DIGESTION

Digestive system

Organisation in living organisms

Cells
The basic building blocks of organisms

Tissues
Groups of similar cells

Organs
Groups of different tissues performing a function

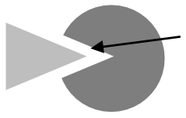
Organ systems
Groups of organs working together to form organisms

The **digestive system** is an organ system responsible for digesting and absorbing food, and excreting waste products.

How does digestion occur?

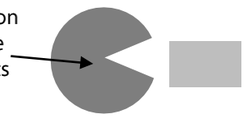
Enzymes catalyse reactions throughout the **digestive system** to **break down food** (carbohydrates, lipids and proteins) into **smaller soluble molecules** that can be absorbed into the **blood** for transport around the body. The resultant molecules can be used to **make new carbohydrates, lipids and proteins**, and some glucose is used in cellular **respiration**.

Enzyme-catalysed reactions



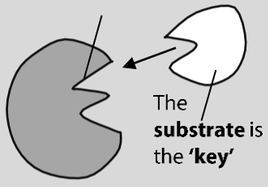
The specific reaction an enzyme catalyses depends on the shape of its **active site**, an area that binds to complementary substrate molecules during reactions.

This enzyme will not catalyse a reaction involving this substrate because the substrate is not complementary to its active site.



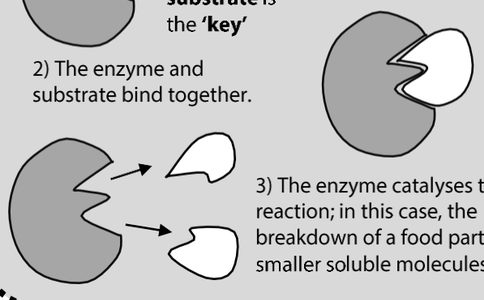
Lock and key model

The enzyme's **active site** is the **'lock'**



1) The substrate fits perfectly into the active site – they are specific to each other (like a key in a lock).

2) The enzyme and substrate bind together.



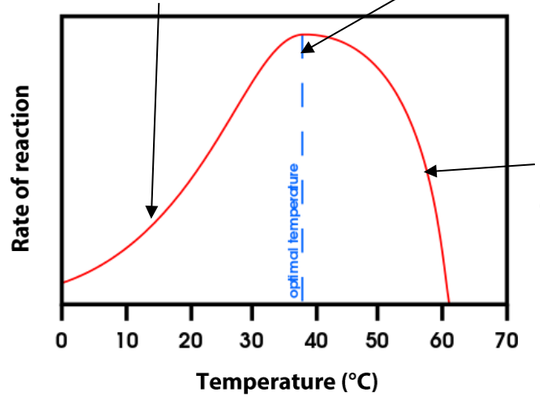
3) The enzyme catalyses the reaction; in this case, the breakdown of a food particle into smaller soluble molecules.

Rate of reaction

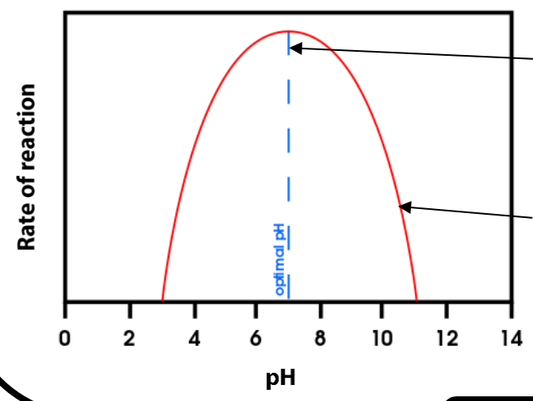
Factors that affect the rate of enzyme-catalysed reactions

As temperature increases, particles have more kinetic energy and move around more. Enzyme and substrate are more likely to collide, so **reaction rate increases**.

Most digestive enzymes in the human body work best at **37 °C**, because this is the temperature of the human body.



If the temperature becomes too high, the enzyme **denatures** (the active site changes shape so that the substrate no longer fits).



Different enzymes work best at different **pH** values.

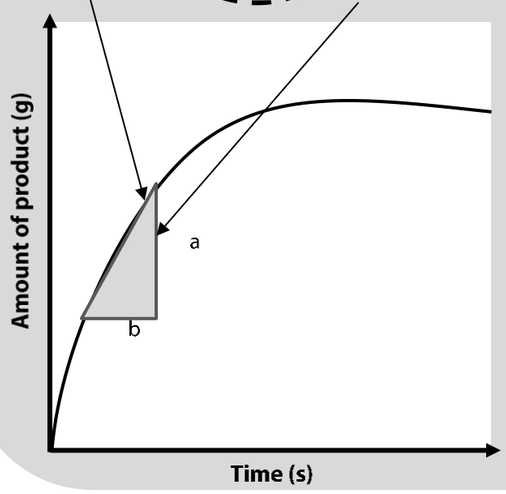
At certain pH values, **bonds in the enzyme break down**, causing the active site to change shape so that the substrate no longer fits inside it.

Practical: investigating effect of pH on rate of reaction of amylase enzyme

Procedure

1) Place test tubes of **starch solutions** in a water bath at 37 °C.
2) Add a **buffer** with a different pH value to each test tube of starch solution.
3) Set up **spotting tiles** with drops of iodine in rows.
4) Add **amylase** into one of the test tubes and start the **stopwatch**.
5) Every 20 seconds, use a pipette to **take a sample** from the test tube and add it to a drop of iodine on the spotting tile.
6) If the reaction has taken place, **iodine** will turn from yellow-red to blue-black.
7) **Repeat** this for each of the test tubes. Record the time it takes for the reaction to take place at each pH in a table.

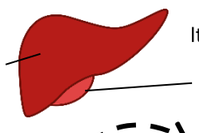
1. Draw a **straight line** on the curve of the graph to represent the gradient at this point – this is the **tangent**.
2. Draw a **horizontal and vertical line** from the tangent to form a right-angled triangle.
3. Measure the **change in product** from the vertical line of the triangle (a) and the **change in time** from the horizontal line of the triangle (b).
4. **Divide (a) by (b)** to find the **gradient**, which is the **rate of reaction**.
5. **Units** for rate of reaction come from the graph. For example, y is in grams (g) and x is in seconds (s), so units for rate are **g/s**.



Digestion of food

Food type	Enzyme	Reaction (breaking down	Where the enzyme is	Food test
Carbohydrate	Amylase, a	Starch →	Small intestine,	**Iodine solution** turns from yellow
				Benedict's solution turns from blue to
Lipid	Lipases	Lipids →	Small intestine,	Dissolve in
Protein	Proteases	Proteins → Amino acids	Small intestine,	**Biuret reagent** (corrosive) turns from blue to purple if protein is present.

Role of bile



Bile is made in the liver.

It is stored in the gall bladder.

Bile is secreted into the small intestine, where it **emulsifies fat into smaller droplets**, increasing the surface area of the lipid.

It also **neutralises hydrochloric acid** from the stomach to make conditions in the small intestine more alkaline.

Overall, the action of bile **speeds up the breakdown of fat** into glycerol and fatty acids by lipases.

CELL TRANSPORT

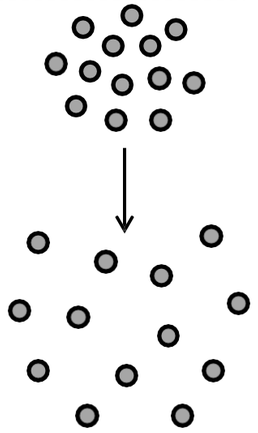
Diffusion

What is diffusion?

The random movement of particles of a gas or a substance in a solution means that they spread out. This causes a net movement of particles down a concentration gradient (from a high concentration to a low concentration).

Why is diffusion important in our bodies?

Diffusion occurs across cell membranes all the time in our bodies, into and out of cells.



For example:

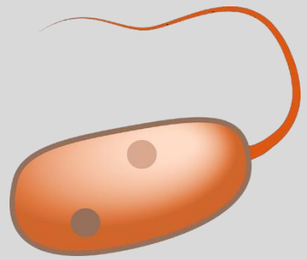
- Urea diffuses out of the cells and into the blood to be excreted by the kidneys.
- Oxygen diffuses into the lungs, and carbon dioxide diffuses out of the lungs, in gas exchange.

Factors that increase diffusion rate:

1. **Steep concentration gradient:** the bigger the difference in concentration between two areas, the faster diffusion will occur
2. **Large surface area of membrane:** the larger the area, the more diffusion will take place within a set period of time
3. **Temperature:** at higher temperatures, particles have more kinetic energy so move more quickly and have a higher rate of diffusion

Single-celled organisms

Single-celled organisms have a large SA:V, so **diffusion** of molecules into and out of the cell provides for all of their needs (exchanging gas, gaining nutrition and removing waste).



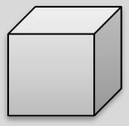
Tissue adaptations for diffusion

Larger multicellular organisms need transport systems because their SA:V is too small for diffusion alone to meet their needs for survival. These transport systems have adaptations to maximise the rate of diffusion.

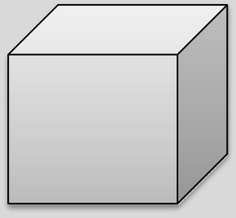
Structure	Short diffusion distance	Large surface area	Steep concentration gradient
Cells lining small intestine	Thin membranes	Membrane folded into villi and microvilli	Concentration of soluble food molecules higher in gut than in bloodstream
Alveoli	Thin membranes	Folded	Good blood supply and well ventilated
Fish gills	Thin filaments	Stacks of thin filaments	Good blood supply and continuous pumping of water over gills by flap called operculum
Plant root hairs	Thin membranes	Long and thin	Water is pulled away from roots by transpiration
Plant leaves	Thin structures	Flat and thin	Lots of air spaces and stomata

Surface area:volume ratio

We can calculate and compare the surface area:volume ratio (SA:V) of different organisms. Here, we use cubes to demonstrate how:



This cube has a width of 2 cm, a height of 2 cm and a depth of 2 cm. To find its surface area, we simply multiply the length and width:
2 × 2 = 4 cm
and then multiply the result by the number of sides (6):
4 × 6 = 24 cm²
To find the volume, we multiply the width by the height and multiply this by the depth:
2 × 2 × 2 = 8 cm³
So, for this cube, the **SA:V = 24:8**, or simplified, **3:1**.



For a larger cube with sides of 4 cm, following the same method, we find that the **SA:V = 96:64** or **1.5:1**. This ratio is smaller than that of the smaller cube. This demonstrates that as objects or organisms increase in size, their surface area to volume ratios decrease.

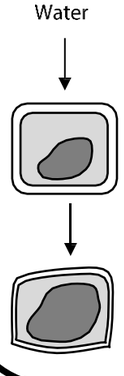
Osmosis

What is osmosis?

Diffusion of water from a more **dilute solution** (lots of water) to a more **concentrated solution** (less water) across a **partially permeable membrane**.

Investigating the effect of different concentrations of salt solution on sweet potato tissue

1. Cut sweet potato into equal-sized cuboids
2. Weigh the pieces
3. Put the pieces into solutions containing different concentrations of salt
4. Remove from solution, dry with paper towel
5. Weigh the pieces again
6. Calculate percentage gain or loss of plant tissue mass



If the tissue has gained mass, water must have diffused into the cells by osmosis because the solution is more dilute than inside the cells of the plant tissue.

If the tissue has lost mass, water has diffused out of the cells into the solution because the solution is more concentrated than inside the plant cells.

Calculating percentage gain/loss

$$\% \text{ change} = \frac{(end\ mass - start\ mass)}{start\ mass} \times 100$$

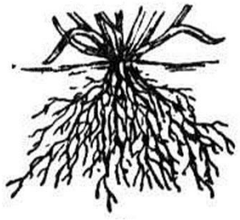
Worked example:
Tissue mass at start: 4.5 g
Tissue mass at end: 6.2 g
(6.2 g – 4.5 g) ÷ 4.5 × 100 = +37.8 g
The plus sign shows a gain in mass. If mass was lost, a minus sign would be in front of the value.

Active transport

What is active transport?

Movement of substances against their concentration gradient (from low to high concentration) using energy in the form of ATP from respiration.

Why is active transport important?



Mineral ions are at low concentration in the soil but are required for plant growth so are taken up by active transport by root hair cells.

Sugar molecules are at a lower concentration in the gut than the blood, but are needed for respiration.

So, sugar molecules are selectively reabsorbed by the kidney, via active transport, and transferred to the blood.