine **uracil** replaces **thymine**

Nucleotide diagram



ATP

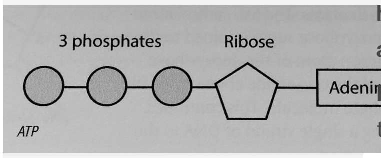
Adenine triphosphate is also a nucleotide: it has a ribose sugar joined to the adenine base, with three phosphate groups attached.

ATP (cont)

When the high-energy bond between the second and third phosphate group is broken via hydrolysis by the enzyme ATPase, 30.6Kg of energy is released for use in the cell, and adenine diphosphate is formed.

This reaction is reversible, requiring energy from respiration of glucose to reform the bond

ATP Diagram



Structure of DNA

DNA consists of **2 polynucleotide** strands that are **arranged** into a **double helix.**

First a **dinucleotide** is formed when a **condensation reaction** occurs between **2 nucleotides:**

The **5th carbon** atom of a **deoxyribose sugar** is joined to the **3rd carbon atom** of the **deoxyribose** sugar of the nucleotide above it, via the **phosphate molecule.**

This continues, building a **single strand** of DNA in the **5'-3' direction.**

DNA then forms a **double-stranded** molecule from **two strands:** one strand runs in the **opposite direction** to the other **(anti-parallel).**

Structure of DNA (cont)

Both strands are held **together** by **hydrogen bonds** that form between **complimentary nitrogenous bases.**

The **double strand** then **twists** to form a **double helix.**

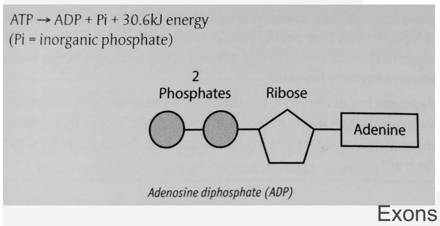
Bases between **both stands** pair up in a certain way which is called the **complementary base pairing rule:**

Guanine forms **hydrogen bonds** with an **adjacent cytosine** molecule and **adenine**forms **hydrogen bonds** with an **adjacent thymine** molecule.

Hydrogen bonds are **weak**, but the sheer number of them present in a **molecule of DNA** over a million **nucleotides** long, means that collectively they are **very strong.**

In fact you would need to **heat DNA** to **over 95 degrees C** to **break** them all.

ADP Diagram



Advantages and roles of ATP

Advantages of ATP:

Energy is **released quickly** from a **one-step reaction** involving just **one enzyme** (hydrolysis of glucose takes many steps)

Advantages and roles of ATP (cont)

Energy is released in **small amounts**, **30.6KJ** where it is needed. By contrast just **one** molecule of **glucose** contains **1880KJ** which **couldn't safely** be released all at once.

It is the **'universal energy currency'**, i.e. it's a common source of **energy** for all reactions in **all living things.**

Roles of ATP in cells:

Used in many **anabolic reactions**, e.g. **DNA** and **protein synthesis**

Active transport

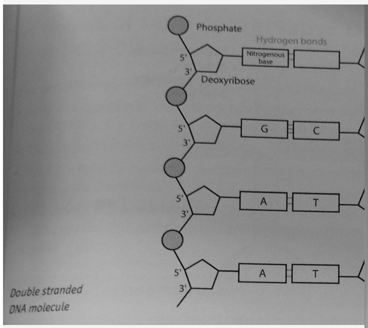
Muscle contraction

Nerve impulse transmission

Key Term

Codon	The **triplet of bases** in **mRNA** that codes for a **particular amino acid**, or a **punctuation signal.**
Introns	**Non-coding** nucleotide sequence in **DNA** and **pre-mRNA**, that is **removed** from **pre-mRNA**, to produce **mature mRNA.**
Exons	**Nucleotide** sequence on **one strand** of the **DNA molecule** and the **corresponding mRNA** that codes for the **production** of a **specific polypeptide.**

Structure of DNA diagram



Extracting DNA

DNA can be **easily extracted** from cells by **grinding** up a sample in a solution of ice cold **salt and washing up liquid.**

The **detergent dissolves** the **lipids** in the **phospholipid membranes**, allowing **DNA** to be **released**, and the **cold temperature protects** the DNA from **cellular DNAases.**

Addition of **protease** will **digest** any remaining **cellular enzymes** and the **histones** that the DNA is wound around.

Finally, **adding ethanol** to the salt already present, will cause the DNA to **precipitate** out from the **solution.**

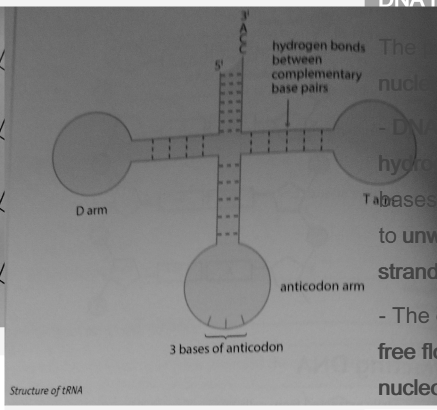
Structure of RNA

RNA is usually **shorter** than **DNA** and **single-stranded.**

Nucleotides also differ in that the **sugar** is **ribose**, the one base **thymine** replaced with **uracil.**

Three different types of RNA are involved in **protein synthesis.**

Structure of tRNA



Types of RNA

mRNA	**Messenger RNA** is a **single-stranded** molecule typically **300-2000** nucleotides long. It is **produced** in the **nucleus** using one of the **DNA strands** as a **template** during **transcription.**
rRNA	**Ribosomal RNA** forms **ribosomes** with the **addition** of **protein.**
tRNA	**Transfer RNA** is a **small molecule** that winds itself into a **cloverleaf** shape. It has an **anticodon** at one end, and an **amino acid** at the other. As the name suggests, it **'transfers'** the correct amino acid to the **growing polypeptide** during **translation.**

Process of semi-conservative DNA replication

The process **requires ATP**, **free nucleotides** and **enzymes.**

- **DNA helicase** breaks the **hydrogen bonds** between the **bases** causing the **double helix** to **unwind** and separate into **two strands.**

- The **exposed bases** bind to **free floating nucleotides** in the **nucleoplasm.**

- **DNA polymerase** binds the **complimentary nucleotides** (forming the **phosphodiester bond).**

- **One strand** acts as the **template** for the **new molecule**, so newly synthesised DNA contains **one parent strand** and a **complimentary** newly synthesised **strand.**

Functions of DNA

DNA has 2 main functions in organisms

1. **Protein synthesis** - the **sequence of bases** in one strand, called the **template strand**, determines the **order** of **amino acids** in the **polypeptide** (primary structure).

2. **Replication** - when **cells divide**, a complete **copy of the DNA** in the cell needs to be made. Both DNA strands **separate** and each strand acts as a **template** to **synthesise** a **complimentary strand.**

Three theories for how DNA replicates have been proposed:

Functions of DNA (cont)

1. **Conservative replication**: **original parent** stranded molecule is **conserved**, and a **new double-stranded DNA** molecule **synthesised** from it.

2. **Semi-conservative** replication: **parental strands separate**, and each strands acts as a **template** to **synthesise** a new strand. The new molecule consists of one original parent strand and one newly synthesised strand.

3. **Dispersive:** the **newly synthesised** molecules contain **fragments** from the **original parent strand** and **newly** synthesised DNA.

Key Term

Silent Mutation	A **change** in the **sequence** of nucleotide **bases** without a **subsequent change** in the **amino acid.**

Meselson-stahl experiment

1. Grow **bacteria** on a **15N** is a **heavy isotope** of nitrogen so all DNA produced would be a **heavier weight** than normal. When DNA was **extracted** by **centrifuging** in **caesium chloride**, the DNA band appeared **low down** in the tube.

Meselson-stahl experiment (cont)

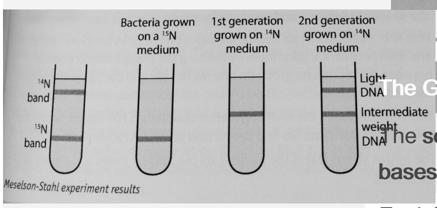
2. **Bacteria** were then grown on a **14N medium** (normal weight nitrogen), and after **one generation** the DNA **extracted** formed an **intermediate band** half way up the tube. This is because the DNA molecule contained **one strand** from the **heavy** parent and **one newly synthesised light** DNA strand. (Because one band was produced this **rules out conservative replication).**

3. The **bacteria** were grown for a **further generation** using **14N medium**. The DNA **extracted** formed an **intermediate band** half way up the tube, and a **lighter band** towards the top of the tube. Because **half** of the DNA was **intermediate weight** and **half light**, this rules out **dispersive replication.**

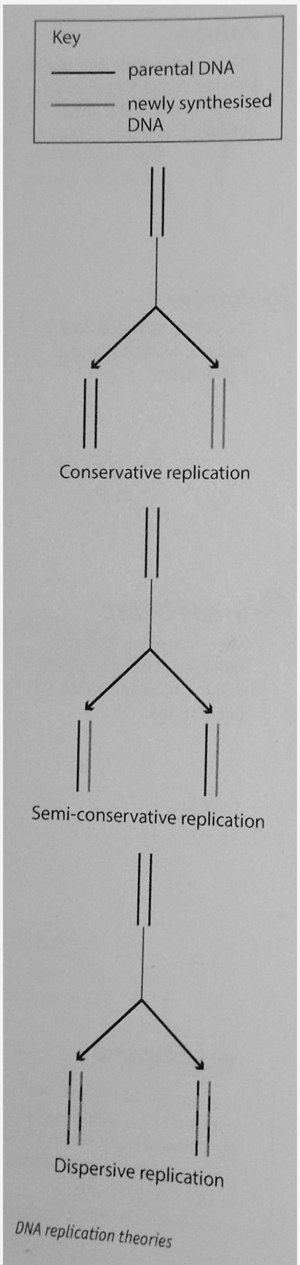
4. **DNA** therefore **replicates semi-conservatively.**

5. If grown for **further generations** using **14N medium**, whilst **intermediate weight** DNA would remain, the **proportion** of **light DNA** produced would **increase.**

Meselson-stahl experiment diagram



DNA replication theories



The Genetic code

The **sequence of nucleotide bases** forms a **code**.

Each **'code word'** has 3 letters called a **triplet code** or **codon**, which codes for a **specific amino acid.**

Genetic code examples:

DNA codon	mRNA codon	Amino acid that is coded for	Amino acid abbreviation
GGG	CCC	Proline	Pro
CGG	GCC	Glycine	Gly
ATG	UAC	Tyrosine	Tyr
TAC	AUG	Methionine	Met
ACT	UGA	Stop	

The Genetic code part 2

There are **20 amino acids** that are coded by **4power3 bases,** i.e. **64 different combinations** of **A, G, C, T(U).**

Therefore, there are **'spare' base codes.**

This is referred to as **degeneracy** or the **'degenerate code'.**

This code is **universal**, i.e. it is the **same** in **all living things.**

One **codon** acts as a **START** codon, marking the point on the **DNA** where **transcription** begins - this is **AUG** on the **mRNA** and codes for **methionine.**

Each gene found on the DNA will code for a **different polypeptide:** this is called the **one gene**, one **polypeptide hypothesis.**

Post-translational modification

Translation produces a **polypeptide**, but **further modification** is needed in order to **produce** a **protein** with a **secondary, tertiary or quaternary** structure.

Post-translational modification (cont)

This **modification** occurs within **the Golgi body.**

Modification also occurs to **produce molecules** such as **glycoproteins, lipoproteins, and complex quaternary structures** such as **haemoglobin.**

To form **haemoglobin**, **2 alpha chains** and **2 beta chains** (coded by 2 different genes) need to be assembled together with **iron** as a **prosthetic group.**

Protein Synthesis

Transcription occurs in the **nucleus.**

Translation occurs at the **ribosomes.**

Post-translational modification occurs in the **Golgi apparatus** prior to **packaging** of the **protein** into **vesicles.**

Transcription

DNA acts as a **template** for the **production** of **mRNA.**

DNA helicase acts on a **specific region** of the DNA molecule called the **cistron**, **breaking** the **hydrogen bonds** between both **DNA strands**, causing the strands to **separate** and **unwind**, exposing **nucleotide bases.**

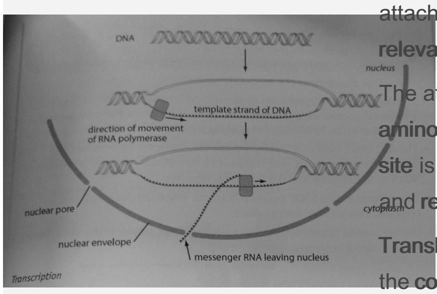
Transcription (cont)

Free RNA nucleotide pair to **exposed bases** on the **DNA template strand** and **RNA polymerase** joins them by **forming** the **phosphodiester bonds** between the **phosphate group** on one nucleotide and the **ribose sugar** on the next.

This continues until the **RNA polymerase** reaches a **STOP codon**, when the **RNA polymerase** detaches and **production** of **mRNA** is complete.

The **mRNA strand** leaves the **nucleus** via the **nuclear pores** and moves to the **ribosomes.**

Transcription diagram



Transcription

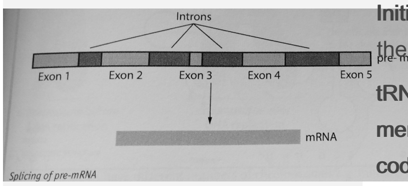
Introns and Exons

In **eukaryotes**, **introns** are present within **many genes** so are also **transcribed** producing **pre-mRNA.**

The **coding regions** are referred to as **exons.**

The **pre-mRNA** is **spliced** to remove the **non-coding regions** before passing to the **ribosomes.** In **prokaryotes**, the DNA does not contain **introns**, and so the **mRNA** is **produced** directly from the **DNA template.**

Splicing of pre-mRNA



Splicing of pre-mRNA

Translation

Involves another **specific RNA** molecule called **transfer RNA** (tRNA).

At one end of the **tRNA** molecule there are **3 exposed bases** called the **anticodon**, these are **complimentary** to the **mRNA codon.**

At the opposite end of the **tRNA** molecule is an **amino acid** attachment site where the **relevant amino acid** is found.

The attachment of the **relevant amino acid** to the **attachment site** is called **amino acid aviation** and **requires ATP.**

Translation involves **converting** the **codons** on the **mRNA** into a **sequence** of **amino acids** known as a **polypeptide.**

Each **ribosome** (found **free** in the **cytoplasm**, or attached to the **rough endoplasmic reticulum**) is made up of **2 subunits** made from **ribosomal RNA** and **protein.**

The **mRNA binds** to the **smaller subunit**, whilst **tRNA** to one of **2 attachment sites** on the **larger subunit.**

The process of translation

Initiation: **ribosome** attaches to the **START codon.**

tRNA molecule with a **complimentary anticodon** to the **first codon** to the **first codon**, binds to the **first attachment site** on the **ribosome.**

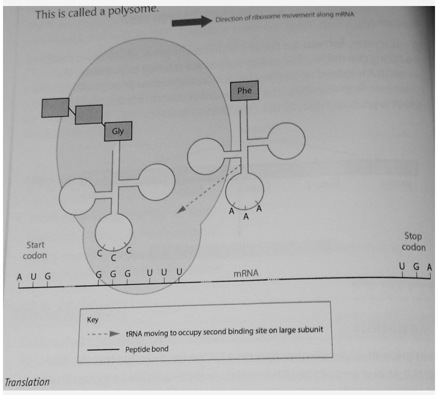
A **second tRNA** molecule joins to the **second attachment site**, and a **ribosomal enzyme catalyses** the **formation** of a **peptide bond** between the **2 amino acids.** This is known as **elongation.**

The **first tRNA** molecule is released and the **ribosome** now moves **one codon** along the **mRNA**, which exposes a **free attachment site** and another **tRNA molecule** joins and the **process** is **repeated.**

This **repeats** until a **STOP codon** is reached, when the **polypeptide** is **released.** This is called **termination.**

Usually **several ribosomes** bind to a **single mRNA** strand at the **same time.** This is called a **polysome.**

Translation Diagram



Translation