Cambridge (CIE) IGCSE Biology

Your notes

Gas Exchange in Humans

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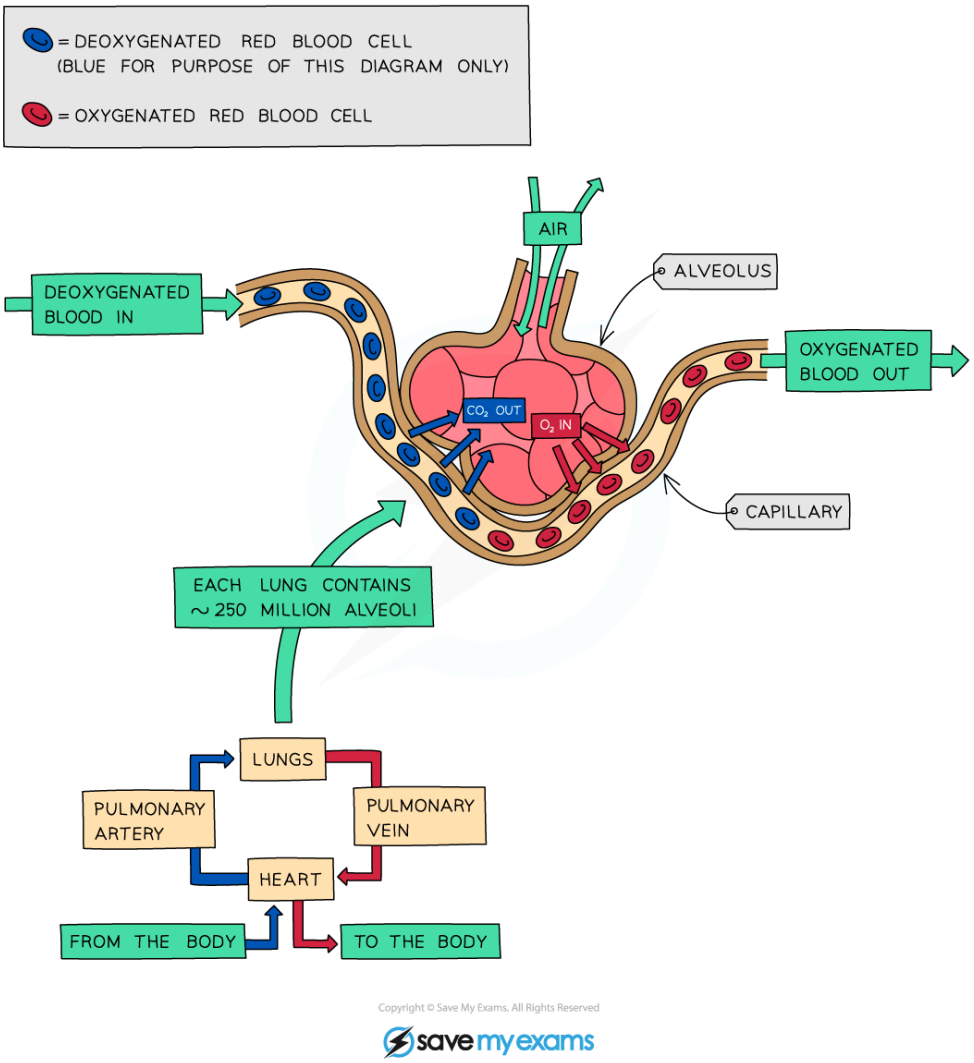
Your notes

Features of gas exchange surfaces

- All **gas exchange surfaces** have features in common
- These features maximise the rate of gas exchange taking place; they include:
  - **Large surface area** to allow faster diffusion of gases across the surface
  - **Thin walls** to ensure diffusion distances remain short
  - **Good ventilation with air** so that diffusion gradients can be maintained
  - **Good blood supply** to maintain a high concentration gradient so diffusion occurs faster



The alveolus is the gas exchange surface in humans

Examiner Tips and Tricks

You may notice that several of the features of alveoli that aid their function are the same as those that make villi, or root hair cells, suited to their function, e.g.

- large surface area
- good blood supply
- steep concentration gradient

These structures are all examples of **exchange surfaces**; they allow the efficient movement of substances across their surface by diffusion, active transport and/or osmosis. So, if you learn the features of one exchange surface, you also know the features of the others!

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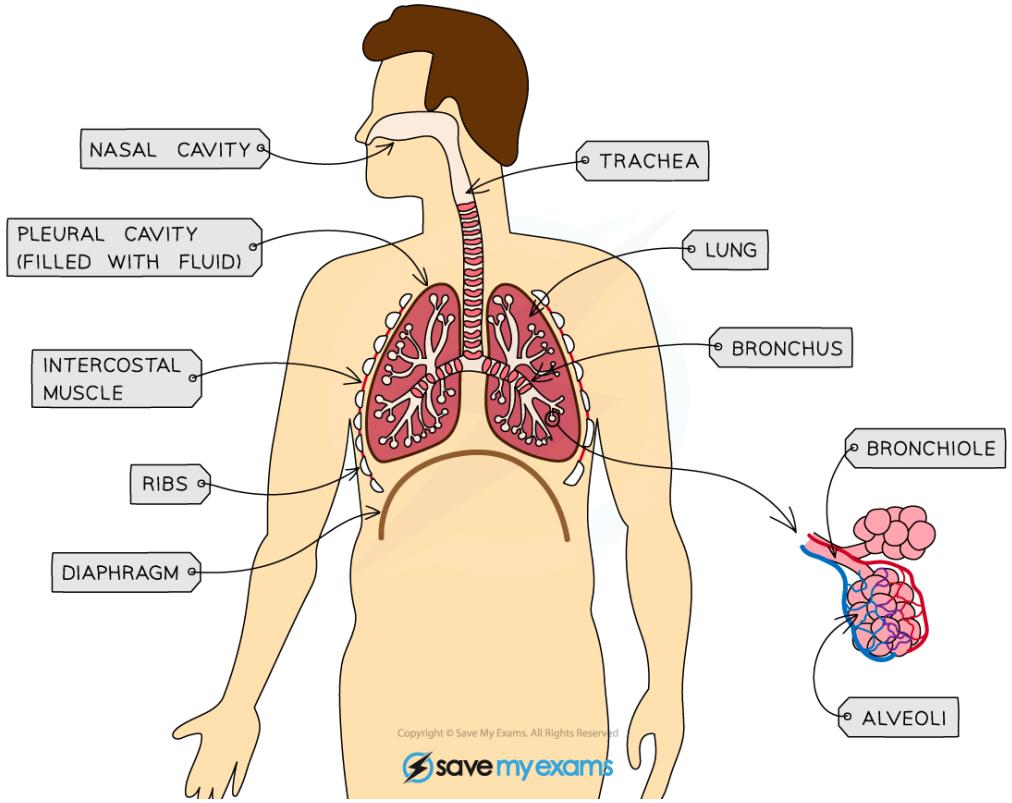
The Breathing System



Structures in the human breathing system

STRUCTURE	DESCRIPTION
RIBS	BONE STRUCTURE THAT PROTECTS INTERNAL ORGANS SUCH AS THE LUNGS
INTERCOSTAL MUSCLE	MUSCLES BETWEEN THE RIBS WHICH CONTROL THEIR MOVEMENT CAUSING INHALATION AND EXHALATION
DIAPHRAGM	SHEET OF CONNECTIVE TISSUE AND MUSCLE AT THE BOTTOM OF THE THORAX THAT HELPS CHANGE THE VOLUME OF THE THORAX TO ALLOW INHALATION AND EXHALATION
TRACHEA	WINDPIPE THAT CONNECTS THE MOUTH AND NOSE TO THE LUNGS
LARYNX	ALSO KNOWN AS THE VOICE BOX, WHEN AIR PASSES ACROSS HERE WE ARE ABLE TO MAKE SOUNDS
BRONCHI (PL)	LARGE TUBES BRANCHING OFF THE TRACHEA WITH ONE BRONCHUS (SIN) FOR EACH LUNG
BRONCHIOLES	BRONCHI SPLIT TO FORM SMALLER TUBES CALLED BRONCHIOLES IN THE LUNGS CONNECTED TO ALVEOLI
ALVEOLI	TINY AIR SACS WHERE GAS EXCHANGE TAKES PLACE

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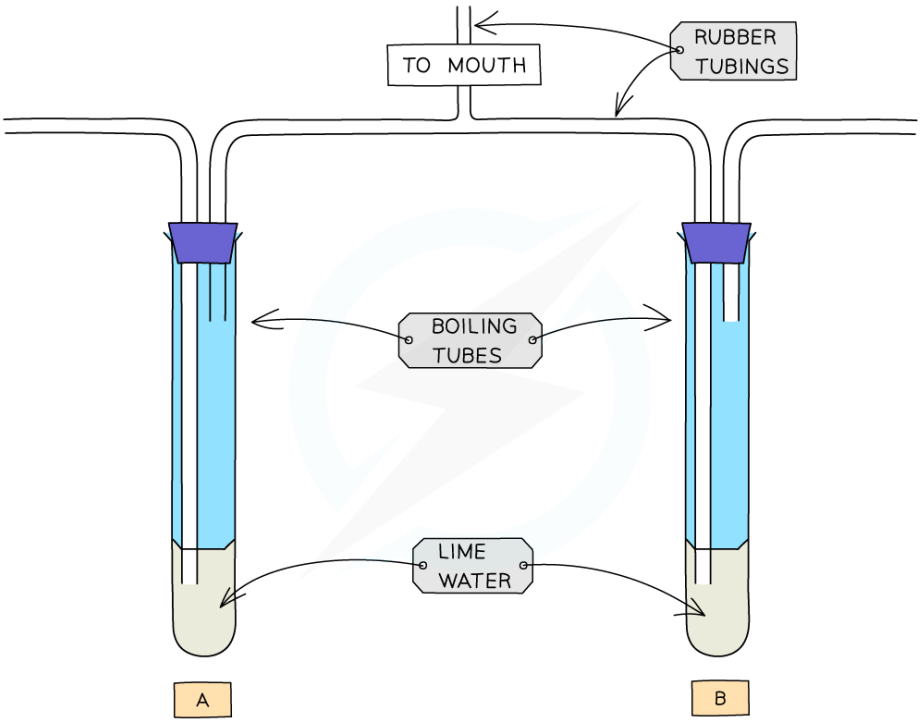
Investigating the Differences in Inspired & Expired Air

- A simple experimental setup can be used to investigate the differences between inspired and expired air



The limewater test

- When we breathe in, the air is drawn through boiling tube A
- When we breathe out, the air is blown into boiling tube B
- **Lime water** is **clear** but becomes **cloudy** (or milky) when carbon dioxide is bubbled through it
- The lime water in **boiling tube A will remain clear**, but the limewater in **boiling tube B will become cloudy**
- This shows us that the **percentage of carbon dioxide in exhaled air is higher than in inhaled air**

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Differences in inspired & expired air

- Air that is inhaled, or breathed in, **differs in its gas composition** to air that is exhaled, or breathed out; this is due to the process of **gas exchange** that takes place in the alveoli
  - Inhaled air can also be referred to as inspired air
  - Exhaled air is also known as expired air
- Inhaled air is drawn from the surrounding atmosphere, and so its gas composition matches atmospheric levels
- During gas exchange in the alveoli **oxygen enters the blood** from the alveoli, and **carbon dioxide** and **water vapour leave the blood** and enter the alveoli
- This gas exchange process means that the gas composition of exhaled air differs to that of the air that was previously inhaled
  - Inhaled air contains around **21 % oxygen** and exhaled air contains around **16 % oxygen**
  - Inhaled air contains around **0.04 % carbon dioxide** and exhaled air contains around **4 % carbon dioxide**
  - Inhaled air contains less water vapour than exhaled air

Composition of inhaled and exhaled air table

Gas	Inspired air / %	Expired air / %
Oxygen	21	16
Carbon dioxide	0.04	4
Water vapour	0.2 - 4	1 - 5
Nitrogen	78	78

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Investigating the Effects of Physical Activity on Breathing

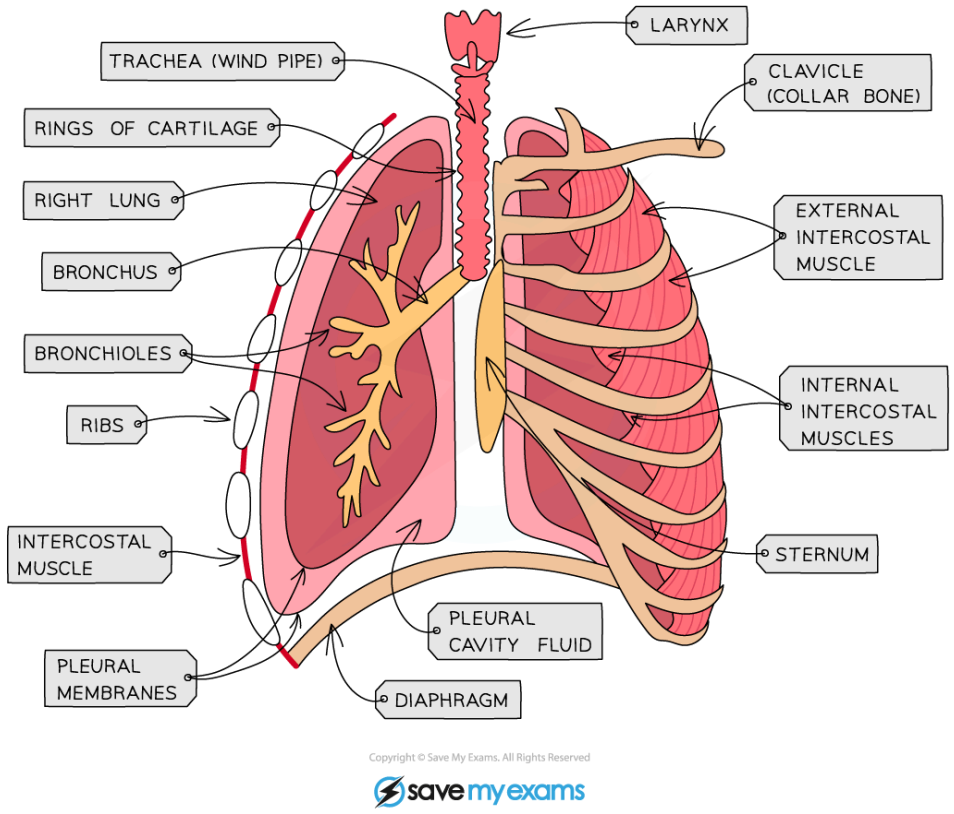
- Exercise increases the **frequency and depth of breathing**
- This can be investigated by **counting the breaths taken during one minute at rest** and **measuring average chest expansion over 5 breaths** using a tape measure held around the chest
- Exercise for a set time (at least 3 minutes)
- Immediately after exercising, **count the breaths taken in one minute and measure the average chest expansion over 5 breaths**
- Following exercise, the **number of breaths per minute will have increased** and the **chest expansion will also have increased**

Your notes

Identifying Intercostal Muscles: Extended

Extended Tier Only

- Muscles are only able to pull on bones, not push on them
- This means that there must be two sets of intercostal muscles; one to pull the rib cage up and another set to pull it down
- One set of intercostal muscles is found on the outside of the ribcage (the **external** intercostal muscles)
- The other set is found on the inside of the rib cage (the **internal** intercostal muscles)



There are 2 sets of intercostal muscles: the external, on the outside of the rib cage, and the internal, on the inside of the rib cage

Your notes

Function of Cartilage in the Trachea: Extended

Extended Tier Only

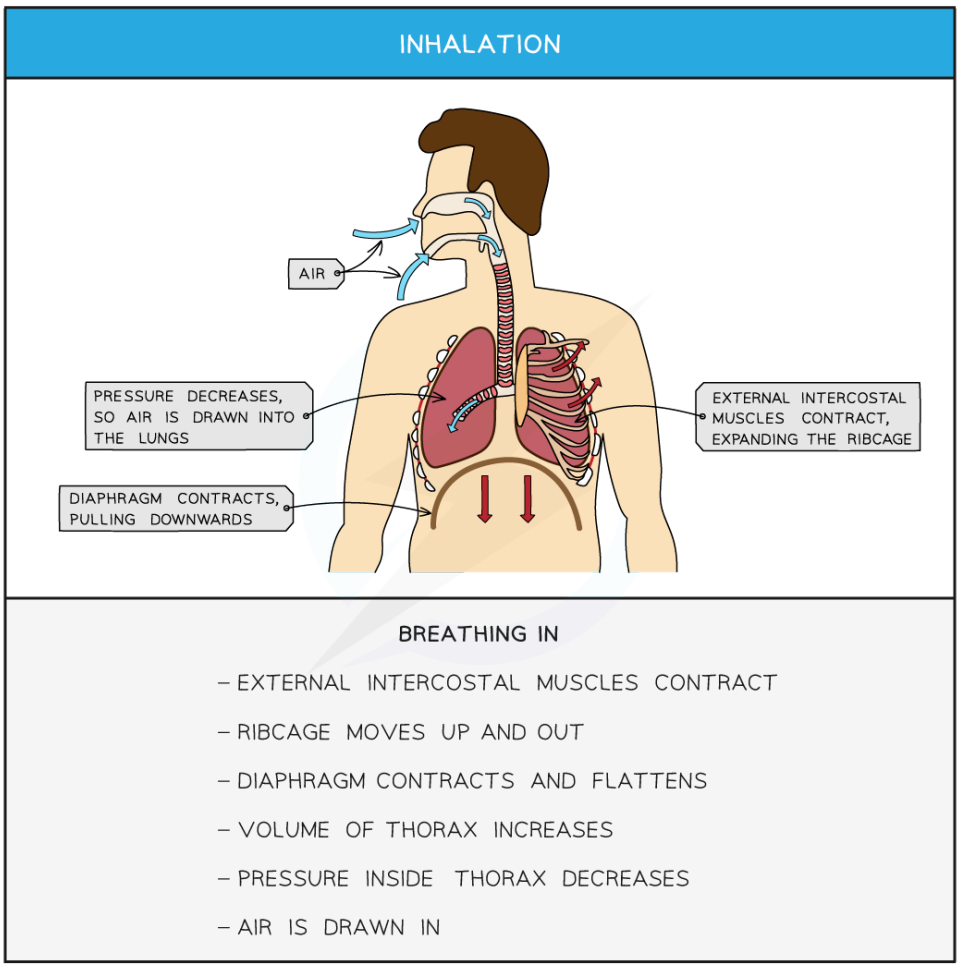
- Rings of **cartilage** surround the trachea (and bronchi)
- The function of the cartilage is to **support the airways** and **keep them open** during breathing
- If they were not present then the sides could collapse inwards when the air pressure inside the tubes drops

Your notes

Volume & Pressure Changes in the Lungs: Extended

Extended Tier Only

- The **diaphragm** is a thin sheet of muscle that separates the chest cavity from the abdomen; it is ultimately responsible for **controlling ventilation** in the lungs
  - When the diaphragm **contracts** it flattens and this **increases the volume** of the chest cavity (thorax), which consequently leads to a **decrease in air pressure** inside the lungs relative to outside the body, **drawing air in**.
  - When the diaphragm **relaxes** it moves upwards back into its domed shape and this **decreases the volume** of the chest cavity (thorax), which consequently leads to an **increase in air pressure** inside the lungs relative to outside the body, **forcing air out**
- The external and internal intercostal muscles work as **antagonistic** pairs (meaning they work in different directions to each other)
- During **inhalation** the **external set of intercostal muscles contract** to pull the ribs **up and out:**
  - **This also increases the volume of the chest cavity (thorax), decreasing air pressure, drawing air in**
- During **exhalation,** the external **set of intercostal muscles relax** so the ribs **drop down and in:**
  - **This decreases the volume of the chest cavity (thorax) increasing air pressure, forcing air out**
- When we need to increase the rate of gas exchange (for example during strenuous activity) the internal intercostal muscles will also work to **pull the ribs down and in** to decrease the volume of the thorax more, forcing air out more forcefully and quickly – this is called **forced exhalation**
  - There is actually a greater need to rid the body of increased levels of carbon dioxide produced during strenuous activity!
- This allows a **greater volume of gases to be exchanged**



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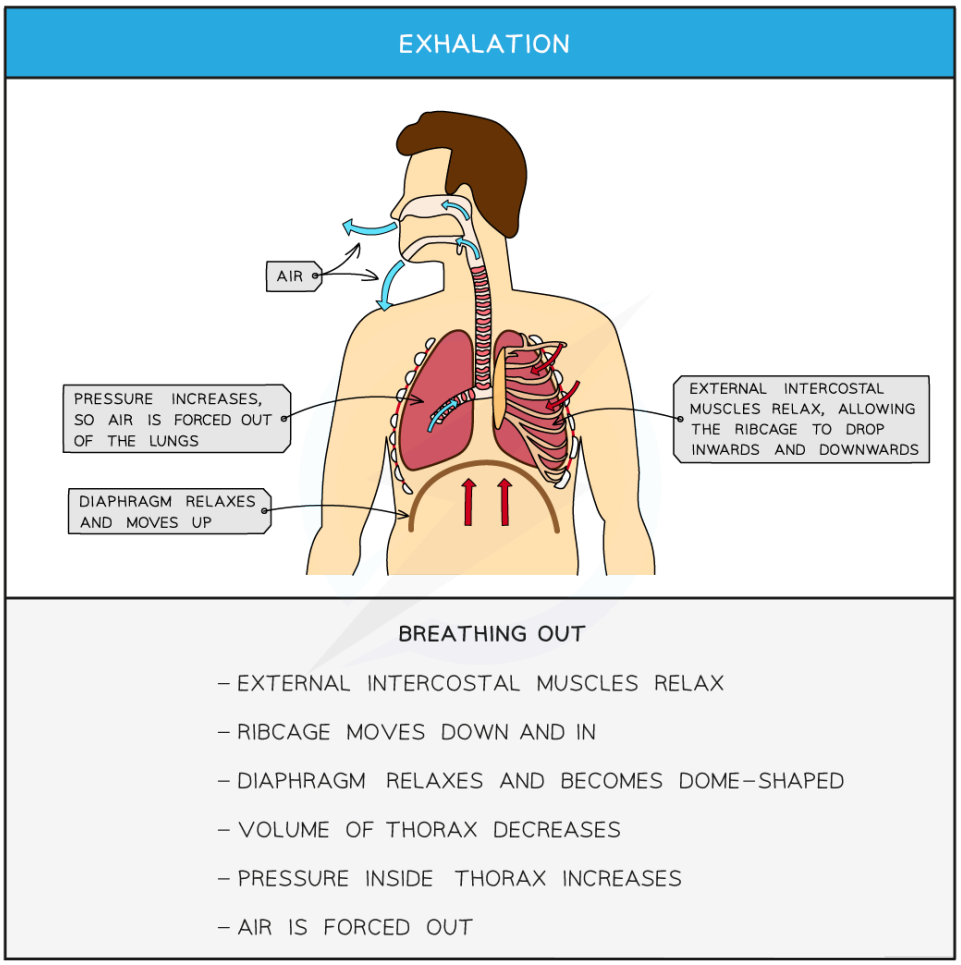

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Examiner Tips and Tricks

You may see the terms **inhalation OR inspiration** (breathing in), and **exhalation OR expiration** (breathing out). Both sets of terms mean exactly the same thing, so don't let them confuse you!This sequence of events is a common exam question and you should be able to **explain in detail** what is happening to the external and internal intercostal muscles, the rib cage, the diaphragm, the volume and the pressure-volume of the lungs when breathing in and out.Remember, if you learn one, the other is almost exactly the opposite.

Your notes

Differences in Inspired & Expired Air: Extended

Extended Tier Only

Reason for Differences Between Inspired & Expired Air Table

GAS	INSPIRED AIR	EXPIRED AIR	REASON FOR DIFFERENCE
OXYGEN	21%	16%	OXYGEN IS REMOVED FROM BLOOD BY RESPIRING CELLS SO BLOOD RETURNING TO LUNGS HAS A LOWER OXYGEN CONCENTRATION THAN THE AIR IN THE ALVEOLI WHICH MEANS OXYGEN DIFFUSES INTO THE BLOOD IN THE LUNGS
CARBON DIOXIDE	0.04%	4%	CARBON DIOXIDE IS PRODUCED BY RESPIRATION AND DIFFUSES INTO BLOOD FROM RESPIRING CELLS; THE BLOOD TRANSPORTS THE CARBON DIOXIDE TO THE LUNGS WHERE IT DIFFUSES INTO THE ALVEOLI AS IT IN A HIGHER CONCENTRATION IN THE BLOOD THAN IN THE AIR IN THE ALVEOLI
WATER VAPOUR	LOWER	HIGHER	WATER EVAPORATES FROM THE MOIST LINING OF THE ALVEOLI INTO THE EXPIRED AIR AS A RESULT OF THE WARMTH OF THE BODY
NITROGEN	78%	78%	NITROGEN GAS IS VERY STABLE AND SO CANNOT BE USED BY THE BODY, FOR THIS REASON ITS CONCENTRATION DOES NOT CHANGE IN INSPIRED OR EXPIRED AIR

Your notes

Explaining the Link Between Physical Activity & Breathing: Extended

Extended Tier Only

- Frequency and depth of breathing **increase when exercising**
- This is because muscles are working harder and aerobically respiring more and they **need more oxygen to be delivered to them** (and carbon dioxide removed) to keep up with the energy demand
- If they cannot meet the energy demand they will also **respire anaerobically**, producing **lactic acid**
- After exercise has finished, the lactic acid that has built up in muscles needs to be **removed** as it **lowers the pH of cells** and can **denature enzymes** catalysing cell reactions
- It can only be removed by combining it with oxygen - this is known as **'repaying the oxygen debt'**
- This can be tested by seeing how long it takes after exercise for the breathing rate and depth to return to normal - **the longer it takes, the more lactic acid produced during exercise and the greater the oxygen debt that needs to be repaid**

Mechanism for increasing breathing during exercise

- The **rate of respiration** increases in muscle cells when exercising heavily
- CO_2 is a **product** of aerobic respiration, so **CO_2 levels increase** in the muscle cells
- This CO_2 diffuses out of the cells into the **blood plasma**
  - CO_2 in solution causes a slight drop in pH so the blood becomes slightly more acidic
- The blood flows around the circulatory system and passes to the brain where the increased carbon dioxide levels are detected by **chemoreceptors** in the brain
  - Chemoreceptors are cells that detect chemical changes in the body
  - They can detect changes in blood gas levels, as well as changes in pH
  - The chemoreceptors are located in the **medulla oblongata** of the brain
- The brain sends nerve impulses to the diaphragm and the intercostal muscles to **increase the rate and depth of muscle contraction**
- The **rate of inspiration increases**, along with the the **volume of air** moved in and out with each breath
- The result is **greater absorption of oxygen** and **removal rate of carbon dioxide**

- This supports the **increased rate of respiration** in the exercising muscle cells

Your notes

Examiner Tips and Tricks

Be sure not to confuse the terms **respiration** and **breathing** in this topic:

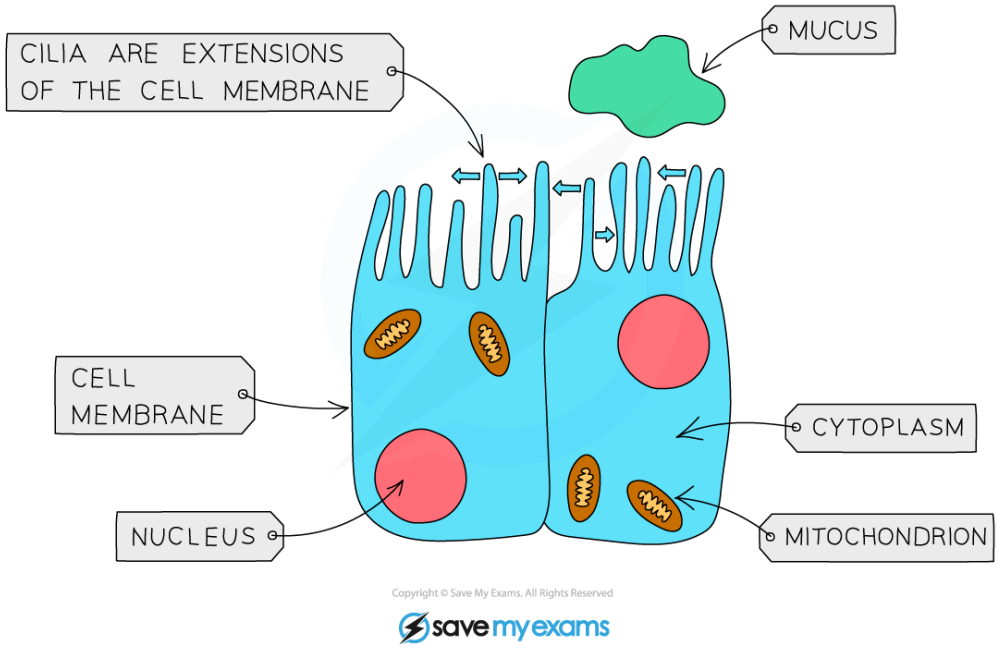
- Respiration is a series of chemical reactions that releases energy from food
- Breathing is the mechanism for moving air in and out of the lungs; this supports the chemical reactions of respiration

Your notes

Protecting the Breathing System: Extended

Extended Tier Only

- The passages down to the lungs are lined with **ciliated epithelial cells**
- Cilia comes from the Latin for eyelash, so unsurprisingly these cells have tiny **hairs** on the end of them that **beat** and **push mucus up the passages towards the nose and throat** where it can be removed
- The **mucus** is made by special mucus-producing cells called **goblet cells** because they are shaped like a goblet, or cup
- The mucus traps **particles, pathogens like bacteria or viruses, and dust** and **prevents them getting into the lungs** and damaging the cells there



Mucus traps particles, dust and pathogens and cilia beat and push it up and away from the lungs

Examiner Tips and Tricks

The function of cilia and mucus is often a 3-mark question on the extended paper.The examiners are looking for you to state the following:

1. The mucus is produced by goblet cells and **traps bacteria, dust, particles**
2. The cilia **beat**
3. And **push the mucus away from the lungs towards the throat**

This is quite simple, but often marks are lost as students haven't been **precise** enough with their explanations!

Your notes