Gaseous exchange

Scope

Topic	Topic Breakdown
Gaseous exchange	Distinguish between the following processes: - Cellular respiration - Breathing - Gas exchange Requirements of efficient gas exchange organs: - Large surface area - Thin - Moist - Well ventilated - Protected - Transport system The structure of the human ventilation system - Trachea - Epiglottis - Bronchi - Bronchioles - Lungs - Ribs - Intercostal muscles - Diaphragm - alveoli Functions and structural adaptations of each part of the ventilation system Processes involved in gaseous exchange - Ventilation of the lungs (inhalation and exhalation) - Gaseous exchange in alveolus - Transport of gases (oxygen and carbon dioxide) around the body - Gaseous exchange in tissues Composition of inspired air compared to expired air Construct a model of the human breathing system. - Explain the limitations of the model. - Demonstrate that expired air contains carbon dioxide. Homeostatic control of breathing

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Gaseous exhange

Breathing is a mechanical process of taking air into and out of the lungs. .

Cellular respiration refers to a chemical process which takes place within cells in order to release energy. Plants and animals need energy for survival.

Gaseous exchange is a physical process which involves the exchange of gases between the air and the blood in the lungs

Requirements

For gases to effectively diffuse across respiratory surfaces, certain requirements need to be met..

Requirement	Reason
large	a large surface area to volume ratio allows enough oxygen and carbon dioxide to diffuse
thin and permeable	diffusion can occur more rapidly and efficiently if the surface is thin and permeable
moist	oxygen and carbon dioxide diffuse when in dissolved in water
protected	all gaseous exchange surfaces need to be protected from mechanical injury as well as from drying out (desiccation)
well-ventilated	ensuring that oxygen rich air for terrestrial organisms and oxygen rich water for aquatic organisms are continually brought into contact with the gaseous exchange surface
vascular	an efficient method of transporting gases to and from the gaseous exchange surfaces is required

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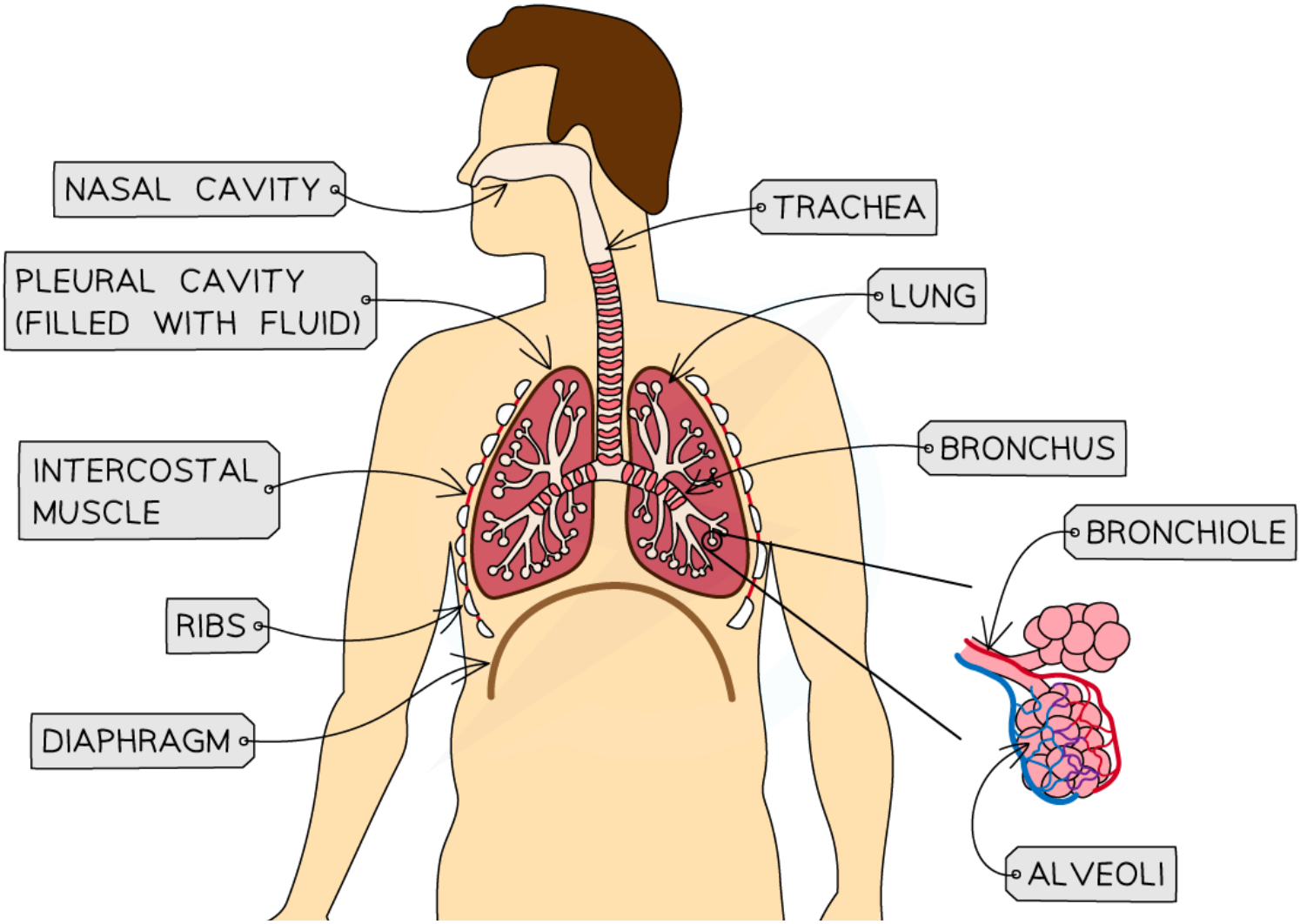
Gaseous exchange

The **human gas exchange system** consists of the following distinct sections:

- air passages
- lungs
- muscles involved in the mechanism of breathing (**ventilation**)

Human gaseous exchange



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Gaseous exchange Functions

Structure	Function
air passages	
2 nostrils	air inhaled through nostrils
2 nasal cavities	• cavities are lined with epithelial and goblet cells • mucous from the goblet cells together with the cilia trap dirt and sweep it out of the nose; keeps cavity moist • blood capillaries warm the incoming air
trachea	• windpipe is situated in front of the oesophagus • C-shaped cartilage rings protect trachea and keep it open for easy movement of air
bronchus / bronchi	• trachea branches into left and right bronchi that enter the upper lobes of the left and right lungs • held open by O-shaped cartilage rings; lined with mucous membranes
bronchiolus / bronchioli	• each bronchus divides into many branches, the bronchioli • these passages are smaller and narrower and do not have cartilage for reinforcement
alveoli	• bronchioli end in a collection of alveoli (air sacs) that are sites for gaseous exchange • many alveoli increase the surface area to maximise the gas exchange
	• have thin walls of squamous epithelial cells allowing for easy diffusion of gases • tissue fluid keeps the walls of the alveoli moist • a large blood capillary network surrounds the alveoli
throat and lungs	
pharynx	• connects the nasal cavity with larynx • lined with mucous membranes • leads into the trachea and the oesophagus
larynx	• larynx contains the vocal chords • air passes over the chords and sound is produced
epiglottis	• a cartilage structure on top of the larynx (voice box) • closes when food is swallowed preventing food from entering the trachea
lungs	• each of the two spongy, elastic lungs are surrounded by the double pleural membrane • pleural fluid acts as a lubricant and helps prevent friction during inhalation and exhalation
ribs and muscles involved in breathing	
ribs	• on either side of the sternum, **protect** the lungs from injury
intercostal muscles	• found between the ribs • contract and relax during inhalation and exhalation altering the volume of air in the chest (thoracic cavity)
diaphragm	• a sheet of muscle below the lungs • contracts and flattens altering the volume of the chest cavity and is important in the breathing

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Gaseous exchange

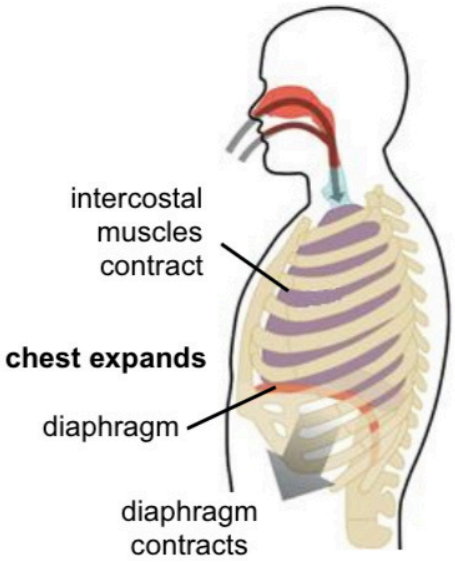
Breathing

The process of **breathing** is a mechanical process. Air moves in and out of the lungs as a result of differences in atmospheric air pressure and the air pressure inside the lungs. It involves different muscles and volume and pressure changes inthe thoracic cavity.

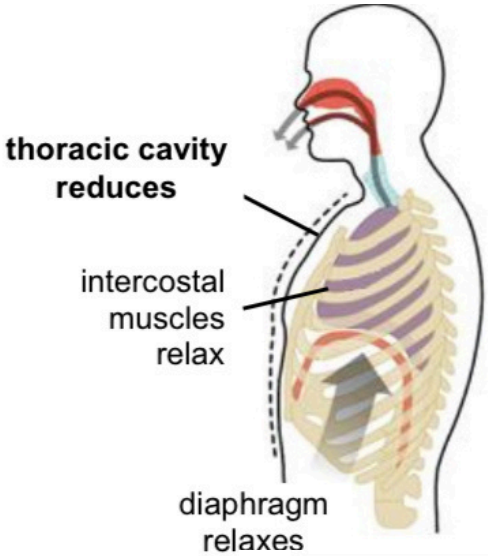
Inhalation

Inhalation – when air moves into lungs

- diaphragm muscle contracts, it flattens and moves downwards
- external intercostal muscles between the ribs contract
- ribcage lifts upwards and pushes outwards
- air pressure in the lungs decreases as the chest volume increases
- atmospheric pressure is greater than the pressure inside the lungs and air flows in
- *inhalation is an active process involving muscle contraction*



Exhalation



Exhalation – when air is pushed out of lungs

- diaphragm relaxes and moves upwards
- external intercostal muscles relax
- ribcage moves down and inward
- air pressure in lungs increases relative to the outside air pressure
- air is forced out to equalise the pressure
- *exhalation is a passive process when muscles relax*

Inspired vs expired air

Gas	Inhaled air (%)	Exhaled air (%) from a sleeping person	Exhaled air (%) from a person exercising
Nitrogen (N_2)	78	78	78
Oxygen (O_2)	21	16	12
Carbon dioxide (CO_2)	0,04	4	9

Nitrogen is not used in the human breathing system. Oxygen is used by the cells in cellular respiration and carbon dioxide is a product of cellular respiration and needs to be removed from the cells.

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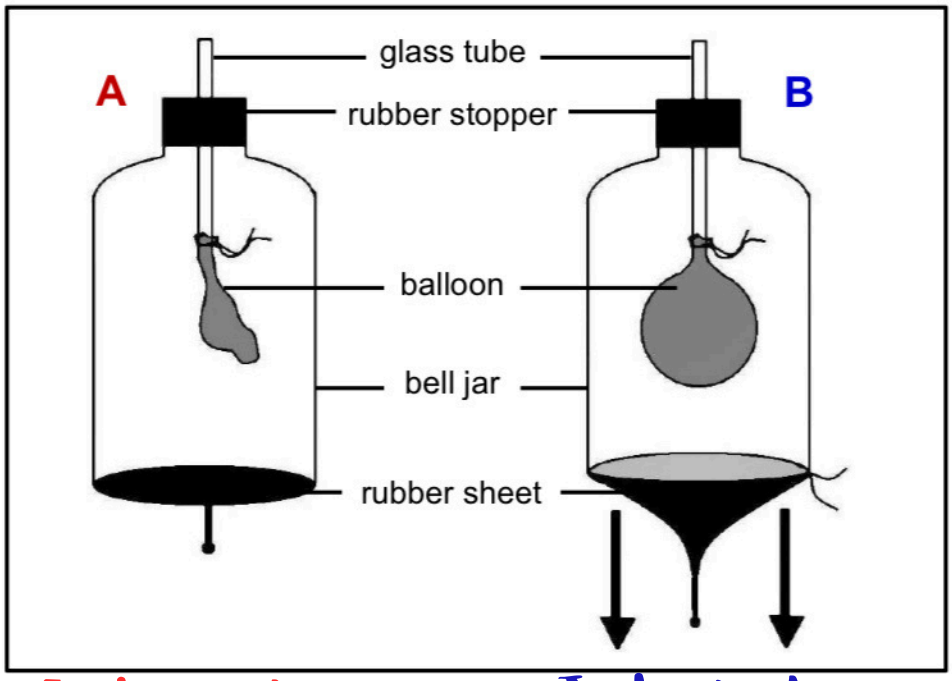
Gaseous exchange Model

The model below can be used to demonstrate the mechanism of breathing.



Exhalation Inhalation

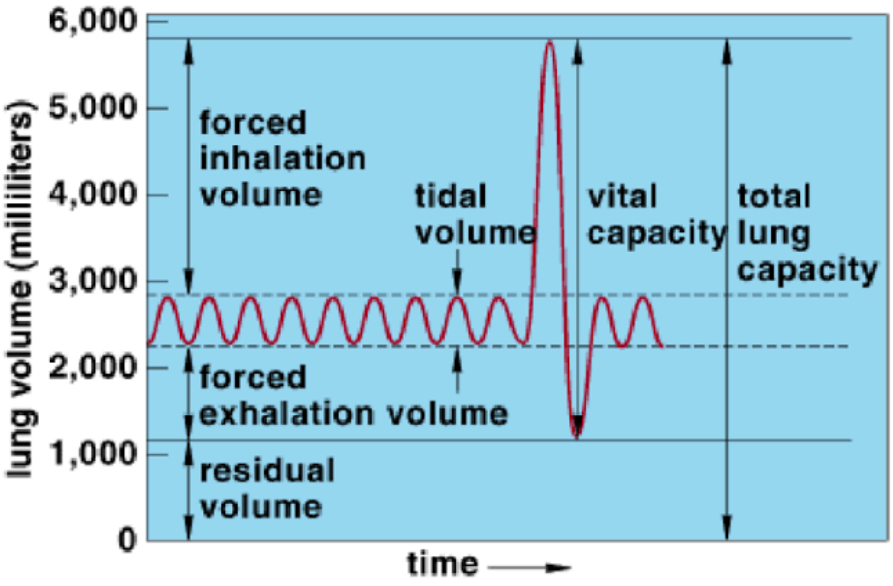
Corresponding parts

Glass tube - Trachea
Balloon - Lunc
Bell jar - Chest/ Thoracic cacity
Rubber sheet - Diaphragm

Limitations

The bell jar does not move but the lungs do
Model demonstrates one lung where humans have 2 lungs

A spirometer is an instrument used to measure the volume of air that enters and leaves the human lungs during inhalation and exhalation.



Not examined

Lung capacity refers to the total amount of air the lungs can hold.

Tidal volume is the amount of air inhaled or exhaled during a normal breath.

Vital capacity refers to the maximum amount of air that a person can exhale after taking the deepest possible breath.

Residual volume is the amount of air remaining in the lungs after a maximal forced exhalation.

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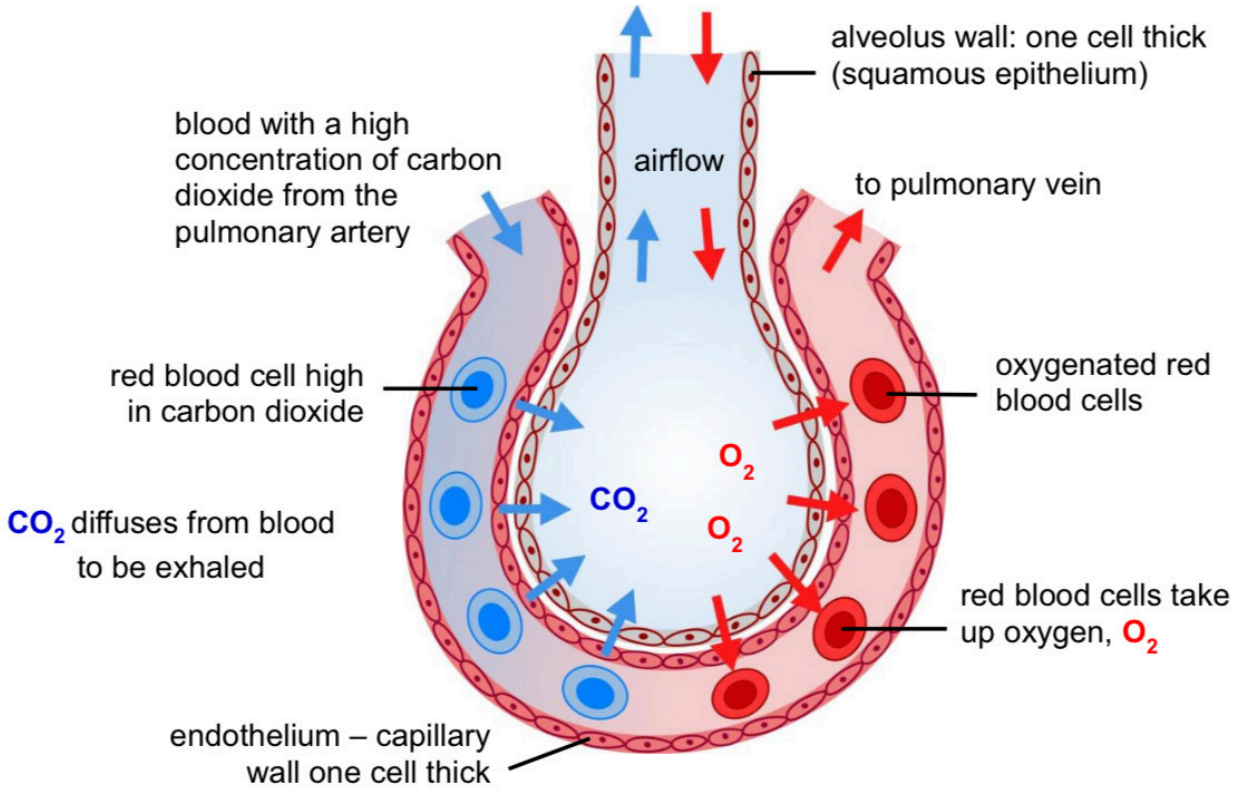
Gaseous exchange Notes

The exchange of gases occurs in two areas in the body. At the alveoli surface (external gaseous exchange) and between the blood and tissues (internal gaseous exchange).

Gaseous exchange in alveolus

- The air entering the alveoli after inhalation has a high oxygen concentration compared to the oxygen concentration in the blood of the surrounding capillaries.
- The inhaled air has a lower carbon dioxide concentration than that of the blood in the surrounding capillaries.
- This results in **oxygen diffusing (moving) from the alveoli into the blood** and **carbon dioxide diffusing (moving) from the blood and back into the alveoli.**



Gases are exchanged due to concentration gradients.

Blood coming from the heart and past the alveoli has a low oxygen concentration – deoxygenated blood.

- The blood that leaves the alveoli has a high concentration of oxygen – oxygenated blood. The blood will take the oxygen to the cells where it is needed.
- The air in the alveoli will be exhaled with more carbon dioxide then the air that had been inhaled.

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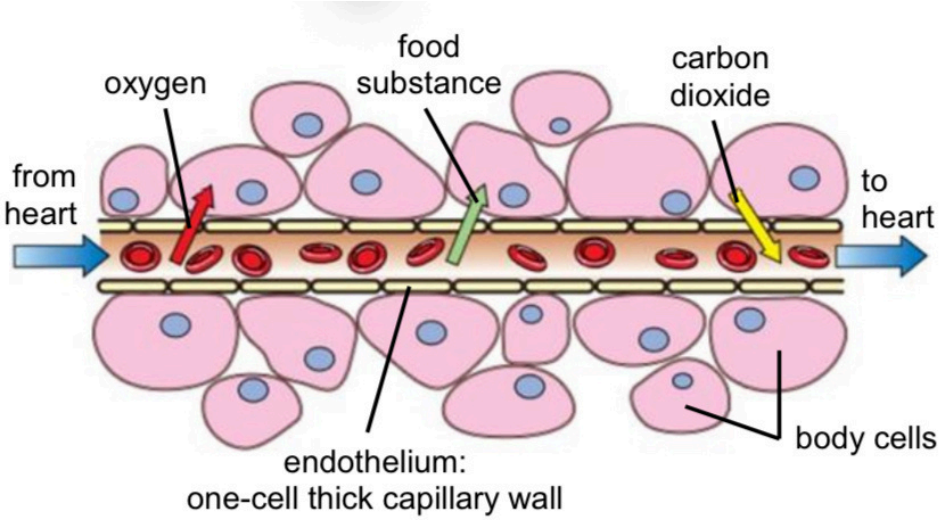
Gaseous exchange Notes

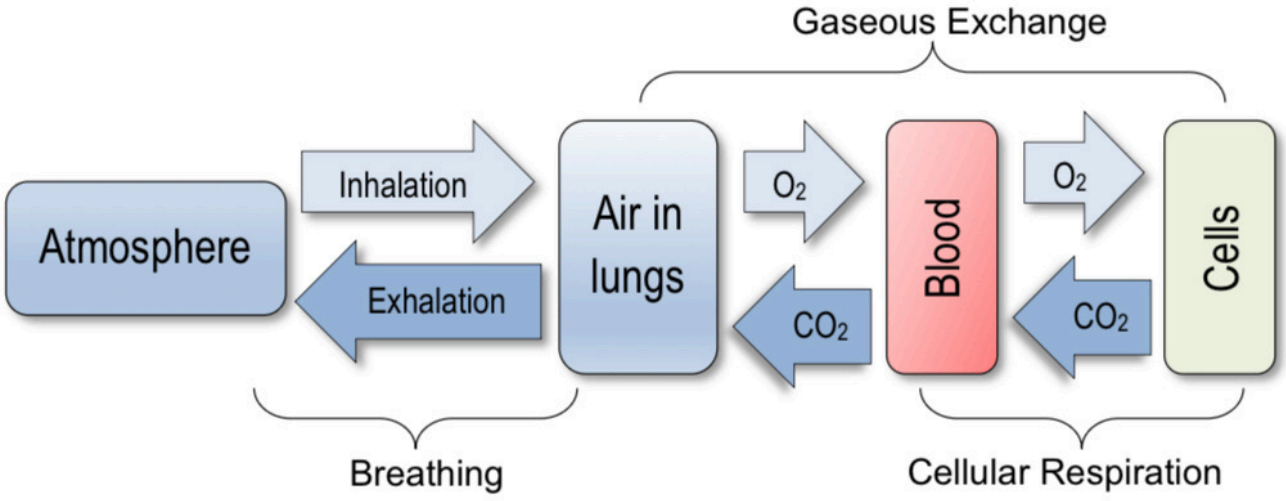
Oxygen is transported mainly by the red blood cells. Most of the oxygen combines with **haemoglobin** present in the red blood cells (**erythrocytes**) to form oxyhaemoglobin. It is transported via the circulatory system to all body cells.
Most of the CO_2 is transported in the blood plasma in the form of **bicarbonate ions.**

Gaseous exchange in tissues

Oxygenated blood arrives from the heart in the capillary network close to tissue cells.
Oxygen will diffuse from the blood and into the neighbouring cells **due to the concentration gradient**.



The cells will have high carbon dioxide concentrations due to continuing cellular respiration. This carbon dioxide moves out of the cells and into the blood and is **transported back to the heart** and **then to the lungs where it is exhaled.**
The cells are also bathed in a tissue fluid which supplies the necessary moisture for gaseous exchange.



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Gaseous exchange

Negative feedback

Negative feedback mechanisms stabilize a system and return it to its normal state.
When at rest, humans have a normal, rhythmic breathing rate. The levels of carbon dioxide in the blood determine the rate and depth of breathing.
When a person begins exercising, cellular respiration is increased due to the demand for oxygen and energy in the muscles. Carbon dioxide levels rise and the cells in the respiratory centre of the **medulla oblongata** of the brain detect this.
The body will respond to ensure that these levels do not reach dangerous levels and respiratory muscles will be targeted. The ability of the body to return the levels to normal is known as **homeostasis**.

Homeostatic control of carbon dioxide

Carbon dioxide (CO_2) levels in the blood increase **above normal levels**

↓

Receptor cells in the carotid artery in the neck are stimulated

↓

Cells send impulses to the medulla oblongata in the brain

↓

Medulla oblongata stimulates breathing muscles (intercostal muscles and diaphragm) and heart

↓

Breathing muscles contract more actively – increases the rate and depth of breathing; the heart beats faster

↓

More CO_2 is taken to and exhaled from the lungs

↓

The **CO_2 levels** in the blood **return to normal**

In homeostatic control:

- **the heart rate increases** – blood flow increases. Rapid transport of gases to and from the cells.
- **Increased rate and depth of breathing** – the intercostal muscles and the diaphragm contract and relax – more oxygen is inhaled, and more carbon dioxide is exhaled.

Effect of altitude

Not examined

Altitude is a measure of the height of a place above sea level and is measured in metres. Altitude affects the exchange of gases.

Less oxygen is absorbed by the red blood cells at high altitudes. The body will compensate for this by trying to produce more red blood cells to help carry more oxygen.

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Gaseous exchange Terminology

terrestrial	(plants and animals) living on land
aquatic	(plants and animals) living in water
gaseous exchange	the exchange of O_2 and CO_2 at a respiratory surface occurs at **two** places in mammals: • at a gaseous exchange surface (lungs) and the blood • between the blood and the body cells at the tissue level
breathing / ventilation	mechanical process of **inhalation** and **exhalation** through which air moves in and out of the respiratory organs enabling the uptake of oxygen and the removal of carbon dioxide.

diffusion	the movement of molecules from a region of high concentration to a region of low concentration until equilibrium is reached
catabolism	the breaking down of complex molecules into simple molecules to release energy
aerobic	occurring in the presence of oxygen
anaerobic	occurring in the absence of oxygen
cellular respiration	the breakdown of organic compounds (glucose / sugar) in the mitochondria of cells into inorganic products (CO_2 and H_2O) with the release of cellular energy (ATP); either aerobic or anaerobic

erythrocytes	red blood cells
haemoglobin	oxygen carrying protein pigment in the blood
altitude	height above sea level
iron (Fe)	the element found in the haemoglobin molecule to which oxygen atoms bind

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