

Gaseous Exchange

Recap:

Identify these processes:

1. A process that produces ATP.
2. Movement of air into and out of the lungs.
3. Movement of oxygen into the blood.

Cellular Respiration, Breathing and Gas exchange

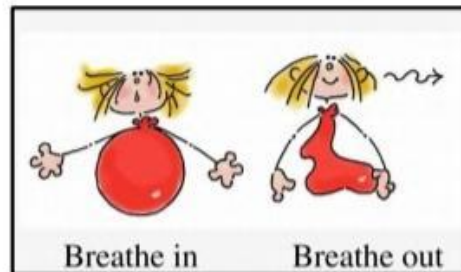
Learning Outcome: Distinguish between Cellular Respiration, Breathing and Gas exchange

Cellular Respiration	Breathing	Gas exchange
Takes place inside the cells	Takes place in the lungs	Takes place in alveoli of the lungs and in body tissues
Chemical process	Mechanical/Physical process	Physical process
Uses oxygen and glucose	Moves air into and out of the lungs	Oxygen is taken into blood and carbon dioxide is taken out
Energy(ATP) is produced	Energy not produced	Energy not produced

Key concepts

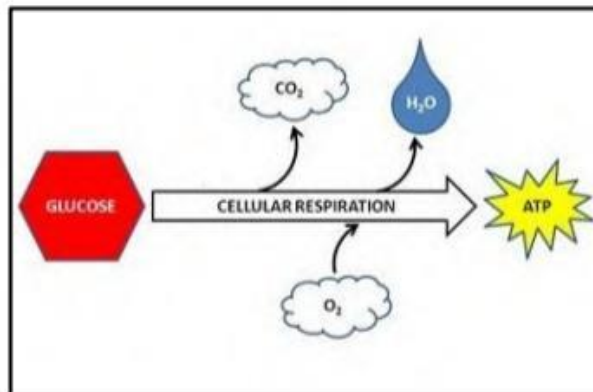
Breathing

This is a mechanical process taking oxygen into the lungs.



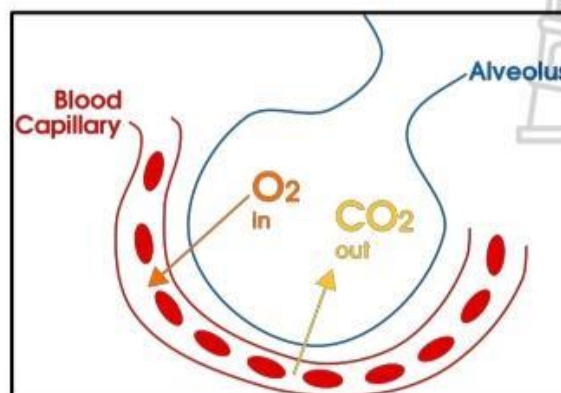
Cellular respiration

A chemical process which takes place in the cells to release energy.



Gaseous exchange

A physical process which involves the exchange of gases between the air and blood in the lungs.



Efficiency of gaseous exchange surfaces in living Organisms

Learning Outcome: Requirements Of efficient gas Exchange Organs

Importance of specialized respiratory surfaces:

- Why can't humans simply absorb oxygen through their skin like an earthworm?

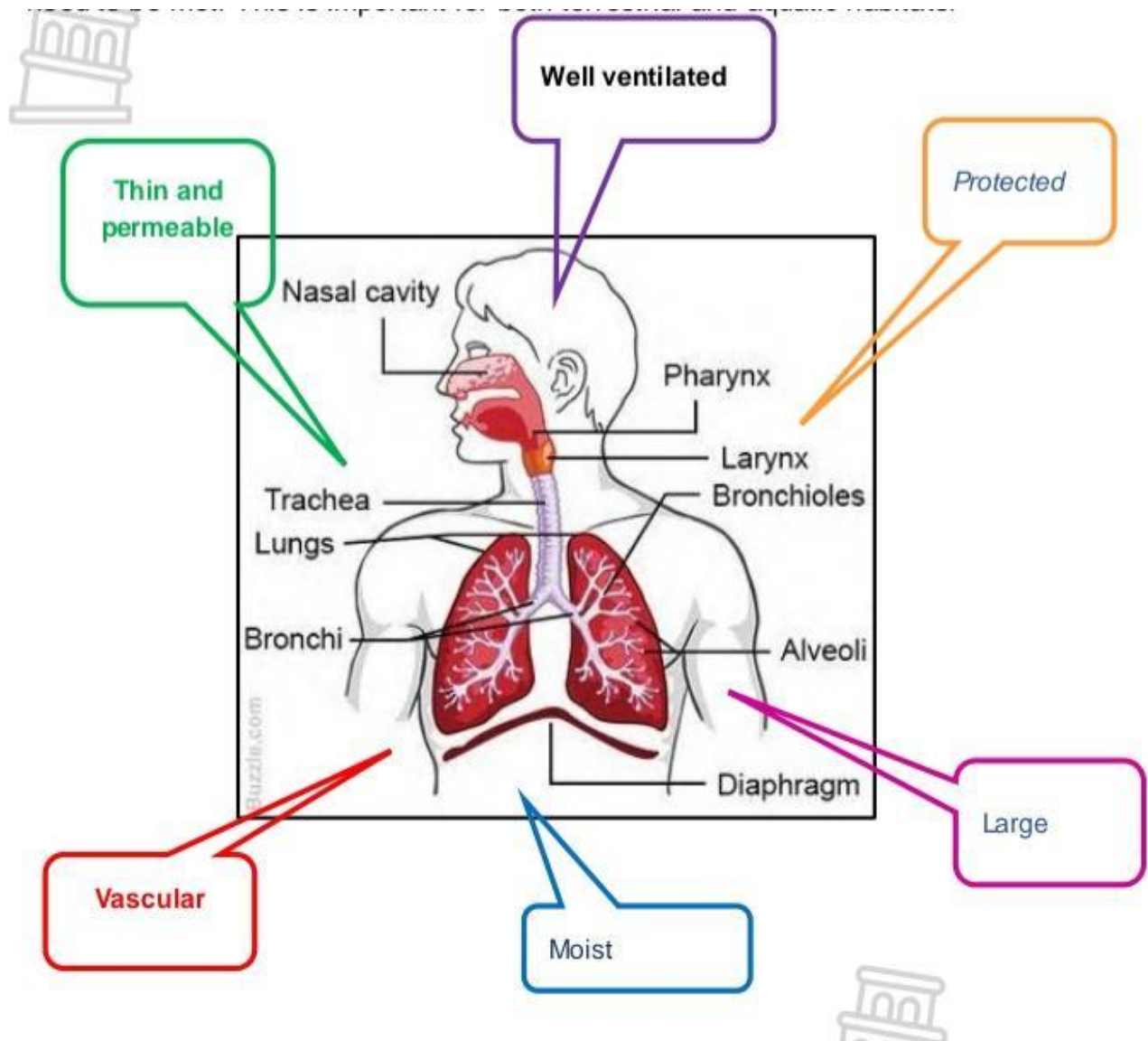


Table 1: The requirements for an efficient gaseous exchange surface.

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

Question 4

Gaseous exchange is the biological process by which gases move passively by diffusion across a surface. In humans this happens in the lungs.

- 4.1 Name the site for gaseous exchange in the lungs. (1)
- 4.2 Name FOUR structural requirements of an efficient gas exchange surface. (4)

[30]

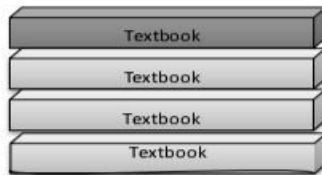
Surface area-to-volume ratio

The amount of O₂ taken up and CO₂ released during gaseous exchange in organisms, depends on the ratio of surface area to volume of the organism. Surface area is the combination of all the exposed surfaces of the organism. The volume is the space taken up by the same organism.

Which arrangement has more exposed surface?

Animal 1:

Use **four** of the textbooks on top of one another to build **Bookus glutinous** as the diagram indicates.



Bookus glutinous

Animal 2:

Bookus skinny will consist out of **4 textbooks** as the diagram below indicates. Remember the textbooks must be of the same size as the other textbooks which you used to build **Bookus glutinous**.



Bookus skinny

Question 3

- 3.1 Which animal has the highest surface area to volume ratio? (1)
- 3.2 In which animal will oxygen reach all cells through the process of diffusion? (1)
- 3.3 Give a reason for your answer in question 3.2. (1)
- 3.4 What systems are in place for an animal with a small surface area to volume ratio to ensure that all cells receive oxygen in the shortest possible time? (2)
- 3.5 Predict what will happen if an animal with a small surface to volume ratio does not have specialized systems in place for oxygen to reach all the cells. (2)

- Key point: The surface area to volume ratio would be the amount of surface an organism has in proportion to its size.

In general, the smaller the organism the larger the surface area to volume ratio.

Relationship between respiratory structures and Efficient gaseous exchange in different organisms

Table 2: Comparison of the respiratory surfaces of various groups of organisms

Requirement for effective gaseous exchange surface					
large	thin & permeable	moist	well-ventilated	protection	transport system
dicotyledonous plant (leaf and spongy mesophyll cells)					
flat surface increases exposure to air	thin-walled cells allow for diffusion	water vapour passes through stomata	air movement around leaves	cuticle and lower epidermis	simple diffusion
earthworm (skin)					
elongated, cylindrical shape	body surface is thin	mucous glands keep the worm moist	not needed – gas exchange surface on outside of body		through the skin
insect (tracheal system)					
extensively branched tracheoles	lining of tracheoles thin	tracheoles are moist	rhythmic body movements move air in and out	exoskeleton	gases in direct contact with tissues
bony fish (gills)					
branched gill filaments increase surface area	thin membranes	aquatic animals live in water	water taken in through mouth is forced out over gills	gills protected by bony cover, the operculum	heart and blood vessels present
mammals (lungs)					
bronchiole divide into many alveoli	alveoli have thin squamous epithelium	alveoli have thin layer of moisture	inhalation and exhalation during breathing	ribs protect the lungs	circulatory system

Human gaseous exchange

Learning Outcome: The structure (macro And tissue level), Location, Adaptations And functioning of the Ventilation system:

Where do you think the air travels before it reaches your blood?

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

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

Structure of the Human Gaseous Exchange System

Figures 1 and 2 show parts of the respiratory system that are directly involved in breathing and gaseous exchange.

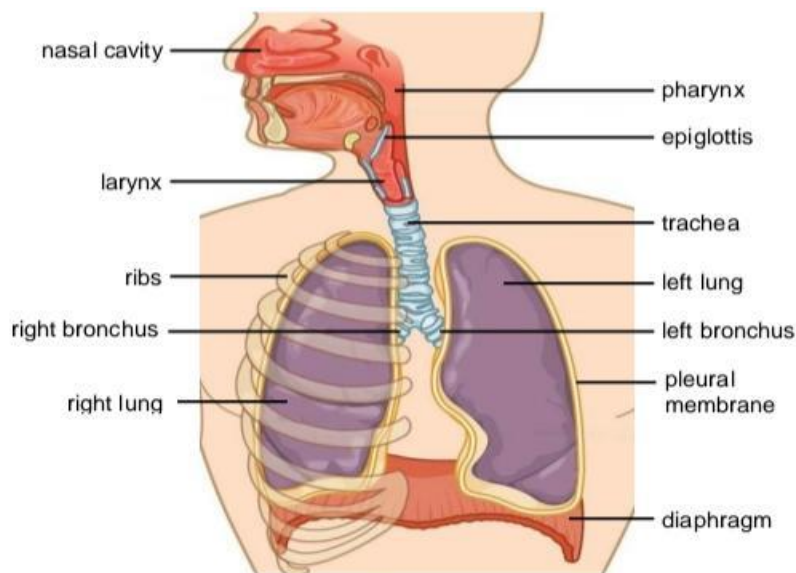


Figure 1: Human respiratory system

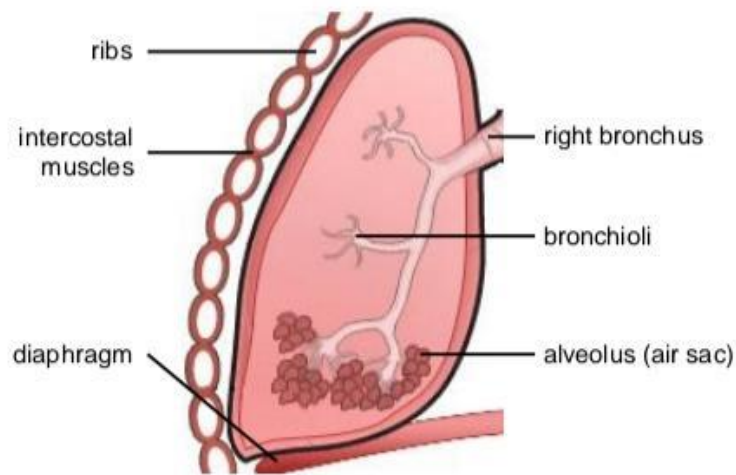


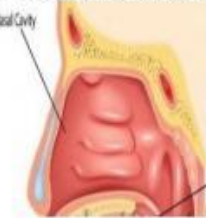
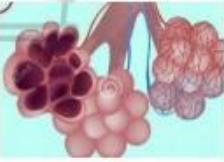
Figure 2: Right lung with alveoli

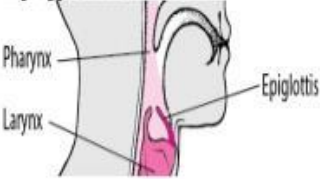
Adaptations of the ventilation system :how each structure is adapted for its function.

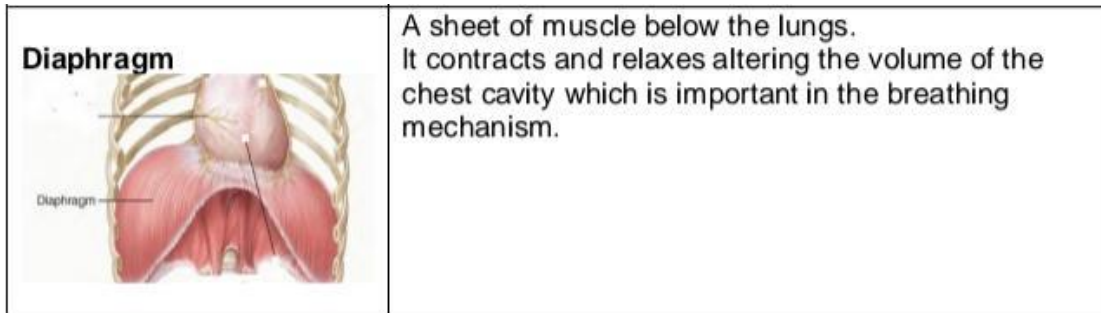
The human gas exchange system is well designed or structurally suited to carry out the function of gaseous exchange.

Table 3 below relates the structure to function of these parts.

Structure	Adaptations	Function / Importance
Nasal cavity	Hairs, mucus, cilia	Trap dust and microorganisms
Nasal cavity	Rich blood supply	Warms incoming air
Nasal cavity	Moist lining	Moistens air for gas exchange
Pharynx	Shared passage for air and food	Allows air passage to larynx
Epiglottis	Flap of cartilage	Prevents food entering trachea
Larynx	Vocal cords	Produces sound
Trachea	C-shaped cartilage rings	Prevents collapse of airway
Trachea	Mucus + cilia	Trap and remove dust
Bronchi	Cartilage support	Keeps airways open
Bronchioles	Smooth muscle	Controls airflow
Alveoli	Many small sacs	Large surface area
Alveoli	One-cell thick walls	Short diffusion distance
Alveoli	Moist lining	Gases dissolve easily
Alveoli	Capillary network	Maintains concentration gradient
Alveoli	Elastic fibres	Allows expansion and recoil
Lungs	Elastic tissue	Expansion and recoil
Pleura	Pleural fluid	Reduces friction
Diaphragm	Dome-shaped muscle	Changes chest volume
Intercostal muscles	Between ribs	Moves rib cage

STRUCTURE	FUNCTION
AIR PASSAGES	
2 Nostrils 	Air from atmosphere inhaled through two openings in nose called nostrils.
2 Nasal cavities 	Cavities are lined with ciliated columnar epithelium with goblet cells. Mucus from the goblet cells together with the cilia trap dust/dirt and sweep it out of the nose. Mucus keeps cavity moist. Blood capillaries warm the incoming air. Has turbinate bones to increase surface for airflow.
Trachea 	Trachea is situated in front of the oesophagus. C-shaped cartilage rings protect trachea and keep it open for easy movement of air into the lungs.
Bronchus / bronchi 	Trachea branches into left and right bronchi that enter the upper lobes of the left and right lungs. Held open by C-shaped cartilage rings so that it does not collapse during breathing. Lined with mucus membranes to keep incoming air moist
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 for easy dissolving gases. A large blood capillary network surrounds the alveoli to allow for rapid diffusion of gases between alveoli and blood.

THROAT AND LUNGS	
Pharynx (throat region)	Connects the nasal cavity with larynx. Allows entry of gases into the trachea and oesophagus
Larynx	Larynx contains the vocal cords. Air passes over the chords and sound is produced.
Epiglottis 	A cartilage structure on top of the larynx (voice box). It closes when food is swallowed preventing food from entering the trachea and allows only air to pass over it into trachea.
Lungs 	Two spongy, elastic lungs are surrounded by the double pleural membrane. This organ receives oxygen from air to be send throughout the body and it receives carbon dioxide from body cells to be expelled into air. Pleural fluid acts as a lubricant and helps prevent friction during inhalation and exhalation.
Ribs 	Rib bones on either side of the sternum form a rib cage to protect the lungs from injury.
Intercostal muscles 	These are muscles found between the rib bones. They contract and relax during inhalation and exhalation altering the volume of air in the chest (thoracic cavity).



Function of the human ventilation system

What would happen if all the carbon dioxide stayed inside your body. ?

Why must it be removed?

The main function of the gaseous exchange system in humans is to:

- Take oxygen from the air into the lungs during inhalation and that this oxygen-rich air reaches the alveoli where gaseous exchange takes place so that the oxygen diffuses into the blood to be transported to the cells of the body .
- It then receives carbon dioxide from the cells of the body after cellular respiration to be expelled out of body via exhalation.

Ventilation of the Lungs

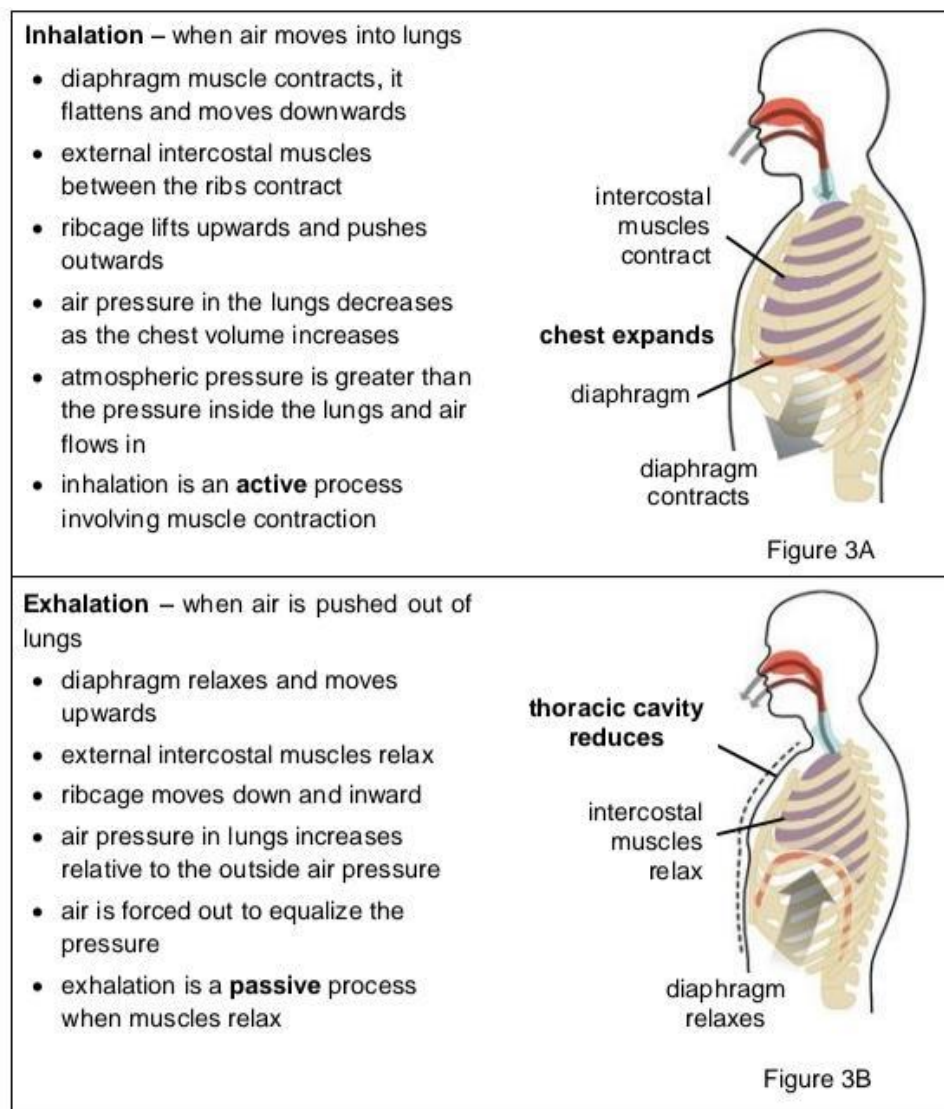
Learning Outcomes:

- *Gaseous exchange in alveoli.*
- *The transport of gases around the body.*
- *Gaseous exchange in tissues.*
- *Composition of inspired air vs. expired air – analyse data.*

The process of breathing(ventilation) 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 in the thoracic cavity.

Breathing involves 2 distinct processes: **inhalation** and **exhalation**.



What happens to lung pressure during inhalation?

Why does air leave the lungs?

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 at the alveoli surface(External)

The gaseous exchange at the alveoli surface is illustrated in Figure 4 below.

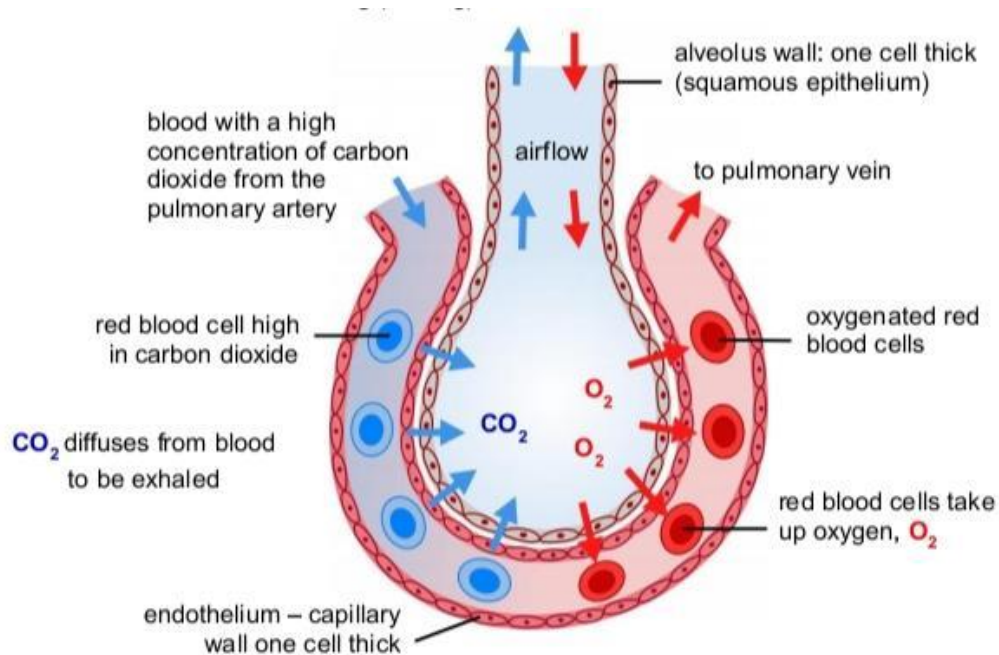


Figure 4: Gaseous exchange at the alveoli surface

Which way will oxygen move?

- 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**.

The transport of gases around the body.

Oxygen transport:

Oxygen is transported mainly by the **red blood cells**(erythrocytes) . 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** for respiration.

Why is it important that oxygen binds to haemoglobin instead of just dissolving in blood plasma?

CO₂ transport:

Most of the **CO₂** is transported in the blood plasma in the form of **bicarbonate ions** from the cells and tissue to the lungs to be exhaled.

Why must carbon dioxide be removed from the body?

Gaseous exchange in tissues. (Internal)

Oxygen is continually entering the blood stream at the alveoli surface and is transported to the body cells. Carbon dioxide is transported from the cells to the alveoli where it is removed from the body.

Which has more oxygen; Blood or body cells?

Oxygen diffusion:

Oxygenated blood arrives from the heart in the capillary network close to tissue cells (see Figure 5). Oxygen will **diffuse from the blood** and into the neighbouring cells to the concentration gradient .

Why does oxygen move from blood into body cells?

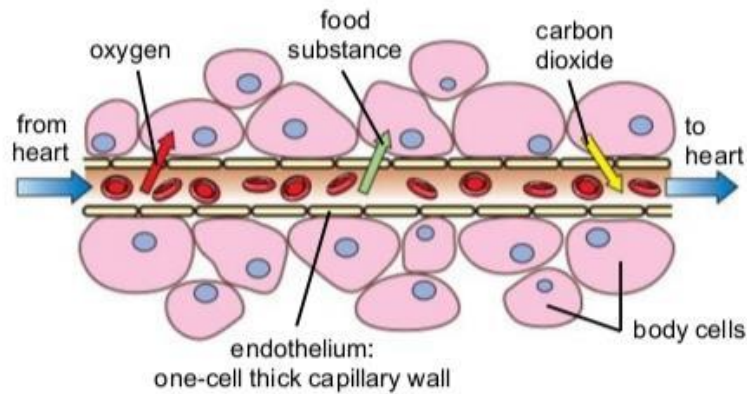


Figure 5: Exchange of gases at the tissue level

Carbon dioxide diffusion:

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**.

Describe the direction of oxygen and carbon dioxide movement at body tissues.

Composition of inspired air vs. expired air – analyse data.

The air in the atmosphere is made up mainly of nitrogen, oxygen, carbon dioxide and water vapour and traces of inert gases. Inhaled air has the same composition as atmospheric air but different to exhaled air. Table 4 shows the difference in composition of the three main gases after exercise and while sleeping.

Table 4: The composition of inhaled and exhaled 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.

By looking at the table above:

- What is the difference between the percentage of oxygen inhaled and that exhaled from a sleeping person?
- What is the percentage oxygen used by the body in each inhalation of a person who is exercising?

The effect of altitude on gaseous exchange

Learning Outcome: Analyse and interpret data showing the effects of altitude on the number of red blood cells and the consequent effect on athletes at different altitudes

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.

Activity 4: Effect of altitude

A study was carried out on eight swimmers (2 females and 6 males). They were all record holders and had participated in National championships and the Olympic games. These swimmers attended a 23 day camp which was at an altitude of 2300 metres above sea level. Before and after the camp their blood was tested for their red blood cell count and haemoglobin concentration. Their performance was also measured before and after the camp by looking at their times in races. Six out of the eight swimmers improved upon their performances after the camp.

The table below shows the average changes in the swimmer's blood before and after the high altitude training camp.

	Before camp	After camp
Red blood cells (millions/mm ³)	4,69	5,37
Haemoglobin (g/dL)	14,8	16,8

(adapted from Biol.Sport 2012: Athletic performance of swimmers after altitude training (2300M above sea level) in view of their blood morphology changes <https://researchgate.net/>)

1. Name two observations that could be made relating to the altitude training.(2)
 2. Provide another name for red blood cells. (1)
 3. What is the function of haemoglobin in the blood? (1)
 4. Which important element is found in haemoglobin? (1)
 5. Calculate the average increase in red blood cells of the swimmers after camp training. (3)
 6. Identify a dependent variable in the above table. (1)
 7. What would the advantage be for a swimmer to train at high altitudes before participating in an Olympic event? (2)
 8. How can the reliability of the results obtained in the above experiment be improved? (2)
- (13)