CAIE Biology A-level

Topic 2: Biological Molecules

Notes

Biochemical Tests

Test for	Reagent used	Steps	Observation
Reducing sugars (all monosaccharides and some disaccharides)	Benedict's solution	Heat the unknown solution with a few drops of Benedict's solution in a water bath	**Positive observation:** - colour change from blue to brick red - reducing sugar is present **Negative observation:** - no colour change - reducing sugar is absent (a non-reducing sugar may be present)
Non-reducing sugars (e.g. sucrose) using acid hydrolysis	Dilute HCl, sodium hydrogen carbonate and Benedict's solution	1. Add dilute HCl to the test solution and heat in a water bath 2. Neutralise with sodium hydrogencarbonate 3. Heat with Benedict's solution	**Positive observation:** - colour change from blue to brick red - non-reducing sugar is present
Starch	Iodine	Add a few drops of iodine solution to the test sample on a spotting tile	**Positive observation:** - colour change to blue/black - starch is present
Lipids using emulsion test	Ethanol	1. Add a few drops of ethanol to sample and shake 2. Add a few drops of distilled water and mix	**Positive observation:** - milky white emulsion forms - lipids are present
Protein using the Biuret test	Sodium hydroxide solution and copper (II) sulfate solution	1. Add a few drops of sodium hydroxide solution and mix 2. Add a few drops of copper (II) sulfate solution and mix	**Positive observation:** - colour changes from blue to purple - proteins are present

Estimating the **concentration of reducing sugars** using a **semi-quantitative Benedict's test**	**Colorimeter** and **Benedict's solution**	1. Do Benedict's test 2. Calibrate colorimeter with distilled water as a control 3. Remove precipitates from each test tube by using a centrifuge (or let it settle for 24 hours) 4. Measure the absorbance using a colorimeter 5. Create a calibration curve of concentration of glucose vs absorbance (this can be used to find glucose concentrations of different unknowns)	

Carbohydrates

Carbohydrates are molecules which consist only of carbon, hydrogen and oxygen and they are long chains of sugar units called saccharides. There are three types of saccharides - **monosaccharides, disaccharides** and **polysaccharides**. Monosaccharides are the **monomers** (single units) that can join together to form the **polymers** such as disaccharides and polysaccharides by **glycosidic bonds** which are formed in **condensation reactions**.

Key definitions

Monomers - single units

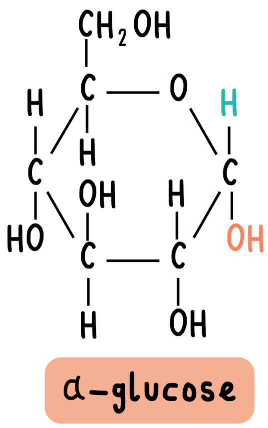
Polymers - many units joined together

Macromolecule - a very large molecule

Monosaccharides

Monosaccharides are small organic molecules used as building blocks of complex carbohydrates. Monosaccharides have a varying number of carbon atoms, for instance:

- **Ribose** is a pentose sugar which is a component of the nucleic acid RNA.
- **Glucose** is a monosaccharide containing six carbon atoms in each molecule, it is the main **substrate for respiration** therefore it is of great importance. It has two **isomers** – alpha and beta glucose.
    - **α-glucose** and **β-glucose** differ in the orientation of the hydroxyl (-OH) group on carbon-1.



Disaccharides:

Disaccharides are formed in a condensation reaction between two monosaccharides, joined by a glycosidic bond.

- **Maltose** is a disaccharide formed by condensation of **two glucose molecules**
- **Sucrose** is a disaccharide formed by condensation of **glucose & fructose**
- **Lactose** is a disaccharide formed by condensation of **glucose & galactose**

Glucose, fructose and maltose are **reducing sugars**, whereas sucrose is a **non-reducing sugar.** Glycosidic bonds in disaccharides and polysaccharides are broken by hydrolysis (e.g. using dilute acid in biochemical tests).

Polysaccharides:

Polysaccharides are formed from many monosaccharides joined together by glycosidic bonds and include:

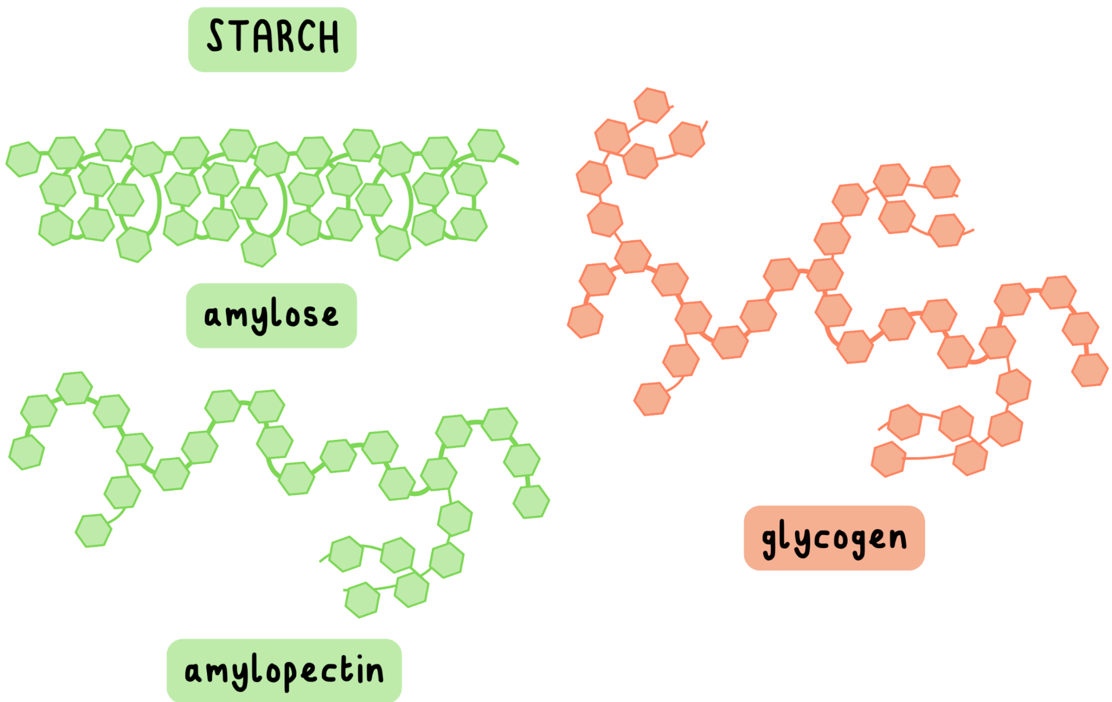
- Glycogen and starch which are both formed by the condensation of alpha glucose
- Cellulose formed by the condensation of beta glucose

Glycogen is the main energy storage molecule in animals and it is formed from many molecules of alpha glucose joined together by 1,4 and 1,6 glycosidic bonds. It has a large number of side branches meaning that energy can be released quickly. Moreover, it is a relatively large but compact molecule thus maximising the amount of energy it can store.

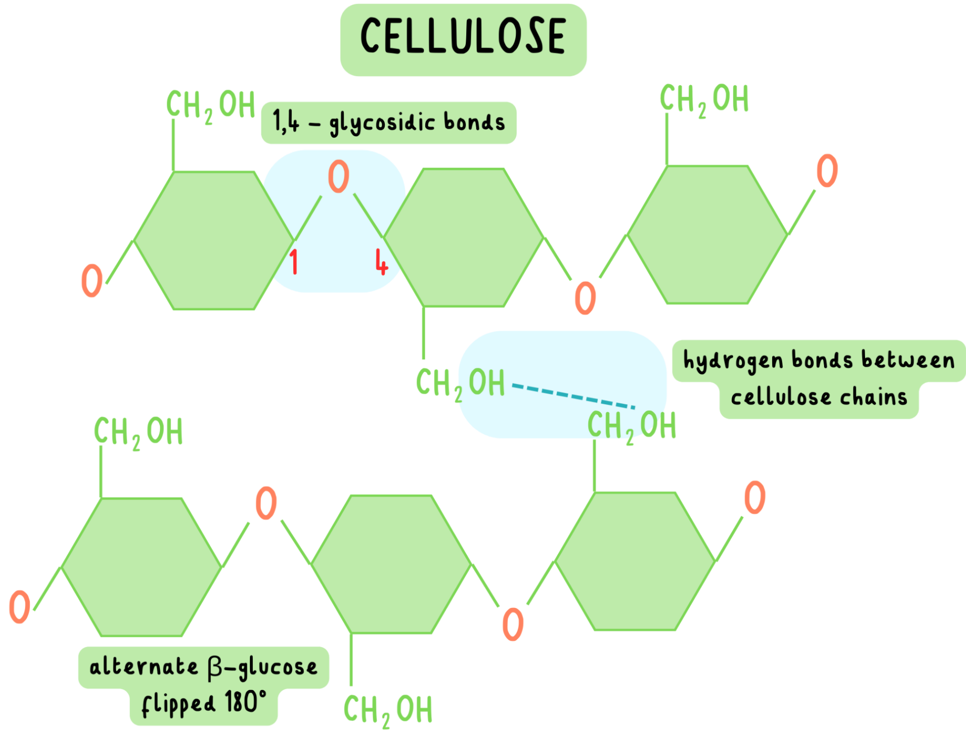
Starch stores energy in plants and it is a mixture of two polysaccharides called amylose and amylopectin:

- Amylose – amylose is an unbranched chain of glucose molecules joined by 1,4 glycosidic bonds. As a result, amylose is coiled and thus it is a very compact molecule meaning it can store a lot of energy in a small space.

- Amylopectin is branched and is made up of glucose molecules joined by 1,4 and 1,6 glycosidic bonds. Due to the presence of many side branches, it is rapidly digested by enzymes therefore energy is released quickly.



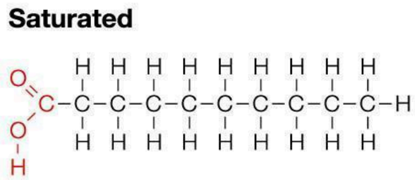
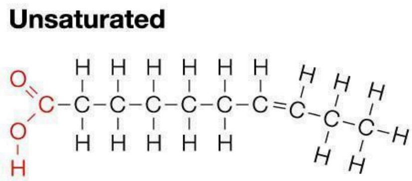
Cellulose is a component of the cell walls in plants and it is composed of long, unbranched chains of **beta glucose** which are joined by **1,4 glycosidic bonds**. Each alternate beta glucose monomer is flipped 180°. **Microfibrils** are strong threads which are made of the long cellulose chains held together by numerous **hydrogen bonds**. The **arrangement** of cellulose molecules (forming microfibrils) contributes to the **high tensile strength** of plant cell walls.



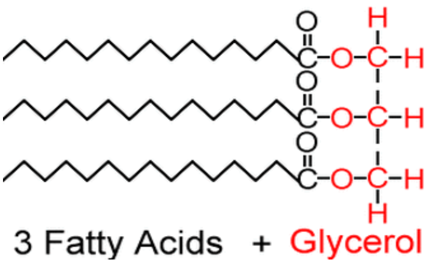
Lipids

Lipids are insoluble in **water** but soluble in **organic solvents** such as alcohols.

There are two types of lipids:

Types of lipids	Saturated lipids	Unsaturated lipids
Structure		
Description	**Saturated lipids** such as those found in **animal fats** – saturated lipids don't contain any carbon-carbon double bonds. Too much saturated fat can increase the cholesterol levels in blood thus increasing the risk of coronary heart disease.	**Unsaturated lipids** which can be found in **plants** – unsaturated lipids contain carbon-carbon **double bonds** and melt at lower temperatures than saturated fats. Unsaturated fats are healthy as they provide essential fatty acids.

The greater the number of unsaturated bonds, the weaker the intermolecular bonds resulting in lower melting point. Hence, saturated fats which don't contain any double bonds are solid at room temperature and unsaturated lipids are liquid at room temperature.

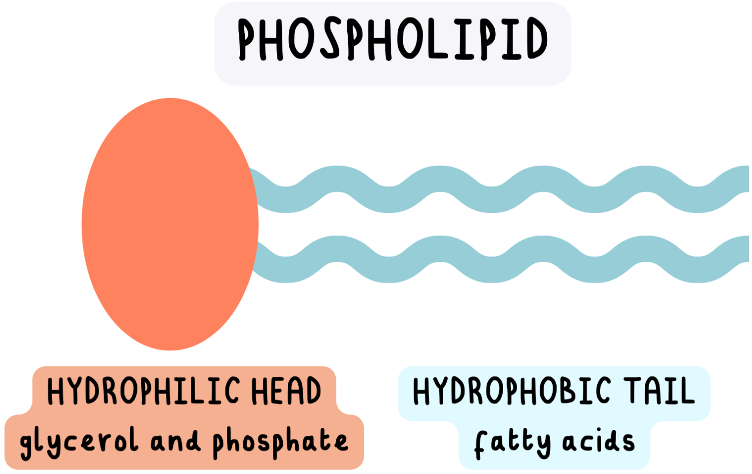


Triglycerides are non-polar and hydrophobic molecules. They are lipids composed of one molecule of **glycerol** and **three fatty acids** joined by ester bonds formed in **condensation reactions**. There are many different types of fatty acids, they vary in chain length, presence and number of double bonds. Also, some triglycerides contain a mix of different fatty acids.

Triglycerides have many uses in plant and animal cells such as:

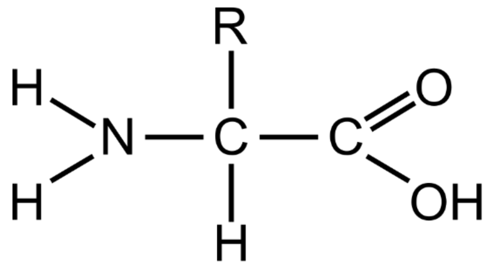
- Long-term energy store
- Insulators of heat
- Protect vital organs by acting as shock absorbers
- Aids buoyancy and waterproofing for aquatic animals due to hydrophobic nature

In **phospholipids**, one of the fatty acids of a triglyceride is substituted by a phosphate-containing group. Phosphate heads are **hydrophilic** and the tails are **hydrophobic** and as a result phospholipids form **micelles** when they are in contact with water as heads are on the outside as they are attracted to water and tails are on the inside as they move away from water. The hydrophobic/hydrophilic nature of phospholipids is what makes cell membranes selectively permeable.



Proteins

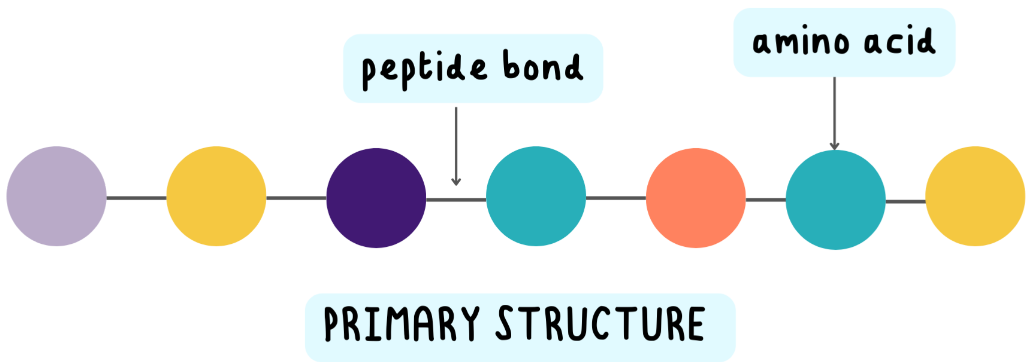
Amino acids are the monomers from which proteins are made. Amino acids contain an amine group (– NH_2), carboxyl group (-COOH) and a variable R group which is a carbon-containing chain. There are 20 different amino acids with different R groups. The general structure of an amino acid is:



Amino acids are joined by **peptide bonds** formed in condensation reactions, and are broken in hydrolysis. A **dipeptide** contains two amino acids and polypeptides contain three or more amino acids.

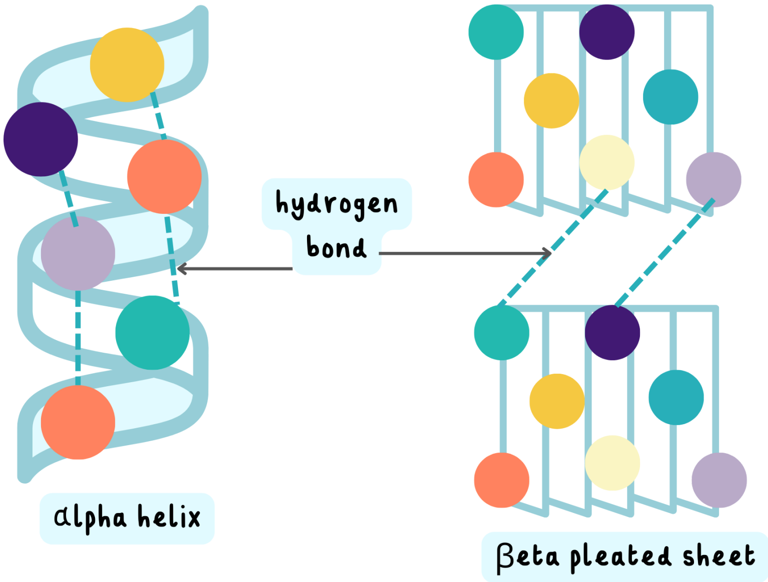
The **structure and function of proteins** is determined by the order and type of amino acids, bonding present and the shape of the protein:

- **Primary structure** of a protein is the sequence/order of amino acids held together by **peptide bonds** in a polypeptide chain.

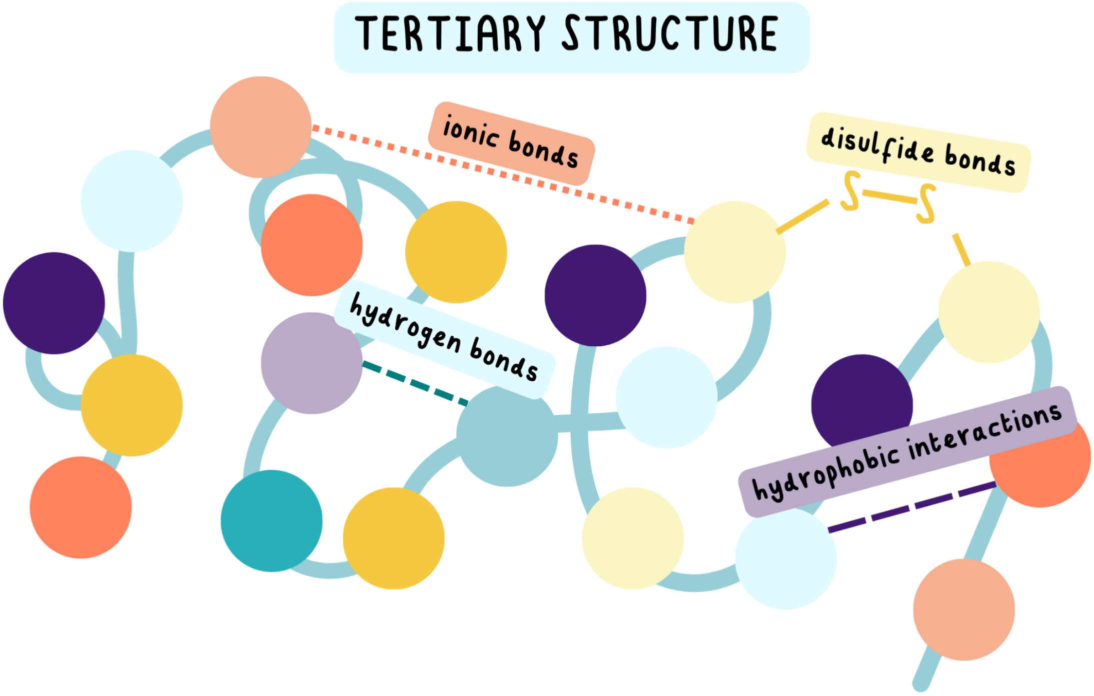


- The **secondary structure** is the local folding of a polypeptide chain – **either alpha helix** or **beta pleated sheet.** Both are held in shape by **hydrogen bonds** between the **–CO– groups** and **–NH– groups** of peptide bonds in different parts of the polypeptide chain.

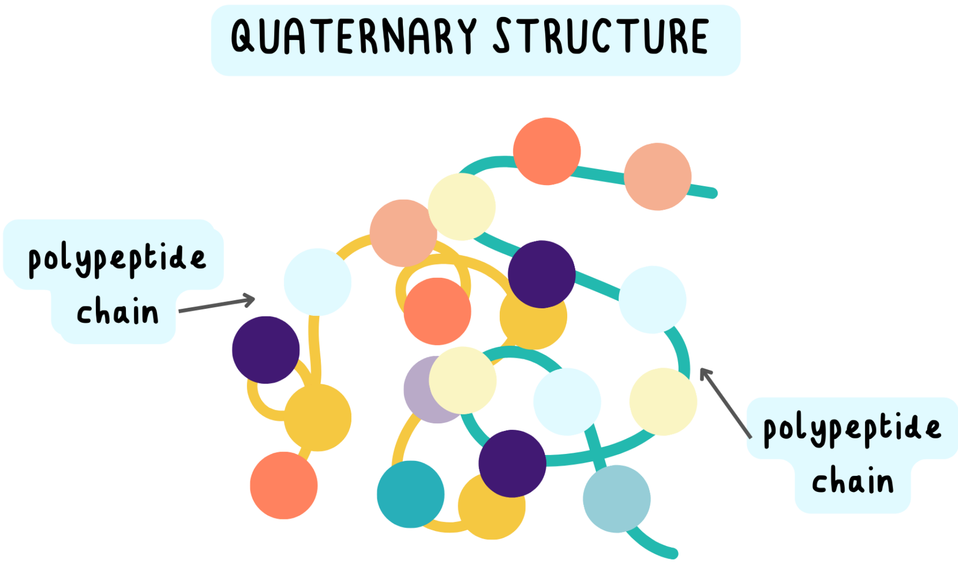
SECONDARY STRUCTURE



- **Tertiary structure** of proteins is the overall 3D shape of a polypeptide, primarily due to 4 types of **interactions between the R groups** of different amino acids.
    - **Hydrogen bonding** - **weak** bonds between a **slightly positively-charged hydrogen atom** and another **slightly negatively-charged atom** (usually nitrogen, oxygen or fluorine).
    - **Ionic bond** - attraction between **oppositely charged R groups.**
    - **Disulphide bonds** - when 2 cysteine amino acids come into close contact and the **sulfur in each cysteine forms a bond**.
    - **Hydrophobic interactions** - some amino acids contain hydrophobic R groups so these amino acids cluster together to avoid contact with water (hydrophobic effect).



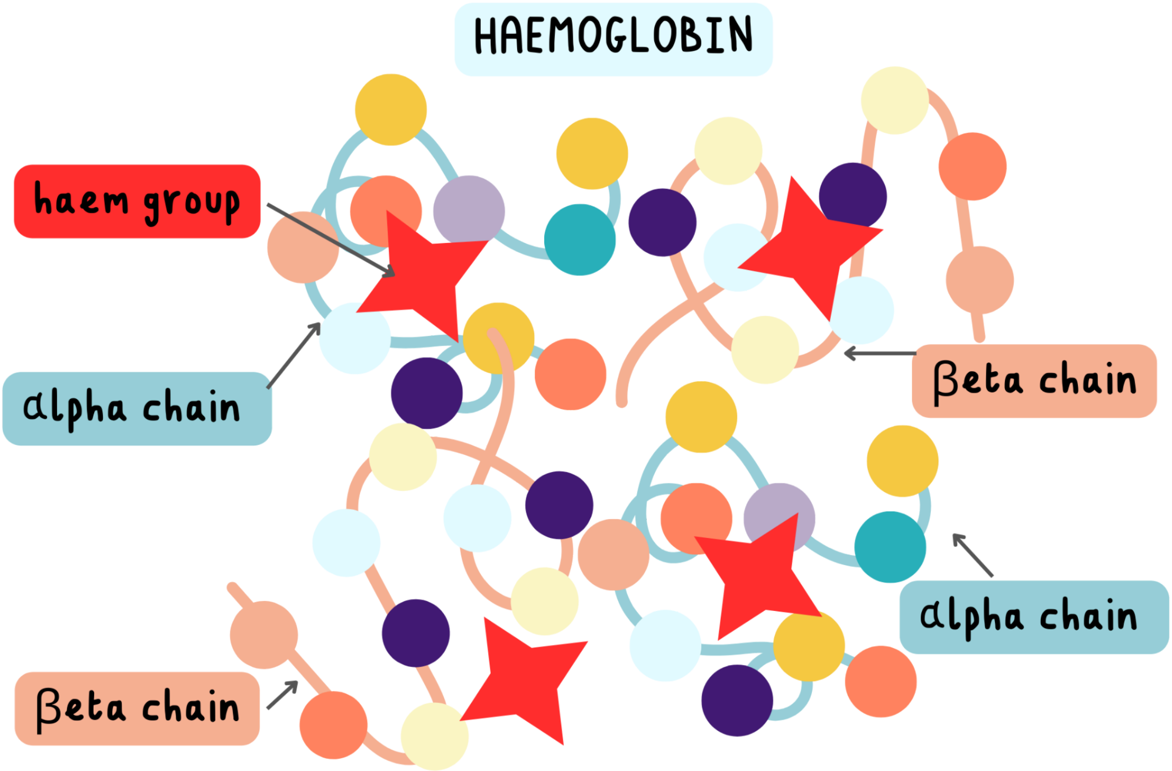
- **Quaternary structure** of proteins consists of 2 or more subunits (polypeptide chains) closely packed together.



Globular Proteins

Globular proteins, such as enzymes, are compact, soluble and generally have physiological functions.

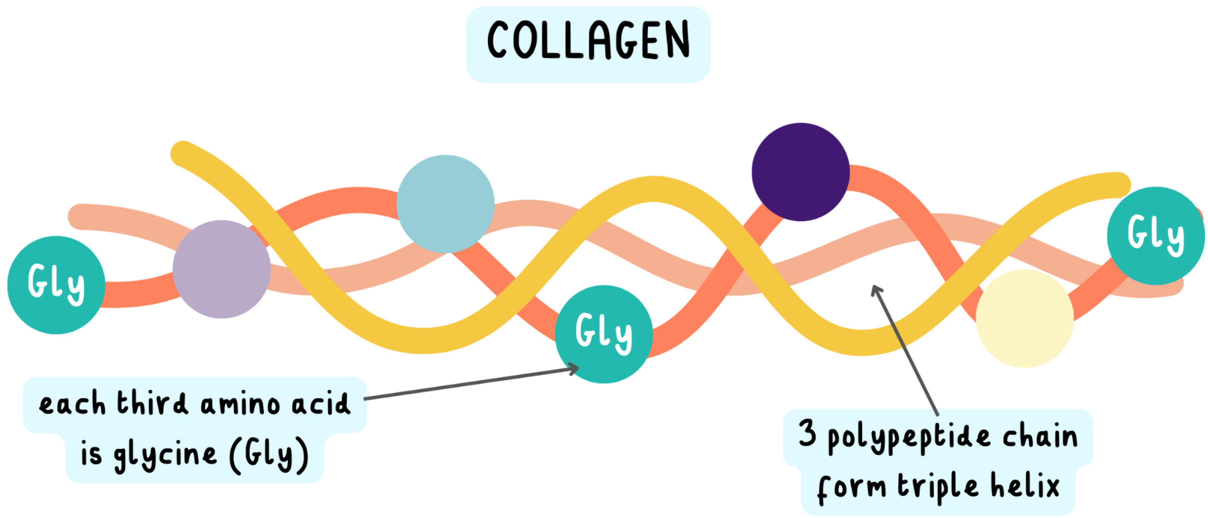
An example of globular protein is **haemoglobin**, a **water soluble globular protein. Haemoglobin** carries oxygen in the blood. It has a **quaternary structure** consisting of **2 alpha subunits** and **2 beta subunits**. Each polypeptide chain contains a prosthetic (non-protein) group - **haem group (containing an iron Fe^{2+} ion).** The iron in the haem group is important as **oxygen** can **bind reversibly** to the haem groups and be released when required.



Fibrous Proteins

Fibrous proteins, such as keratin, are long and thus can be used to form fibres. They are insoluble and have structural roles.

For instance, **collagen** is a **fibrous** protein of high tensile strength due to the presence of both **hydrogen and covalent bonds** in the structure. Three collagen polypeptide chains wrap around each other into triple helices which form fibrils that combine into strong collagen fibres. Each third amino acid is **glycine**, the smallest amino acid, so the structure is tightly packed. Collagen forms the structure of **bones, cartilage and connective tissue** and is a main component of **tendons** which connect muscles to bones.



Water

Water is a very important molecule and a major component of cells, for instance:

- Water is a **polar molecule** due to **uneven distribution of charge** within the molecule – the oxygen atom attracts electrons a bit more strongly than the hydrogen atoms. The unequal sharing of electrons gives the water molecule a slightly negative charge near its oxygen atom and a slight positive charge near its hydrogen atoms.

- It is a **solvent** in which many metabolic reactions occur.

- It has a **high specific heat capacity** meaning that a lot of energy is required to warm water up therefore **minimising temperature fluctuations** in living things, so it acts as a **buffer.**

- It has a **relatively large latent heat of vaporisation,** meaning evaporation of water provides a **cooling effect** with little water loss.