Gas Exchange

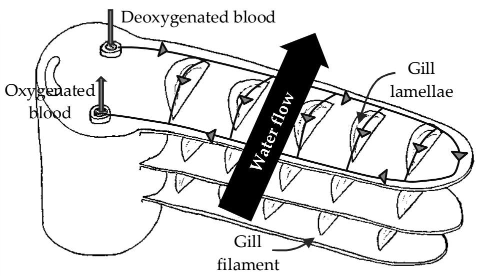
- AQA Biology (Oxford): pp. 130–150
- AQA Biology (Hodder Education): pp. 108–135

THE BASICS

Surface area: Volume

- **Smaller organisms** have a **larger surface area** relative to their volume, e.g. worms. While **larger organisms** have a large surface area but their ratio of surface area to volume decreases, e.g. elephants.
- Large surface areas provide **good exchange surfaces**; a small volume means molecules can **diffuse**, removing the need for complex **organ systems** (e.g., worms get oxygen by diffusion through their bodies.
- Animals in **hot environments** have a large **surface area** to lose heat, e.g. an elephant's ears. **Small animals** with a large surface area, e.g. mice, lose heat and need a **higher metabolic rate** to keep warm.
- Animals in **cold environments decrease their surface area to volume**.
- Cells within multicellular organisms require exchange and transport systems to exchange **gases**, **nutrients**, **heat** and **waste products**.

Fish



Fish gills have highly efficient gas exchange due to **counter-current flow**.

Blood and water flow in **opposite directions** over the lamellae.

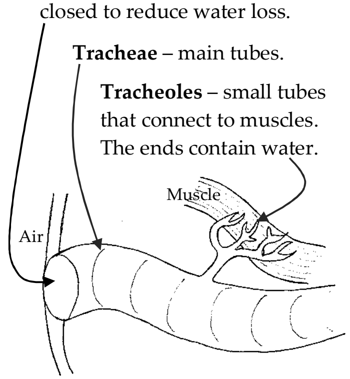
High oxygenated water meets high oxygenated blood at the front of the filament. Low oxygenated water towards the back of the filament meets deoxygenated blood. This maintains the **concentration gradient** so oxygen diffuses into the blood along the length of the lamellae. This is called **counter-current exchange**.

Insects

Spiracle – small pores. Can be closed to reduce water loss.

Tracheae – main tubes.

Tracheoles – small tubes that connect to muscles. The ends contain water.



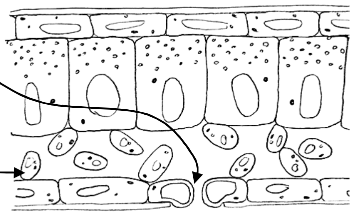
Insects have a **tracheal system** of tubes around their bodies.

When the insect's muscles respire **anaerobically**, lactic acid builds up. This causes water to enter the cells from the tracheoles. Air is drawn further down the tracheoles, delivering oxygen to more cells.

Insects also conserve water with a thick, waterproof **cuticle** over their exoskeleton.

Plants

Plants have a system of closable pores, called **stomata**, and **air spaces** within the **mesophyll tissue** of their leaves. The spread out cells provide a **large surface area** for exchange within the leaf.



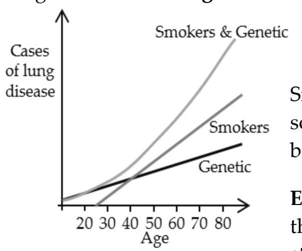
During photosynthesis, carbon dioxide diffuses in and oxygen out of the leaf. This is reversed for respiration.

All plants can **close their stomata** to reduce water loss. Plants with specialist adaptations to reduce water loss are called **xerophytes**. These adaptations include:

- thick, waxy **cuticle** on upper side of leaf
- **decreased surface area to volume ratio**, e.g. needle leaves
- **leaf rolling, hairy leaves, sunken stomata** trap vapour to minimise Ψ gradient and, therefore, diffusion out of the leaf.

Lung Disease

Lung disease can be a **genetic** condition, developed due to **risk factors** such as smoking and pollution or an **interaction** of both factors.



Smoking and pollution **paralyse cilia**, so mucus builds up and irritates the bronchi, causing coughing.

Emphysema is irrecoverable damage to the alveoli – they become permanently stretched or burst.

Humans

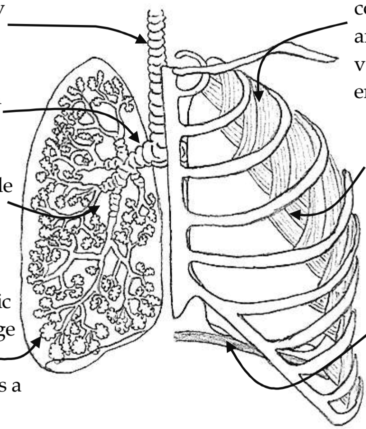
Gas exchange takes place in the lungs. The **squamous epithelia** have adaptations to increase **diffusion rates**. Intercostal muscles and the diaphragm cause **ventilation**, ensuring there is a **tidal flow** of fresh air entering and waste gases leaving.

Trachea – main, flexible airway surrounded by cartilage.

Bronchi – one branch into each lung, supported by cartilage.

Bronchioles – lined with muscle fibres to control air flow.

Alveoli – minute air sacs supported by collagen and elastic fibres. Provide large gas exchange surface. Wet surface increases diffusion rate and water contains a surfactant to stop walls sticking.



External intercostal muscles – contract to pull the rib cage up and out, increasing thoracic volume and causing air to enter the lungs (inspiration).

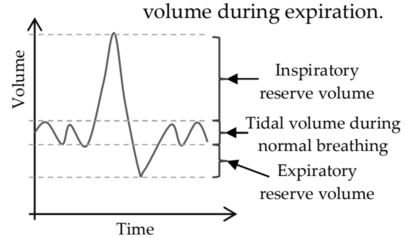
Internal intercostal muscles – antagonistic to external intercostal muscles, these contract to pull the rib cage in and down, decreasing thoracic volume and causing air to leave the lungs (expiration).

Diaphragm – contracts and pulls down, increasing thoracic volume during inspiration. Relaxes and moves up, decreasing thoracic volume during expiration.

Squamous epithelia: single-cell thick walls of alveoli with a large surface area to maximise diffusion.

Goblet cells produce mucus in the trachea and bronchi to trap dirt and pathogens. **Cilia** move the mucus up to the oesophagus to be swallowed.

The graph shows a reading from a **spirometer**, measuring four normal breaths and one deep breath.



Tidal volume and ventilation rate

Tidal volume: volume inhaled in resting conditions.

Ventilation rate: number of breaths in a given time (usually per minute).

Pulmonary ventilation rate: total volume of air moved through the lungs in a given time.

$$\underset{(dm^3 min^{-1})}{\text{Pulmonary ventilation rate}} = \underset{(dm^3)}{\text{Tidal volume}} \times \underset{(min^{-1})}{\text{Ventilation rate}}$$

Word cloud

Surface area, Cilia, Ventilation, Trachea, Volume, Diaphragm, Bronchi, Spiracle, Goblet cells, Bronchioles, Tracheae, Emphysema, Alveoli, Tracheoles, Stomata, Intercostal muscles, Xerophytes, Mesophyll, Squamous epithelia, Counter-current flow

Human Digestion and Plant Transport

- AQA Biology (Oxford): pp. 151–157; 183–193
- AQA Biology (Hodder Education): pp.139–151, 181–189

THE BASICS

Digestion and Absorption

- The **digestive organ system** has **specialised tissues** to **produce and secrete enzymes**, maintain favourable environments so enzymes can work **optimally**, then **absorb** the products of digestion.
- **Carbohydrates**, **proteins** and **lipids** need to be broken down and absorbed by the body. This often involves other molecules, such as **sodium ions** (salt) and **vitamins**.
- **Physical breakdown** occurs in the **mouth** and by the churning of the **muscular stomach walls**. **Chemical breakdown** occurs by the action of **enzymes catalysing hydrolysis reactions within polymers**.

Carbohydrates

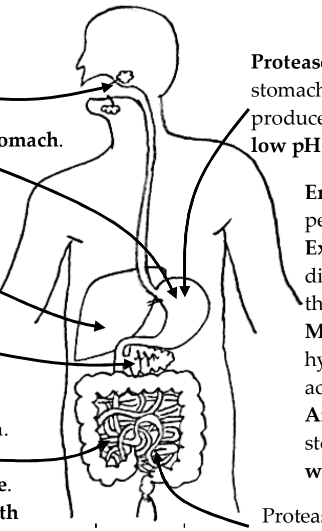
Salivary amylase hydrolyses carbohydrates into **maltose**.

Salivary amylase **denatures** in pH of **stomach**.

Bile salts from the **liver** restore neutral pH in the ileum for **carbohydrase** function.

Pancreatic amylase released into the ileum. Pancreas also releases lactase and sucrase.

Pancreatic amylase digests remaining carbohydrates into maltose in the ileum. **Membrane-bound maltase** in the epithelium digests maltose to **α-glucose**. Glucose is absorbed by **co-transport with sodium ions**.



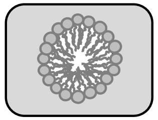
Proteins

Proteases are produced by glands in the stomach lining. The stomach also produces **hydrochloric acid** to create the **low pH** for proteases to work.

Endopeptidases hydrolyse internal peptide bonds.
Exopeptidases remove terminal dipeptides and amino acids from the ends of polypeptides.
Membrane-bound dipeptidases hydrolyse dipeptides into amino acids.
Amino acids are absorbed into the stomach epithelium by **co-transport with sodium ions**.

Proteases **denature** in the alkaline conditions of the ileum.

Lipids



Large globules of lipids are **emulsified** by **bile salts** from the liver into smaller droplets (**micelles**).

Micelles have a larger **surface area** for enzyme action and can **transport non-water soluble compounds** such as vitamins in their **hydrophobic** centre.

The micelles fuse with the epithelial cell's membrane, non-soluble products are absorbed and **lipases** digest the lipids **into fatty acids** and **glycerol**.

Endoplasmic reticulum and **Golgi apparatus** form fatty acids and glycerol into **triglycerides**, then combine triglycerides with **cholesterol** and **lipoproteins** to form **chylomicrons**. These are secreted by **exocytosis** into **lacteals** (lymph capillaries) that transport the chylomicrons to the blood.

Absorption

The **ileum** is adapted to absorb the products of digestion with:

- **villi** (1 mm long) and **microvilli** that increase the **surface area**
- microvilli are very thin and, therefore, have a **short diffusion distance**
- villi contain **muscle** to stir the content within the **lumen** and absorb products
- large blood supply ensures products are removed from epithelial cells quickly, therefore maintaining a **concentration gradient**.

The **colon** absorbs **water**.

THE BASICS

Mass Transport in Plants

- Mass transport in plants includes the **xylem**, that transports **water**, and the **phloem**, that transports **dissolved organic materials**, such as **sugars**.
- Transport of molecules depends on several basic properties of **water** (see Biological Molecules i).
- Water can travel between cells via the **cell wall pathway** or **cytoplasmic pathway**.
- Xylem and phloem have key differences: xylem are **dead** cells, strengthened by **lignin** and have **unidirectional** flow of water; phloem are **living** cells that can have **bidirectional** flow of dissolved substances.

Xylem

Cohesion-tension theory: how water moves through the xylem.

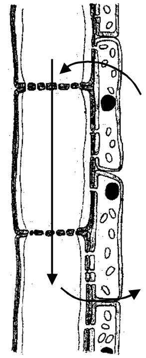
Cohesion is due to **hydrogen bonds** between water molecules forming a continual stream of water.

Tension is created by **transpiration** of water from the leaves. Water evaporates from the **stomata** into an area of more negative water potential (the air), which pulls the water up the xylem.

Potometer experiment

- Cutting attached to a glass tube filled with water.
- A small air bubble is introduced into the tube.
- Movement of the bubble up the tube is measured over time to determine rate of water loss by transpiration.

Phloem



Mass-flow hypothesis for translocation: how solutes are transported by the phloem.

Source: sucrose from photosynthesis is **co-transported** with **hydrogen ions** into **companion cells**. Companion cells are **cytoplasmically linked** to **sieve cells** (long cells with **sieve plates**).
Sucrose decreases Ψ in phloem, so water enters from xylem. This creates **hydrostatic pressure** that **pushes fluid** along the phloem.

Sink: Sucrose is required by cells for **respiration** or converted into **starch** for storage, so companion cells **actively transport** sucrose out of the phloem. This causes surrounding cells to have a more negative Ψ than the phloem, so water leaves the phloem and enters the cells, causing fluid to be **pulled towards** the sink.

Evidence for and against the mass-flow hypothesis includes:

For	Against
If phloem is cut, hydrostatic pressure causes sap to seep from the cut	Role of sieve plates is unknown, they may hinder movement of solutes
Sucrose concentration is higher in the source than in the sink areas	
Low light slows translocation due to reduced sucrose production from photosynthesis	Different types of solutes move at different speeds; they should all move at the same speed in mass flow
Low oxygen slows translocation due to reduced ATP production from respiration, limiting active transport	

Ringing experiment

- Outer layer of stem containing phloem removed.
- Stem above the missing ring swells as sugary fluid accumulates.
- Non-photosynthetic tissue below dies as has no sugars.

Tracer experiment

- Plant kept in ^{14}C carbon dioxide atmosphere.
- Sugars incorporate ^{14}C.
- X-ray film responds to ^{14}C and darkens only over locations of phloem.

Word cloud
Key words in bold for both sections

Mass Transport in Animals

- AQA Biology (Oxford): pp. 161–182
- AQA Biology (Hodder Education): pp. 154–177

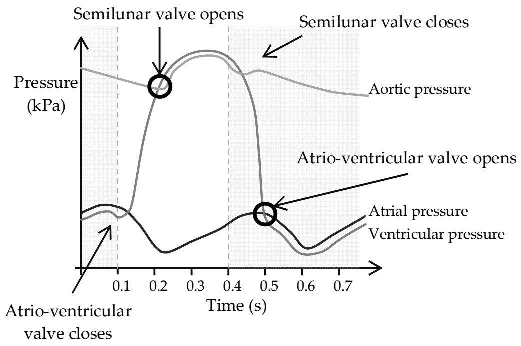
Human Circulatory System

- The circulatory system in humans is a **double circulatory system** consisting of the **systemic** and **pulmonary** circulations. The pulmonary circulation transports blood between the **heart** and **lungs** while the systemic circulation transports blood between the heart and the rest of the **body**.
- The **quaternary protein haemoglobin** associates with **four oxygen molecules** in the lungs to form **oxyhaemoglobin**.
- Carbon dioxide diffuses into the blood plasma as a waste product.

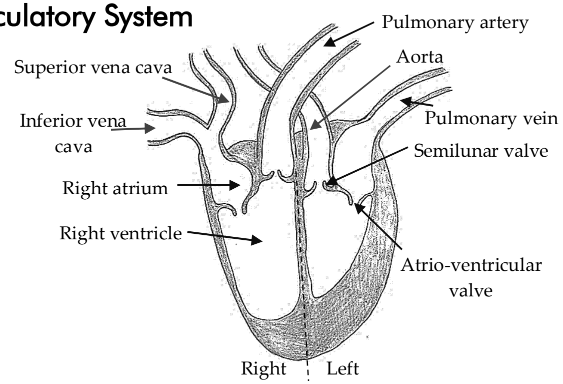
Structure of Human Heart and Circulatory System

The heart has four **chambers** and four **valves**. Valves prevent blood flowing backwards and open when the pressure behind the valve from incoming blood exceeds pressure in the ventricle or arteries.

Atrial systole: first phase, atria contract. **Ventricular systole:** second phase, ventricles contract. **Diastole:** final phase, atria and ventricles relax.



The thicker **cardiac muscle** on the left side means blood enters the **aorta** under higher pressure and can travel to the extremities of the body.

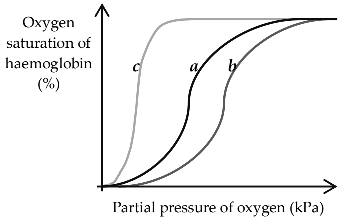


The **pulmonary artery** carries deoxygenated blood to the **lungs**, and the **pulmonary vein** carries oxygenated blood to the heart. All other arteries carry oxygenated blood to the body, e.g. the **coronary artery** takes blood to the **heart muscle**. All other veins carry deoxygenated blood back to the heart, e.g. the **renal vein** takes blood away from the **kidney**.

Cardiac output = stroke volume x heart rate

Haemoglobin

Haemoglobin has an **oxygen dissociation curve**, showing at what partial pressures oxygen dissociates from haemoglobin.



Low partial pressures: e.g. in blood returning to the lungs or around respiring muscle, the oxygen **dissociates**, leaving little haemoglobin saturated. Curve ***a:*** standard curve for humans.

High partial pressures: e.g. in the lungs, haemoglobin **associates** with oxygen. Each subsequent oxygen needs a smaller increase in partial pressure – **positive cooperativity**.

Curve ***b:*** vigorous exercise causes shift in the oxygen curve in high CO_2 conditions – the **Bohr effect**. Oxygen dissociates from haemoglobin at a much **higher partial pressure** of oxygen, supplying the **respiring muscles** with more oxygen.

Curve ***c:*** curve from an animal adapted to **high altitudes**. The haemoglobin **more readily associates** with oxygen, therefore making it easier to obtain oxygen from the low-oxygen air.

Blood Vessels

Blood vessels have different **tissues** that adapt them to their **function**.

	Muscle layer	Elastic layer	Overall thickness	Valves	Carries blood…
Arteries	Thick	Thick	Thick	None	from heart to arterioles
Arterioles	Thickest	Thin	Medium	None	from arteries to capillaries
Capillaries	None	None	One cell thin	None	around cells and tissue fluid
Veins	Thin	Thin	Thin	Present	from body cells to heart

Arteries have a thick **elastic layer** because the blood from the heart has a highly fluctuating pressure. **Lumen** of **capillaries** are the width of a red blood cell and the walls are one cell thin to maximise diffusion.

Pocket valves in veins stop blood flowing backwards where pressure is low far from the heart. **Muscle contraction** from body movement also helps move the blood back towards the heart.

Exam Tip!

1. Remember the heart is reversed on diagrams.
2. Think through blood flow logically within the heart and different blood vessels.
3. Also, do not say red or blue blood! Use oxygenated or deoxygenated.

Cardiovascular Disease

Cardiovascular disease weakens the heart and **reduces cardiac output**. It also puts people at risk of a **myocardial infarction** (heart attack).

Myocardial infarctions: a blockage in the **coronary artery** reduces oxygen delivered to the heart. Cardiac muscle cells die and the heart may stop beating.

Risk factors that cause cardiovascular disease include:

- excess **saturated fats** in food – causes build-up of **atheroma**
- **smoking** – cigarette smoke contains **carbon monoxide** that irreversibly binds with haemoglobin, reducing oxygen saturation in the blood
- **high cholesterol** levels – cholesterol is transported by low-density lipoproteins from the liver, where it contributes to **atheroma** formation

Tissue Fluid

Tissue fluid acts as an **exchange medium** between cells and blood capillaries. The fluid is transported in the **lymphatic system** and relies on **hydrostatic pressure** and **muscle contraction** to help transport substances.

Small molecules forced out of capillaries by hydrostatic pressure (**ultrafiltration**) include:

- oxygen
- monosaccharides
- amino acids
- white blood cells

Large molecules stay in the blood, so water from tissue fluid re-enters by osmosis, or **lymph vessels** return tissue fluid to the blood.

Word cloud

Oxyhaemoglobin
Coronary
Dissociation curve
Ultrafication
Partial pressure
Lymphatic
Positive cooperativity
Renal
Bohr effect
Arteries
Cardiac muscle
Myocardial infarction
Aorta
Capillaries
Atrial systole
Veins
Ventricular systole
Pocket valves
Diastole
Arterioles
Pulmonary
Atheroma