Biological Molecules (i)

- AQA Biology (Oxford): pp. 2–16, 46–49
- AQA Biology (Hodder Education): pp. 1–18, 64–65, 183–185, Inorganic ions: pp. 26, 57, 64, 161.

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THE BASICS

Monomers and Polymers

- **Monomers**: small molecules that form the basic units of polymers.
- **Polymers:** can be long, single strands or highly branched.
- Carbon forms the 'backbone' of many polymers because carbon atoms readily form bonds.
- Monomers undergo **polymerisation** to form polymers through a **condensation reaction** which releases a water molecule.
- Polymers split into shorter chains of monomers through a **hydrolysis reaction** which uses a water molecule.
- Polymers have storage and structural uses and form functional molecules such as protein and DNA.

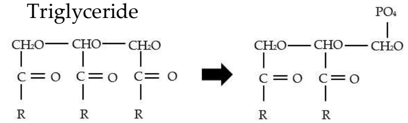
Lipids

Lipids are fats and oils, they:

- combine with phosphate to form **phospholipid cell membranes**
- provide an **energy** source when oxidised
- are **insoluble** and, therefore, used for waterproofing
- are slow heat conductors and, therefore, used for **insulation**
- form **protective** layers around delicate organs

Triglyceride

Phospholipid



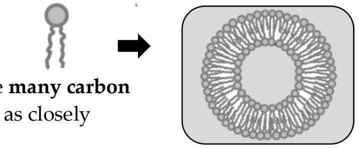
Emulsion Test

- Add ethanol, shake
- Add water, shake
- Turns cloudy if lipids are present

Triglycerides have a **hydrophilic glycerol** head and form an **ester bond** with three **hydrophobic fatty acid tails** (R groups). This means they form a **bilayer** around water.

Phospholipid

Phospholipid bilayer



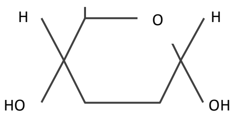
If the fatty acid tails have **no double bonds** between carbon atoms, they are **saturated**. If the fatty acid tails have **many carbon double bonds** they are **polyunsaturated**. The double bonds cause the tails to bend, so lipid molecules cannot fit as closely together. This means unsaturated membranes are more fluidic and remain liquid at lower temperatures.

Carbohydrates

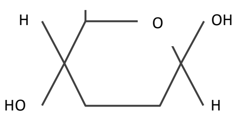
Carbohydrates are used to produce energy in respiration and as structural polymers in plant cell walls.

Monosaccharides are single sugars with the formula $(CH_2O)_n$, including glucose, fructose and galactose. Glucose has an alpha (α) and beta (β) isomer.

α-glucose

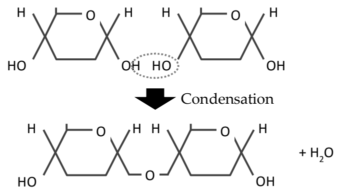


β-glucose



Exam Tip!
Remember, the second hydrogen in glucose is <u>a</u>bove in α, <u>b</u>elow in β

Two α-glucose molecules form a α1-4 **glycosidic bond** to create a **disaccharide**. Different monosaccharides can join to form different disaccharides.



Monosaccharide	Disaccharide
α-glucose + α-glucose	Maltose
Glucose + fructose	Sucrose
Glucose + galactose	Lactose

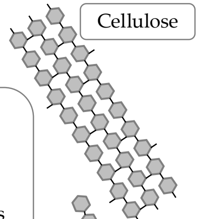
Multiple monosaccharides form a polysaccharide. Glucose polysaccharides include:

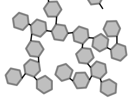
Glycogen
- Made from α-glucose
- Found in animals
- Highly branched
- Used for storage

Starch
- Made from α-glucose
- Found in plants
- Highly branched
- Used for storage

Cellulose
- Made from β-glucose
- Found in plants
- Parallel, long single chains
- Hydrogen bond cross-linkages
- Used for cell wall strength

Cellulose





Glycogen and starch

Potassium iodide is used to test for starch – if starch is present it turns blue-black in colour.

Benedict's reagent is heated with a solution – the solution stays blue if reducing sugars are not present, turns yellow with medium and red with high concentration of reducing sugars.

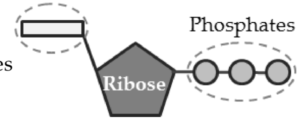
ATP

Adenosine triphosphate provides an **immediate** source of energy for cells. T**hree phosphate groups** are removed by **hydrolysis**, catalysed by the enzyme **ATP hydrolase**, producing progressively less energy.

ATP synthase then reconnects the inorganic phosphate ions (P_i) with **AMP** and **ADP** through **condensation** reactions. This process occurs during photosynthesis in plants (**photophosphorylation**) and during respiration in animals (**oxidative phosphorylation**).

Hydrolysis of ATP is used in:

- muscle contraction
- nerve cells
- active transport
- metabolic processes



Water

Water has many key roles, including:

- **metabolite** for condensation and hydrolysis reactions
- **solvent** for reactions between and transport of dissolved substances
- temperature buffer due to a **high heat capacity**
- cooling effect with little evaporative loss due to **large latent heat of vaporisation**
- used for **transport** in plants due to strong **cohesion** between water molecules.

Inorganic Ions

Inorganic ions have a positive or negative **charge** and are often found in the cytoplasm of cells.

They perform crucial roles in metabolic reactions and within structures.

Ion	Role
Iron ion	Within haemoglobin
Phosphate ion	Within DNA and ATP
Hydrogen ion	Determining pH
Sodium ion	Stimulating co-transport of amino acids and glucose

Word cloud

Polymerisation, *Triglyceride*, *Hydrolysis*, *Phospholipid*, *Condensation*, *Ester bond*, *Saccharide*, *Hydrophilic*, *Metabolite*, *Hydrophobic*, *Glycosidic bond*, *Polyunsaturated*, *Heat of vaporisation*, *ATP hydrolase*, *Phosphorylation*, *ATP synthase*, *Heat capacity*, *Solvent*, *Adenosine triphosphate*

Biological Molecules (ii)

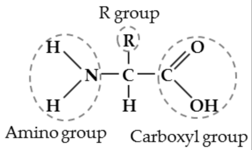
- AQA Biology (Oxford): pp. 19–33
- AQA Biology (Hodder Education): pp.10–33,148 (Chromatography)

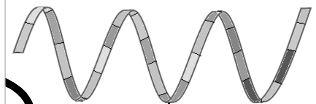
Proteins and Enzymes

- **Amino acids** are nitrogen-containing monomers.
- There are about 20 amino acids, each with a different **R group**.
- Amino acids polymerise by condensation reactions to form **proteins**.
- The bond that links them is called a **peptide bond**, the polymer is a **polypeptide**.
- Proteins fold to form a **specific shape**, their shape allows them to carry out specific roles in the body.

Protein Structure

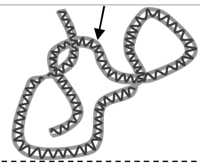
Primary Structure:
The carboxyl and amino groups of amino acids join to form a sequence of amino acids.

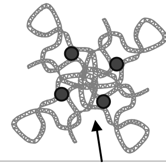




Secondary Structure:
Weak **hydrogen bonds** between the hydrogen (amino group) and oxygen (carboxyl group) cause the polypeptide to form an **α-helix.**

Tertiary Structure:
Ionic bonds and strong **disulphide bridges** cause the helix to fold. The bonds give the protein a specific three-dimensional shape.





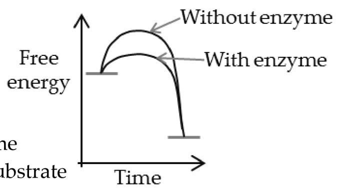
Quaternary Structure:
Formed of many different proteins and non-protein (prosthetic) substances. For example, haemoglobin has four proteins and four iron ions.

Fibrous proteins are long, unbranched, and tightly wound together. They have structural functions, such as **collagen** in muscles.

Globular proteins are smaller and can be easily secreted from a cell. They have metabolic functions, such as **enzymes** and **hormones**.

Enzymes as Catalysts

Enzymes are proteins that **catalyse** chemical reactions by lowering the **activation energy**.

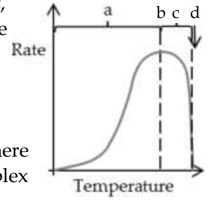


The part of the enzyme that binds with the substrate is the **active site**. They bind to form an **enzyme-substrate complex**.

Induced-fit model of enzyme action: the active site changes shape to better fit the substrate, which causes the change in the substrate that lowers the activation energy.

Temperature

As temperature increases during *a*, **kinetic energy** increases. There are more encounters between molecules so more enzyme-substrate complexes are formed.



b is the **optimum temperature**, where the rate of enzyme-substrate complex formation is maximal.

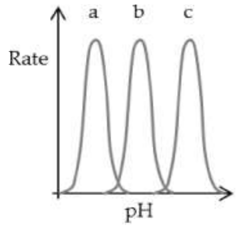
At *c* enzymes start to **denature**, the active site changes shape and is no longer **complementary**.

At *d* all enzymes are denatured.

pH

Changes in pH break the bonds within an enzyme, causing it to become **denatured**, so the active site changes and is no longer **complementary**.

Different enzymes have different **optimum** pH levels and, therefore, work best in different areas of the body.



Chromatography

- We can identify amino acids based on their Rf value.
- The calculation involves dividing the distance travelled by the dissolved amino acid over the distance travelled by the solvent.

Biuret Test

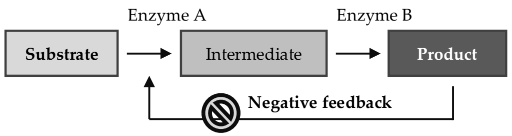
- Add equal amount of sodium hydroxide solution to sample.
- Add few drops dilute copper(II) sulfate and mix.
- Turns from blue to purple if proteins are present.

Inhibition and Negative Feedback

Competitive inhibitors bind to an enzyme's active site and block access for the substrate.

Non-competitive inhibitors bind at a different location on the enzyme and alter the structure, therefore altering the shape of the active site.

Negative feedback or End product inhibition is caused when the final product of an enzyme-driven metabolic pathway inhibits the action of one of the previous enzymes. This stops too much product being produced.



Exam Tip!
The active site is **induced** to change by the substrate, but denaturing **disrupts** the shape.

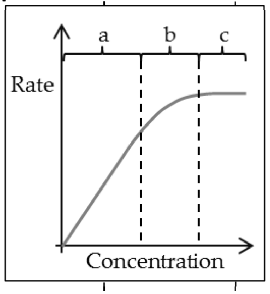
Effects of different conditions on enzyme action

Enzyme concentration

As enzyme concentration increases during *a*, **excess substrate** is increasingly forming enzyme-substrate complexes.

During *b* almost all the substrate is occupying an enzyme's active site.

During *c*, the addition of more enzymes has **no effect** as all the substrate is being catalysed, so the rate of reaction cannot increase.



Substrate concentration

As substrate concentration increases during *a*, substrate is occupying more of the available active sites.

During *b* almost all the enzymes' active sites are occupied by substrate.

During *c*, the addition of more substrate has **no effect** as all the available enzymes' active sites are occupied, so the rate of reaction cannot increase.

Word cloud

Amino acid
Globular
Peptide bond
Enzyme
Protein
Catalyst
Optimum
Activation energy
R group
Enzyme-substrate complex
Polypeptide
Induced-fit model
Hydrogen bond
Kinetic energy
α-helix
Denatured
Ionic bond
Inhibitors
Disulphide bridge
Negative feedback
Fibrous
Chromatography

Biological Molecules (iii)

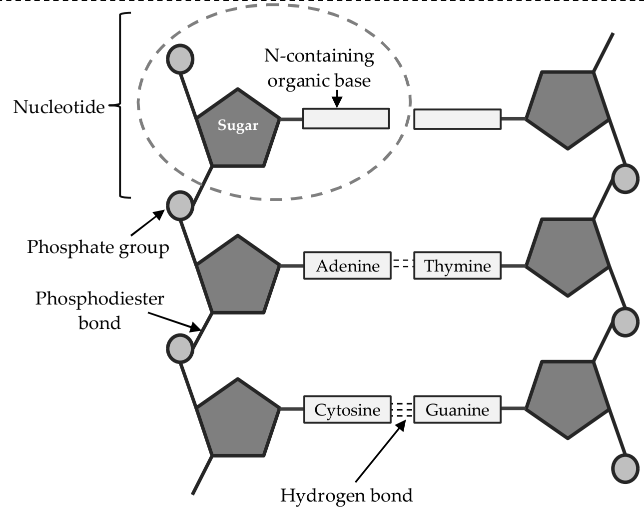
- AQA Biology (Oxford): pp. 36–45
- AQA Biology (Hodder Education): pp.1–18, 64– 65, 183–185, Inorganic ions: pp. 26, 57, 64, 161.

THE BASICS

DNA, DNA Replication and RNA

- **DNA**, **deoxyribonucleic acid**, contains genetic information that determines how life grows, develops, and functions.
- DNA: **double stranded,** forms a coiled **double helix**, and is coiled into **chromosomes** within the cell's **nucleus**.
- **RNA**, **ribonucleic acid**, transfers the genetic information to **ribosomes** to make proteins.
- DNA and RNA are **polynucleotides**. Condensation reactions form **phosphodiester bonds** between nucleotides.

DNA Structure



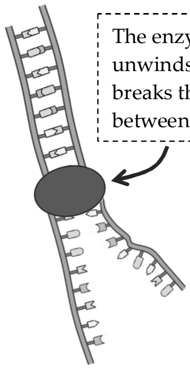
DNA contains a **deoxyribose sugar**, four **complementary bases** and a **sugar-phosphate backbone**. The two strands are **antiparallel**, i.e. they run the opposite way.

Its main purposes are to code for **protein synthesis**, regulate **cell functions** and cell division and to allow genetic information to be **inherited** by the next generation.

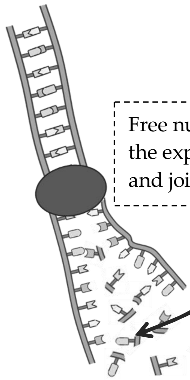
DNA has the following adaptations for its roles:

- The sugar-phosphate backbone makes the molecule **very stable** and protects from chemicals that would interfere with the DNA.
- Two **weak hydrogen bonds** between adenine and thymine, and three between guanine and cytosine, allow strands to **separate easily for replication** and protein synthesis.
- DNA strands can be very long and **tightly coiled** to fit a lot of genetic information into a small space.

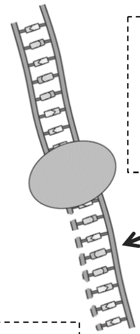
DNA Replication



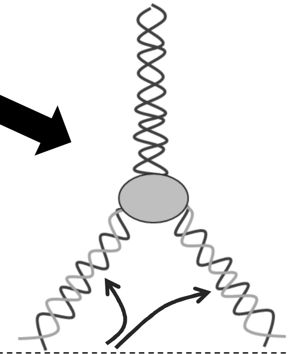
The enzyme **DNA helicase** unwinds the double helix and breaks the hydrogen bonds between strands.



Free nucleotides are attracted to the exposed complementary bases and join with hydrogen bonds.



The enzyme **DNA polymerase** initiates condensation reactions to create phosphodiester bonds and join the sugar-phosphate backbones together on both new strands.



Half of the original DNA is now part of each new DNA fragment. This process is called **semi-conservative replication**. This process ensures that new DNA is accurate and the genetic code can be preserved through generations of cells.

This theory was proposed by Watson, Crick and Franklin, and replaced the conservative model of DNA replication.

RNA Structure

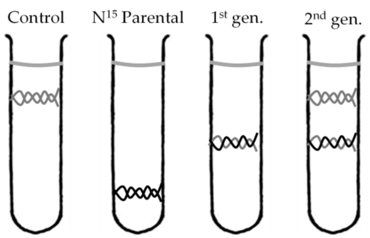
There are a few key differences between DNA and RNA.

DNA	RNA
• Deoxyribose sugar	• **Ribose** sugar
• Thymine	• **Uracil**
• Long, double stranded helix	• Short, single chain
• Contains genetic information	• Transfers information in protein synthesis
	• A structural component of ribosomes

Meselsohn and Stahl

These two scientists designed an experiment to test the semi-conservative model of DNA replication.

They grew bacteria in two Petri dishes, one containing **N^{14}**, the other containing the **heavier isotope N^{15}**. They continued to grow these colonies on N^{14} media, and **extracted and centrifuged the DNA** after each generational stage.



The **N^{15} parental** generation had the **heaviest DNA**.

The **first generation** of N^{15} bacteria grown on N^{14} media had an **intermediate** band, because half of their strands had heavy DNA and half had light DNA.

The **second generation** had a **lighter** band and an **intermediate** band because the new N^{14} strands from the first generation had paired with N^{14} bases from the media to form entirely light DNA.

If the conservative model were correct there would be an original heavy band and new bands would be light.

Word cloud

Generation
Ribonucleic acid
Deoxyribonucleic acid
Ribosomes
Nitrogenous bases
Cytosine
Complementary
Thymine
Isotope
Hydrogen bond
Guanine
Uracil
Phosphodiester bond
DNA polymerase
Antiparallel
DNA helicase
Sugar-phosphate backbone
Adenine
Semi-conservative replication