# 11 GAS EXCHANGE IN HUMANS

YOUR NOTES

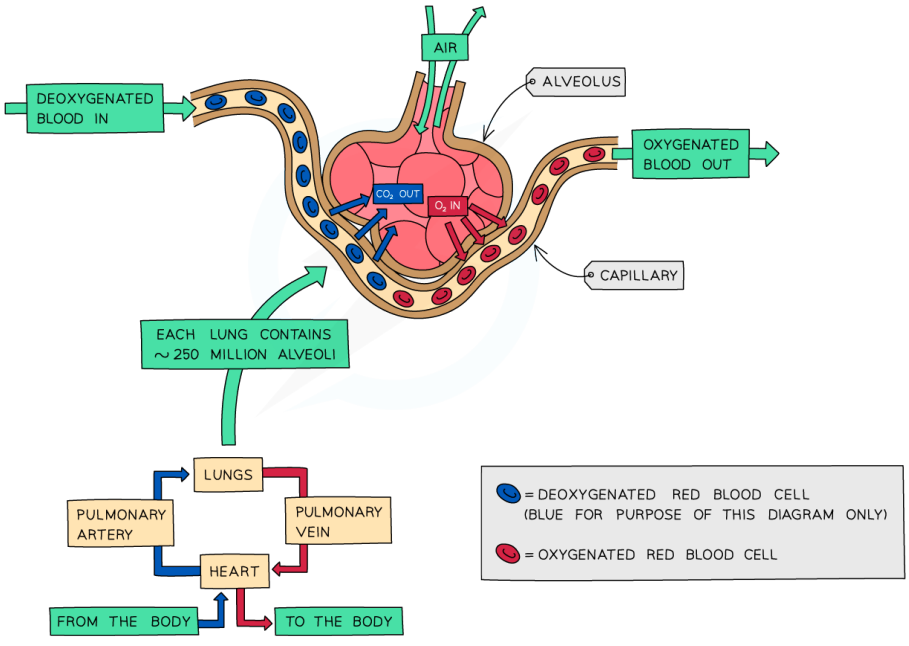
CONTENTS:



## 11.1 THE BREATHING SYSTEM

### Features of Gas Exchange Surfaces

- The surfaces where gas exchange occurs in an organism are very different and different organisms have evolved different mechanisms for getting the gases to the gas exchange surface depending on size, where they live etc.
- All gas exchange surfaces have features in common
- These features allow the maximum amount of gases to be exchanged across the surface in the smallest amount of time
- 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

# 11 GAS EXCHANGE IN HUMANS

## 11.1 THE BREATHING SYSTEM cont...

YOUR NOTES

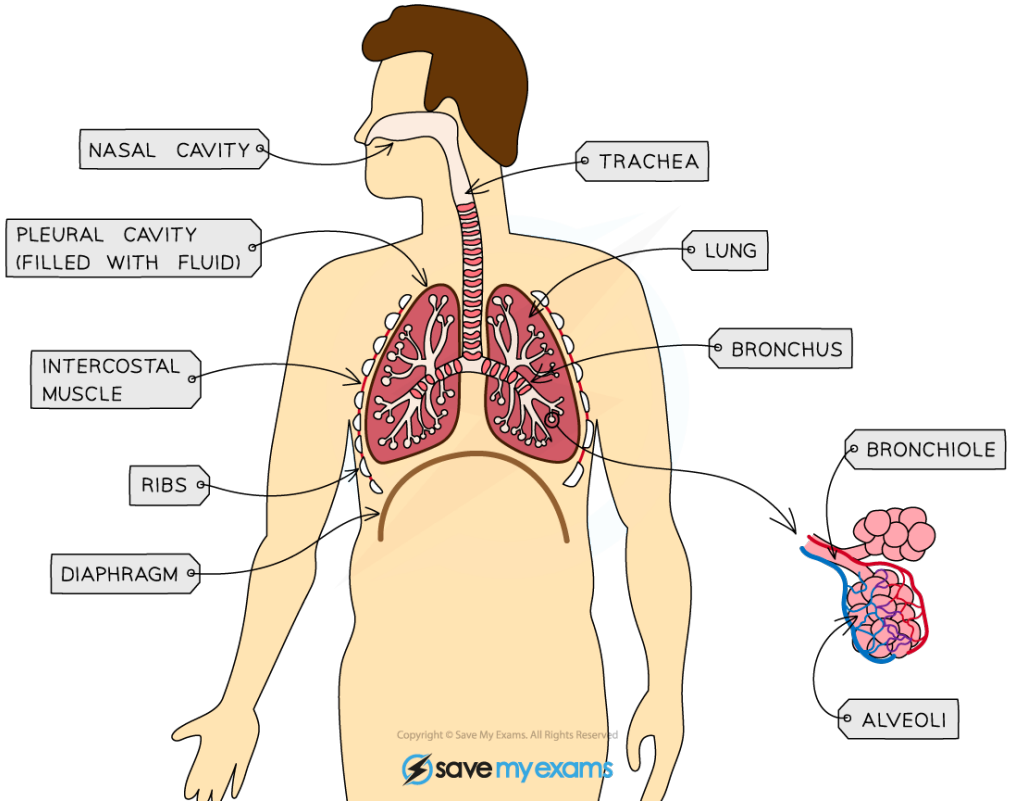
### EXAM TIP

Several of the features of alveoli that make them suited to their function are the same as those that make villi suited to their function; or root hair cells suited to their function.

This is because all of these structures are involved in transporting substances across their surfaces – by diffusion, active transport, osmosis or a combination.

So if you learn the features for one, you also know many of the features of the others!

### Structure of the Breathing System




Structures in the human breathing system

# 11 GAS EXCHANGE IN HUMANS

## 11.1 THE BREATHING SYSTEM cont...

YOUR NOTES

| 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 |

# 11 GAS EXCHANGE IN HUMANS

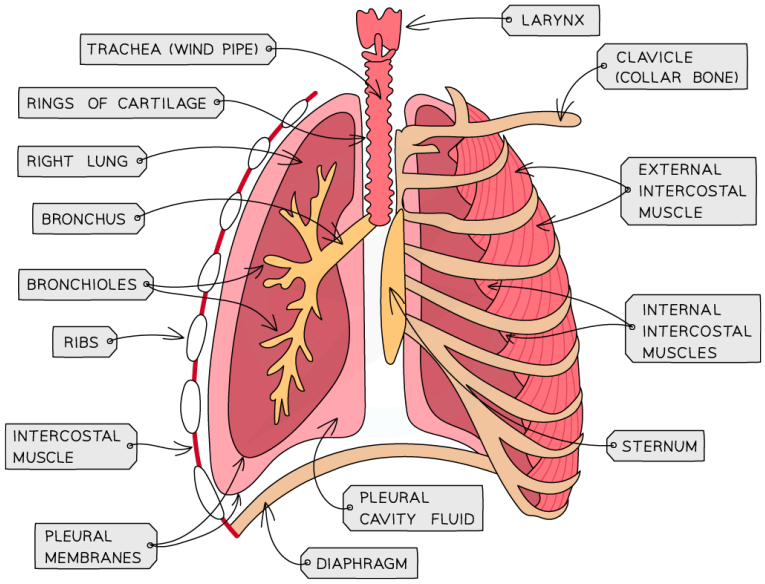
## 11.1 THE BREATHING SYSTEM cont...

YOUR NOTES

EXTENDED ONLY

### The Intercostal Muscles

- 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)




The lungs

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

### The Trachea

- 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 may collapse inwards when the air pressure inside the tubes drops

# 11 GAS EXCHANGE IN HUMANS

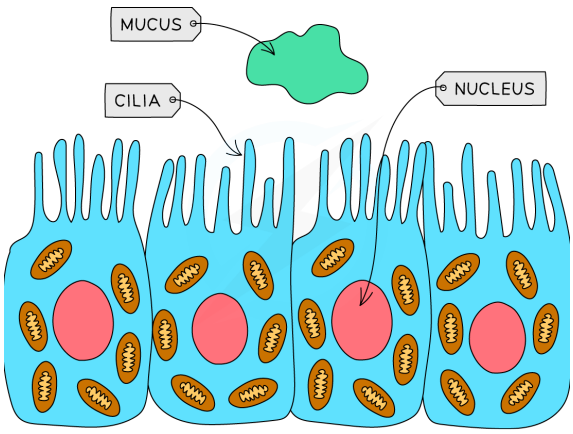
## 11.1 THE BREATHING SYSTEM cont...

YOUR NOTES

EXTENDED ONLY cont...

### The Function of Cilia & Mucus

- 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




Ciliated cells

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

EXAM TIP

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

- The mucus is produced by goblet cells and traps bacteria, dust, particles
- The cilia beat
- 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!

# 11 GAS EXCHANGE IN HUMANS

## 11.2 VENTILATION OF THE LUNGS

YOUR NOTES

EXTENDED ONLY

### Inhalation & Exhalation

- 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**
- During **exhalation** the **internal set of intercostal muscles contract** to pull the ribs **down and in**
- The point of this is to increase or decrease the **volume** of the chest cavity (**thorax**) so that the lungs can follow and increase or decrease in size
- The **muscle surrounding the diaphragm** also helps to increase and decrease the volume of the thorax
- This means that when we are doing 'quiet breathing' there may be no noticeable chest movement as the lungs are ventilated mainly by changes in the **shape of the diaphragm**
- When we need to increase the rate of gas exchange (for example during strenuous activity) the intercostal muscles will also work to **pull the ribs up and out** and increase the volume of the thorax more
- This is because we now require a **greater volume of gases to be exchanged**, so we need to inflate the lungs quicker and almost to their maximum
- As the **volume of the thorax increases, the pressure inside the lungs decreases**
- Once it drops **below** the air pressure **outside** the lungs, air will be forced in
- During **exhalation**, the reverse occurs; volume **decreases**, pressure in the thorax **increases** and air is forced out

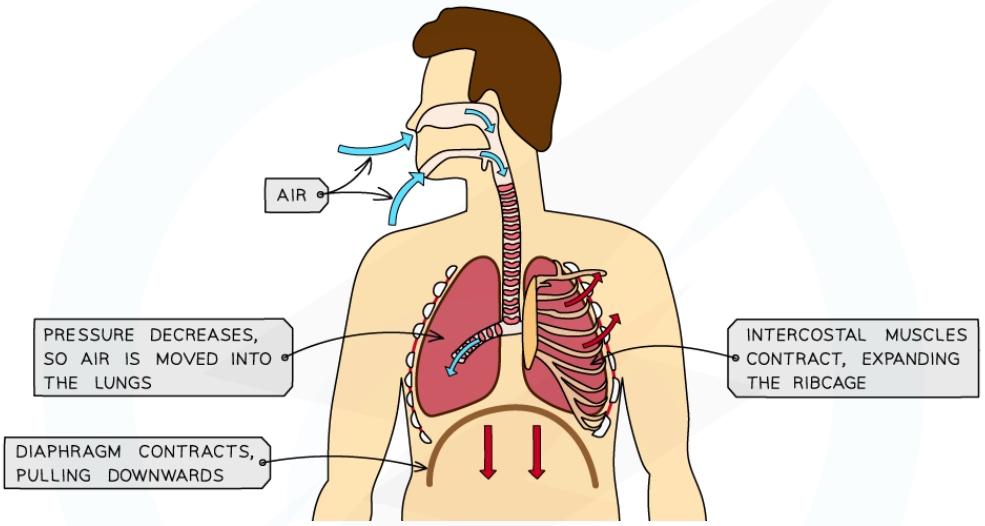
# 11 GAS EXCHANGE IN HUMANS

## 11.2 VENTILATION OF THE LUNGS cont...

YOUR NOTES

EXTENDED ONLY cont...

### INHALATION




**BREATHING IN**

- EXTERNAL INTERCOSTAL MUSCLES CONTRACT
- INTERNAL INTERCOSTAL MUSCLES RELAX
- RIBCAGE MOVES UP AND OUT
- DIAPHRAGM CONTRACTS AND FLATTENS
- PRESSURE INSIDE THORAX DICREASES
- AIR IS DRAWN IN

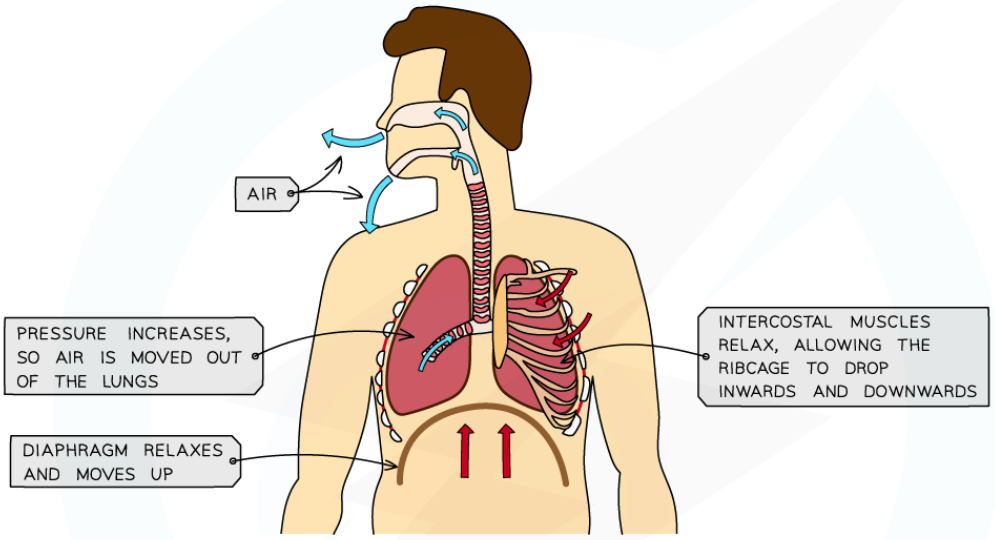
# 11 GAS EXCHANGE IN HUMANS

## 11.2 VENTILATION OF THE LUNGS cont...

YOUR NOTES

EXTENDED ONLY cont...

### EXHALATION




**BREATHING OUT**

- INTERNAL INTERCOSTAL MUSCLES CONTRACT
- EXTERNAL INTERCOSTAL MUSCLES RELAX
- RIBCAGE MOVES DOWN AND IN
- DIAPHRAGM RELAXES AND BECOMES DOME-SHAPED
- PRESSURE INSIDE THORAX INCREASES
- AIR IS FORCED OUT

# 11 GAS EXCHANGE IN HUMANS

## 11.2 VENTILATION OF THE LUNGS cont...

YOUR NOTES

EXAM TIP

- This sequence of events is a common exam question
- So be able to explain in detail what is happening when breathing in and out to:
  - **the external and internal intercostal muscles**
  - **the rib cage**
  - **the diaphragm**
  - **the volume and the pressure of the lungs**
- Remember, if you learn one, the other is almost exactly the opposite.
- 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!

## 11.3 COMPOSITION OF AIR

### Differences between Inhaled & Exhaled Air

- Air that is breathed in and air that is breathed out has **different amounts of gases** in it due to exchanges that take place in the **alveoli**
- Atmospheric air contains around **20 – 21% oxygen**, of which we only absorb around 4 – 5%, breathing out air containing around **16% oxygen**
- Normal **carbon dioxide content of air is around 0.04%** and, as carbon dioxide diffuses into the alveoli from the blood, we breathe out air containing around **4% carbon dioxide**
- We also breathe out air containing **more water vapour** than the air we breathe in, and the temperature of exhaled air is **higher** than inhaled air

| GAS | INSPIRED AIR | EXPIRED AIR |
|---|---|---|
| OXYGEN | 21% | 16% |
| CARBON DIOXIDE | 0.04% | 4% |
| NITROGEN | 78% | 78% |

# 11 GAS EXCHANGE IN HUMANS

## 11.3 COMPOSITION OF AIR

YOUR NOTES

EXTENDED ONLY

### Reasons for Differences in Inhaled & Exhaled Air

| 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 |

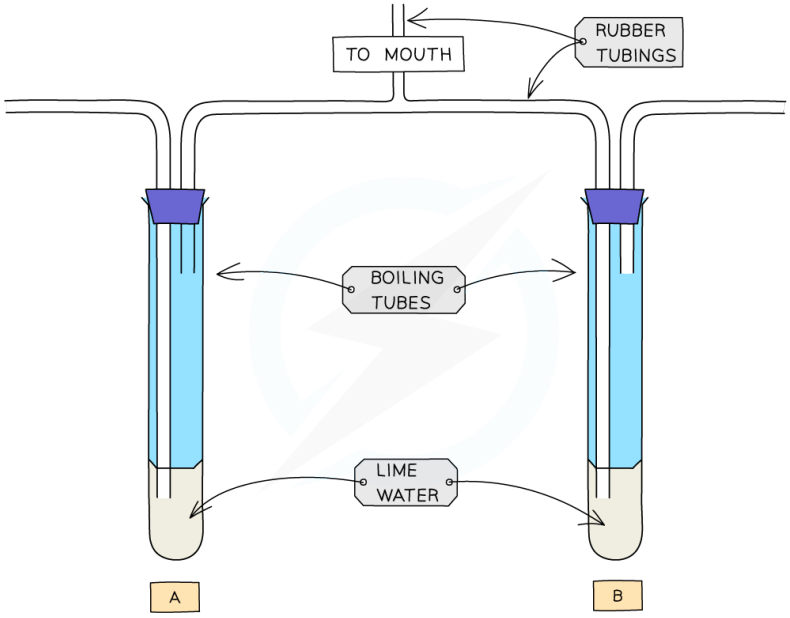
### Using Limewater to Test for $CO_2$ in Exhaled Air

- We can use the apparatus below to investigate the difference between the amount of carbon dioxide in inhaled air and exhaled air

# 11 GAS EXCHANGE IN HUMANS

## 11.3 COMPOSITION OF AIR cont...

YOUR NOTES




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**

## 11.4 EXERCISE & BREATHING

### Investigating the Effect of Exercise 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**

# 11 GAS EXCHANGE IN HUMANS

## 11.4 EXERCISE & BREATHING

YOUR NOTES

EXTENDED ONLY

### Explaining the Effect of Exercise on Breathing

- 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**

### Carbon Dioxide Concentration & The Brain

- As respiration rates increase, **more carbon dioxide is produced** and enters the blood
- Carbon dioxide is an **acidic gas** in solution and so it can affect the working of enzymes in the cells and needs to be removed as quickly as possible
- As blood flows through the **brain**, the increase in carbon dioxide concentration stimulates **receptor cells**
- These send impulses to the muscles of the lungs, causing them to contract **faster and more strongly**
- This causes the **frequency and depth of breathing to increase** until the carbon dioxide concentration of the blood has lowered sufficiently

> NOW TRY SOME EXAM QUESTIONS

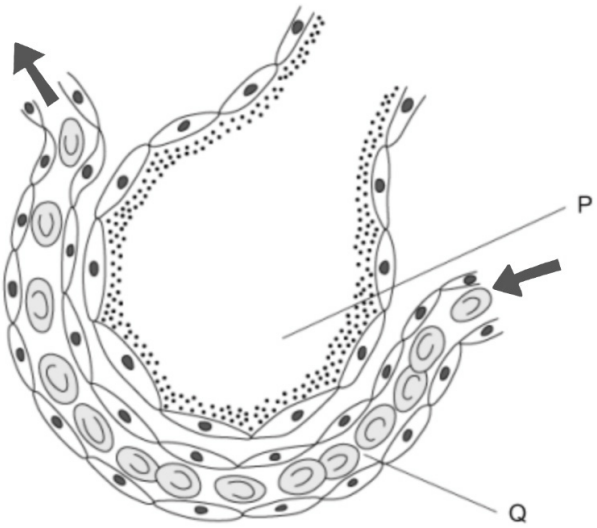
# 11 GAS EXCHANGE IN HUMANS

## EXAM QUESTIONS

YOUR NOTES

### QUESTION 1

The diagram below shows a cross-section through an alveolus and a capillary.




Why does oxygen move from P to Q?

**A** The concentration of carbon dioxide is lower in the alveolus than in the blood.

**B** The concentration of oxygen in the blood is lower than in the air in the capillary

**C** Oxygen must replace carbon dioxide.

**D** The concentration of oxygen in the blood is lower than the air in the alveolus.

### QUESTION 2

What makes the alveoli suitable as a gas exchange surface in mammals?

| | a dense capillary network | large total surface area |
|---|---|---|
| **A** | ✘ | ✘ |
| **B** | ✔ | ✘ |
| **C** | ✘ | ✔ |
| **D** | ✔ | ✔ |

# 11 GAS EXCHANGE IN HUMANS

## EXAM QUESTIONS cont...

YOUR NOTES

### QUESTION 3

What of the following shows the correct path of oxygen as it enters the lungs?

**A** trachea → bronchiole → bronchus → alveolus

**B** trachea → bronchus → bronchiole → alveolus

**C** alveolus → bronchus → bronchiole → trachea

**D** alveolus → bronchiole → bronchus → trachea

### QUESTION 4

Some amphibians, such as frogs, can use their skin as a gas exchange surface.

What are the most likely characteristics of the surface of the skin in these amphibians?

| | surface area | type of skin |
|---|---|---|
| **A** | small | thick |
| **B** | large | thick |
| **C** | small | thin |
| **D** | large | thin |

### QUESTION 5

What of the following correctly describes the actions of the intercostal muscles and the diaphragm when we breathe in?

| | external intercostal muscles | internal intercostal muscles | diaphragm |
|---|---|---|---|
| **A** | contract | relax | domed |
| **B** | contract | relax | flat |
| **C** | relax | contract | domed |
| **D** | relax | contract | flat |

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