

Edexcel IGCSE Biology

Topic 2: Structure and Functions in Living Organisms

Notes

(Biology only in bold)

Cell structure

Level of organisation (2.1)

Organelles: specialised subcellular structures found within living cells (detailed in the next section)

Cells: basic structural unit of a living organism,

Tissues: group of cells with similar structures, working together to perform the same function

Organs: group of tissues, working together to perform specific functions

Organ systems: group of organs with similar functions, working together to perform body functions

An example of this would be the respiratory **organ system**, containing the **lungs** (organ), which is made up of epithelial **tissue** consisting of epithelial **cells**.

Subcellular structures (2.2-2.4)

Found in plant and animal cells:

Structure	Function
Nucleus	<ul style="list-style-type: none"> ● Contains the genetic material, which codes for a particular protein ● Enclosed in a nuclear membrane.
Cytoplasm	<ul style="list-style-type: none"> ● Liquid substance in which chemical reactions occur. ● Contains enzymes (biological catalysts, i.e. proteins that speed up the rate of reaction). ● Organelles are found in it
Cell membrane	<ul style="list-style-type: none"> ● Contain receptor molecules to identify and selectively control what enters and leaves the cell
Mitochondria	<ul style="list-style-type: none"> ● Where aerobic respiration reactions occur, providing energy for the cell
Ribosomes	<ul style="list-style-type: none"> ● Where protein synthesis occurs. ● Found on a structure called the rough endoplasmic reticulum.

Found only in plants:

Structure	Function
Chloroplasts	<ul style="list-style-type: none"> ● Where photosynthesis takes place, providing food for the plant ● Contains chlorophyll pigment (which makes it green) which harvests the light needed for photosynthesis.
Permanent vacuole	<ul style="list-style-type: none"> ● Contains cell sap ● Found within the cytoplasm ● Improves cell's rigidity
Cell wall	<ul style="list-style-type: none"> ● Made from cellulose ● Provides strength to the cell

Cell differentiation and specialisation

Specialised cells (2.5B)

- Specialised cells are those which have develop certain characteristics in order to perform particular functions.
- Cells specialise by undergoing **differentiation**: a process that involves the cell gaining new sub-cellular structures in order for it to be suited to its role.
- Cells can either differentiate once early on or have the ability to differentiate their whole life (these are called **stem cells**).
- In animals, most cells only differentiate once, but in plants many cells retain the ability.

Examples of specialised cells in animals

Sperm cells: specialised to carry the male's DNA to the egg cell (ovum) for successful reproduction

- Streamlined head and long tail to aid swimming
- Many mitochondria (where respiration happens) which supply the energy to allow the cell to move
- The acrosome (top of the head) has digestive enzymes which break down the outer layers of membrane of the egg cell

Nerve cells: specialised to transmit electrical signals quickly from one place in the body to another

- The axon is long, enabling the impulses to be carried along long distances
- Having lots of extensions from the cell body (called dendrites) means branched connections can form with other nerve cells
- The nerve endings have many mitochondria which supply the energy to make special transmitter chemicals called neurotransmitters. These allow the impulse to be passed from one cell to another.

Muscle cells: specialised to contract quickly to move bones (striated muscle) or simply to squeeze (smooth muscle, e.g found in blood vessels so blood pressure can be varied), therefore causing movement

- Special proteins (myosin and actin) slide over each other, causing the muscle to contract
- Lots of mitochondria to provide energy from respiration for contraction
- They can store a chemical called glycogen that is used in respiration by mitochondria

Examples of specialised cells in plants

Root hair cells: specialised to take up water by osmosis and mineral ions by active transport from the soil as they are found in the tips of roots

- Have a large surface area due to root hairs, meaning more water can move in

- The large permanent vacuole affects the speed of movement of water from the soil to the cell
- Mitochondria to provide energy from respiration for the active transport of mineral ions into the root hair cell

Xylem cells: specialised to transport water and mineral ions up the plant from the roots to the shoots

- Upon formation, a chemical called lignin is deposited which causes the cells to die. They become hollow and are joined end-to-end to form a continuous tube so water and mineral ions can move through
- Lignin is deposited in spirals which helps the cells withstand the pressure from the movement of water

Phloem cells: specialised to carry the products of photosynthesis (food) to all parts of the plants

- Cell walls of each cell form structures called sieve plates when they break down, allowing the movement of substances from cell to cell
- Despite losing many sub-cellular structures, the energy these cells need to be alive is supplied by the mitochondria of the companion cells.

Stem cells in medicine (2.6B)

Characteristics

- A stem cell is an undifferentiated cell which can undergo division to produce many more similar cells
- Some of these will differentiate to have different functions, such as the specialised cells mentioned above
- They are important in **development, growth and repair**

Types of stem cells

1. Embryonic stem cells

- Form when an egg and sperm cell fuse to form a **zygote**
- They can differentiate into **any** type of cell in the body
- Scientists can clone these cells (through culturing them) and direct them to differentiate into almost any cell in the body
- These could potentially be used to replace insulin-producing cells in those suffering from diabetes, new neural cells for diseases such as Alzheimer's, or nerve cells for those paralysed with spinal cord injuries

2. Adult stem cells

- If found in **bone marrow** they can form **many** types of cells (not any type, like embryonic stem cells can) including blood cells

3. Meristems in plants

- Found in root and shoot tips

- They can differentiate into any type of plant, and have this ability throughout the life of the plant
- They can be used to make **clones** of the plant- this may be necessary if the parent plant has certain desirable features (such as disease resistance), for research or to save a rare plant from extinction

Stem cells in medicine

Benefits	Risks
Can be used to replace damaged cells , such as in type 1 diabetes, multiple sclerosis and paralysis caused by spinal cord injuries	Ethical issues of destroying unused embryos
Bone marrow transplants for adult stem cells can be used to treat blood cell cancers, such as leukaemia	No guarantee in how successful these therapies will be and if there will be any long term effects
Can grow whole organs for transplants	Mutations could occur in cultured stem cells
No rejection , if it is made from the patient's own cells	Difficult to find suitable stem cell donors
Can allow for the testing of millions of potential drugs without animal testing	

Biological molecules

Carbohydrates, proteins and lipids (2.7-9)

Carbohydrates

- They are made of **carbon, oxygen and hydrogen**.
- They are polymers that break down into **simple sugars**

Proteins

- They are made of **carbon, oxygen, hydrogen, sulfur, nitrogen and phosphorous**.
- They are polymers that are broken down into its monomers: **amino acids**

Lipids

- Lipids (fats and oils) are made of **carbon, oxygen and hydrogen**.
- They are large polymers that are broken down into **3 fatty acids** molecules and a **glycerol** molecule.

Practical: investigate food samples for the presence of glucose, starch, protein and fat

Test for glucose:

- 1) Add the sample solution into a test tube

- 2) Add drops of **Benedict's solution** into the test tube
- 3) Heat in a water bath at 60-70°C for 5 minutes
- 4) Take test tube out and record the colour
 - If glucose is present the solution will turn **brick red**
 - If glucose is not present that the solution will remain **blue**

Test for starch

- 1) Pipette the sample solution into wells or on a tile
- 2) Add drops of **iodine solution** and leave for 1 minute
- 3) Record any colour change
 - If starch is present the solution will turn **blue-black**
 - If starch is not present the solution will remain **brown**

Test for protein

- 1) Add the sample solution into a test tube
- 2) Add drops of **Biuret solution** into the test tube
- 3) Leave for 1 minute and then record the colour
 - If protein is present the solution will turn **purple**
 - If protein is not present that the solution will remain **blue**

Test for fat

- 1) Add 2cm³ of **ethanol** to the test solution
- 2) Add 2cm³ of **distilled water**
- 3) Leave for 3 minutes and then record the colour
 - If fat is present a **milky white emulsion** will form
 - If fat is not present that the solution will remain **colourless**

Enzymes (2.11-2.14B)

Enzymes are biological **catalysts** (a substance that increases the rate of reaction without being used up). They are protein molecules and the shape of the enzyme is vital to its function. This is because each enzyme has its own uniquely shaped **active site** where the **substrate** binds.

A simplified way to look at how they work is the **Lock and Key Hypothesis**:

- The shape of the substrate is complementary to the shape of the active site (**enzyme specificity**), so when they bond it forms an enzyme-substrate complex.
- Once bound, the reaction takes place and the products are released from the surface of the enzyme

Effect of temperature

- The optimum is around **37°C** (body temperature)
- The rate of reaction increases with an increase in temperature up to this optimum, but above this temperature it rapidly decreases and eventually the reaction stops.
- When the temperature becomes too hot, the bonds in the structure will break
- This changes the shape of the active site, so the substrate can no longer fit in

- The enzyme is said to be **denatured** and can no longer work

Practical: investigate how enzyme activity can be affected by changes in temperature

- 1) Starch solution is heated to set temperature
- 2) Amylase is added
- 3) Iodine is added to each well after a minute
- 4) Measure the time it takes until the iodine stops turning blue-black (this means that starch is not present as amylase has broken the starch down into glucose)
- 5) Repeat the test with different temperature

Effect of pH

- The optimum pH for most enzymes is 7, but some that are produced in acidic conditions, such as the stomach, have a lower optimum pH
- If the pH is too high or too low, the forces that hold the amino acid chains that make up the protein will be affected
- This will change the shape of the active site, so the substrate can no longer fit in
- The enzyme is said to be denatured and can no longer work

Practical: investigate how enzyme activity can be affected by changes in pH

The enzyme being used is called **amylase** - which breaks down carbohydrates such as starch into simple sugars such as **maltose** (see section 1.12 below). We can use **iodine (dark orange colour)** to check for the presence of starch in the solution at any time. When starch is present, the iodine solution will turn to a **blue-black colour**.

Amylase has an optimal pH, and we can use this experiment to estimate what it might be.

Materials required:

1% amylase solution, 1% starch solution, iodine solution, labelled buffer solutions of different pH.

Method:

1. Place a **beaker of water** on a gauze above a **Bunsen burner**
2. Place single drops of **iodine solution** on each **well** of a tray.
3. Add 2cm³ of **amylase solution**, 2cm³ of **starch solution** and 1cm³ of **pH solution** in a test tube and mix the solution.
4. Put this test tube into the water beaker and start a stopwatch. We keep it in this water beaker above a Bunsen Burn to keep it the same temperature so temperature is a **controlled variable**.
5. Every 10 second use a pipette to place a drop the solution into one of the wells containing iodine solution. The mixture should turn **blue-black** to indicate that starch is still present and has not yet been broken down.
6. Continue repeating until the solution stops turning black and **becomes orange** and record the time taken
7. Repeat Steps 1-6 with different pH solutions.

8. Record your results on a graph of pH (on the x-axis) and time taken to complete reaction (on the y-axis).

We can see what the optimum pH of amylase is, as it will be the pH where the reaction is completed the fastest. This should be somewhere around pH 7.0.

Movement in and out of cells (2.15-2.17)

Diffusion

- Diffusion is the spreading out of the particles resulting in a net movement from an area of higher concentration to an area of lower concentration.
- It is a passive process as no energy is required.
- The molecules have to be small in order to be able to move across, for example oxygen, glucose, amino acids and water, but larger molecules such as starch and proteins cannot.

Examples in living organisms:

- Single-celled organisms can use diffusion to transport molecules into their body from the air- this is because they have a relatively large surface area to volume ratio. Due to their low metabolic demands, diffusion across the surface of the organism is sufficient enough to meet its needs.
- In multicellular organisms the surface area to volume ratio is small so they cannot rely on diffusion alone. Instead, surfaces and organ systems have a number of adaptations that allows molecules to be transported in and out of cells. Examples include alveoli in the lungs, villi in the small intestines and root hair cells in plants.

Many factors affect the rate of movement:

Factor	Effect
Concentration gradient	The greater the difference in concentration, the faster the rate of diffusion. This is because more particles are randomly moving down the gradient than are moving against it.
Temperature	The greater the temperature, the greater the movement of particles, resulting in more collisions and therefore a faster rate of diffusion.
Surface area:volume ratio	The greater the surface area, the more space for particles to move through, resulting in a faster rate of diffusion.
Distance	The further the particles have to travel the longer it will take

Osmosis

- Osmosis is the movement of water from a less concentrated solution to a more concentrated one through a partially permeable membrane.

- A dilute solution of sugar has a **high** concentration of water (and therefore a **high water potential**). A concentrated solution of sugar has a low concentration of water (and therefore a **low water potential**). Water moves from a dilute solution to a concentrated solution because it moves from an area of high water potential to low water potential- down the concentration gradient.
- It is passive, as it does not use energy.
- If the concentration of sugar in an external solution is the same as the internal, there will be no movement and the solution is said to be **isotonic** to the cell
- If the concentration of sugar in external solution is higher than the internal, water moves out, and the solution is said to be **hypertonic** to the cell
- If the concentration of sugar in external solution is lower than the internal, water moves in, and the solution is said to be **hypotonic** to the cell

Examples in living organisms:

- Osmosis in animals:
 - If the external solution is more dilute (higher water potential), it will move into animal cells causing them to **burst**.
 - If the external solution is more concentrated (lower water potential), excess water will leave the cell causing it to become **shriveled**.
- Osmosis in plants:
 - If the external solution is more dilute, water will move into the cell and into the vacuole, causing it to swell, resulting in pressure called **turgor** (essential in keeping the leaves and stems of plants rigid).
 - If the external solution is less dilute, water will move out of the cell and they will become soft. Eventually the cell membrane will move away from the cell wall (called **plasmolysis**) and it will die.

Active transport

- Active transport is the movement of particles from an area of **lower concentration** to an area of **higher concentration**, i.e. **against the concentration gradient**.
- This requires energy from respiration as it is working against the gradient, which is why it is called active.

Examples in living organisms:

- In **root hair cells**:
 - They take up **water and mineral ions** (for healthy growth) from the soil
 - Mineral ions are usually in higher concentrations in the cells, meaning diffusion cannot take place
 - This requires energy from respiration to work
- In the **gut**:
 - Substances such as glucose and amino acids from your food have to move from your gut into your bloodstream

- Sometimes there can be a lower concentration of **sugar molecules** in the gut than the blood, meaning diffusion cannot take place
- Active transport is required to move the sugar to the blood against its concentration gradient

Practical: investigate diffusion in non-living systems

- 1) Cut a 1cm³ cube of agar made of sodium hydroxide and phenolphthalein indicator
- 2) Place cube in solution of hydrochloric acid
- 3) Remove the cube and wash with water to stop further reaction
- 4) Cut the cube in half and measure the distance that the acid has caused agar to become colourless from outside inwards
- 5) Repeat the experiment two more times and calculate the mean
- 6) Repeat with different concentrations of hydrochloric acid

Practical: investigating osmosis in potatoes

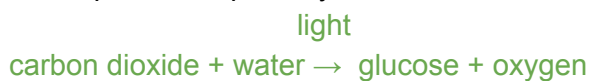
- 1) Place different sucrose solutions including 0% for a control, in different boiling tubes
- 2) Dry potato strips on a paper towel and measure the masses
- 3) Place each potato strip into each sucrose solution for 20 minutes and record how the mass changed
- 4) Repeat tests at each solution several times with potato strips of similar masses

Nutrition

Photosynthesis in plants (2.18-2.21)

Photosynthesis is the process of making glucose from sunlight in the leaves of the plant. It is an **endothermic reaction** in which light energy is converted into chemical energy within the chloroplasts.

The equation for photosynthesis is:



Carbon dioxide = CO₂, Water = H₂O, Oxygen = O₂, Glucose = C₆H₁₂O₆

Factors affecting photosynthesis:

Temperature:

- With an increase in temperature, the rate of photosynthesis **increases**.
- However, as the reaction is controlled by **enzymes**, this trend only continues up to a certain temperature until the enzymes begin to **denature** and the rate of reaction decreases.

Light intensity:

- For most plants, the higher the light intensity, the rate of photosynthesis **increases**.
- As the distance between the light source and the plant increases, the light intensity decreases, i.e. It is inversely proportional to the square of the distance: **light intensity** \propto **1/distance²**

- This means that if a lamp is 2 metres away from a plant, then light intensity of the lamp is a $\frac{1}{4}$ of its original value $\rightarrow 1/2^2 = \frac{1}{4}$

Carbon dioxide concentration:

- Carbon dioxide is also needed to make glucose (see equation).
- As the concentration of carbon dioxide increases, the rate of reaction **increases**.

Practicals investigating photosynthesis:

- Use water plants, such as *Elodea* which release bubbles of oxygen when photosynthesising
- A lamp with an **LED bulb** is set up beside the beaker of water containing the water plant. An LED is best as it will not raise the temperature of the water.
- **Sodium hydrogen carbonate (NaHCO_3)** is added to the water to supply carbon dioxide
- This can set up can be used to investigate the evolution of oxygen from a water plant.

Investigating the effect of light intensity:

- 1) Place **pondweed** in water and set up a desk lamp next to alongside a ruler so that you can measure the distance between the light and the beaker
- 2) Move the lamp away by 10cm
- 3) Leave for 5 minutes to allow for the pondweed to adapt
- 4) Count the number of bubbles given off in 1 minute and record
- 5) Repeat steps 2-4

Investigating the effect of carbon dioxide:

Complete the experiment above but instead of testing the variable of light intensity by using a lamp, use different concentrations of **sodium hydrogen carbonate solution**, whilst keeping the other variables the same.

Investigating starch production:

- 1) Cover half of a small leaf with foil
- 2) Place the plant on a windowsill for 48 hours so that light can reach it
- 3) Put the leaf into boiling water to kill and preserve it.
- 4) Put the leaf in a boiling tube containing hot ethanol for 10 minutes (this removes the chlorophyll pigment).
- 5) Dip the leaf in boiling water to soften it.
- 6) Put leaf in a Petri dish and cover with **iodine solution**.
- 6) The covered half of the leaf will remain **orange-brown**, whereas the exposed half will change to **blue-black** (as iodine solution changes colour in the presence of starch, as photosynthesis turned the glucose into starch for storage)

Experiment provide photosynthesis requires chlorophyll

Repeat the experiment above but with a **variegated** leaf. Variegated plants are white and green and only contain chlorophyll in the green parts. Therefore only the green areas of the plant will test positive for starch (i.e. turn **blue-black**) as a result of photosynthesis occurring. The white areas that do not contain chlorophyll remain an **orange-brown** colour.

Leaf structures

Structure	Description
Waxy cuticle	Helps to reduce water loss by evaporation and is a protective layer found at the top of the leaf
Upper epidermis	Very thin and transparent in order to let light in to the palisade mesophyll
Palisade mesophyll	Contain lots of chloroplasts so that photosynthesis can happen rapidly
Spongy mesophyll	Have lots of air spaces to allow gases to diffuse in and out of cells faster, as it increases the surface area to volume ratio
Lower epidermis	Contains guard cells and stomata (gaps)
Guard cell	Kidney-shaped cells that open and close the stomata by absorbing or losing water. When lots of water is available, the cells fill and open stomata
Stomata	Where gas exchange and loss of water by evaporation takes place - opens during the day and closes at night

Mineral ions**Magnesium:**

- Required for chlorophyll production
- Deficiency: causes leaves to turn yellow

Nitrate:

- Required to produce amino acids
- Deficiency: causes stunted growth and turns leaves yellow

Nutrition in humans (2.24-2.33B)

Humans need to eat a balanced diet in order to maintain their health. This should consist of carbohydrates, proteins, lipids, dietary fibre, vitamins, minerals and water.

	Source	Function
Carbohydrates	Bread, cereals, pasta, rice, potatoes	A high energy source
Proteins	Meat, fish, eggs, pulses	For growth and repair
Lipids	Butter, oil, nuts	A high energy source and for insulation
Dietary fibre	Vegetables, bran	To provide roughage to keep food moving

		through gut - deficiency causes constipation
Vitamin A	Carrots, green vegetables	Needed for vision, especially in the dark, and for growth
Vitamin C	Citrus fruits, broccoli, peppers	Helps to absorb iron
Vitamin D	Margarine, oily fish	Helps to absorb calcium
Calcium	Milk	For bone and teeth strength - deficiency can cause rickets (curving of bones)
Iron	Red meat	Needed for haemoglobin - deficiency can cause anaemia
Water	Water, juice, milk	Needed for cell reactions to take place

Factors affecting energy requirements

Age:

- Energy requirements generally increases as we approach adulthood
- Energy needs of adults go down as they age

Activity levels:

- If you are more active then you will need more energy for movement

Pregnancy:

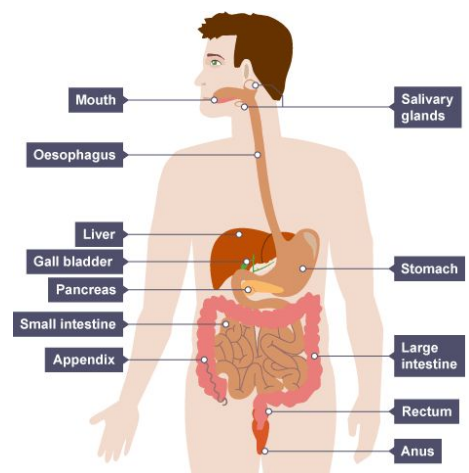
- Energy requirements will increase in order to support growth of the foetus
- Energy needs also increase due to the extra mass of the baby

Human alimentary canal

The **alimentary canal** is the passage food moves through once it has been eaten.

Mouth

- Mechanical digestion: **teeth** break up large food pieces into smaller pieces with larger surface area to volume ratio (food **bolus**)
- Chemical digestion: **amylase** breaks down starch into glucose
- **Salivary glands** produce saliva to lubricate the food bolus so it can be swallowed easily



Oesophagus

- Tube from the mouth to the stomach
- Food bolus moves down due to unidirectional wave-like contractions (**peristalsis**) created by **circular muscles** and **longitudinal muscles** that create a squeezing action

Pancreas

- Produces carbohydrase, protease and lipase enzymes
- Secretes enzymes into the stomach and small intestine

Stomach

- **Gastric juice** is released from stomach lining when it detects food in the stomach
- Gastric juice is made of
 - **Pepsin**: enzyme breaking down proteins
 - **Hydrochloric acid**: makes stomach acidic in order for pepsin to work and to kill any ingested bacteria
- **Peristalsis** also occurs here
- The digested food is now called **chyme**

Small intestine

Duodenum:

- The first part of the small intestine
- Carbohydrases, proteases and lipases digest food here
- Bile is released into the duodenum
 - Bile is produced in the **liver** and stored in the **gallbladder**. It has 2 roles:
 - 1) It is **alkaline** to neutralise the hydrochloric acid which comes from the stomach. The enzymes in the small intestine have a higher (more alkaline) optimum pH than those in the stomach.
 - 2) It breaks down large drops of fat into smaller ones (**emulsifies** it). The larger surface area allows lipase to chemically break down the lipid into glycerol and fatty acids faster.
- **Peristalsis** also occurs here

Ileum:

- Lined with **villi** (finger-like projections) to maximise absorption of digested soluble molecules into blood
- Villi have a thin lining, a large network of capillaries and have a large surface area

Large intestine

- Water is absorbed here, to produce **faeces**
- Faeces is stored in the **rectum** and the removed through the **anus**

Digestive enzymes

Carbohydrates (starch):

- Broken down by **carbohydrases**
- Starch → maltose by **amylase**
- Maltose → glucose by **maltase**

Proteins:

- Broken down by **proteases** in the stomach and small intestine
- Proteins → **amino acids**

Lipids:

- Broken down by **lipases**
- Lipids → **glycerol + 3 fatty acids**

Practical: investigate the energy content in a food sample

This can be measured by using **calorimetry**.

- 1) Pour cold water into a boiling tube
- 2) Record the starting temperature of the water with a thermometer
- 3) Record the mass of the food sample on a scale
- 4) Heat the food on a Bunsen burner until it catches fire
- 5) Put the sample underneath the test tube base to heat the water
- 6) Record the final temperature once the food stops burning

Energy transferred (J) = temperature increase (°C) mass of water (g) x 4.2 (J/g°C)

4.2J/g°C is the specific heat capacity of water, which means that it takes 4.2 joules of energy to raise 1g of water by 1°C.

Respiration (2.34-2.39)

Respiration occurs in every cell in the body of all living things to supply ATP to cells. Cellular respiration is an exothermic reaction. There are 2 types of respiration: aerobic and anaerobic.

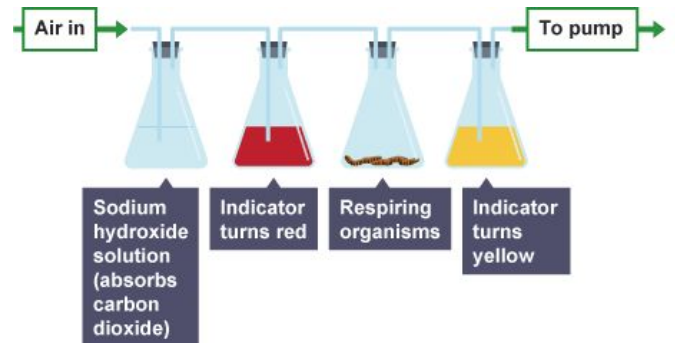
Aerobic respiration	Anaerobic respiration
<p>This uses oxygen. It yields the most energy. Most of the reactions that make up aerobic respiration occur in the mitochondria.</p> $\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ <p>$\text{C}_6\text{H}_{12}\text{O}_6$ = glucose O_2 = oxygen CO_2 = carbon dioxide H_2O = water</p>	<p>Occurs when there is not enough oxygen. It does not yield as much energy as aerobic respiration. It is only used as a last resort, for example during a sprint where it is difficult to breathe in enough oxygen. The oxidation of glucose is complete.</p> <p>In animals: Glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) → Lactic acid</p> <p>In plant and yeast cells it is called fermentation): Glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) → Ethanol + Carbon dioxide (CO_2) This reaction is used to make bread and alcoholic drinks.</p>

Practical: investigate the evolution of carbon dioxide from respiring seeds or other suitable living organisms

- 1) Connect a capillary tube from the air into a flask containing **sodium hydroxide**, which will absorb carbon dioxide
- 2) Connect this flask with a capillary tube to another flask containing **hydrogen carbonate indicator** (which is red at neutral pH and yellow at low pH, i.e. when carbon dioxide is present)

- 3) Connect the second flask to a third flask containing either **germinating seeds** or **respiring animals**, such as worms
- 4) Connect the third flask to another flask containing **hydrogen carbonate indicator**, such as in step 2

The sodium hydroxide solution in the first flask will absorb carbon dioxide from the air, which will turn the second flask **red**, as it will have neutral pH. However, the respiring organism will produce carbon dioxide and will therefore turn the indicator **yellow**.



Practical: investigate the evolution of heat from respiring seeds or other suitable living organisms

- 1) Use 2 vacuum flasks, one containing **living germinating seeds** and the other containing dead or **boiled seeds** (as a **control**)
- 2) Put a **thermometer** wrapped in **cotton wool** (to prevent heat from escaping) to measure temperature
- 3) Measure initial temperature
- 4) Leave seeds for a few days and then measure end temperature

The live germinating seeds will release heat due to aerobic respiration and so the temperature will increase.

Gas exchange
In plants (2.40B-2.45B)
Biology only

Diffusion has already been described in section 2.15.

light

carbon dioxide + water → glucose + oxygen

In order for plants to photosynthesise and respire gas exchange of oxygen and carbon dioxide are needed and this requires diffusion of gases.

Adaptations of leaves for gas exchange

Many of these adaptations have been mentioned before in the photosynthesis section (2.18), as gas exchange is a vital process in photosynthesis.

Spongy mesophyll	Have lots of air spaces to allow gases to diffuse in and out of cells faster, as it increases the surface area to volume ratio
Guard cell	Kidney-shaped cells that open and close the stomata by absorbing or losing water. When lots of water is available, the cells fill and open stomata

Stomata	Where gas exchange and loss of water by evaporation takes place - opens during the day and closes at night
Thin	Short distance of diffusion for carbon dioxide to diffuse into the leaf and oxygen to diffuse out
Flattened shape	Increases surface area for absorption of light and carbon dioxide dioxide

Night vs day

Respiration occurs during night and day, as plants require energy at all times. However, photosynthesis can only occur when light is present (refer to the word equation above) and so cannot occur during the night.

There is a **net balance** of gases during the day, as respiration generally occurs at the same rate as photosynthesis and so carbon dioxide comes out of the air through photosynthesis and is replaced through respiration. The opposite occurs for oxygen.

However, during the night there is no photosynthesis so more oxygen is taken into the plants through respiration and **more carbon dioxide is released** into the atmosphere.

Practical: investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator

- 1) Set up a beaker with a water plant in water and **hydrogencarbonate indicator**
 - Hydrogencarbonate indicator reflects CO₂ concentration
 - It is red at atmospheric concentration of carbon dioxide, purple at low concentration and yellow at high concentration.
- 2) Set up a desk lamp a certain distance away
- 3) Leave the plant for a few minutes
- 4) Record colour of indicator
- 5) Change the distance of the lamp in increments

The closer the lamp is to the plant, the stronger the light intensity and therefore the rate of photosynthesis increases. This means that there is more carbon dioxide taken in by the plant. Low carbon dioxide concentration turns hydrogencarbonate indicator **purple**.

As the light moves further away, less photosynthesis occurs so the rate of respiration is higher than the rate of photosynthesis. There is more carbon dioxide present and so the indicator turns **yellow**.

In humans (2.46-2.50)

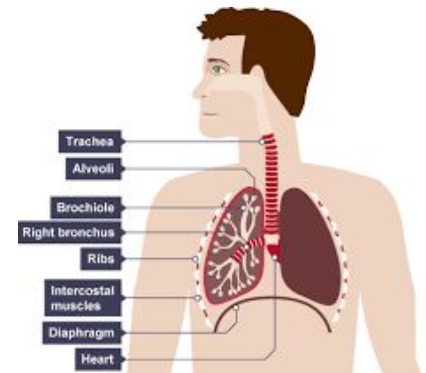
Structure of thorax

Ribs	Bone 'cage' surrounding the lungs to provide protection of internal organs
Intercostal muscle	Muscles found between the ribs that control inhalation and exhalation

Diaphragm	Muscular dome at the bottom of the thorax that changes the pressure in order to control inhalation and exhalation
Trachea	The windpipe , where air enters the thorax and flows to the lungs
Bronchi	The trachea divides into 2 bronchi - one to each lung
Bronchioles	The bronchi further divide into smaller tubes that connect to the alveoli
Alveoli	Tiny air sacs that are the place of gas exchange
Pleural membranes	Found on the outside of the lungs and inside of chest cavity to lubricate the lungs - reducing friction when breathing

Intercostal muscles and diaphragm in ventilation

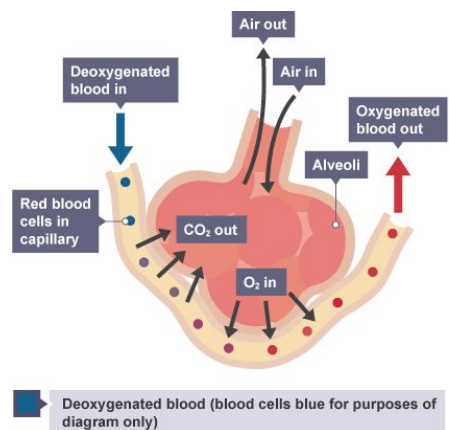
Order of change	Inhalation	Exhalation
Intercostal muscles	Contract	Relax
Ribcage	Up and out	Down and in
Diaphragm	Contracts downwards	Relaxes upwards
Pressure	Decreases	Increases
Air movement	Moves in	Moves out



Air moves from areas of **high pressure to low pressure**, so when the thorax pressure decreases (as a result of **increased volume** created by the intercostal muscles moving the ribcage up and out and the diaphragm flattening) air moves from the higher pressure air down into the lower pressure thorax.

Alveoli adaptations

- **Thin cell walls** - one cell thick so there is a shorter distance of diffusion
- **Folded** - to increase surface area for diffusion
- **Large network of tiny capillaries** - increases concentration gradient between air in alveoli and the blood, as oxygen can move away in the blood and carbon dioxide can be breathed out



Transport (2.51 and 2.52)

Diffusion is a passive process of the spreading out of small particles resulting in a net movement from an area of **higher concentration** to an area of **lower concentration**.

In small **single-celled organisms** can use diffusion to transport molecules into their body from the air- this is because they have a relatively large **surface area to volume ratio**. Due to their low metabolic demands, diffusion across the surface of the organism is sufficient enough to meet its needs.

However, **multicellular organisms** have a small surface area to volume ratio so they cannot rely on diffusion alone. Instead, surfaces and organ systems have a number of adaptations that allows molecules to be transported in and out of cells. Examples include alveoli in the lungs, villi in the small intestines and root hair cells in plants.

Transporting substances in plants (2.53 and 2.54)

Phloem adaptations

- Transport sucrose and amino acids between leaves and other parts of plants (**translocation**)
 - They can be stored in parts of plants that
- Found in the roots, stems and leaves
- Elongated cells with holes in the cell walls (the end walls are called **sieve plates**)
- Many organelles from the cells are removed so cell sap can move through.
 - However, there are many mitochondria in companion cells which provide the energy the cells require
- Food substances can be moved in both directions (**translocation**), from the leaves where they are made for use, or from storage (underground) to parts of the plant that need it.

Xylem adaptations

Water travels up xylem from the roots into the leaves of the plant to replace the water that has been lost due to transpiration. Xylem is adapted in many ways:

- A chemical called **lignin** is deposited which causes the cells to die.
- These cells then become hollow and join end-to-end to form a continuous tube for water and mineral ions to travel through from the roots
- Water molecules are attracted to each other by **hydrogen bonding** - creating a continuous column of water up the plant
- The water evaporates from the leaves of the plant, creating the **transpiration stream**.
- Lignin strengthens the plant to help it withstand the pressure of the water movement
- Lignin contains **bordered pits**, which are holes to allow specific areas for water and therefore minerals to enter the plant

Transpiration (2.55B-2.58B)

Water absorption

Water is taken up by plants through **root hair cells, which were detailed in the 2.5B. These are specialised cells with a very large surface area to absorb water via **osmosis**. If the rate of transpiration increases then the rate of water uptake will also increase as the plant attempts to replenish the loss.**

Transpiration and water uptake

Transpiration is the evaporation of water from the surface of a plant. It is a consequence of **gaseous exchange**, as the stomata are open so that this can occur.

- Water also evaporates at the open stomata
- As water molecules are attracted to each other, when some molecules leave the plant the rest are pulled up through the xylem
- This results in more water being taken up from the soil resulting in a continuous **transpiration stream** through the plant

Factors affecting transpiration:

<u>Factor</u>	<u>Effect</u>
Increase in light intensity	This leads to an increased rate of photosynthesis, so more stomata open to allow gaseous exchange to occur. This means more water can evaporate, leading to an increased rate of transpiration.
Increase in temperature	The molecules move faster, resulting in evaporation happening at a faster rate and therefore the rate of transpiration increases. The rate of photosynthesis increases, meaning more stomata are open for gaseous exchange, so more water evaporates and the rate of transpiration increases .
Increased air movement (wind)	If more air is moving away from the leaf due to it being blown away, then the concentration of water vapour surrounding the leaf will be lower. This will mean there will be a steeper concentration gradient resulting in diffusion happening faster. This will increase the rate of transpiration.
Increase in humidity	If the relative humidity is high, then there will be a reduced concentration gradient between the concentrations of water vapour inside and outside the leaf, resulting in a slower rate of diffusion. This will decrease the rate of transpiration.

Practical: investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot

A **potometer** can be used to investigate how these factors affect water uptake.

- 1) Set up potometer underwater to remove air bubbles in the xylem so that there is a continuous stream of water and the system is made airtight, apart from a singular bubble of air.
- 2) Measure the distance this air bubble in the capillary tube moves over time
- 3) Change an environmental condition, such as light intensity, each time to see how it affects the plant

If the air bubbles moves faster then it means that there is a greater rate of water uptake and therefore rate of transpiration.

Transport in humans (2.59-2.62)

Composition of blood

Plasma

- The liquid which carries the components in the blood, e.g. cells, platelets, amino acids, hormones etc.
- Plasma is important for the **transport** of carbon dioxide, digested food, urea, hormones and heat energy

Red blood cells

- Carry oxygen molecules from the lungs to all the cells in the body
- Contain **haemoglobin**: a red protein that combines with oxygen to allow for transport
- No nucleus: to create more space for haemoglobin
- **Biconcave** shape: to maximise surface area for oxygen to be absorbed
- Flexible: so they can fit through very narrow blood vessels

White blood cells

- They are a part of the **immune system**, which is the body's defence against pathogens
- There are 3 types of WBCs:
 - 1) Phagocytic white blood cells
 - One type of white blood cell can do a process called **phagocytosis**, where the pathogen is engulfed and killed
 - As they are able to do this with any type of pathogen it is a non-specific function
 - 2) Producing **antibodies (lymphocytes)**
 - Each pathogen has an **antigen** on their surface, which is a structure which a specific **complementary antibody** can bind to.
 - Once antibodies begin to bind to the pathogen, the pathogens start to clump together, resulting in it being easier for white blood cells to find them.
 - If you become infected again with the same pathogen, the specific complementary antibodies will be produced at a faster rate. The individual will not feel the symptoms of the illness. They are said to be **immune**.
 - 3) Producing antitoxins
 - WBCs **neutralise** the toxins released by the pathogen by binding to them

Platelets

- 1) When the skin is broken (i.e. there is a wound) platelets arrive to stop the bleeding
- 2) A series of reactions (the **clotting cascade**) occur within the blood plasma
- 3) Platelets release chemicals that cause **fibrinogen** proteins to form a mesh of insoluble **fibrin** across the wound, trapping red blood cells and therefore forming a **clot**.
- 4) The clot eventually develops into a **scab** to protect the wound from bacteria entering

- Lack a nucleus
- Produced in the bone marrow

Vaccination

Vaccinations involve making an individual **immune** to a certain disease. By immunising a large proportion of the population, the spread of the pathogen is reduced as there are less people to catch the disease from (called **herd immunity**).

Vaccines contain either a dead or inactivated form of the pathogen. When injected, they stimulate the immune system to the white blood cells to produce the correct **complementary antibody** to combat it, but since it is dead or inactivated it does not cause any symptoms.

Some of these white blood cells remain in the body as **memory cells**. If this person is then exposed to the actual pathogen, these memory cells will produce antibodies much faster in a greater quantity, so the pathogen can be destroyed before symptoms are felt.

Advantages	Disadvantages
They have eradicated many diseases so far (e.g smallpox) and reduced the occurrence of many (e.g rubella).	They are not always effective in providing immunity.
Epidemics (lots of cases in an area) can be prevented through herd immunity.	Bad reactions (such as fevers) can occur in response to vaccines (although very rare).

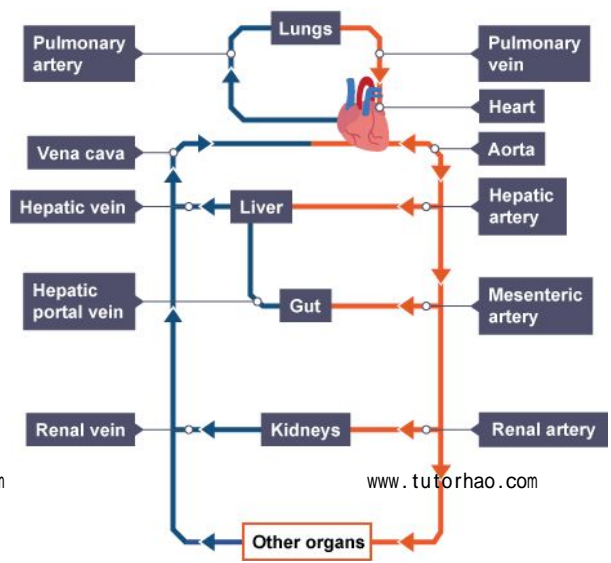
The heart (2.65-2.69)

Human circulatory system

The **heart** is an organ in the **circulatory system**. The circulatory system carries oxygen and nutrients to every cell in the body and removes the waste products.

The heart pumps blood around the body in a **double circulatory system**. This means there are two circuits. Mammals require this double system because the metabolic rate is higher and so need a faster system.

- System 1: Deoxygenated blood flows into the **right atrium** and then into the **right ventricle** which pumps it to the lungs to undergo gaseous exchange
- System 2: Oxygenated blood flows into the **left atrium** and then into the **left ventricle** which pumps oxygenated blood around the body



You need to know the names of each of the main blood vessels leading to and from the heart, lungs, liver, gut and kidneys.

Structure of the heart

- Muscular walls to provide a strong heartbeat
- The muscular wall of the left ventricle is thicker because blood needs to be pumped all around the body rather than just to the lung like the right ventricle.
- 4 **chambers** that separate the oxygenated blood from the deoxygenated blood: 2 atria above and 2 ventricles below
- **Valves** to make sure blood does not flow backwards
- **Coronary arteries** cover the heart to provide its own oxygenated blood supply

Process:

1. Blood flows into the right atrium through the **vena cava**, and left atrium through the **pulmonary vein**.
2. The atria contract forcing the blood into the ventricles.
3. The ventricles then contract, pushing the blood in the right ventricle into the **pulmonary artery** to be taken to the lungs, and blood in the left ventricle to the **aorta** to be taken around the body.
4. As this happens, valves close to make sure the blood does not flow backwards.

Structure of blood vessels

Arteries carry blood AWAY from the heart

- Layers of muscle in the walls make them strong
- **Elastic fibres** allow them to stretch
- This helps the vessels withstand the high pressure created by the pumping of the heart

Veins carry blood TOWARDS the heart

- The **lumen** (the actual tube in which blood flows through) is wide to allow the low pressure blood to flow through
- They have valves to ensure the blood flows in the right direction

Capillaries allow the blood to flow very close to cells to enable substances to move between them

- One cell thick walls create a short diffusion pathway
- Permeable walls so substances can move across them

Heart rate changes

Exercise

- When exercising, muscles require energy and so will be **respiring** at a higher rate
- This means that the **heart rate** will increase in order for the heart to pump more oxygen and nutrients around the body and to remove the waste carbon dioxide from respiring muscles
- **Stroke volume** will also increase, meaning that the heart will pump more powerfully as well as faster

- When **anaerobic respiration** occurs during high intensity exercises, such as sprints, an **oxygen debt** is created. Oxygen is then needed to be transferred around the body quickly so that the **lactic acid** produced by the anaerobic respiration does not cause muscle cramps.

Adrenaline

- Adrenaline is a hormone produced by the **adrenal glands** above the kidney
- It is responsible for the '**fight or flight**' reaction
- Increased **heart rate** to deliver more oxygen to respiring muscles that will be contracting more frequently
- Increased **breathing rate**, so more gas exchange occurs and more oxygen diffuses into the blood and more carbon dioxide diffuses out.
- Blood flow is diverted away from digestive system and towards respiring muscles
- Adrenaline also causes other body changes, such as pupils to dilate to let in more light,

Coronary heart disease (CHD)

The coronary arteries supply blood to the heart and in CHD these arteries become blocked, due to a build-up of fatty plaques (atherosclerosis). This can cause ischaemia (lack of blood and oxygen) which can eventually lead to a muscle death and therefore a heart attack.

Causes of CHD:

- Poor diet
 - A diet rich in saturated fat increases cholesterol levels, which can increase the chance of fatty plaques building up
 - High levels of salt can increase blood pressure which damages the blood vessels and increases the chances of fatty deposits building up
- Smoking
 - Nicotine causes narrowing of blood pressure and increases blood pressure, which can increase the chance of a blockage in the coronary arteries
- Stress
 - Hormones produced in times of stress can increase blood pressure which can damage the vessel walls

Excretion

In flowering plants, carbon dioxide and oxygen are the waste products of metabolism and they diffuse out of the leaf via the stomata. This was described in detail in the photosynthesis section of nutrition (2.18-2.21) earlier on.

In the human body, there are three main **organs of excretion**. The lungs excrete carbon dioxide, the kidneys secrete urea, excess water and salts and the skin excretes excess water and salts through sweat.

Kidney excretion (2.72B-2.79B)

Roles of the kidney

The kidneys are very important in maintaining the balance of water and other substances in the body.

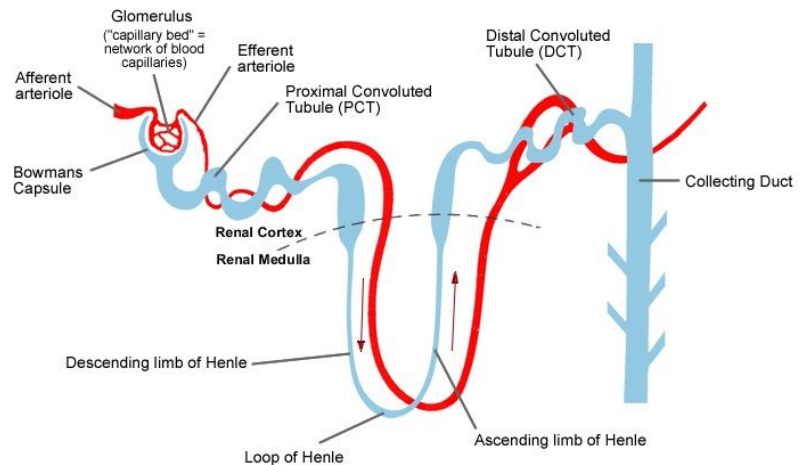
- **Filtration:** filters out the waste products, such as water, ions and urea (from amino acids), at high pressures to form urea
- **Selective reabsorption:** useful substances such as glucose, ions and water are reabsorbed
- **Osmoregulation:** controlling water content in the body
- **Excretion:** removal of waste products from metabolism

Structure of the urinary system

- The inner part of the kidney is called the **medulla** and the outer part is called the **cortex**.
- The **ureter** carries from kidneys to the **bladder** to be excreted out the body.
- The kidney is supplied by the **renal artery** and a **renal vein** takes blood away.
- Each kidney contains millions of kidney tubules or **nephrons**

The nephron

- 1) The **renal artery** transports oxygenated blood to the **Bowman's capsule** under high pressure
- 2) In the **glomerulus** (ball of capillaries within the capsule) the pressure increases even further as the capillaries leaving (**efferent arteriole** = exiting to renal vein) is narrower than the capillary entering (**afferent arteriole**)
- 3) This pressure leads to **ultrafiltration**
 - water, salts, glucose and urea pass out of the capillary and into the **Bowman's capsule** and into the tubules
- 4) Proteins and blood cells are too big to leave the capillaries and so stay within the blood
- 5) All **glucose** is reabsorbed at the **proximal convoluted tubule** by **active transport**, whilst the rest of the filtrate continues through the tubules. There are many **mitochondria** here to provide the energy for active transport.
- 6) Salts are reabsorbed by the **loop of Henle**
- 7) Water is reabsorbed into the blood at the **collecting ducts**, depending on the levels of water levels in the body (and therefore **ADH** produced - more on **ADH** below)
- 8) The remaining filtrate (water, salts and urea) in the collecting duct will form **urine**
- 9) This is transported through the **ureters** to be stored in the bladder and then through the **urethra** to leave the body



ADH

Anti-diuretic hormone (ADH) is a hormone involved in the control of the loss of water as urine.

It is released into the pancreas by the **pituitary gland** when a receptor in the brain detects that the blood is too concentrated.

- It travels in the bloodstream to the **kidney tubules**
- An increased amount of ADH reaching the tubules **increases their permeability to water**, so more moves out of the tubule and back into the bloodstream
- This results in a smaller volume of more concentrated (yellow) urine and the blood becoming less concentrated as more water moves into it.

This is an example of a negative feedback loop, because if the concentration of the blood increases/decreases, more/less ADH is secreted to reverse this change.

In high temperatures, increased sweating can lead to dehydration. This can lead to salt loss in sweat, meaning that the kidneys may try to compensate for the change by increasing salt retention. The brain detects this and makes us feel that we are thirsty so that we drink more water to dilute the salts in our blood.

Coordination and response

Homeostasis and responses (2.80-2.82)

Homeostasis is the maintenance of a constant internal environment, for example, maintaining body temperature or body water content.

Coordinating responses there needs to be a **stimulus** (such as heat), a **receptor** which detects the stimulus (such as the skin on the fingertip) and then an **effector** which produces the response (such as arm muscles moving the hand away)

Tropisms in plants (2.83-2.85)

Plants need hormones to coordinate and control growth. Examples of these include **phototropism**, the response to light, and **gravitropism** or **geotropism**, the response to gravity. Hormones move from the place they are made to where they are needed in order to produce the appropriate response.

Auxins

Most plants show **positive phototropism** because they grow towards the light source.

- The plant is exposed to light on one side.
- **Auxin**, a growth hormone, moves to the shaded side of the shoot.
- Auxin stimulates cells to grow more here.
- This means the shoot bends towards the light.
- The plant receives more light, meaning photosynthesis can occur at a faster rate.

Most shoots show **negative gravitropism** as they grow away from gravity. If a shoot is horizontal:

- Auxin moves to the lower side.
- The cells of the shoot grow more on the side with most auxin, so it stimulates cells to grow more here.

- This makes the shoot bend and grow away from the ground.
- This is beneficial as light levels are likely to be higher further away from the ground.

Most roots show **positive gravitropism** as they grow towards gravity. If a root is horizontal:

- Auxin moves to the lower side.
- The cells of the root grow more on the side with less auxin, so it stimulates cells to grow on the upper side.
- This makes the root bend and grow downwards.
- This is beneficial as there are more likely to be increased levels of water and nutrients lower down, and it provides stability for the plant.

When the auxin distribution becomes equal on both sides it grows straight in that directions.

The human nervous system (2.86-2.92)

Nervous vs endocrine system

The **nervous system** is made up of nerve cells that carry impulses around the body.

The **endocrine (hormonal) system** is made up of glands that produce hormones that stimulate changes in the body.

Both systems require stimuli, receptors and effectors and chemicals are involved in both, but there are also key differences between them:

	Nervous system	Endocrine system
Type of signal	Electrical	Chemical
Transmitter	Nerve cells	Hormones in bloodstream
Speed of response	Very fast	Slower
Duration of response	Short	Long

The CNS

The central nervous system (CNS) consists of the brain and the spinal cord. It allows us to make sense of our surroundings and respond to it in order to survive.

- 1) **Receptor** cells in **sense organs** convert a **stimulus** (such as a bright light) into an electrical impulse.
- 2) This electrical impulse travels along cells called **sensory neurons** to the central nervous system (CNS).
- 3) Here, the information is processed and the appropriate response is coordinated, resulting in an electrical impulse being sent along **motor neurones** to effectors.

- The **effectors** carry out the response (this may be muscles contracting or glands secreting hormones).

Synapses

A **synapse** is the gap between two neurons. Transmission of impulses across the synapse is chemical and uses neurotransmitters.

Neurotransmitters are the chemical released at one end of a nerve fibre.

When an electrical impulse is carried along an axon it triggers the nerve-endings to release neurotransmitters. This is because the **electrical impulse** cannot directly travel across the synapse (gap) and so needs to be converted to a chemical and then back to an electrical impulse. The neurotransmitter **diffuses** across the synapse and binds to receptor molecule on the next neuron. This **stimulates** the second neuron to transmit the electrical impulse.

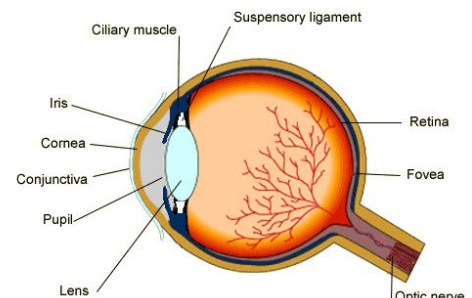
The reflex arc

The reflex arc is a subconscious response to a dangerous stimuli, such as a hot surface. Sometimes an extremely quick response is needed and there is not enough time for it to go through the conscious portion of brain so the CNS is involved instead.

- A stimulus is detected by **receptors**, such as thermoreceptors in fingertips detecting heat
- Impulses are sent along a **sensory neuron**.
- In the CNS the impulse passes to a **relay neuron**.
- Impulses are sent along a **motor neuron**
- The impulse reaches an **effector** resulting in the appropriate response, such as a contraction of the biceps to move the arm away from the heat source

The eye

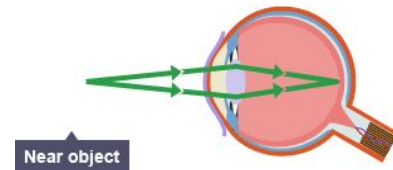
- Cornea:** the transparent outer part of the eye
 - It refracts light to reach the retina
- Iris:** the coloured part of the eye that does not allow light to go through
 - Controls how much light enters eye
 - In bright light, the **circular muscles** contract and **radial muscles** relax to make the pupil smaller, avoiding damage to the retina.
 - In dim light, the **circular muscles** relax and the **radial muscles** contract to make the pupil larger, so more light can enter to create a better image.
- Lens:** transparent, biconvex disc that attaches to ciliary muscles by the suspensory ligaments
 - Focuses light onto the retina
- Retina:** contains light receptors
 - Contains rods (respond to dim light) and cones (respond to colour)
- Optic nerve:** carries impulses between the eye and the brain



Accommodation

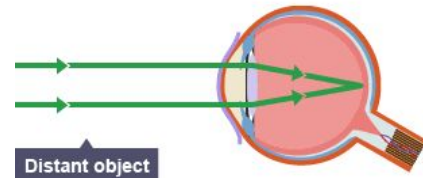
Near object

- Ciliary muscles contract
- Suspensory ligaments slacken
- This allows the lens to become fatter so the light is refracted more
- Light converges on the retina



Distant object

- Ciliary muscles relax
- Suspensory ligaments stretch
- This allows the lens to become thin so the light is refracted less
- Light converges on the retina



Temperature regulation

Human body temperature is 37.5 degrees celsius. The **thermoregulatory centre** which monitors and controls body temperature to ensure it remains this temperature is found in the brain.

- Has receptors that monitor the temperature of the blood
- Has receptors in the skin that send impulses to the thermoregulatory centre

When it is hot:

- **Sweat** (evaporates from skin surface resulting in increased energy transfer away from body) is produced from sweat glands
- **Vasodilation** means more blood flows closer to the surface of the skin, resulting in increased energy transfer from the body

When it is cold:

- Sweating stops
- Skeletal muscles contract rapidly (**shivering**) to generate heat from respiration
- Hairs stand on end to create an insulating layer, trapping warm air
- **Vasoconstriction** means blood does not flow so close to the surface, resulting in less heat lost

The endocrine system (2.94 and 29.5B)

Hormones are chemical messengers that are secreted by **endocrine glands** into the bloodstream, where they are transported around the body to **receptors on the target organ**. The pituitary gland, mentioned before, is one of the most important glands.

	Source	Roles	Effects
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Adrenaline	Adrenal gland	Prepares the body for 'fight or flight' response	Increases heart rate and breathing rate
Insulin	Pancreas	Lowers blood glucose levels	Converts glucose in the blood into glycogen for storage in muscles and liver
Testosterone	Testes	Main sex hormone in males	Produces secondary sexual characteristics in males (e.g. hair growth, deeper voice)
Progesterone	Ovaries	Maintains pregnancy	Maintains the uterus lining so that the fertilised egg can implant
Oestrogen	Ovaries	Main sex hormone in females	Produces secondary sexual characteristics in females (e.g. breasts developing) and controls menstrual cycle
ADH	Pituitary gland	Regulates water content in the body	Increases the permeability of the collecting ducts in the kidneys to reabsorb more water into the blood
FSH	Pituitary gland	Causes ovary to develop into mature egg	Stimulates the development of the egg in the ovary and the release of oestrogen
LH	Pituitary gland	Causes ovary to release mature egg	Stimulates the release of the egg cell and the release of progesterone