Specialised Cells and Gas Exchange

Surface Area : Volume

- Cells form **tissues**, which are arranged into **organs** and **organ systems**.
- **Larger organisms** have a small surface area compared to their volume (**low surface area : volume ratio**), e.g. elephants.
- Smaller organisms have a large surface area compared to their volume (**high surface area : volume ratio**), e.g. mice.
- Large surface areas are **good exchange surfaces**; a small volume means molecules can **diffuse**, removing the need for complex **organ systems**.
- **Small animals** with a large surface area, e.g. mice, lose heat and need to maintain a **higher metabolic rate** to keep warm.
- Cells within multicellular organisms require exchange and transport systems to exchange **gases**, **nutrients**, **heat** and **waste products**.
- **Specialised** cells adapted for specific roles all **differentiate** from different types of **stem cell**. Stem cells are being researched for use in treating **injury** and **genetic diseases**.

Tidal Volume, Vital Capacity and Oxygen Uptake

Tidal volume: the volume inhaled in resting conditions.

Ventilation rate: the number of breaths taken in a given time.

Maximum pulmonary ventilation: the total volume of air moved through the lungs in a given time.

Vital capacity: the largest amount of air that can be moved in and out of the lungs in one breath.

The volume of **oxygen** taken up during breathing can be measured by the reduction of gas within the spirometer, as the carbon dioxide breathed out is absorbed by soda lime.

Specialisation and Stem Cells

During development, the cells in multicellular organisms **differentiate** and become **specialised** for particular functions.

Cell type:	Adaptations
Erythrocytes	No nucleus or organelles, biconcave disc shape
Neutrophils	Many organelles for lysosome production
Epithelia	Thin (squamous) or ciliated for large surface area
Sperm cells	Enzyme-containing acrosome, many mitochondria
Palisade cells	Many chloroplasts in upper part of cell
Guard cells	Large vacuole for uptake of water to make turgid
Xylem/phloem	Elongated cells for water/sugar transport

There are three types of stem cell:

- **Totipotent** – can mature into any type of cell
- **Unipotent** – are specialised but can undergo unlimited division
- **Multipotent** – partly specialised but can form different cells within a related group, e.g. **bone marrow** stem cells and plant **meristems**

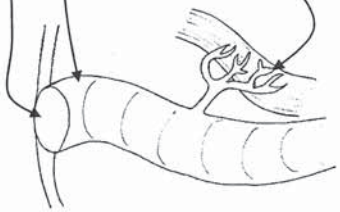
Stem cells can be used to repair **tissues** without rejection and treat **conditions** such as Parkinson's, Alzheimer's and muscular dystrophy.

Insects

Spiracle – small pores forming the entrance to the tracheae. Can be closed to reduce water loss.

Tracheae – main tubes.

Tracheoles – small tubes that connect to muscles. The ends are filled with water.

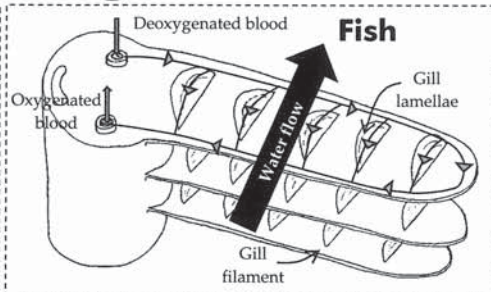


Insects have a **tracheal system** with **ventilation** by thoracic and abdominal movement.

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

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

Fish



Fish's gills have highly efficient gas exchange due to a **counter-current flow** system.

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

The **buccal** (mouth) **cavity** is increased to draw water in and the **operculum** (gill flaps) ensure water flows continuously over the gills to maintain the **concentration gradient**.

High-oxygenated water meets high-oxygenated blood at the front of the filament, and low oxygenated water meets deoxygenated blood towards the back of the filament. This maintains the **concentration gradient** along the length of the lamellae. This is called **counter-current exchange**.

Mammals

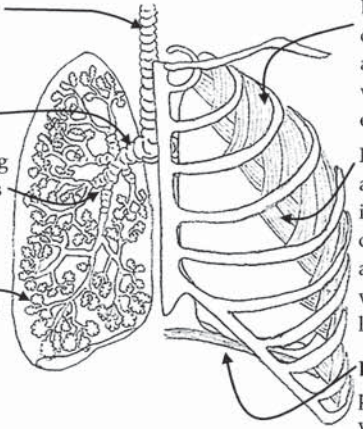
Gas exchange takes place in the lungs. Intercostal muscles and the diaphragm cause **ventilation**, ensuring there is a **tidal flow** of fresh air entering the lungs and air with waste gases leaving. This combined with constant blood flow maintains the concentration gradient.

Trachea – large flexible airway surrounded by cartilage that is the main airway to the lungs.

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

Bronchioles – smaller, branching airways lined with muscle fibres to control air flow into alveoli.

Alveoli – minute air sacs lined with collagen (strength) and elastic fibres. Provide large, thin gas exchange surface. Wet surface increases diffusion rate and water contains a surfactant to stop walls sticking together.



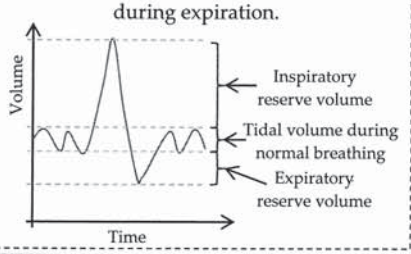
External intercostal muscles – contract to pull the ribcage up and out, increasing thoracic volume and causing air to enter the lungs (inspiration).

Internal intercostal muscles – antagonistic to external intercostal muscles, these contract to pull the ribcage 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 form single-cell thick walls of alveoli with a large surface area to minimise diffusion distance.

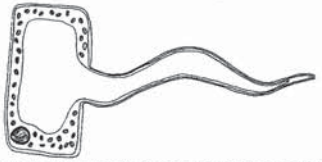
Goblet cells produce mucus in the trachea and bronchi to trap dirt and pathogens. **Cilia** move the mucus up to the oesophagus to be swallowed.



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

Plants

Plants have **root-hair cells** that have a large **surface area** and thin **diffusion distance** to increase the rate of diffusion of ions and water into the plant.



Word cloud

Surface area : volume
Metabolism
Spiracles
Tracheae
Tracheoles
Buccal cavity
Counter-current exchange
Ventilation
Trachea
Bronchi
Bronchioles
Alveoli
Intercostal muscles
Diaphragm
Goblet cells
Vital capacity
Erythrocytes
Neutrophils
Epithelia
Totipotent
Unipotent
Multipotent
Meristems

OCR Biology (Oxford): pp. 102–132
OCR AS Biology (Pearson): pp. 153–163, pp. 168–179