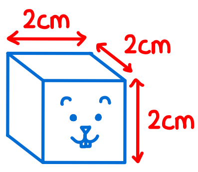
SURFACE AREA AND VOLUME

Surface area : volume ratio

- Smaller organisms have a larger surface area : volume (SA:V) ratio
- As size increases, SA:V ratio decreases

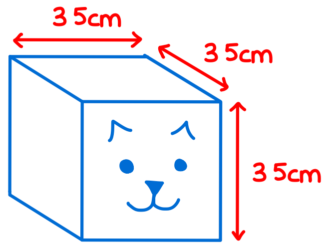
ratio = $\frac{\text{surface area}}{\text{volume}}$



surface area
= (2×2)×6 = 24cm²

volume
= 2×2×2 = 8cm³

SA V = 24 8 = 3 1



surface area
= (3 5×3 5)×6 = 73 5cm²

volume
= 3 5×3 5×3 5 = 42 9cm³

SA V = 73 5 42 9 = 17 1

Exchange and transport

- Organisms need to exchange substances with the environment
  - → waste products (e.g. carbon dioxide, urea) need to be excreted
  - → oxygen and glucose are needed for aerobic respiration
  - → heat is also exchanged
- Unicellular organisms → can rely on diffusion to exchange substances
  - → short diffusion distance from cell surface to centre of cell
  - → larger SA:V ratio
- Multicellular organisms → need exchange and transport systems
  - → long diffusion distance from body surface to centre of body so diffusion would take much too long
  - → smaller SA:V ratio so cannot exchange enough substances through surface by diffusion at a sufficient rate

Oxygen consumption

- As body mass increases, rate of oxygen consumption decreases
  - → respiration releases heat
  - → a small animal with a higher SA:V has faster heat loss per gram of body mass, so has a faster rate of respiration to replace heat
  - → larger organisms lose less heat through their surface due to smaller SA:V ratio so less respiration is required to replace heat

> Remember when comparing heat loss you have to look at heat loss per unit of body mass in order to make valid comparisons.

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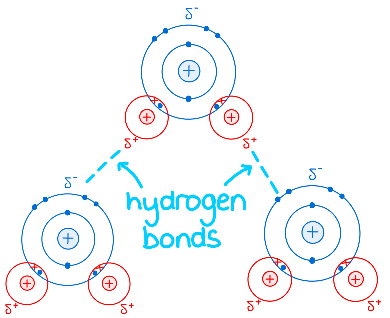
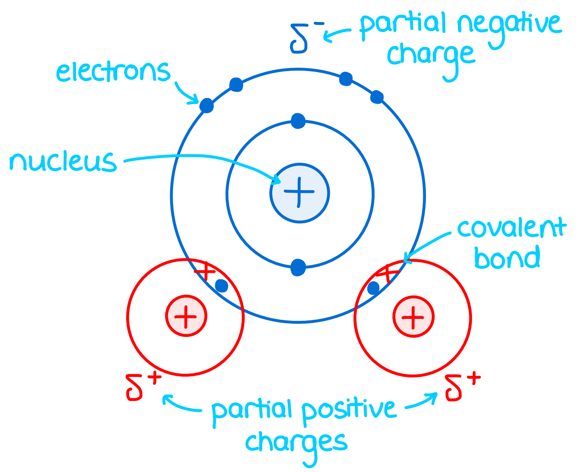
WATER

Structure

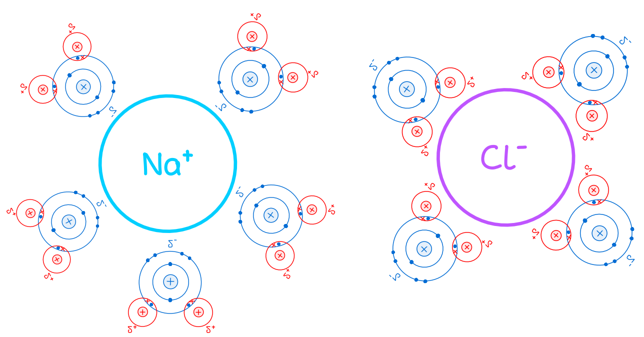
- Two hydrogen atoms share electrons with one oxygen atom (covalent bonds)
- Electrons pulled towards oxygen → hydrogens have a partial positive charge
- Oxygen has two lone (unshared) electron pairs → oxygen has a partial negative charge
- A dipolar molecule due to uneven charge
- Partial charges attract other water molecules
  - → this forms hydrogen bonds





Properties

- Good solvent → dipolar water molecules surround and are attracted to ions, which separates them
  - → water molecules form hydrogen bonds with other polar molecules so they dissolve and can be transported



Ions are charged (either positive or negative).

- Strong cohesion → dipolar water molecules stick together with hydrogen bonds
  - → water flows well because it is a cohesive liquid

- High latent heat of vaporisation → lots of energy needed to break hydrogen bonds
  - → uses lots of heat energy to evaporate so it has a cooling effect

Sweat forms droplets on the skin then uses heat energy from the skin to evaporate, cooling you down in the process.

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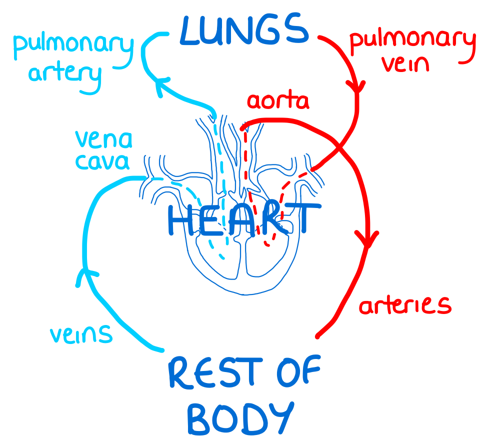
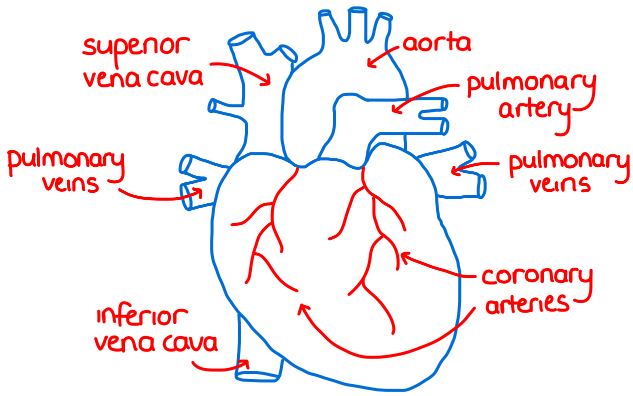
CIRCULATORY SYSTEM

Human circulatory system

- Consists of the heart and blood vessels
- Double circulatory system → one loop through the heart and lungs, one loop through the heart and body
- Transport system needed due to low surface area to volume ratio
- Blood transports oxygen, carbon dioxide, glucose, amino acids, urea, hormones, and many other things

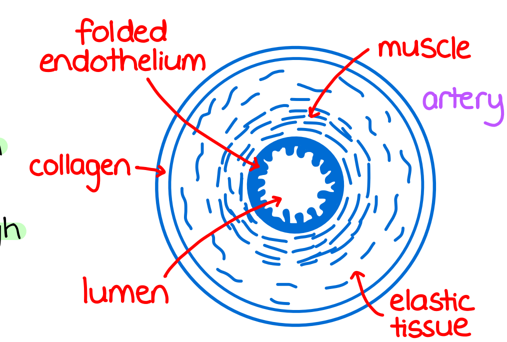




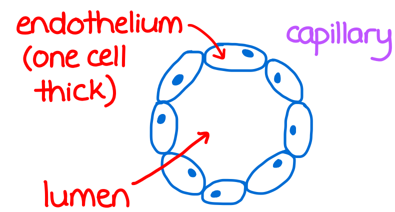
This is the external structure of the heart. The blood vessels may appear branched and crossed over. More about the heart on the next page.

Blood vessels

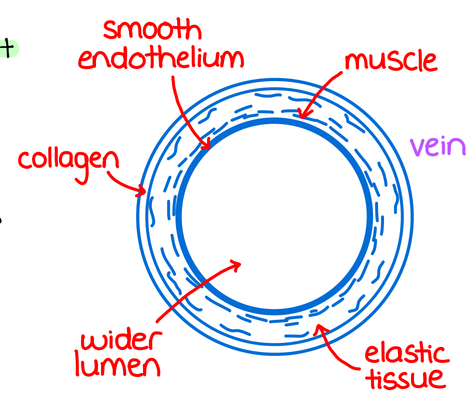
- Arteries → carry oxygenated blood from the heart to the body (except pulmonary artery)
  - → thick layer of muscle tissue can contract to maintain high blood pressure
  - → elastic fibres allow stretch and recoil to maintain high blood pressure
  - → collagen layer to withstand high blood pressure
  - → folded endothelium allows stretching
  - → coronary arteries supply the heart muscle with blood



- Capillaries → endothelium is one cell thick to give a short diffusion distance for exchange
  - → site of gas exchange
  - → large number to increase surface area for exchange



- Veins → carry deoxygenated blood from the body back to the heart (except pulmonary vein)
  - → wider lumen to reduce resistance to blood flow under low pressure
  - → thinner walls (less muscle and elastic tissue) than arteries because blood pressure is lower
  - → blood under low pressure so valves prevent backflow
  - → smooth endothelium to reduce resistance to blood flow



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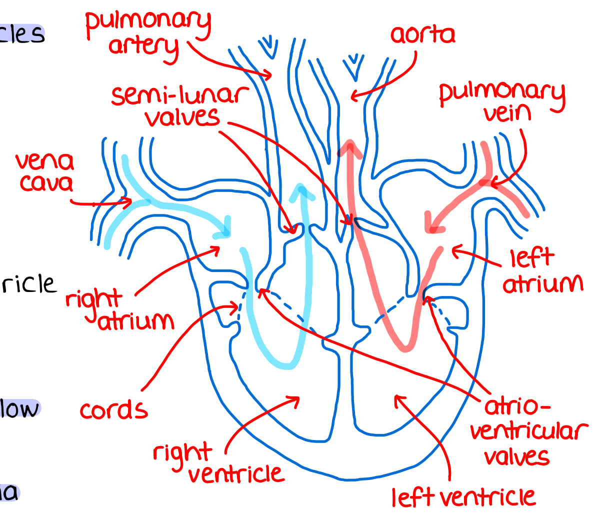
ZH Tutorials

THE HEART

Human heart structure

- Four chambers with muscular walls → two atria, two ventricles
- Right side pumps deoxygenated blood to the lungs
- Left side pumps oxygenated blood to the body
- Walls of ventricles have more muscle than walls of atria
  → more contraction force needed to produce higher blood pressure to get blood to the whole body and lungs
- Wall of left ventricle has more muscle than the right ventricle
  → blood must be under higher pressure to travel round the whole body rather than the lungs
- Atrioventricular valves and semi-lunar valves prevent backflow of blood when they close
- Cords prevent atrioventricular valves being forced into atria

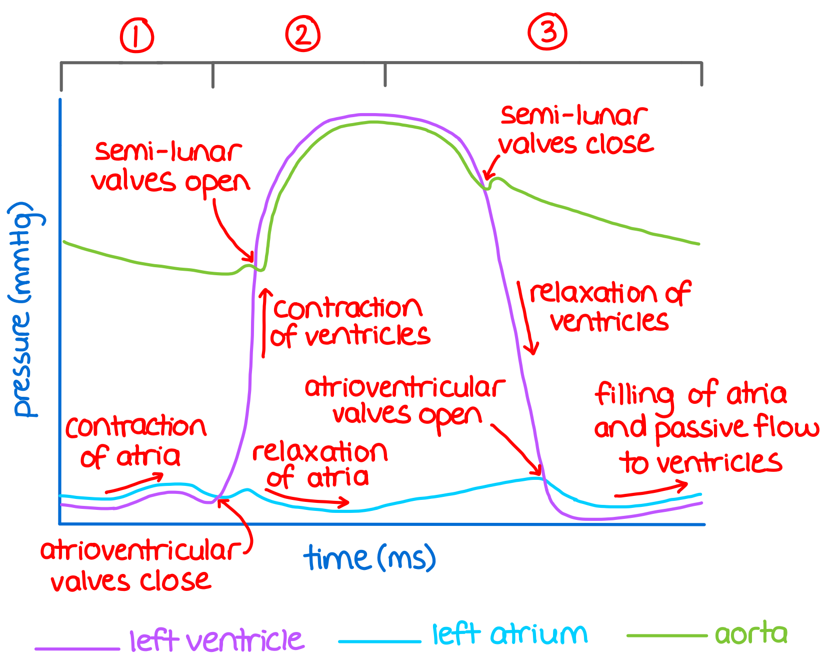


Cardiac cycle

- Changes in volume and pressure due to contraction and relaxation of the atria and ventricles
- One cycle = one heartbeat

① Atrial systole:
- Ventricles relax (ventricular diastole)
- Atria contract → volume decreases, pressure increases
- Atrioventricular valves are open
- Blood forced into ventricles (volume and pressure rise slightly)

② Ventricular systole:
- Atria relax (atrial diastole)
- Ventricles contract → volume decreases, pressure increases
- Atrioventricular valves close
- Semi-lunar valves open
- Blood forced into aorta and pulmonary artery



③ Cardiac diastole:
- Atria still relaxed
- Ventricles relax
- Semi-lunar valves close
- Blood returns to the atria → volume and pressure increase
- Atrioventricular valves open → passive flow from atria to ventricles

> The last stage is called cardiac diastole because all chambers are relaxed.

- Blood flow is unidirectional → pressure changes cause valves to open or close
  e.g. when pressure is higher in the atria than the ventricles the atrioventricular valves open, and when pressure is higher in the ventricles than the atria the atrioventricular valves close

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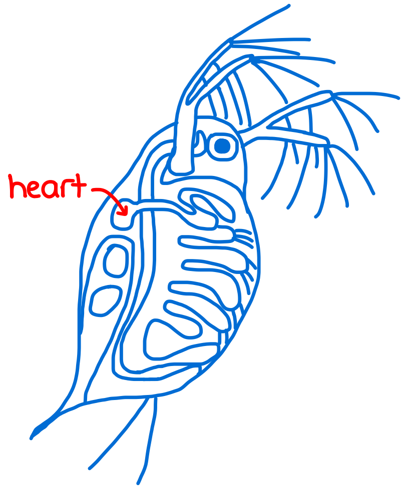
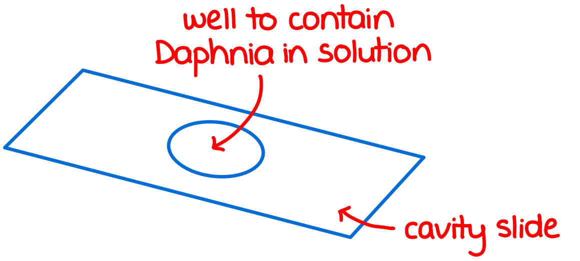
THE HEART

Investigating the effect of caffeine on heart rate

- Daphnia are good organisms to use
  - → transparent bodies so the heart is visible
  - → invertebrates have undeveloped nervous systems so do not feel pain (but could still be considered unethical to use a living organism that cannot consent for an experiment)
  - → aquatic organisms so can take in caffeine from a solution by diffusion
- Immobilise a Daphnia using a cavity slide
  - → add the same volume of caffeine solution and allow time for it to acclimatise and the caffeine to be absorbed
  - → have a control solution with no caffeine to allow comparison of heart rate
- Use at least 10 Daphnia for each caffeine concentration → allows calculation of a mean and identification of anomalous results (increases validity of comparisons)
- Count heart rate for a short amount of time e.g. 20 seconds → heart rate is very fast so less chance of errors
- Control biotic factors e.g. age and size of Daphnia
- Control abiotic factors e.g. temperature of solution
- There is a positive correlation between caffeine concentration and heart rate
  - → use a statistical test to see if the correlation is significant





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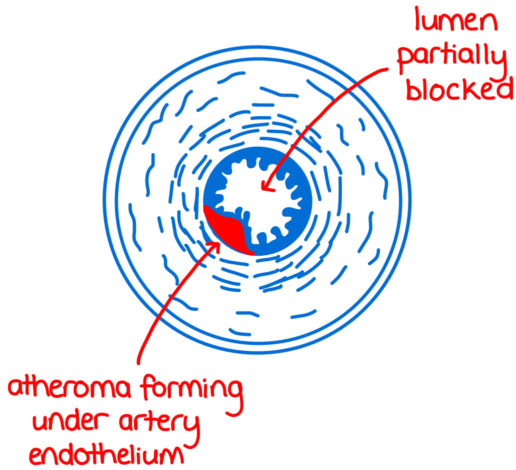
CARDIOVASCULAR DISEASE

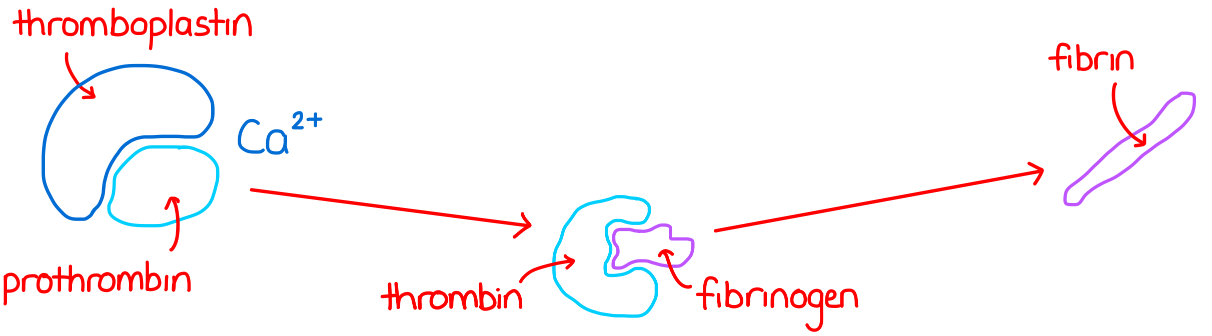
Atherosclerosis

- High blood pressure damages the artery endothelium
- Inflammatory response to damage
  → white blood cells and cholesterol from LDL cholesterol accumulate to form an atheroma
- Calcium salts and fibrous tissue build up with the atheroma and a plaque forms
- Atheroma narrows the artery lumen
  → blood flow is reduced and blood pressure increases further
- If the blockage is in the coronary arteries it can lead to a myocardial infarction (heart attack)
  → the heart muscle tissue is not receiving enough oxygen for aerobic respiration
  → cardiac muscle contraction is weaker and tissue death can occur



Blood clotting

- Damage to the artery endothelium exposes collagen → thromboplastin is released by platelets
- Thromboplastin → enzyme which converts prothrombin to thrombin
- Calcium ions are needed for the conversion of prothrombin to thrombin
- Thrombin → enzyme which converts fibrinogen (soluble protein) to fibrin (insoluble protein)
- Fibrin forms a mesh of protein fibres and traps red blood cells → a blood clot forms
- Blood clots can block arteries → blocking the coronary arteries could result in a heart attack
  → blocking an artery in the brain could result in a stroke



Cardiovascular disease (CVD) treatments

- Antihypertensives → lower blood pressure so reduce risk of damage to artery endothelium and atheroma formation
  → side effects include dizziness, nausea, muscle cramps, kidney failure, fainting
- Statins → reduce LDL cholesterol produced by the liver so reduces risk of atheroma formation
  → side effects include headaches, dizziness, nausea, liver damage, muscle pain
- Anticoagulants → reduce blood clotting so reduce risk of arteries becoming blocked
  → side effects include blood in urine or faeces, severe bruising, prolonged nosebleeds
- Platelet inhibitors → reduce risk of blood clots forming so arteries are less likely to be blocked
  → side effects include rashes, digestive problems, prolonged nosebleeds, nausea

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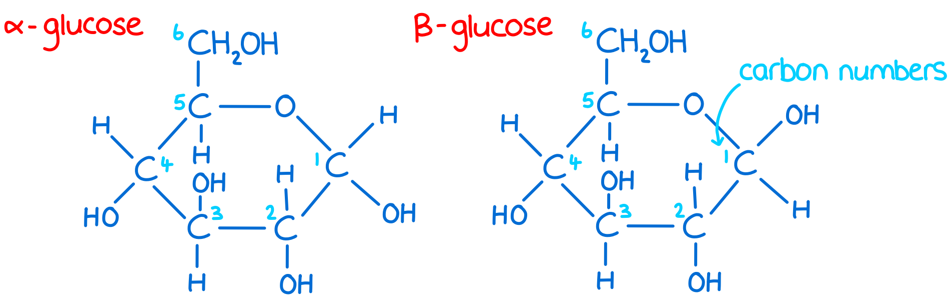
CARBOHYDRATES

- Carbohydrates contain carbon, hydrogen and oxygen, usually with the general formula $C_nH_{2n}O_n$

Glucose

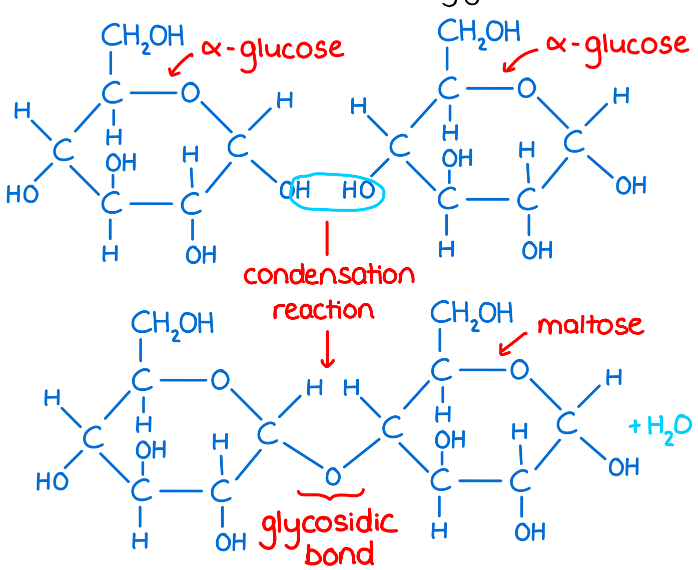
- A monosaccharide with the formula $C_6H_{12}O_6$
- A hexose monosaccharide (six carbon atoms) in a ring structure
- Soluble in water → easily transported
- Main energy source for animals and plants
  → used in respiration
- Two isomers: α-glucose and β-glucose → H and OH groups on carbon 1 inverted in β-glucose

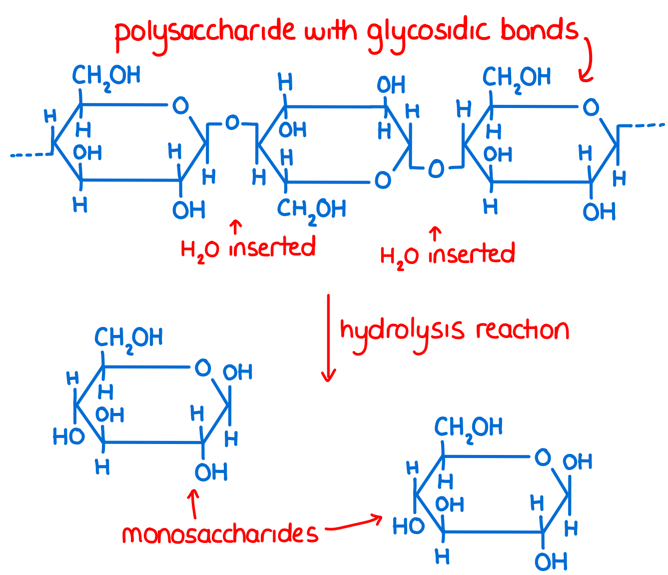
Monosaccharides are small soluble carbohydrate monomers. They also include fructose and galactose.



Glycosidic bonds and condensation/hydrolysis reactions

- Condensation reaction: two molecules join to form a new chemical bond and a water molecule is eliminated
- Condensation reactions form glycosidic bonds between monosaccharides to create disaccharides and polysaccharides
- Hydrolysis reaction: a water molecule is used and the chemical bond is broken (reverse of a condensation reaction → breaks glycosidic bonds)





Disaccharides

- Two monosaccharides joined together with a glycosidic bond in a condensation reaction
- Maltose = α-glucose + α-glucose
- Sucrose = α-glucose + fructose
- Lactose = β-glucose + galactose

Monosaccharides and disaccharides are sugars.

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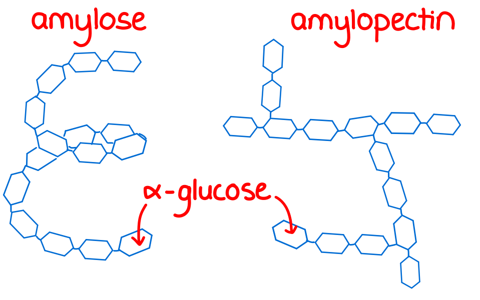
CARBOHYDRATES

Polysaccharides

- Large polymers of monosaccharides joined with glycosidic bonds
- Starch and glycogen are large energy storage molecules which cannot leave cells → too large to diffuse across the cell-surface membrane

Starch

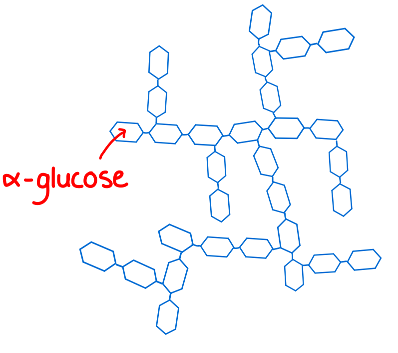
- Glucose storage in plants
  → hydrolysed when glucose is needed for respiration
- Insoluble in water → does not have an osmotic effect on the cell
- Amylose → unbranched α-glucose polysaccharide (1,4 glycosidic bonds)
  → compact (coiled structure) so more can be stored
- Amylopectin → branched α-glucose polysaccharide (1,4 and 1,6 glycosidic bonds)
  → branches mean it can be rapidly hydrolysed by enzymes (amylase) to release glucose



Branches are attached with 1,6 glycosidic bonds.

Glycogen

- Excess glucose storage in animals
  → hydrolysed when glucose is needed for respiration
- Insoluble in water → does not have an osmotic effect on the cell
- Highly branched α-glucose polysaccharide (1,4 and 1,6 glycosidic bonds) → more terminal ends for rapid hydrolysis
- Compact so more can be stored



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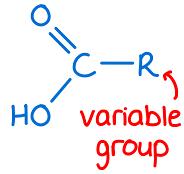
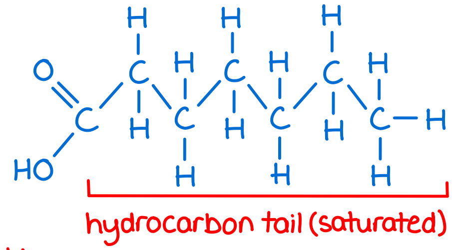
LIPIDS

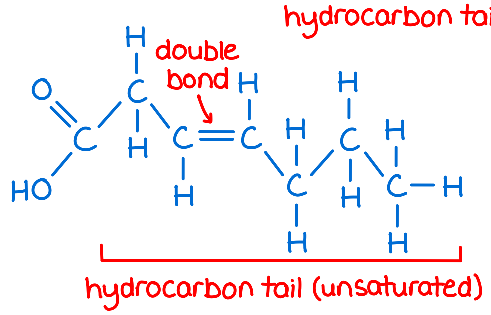
- Lipids contain carbon, hydrogen and oxygen

Fatty acids

- Have a variable R group → the hydrocarbon tail
- Saturated fatty acids have no double C=C bonds in the hydrocarbon tail
- Unsaturated fatty acids have one or more double C=C bonds in the hydrocarbon tail so the chain kinks
- Hydrocarbon tails are hydrophobic (insoluble in water)
- Can lower pH because they are acidic

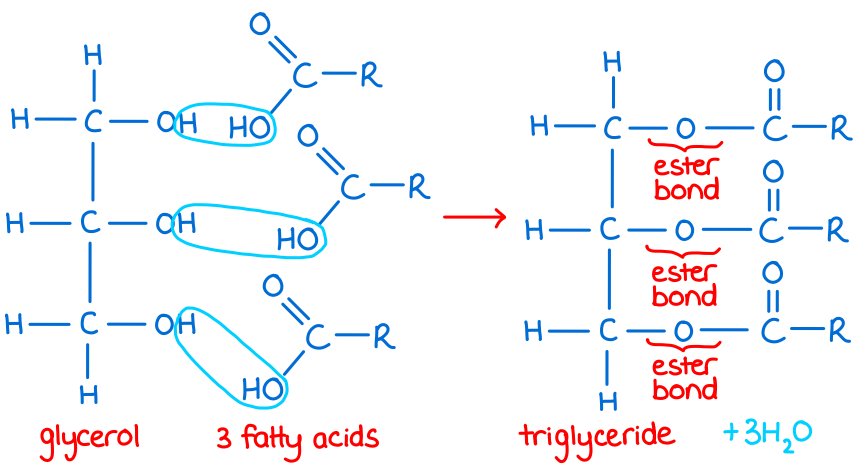




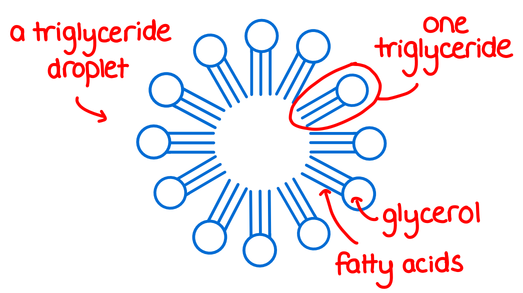


Triglycerides

- One molecule of glycerol bound to three fatty acids
- Fatty acids join to glycerol in a condensation reaction → an ester bond is formed and a water molecule is released
- Three water molecules released and three ester bonds formed for each triglyceride
- Ester bonds are broken by a hydrolysis reaction
- Energy store → hydrocarbon tails release a lot of energy when broken down
- Insoluble in water → do not have an osmotic effect on the cell
- Clump together in droplets with the hydrophobic hydrocarbon tails facing inwards



Know how to relate structure to function.



Lipase hydrolyses triglycerides to fatty acids and glycerol in the gut. Fatty acids and glycerol can be absorbed.

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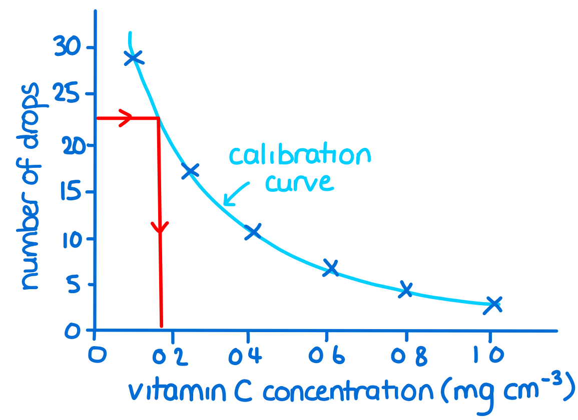
VITAMIN C CONTENT

Investigating vitamin C content

- DCPIP → a blue indicator dye which turns colourless when vitamin C is present
- Titration with DCPIP can be used to find vitamin C content of food and drink
- To produce a calibration curve using known concentrations of vitamin C:

1) Make about six different concentrations of vitamin C solution.
2) Measure a set volume and concentration of DCPIP into six tubes.
3) Add a vitamin C solution dropwise to each one, shaking after each addition for the same amount of time.
4) Record the number of drops or volume taken to turn each tube colourless.
5) Repeat twice more and calculate a mean for each concentration. Only use concordant results (do not use anomalous results).
6) Plot on a graph and draw a best fit curve.



The calibration curve can be used to test vitamin C solutions of unknown concentration.

- If extracting vitamin C from solid food, extract from the same mass of sample by soaking in water for a set amount of time
- Consider relevant control variables e.g. temperature, volume and concentration of DCPIP

> Raw foods will contain more vitamin C than cooked food because it is able to diffuse into cooking water and be destroyed by the heat.

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HEALTH RISK FACTORS

Blood cholesterol and CVD

- LDL cholesterol
  - → a lipoprotein consisting of saturated triglycerides packaged with cholesterol and protein
  - → transports cholesterol in the blood
  - → binds to receptors on cell-surface membranes and gets taken into cells by endocytosis
  - → accumulates in the blood if all receptors are occupied and can be deposited to form atheromas in arteries
  - → increases total blood cholesterol
- HDL cholesterol
  - → a lipoprotein consisting of unsaturated triglycerides packaged with cholesterol and protein
  - → transports cholesterol from the blood to the liver for excretion or recycling
  - → reduces total blood cholesterol
- The ratio of LDL to HDL cholesterol is a risk factor for CVD
  - → high LDL cholesterol relative to HDL cholesterol increases total blood cholesterol and CVD risk
  - → blood tests can check this ratio

Other CVD risk factors

- Genetics → some alleles increase the chances of having high blood pressure or high blood cholesterol
- Diet → a high salt diet increases blood pressure which increases risk of damage to the artery endothelium
  - → a high saturated fat diet can increase blood LDL cholesterol
- Age → CVD risk increases with age
- Gender → men are more likely to develop CVD than women
- High blood pressure → increases risk of damage to the artery endothelium
- Smoking → nicotine stimulates release of adrenaline which increases blood pressure
  - → carbon monoxide reduces the amount of oxygen transported in the blood so tissues (e.g. heart muscle) receive less oxygen
- Inactivity → not getting enough exercise increases blood pressure and means someone is more likely to be obese
- Obesity → a high body mass index (BMI) can increase blood pressure
- Perceived risk can be different to actual risk
  - → people could inaccurately report their dietary intake or exercise
  - → people could overestimate or underestimate the importance of certain risk factors due to lack of reliable information
  - → family history may not be fully known
  - → lack of education means that people might not be aware of risk factors

> People can use knowledge of these risk factors to change their lifestyle and lower their risk, but some are not controllable.

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HEALTH RISK FACTORS

Energy imbalance and body mass index (BMI)

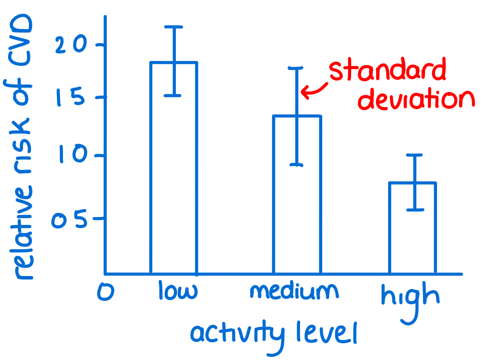
- Energy budget → the amount of energy taken in (in food and drink) versus the amount of energy used up e.g. in metabolic reactions and through exercise
- An imbalanced energy budget can result in weight gain or weight loss
- Excess energy is stored as glycogen and fat in cells → leads to weight gain and increased BMI
- Excess sugars are converted to fat → leads to weight gain and increased BMI
- BMI is calculated within a range on a scale of values → a healthy BMI is between 18 and 25
  → greater than 30 is classed as obese
- High BMI is related to high blood pressure (therefore increased CVD and stroke risk)
- Increased body mass can damage cartilage in joints
- High BMI is related to reduced sensitivity of insulin receptors and increased risk of type 2 diabetes
- Waist to hip ratio is another way to assess whether someone is obese
  → ratio above 1 is a risk factor for CVD

$$\text{BMI} = \frac{\text{body mass (kg)}}{\text{height}^2\ (\text{m}^2)} \qquad \text{waist to hip ratio} = \frac{\text{waist (cm)}}{\text{hips (cm)}}$$

> Lipase inhibitors could help treat obesity by reducing lipase activity in the gut.

Evaluating studies

- Studies need to be valid and reliable
  → a valid study is well controlled so only one variable is being tested
  → a reliable study uses a large sample size, using people who are representative of the population being studied e.g. British women who do not smoke
  → a reliable study can be repeated by other scientists to get the same result
- Evidence can be conflicting → one study may identify something as a risk factor whereas another study might conclude it is not a risk factor
- Standard deviation is an indication of the spread of data around the mean
  → overlapping standard deviations shows there is likely to be no significant difference between the means (but this should be confirmed with a statistical test e.g. a t-test)
  → using standard deviation increases the validity of the mean



In this (made up!) data, increasing activity level is associated with a decrease in relative CVD risk. However there is no significant difference between low and medium, and medium and high, because the standard deviations overlap. There is only a significant difference between low and high. However this does not necessarily mean that there is a casual relationship (see below).
In an evaluation, you would also need to comment on the validity of the conclusion e.g. was it a large sample size.

Correlation vs causation

- A correlation means that a change in one variable is associated with a change in another
  → does not necessarily mean that the change in one variable caused the change in the other
  → correlation can be positive or negative
- Controlling as many variables as possible makes a conclusion of a casual relationship more valid

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