14 THE RESPIRATORY SYSTEM

Syllabus : Respiratory System: Organs; mechanism of breathing; tissue respiration, heat production.
Structures of the respiratory system. Differences between anaerobic respiration in plants and in man. Role of diaphragm and intercostal muscles in breathing to provide a clear idea of breathing process. Brief idea of gaseous transport and tissue respiration. Brief understanding of respiratory volumes. Effect of altitude on breathing : asphyxiation and hypoxia.

Respiration is a vital process in all living organisms. It goes on non-stop throughout life. This chapter explains the various aspects related to respiration — the raw material used, the end products formed and the amount of energy liberated, etc. Some experiments to demonstrate the mechanism of breathing are very interesting.

14.1 THE NEED FOR RESPIRATION

Respiration is the chemical process of releasing energy by breaking down glucose for carrying out life processes.

This chemical breakdown occurs by utilizing oxygen and is represented by the following overall reaction :

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

There are **five** important points to remember about this chemical reaction in respiration.

1. This part of respiration, yielding energy, occurs inside the living cells and hence, it is better known as **cellular** or **tissue** respiration.
2. The breakdown of glucose ($C_6H_{12}O_6$) to carbon dioxide and water does not occur in a single step but in a **series of chemical steps**. Some of these steps occur in the cytoplasm of the cell and some inside the mitochondria.
3. Each breakdown step is due to a particular **enzyme**.
4. The **energy** liberated in the breakdown of the glucose molecule is not all in the form of heat, but a large part of it is converted into chemical energy in the form of ATP - a chemical substance called **adenosine triphosphate**.

   [As you have read in the case of plants when the energy in the form of ATP is used, it is converted to ADP (adenosine diphosphate) and again when more energy is available by further breakdown of glucose, the ADP is reconverted to ATP and so it goes on and on. ATP is a sort of **"currency of energy"** inside the cell. One mole of glucose on complete oxidation yields 38 molecules of ATP.]
5. The essential steps of cellular respiration are same in plants and animals.

WHY WE NEED ENERGY

Body cells need energy for a vast variety of activities in them. Some of these are :

1. **Synthesis of proteins from amino acids**
2. **Production of enzymes**
3. **Contraction of muscles for movement**
4. **Conduction of electrical impulse in a nerve cell**
5. **Production of new cells by cell division**
6. **In keeping the body warm (in warm-blooded animals, *i.e.* birds and mammals)**

14.2 ANIMALS NEED MORE ENERGY

The need for production of energy is greater in animals than in plants. This is because animals consume more energy in doing physical work.

- They have to **move about** for obtaining food or run away to escape enemies.
- They have to **chew their food** and have to **look after their eggs** or **young ones**, and so on.

Birds and mammals need still more energy

The birds and mammals including ourselves have also to **produce a lot of heat for keeping the body warm**. This heat comes through respiration in the cells. The amount of heat to keep the body warm is quite large. Think about the cold winter days when the outside temperature is far below our body temperature. We are constantly losing heat to the outside air, and more of it has to be continuously produced to make up the loss. Liver cells in particular produce much heat, and the muscle cells also contribute to it.

> **Shivering** and **clattering of teeth** (when one feels too cold) is an emergency activity of the muscle cells to produce extra heat.

The energy used in all the cellular activities is obtained from the oxidation of glucose ($C_6H_{12}O_6$), a carbohydrate.

14.3 GLUCOSE HAS NO ALTERNATIVE FOR RESPIRATION

If the simple carbohydrate (glucose) is not available directly, the cells may break down the proteins or fats to produce glucose for respiratory needs.

Think for a while about the wild animals which are totally **flesh-eaters**. The main constituent of their diet is protein with very little carbohydrates. The excess amino acids absorbed through protein-digestion are broken down in the liver to produce sugar (glucose) and the nitrogenous part is converted into urea which gets excreted out. The glucose thus produced may be used immediately or may get stored in the liver cells as glycogen for future needs. A similar process takes place in humans if they take excessively protein-rich food.

? *PROGRESS CHECK*

1. Given below is the definition of respiration with a few blanks to be filled in. Write suitable words in the blanks :
   Respiration is a process of releasing .... by breaking down .... for carrying out .... processes.
2. Write the overall chemical equation representing the above definition of respiration.
3. In what form is the energy liberated in respiration?
4. Give two examples of life activities which need energy.

14.4 TWO KINDS OF RESPIRATION — AEROBIC AND ANAEROBIC

In animals there is normally **aerobic respiration** using oxygen. **Anaerobic respiration** (in the absence of oxygen) is only exceptional in some cases as in the tapeworms living inside the human intestines.

Anaerobic respiration may occur even in our own body in the fast-working skeletal muscles temporarily. During continuous physical exercise as in fast running, walking over long distances, swimming, wrestling, weight-lifting, etc., our muscles work too fast but not getting enough oxygen. In this situation, the muscles are working in the absence of oxygen (anaerobic respiration) to provide extra energy. The product of anaerobic respiration in such muscles is **lactic acid**. Accumulation of lactic acid gives the feeling of fatigue. This is a condition which may be called **oxygen-debt**. When you rest after such exercise, the lactic acid gets slowly oxidised by the oxygen later available and then the "debt is cleared" producing carbon dioxide in the process.

CHEMICAL STEPS IN RESPIRATION

Aerobic respiration in animals

The chemical changes taking place in aerobic respiration in animals are the same as in the aerobic respiration in plants. The overall chemical change can be represented by the equation :

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \longrightarrow \underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{Energy}}{686 \text{ kcal/mole}}$$

The above equation depicts the chemical substances in mole. Thus by taking 180 g of glucose the energy released is 686 kilocalories, or if expressed in kJ (kilojoules) the energy released is about 2890 (686 × 4·2) kJ.

In the above equation we can represent energy in the form of ATP as follows :

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{enzymes}} 6CO_2 + 6H_2O + \underset{\text{chemical energy}}{38ATP} + \underset{\text{heat energy}}{420 \text{ kcal}}$$

[One mole of ATP requires 7 kcal, so 38 ATP are produced by consuming 38 × 7 = 266 kcal, the rest of the energy *i.e.* 686 – 266 = 420 kcal is released as heat].

Anaerobic respiration in animals

In animal cells, particularly in the skeletal muscle cells, anaerobic respiration may occur when they have to work very fast with insufficient oxygen. The overall chemical reaction in anaerobic respiration is summarised as follows :

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{enzymes}} \text{lactic acid} + 2ATP + \text{heat energy}$$

Special points to note in the above chemical reaction in anaerobic respiration in animals, are as follows :

1. It is a **slow process**.
2. The reaction cannot continue for long time. The product **lactic acid** has a toxic effect on cells, which causes muscle fatigue and aches.
3. No CO_2 is produced.
4. Total **energy** released per mole of glucose is **much less** compared to aerobic respiration.

The basic steps in cellular respiration are same in plants and animals. However, the anaerobic respiration is different in the two in some respects.

Table 14.1 Differences in anaerobic respiration in plants and animals.

Anaerobic respiration in PLANTS	*Anaerobic respiration in ANIMALS*
1. Products of glucose are **ethanol** and CO_2	1. Product of glucose is **lactic acid** (and no CO_2)
2. Released heat energy is **more**	2. Released heat energy is **less**
3. CO_2 released causes foaming	3. No CO_2 released, so no foaming.

14.5 PARTS OF RESPIRATION

In humans (as in most other animals) there are *four* major parts of respiration :

1. ***Breathing :*** This is a physical process in which the atmospheric air is taken in and forced out of the oxygen-absorbing organs, the lungs.
2. ***Gaseous transport :*** The **oxygen** absorbed by the blood in the lungs is carried by the RBCs as ***oxyhaemoglobin*** throughout the body by means of arteries. The carbon dioxide from the tissues is transported to the lungs by the blood by means of veins in *two* ways:
   (i) as **bicarbonates** dissolved in plasma, and partly,
   (ii) in combination with the haemoglobin of RBCs as **carbamino-haemoglobin.**
3. ***Tissue respiration :*** The terminal blood vessels, i.e., the capillaries deliver the oxygen to the body cells or tissues where oxygen diffuses through their thin walls and in a similar way, the capillaries pick up the carbon dioxide released by them (Fig. 14.1).
4. ***Cellular respiration :*** The complex chemical changes which occur inside the cell to release energy from glucose.

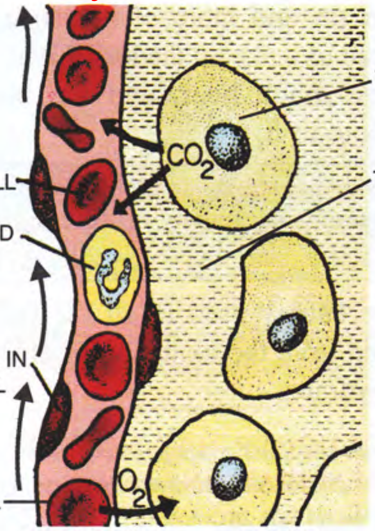

Fig. 14.1 Tissue respiration. Gaseous exchange between blood in a capillary and tissue cells.

? PROGRESS CHECK

1. State whether the following statements are **true** (T) or **false** (F) :
   (i) Strenuous physical exercise may cause fatigue due to accumulation of CO_2 in the blood. (T/F)
   (ii) No CO_2 is produced in anaerobic respiration in the human body. (T/F)
   (iii) Breathing and gaseous transport are one and the same thing. (T/F)
   (iv) CO_2 is transported to the lungs by the blood in two forms : as bicarbonates and as carbamino-haemoglobin. (T/F)
   (v) Tissue respiration means chemical changes occurring inside the cell. (T/F)

Where does respiration occur in a cell?

*The cellular respiration occurs in two main phases at **two different places** inside the cell :*

1. *Glycolysis (breakdown of glucose) :*
   - *occurs **in cytoplasm** outside the mitochondria*
   - *breakdown into pyruvic acid which further breaks down into **ethanol** in plants and **lactic acid** in animals.*
   - ***anaerobic** (not requiring oxygen)*
   - ***very little** energy released.*
2. *Krebs cycle :*
   - *occurs **inside mitochondria***
   - *needs oxygen*
   - *step by step break down of pyruvic acid/lactic acid to produce ATP and CO_2*
   - *H^+ ions released in the cycle are removed through the oxygen supplied by forming H_2O.*
   - *much energy produced*

*So now you know what for our body needs oxygen — **Yes, to remove the H^+ ions.***

A common misconception

Many people wrongly say "We inhale oxygen and exhale carbon dioxide". Instead we should say "We inhale air containing much oxygen and very little carbon dioxide and exhale air containing less of oxygen and more of carbon dioxide than before.

14.6 RESPIRATORY ORGANS (BREATHING)

The respiratory system in humans consists of air passages **(nose, pharynx, larynx, trachea, bronchi)** and the **lungs**.

The Nose : The external part of the nose bears two ***nostrils*** separated by a cartilaginous septum. The ***hairs*** present in the nostrils prevent large particles from entering the system. The two nostrils open into a pair of ***nasal chambers***. The inner lining of the nasal chambers performs *three* functions :

(1) It **warms** the air as it passes over.

(2) It **adds moisture** to the air.

(3) Its mucous secretion **entraps harmful particles**.

So, always breathe through the nose and not through the mouth.

An additional function of the nose is to **smell**. The sensory cells of smell are located in a special pocket situated high up in the nasal chambers (Fig. 16.2) When you smell something special, you give a little sniff which carries the odour up into this pocket.

DOES THE NOSE HELP IN SPEAKING ?

Close your nose by your fingers and try to speak "Nanaji goes to Nandgram and not Nagpur", *etc.*

The Pharynx : The nasal chambers open at the back into a wide cavity, the pharynx, situated at the back of the mouth. It is a common passage for air and food. It leads into an air tube, the **trachea (windpipe)** and a **food tube (oesophagus)** located dorsally behind the trachea. When not in use, the food tube is partially collapsed as it has soft walls. The entrance to the trachea is guarded by a flap called **epiglottis** which closes it at the time of swallowing food. **Incomplete closure of epiglottis during swallowing causes cough**.

The Larynx : The larynx or the voice-box (popularly called "Adam's apple") is a hollow cartilaginous structure located at the start of the windpipe (Fig. 14.2 & 14.3). You can feel it with your fingers in the front part of your neck. **When you swallow something, this part rises and falls**. The larynx contains two ligamentous folds called vocal cords not shown in the figure. Air expelled forcibly through the vocal cords vibrates them producing sound. By adjusting the distance between the two cords and their tension by means of attached muscles, a range of sounds can be produced.

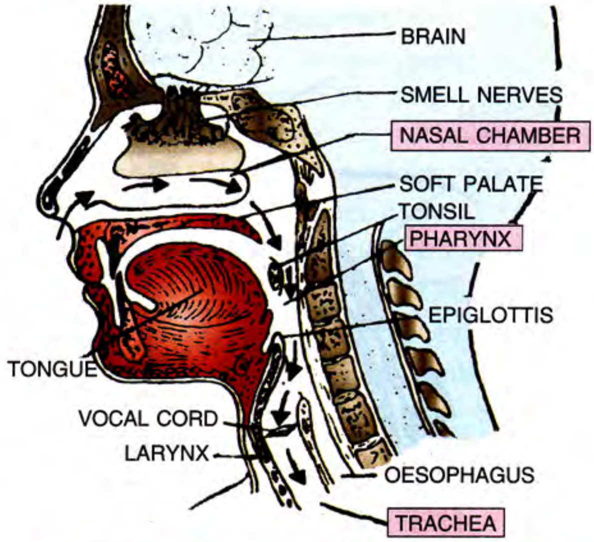

Fig. 14.2 The air passage in the nose and throat

VOICE AND SPEECH

Voice is the sound produced by the vocal cords of the larynx.

Speech is a character given to the voice by the complex movements of lips, cheeks, tongue and jaws. Speech consists of words or syllables, and it is a speciality of only the human species.

The Trachea : The trachea or the windpipe emerges from the larynx (Fig. 14.3) down below in the neck where it is partly covered by the thyroid gland. Its walls are strengthened by C-shaped rings of cartilage, the incomplete parts of the rings being on the back side. The rings provide flexibility and keep the trachea distended permanently.

The Bronchi : Close to the lungs, the trachea divides into two tubes, called the bronchi (*sing.* bronchus), which enter the respective lungs. On entering the lungs, each bronchus divides into fine **secondary bronchi**, which further divide into still finer **tertiary**

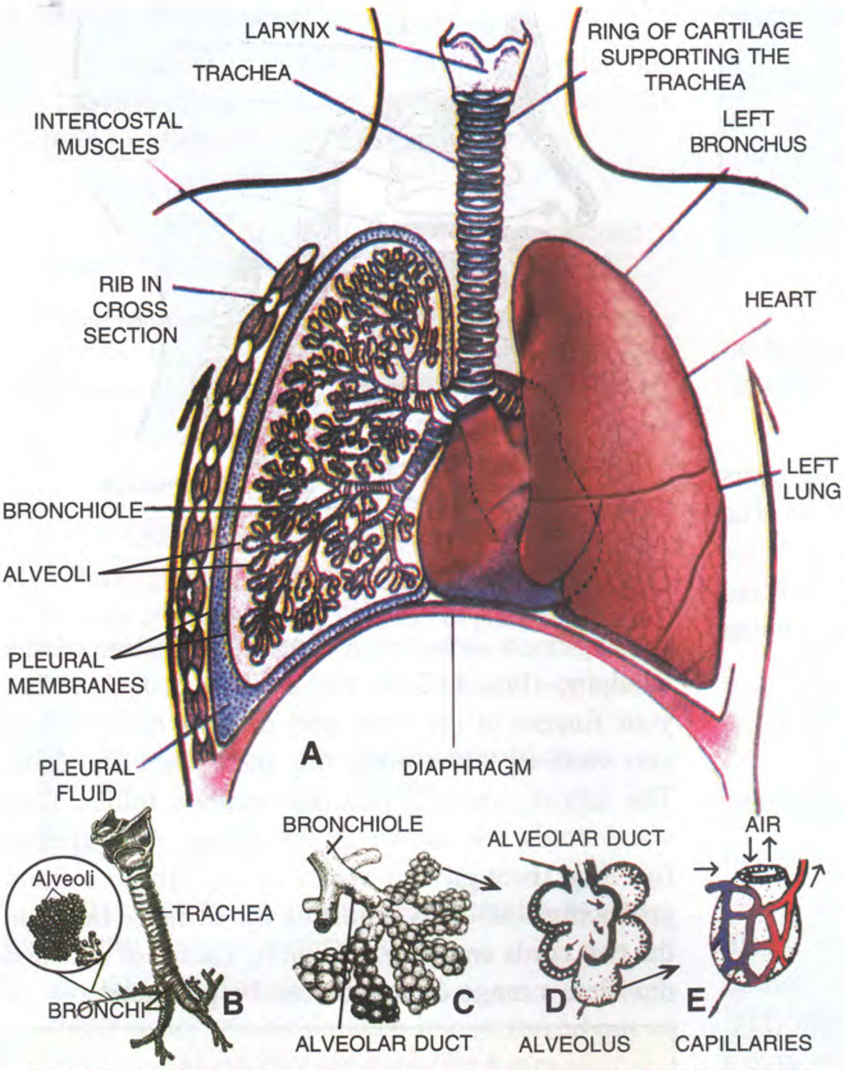

Fig. 14.3 A – Human respiratory system (front view, with right lung shown from inside, B. Scheme of branching of air passage from the trachea onward up to alveoli, and the terminal parts of the air passages (C, D, E).

bronchi. The cartilaginous rings, as those present on the trachea, are also present on the smaller bronchi to keep them distended. **Bronchioles** are the subsequent still finer tubes of tertiary bronchi which acquire a diameter of about 1 mm and are without cartilage rings. By repeated branching, the bronchioles ultimately end in a cluster of tiny air chambers called the **air sacs** or **alveoli** (*sing.* alveolus) (C, D). A network of blood capillaries surrounds the wall of each alveolus (E). The walls of the alveoli are extremely thin (one-cell thick) and moist, thus allowing gaseous diffusion through them (Fig. 14.4). Oxygen from air first dissolves in a thin layer of water/fluid that covers the surface of alveoli.

> ***The lungs provide an enormous surface area!***
>
> ***The number of alveoli in the two lungs in an adult human - about 700 million.***
>
> ***Total surface area of the alveoli - about 70 square metres (nearly equal to the area of a tennis court, or nearly hundred times the surface of the skin).***

Protective inner lining of respiratory passage. The entire inner lining of the larynx, trachea, bronchi and bronchioles is formed of **ciliated**

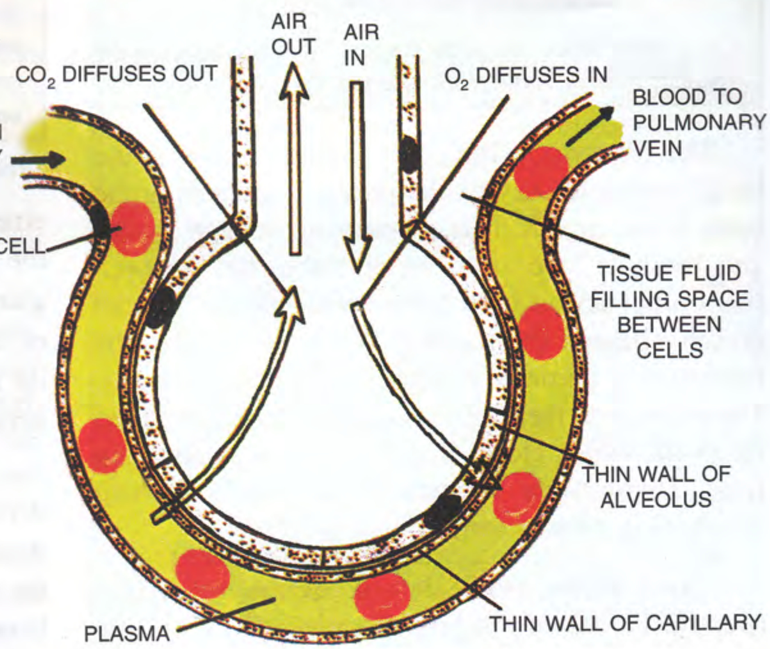

Fig. 14.4 Gas exchange in an alveolus. Notice that the walls of both the alveolus and the capillary are only one cell thick.

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Fig. 14.5 Two kinds of cells lining the trachea – ciliated cells and mucus secreting cells.

epithelium. During lifetime the cilia are constantly in motion driving any fluid (mucus) that is on them and also any particles that may have come in with the air towards the mouth (Fig. 14.5).

The Lungs are a pair of spongy and elastic organs formed by the air sacs, their connecting bronchioles, blood vessels, etc. The two lungs are roughly cone-shaped, tapering at the top and broad at the bottom. The left lung has two lobes and the right lung has three. The left lung is slightly smaller to accommodate the heart in between.

Membranous coverings of the lungs. Each lung is covered by two membranes — the inner **(visceral) pleura** and outer **(parietal) pleura** with a watery fluid **(pleural fluid)** in the pleural cavity found between the two membranes (Fig. 14.3). This arrangement provides lubrication for free movement of the expanding and contracting lungs.

The lungs occupy the greater part of the thoracic cavity. They are located close to the inner surface of the thoracic wall and their lower bases closely rest on the diaphragm.

Blood supply to the lungs

The right auricle pumps all the deoxygenated blood received in it from the body into the right ventricle, which in turn, pumps it into the lungs through the main pulmonary artery. The pulmonary artery, soon after its emergence, divides into two branches entering their respective lungs. Inside the lungs, they divide and redivide several times to ultimately form capillaries around the air sacs. Veins arising from these capillaries join and rejoin to form two main pulmonary veins from each lung which pour the oxygenated blood into the left auricle of the heart.

The Fig. 14.6 represents the branching of respiratory passages and the blood circulation in the lungs. The bright red parts represent oxygenated blood and the dull brownish parts represent deoxygenated blood. The interconnecting capillaries between arteries and veins have not been shown in the upper figure to avoid complexity in the diagram. The lower figure shows a small part of the lung highly magnified depicting air sacs (alveoli), the capillaries surrounding them and the connected pulmonary artery and pulmonary vein.

16.7 BREATHING – RESPIRATORY CYCLE

Respiration vs. Breathing

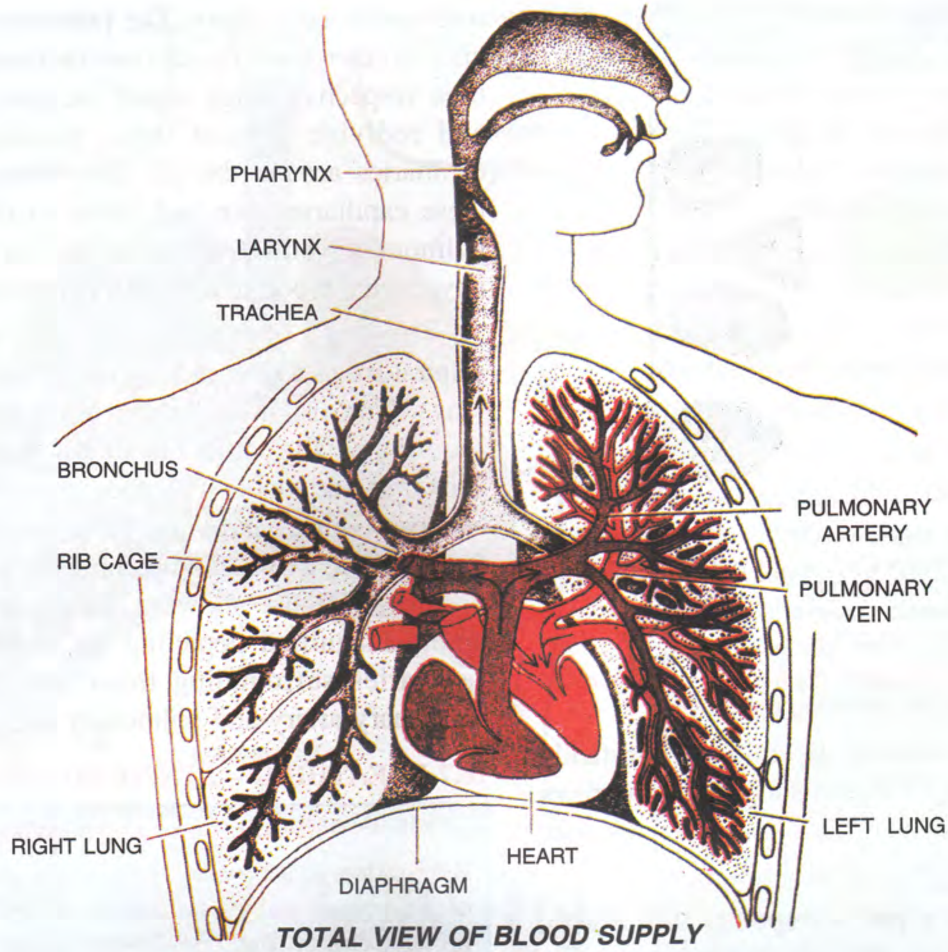
Respiration is a broader term which includes intake of air/oxygen and its utilization in the body cells to produce energy, But, breathing is simply a mechanical process of inhaling and exhaling the air in other words it is a muscular process. So, "Respiration therefore includes breathing but not vice-versa". (Gk. *re* : again, *spirare* : to blow).

The respiratory cycle consists of **inspiration** (breathing in), **expiration** (breathing out) and a very short **respiratory pause**. In normal adults, the breathing rate is 12-18 breaths per minute. A new born breathes 60 times per minute. Slight increase in CO_2 content in blood increases breathing rate.

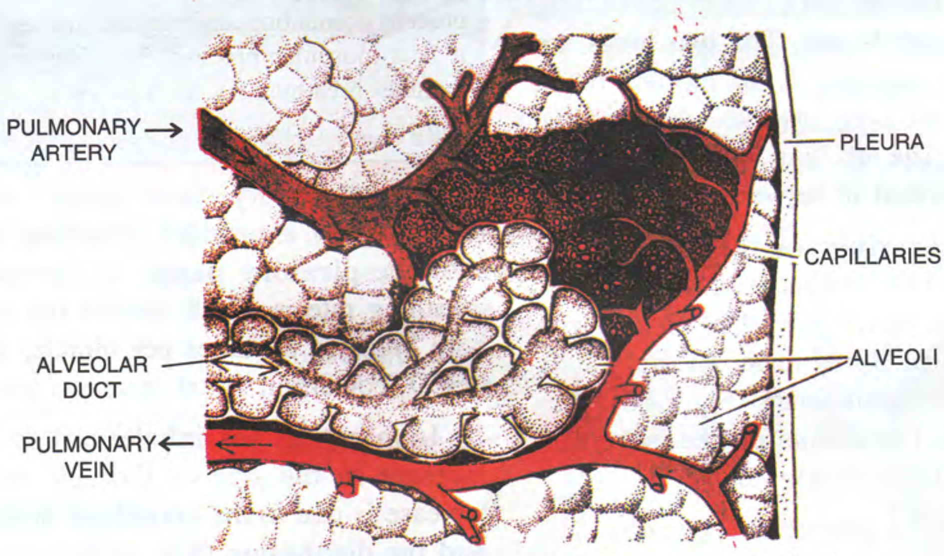
1. Inspiration (or inhalation) is the result of increase in the size of thoracic cavity and this increase is due to the **combined action of the ribs and the diaphragm** (Fig. 14.7).

The **ribs** are moved upward and outward due to the contraction of the external intercostal muscles stretched between them, thus enlarging the chest cavity all around. (The internal intercostal muscles are relaxed).

The **diaphragm** a sheet of muscular tissue, which normally remains arched upward like a dome,



TOTAL VIEW OF BLOOD SUPPLY



ALVEOLI AND CAPILLARIES, HIGHLY MAGNIFIED

Fig. 14.6 Blood supply in lungs

towards the base of the lungs, contracts and **flattens** from the dome-shaped outline to an almost horizontal plane and thus contributes to the enlargement of the chest cavity lengthwise. As the diaphragm flattens, it presses the organs inside the abdomen and with the abdominal muscles relaxed, the abdominal wall moves outwards leading to increase in volume of chest cavity and decrease of pressure.

Decreased pressure inside the lungs draws the air inward. The outside air being at a greater pressure, rushes in to equalize the pressure.

(When the thoracic (chest) cavity increases in size, its internal pressure is decreased.

The lungs expand and as a result, the pressure inside the lungs is lowered below the atmospheric pressure).

2. **Expiration** (or exhalation) is the result of reverse movements of the ribs and diaphragm. The external intercostal muscles relax and the ribs move in automatically. The **diaphragm** is relaxed and **move upwards to its dome-like outline**. As a consequence of the above-mentioned movements of ribs and diaphragm, the volume of the thorax cavity is decreased and the lungs are compressed, forcing the air out into the atmosphere.

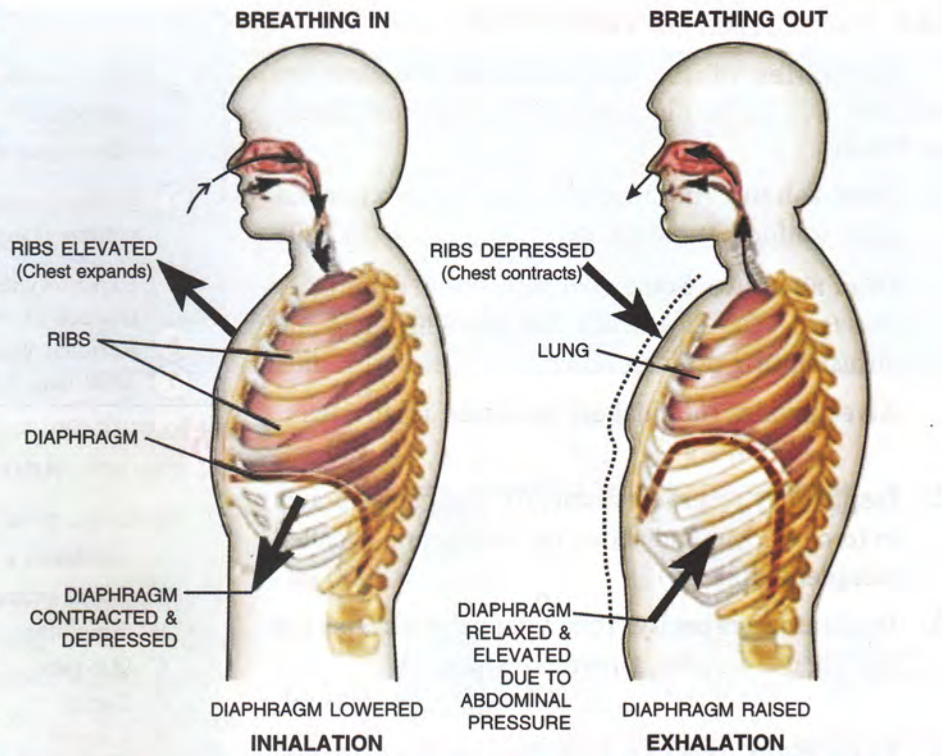


Fig. 14.7 Ribs and diaphragm movements during breathing (inhalation and exhalation)

When we breathe out forcibly or naturally as it happens during intense physical exercise, the internal intercostal muscles also contract causing further contraction of the rib cage to expel out more air for larger intake of oxygen.

Tissue or Internal Respiration. The process by which the cells of the body use the oxygen to oxidise the food and release energy. Carbon dioxide formed as a waste product of break down of glucose molecule is sent out in expiration.

Have you ever observed the outward rise and inward fall of people's belly alternately with inspiration and expiration? Now you know the reason for it.

CONTROL OF BREATHING MOVEMENTS

The breathing movements are largely controlled by a ***respiratory centre*** located in the medulla oblongata of the brain. This centre is ***stimulated by the carbon dioxide content of the blood***. More the carbon dioxide content in the blood, faster is the breathing. The breathing movements are normally not under the control of the will, *i.e.*, they are involuntary, but to some extent, one can consciously increase or decrease the rate and extent of breathing. If you forcibly hold the breath, a stage would come when you cannot hold it any longer.

Table 14.2 Breathing movement in humans

Part of respiratory system	Inspiration	Expiration
1. Diaphragm	Contracts and flattens downwards	Relaxes and moves upwards to dome shape
2. External inter-costal muscles	Muscles contract	Muscles relax
Internal inter-costal muscles	Relaxed/stretched	Contract for forced expiration
3. Rib cage and sternum	Move upwards and outwards	Move downwards and inwards
4. Thoracic cavity	Increases	Decreases
5. Air pressure	Decreases inside thorax and lungs	Increases inside thorax and lungs
6. Air movement	External air pressure drives air *into* lungs at low pressure	Air forced out of lungs by thorax *compression* and *elastic recoil* of lungs

14.8 CAPACITIES OF THE LUNGS

Capacities of the lungs or the Respiratory volumes in a normal human adult are approximately as follows:

1. **Tidal volume.** Air breathed in and out in a **normal** quiet (unforced) breathing = 500 mL

   Dead air space. Some tidal air is left in respiratory passages such as trachea and bronchi where no diffusion of gases can occur = 150 mL

   Alveolar air. The tidal air contained in air sacs = 350 mL

2. **Inspiratory reserve volume.** Air that can be drawn in forcibly over and above the tidal air (also called **complemental air**) = 3000 mL

3. **Inspiratory capacity.** Total volume of air a person can breathe in after a normal expiration. = 3500 mL

4. **Expiratory reserve volume.** Air that can be forcibly expelled out after normal expiration (also called **supplemental air**) = 1000 mL

5. **Vital capacity.** The volume of air that can be taken in and expelled out by maximum inspiration and expiration = 4500 mL

6. **Residual volume.** Some air is always left in the lungs even after forcibly breathing out. This is the leftover (**residual**) air = 1500 mL

7. **Total lung capacity.** Maximum air which can at any time be held in the two lungs = 6000 mL

All the above respiratory volumes (in millilitres) in a normal human adult are shown in Fig. 14.8 and have been summarized in the box, next.

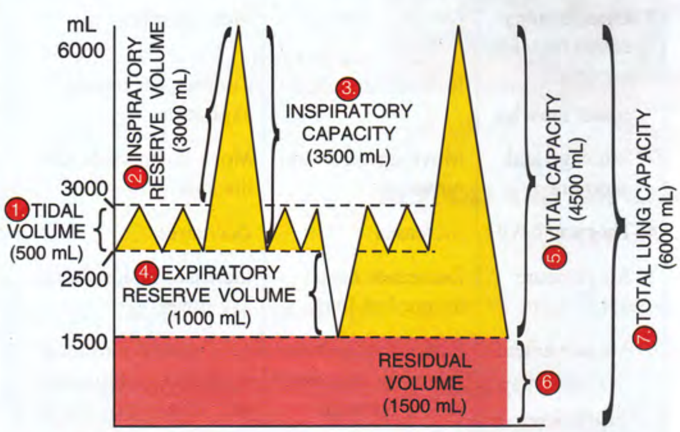


Fig. 14.8 Volumes of air exchanged in the lungs.

SUMMARY OF RESPIRATORY VOLUMES

1. Tidal volume
   - Alveolar air 350 + Dead space air 150 = 500
2. Inspiratory reserve volume (Deep inspiration) 3000
   - 500 + 3000 = 3500 → 3. Inspiratory capacity
4. Expiratory reserve volume (Forced expiration) 1000
   - 3500 + 1000 → 5. Vital capacity **4500 mL**
6. Residual volume .... **1500 mL**
7. *Total lung capacity* .... **6000 mL**

? PROGRESS CHECK

1. Match the items in Column I with those in Column II.

Column I	Column II
A. Nasal chamber	(i) Production of voice
B. Epiglottis	(ii) C-shaped rings
C. Air-sacs	(iii) Warms air
D. Lungs	(iv) Drives mucus
E. Larynx	(v) Closes wind-pipe during swallowing
F. Trachea	(vi) Network of capillaries
G. Cilia	(vii) Spongy and elastic

2. How do the following contribute in inspiration during breathing ?
   (i) Ribs (ii) Diaphragm

3. Match the lung capacities in Column I with the quantities given in Column II.

Column I	Column II
A. Residual air	4500 mL
B. Vital capacity	6000 mL
C. Total lung capacity	1500 mL
D. Dead air space	150 mL

14.9 INSPIRED AIR *vs.* EXPIRED AIR

The **air inside the lungs is never replaced completely**. It is always a mixture of the air left inside and the air inspired. In other words, the air in the lungs is only becoming **better and worse** with each inspiration and expiration.

Qualitywise, the expired air differs from inspired air in the following respects :

1. It contains **less oxygen.**
2. It contains **more carbon dioxide.**
3. It contains **more water vapour.**
4. It is **warmer** (or at the same temperature as that of the body).
5. It may contain **some bacteria.**

Table 14.3 : The average composition of inspired and expired air

Component	Inspired air	Expired air	Basis of difference
1. Oxygen	20.96%	16.4%	Absorbed at the alveolar surface
2. Carbon dioxide	0.04%	4.0%	Released at the alveolar surface
3. Nitrogen	79.00%	79.6%	Unused
4. Water vapour	low	high	Evaporation of the water from respiratory passages
5. Dust particles	Variable but usually present	Little, if any	Caught in mucus
6. Temperature	Variable	About body temperature (37°C)	Warmed by the respiratory passages.

Table 14.3 gives the **average composition** of the expired and inspired air of a person at rest and the basis of difference.

EFFECT OF ALTITUDE ON BREATHING

As we go higher up, the air we breathe in decreases in pressure accompanied by a gradual decrease in oxygen content. At about 4,500 metres above sea level, one may suffer from air sickness, in which lack of oxygen leads to dizziness, unsteady vision, loss of hearing, lack of muscular coordination and even complete blackouts.

14.10 HYPOXIA AND ASPHYXIATION

HYPOXIA is the deficiency of oxygen reaching the tissues. It may result due to sitting for long hours in a crowded room with poor ventilation. It may also be experienced at high altitudes where the oxygen content of the air is low.

ASPHYXIATION is a condition in which the blood becomes more venous by accumulation of more carbon dioxide and the oxygen supply is diminished. This may result due to several causes, such as, strangulation, drowning, or any obstruction in the respiratory tract. Death follows if the cause is not removed quickly. Artificial respiration is helpful in certain cases.

14.11 SOME EXPERIMENTS ON BREATHING AND RESPIRATION

1. **To demonstrate that water is lost during breathing :** Gently breathe upon a **cold** surface such as a piece of glass or slate; the water droplets appearing on the surface prove the presence of moisture in expired air.

2. **To demonstrate that CO_2 is given out in breathing :** Set up an apparatus as shown in Fig. 14.9. Clip (C) is opened and clip (D) is closed.

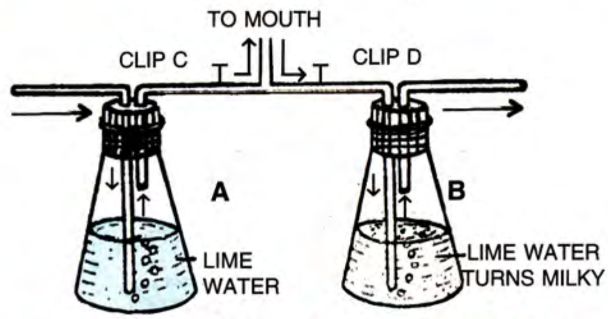


Fig. 14.9 Experiment to show that expired air contains more CO_2 than the inspired air.

Air is sucked in by the mouth, through the tube at the centre. Atmospheric air rushes in flask (A) bubbling through the lime water. Next, clip (C) is closed and clip (D) is opened and the exhaling air is blown through the same central tube. This time the air is forced into flask (B) bubbling through its lime water. The process is repeated about ten times. The lime water in flask (B) turns milky much faster than in flask (A). This proves that the expired air contains more carbon dioxide than the inspired air.

3. **To demonstrate the action of the diaphragm during breathing :** Set up an experiment as shown in Fig. 14.10. The rubber sheet tied around the bottom edge of the Bell jar represents the

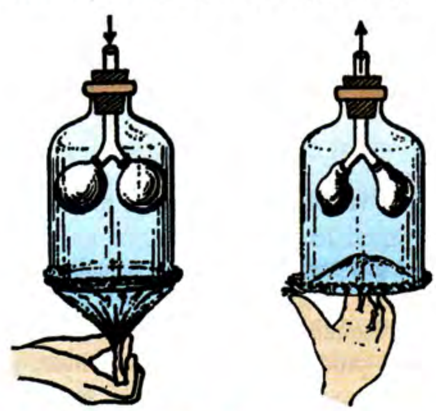


Fig. 14.10 An experiment to demonstrate the action of diaphragm in breathing.

diaphragm. When the sheet is pulled downward volume is increased pressure inside the bell jar lowered, the rubber balloons are expanded by the air rushing in through the tube at the top. When the sheet is pushed upward volume is decreased pressure inside the jar increased, the balloons collapse due to the air rushing out. The balloons represent the two lungs.

4. **To measure the volume of expired air :** Set up an apparatus as shown in Fig. 14.11. Fill your chest with air to the maximum, and then blow out through the short tube expelling as much air as you can. The water expelled from the other tube when measured gives the volume of the air exhaled.

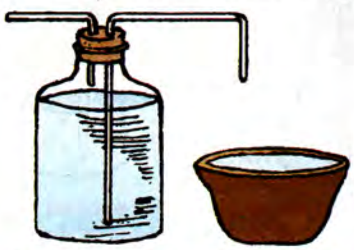


Fig. 14.11 An apparatus to measure the volume of air breathed out.

5. **To show that oxygen is taken in by animals during respiration :** Use a small animal such as a cockroach or snail in this experiment. Take **two conical flasks A and B.** Place a live cockroach in one flask (A) and a dead cockroach that has been soaked in formalin to prevent decay in the other flask (B). This flask with the dead cockroach acts as a control. Fit a rubber cork in the mouth of each flask and make sure that the apparatus is air-tight. Leave the flasks for a few hours, after which introduce a small burning candle into each flask as shown in the Fig. 14.12. Immediately after introducing the candle, close the mouth of the flask tightly. Note the time taken for the candle flame to go out. You will find that the flame goes out faster in the flask (A) containing the living animal, showing that some oxygen has been used up by it during respiration.

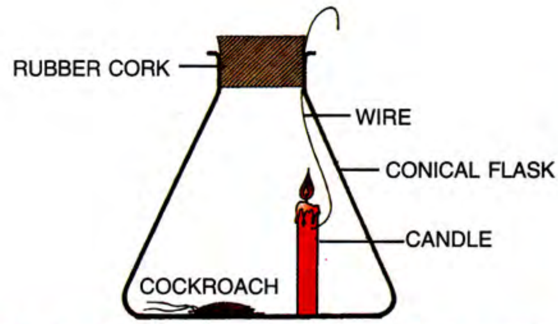


Fig. 14.12 To show that oxygen is taken in during respiration.

? PROGRESS CHECK

1. Mention any two points of difference in the quality of inspired and expired air.
2. Give reasons for :
   (i) People climbing to high altitudes may suffer from dizziness and unsteady vision.
   (ii) Use of lime water in most experiments on respiration
   (iii) Respiration rate is higher in animals than in plants
3. Given alongside is an experiment intended to demonstrate the action of diaphragm, but some thing has gone **wrong**.
   (i) What is the mistake in the diagram? Explain.

Table 14.4 Comparison of respiration in plants and animals

Plant Respiration	*Animal Respiration*
Similarities	
1. Cellular respiration produces energy stored as ATP, in mitochondria.	
2. Aerobic respiration forms CO_2 and water.	
Differences	
1. No **external ventilation** (breathing) movements.	1. **External ventilation** (breathing) movements (except in extremely small animals like amoeba or hydra).
2. **No special gas transport** system (usually direct. diffusion from air spaces, or from cell to cell).	2. **Blood system transports** oxygen.
3. Anaerobic respiration forms **ethanol and CO_2**	3. Anaerobic respiration forms **lactic acid only** and no CO_2.
4. Green plants produce **little detectable heat.**	4. Animals produce **considerable detectable heat.**
5. Green plants have **additional oxygen source** from photosynthesis.	5. Aerobic animals have only air as the oxygen source.
6. Respiration rate is **low.**	6. Respiration rate is **high.**

POINTS TO REMEMBER

- *Respiration is the chemical process of releasing energy by breaking down glucose for carrying out life processes.*
- *Breakdown of glucose occurs in a series of chemical steps — some in cytoplasm and some inside mitochondria.*
- *The overall chemical equation during aerobic respiration is :-*

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38\ ATP + 420\ Kcal\ (Heat\ energy)$$

- *Anaerobic respiration in animals occurs when the muscles have to work very fast with relatively insufficient oxygen, and the summary reaction is as follows :-*

$$C_6H_{12}O_6 \rightarrow \text{lactic acid} + 2\ ATP + \text{heat energy}$$

- *Human respiration involves four major steps — breathing, gaseous transport, tissue respiration (delivering O_2 to cells and collecting CO_2 from cells), and cellular respiration (breakdown of glucose to yield energy inside the cell).*
- *The human respiratory system consists of air passages — nose, pharynx, larynx, trachea (wind pipe), bronchi and lungs.*
- *Tracheal walls are supported by C-shaped cartilaginous rings to prevent its collapsing.*
- *The lungs are a pair of spongy elastic organs.*
- *Inspiration (inhalation) is caused by moving the ribs upward and lowering the diaphragm, and expiration (exhalation) by the reverse movements.*
- *There are seven capacities of lungs — Tidal volumes (500 mL), Inspiratory reserve volume (3000 mL), Inspiratory capacity (3500 mL), Expiratory reserve volume (1000 mL), Vital capacity i.e., maximum inspiration and expiration (4500 mL), residual volume (1500 mL) and total lung capacity (6000 mL).*

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

1. During inspiration, the diaphragm
   (a) relaxes (b) contracts
   (c) expands (d) gets folded
2. The ultimate end parts of the respiratory system in humans are known as
   (a) alveoli (b) bronchioles
   (c) tracheoles (d) bronchi
3. During respiration there is
   (a) gain in dry weight
   (b) loss in dry weight
   (c) no change in dry weight
   (d) increase in the overall weight

B. VERY SHORT ANSWER TYPE

1. Choose the **odd** one out in each of the following groups of four items each :
   (a) Trachea, Bronchus, Alveolus, Diaphragm
   (b) Ethyl alcohol, Carbon dioxide, Starch, Oxygen absence
   (c) Diffusion, Respiratory gases, Alveoli, Capillary network
   (d) Trachea, Ciliated epithelium, Mucus, Diffusion
   (e) Oxyhaemoglobin, Carbaminohaemoglobin, Hypoxia, Carboxyhaemoglobin
   (f) Hairy, Moist, Nostril, Vocal cord.
2. **Name** the body structure concerned with the given functional activity :
   (a) Prevents food from entering the trachea during swallowing.
   (b) Transports oxygen to the body cells.
   (c) Helps to increase the volume of the chest cavity lengthwise.
   (d) Combines with the oxygen in the lungs.
   (e) Protects the lungs from mechanical injuries.
   (f) Provides actual diffusion of respiratory gases in lungs.
3. **What** is the normal percentage composition of gases in inspired air and expired air respectively ?
4. Which chemical compound inside a cell can be termed **"Currency of Energy"**.

5. **Match** the items in Column I with the ones most appropriate in Column II. Rewrite the matching pairs :

Column I	Column II
(a) Alveoli	(i) where aerobic respiration takes place
(b) Bronchioles	(ii) lined with hair
(c) Nasal chamber	(iii) diffusion of gases
(d) Bronchi	(iv) small air tubes
	(v) An inverted Y-shaped tube
	(vi) A common passage for food and air

C. SHORT ANSWER TYPE

1. Given below is an example of a certain structure and its special functional activity:

"Kidney and excretion."

Fill in the blanks on a similar pattern.

(a) Alveoli and ....
(b) Mitochondria and ....
(c) Epiglottis and ....
(d) Pleura and ....
(e) Diaphragm and ....
(f) 'C' shaped cartilage rings and ....

2. State **one** function of each of the following :
(a) Ciliated epithelium lining the respiratory tract
(b) Mitochondria
(c) Diaphragm
(d) Intercostal muscles
(e) Pleural fluid

3. **Match** the items in Column A with those in Column B.

Column A	Column B
Cartilaginous	Epiglottis
Large surface area	Diaphragm
Breathing movements	Bronchi
Voice	Alveoli
Complemental air	Larynx
Swallowing	Extra inhalation

4. Under what **conditions** would the breathing rate increase ?

5. How would you prove that the air you breathe out is **warmer** ?

6. How is the respiratory passage kept **free of dust particles** ?

7. What is wrong in the statement "We breathe in oxygen and breathe out carbon dioxide"?

D. LONG ANSWER TYPE

1. **Differentiate** between the following pairs on the basis of the aspect given in the brackets.
(a) Aerobic and anaerobic respiration (end products of the process)
(b) Respiration and photosynthesis (Gas released)
(c) Photosynthesis and respiration (Reactants)
(d) Inspired air and alveolar air (CO_2 content)
(e) Respiration and breathing (organs involved)
(f) Tidal volume and residual volume (quantity of air)

2. Give suitable **explanations** for the following :
(a) Breathing through the nose is said to be healthier than through the mouth.
(b) Why does gaseous exchange continue in the lungs even during expiration ?
(c) Why does a person feel breathlessness at higher altitudes ?

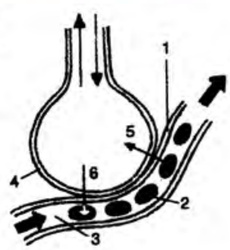
3. With regard to the respiratory system and the process of respiration in man, answer the following questions:
(a) **Name** the two muscles that help in breathing.
(b) Briefly **describe** how the above mentioned muscles help in the inspiration of air.
(c) Give the **overall chemical equation** to represent the process of respiration in humans.
(d) What is meant by :
1. Residual air 2. Dead air space.

4. Starting from the nostrils, trace the **path in sequence** which the inspired air takes until it reaches the air sacs.

5. What are the **functions** of the following in breathing?
(a) Ribs,
(b) Diaphragm,
(c) Abdominal muscles

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given alongside is a diagrammatic sketch of a part in human lungs
(i) Name the parts numbered 1– 4
(ii) What do the arrows 5 and 6 indicate ?



2. Given below is an overall chemical reaction of a certain process :

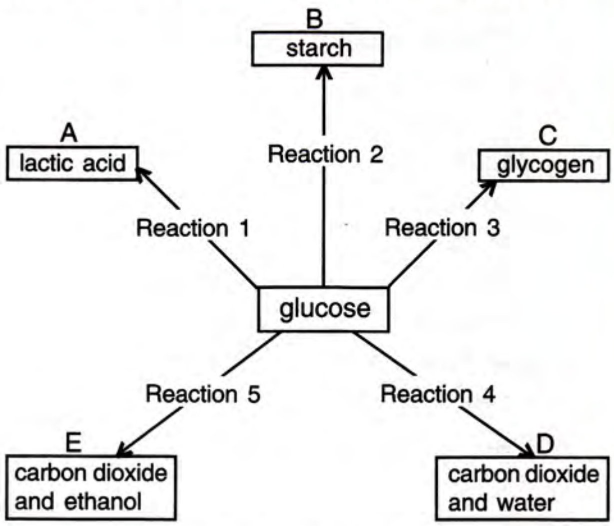
$C_6H_{12}O_6 \rightarrow$ lactic acid + 2ATP + heat energy

(a) Name the process.

(b) Is this reaction applicable to animals or to plants or to both animals and plants ?

(c) Name one tissue in which this reaction may occur.

3. Given below are chemical reactions (1 to 5) involving glucose and five other chemical products (A–E).



(a) Write the reaction number of the following :

(i) Anaerobic respiration in plants ....

(ii) End-products in aerobic respiration ....

(iii) Reaction occurring in liver ....

(iv) Anaerobic respiration in animals ....

(v) Storage in the liver ....

(b) Which reactions (1–5) in the above correspond to the following (write the corresponding number of reaction next to them).

(i) Aerobic respiration ☐

(ii) Change taking place in the liver ☐

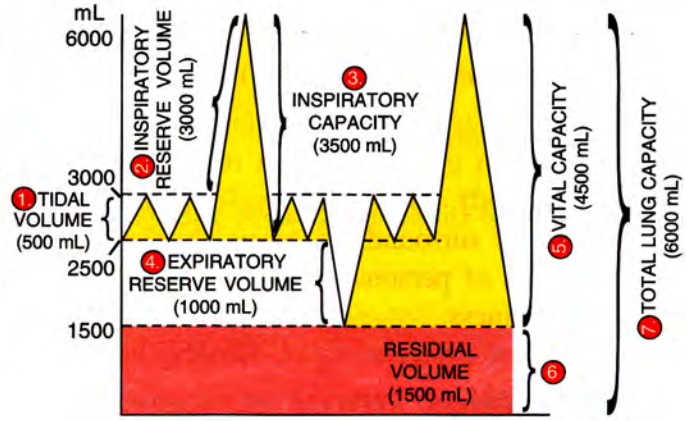
(iii) Anerobic respiration in yeast. ☐

(iv) Change taking place in a plant storage organ, *e.g.*, potato. ☐

(v) Anaerobic respiration in animals ☐

3. The volume of air in the lungs and the rate at which it is exchanged during inspiration and expiration was measured.

The following diagram shows a group of the lung volumes and capacities :



Study the diagram carefully and explain briefly the following :

(a) Tidal volume

(b) Inspiratory reserve volume

(c) Expiratory reserve volume

(d) Vital capacity

(e) Residual volume

THREE COMMON EXPERIENCES RELATED TO BREATHING

Hiccups – "Jerky incomplete inspiration" (nothing to do with some one remembering you).

Sneezing – "Forceful sudden expiration" (A protective reflex).

Snoring – "Vibration of the soft palate during breathing while sleeping."

For efficient performance, the lungs need moist, warm and clean air. How are these needs fulfilled ?

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