1.1 Monomers and polymers

Monomers and polymers

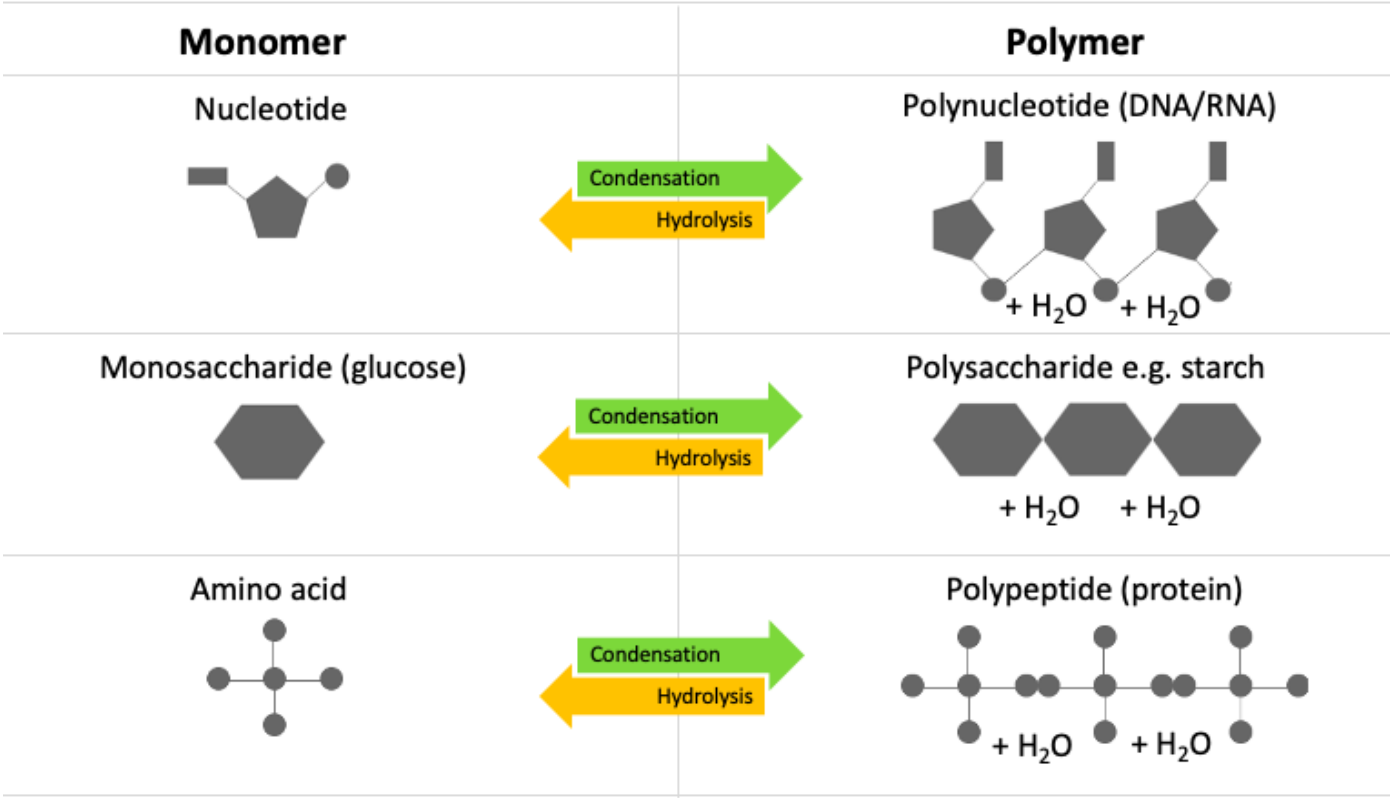
- **Monomer**: small, single molecule, many of which can be joined together to form a polymer
- **Polymer**: large molecule made up of many similar / identical monomers joined together

Condensation and hydrolysis reactions

A **condensation reaction:**
- Joins 2 molecules together
- Eliminates a water molecule
- Forms a chemical bond e.g. glycosidic bond

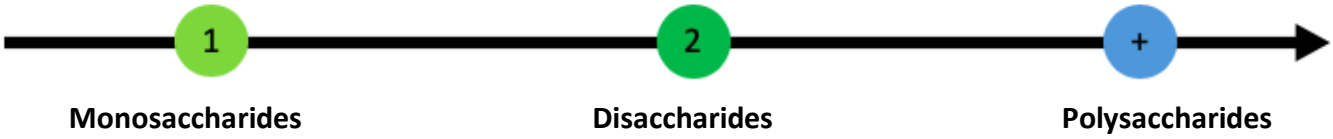
A **hydrolysis reaction:**
- Separates 2 molecules
- Requires addition of a water molecule
- Breaks a chemical bond

Exam tip: to get full marks for a diagram of a condensation or hydrolysis reaction, you need to include the H_2O molecule that is added or removed



1.2 Carbohydrates

Carbohydrates can be classified into 3 groups based on how many units they are made of (1, 2 or many)



Monosaccharides	Disaccharides	Polysaccharides
The monomers from which larger carbohydrates are made	Formed by the condensation of 2 monosaccharides	Formed by the condensation of many monosaccharides

Monosaccharides and disaccharides

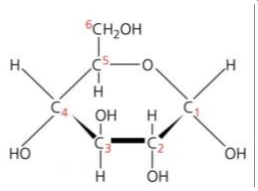
Monosaccharides and disaccharides are simple carbohydrates (sugars)

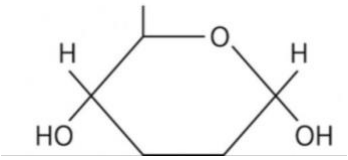
Monosaccharides

- Monosaccharides are the monomers from which larger carbohydrates are made
- E.g. glucose, fructose and galactose

Structure of glucose

- 6 carbon atoms, labelled in red on diagram **(a)**
- Learn how to draw glucose in as much detail as diagram **(b)**

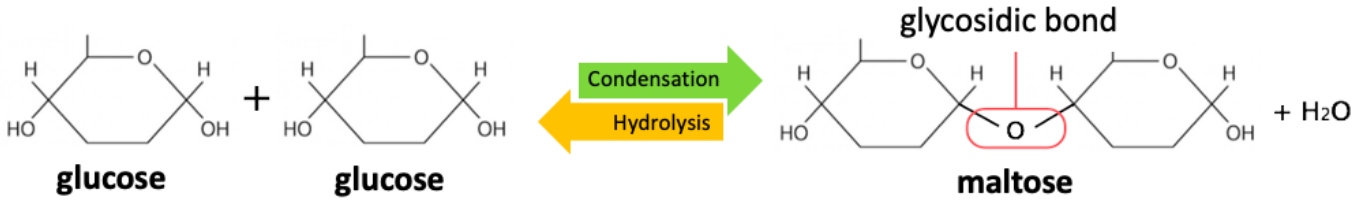




Disaccharides

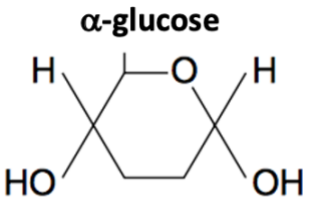
- Glucose + glucose = **maltose**
- Glucose + fructose = **sucrose**
- Glucose + galactose = **lactose**

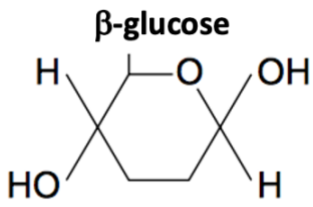
A condensation reaction between 2 monosaccharides forms a **glycosidic bond**



Isomers of glucose: α- and β-glucose

- **Isomer**: same molecular formula but differently arranged atoms
- **Difference in structures:** OH group is below C1 on α-glucose but above C1 in β-glucose

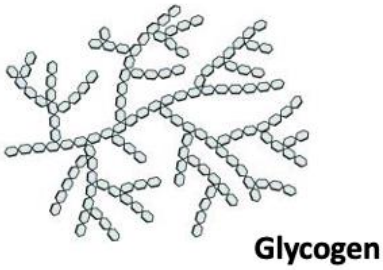




Polysaccharides

Examples: starch, glycogen and cellulose

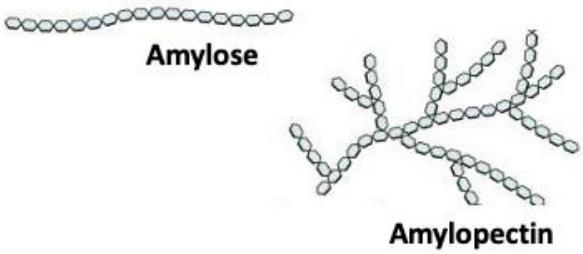
Glycogen



- **Function:** energy store in animal cells
- **Structure:** polysaccharide of α-glucose with C1-C4 and C1-C6 glycosidic bonds so branched

Structure of glycogen related to its function:
- ✓ Branched; can be rapidly hydrolysed to release glucose for respiration to provide energy
- ✓ Large polysaccharide molecule; can't leave cell
- ✓ Insoluble in water; water potential of cell not affected i.e. no osmotic effect

Starch



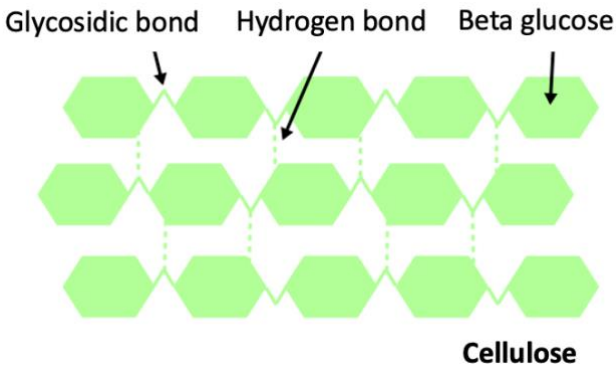
- **Function:** energy store in plant cells
- **Structure:** polysaccharide of α-glucose. Mixture of amylose and amylopectin; amylose has C1-C4 glycosidic bonds so is unbranched, while amylopectin has C1-C4 and C1-C6 glycosidic bonds so is branched

Structure of starch related to its function (amylose):
- ✓ Helical; compact for storage in cell
- ✓ Large polysaccharide molecule; can't leave cell
- ✓ Insoluble in water; water potential of cell not affected i.e. no osmotic effect

Cellulose

- **Function:** provides **strength** and structural support to **plant cell walls**
- **Structure:** polysaccharide of b-glucose. Alternate 180 degree rotation. C1-C4 glycosidic bonds so is unbranched. Chains of glucose molecules are arranged in a linear pattern

Structure related to function:
- ✓ Every other beta-glucose molecule is inverted in a long, straight, unbranched chain
- ✓ Many hydrogen bonds link parallel strands (crosslinks) to form micro fibrils (strong fibres)
- ✓ H bonds are strong in high numbers
- ✓ Provides strength and structural support to plant cell walls



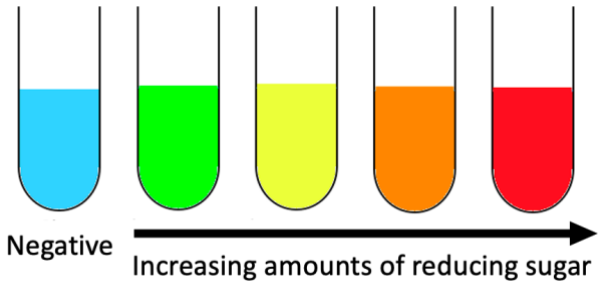
Biochemical tests for carbohydrates

Benedict's test for sugars

Reducing sugar	Non-reducing sugars
• All monosaccharides e.g. glucose	• No monosaccharides
• Most disaccharides e.g. maltose / lactose	• Some disaccharides e.g. sucrose

Benedict's test for reducing sugars

1. Add benedict's reagent (blue) to sample
2. Heat in a boiling water bath
3. Positive = green / yellow / orange / red precipitate (reducing sugar present)



Benedict's test can also be used to test for non-reducing sugars, indirectly:

Benedict's test for non-reducing sugars

1. Add a few drops of dilute hydrochloric acid (hydrolyse sugar into its constituent reducing sugars)
2. Heat in a boiling water bath
3. Neutralise with sodium bicarbonate
4. Add Benedict's reagent and heat again
5. Non-reducing sugar present = green / yellow / orange / red precipitate

Determining glucose concentration

1. Produce a **dilution series** of glucose solutions of known concentrations
2. Perform a **Benedict's test** on each sample
   - Heat with Benedict's solution
   - Use same amount of solution for each test
   - Use excess Benedict's
   - Remove precipitate by filtering
3. Using a **colorimeter**, measure the **absorbance** of each sample and plot a **calibration curve**
   - Calibrate colorimeter using unreacted Benedict's
   - Use a red filter
   - Less absorbance of filtrate = more sugar present (as removed precipitate)
   - Plot absorbance against glucose concentration
4. Repeat with unknown sample (find absorbance) and use graph to **determine glucose concentration**

Iodine test for starch

1. Add **iodine dissolved in potassium iodide** to solution and **shake/stir**
2. **Blue-black** colour = starch present

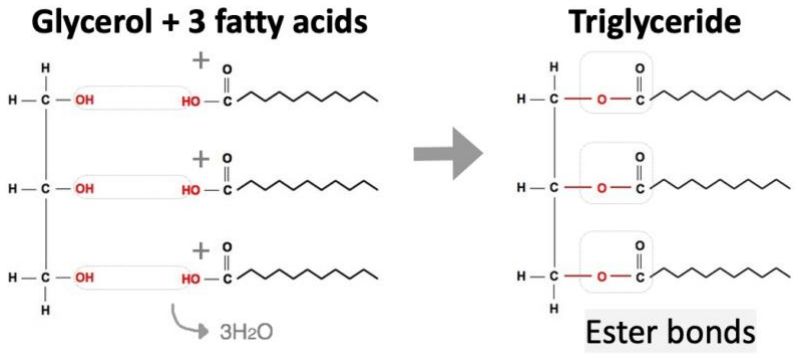
1.3 Lipids

Triglycerides and phospholipids are 2 groups of lipids

Triglycerides

Triglycerides are formed by the condensation of **1 molecule of glycerol and 3 fatty acids**

A condensation reaction between glycerol and a fatty acid (RCOOH) forms an **ester bond**



Zig zags represent a simplified hydrocarbon tail, also sometimes represented as 'R'

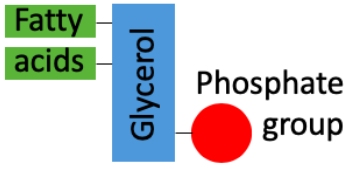
Properties related to structure

Triglycerides: energy storage molecules

- High ratio of C-H bonds to C atoms in hydrocarbon tail
  so release more energy than the same mass of carbohydrates
- Insoluble in water (clump together as droplets)
  so no effect on water potential of cell

Phospholipids

In phospholipids, one of the fatty acids of a triglyceride is substituted by a phosphate-containing group



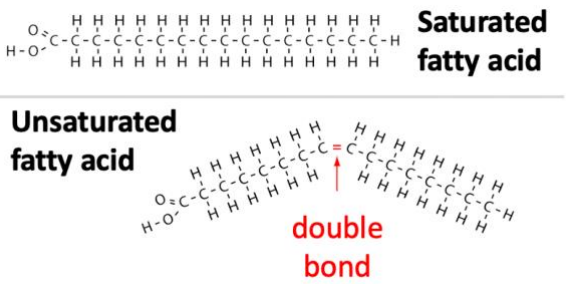
Properties related to structure

Phospholipids: form bilayer in cell membrane, allowing diffusion of non-polar / small molecules

- Phosphate heads are polar / hydrophilic
  so are attracted to water → orient to aqueous environment either side of membrane
- Fatty acid tails are non-polar / hydrophobic
  so are repelled by water → orient to interior of membrane → repels polar / charged molecules

Saturated & unsaturated fatty acids

- **Saturated:** no C=C double bonds in hydrocarbon chain; all carbons fully saturated with hydrogen
- **Unsaturated:** one or more C=C double bonds in hydrocarbon chain



Emulsion test for lipids

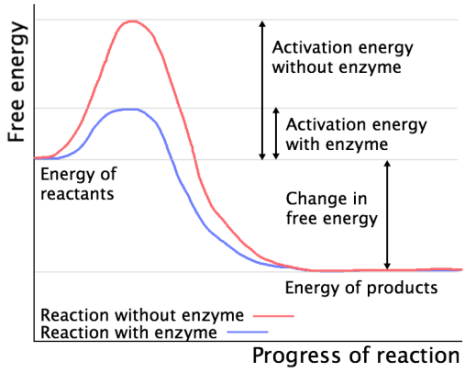
1. Add ethanol and shake (dissolves lipids)
2. **Then** add water
3. Positive: milky/cloudy white emulsion

To get the marks in the exam, you must state steps 1 and 2 in the correct order

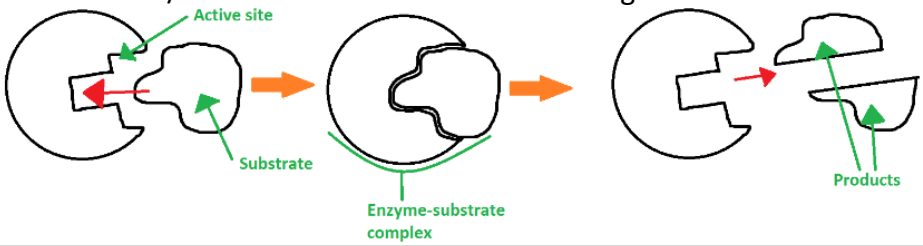
4.2 Many proteins are enzymes

Introduction to enzymes

- Each enzyme **lowers the activation energy** of the reaction it catalyses (see diagram) → speed up rate of reaction
- Enzymes are **biological catalysts**; they catalyse a wide range of intracellular (within cells) and extracellular (outside cells) reactions that determine structures and functions from cellular to whole-organism level.



Models of enzyme action

Lock and Key model	Induced Fit model
Old, outdated	Recent, accepted
• Active site is a fixed shape / doesn't change shape; it is complementary to one substrate • After a successful collision, an enzyme-substrate complex forms leading to a reaction	1. Before reaction, enzyme active site not completely complementary to substrate / doesn't fit substrate 2. Active site shape changes as substrate binds and enzyme-substrate complex forms 3. This stresses / distorts bonds in substrate leading to a reaction 

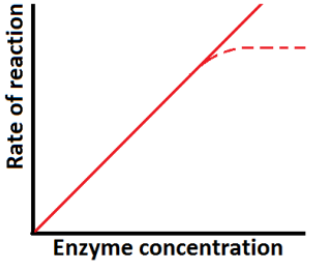
The specificity of enzymes

- Enzymes have a **specific shaped tertiary structure and active site**
  - Sequence of amino acids (primary structure) determines tertiary structure
- Active site is **complementary** to a specific substrate
- Only this substrate can **bind** to the active site, inducing fit and forming an **enzyme-substrate complex**

Factors affecting rate of enzyme-controlled reactions

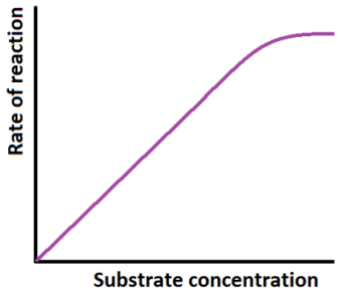
Enzyme concentration

- Increasing enzyme conc. → rate of reaction increases
  - **Enzyme conc. = limiting factor** (substrate in excess)
  - More enzymes → more available **active sites**
  - More successful **E-S collisions and E-S complexes**
- At a certain point, rate of reaction **plateaus**
  - **Substrate conc. = limiting factor** (all substrates in use)



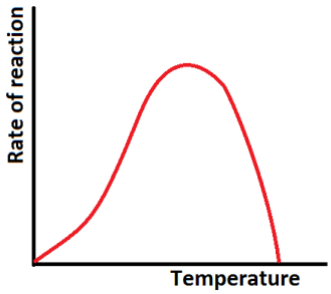
Substrate concentration

- Increasing substrate conc. → rate of reaction increases
  - **Substrate concentration = limiting factor** (too few enzyme molecules to occupy all **active sites**)
  - More successful **E-S collisions and E-S complexes**
- At a certain point, rate of reaction **plateaus**
  - **Enzyme conc. = limiting factor** (all active sites saturated; excess substrate)



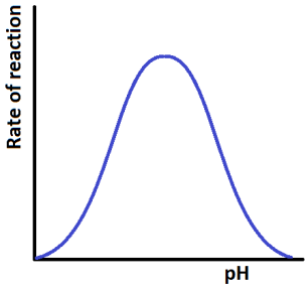
Temperature

- Increasing temp. up to optimum → rate of reaction increases
  - Increase in **kinetic energy**
  - More successful E-S collisions and **E-S complexes**
- Increasing temp. above **optimum** → rate of reaction falls
  - Enzymes **denature**; **tertiary structure** and **active site change shape** (hydrogen / ionic **bonds break**)
  - Fewer **E-S collisions and E-S complexes** (substrate no longer binds to active site)
- Rate of reaction **0** when **all** enzymes denatured



pH

- pH above / below optimum pH → rate of reaction decreases
  - Enzymes **denature; tertiary structure** and **active site change shape** (hydrogen and ionic **bonds break**)
  - Complementary substrate can no longer bind to active site
  - Fewer **E-S collisions and E-S complexes**
- pH = - $\log_{10}$ [H^+]



Concentration of competitive and non-competitive inhibitors

Competitive inhibitors decrease rate of reaction

- **Similar shape to substrate**
- Competes for / binds to / blocks **active site** so substrates can't bind
- Fewer E-S complexes
- **Increasing substrate conc. reduces effect** of inhibitor (level of inhibition dependent on relative concs. of substrate and inhibitor)

Non-competitive inhibitors decrease rate of reaction

- Binds to **site away from the active site** (allosteric site)
- Enzyme **tertiary structure / active site change shape** so substrate can't bind to active site
- Fewer E-S complexes
- **Increasing substrate concentration has no effect** on rate of reaction as causes permanent change to active site