1.1 Introduction to biological molecules

Covalent bonding	Atoms share a pair of electrons in the outer shell, full atoms become stable
Ionic bonding	Electrostatic attraction (atoms of opposite charges attract); weaker than covalent bonds
Hydrogen bonding	Weak on its own and strong collectively

Monomer	A single carbon-based unit of a polymer
Polymer	Many monomers linked together by polymerisation

- Polar molecule: electrons that aren't evenly distributed within a molecule ex. water

1 mol = 6.022 x 10^23 – Avogadro's number
A molar solution has 1 mol of solute in each 1L of solution

Condensation	When 2 molecules join to form a larger molecules by removal of water
Hydrolysis	Splitting of a large molecule into a smaller one by addition of water

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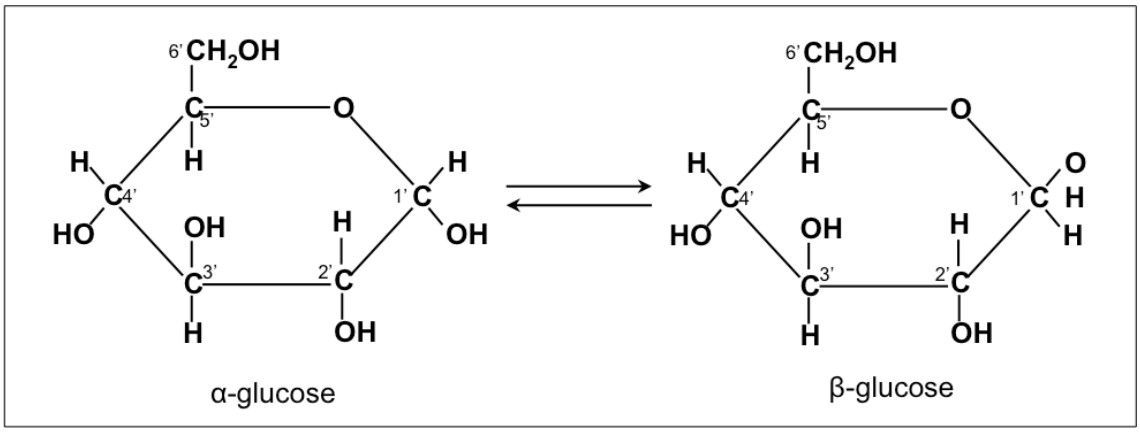
1.2 Carbohydrates: monosaccharides

- Monosaccharides: monomer
- Disaccharides: a pair of monosaccharides
- Polysaccharide: a chain of monosaccharides

Monosaccharides
- Sweet-tasting
- $(CH_2O)_n$
- Ex. glucose, galactose, fructose

Glucose has 2 isomers:



Test for reducing sugars: (Benedict's)
- All monosaccharides and some disaccharides are reducing sugars
- A reducing sugar is a sugar that can donate electrons

1. Add 2cm^3 of food sample in liquid form
2. Add an equal volume of Benedict's solution
3. Heat the mixture in a water bath

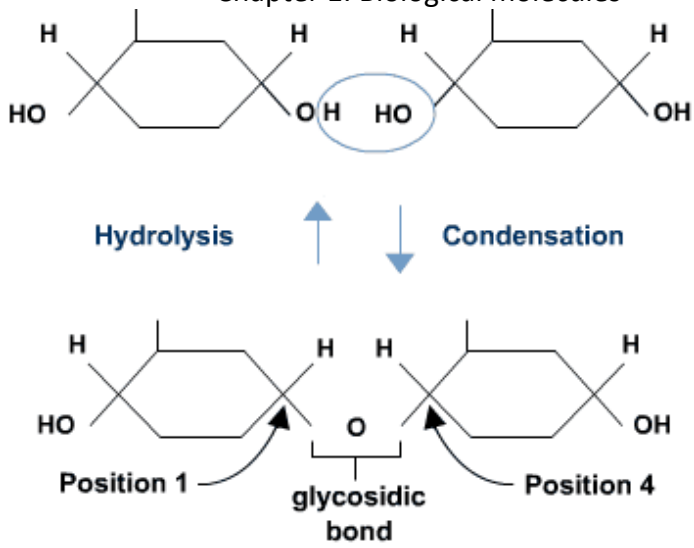
Positive result: brown/orange
Negative result: no colour change

1.3 Carbohydrates: disaccharides and polysaccharides

- Joined by a glycosidic bond through a condensation reaction

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

Polysaccharides:
- Insoluble: suitable for storage
- Some provide support in structures ex. cellulose and starch



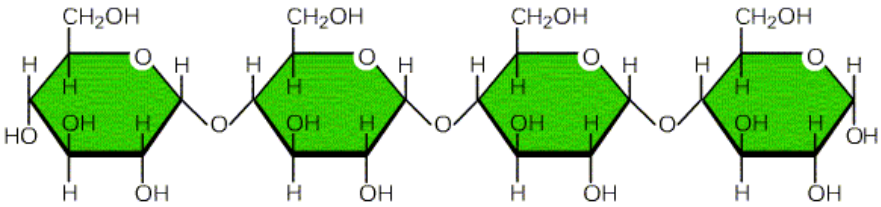
Test for non-reducing sugars (disaccharides and polysaccharides): (Benedict's)

1. Add 2cm^3 of food sample in liquid form
2. Add an equal volume of Benedict's solution
3. Heat the mixture in a water bath
4. No colour change
5. Add another 2cm^3 of food and 2cm^3 of dilute HCl (hydrochloric acid)
6. Place it into a water bath for 5 minutes. HCl will hydrolyse any disaccharides present into monosaccharides
7. Slowly add hydrogen-carbonate solution to neutralise HCl. Test with pH paper to check that the solution is alkaline
8. Add 2cm^3 of Benedict's solution and heat it in a water bath for 5 minutes

Positive result: brown/orange
Negative result: no colour change

1.4 Starch, glycogen ad cellulose

Starch



- Polysaccharides
- a-glucose
- never found in animal cells

Test for starch:

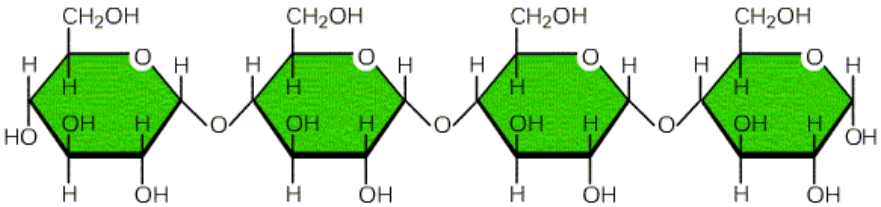
1. Add 2cm^3 of sample to a tile
2. Add 2 drops of iodine solution

Positive result: blue/black
Negative result: no colour change

Structure of starch:

- Insoluble: doesn't affect water potential (can't diffuse out of cells)
- Good storage
- Compact
- When a-glucose is hydrolysed, it's easily transported and used for respiration
- Branched – many enzymes can act simultaneously hence glucose monomers are released quicker

Glycogen

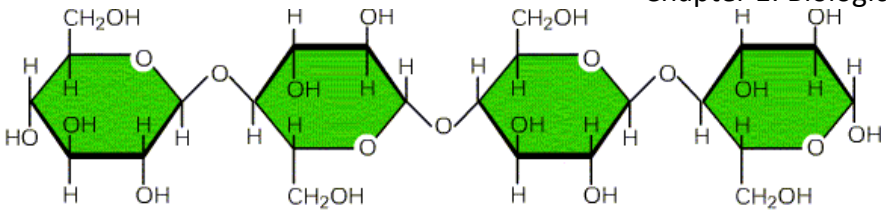


- Found in animal and bacteria cells, never in plant cells
- a-glucose
- stored in muscles and liver

Structure of glycogen:

- insoluble
- compact
- more branched than starch (important for animals as they are very active and have a high metabolic rate)
- shorter chains than starch
- mass of storage is small as fat is the main storage

Cellulose



- b-glucose
- unbranched chains parallel to one another allowing hydrogen bonds to form cross-linkages between the chains
- collectively cellulose forms microfibrils from fibers
- provides rigidity in plant cell walls and prevents cells from bursting by exerting an inward pressure that stops further influx of water

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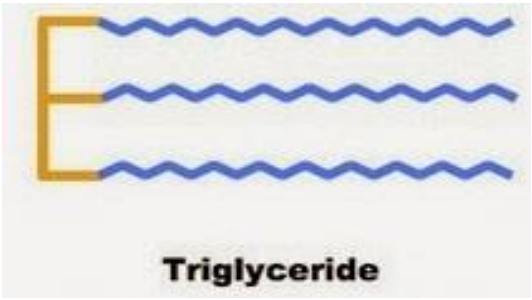
1.5 Lipids

- Made up of carbon, hydrogen and oxygen
- Insoluble in water
- Soluble in organic substances ex. alcohol and acetone

Role of lipids:
- Cell membranes
- Phospholipids (flexibility of the membrane)
- Waterproofing
- Insulation
- Source of energy (when lipids get oxidised)
- Protection of organs

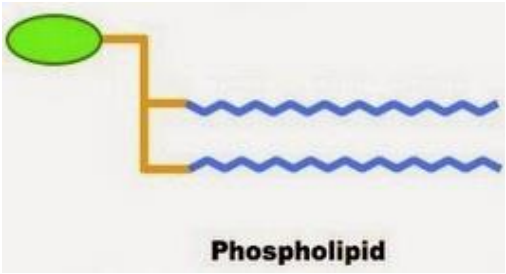
Saturated	No carbon double bonds
Monounsaturated	Only 1 carbon double bond
Polyunsaturated	More than 1 carbon double bonds

Triglycerides:
- 3 fatty acids and 1 glycerol
- Ester bond between fatty acid and glycerol



Structure of triglycerides:
- High ratio of energy storing carbon (H+ bonds of carbon atoms)
- Low mass to energy ratio – good storage
- Non-polar
- Insoluble in water
- High ratio of hydrogen to oxygen atoms – source of water

Phospholipids
- 2 fatty acids + 1 phosphate
- Fatty acids (tail) are hydrophobic - repel water
- Phosphates (heads) are hydrophilic - attracts water
- A polar molecule as 2 poles have different charges



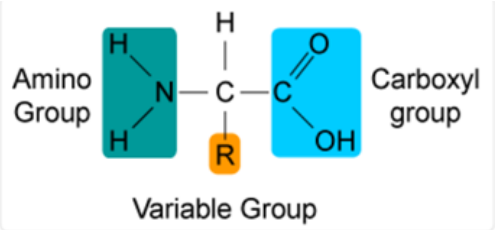
Structure of phospholipids:
- Phospholipids form a lipid bilayer within a cell-surface membrane, forming a barrier.
  - This allows the formation of glycolipids (carbohydrate + lipid)

Test for lipids: (Emulsion)
1. Add 2cm^3 of sample and 5cm^3of ethanol sample
2. Shake gently
3. Add 5cm^3 of water and shake

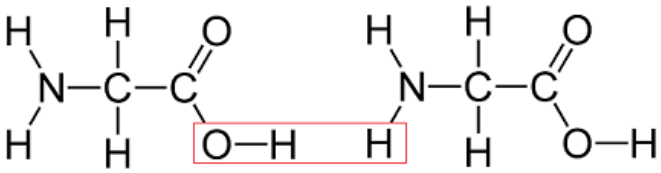
Positive result: a cloudy-white colour (due to lipids being finely dispersed in the water - emulsion)
Negative result: solution remains clear

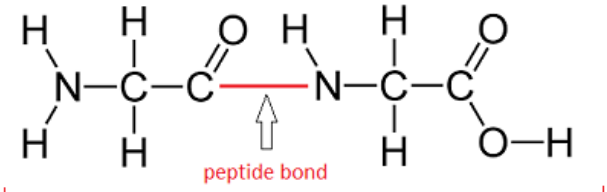
1.6 Proteins

Structure of an amino acid
- Amino acid: monomer
- Polypeptide: polymer
- Proteins: polypeptides



- 2 amino acids
- Condensation reaction
- Peptide bond
- Dipeptide





DIPEPTIDE

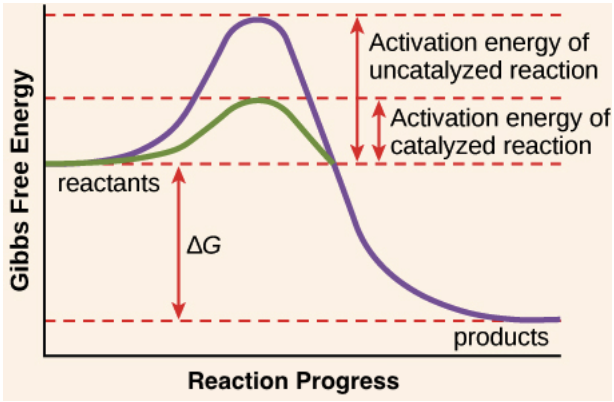
Structure of proteins:
- Primary structure: DNA determines the sequence of amino acids, which specifies shape and function of protein
- Secondary structure: forms weak hydrogen bonds and the chain twists into an a-helix shape
- Tertiary structure: the chain folds into a 3D shape and is maintained by the following bonds: disulphide bridges ionic and hydrogen
- Quaternary structure: a combination of 2 or more peptide chains to form a polypeptide chain

Test for proteins: (Biuret)
1. Add an equal volume of NaOH to the sample
2. Add a few drops of dilute copper (II) sulfate and mix

   Positive result: purple colour change

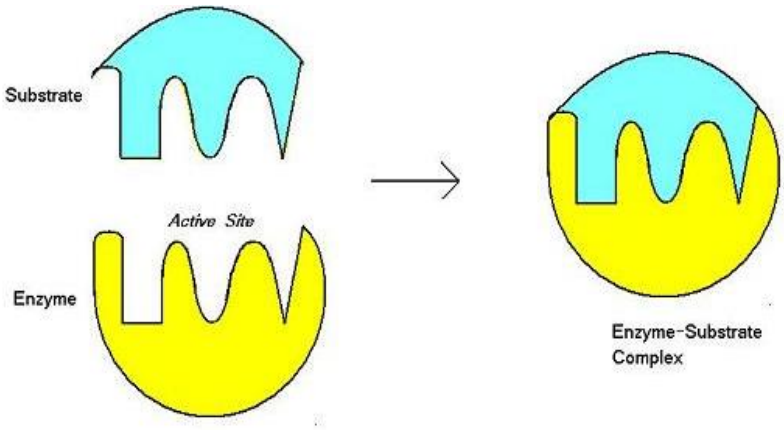
   Negative result: no colour change

1.7 Enzyme action



Enzymes: globular proteins that act as catalysts which speed up the chemical reaction without being used up (reusable). It's effective in small amounts.

Any reaction (sucrose + water → glucose + fructose) needs to meet the following conditions to take place:
1. Substrate molecules must have a high collision rate
2. Free energy of products must be less of substrates
3. To initialise the reaction, a minimum amount of activation energy is needed
4. Enzymes lower the activation energy, which allows reactions to happen in lower temperatures and result in faster metabolic rates



Without the activation energy the enzymes would work too slowly

- Enzymes act on substrates when they come together they form an enzyme-substrate complex
- As substrates change the shape of the enzyme slightly, it puts a strain on the substrate, which breaks the hydrogen bonds. The activation energy lowers the strain that is put onto these bonds.

1.8 Factors affecting enzyme action

- Measure the time course to measure the progress of an enzyme-catalysed reaction. Measure:
  - Formation of products
  - Disappearance of substrate

- Measuring the rate of reaction from a graph (gradient):
  - Draw a tangent to the curve
  - Rise/run

Effect of temperature on enzymes:

- Temperature rises
- KE increases
- Rate of successful collisions increases
- More enzyme-substrate complexes are formed
- Rate of reaction increases

- Temperature can't go above a certain point as it will break the hydrogen bonds and reshape the enzyme which will lead to denaturation.

Effect of pH on enzymes:

- Change in pH alters charges on amino acids that make up the active sites
- This alters shape/bonds of active sites so substrates can't bind to the active sites anymore
- Reaction stops

Effect of enzyme concentration on the rate of reaction:

1. Low enzyme concentration:
   - Substrates have to wait
   - Reaction is ½ of its fullest
2. Intermediate enzyme concentration:
   - Number of enzymes and substrates is equal
   - Reaction is at its fullest
3. High enzyme concentration
   - No increase in rate of reaction due to all the substrates being accommodated

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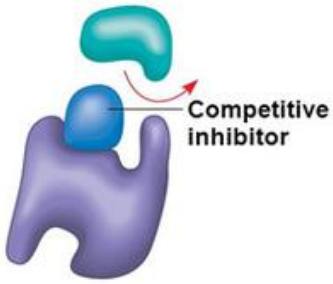
1.9 Enzyme inhibition

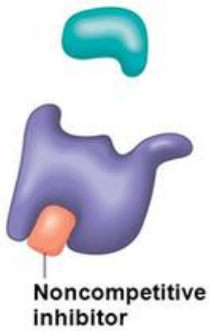
Competitive inhibitors (competes for the active site):

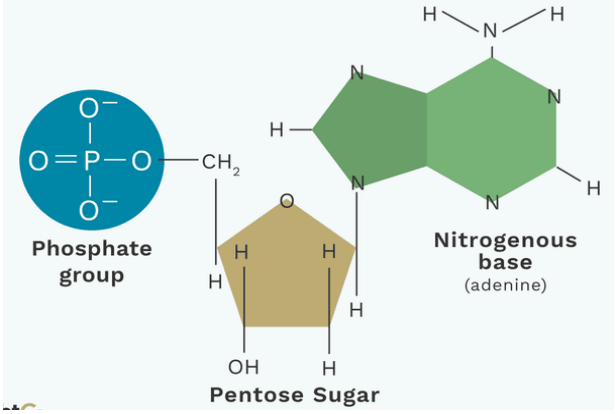
- Binds to active site
- Prevents substrate from binding to the active site



Non-competitive inhibitors:

- Attach themselves to the enzyme at a binding site (anywhere except for the active site)
- Enzyme changes shape

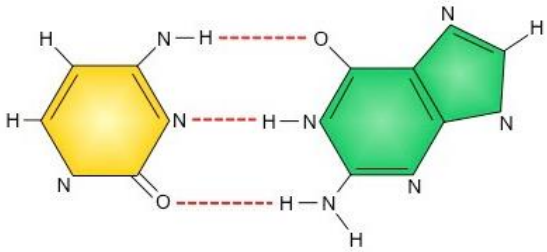




2.1 Structure of RNA and DNA

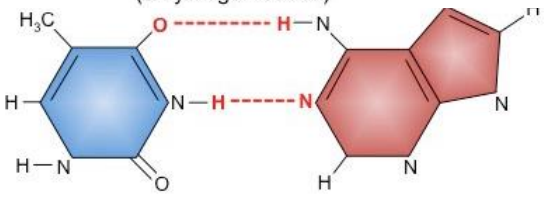
Nucleotides are joined together by a **phosphodiester bond** in a condensation reaction.

- Mononucleotide
- Dinucleotide
- Polynucleotide

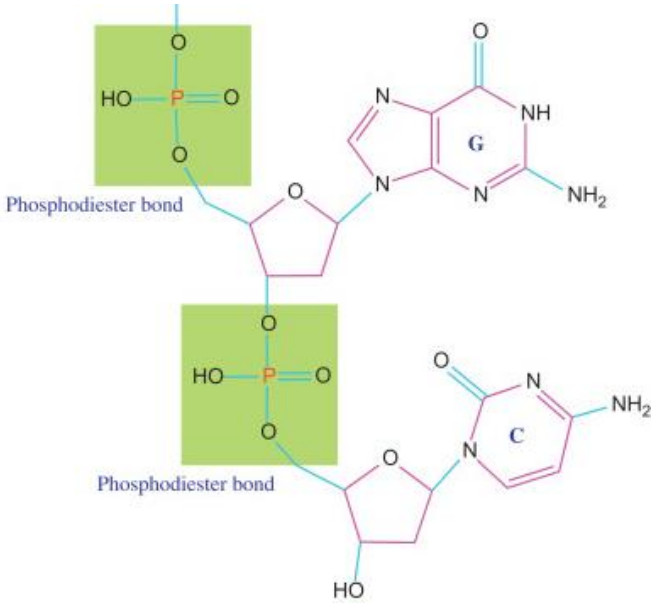


RNA	DNA
Ribonucleic acid	Deoxyribonucleic acid
Single strand	Double strand
Short	Long
Ribose pentose sugar	Deoxyribose pentose sugar
Adenine – Uracil	Adenine – Thymine

Cytosine pairs with Guanine
(3 hydrogen bonds)



Thymine / Uracil pairs with Adenine
(2 hydrogen bonds)



Phosphodiester bonds
act as a backbone to protect the more reactive bases. Hydrogen bonds between bases make DNA more stable.

Function of DNA:
- Holds and passes genetic material from cell to cell
- Large variety of base combinations provides genetic diversity
- Rarely mutates when passed on to offspring
- DNA replication

2.2 DNA replication

Cell division:
1. Nuclear division: where the nucleus splits (mitosis and meiosis)
2. Cytokinesis: where the whole cell divides

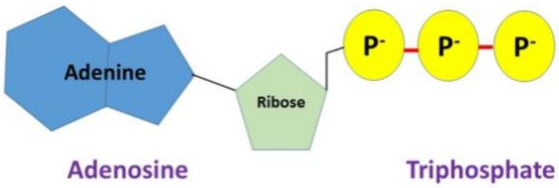
The **semi-conservative replication** has 4 conditions:
1. All 4 bases must be present
2. Both strands of DNA act as a template
3. DNA polymerase enzyme must be resent
4. A source of chemical energy

DNA replication:
- DNA unwinds
- DNA helicase enzyme splits base pairs by breaking the hydrogen bonds
- Free nucleotides in the pool bind specifically to their complementary bases
- Bases are joined together by DNA polymerase which forms phosphodiester bonds (the backbone) to make a complete polynucleotide chains of 2 identical strands of DNA

2.3 Energy and ATP

$$ATP + H_20 \longrightarrow ADP + P_i + Energy$$

ATP – adenosine triphosphate



- Bonds between phosphates are unstable
- Lowering the activation energy
- Easily broken by hydrolysis
- Reactions is catalysed by ATPase
- Release energy

Synthesis of ATP:

- Reversible reaction
- Synthesis of ATP from ADP occurs in 3 ways:
  1. Chlorophyll-containing plants during photosynthesis
  2. Plants and animal cells during respiration
  3. Plant and animal cells when pH groups are transferred from donor to ADP.

Roles of ATP:

- Immediate energy source
- Metabolic processes
- Movement
- Active transport
- Secretion (forms lysosomes)
- Activation of molecules (phosphate can be used to lower activation energy and enzyme catalysed reactions)
- Better than glucose because:
  1. It requires less energy to release ATP molecules
  2. ATP is released in small quantities and is therefore manageable
  3. Hydrolysis of ATP is a single, one-step reaction

- ATP can't be stored; it's continuously produced in the mitochondria
- ATP is mostly present in the small intestine and muscle fibers.

2.4 Water and its functions

Properties:

- Polar molecule
- Hydrogen bonds between water molecules
- Acts as a buffer against sudden temperature fluctuations
- **High latent heat of vaporisation** (how much energy it takes to evaporate 1 g of water)
- **Cohesive** (tendency for water molecules to stick together which allows water to be pulled up a tube)
- **Surface tension** (when water molecules meet air they tend to pull back into the body of water than escape it)

General uses:

- Mammals are around 65% water
- Hydrolysis and condensation reactions
- Chemical reactions
- Photosynthesis
- Water as a solvent for enzymes
- Evaporates leaving organisms cool

Inorganic uses:

- Iron ions – haemoglobin
- Phosphate ions – structural role in DNA and storing energy by ATP
- Hydrogen ions – determine pH and function of enzymes
- Sodium ions – transportation of glucose and amino acids across cell membranes

3.1 Methods of studying cells

Microscopy:
- Produces a magnified image
- Convex glass lens
- Light microscopes can only distinguish between objects which are 0.2um apart
- Electron microscopes can distinguish objects that are 0.1um apart.

$$\text{magnification} = \frac{\text{size of image}}{\text{actual size of object}}$$

Magnification	The size of the image is compared to real life
Resolution	The smallest distance where 2 discrete objects will be seen as separate

Cell fractionation	Process where cells are broken up and the cells are separated
	Conditions necessary: 1. Cold – to reduce enzyme activity 2. Equal water potential as tissue – to prevent organelles from bursting and shrinking 3. Buffered – so pH doesn't fluctuate
Stage 1: Homogenation	➢ Cell are broken up by a homogeniser ➢ This releases organelles from the cell = homogenate ➢ The homogenate is filtered
Stage 2: Ultracentrifuge	A process where the homogenate is separated in a centrifuge. ➢ Tube of filtrate is placed in centrifuge and spun at low speed ➢ Heaviest organelle (nuclei) is forced to the bottom which forms a sediment/pellet ➢ The supernatant (fluid on top) is removed, leaving the sediment ➢ The centrifuge is spun at a faster speed to form a second sediment consisting of the next heaviest organelle (mitochondria) ➢ The process continues

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3.2 The electron microscope
- Beam has a short wavelength meaning it has a high resolution power
- As electrons are negatively charged the beam can be formed by electromagnets

Transmission Electron Microscope (TEM)	**Scanning Electron Microscope (SEM)**
➢ Electron gun produces beam ➢ Beam focused onto specimen by a condenser electromagnet ➢ Beam passes through the specimen. If beam falls onto the specimen, it's absorbed and that part appear dark. If beam doesn't fall onto the specimen, it appears white - Photomicrograph (it can be photographed)	➢ Electron gun produces beam ➢ Beam focused onto specimen by a condenser electromagnet ➢ Beam bounces off the surface of the specimen to produce a 3D image - Photomicrograph (it can be photographed)
Limitation: - Must be in a vacuum, therefore no living specimen - Complex staining process therefore may contain artefacts - Image is in black and white and in 2D - Specimen must be very thin	- Specimen doesn't need to be thin - Lower resolution than TEM

3.3 Measurements and calculations

You can measure cells by using an eyepiece graticule (a glass disk). Depending on the magnification it will need to be calibrated. Calibrating the microscope:

1. Place of stage micrometre onto the stage of the light microscope
2. Focus the microscope so that both the stage micrometre and eyepiece graticule are in clear view