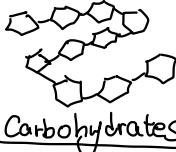


# Biological Molecules 1

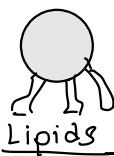
A-Level Biology

[www.factrecall.com](http://www.factrecall.com)

There are four main types of biological molecule which are found in all organisms:



Carbohydrates



Lipids



Proteins



Nucleic acids

### Monomers and polymers

- Most carbohydrates, proteins and nucleic acids are polymers.
- Examples of monomers include monosaccharides, amino acids and nucleotides.
- GCSE Chemistry:** Condensation polymerisation reactions are used to make polymers.  
Polymers can be broken down into monomers by hydrolysis reactions.

## Carbohydrates

### Monosaccharides

- All carbohydrates contain the elements Carbon, Hydrogen and Oxygen.
- Carbohydrate is a polymer made from monomers called **monosaccharides**, like glucose, fructose and galactose. (All of them are hexose monosaccharides)

- General formula for monosaccharides:

$$(CH_2O)_n$$

### Carbohydrates

Monosaccharides

Disaccharides

Poly saccharides

Glucose  
Fructose  
Galactose

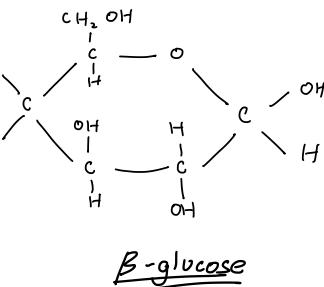
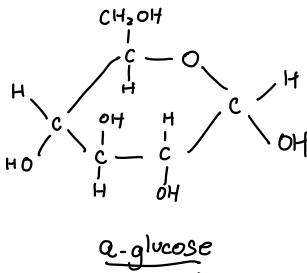
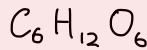
General term:  
sugars

Simple carb's  
Sugars

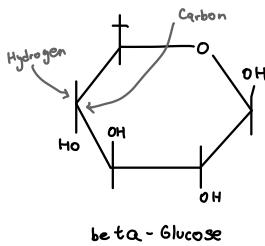
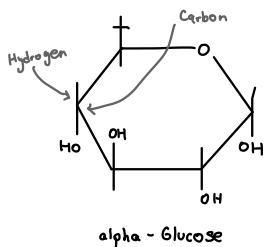
Amount of carbon atoms	Type of sugar (monosaccharide)	$(CH_2O)_n$	Example	
3	Triose	$C_3H_6O_3$	Glyceraldehyde	
4	Tetrose	$C_4H_8O_4$	Threose	
5	Pentose	$C_5H_{10}O_5$	Ribose	
6	Hexose	$C_6H_{12}O_6$	Glucose	

### Glucose

- A hexose sugar - a monosaccharide with 6 carbon atoms
- There are two types of glucose:  $\alpha$ -glucose and  $\beta$ -glucose.



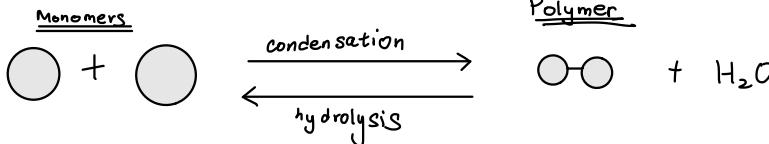
Isomers for glucose (different structural form)



### Lactose intolerance

- Person lacks the lactase enzyme to break down lactose hence allergic to lactose in milk etc.

### Making and breaking polysaccharides



### Synonym to remember biomolecules elements

• CHO	CHO	CHON	CHONP
↓	↓	↓	↓
Carbon	Carbon	Carbon	Carbon
Hydrogen	Hydrogen	Hydrogen	Hydrogen
Oxygen	Oxygen	Oxygen	Oxygen
		Nitrogen	Nitrogen
			Phosphorus

### Reducing Sugars — What are they?

→ hence could form glycosidic bond

- The H (Hydrogen) could dissociate from the carbon ring if it IS a reducing sugar.
- Maltose ✓ Reducing Sugar
- Lactose ✓ Reducing Sugar
- Sucrose X Non-reducing sugar → Sucrose and sucrose cannot form a polysaccharide as the hydrogen could not dissociate and could not form a glycosidic bond.
- Reducing Sugar turns Benedict's Solution red (positive test)

## Disaccharide

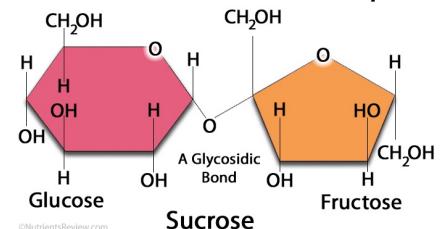
- A disaccharide is formed when two monosaccharides join together.
- Monosaccharides are joined together by condensation reaction &  $\hookrightarrow$  a glycosidic bond forms



## Disaccharide formation

<u>Mono saccharides</u>	<u>Disaccharide</u>
$\alpha$ -glucose + $\alpha$ -glucose	$\rightarrow$ Maltose
glucose + fructose	$\rightarrow$ Sucrose
glucose + galactose	$\rightarrow$ Lactose

## A Disaccharide Example



## Polysaccharides

- A polysaccharide is formed when more than two monosaccharides are joined together by condensation reactions.
- Polysaccharides can be broken down into their monosaccharides by hydrolysis reactions.

There are three polysaccharides we need to know:

- Starch
- Glycogen
- Cellulose

! smaller chains of polysaccharides are called oligosaccharides

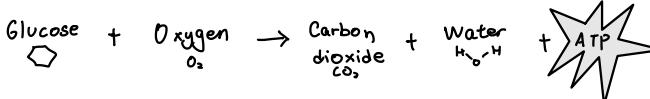


Unlike monosaccharides and disaccharides, polysaccharides are not sweet-tasting nor easily soluble they are not sugars.

Different polysaccharides function can be altered by changing their respective monosaccharides as well as changing how the monosaccharides are bonded together.

e.g. 1,4 Glycosidic vs 1,6 Glycosidic Bonds

Respiration takes in alpha glucose to produce energy for plants and animals. It is the main source of energy.



Let's say a person has a very sugary meal and has excess glucose not needed to be converted to energy in respiration:

- Excess chemical energy is stored in cells by forming polysaccharides of alpha glucose.
- $\alpha$ -glucose polysaccharides are well-suited for energy storage, this is because:

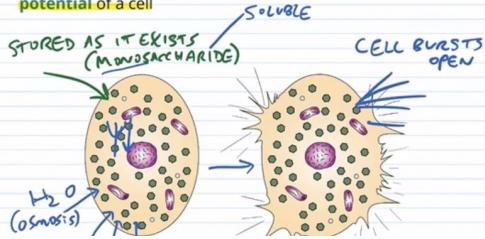
- They are compact (lots of energy in small space)
- They are insoluble hence cells would not burst due to osmosis leading to cytolysis
- They are large so they do not diffuse in and out of the cell



- They are easily hydrolysed (broken down) to form energy

Properties of polysaccharides	Importance for Energy Storage
Large molecule	Cannot diffuse out of cell
Insoluble molecule	Does not affect the water potential of cell
Compact	Lots of energy stored in little space
Easily broken down	Readily accessible energy

- They are insoluble in water so do not impact the water potential of a cell



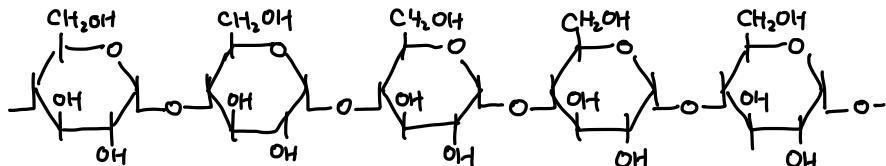
## Starch

- An example of a polysaccharide that stores energy is starch. (glycogen as well)

- Found in leaves and storage organs
- It is compacted into dense, insoluble grains stored in amyloplasts.
- Since amyloplasts store starch, storage organs contain cells with numerous amyloplasts to ensure the plant always have a sufficient amount of energy
- Starch consists of two polysaccharides: amylose & amylopectin

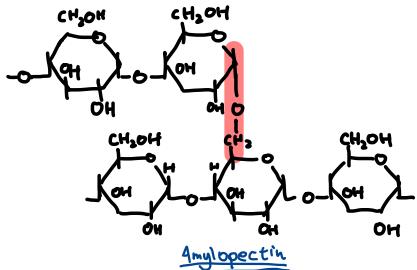
### Amylose

→ Amylose is a long chain of alpha glucose molecules joined together by 1, 4 glycosidic bonds.



GCSE Biology Recap: Carbohydrases help break down carbohydrates into simple sugars. The enzyme amylose breaks down starch.

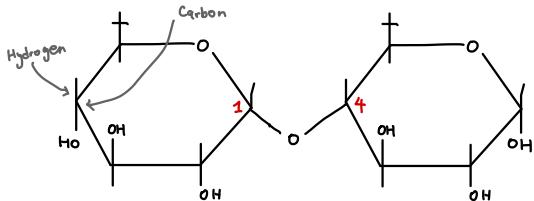
Amylose helps break down amylose.



- Amylopectin is also found in starch.
- This causes more accessible sites for amylase to break down, hence energy can be broken down faster from respiration.

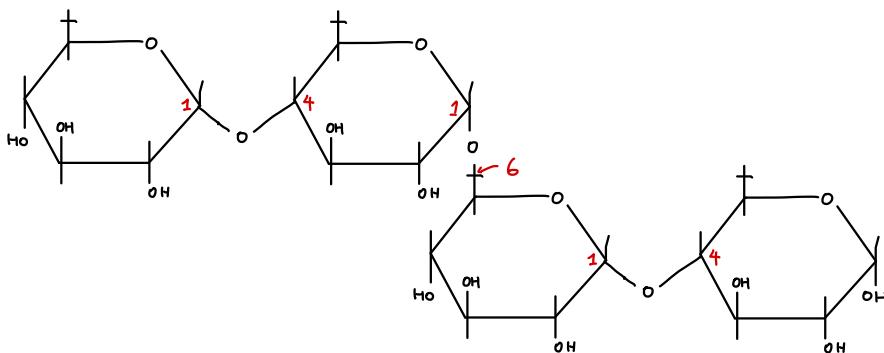


### 1-4 Glycosidic bond



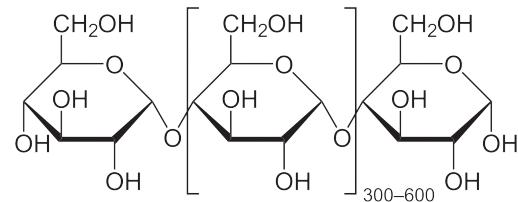
### 1-6 Glycosidic bond in starch (polysaccharide)

- We want it to be a compact store of glucose by having more branches by 1-6 Glycosidic bond
- 1-6 Glycosidic bond can be formed on each glucose molecule
- This makes it better for glucose storage instead of one big line of polysaccharide



## Amylose

- A long, unbranched chain of  $\alpha$ -glucose
- Compact - good for storage of energy

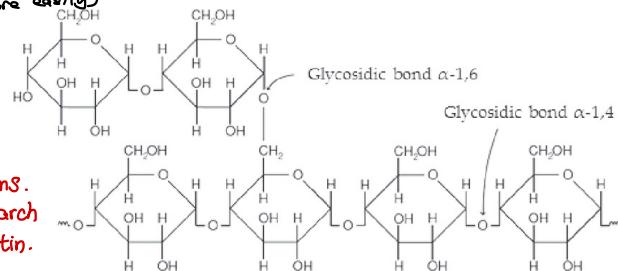


## Amylopectin

- A long, branched chain of  $\alpha$ -glucose.
- Glucose can be released quickly (as enzymes can break down glycosidic bond more easily)

## Summary

- There are many polysaccharides: e.g., Starch, Glycogen, Cellulose.
- Polysaccharides are formed from many monosaccharides under condensation reactions.
- The two components that make up starch are polysaccharides: amylose and amylopectin.

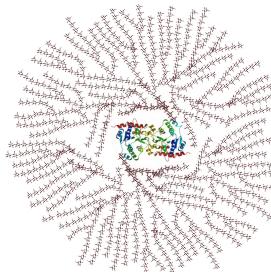


## Glycogen

- Glycogen is the equivalent of starch but for animals.
- They are used to store excess glucose.
- Glycogen is another polysaccharide of  $\alpha$ -glucose, besides amylose and amylopectin.

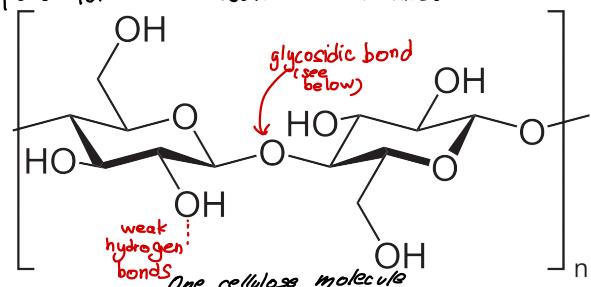
## Structure of Glycogen

- Structure similar to amylopectin (a component of starch) (both with side branches)
- Glycogen has more side branches though
  - Hence ↓
- Stored glucose can be released quickly.
- Glycogen is also a compact molecule, so good for storage. (as with other alpha-glucose polypeptides)



## Cellulose

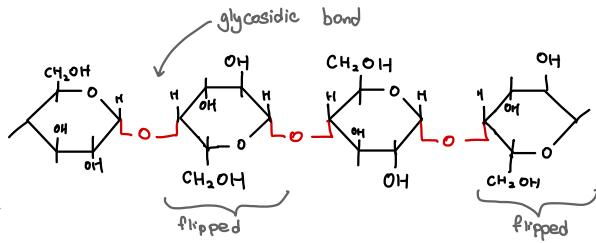
- Cellulose provides structural support for cells (found in cell walls)
- Made of long, unbranched chains of beta-glucose (joined by hydrogen bonds)
  - Hence ↓
- The cellulose chains (to right) are linked together by hydrogen bonds to form strong fibres called microfibrils.
  - Hence ↓
- Strong fibres provide strength for cell walls.



- Cellulose is broken down by cellulase.

### Chemical Structure of Cellulose

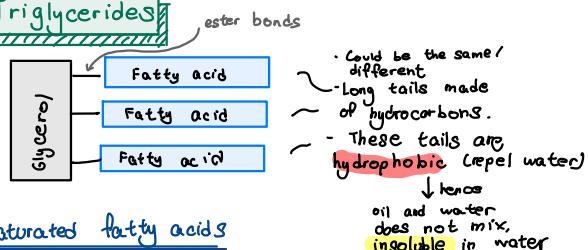
- Cellulose contains alternating beta-glucose
- They are joined by condensation with a glycosidic bond.
- There is a 1:4 linkage with its carbon atoms. (Carbon 1 is bonded with carbon 4)
- Every alternate  $\beta$ -glucose is flipped over.
- Hydrogen bonds



# Lipids

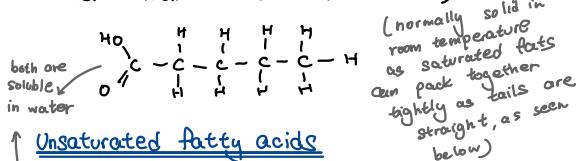
- Lipids are made from a variety of different components, but they all contain hydrocarbons.
- There are two groups of lipids:
  - Triglycerides
  - Phospholipids

## Triglycerides



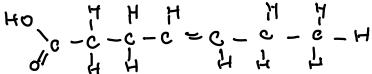
### Saturated fatty acids

- They do not have any double bonds between their carbon atoms. (like alkanes)



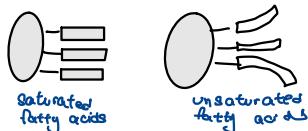
### Unsaturated fatty acids

- They do have double bonds between carbon atoms, (like alkenes)

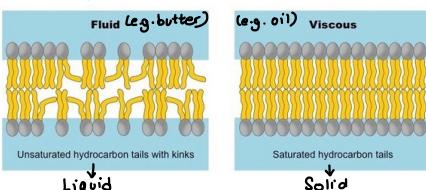


Why are unsaturated fatty acids in the form of liquids (like oil)?

- The carbon double bonds in unsaturated hydrocarbon chains cause the fatty acid tails to bend. (kinked)



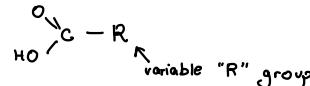
- This bend weakens the intermolecular forces so they form a liquid in room temperature.



There are two types of fatty acids: bad for you

- Saturated fatty acids (as seen in food labels)
- Unsaturated fatty acids

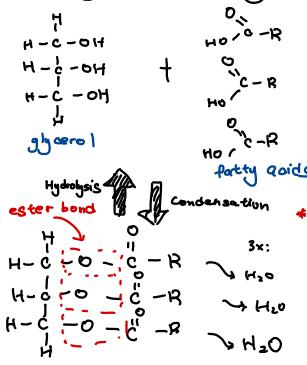
### Structure of a general fatty acid:



- \* This is not a polymer
- \* Fatty acids are considered carboxylic acids since it has  $\text{COOH}$  group (GCSE Chemistry)

### Triglyceride formation

- They are formed by condensation reactions.

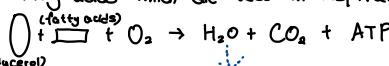


\* GCSE Chemistry:  
carboxylic acid  $\approx$  fatty acid + alcohol  $\downarrow$  ester water  $\approx$  glycerol + water  $\approx$  triglyceride + water

- The above is a condensation reaction - reverse being hydrolysis.

### What are triglycerides used for?

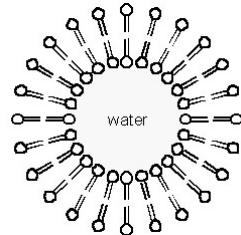
- For energy production  $\rightarrow$  they are broken down into glycerol and fatty acids which are used in respiration.



- A good source of water

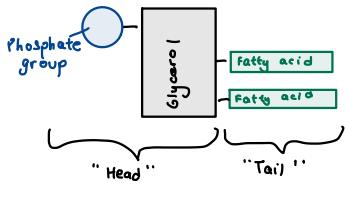
## Properties of Triglycerides

- Triglycerides are excellent molecules for energy storage since:
  - ↳ Long hydrocarbon tails ( $-C-C-C-C-$ ) contain lots of chemical energy ( $\xrightarrow{\text{form ATP}}$ )  
↓ hence
  - ↳ Lipids contain twice as much energy (in form of ATP) per gram as carbohydrates
  - ↳ They do not affect the osmotic balance of cells in the body (water potential)
  - ∴ Triglycerides are **insoluble** in water  
↓ hence
  - ↳ Cells don't swell due to water entering the cells by **osmosis**.
- Triglycerides bundle together as insoluble droplets in cells
  - ∴ fatty acids are **hydrophobic** (they repel water)  
↓ hence
- The fatty acids tail face inwards, shielded from water by glycerol heads.



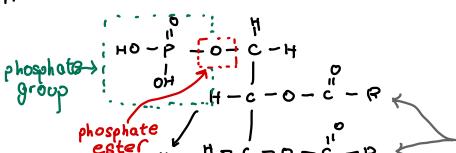
## Phospholipid

- Phospholipids are found in cell membranes.



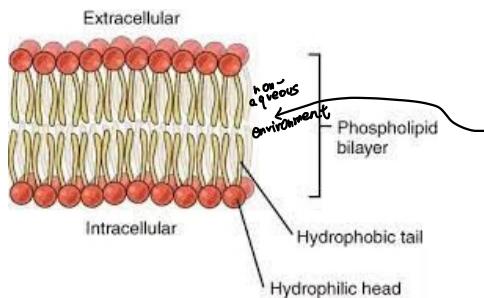
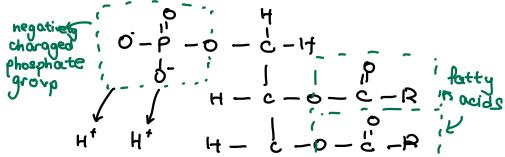
- The phosphate group is **hydrophilic** (attracts water)
- The fatty acid tails are **hydrophobic** (repels water)

### Molecular Structure of Phospholipid



In phospholipids, one is saturated (no double bonds) and one is unsaturated (contains double bonds)

When phospholipid is surrounded by water, the hydrogen ions dissociate from the phosphoric acid:



- Since the phospholipid head is negatively charged, it is **hydrophilic**. (as phosphate group is charged)
- A **hydrophilic molecule** is one that is attracted to water due to having a charge.
- The phospholipid tails, however, are **hydrophobic**.

↓ hence

• Phospholipids could form a monolayer or a bilayer (phospholipid heads facing out towards the water)

- Hydrophobic tails are sheltered in the middle where there is **no water**
- The centre of the bilayer is hydrophobic, so **water-soluble substances** can't easily pass through it

↓ hence

• Only non-polar molecules like  $O_2 / CO_2$  can pass through membrane, making it **partially permeable**.

## Uses of fats

- Brown fat in babies
- Insulation
- Protection (e.g. kidney)
- Energy store (long term)

## Complex Lipids

- Triglycerides
- Phospholipids
- waxes

## Simple Lipids

- steroids
- Cholesterol
- Hormones
- Vitamin D
- Bile Salts

Lipid soluble, hence could go through phospholipid bilayer (cell membranes)

## Proteins

## What are proteins? (from Google)

- Proteins are macromolecules (big) formed by amino acids. Proteins are polymers of structural unit called amino acids.

What are the functions of proteins?

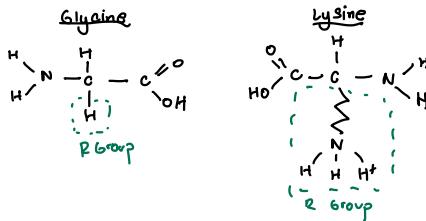
- Structural roles (muscles)
  - Metabolic roles (e.g. enzymes)
  - Antibodies for immune response
  - Transport roles (e.g haemoglobin)

## What are amino acids?

- Amino acids are the monomer units used to make proteins. All amino acids have the same basic structure with different R groups.

## What's in the R Groups?

- R Groups Differ massively in size.
  - R groups generally contain carbon, except glycine

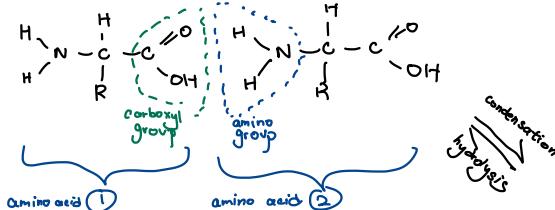


## Polypeptide

Under condensation reactions:

- 2 amino acids join together to create dipeptide
  - Many amino acids join together to create a polypeptide
  - Proteins are made up of one or more polypeptides.

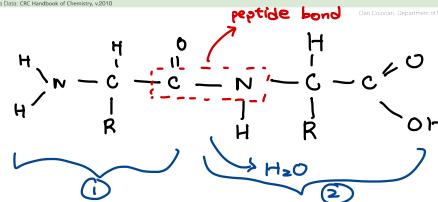
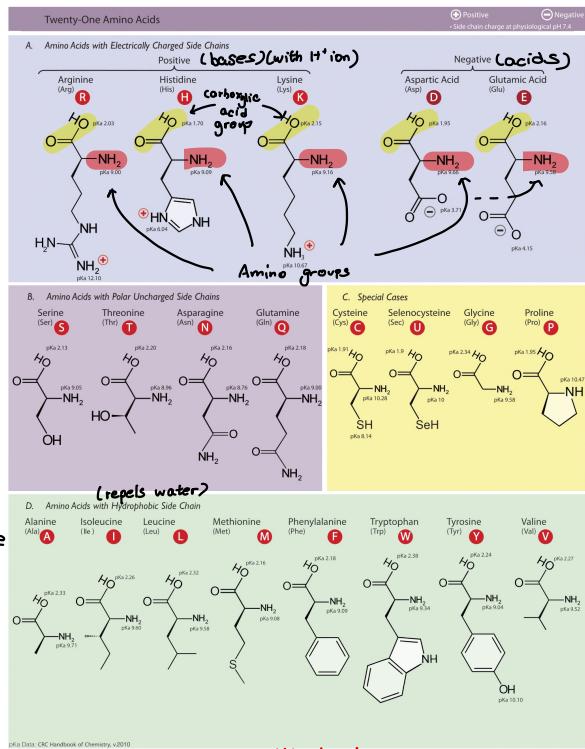
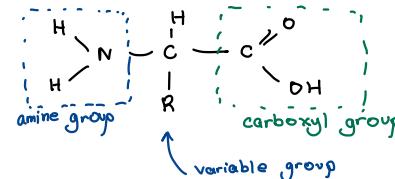
## Dipeptide formation



## Amino Acid

- All amino acids have the same basic structure.

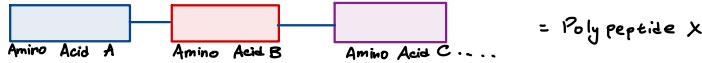
- There are only 20 amino acids



# Protein Structure

## Primary Structure

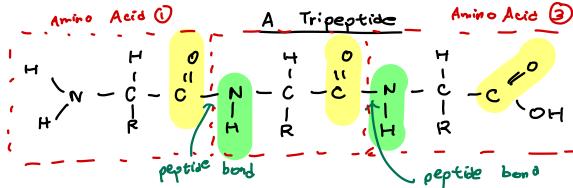
- The primary structure of a protein is the sequence of amino acids.



- The combinations possible are MASSIVE. (20 amino acid combinations)

## Secondary Structure

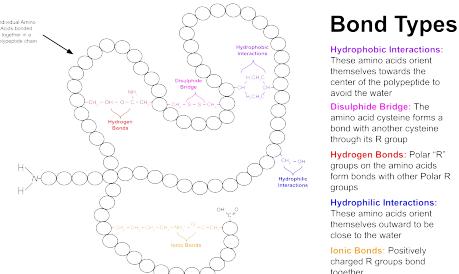
- The polypeptide chain is NOT FLAT. It could coil into an alpha helix or a beta pleated sheet.
- This is due to hydrogen bonds between the amino acids.



- Although hydrogen bonds are weak, hundreds of them keep the secondary structure stable.
- The secondary structure of a protein is the curling or folding of the polypeptide chain into  $\alpha$ -helices and  $\beta$ -pleated sheets due to the formation of hydrogen bonds.

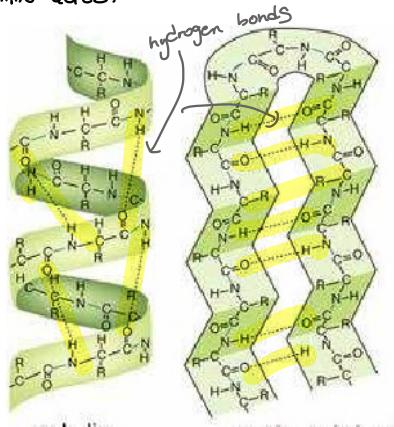
## Tertiary Structure (Shape of protein)

- The  $\alpha$ -helices and  $\beta$ -pleated sheets also twist and turn to form a protein with a unique 3D structure.



## Example of a protein - Casein

- Casein is a phosphoprotein (a protein with a phosphate group attached).
- Found in milk (80% of proteins in cow's milk).
- As a food source, casein supplies amino acids, carbohydrates, calcium and phosphorus.
- No disulfide bridges hence little tertiary structure.
- Relatively hydrophobic, making it poorly soluble in water.
- For protein supplements: casein is very efficient in nutrient supply - provides a sustained slow release of amino acids into the blood stream. Often casein is available as hydrolyzed casein, whereby it is hydrolyzed by a protease such as trypsin.
- Also used in paint, glue, food items and cheesemaking.
- Great for muscle growth.



- Hydrogen bonds form between polar R Groups.
- Ionic bonds form between positive and negatively charged R-Group.
- Disulfide bridges also form when two molecules of cysteine comes close together. (very strong covalent bond)

↓ hence

- The primary structure determines the tertiary structure. ∵ The overall 3D structure is a result of R group properties and interactions.
- The tertiary structure of a protein is the overall specific 3D shape of a protein. This is determined by interactions between R-groups and properties of R groups.

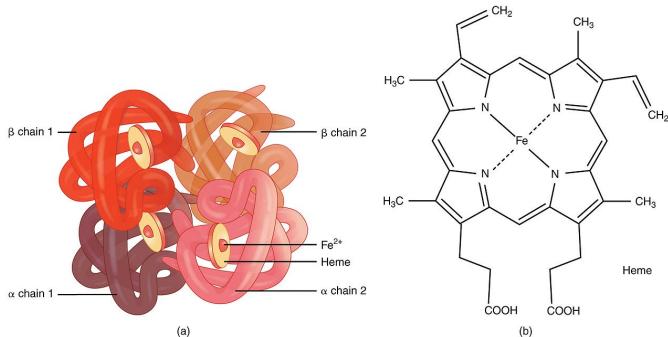
## Quaternary Structure

- Some proteins are made of several different polypeptide chains held together by bonds: e.g. haemoglobin, insulin, collagen, chlorophyll.
  - The quaternary structure is the way these polypeptide chains are assembled together.
  - Prosthetic groups may also be associated with the polypeptide chains.
- The quaternary structure of a protein is the specific 3D shape of a protein that is determined by the multiple polypeptide chains and/or prosthetic groups bonded together.

## Protein shape and function

- A protein's shape determines its function.
- All proteins have different structures and shapes which makes them specialised to carry out particular jobs.
- Examples of proteins include:

### Protein Examples



## Enzymes

- Spherical in shape due to tight folding of the polypeptide chains
- Have roles in metabolism and synthesise (make) large molecules.

## Antibodies

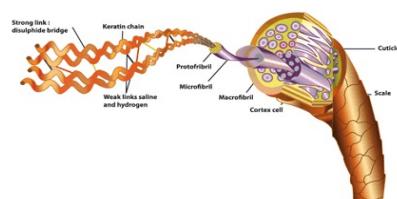
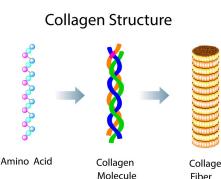
- Involved in the immune response
- Made up of two light polypeptide chains and two heavy polypeptide chains bonded together

## Transport proteins

- Channel proteins are present in cell membranes
- These proteins fold up and transport molecules and ions across membranes.

## Structural proteins

- Strong proteins as they consist of long polypeptide chains lying parallel to each other with cross-links between them.
- Structural proteins include keratin (found in hair and nails) and collagen (found in connective tissue).
- Collagen has 3 polypeptide chains tightly coiled together, which makes it strong.



# Enzymes

- Enzymes are proteins that speed up chemical reactions by acting as biological catalysts.

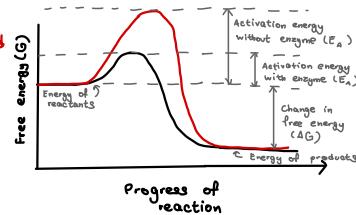
## Enzyme Properties

- Enzymes catalyse metabolic reactions - this could be anabolic or catabolic.
- Enzymes have an active site, which has a specific shape.  
→ The active site is the part of the enzyme where the substrate molecules bind to.
- Enzymes are highly specific due to their tertiary structure.
- Enzymes can affect structures in an organism as well as functions (like respiration).
- Enzyme action can be intracellular (within cells), or extracellular (outside cells).

## How do enzymes speed up reactions?

Activation energy ( $E_a$ ) is the energy that must be provided to compounds to result in a chemical reaction.

Enzymes speed up the rate of reaction by lowering the amount of activation energy that's needed, often making reactions happen at a lower temperature than they could without an enzyme.



## How do enzyme-substrate complexes lower the activation energy?

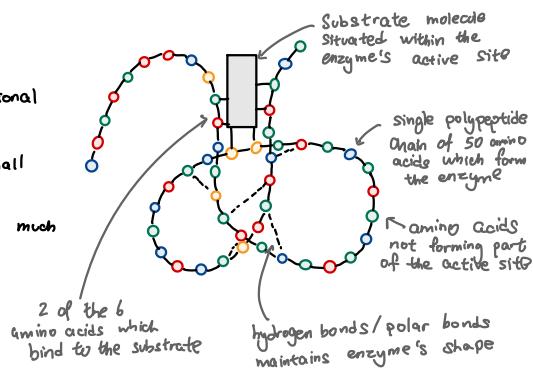
- When a substrate fits into the enzyme's active site it forms an enzyme-substrate complex which lowers the activation energy. Reasons why:
  - If two substrate molecules need to be joined, being attached to the enzyme holds them close together, reducing any repulsion between the molecules so they can bond more easily.
  - If the enzyme is catalysing a breakdown reaction, fitting into the active site puts a strain on bonds in the substrate, so the substrate molecule breaks up more easily.

## Enzyme Structure

- Enzymes, being globular proteins, have a specific 3D shape that is the result of their sequence of amino acids. (primary structure).

## Active Site

- The specific region of the enzyme that is functional is known as the active site.
- The active site is made up of a relatively small number of amino acids.
- The active site forms a small depression within the much larger enzyme molecule.



## Substrate

- The molecule on which the enzyme acts is called the substrate.

- The substrate fits neatly into the active site depression and forms an enzyme-substrate complex.
- The substrate molecule is held within the active site by bonds that temporarily form between certain amino acids of the active site and groups on the substrate molecule.

### "Induced Fit" Model

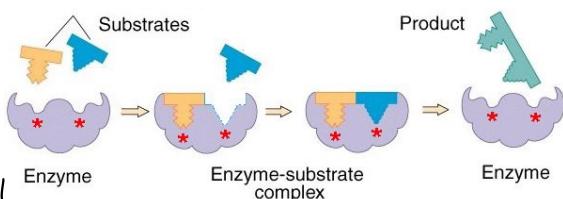
This model shows that the active site is flexible and change in enzyme allows substrate to fit and causes the enzyme-substrate complex to form.

The induced fit model of enzyme action proposes that the active site forms as the enzyme and substrate interact.

The proximity of the substrate (a change in the environment of the enzyme) leads to a change in the enzyme that forms the functional active site.

Any change in an enzyme's environment is likely to change its shape.

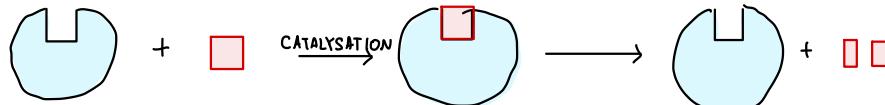
The very act of colliding with its substrate is a change in its environment and so its shape changes, hence the name "induced fit".



### Specificity & Denaturation

#### Why are enzymes so specific?

- This is because only one complementary substrate will fit into the active site.
- The active site's shape is determined by the enzyme's tertiary structure (which is determined by the enzyme's primary structure).
- Each different enzyme has a different tertiary structure and so a different shaped active site.
- If the substrate shape doesn't match the active site, an enzyme-substrate complex won't be formed and the reaction won't be catalysed.



#### What is enzyme denaturation?

If the tertiary structure of a protein is altered in any way, the shape of the active site will change.

Hence the substrate won't fit into the active site, an enzyme-substrate complex won't be formed and the enzyme will no longer be able to carry out its function.

- The enzyme is denatured.
- The tertiary structure could also change if mutation occurs in the primary structure of a protein.
- The tertiary structure could also be altered by pH or temperature changes.



# Factors Affecting Enzyme Action

- For an enzyme to work, it must:

→ Come into physical contact with its substrate  
→ Have an active site which fits the substrate

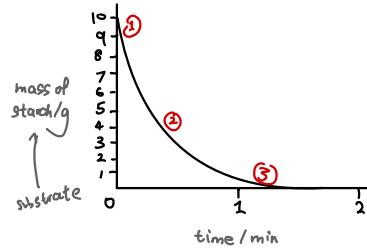
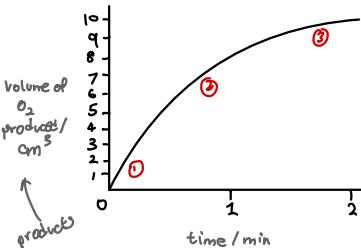
## Measuring enzyme activity

### Method 1: How fast the product is made

By measuring the amount of end product present at different times during the experiment the reaction rate can be calculated.

### Method 2: How fast the substrate is broken down

- To produce the end products in a reaction, substrate molecules have to be used up.
- By measuring the amount of substrate molecules left at different times during the experiment the reaction rate can be calculated.



- ① At first there is a lot of substrate but no product.  
It is very easy for substrate molecules to come into contact with **empty active sites** on the enzyme molecules.
- ② All **enzyme active sites** are filled at any given moment and the substrate is rapidly broken down into its products.  
The amount of **substrate** decreases as it is broken down, resulting in an increase in the amount of **product**.
- ③ It becomes **more difficult** for the **substrate molecules** to come into contact with the **enzyme molecules**.  
Hence it takes longer for the **substrate molecules** to be broken down by the **enzyme** and so **rate of substrate break down decreases**, and consequently, the **rate of formation of product also slows**.
- ④ The graphs **flatten out** because all the **substrate has been used up** and so no new **product** can be produced.

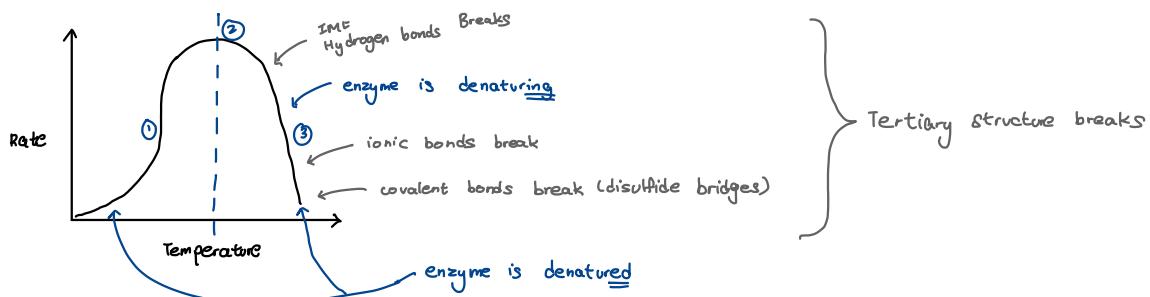
### Measuring rate of change

- This can be done by drawing a tangent and finding

$$\text{gradient: } \frac{\Delta y}{\Delta x}.$$

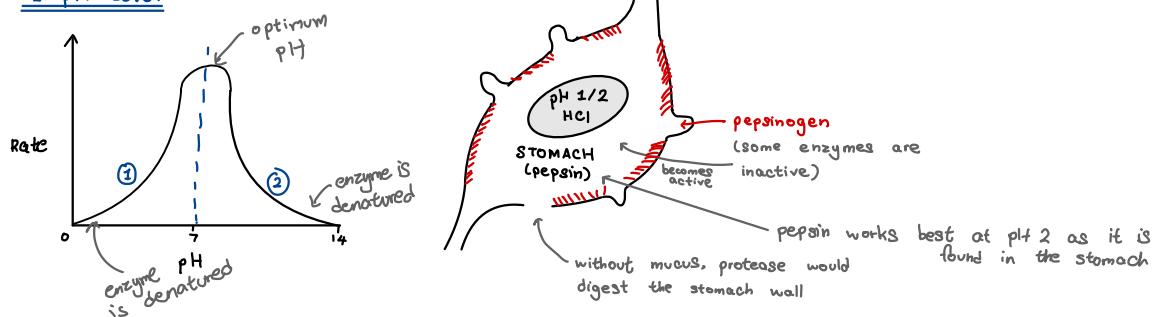
## Factors that Affect the Rate of Enzyme Reactions

### 1. Temperature



- ①: When temperature is increasing, particles have more **kinetic energy**, the **frequency of collisions** increases hence it is easier for the enzyme to catalyse and form an **enzyme-substrate complex**.
- ②: At the optimum temperature, particles have the **MOST kinetic energy**, hence the **most amount of enzyme-substrate complexes** are created.
- ③: The enzyme starts to denature due to bonds in the enzyme breaking from weak to strong bonds. The active site changes shape and the enzyme and substrate no longer fit together.

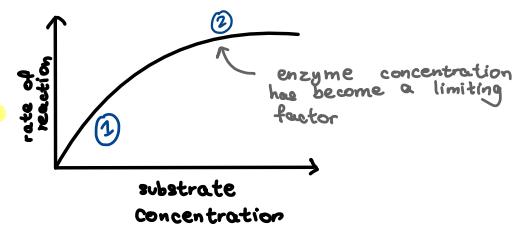
### 2. pH Level



- ③ + ②:
- Above and below the optimum pH, the  $H^+$  and  $OH^-$  ions found in acids and alkalis can disrupt the ionic bonds and hydrogen bonds that hold the enzyme's tertiary structure in place.
  - The enzyme becomes denatured, and the active site changes shape.

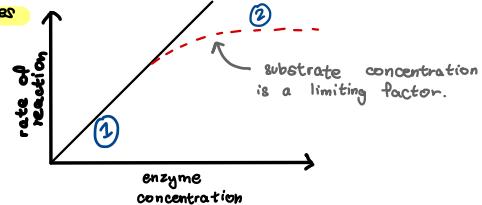
### 3. Substrate Concentration

- ①: More substrate molecules means a collision between **substrate and enzyme is more likely** and so more active sites will be occupied.
- ②: There are so many **substrate molecules** that all the **active sites are occupied**. So adding **more substrates make no difference**.



## 4. Enzyme concentration

- ①: The more enzyme molecules there are in a solution, the more likely a substrate molecule is to collide with one and form an enzyme-substrate complex.  
So increasing the concentration of the enzyme increases the rate of reaction.
- ②: Once the amount of substrate has become a limiting factor, there's more enzyme molecules to deal with all the available substrate, so adding more enzyme has no further effect.

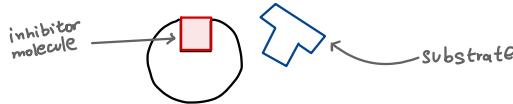


## Enzyme Inhibition

→ Enzyme inhibitors are substances that directly or indirectly interfere with the functioning of the active site of an enzyme and so reduce its activity.  
· There are a number of types of enzyme inhibitor, two of which are:

### 1. Competitive Inhibitors

- Competitive inhibitor molecules have a similar shape to that of the substrate molecules.
- Competitive inhibitors bind to the active site of the enzyme and therefore compete with the substrate for the available active sites.
- How much the enzyme is inhibited depends on the relative concentrations of the inhibitor and substrate.
- If there's a high concentration of the inhibitor, it will take up nearly all the active sites and hardly any of the substrate will get to the enzyme.
- If there's a higher concentration of substrate, then the substance's chances of getting to an active site before the inhibitor increase.



### 2. Non-competitive Inhibition

- Non-competitive inhibitor molecules bind to the enzyme away from its active site.
- This causes the active site to change shape so the substrate molecules can no longer bind to it.
- As non-competitive inhibitors molecules don't compete with the substrate molecules to bind to the active site, increasing the concentration of substrate has no effect.

