Edexcel GCSE Chemistry

Your notes

Polymers

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Your notes

Polymers

- Polymers are large molecules of **high relative molecular mass** and are made by linking together large numbers of smaller molecules called **monomers**
- Each monomer is a **repeat unit** and is connected to the adjacent units via **covalent bonds**
- Polymerisation reactions usually require **high pressures** and the use of a **catalyst**
- Many everyday materials such as **resins, plastics, polystyrene** cups, **nylon** etc. are polymers
- These are manufactured and are called **synthetic** polymers
- Nature also produces polymers which are called **natural** or **biological** polymers

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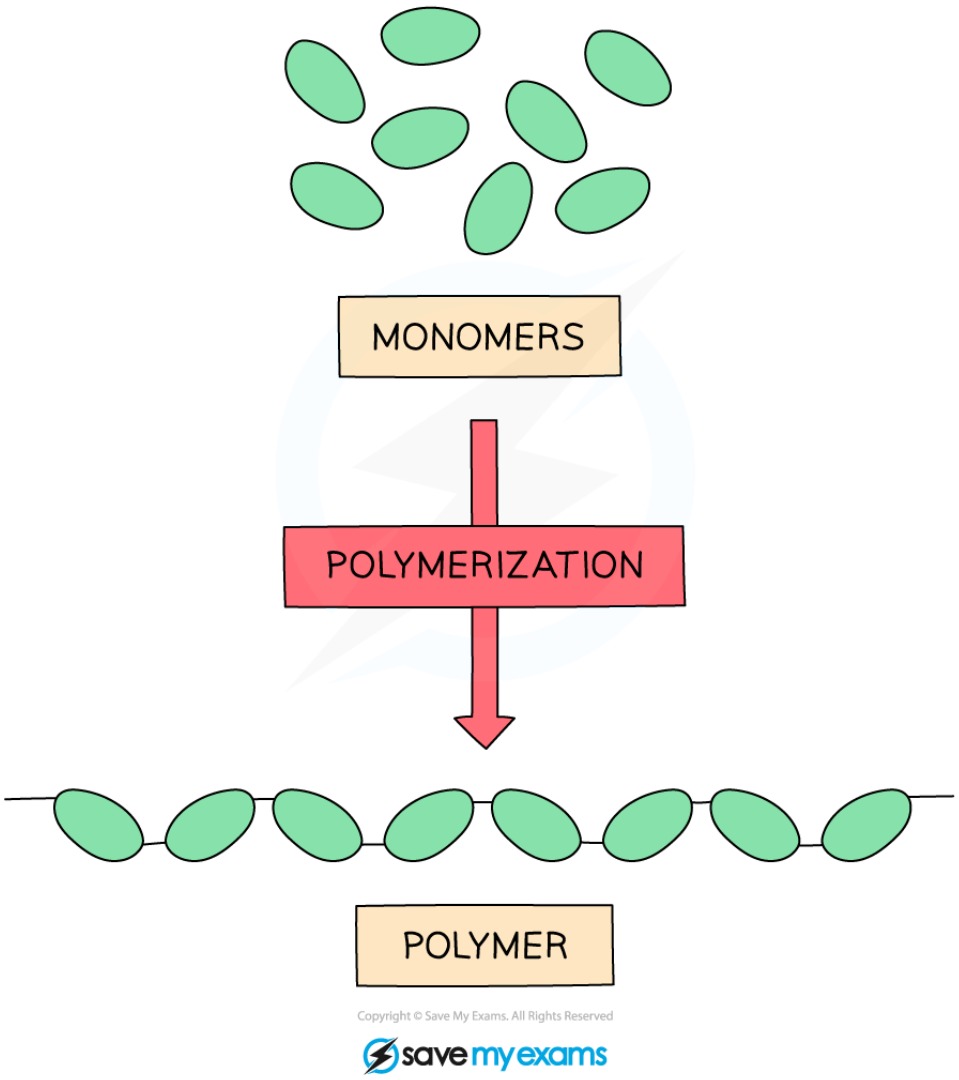


Diagram showing how lots of monomers bond together to form a polymer

Examiner Tips and Tricks

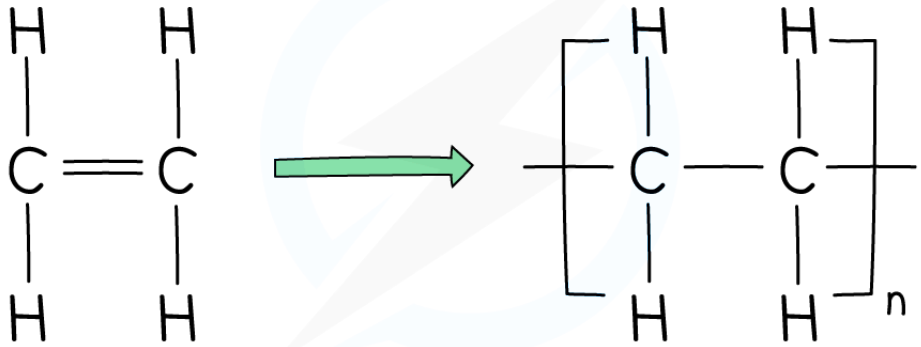
Polymers are made from smaller units called monomers that link together to form a long polymer chain.

Addition Polymers

Your notes

Formation of Polythene

- Addition polymers are formed by the joining up of many monomers and only occurs in monomers that contain C=C bonds
- **One** of the bonds in each C=C bond breaks and forms a bond with the adjacent monomer with the polymer being formed containing **single bonds** only
- Many polymers can be made by the addition of alkene monomers
- Poly(ethene) is formed by the addition polymerisation of **ethene monomers** and is most commonly called polythene

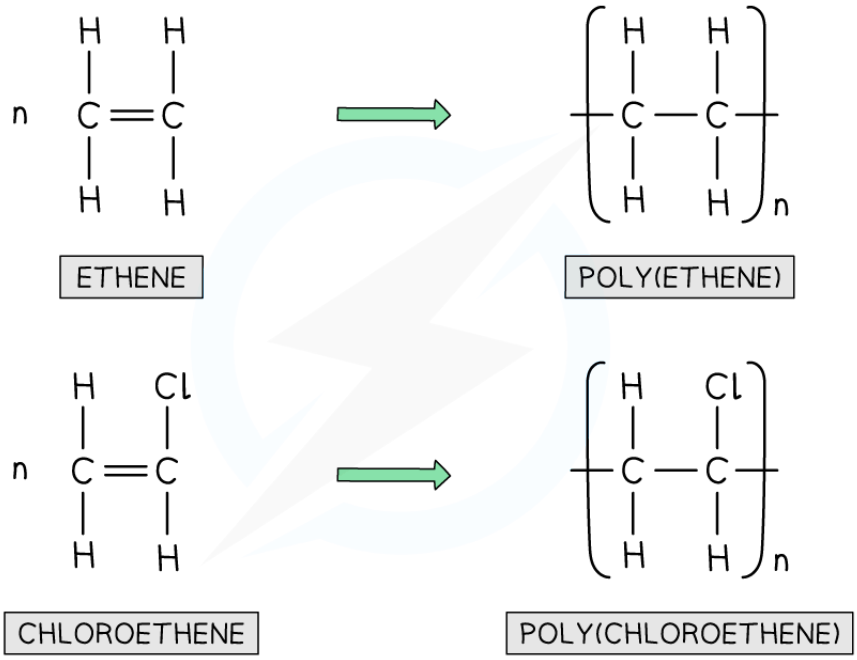


Ethene monomers join up to form poly(ethene)

Other Addition Polymers

- Other addition polymers are made from alkene monomers with different atoms attached to the **monomer** such as chlorine, fluorine or a methyl group
- The name of the polymer is deduced by putting the name of the monomer in brackets and adding poly- as the **prefix**

- For example if propene is the alkene monomer used, then the name is **poly(propene)**



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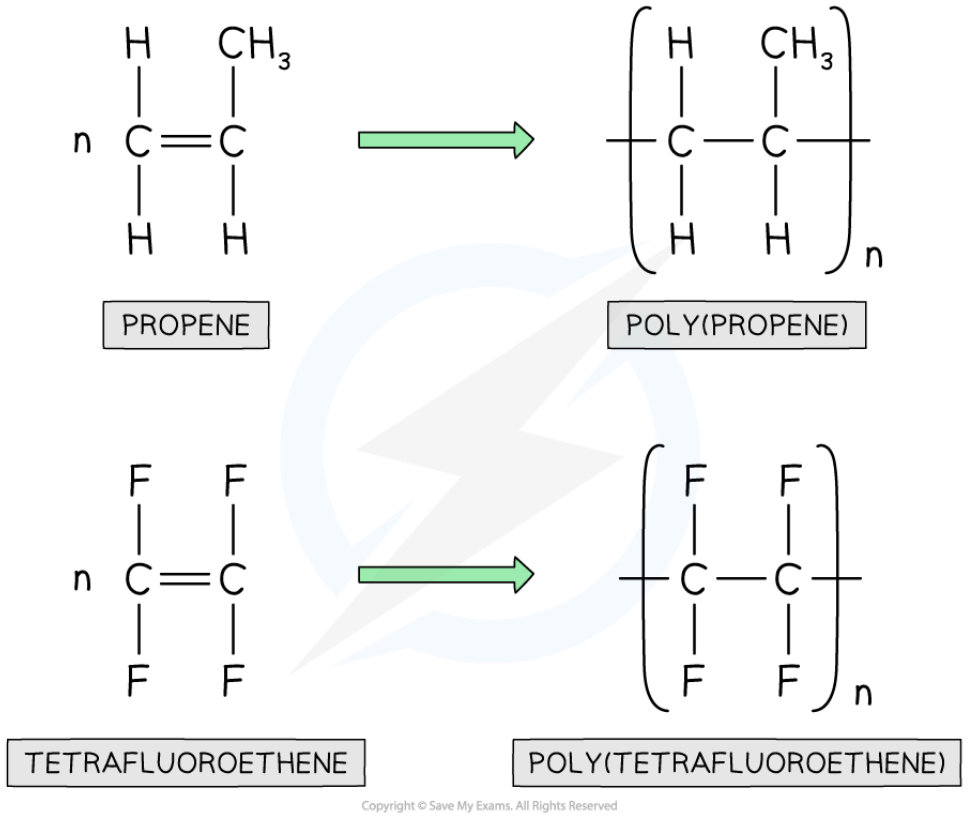

Further examples of addition polymerisation: poly(chloroethene)(PVC), poly(propene) and poly(tetrafluorethene)(PTFE)

Deducing Structures

Deducing the polymer from the monomer

- Polymer molecules are very large compared with most other molecule
- **Repeat units** are used when displaying the formula
- To draw a repeat unit, change the double bond in the monomer to a **single bond** in the repeat unit
- Add a bond to each end of the repeat unit
- The bonds on either side of the polymer must **extend** outside the brackets (these are called extension or continuation bonds)
- A small **subscript** n is written on the bottom right hand side to indicate a large number of repeat units
- Add on the rest of the groups in the **same order** that they surrounded the double bond in the monomer

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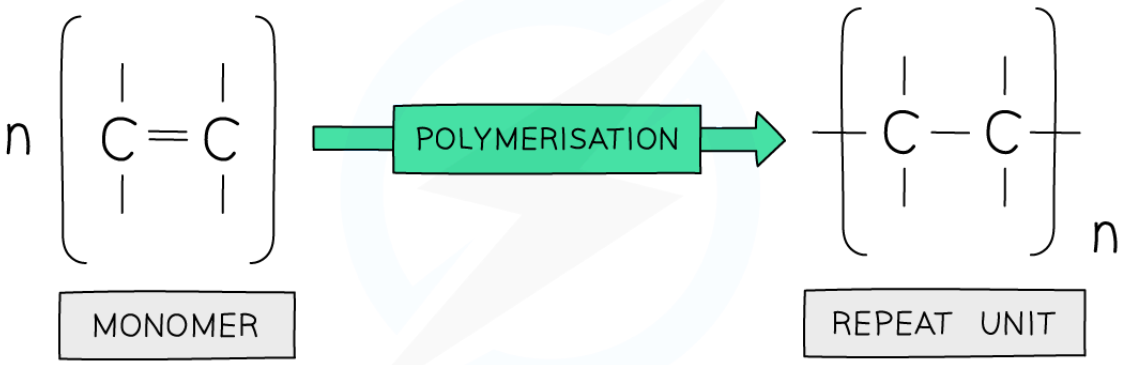

Diagram showing the concept of drawing a repeat unit of a monomer

Deducing the monomer from the polymer

- Identify the repeating unit in the polymer
- Change the single bond in the repeat unit to a **double bond** in the monomer
- Remove the bond from each end of the repeat unit and the subscript **n** (which can be placed in front of the monomer)

Diagram showing the monomer of the repeat unit of polymer

Uses of Polymers

Your notes

- Addition polymers can be engineered to have distinctive properties depending on their intended use
- This is done by the selection of the monomer
- Four common polymers are listed with their properties and uses

Uses of Common Polymers Table

Polymer	Properties	Use
Polythene	Flexible, cheap and electrically insulating	◦ Plastic Bags (low density polythene) ◦ Plastic Bottles (high density polythene)
Polypropene	Flexible and strong	◦ Food Packaging ◦ Ropes ◦ Carpets
PVC	Long-lasting, tough and cheap	◦ Plastic Sheets ◦ Artificial Leather ◦ Drainpipes and Gutters ◦ Insulation on Wires
PTFE	Very tough, non-stick and resistant to high temperatures	◦ Cookware (non stick pans) ◦ Pipework

Condensation Polymers

Your notes

Condensation Polymers

- Condensation polymers are formed when **two different monomers** are linked together with the **removal** of a small molecule, usually **water**
- This is a key difference between condensation polymers and addition polymers:
  - Addition polymerisation forms the polymer molecule **only**
  - Condensation polymerisation forms the **polymer** molecule and one **water** molecule **per linkage**
- The monomers have two **functional** groups present, one on **each end**
- The functional groups at the ends of one monomer react with the functional group on the end of the other monomer, in so doing creating long chains of **alternating monomers**, forming the polymer
- Polyesters are formed from two different monomers and produce water
- For every ester linkage formed in condensation polymerisation, one molecule of water is formed from the combination of a -H and an -OH group
- An example is terylene which is a **polyester** made from **dicarboxylic** acid monomers (a carboxylic with a -COOH group at **either** end) and **diols** (an alcohol with an -OH group at **either** end)
- Each -COOH group reacts with another -OH group on another monomer
- An ester linkage is formed with the subsequent loss of **one** water molecule per link

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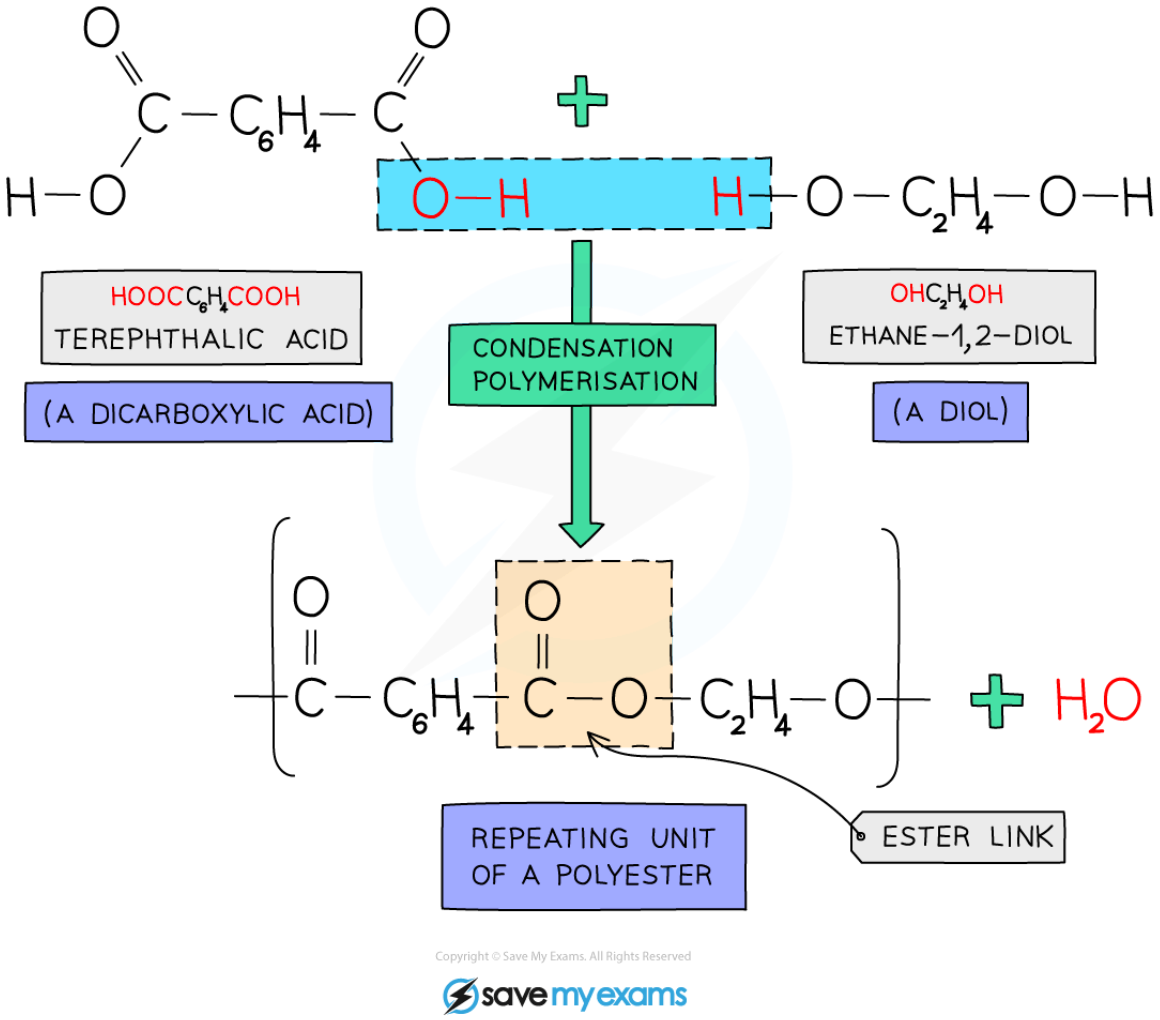

The condensation reaction in which the polyester terylene is produced

- The structure of terylene can be represented by drawing out the polymer using boxes to represent the carbon chains
- This can be done for all polyesters

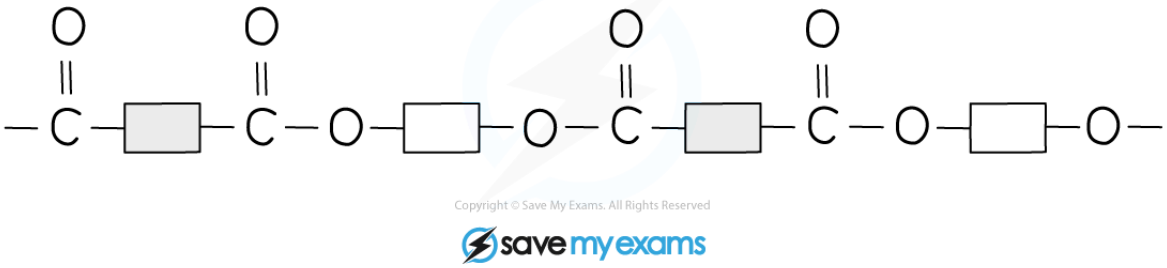

Diagram showing a section of the polyester terylene

Examiner Tips and Tricks

Notice that the sequence of bonding in the polyester is the mirror image at either end of the link, NOT the link repetition due to the monomers containing the same functional group at either end.

Your notes

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Problems with Polymers

- Polymers are formed by the joining up of many small molecules with strong covalent bonds
- This makes polymers unreactive and chemically **inert** so they don't easily biodegrade

Disposal of polymers is an environmental problem

Landfills

- Waste polymers are disposed of in landfill sites but this takes up valuable land, as polymers are non-biodegradable so micro-organisms such as decomposers cannot break them down
- This causes sites to quickly fill up

Incineration

- Polymers release a lot of heat energy when they burn and produces carbon dioxide which is a greenhouse gas that contributes to climate change
- Polymers that contain chlorine such as PVC release toxic hydrogen chloride gas when burned
- If incinerated by incomplete combustion, carbon monoxide will be produced which is a toxic gas

Recycling

- Polymers can be recycled but different polymers must be separated from each other
- This process is difficult and expensive

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Recycling Polymers

Advantages

- Recycling is a more **economically viable** process than manufacturing from scratch
- It decreases the use of crude oil which allows it to be kept for other purposes
- It is better for the **environment** as plastic waste is being collected and reused, hence recycling reduces the emissions of greenhouse gases and other toxic gases produced during the manufacturing process
- It also reduces the amount of **landfill sites** needed
- Recycling is itself an entire industry which creates **employment** and economic growth

Disadvantages

- Sorting plastics by type of polymer is a tedious and **labour intensive** process which is costly
- Recycling counts on what is collected in as the raw material, therefore production of certain types of polymers may not be possible due to a lack of **starting ingredients**
- Melting polymers produces **toxic gases** that are harmful to plants and animals
- Polymers can only be recycled a number of times before they lose their properties and become useless
- Recycling runs the risk of mixing different polymers together, which again will affect their properties. This is particularly risky for polymers designed for **specialist** use such as aircraft or automobile parts, where **safety** is of utmost importance

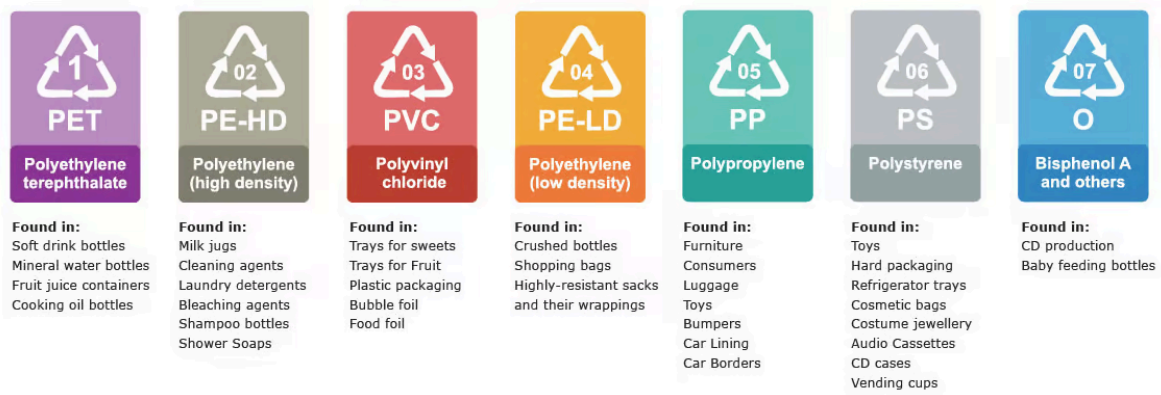

Diagram showing the categories into which they must be sorted before recycling

Your notes

Examiner Tips and Tricks

You should be able to evaluate the pros and cons of recycling polymers, given appropriate information.


Your notes

Natural Polymers

DNA

- Deoxyribonucleic acid (DNA) is a large molecule which is essential to all life
- It contains **genetic information** which it encodes as instructions which organisms need to develop and function correctly
- DNA consists of four different monomers called **nucleotides** which contain small molecules called **bases** and which are abbreviated to A, T, C, and G which are bound together by polymerisation
- The nucleotides form two strands that **intertwine**, giving the famous **double helix** shape of DNA
- The bases on either polymer chain pair up in **specific sequences** forming cross links that hold the strands together, giving rise to the double helix shape
- It is a complex molecule that contains **genetic information** which is stored in the order in which the bases organise themselves, which is a code for the organisms gene

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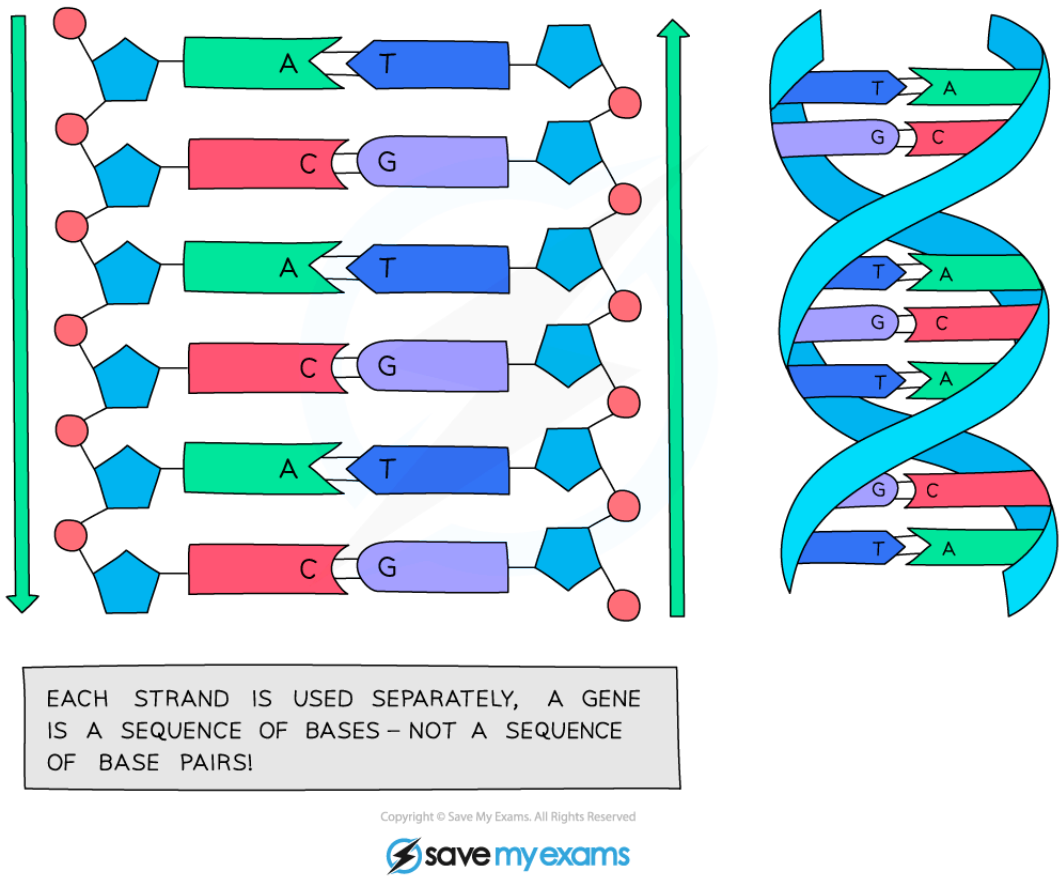

Diagram showing the complex double helix structure of DNA

Starch

- Carbohydrates are compounds of **carbon, hydrogen** and **oxygen** with the general formula $C_x(H_2O)_y$
- There are **simple** carbohydrates and **complex** carbohydrates
- Simple carbohydrates are called **monosaccharides** and are **sugars** such as fructose and glucose
- Complex carbohydrates are called **polysaccharides** such as **starch**
- The monomers from which starch is made are sugars
- Starch is used to store energy
- Complex carbohydrates are condensation polymers formed from simple sugar monomers and, unlike proteins, are usually made up of the same monomers

- An H_2O molecule is eliminated when simple sugars polymerise
  - The linkage formed is an -O- linkage and is called a **glycosidic** linkage

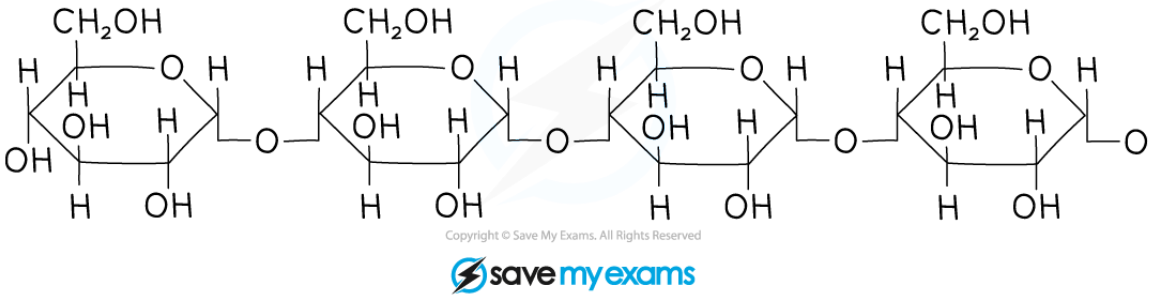

Diagram of the starch amylose showing glycosidic linkages (-O-) which bind the monomers together, Amylose makes up approximately 20-30% of starch

Proteins

- Proteins are **condensation polymers** which are formed from amino acid monomers joined together by peptide bonds
- Amino acids are small molecules containing amine ($-NH_2$) and carboxylic acid (-COOH) functional groups

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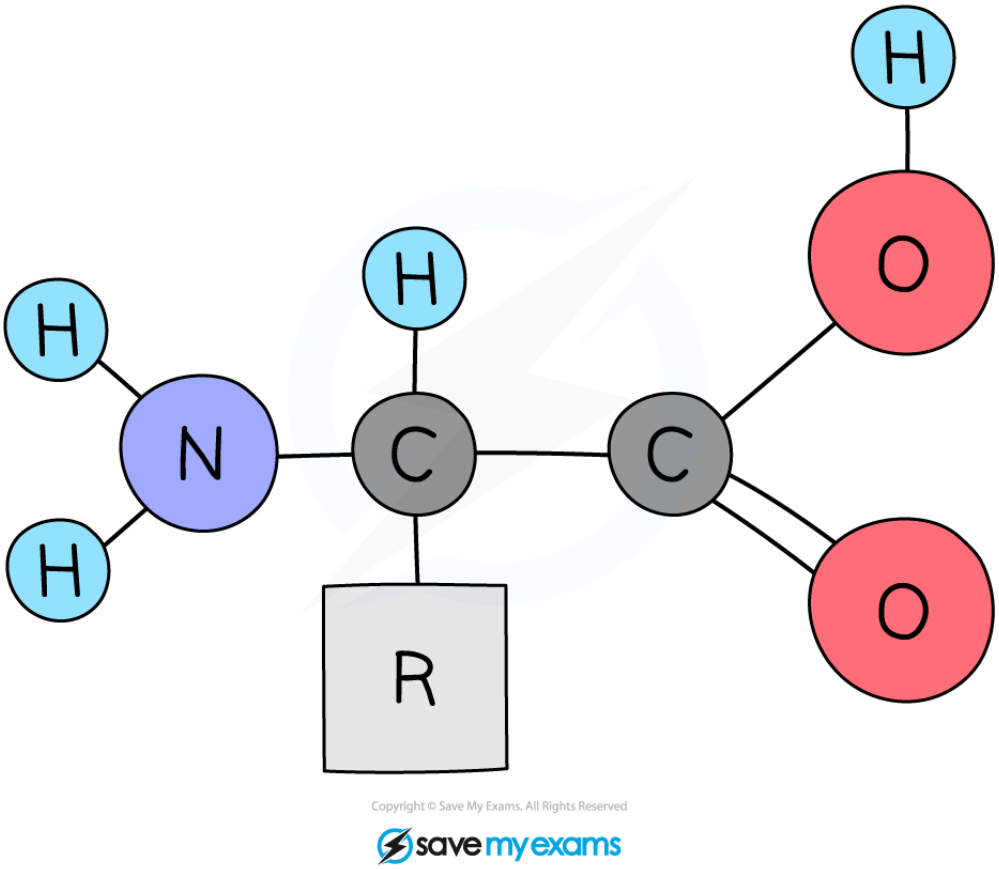

The structure of naturally occurring amino acids have an amino group on the second carbon along from the carboxyl group. The R represents a varying side group.

- A peptide link is formed when a **carboxylic acid** and an **amine** react:

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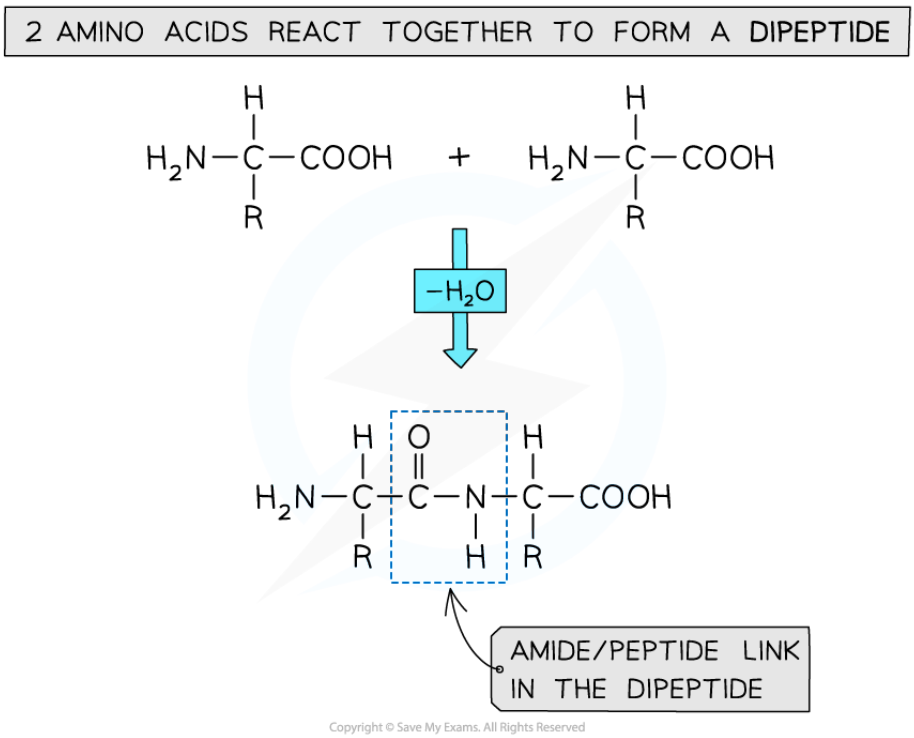

Amino acids join together to form dipeptides and long chains of amino acids which are the polymers that make up proteins

- Proteins are important natural polymers with specific biological functions
- Some examples of proteins and their functions include:
  - **Haemoglobin** which transports oxygen in the blood
  - **Antibodies** in the immune system help protect the body from viruses and bacteria
  - **Enzymes** which are biological catalysts