



Term 3



WEEK 1: TOPIC: Gaseous exchange

SUB-TOPIC: Difference between cellular respiration, breathing and gas exchange.

NOTES & EXAM TIPS

Biological terminology

Aerobic	occurring in the presence of oxygen
Anaerobic	occurring in the absence of oxygen
Aquatic	(plants and animals) living in water
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
Carbohydrate	a large group of organic compounds found in cells, including glucose, sucrose, and starch
Cellular respiration	the breakdown of organic compounds (glucose / sugar) in the mitochondria of cells into inorganic products (CO ₂ and H ₂ O) with the release of cellular energy (ATP); either aerobic or anaerobic
Diffusion	the movement of molecules from a region of high concentration to a region of low concentration until equilibrium is reached
Gaseous exchange	the exchange of O ₂ and CO ₂ at a respiratory surface occurring between the air and blood and blood and cells
Glucose	a simple sugar which is an important energy source in living organisms and is a component of many carbohydrates
Mitochondrion	an organelle found in large numbers in most cells, in which the cellular respiration and energy production occur
Respiratory surface	is a membrane through which gas exchange takes place
Terrestrial	(plants and animals) living on land

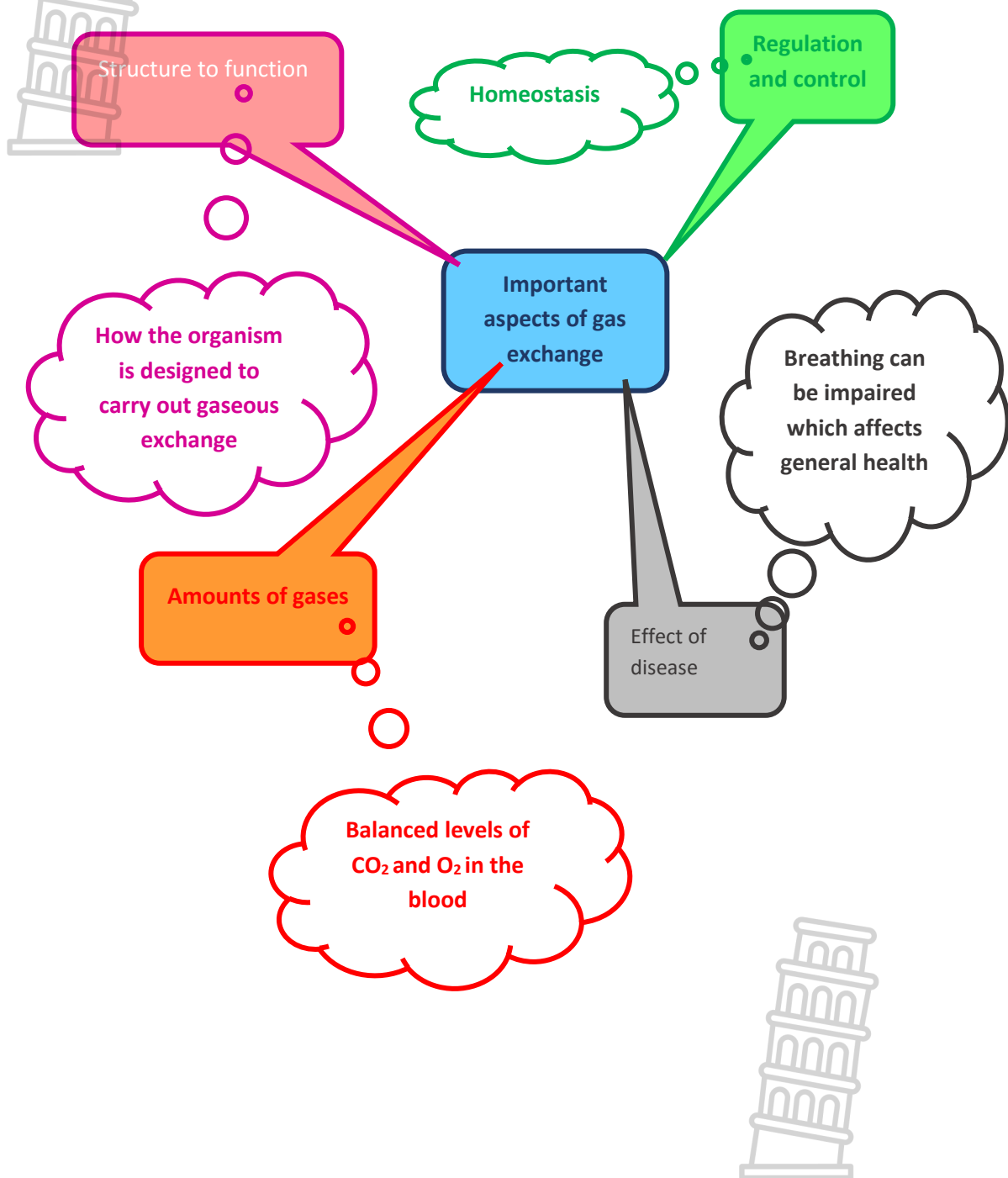
Introduction

It is important to distinguish between **breathing**, **gaseous exchange** and **cellular respiration**.

Why do we need to breathe?

All organisms, from simple, unicellular to more advanced multicellular organisms need oxygen (O₂) to sustain cellular functions. Oxygen is used to release energy from carbohydrates found in cells. Plants and animals need energy for survival. Organisms are structurally suited to ensure that the process of the exchange of

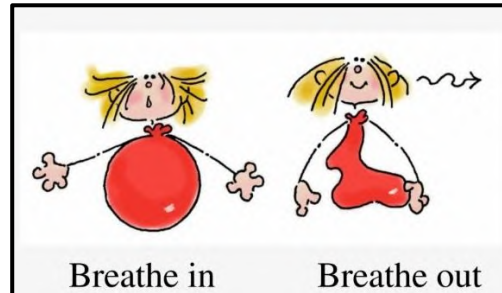
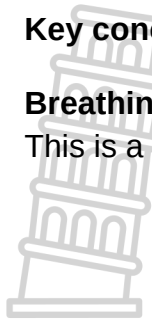
gases is optimised. More complex animals have a mechanism of breathing that ensures that gases enter their bodies, and this enables gaseous exchange and cellular respiration to occur efficiently.



Key concepts

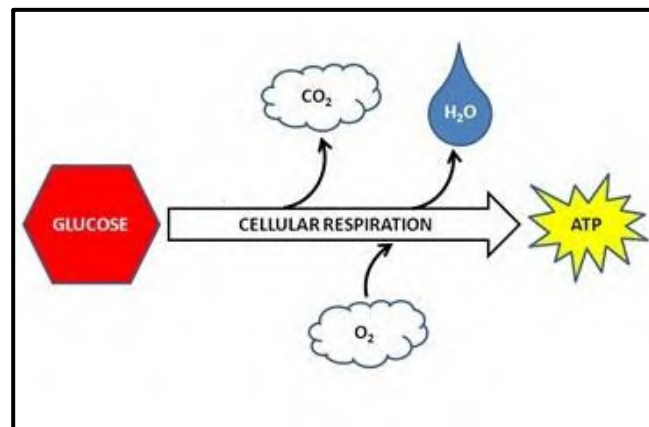
Breathing

This is a mechanical process taking oxygen into the lungs.



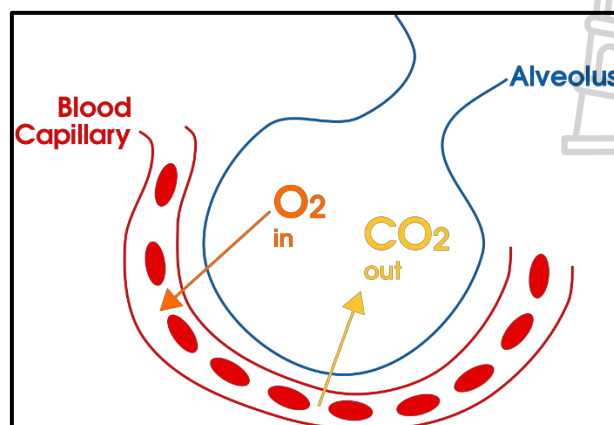
Cellular respiration

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



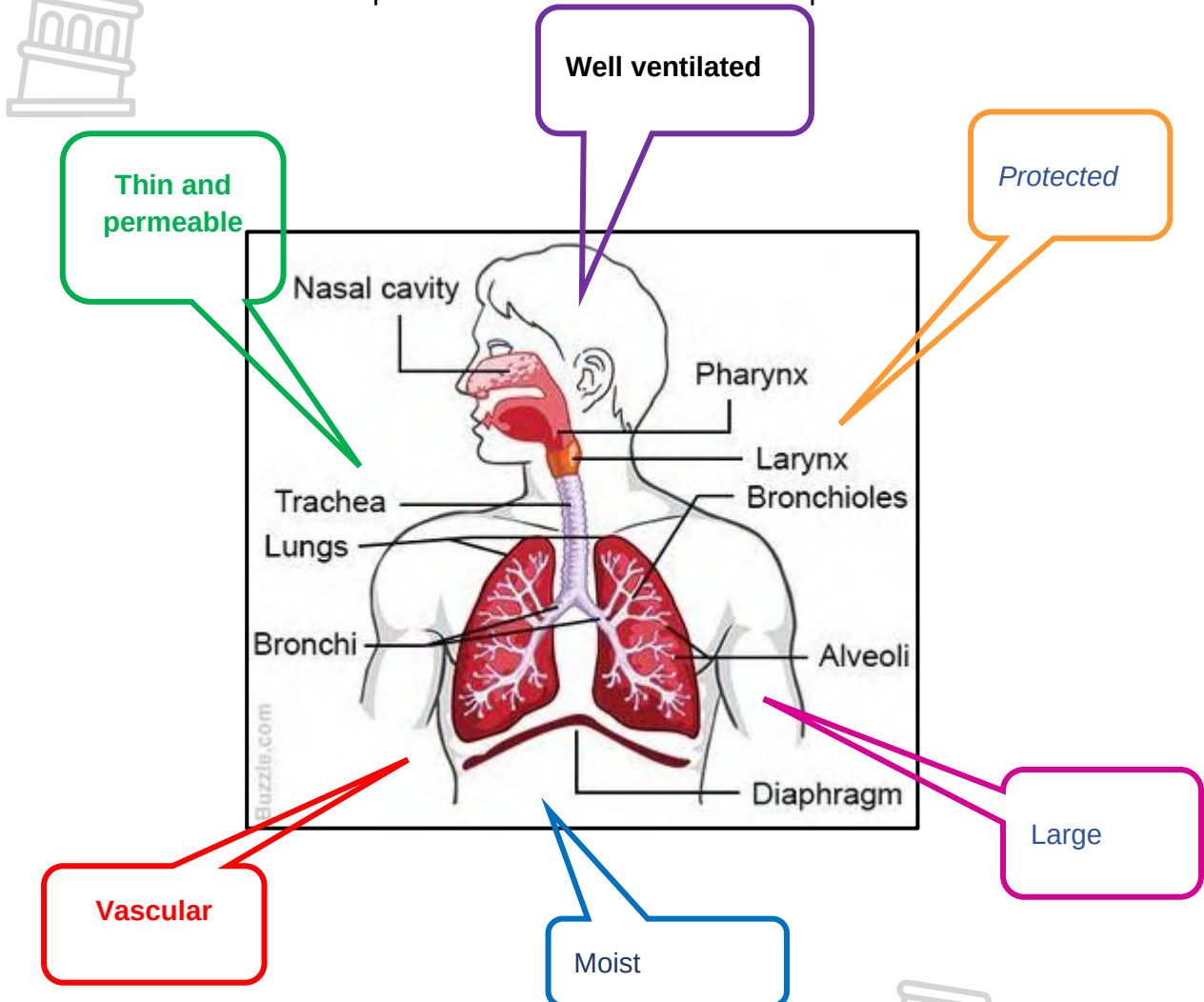
Gaseous exchange

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



SUB-TOPIC: Requirements of efficient gas exchange organs

For gases to effectively diffuse across respiratory surfaces, certain **requirements** need to be met. This is important for both terrestrial and aquatic habitats.



Relationship between respiratory structures and efficient gaseous exchange in different organisms

All organisms, from simple unicellular to complex multicellular, rely on gaseous exchange for survival. The amount of O_2 taken up and CO_2 released depends on the ratio of surface area to volume of the organism.

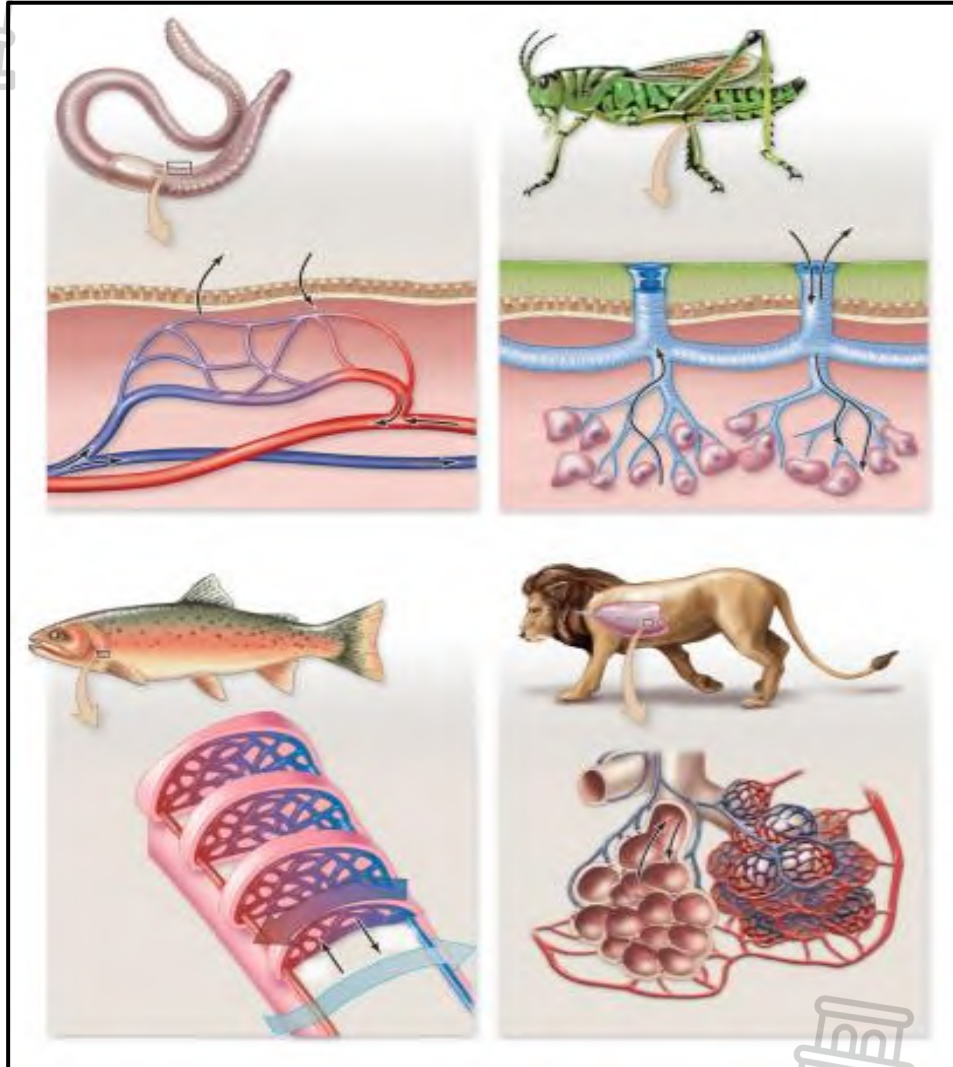
What does this mean?

- Surface area is the combination of all the exposed surfaces of the organism.
- The volume is the space taken up by the same organism.
- Therefore, the surface area to volume ratio would be the amount of surface an organism has relative to its size.

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

Both terrestrial and aquatic plants and animals have gaseous exchange surfaces and respiratory structures that ensure effective exchange of gases (O_2 and CO_2).

Comparison of the respiratory surfaces of various groups of organisms



Requirements for effective gaseous exchange surface					
large	thin & permeable	moist	well-ventilated	protection	transport system
Dicotyledonous plant (leaf and spongy mesophyll)					
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 covering is thin	mucous glands keep the skin moist	air movement around the body	thin cuticle	diffusion
Insect (tracheal system)					
extensively branched tracheae and tracheoles	lining of tracheoles is thin	tracheoles are moist	rhythmic body movements move air in and out	exoskeleton and chitin rings	network of tubules throughout the body
Bony fish (gills)					
branched gill filaments increase surface area	thin membranes	aquatic animals live in water	water taken in through the mouth is forced out over the gills	gills are protected by a bony cover, the operculum	heart and blood vessels
Mammals (lungs)					
bronchioles divide into many alveoli	alveoli have thin squamous epithelium layer	mucus cells secrete a thin layer on moisture	diaphragm and ribcage regulate inhalation and exhalation	ribs protect the lungs	circulatory system

EXAM QUESTIONS

QUESTION 1 (Questions taken from various sources)

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A to D) next to the question number (1.1 to 1.2) in your ANSWER BOOK, for example 1.3 D.

1.1 Study the table and answer the question below

Gas	Concentration in inhaled air (%)	Concentration in exhaled air (%)
Oxygen	21	16
Carbon dioxide	0,04	4
Nitrogen	78	78
Water vapour	0,96	2

The reason for the amount of oxygen being higher in inhaled air than in exhaled air is that...

- A oxygen is taken into the bloodstream and some diffuses back to the alveoli to be breathed out
- B some oxygen does not reach the alveoli but remains in the bronchiole until exhalation occurs
- C oxygen is used in the body, but oxygen is produced in the body as a waste product, which is then exhaled
- D some oxygen from inhaled air diffuses into the blood and is used by the cells

1.2 Several features are listed below.

1. Large surface area
2. Thin surface
3. Moist surface
4. Many capillaries

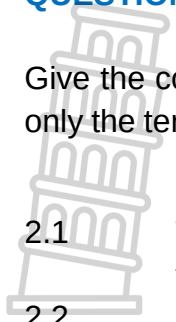
Which of the above are features of an efficient gaseous exchange surface?

- A 1, 2, 3 and 4
- B 1, 2 and 4
- C 1, 3 and 4
- D 2, 3 and 4

(2 x 2) (4)

QUESTION 2 (Questions taken from various sources)

Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number (2.1 to 2.3) in your ANSWER BOOK.

- 
- 2.1 The pores on the leaves of plants through which gas exchange takes place
- 2.2 A pigment that transports oxygen in humans
- 2.3 Organelle that serves as the powerhouse of the cell (3)

WEEK 2: TOPIC: Gaseous exchange

SUB-TOPIC: Human gas exchange –structure, location, functions and adaptations of the ventilation system.

NOTES & EXAM TIPS

When you breathe in, **air** enters your body through your nose or mouth. It then travels down your throat through the larynx (or voice box) and into the trachea or windpipe) before entering your lungs.

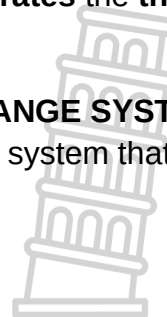
LOCATION OF THE HUMAN GASEOUS SYSTEM

The human gaseous exchange /ventilation system **begins from the nose** in the head and moves down the windpipe/ trachea located in the neck and **extends into** the bronchi and lungs within the **thoracic cavity(chest)**.

The **diaphragm** is the gaseous exchange **muscle** that **separates** the **thoracic (chest) cavity** from the **abdominal cavity**.

STRUCTURE OF THE HUMAN GASEOUS EXCHANGE SYSTEM

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



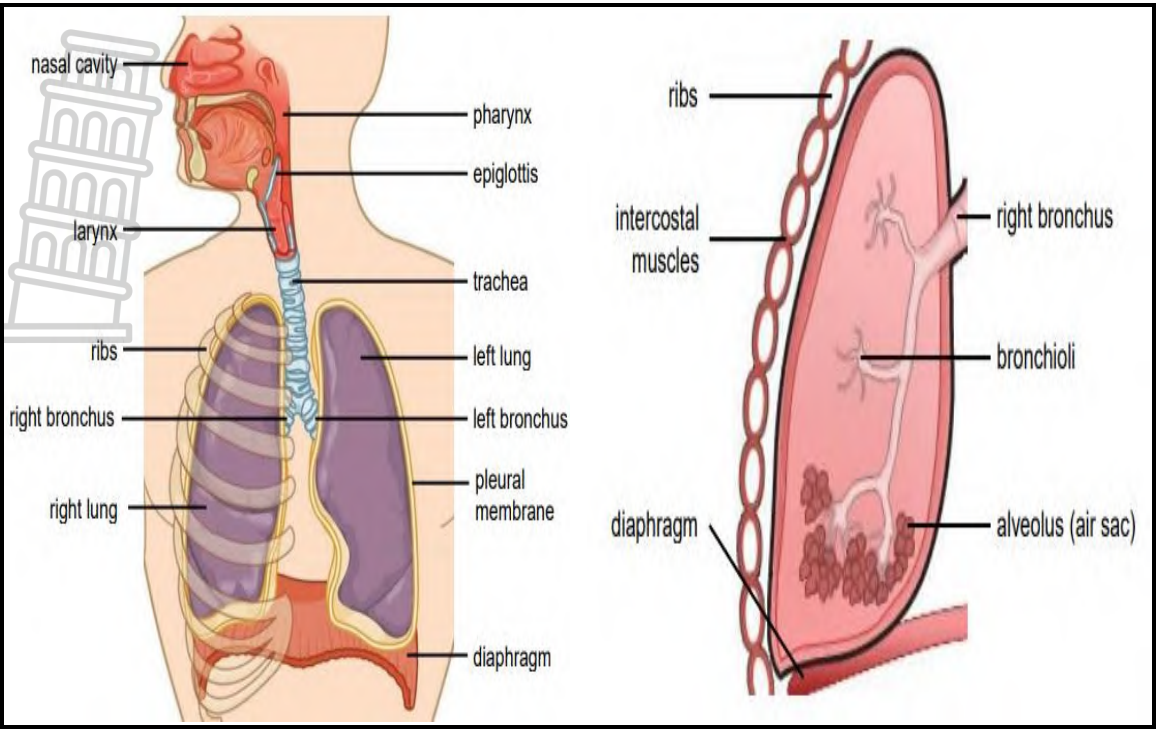
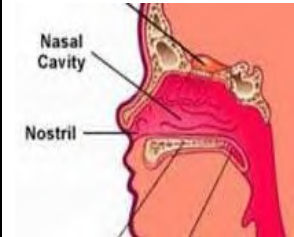
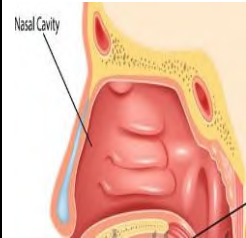


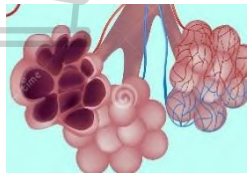
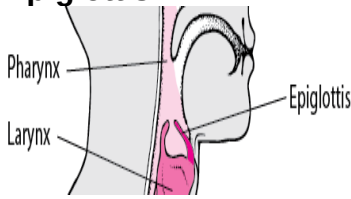
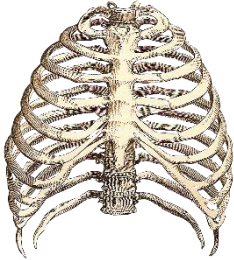
FIGURE 1

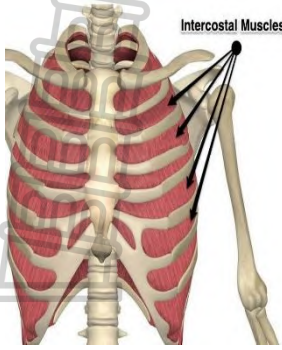
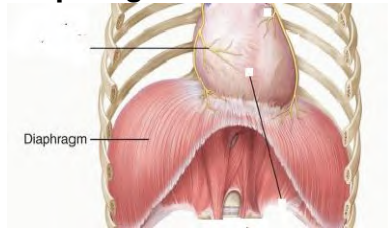
FIGURE 2

STRUCTURAL SUITABILITY OF GASEOUS EXCHANGE SYSTEM

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

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 AND MUSCLES INVOLVED IN BREATHING	
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).
Diaphragm 	A sheet of muscle below the lungs. It contracts and relaxes altering the volume of the chest cavity which is important in the breathing mechanism.

FUNCTIONS OF THE GASEOUS EXCHANGE SYSTEM

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**.

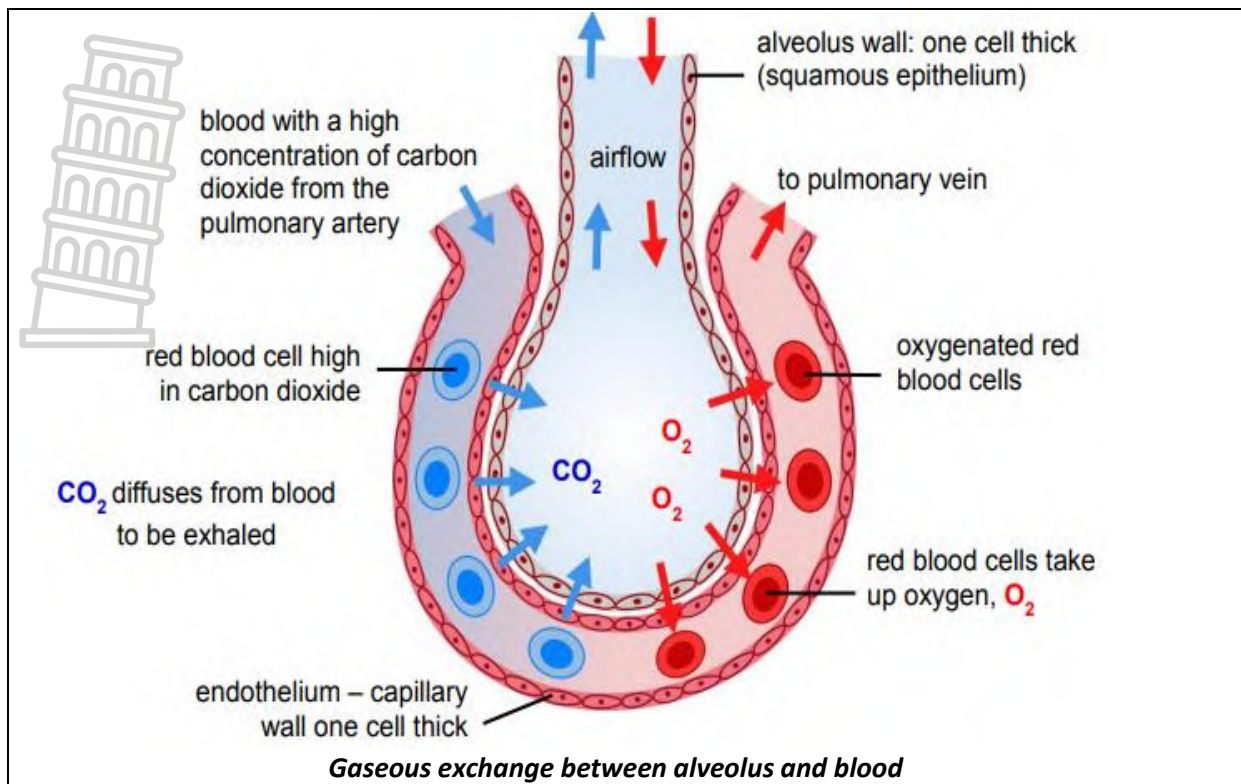
The exchange of gases occurs in two areas in the body: At the

1. Alveoli surface (external gaseous exchange) and
2. Between the blood and tissues (internal gaseous exchange).

GASEOUS EXCHANGE IN THE LUNGS AT THE ALVEOLI SURFACE

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** to be **exhaled**.

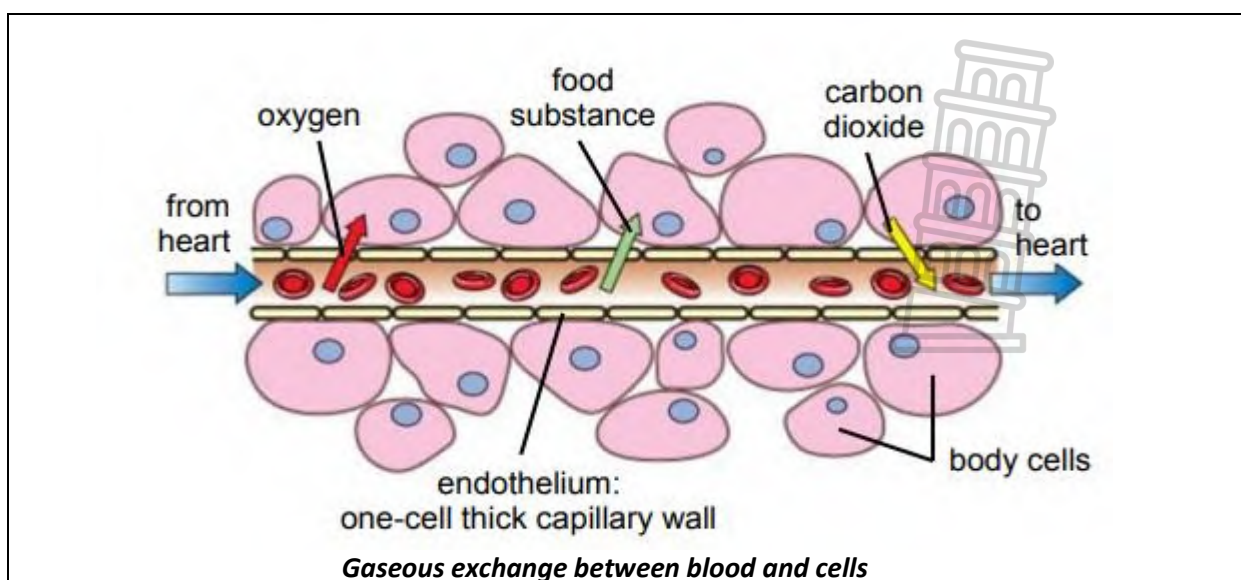


GASEOUS EXCHANGE BETWEEN THE BLOOD AND TISSUES

The **cells** will have a **high carbon dioxide** concentration due to continuing cellular respiration. This carbon dioxide moves out of the cells and diffuses into the blood and is transported back to the heart and then **to the lungs where it is exhaled**.

Carbon dioxide is transported from the cells to the alveoli where it is removed from the body.

The **air in the alveoli will be exhaled with more carbon dioxide** than the air that had been inhaled.



Oxygen is **transported** mainly by the **red blood cells**. Most of the oxygen combines with the **pigment haemoglobin** present in the red blood cells (erythrocytes) to form **oxyhaemoglobin**. It is transported via the circulatory system to all body cells for respiration to produce energy (ATP) for the cells.

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

ACTIVITIES/WORKSHEETS/EXAM TYPE QUESTIONS

QUESTION 1

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A to D) next to the question number (1.1 to 1.4) in your ANSWER BOOK, for example 1.5 D.

1.1 Cilia are found lining which of the following structures?

- A Larynx
- B Alveoli
- C Trachea
- D Pleural membranes

1.2 Air breathed out is different from air breathed in because it:

- A contains less carbon dioxide.
- B is cooler.
- C is drier.
- D contains less oxygen

1.3 The lungs of a long-term smoker will have:

- A constricted bronchioles.
- B thinner walls.
- C a large surface area.
- D an increased capacity for gaseous exchange.

1.4 Which of the following does not occur during inhalation in a human?

- A Pressure within the thoracic cavity increases.
- B The lungs expand.
- C The diaphragm contracts.
- D Pressure in the abdominal cavity increases.

(8)

QUESTION 2 (Questions taken from various sources)

Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number (2.1 to 2.5) in your ANSWER BOOK.

- 2.1 The double membrane that covers the outer surface of the lungs.
 2.2 The cartilaginous structure that contains the vocal cords.
 2.3 Tiny air sacs at the end of each bronchiole.
 2.4 Dome-shaped muscle separating the thorax from the abdomen.
 2.5 The main branches of the trachea that lead to the lungs.

(5)

QUESTION 3 (Questions taken from various sources)

Indicate whether each of the statements in COLUMN I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in COLUMN II. Write **A only**, **B only**, **both A and B**, or **none** next to the question number (3.1 to 3.3) in the ANSWER BOOK.

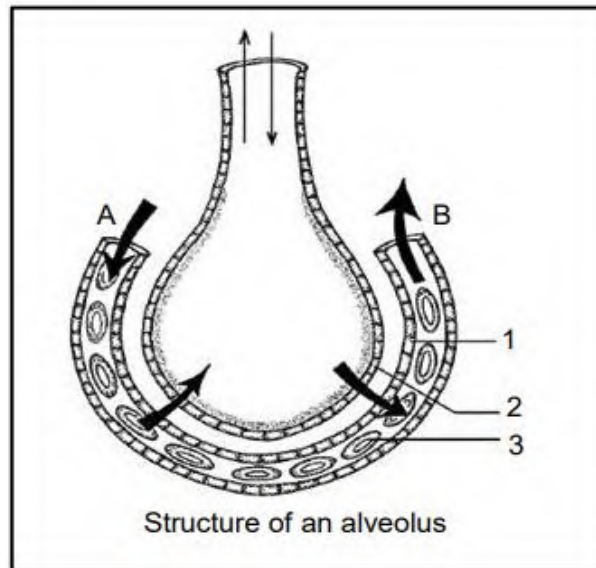
COLUMN I		COLUMN II	
3.1	Breathing muscles	A B	Intercostal Diaphragm
3.2	C – shaped cartilaginous rings	A B	Oesophagus Bronchioles
3.3	The structure that prevents food particles from entering lungs	A B	Epiglottis Glottis

(6)

QUESTION 4

The diagram below represents a section through an alveolus and a surrounding blood capillary in the human body.

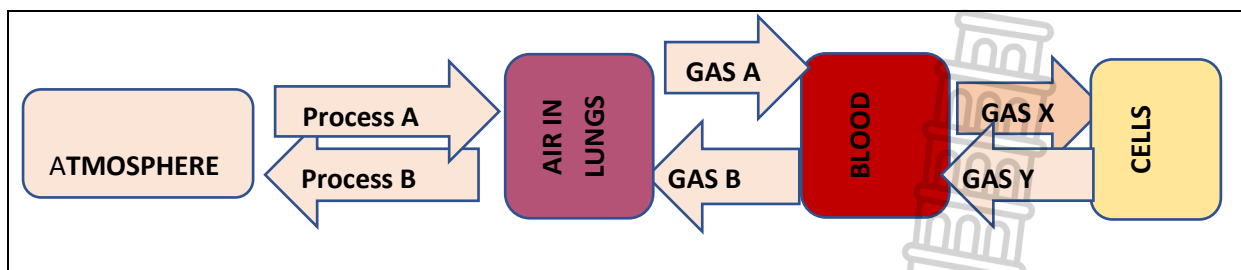




- 4.1 Name the type of epithelial tissue numbered **1** and **2**. (2)
 - 4.2 Identify the blood cell labelled **3**. (1)
 - 4.3 What pigment is found in the cell mentioned in QUESTION 4.2? (1)
 - 4.4 Which type of blood:
 - a) enters the blood capillary at **A**? (1)
 - b) leaves the blood capillary at **B**? (1)
 - 4.5 In which form is most oxygen carried in the blood? (1)
 - 4.6 Supply two structural adaptations of the alveoli which make them well suited for gaseous exchange. (2)
- (9)**

QUESTION 5

Use the flow chart below which summarises the gaseous exchange process in humans to answer the questions which follow.



- 5.1 Label process **A** and **B**. (2)
 - 5.2 Label gas **X** and **Y**. (2)
- (4)**

WEEK 3: TOPIC: Gaseous exchange

SUB-TOPIC: Ventilation of the lungs. Homeostatic control of breathing

NOTES & EXAM TIPS

TERMINOLOGY

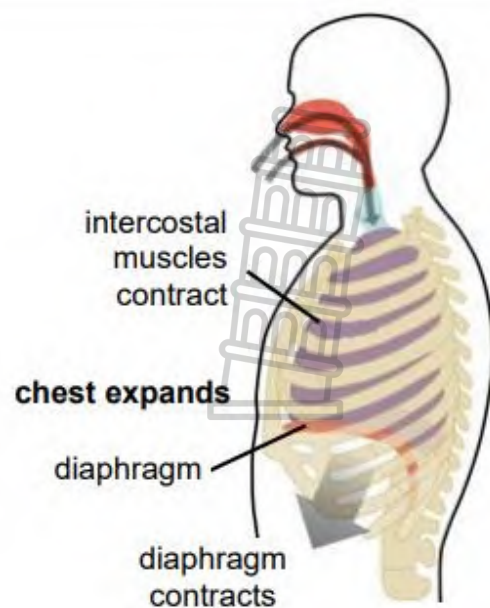
- **Ventilation:** The exchange of air between the lungs and the atmosphere so that oxygen can be exchanged for carbon dioxide in the alveoli.
- **Alveoli:** The tiny air sacs in the lungs.
- **Homeostasis:** It is a process of maintaining a constant internal environment within the body. (Level of oxygen and carbon dioxide in the body)
- **Inhalation:** The breathing in of air
- **Exhalation:** The breathing out of air
- **Spirometer:** An instrument used to measure the volume of air that enters and leaves the human lungs during inhalation and exhalation

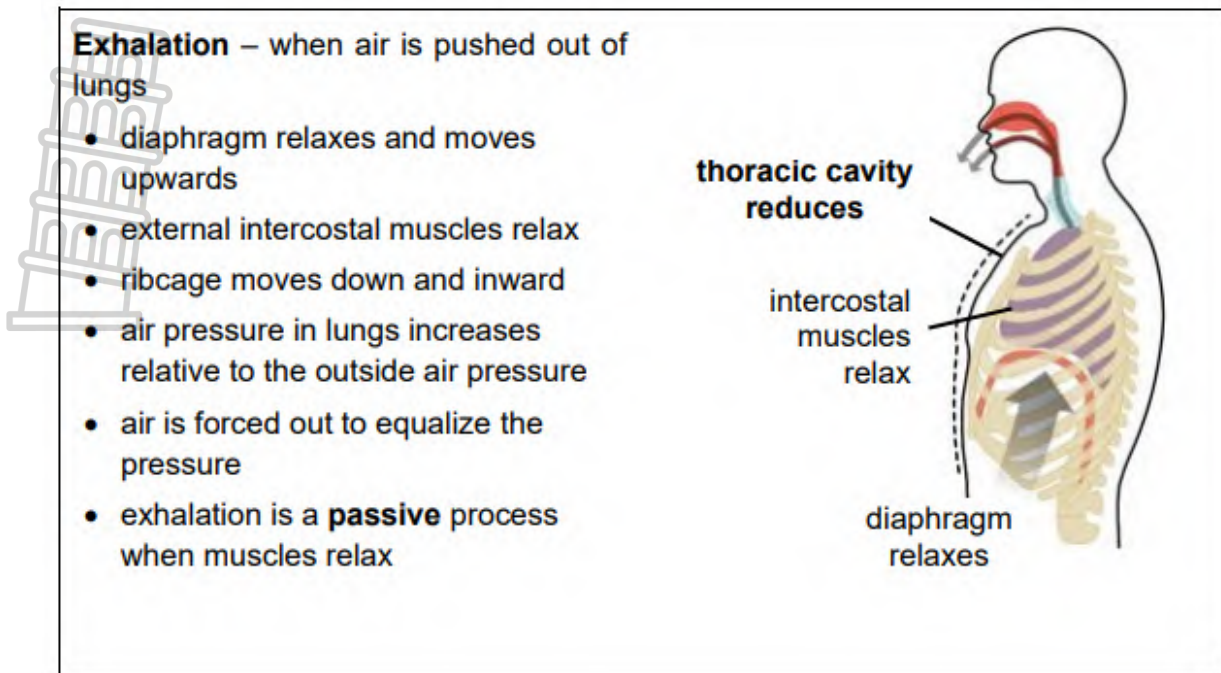
VENTILATION

- Inhalation **is** the process of **taking** air into the **lungs**. It **is** the active phase of **ventilation** because it **is** the result of muscle contraction. During inspiration, the diaphragm contracts and the thoracic cavity increases in volume. This decreases the pressure so that air flows into the **lungs**.

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



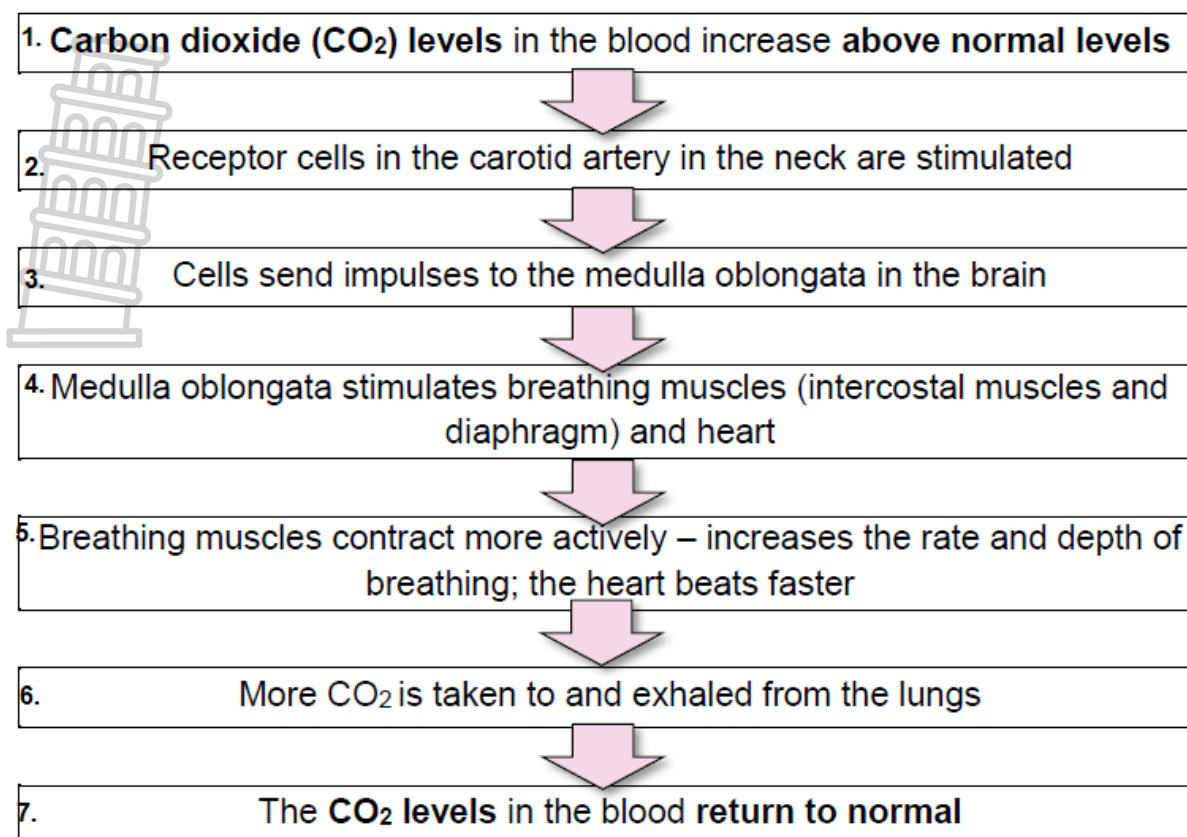


HOMEOSTATIC CONTROL OF BREATHING

- When the heart rate increases, blood flow also increases.
- Rapid transport of gases to and from the cells occurs.
- When carbon dioxide levels rise, the cells in the respiratory centre of the medulla oblongata of the brain are stimulated.
- Increased rate and depth of breathing causes the intercostal muscles and the diaphragm to contract and relax.
- **More oxygen is inhaled, and more carbon dioxide is exhaled.**
- The levels of **carbon dioxide** in the **blood** determine the **rate and depth of breathing**.
- The ability of the body to **return the levels the normal** is known as **homeostasis**

The flow diagram below represents the negative feedback mechanism for homeostatic control of breathing:





ACTIVITIES/WORKSHEETS/EXAM TYPE QUESTIONS

ACTIVITY 1

QUESTION 1

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A to D) next to the question number (1.1 to 1.3) in your ANSWER BOOK, for example 1.4 D.

- 1.1 The rate of breathing is regulated by the medulla oblongata, mainly...
- A under voluntary control.
 - B according to oxygen level of blood.
 - C according to the blood pressure.
 - D according to carbon dioxide level of blood.
- 1.2 The following will determine the rate of breathing in humans:
- A Carbon dioxide in the blood
 - B Bronchioles in the lungs
 - C Oxygen in the exhaled air

- D haemoglobin in the tissues
- 1.3 The breathing centre in the medulla oblongata is most sensitive to change in the...
- A glucose level of the blood
B oxygen level of the tissue fluid
C carbon dioxide levels of the blood.
D ATP levels of mitochondria
- (3x2) (6)

QUESTION 2 (Questions taken from various sources)

Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number (2.1 to 2.3) in your ANSWER BOOK.

- 2.1 The muscles between the ribs that are involved in the mechanism of breathing.
- 2.2 The tendency of living organisms to maintain a constant internal environment.
- 2.3 Air sacs in the lungs.
- (3)

QUESTION 3 (Questions taken from various sources)

Indicate whether each of the statements in COLUMN I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in COLUMN II. Write **A only**, **B only**, **both A and B**, or **none** next to the question number (3.1 to 3.3) in the ANSWER BOOK.

COLUMN I		COLUMN II	
3.1	The exchange of air between the lungs and the atmosphere.	A B	Ventilation Homeostasis
3.2	Movement of gases with the aid of muscular activity	A B	Breathing Gaseous exchange
3.3	Controlling center for homeostatic breathing control	A B	Brain Medulla oblongata

(3 x 2) (6)

ACTIVITY 2

QUESTION 1 (Question adapted from grade 12 NSC 2020 question paper: P1)

Describe how the human body maintains the carbon dioxide concentration in the blood when it rises above normal limits.

(5)

QUESTION 2

An investigation was carried out on a person in which the volume of air taken in at each breath and number of breaths per minute were measured at rest and after running.

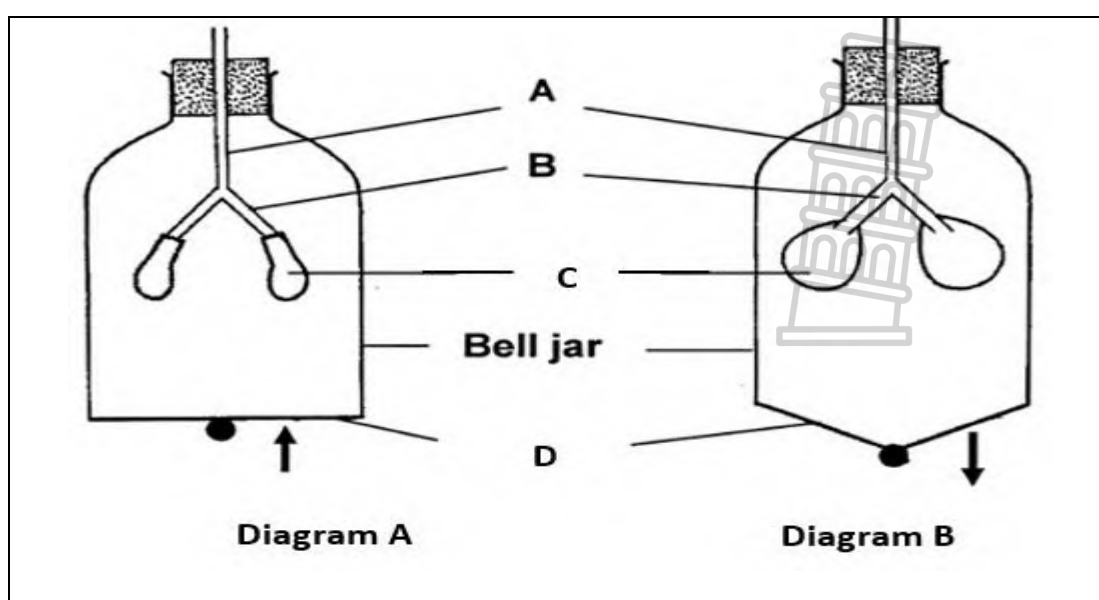
The results are shown in the table below.

	Volume of air per breath	Breaths per minute
At rest	450 cm ³	20
After running	1 000 cm ³	38

- 2.1 Explain why the amount of oxygen taken up into the blood increases after exercise. (3)
 - 2.2 Describe the changes that took place in the human body to bring about an increase in the breathing rate of the person. (5)
 - 2.3 20% of the air breathed in consist of oxygen, but only 16% of the air breathed out consist of oxygen. Calculate the amount of oxygen entering the blood per breath after running. Show your calculations (3)
- (11)**

QUESTION 3 (GDE 2021 Exemplar P1)

The diagram below is a model that can be used to demonstrate the breathing mechanism in humans.



- 3.1 What do each of the following parts represent in the human breathing system?
(a) **A**
(b) **B**
(c) **C** (3)
- 3.2 Explain ONE way in which part **A** in humans is adapted for its function. (2)
- 3.3 Which diagram (**A** or **B**) represents inhalation? (1)
- 3.4 Give TWO visible reasons from the diagrams to support your answer to QUESTION 3.3. (2)
- 3.5 Describe the mechanism of inhalation in humans. (5)
(13)

WEEK 4: TOPIC: Excretion in humans

SUB-TOPIC: Excretion in various organs.

NOTES & EXAM TIPS

Excretion is the process where all the metabolic wastes are removed from the body. Excretion in humans is carried out through different body parts and internal organs in a series of processes. Excretory waste products include CO_2 , H_2O , bile pigments, urea and mineral salts.

