

Respiration - The energy releasing system

Using food to carry out life processes is key to life for all living beings in both multicellular or unicellular. In the chapter, on nutrition we have discussed how the body draws out nutrients from the food taken in. The food provides energy for all bodily activities only after break down through the process known as respiration. Thus, respiration leads to final utilization of food. When oxygen is plentiful respiration normally takes over. Cells of the living body use food constantly to help our body to function properly. They require the presence of gas, food material and some chemicals.

The term 'respiration' derived from Latin word 'respire' meaning 'to breathe', refers to the whole chain of processes from the inhalation of air to the use of oxygen in the cells. To begin with, we shall study the relation of gases and the process of respiration.

Discovery of gases and respiration

The term respiration came into use, a century after the word breathing was used, way back in the 14th century. It was used much before people knew that air is a mixture of gases. They hardly knew anything about all the life processes that took place internally in a living body. Respiration which was used as a medical term, usually referred to as a process involving passage of air and production of body heat.



fig-1: Lavoisier

It was not until 18th century when Lavoisier and Priestley did a comprehensive work on properties of gases, their exchange and respiration that we came to know something about how the process of gaseous exchange goes on, in our body. You have already studied about

some of Priestley's experiments in earlier classes (You have an account of it in the chapter on nutrition as well). Recall the concepts and answer the following.

- *Can it be said that Priestley's experiment helped us to find out more about composition of air? How?*

Lavoisier also carried out several experiments to understand the property of gases. In his early experiments, it is clear that Lavoisier thought that the gas liberated on heating powdered charcoal in a belljar kept over water in a trough was like fixed air. In those days carbon dioxide was known as fixed air. The next series of experiments dealt with the combustion of phosphorus in a belljar. From these studies Lavoisier showed that whatever in the atmospheric air which combined with the phosphorus, was not water vapor. His final words are that the substance which combines with the phosphorus is "either air itself, or another elastic fluid present, in a certain proportion, in the air which we breathe". This was the respirable air, a component of air that also helped in burning.

- *What was produced by combustion according to Lavoisier?*
- *What did Lavoisier find out about air from his experiments?*
- *What conclusion can be drawn from Lavoisier's experiments?*

Lavoisier noted that there was a profound difference between the air in which combustion of a metal had been carried out and the one which had served for respiration. The air that we breathe out precipitated lime water while that after heating metal did not.

From this he deduced that there were two processes involved in respiration, and that of these he probably knew only one. Therefore, he carried out another experiment by which he showed that about one sixth of the volume of 'vitiating air' (a term used then to show air from which the component needed for burning had been removed) consists of chalky acid gas (fixed air). Therefore, to recreate common air from vitiating air, it was not enough merely to add the appropriate amount of air needed for burning or respirable air; the existing chalky acid gas must also be removed.

He drew immediately the logical conclusion regarding the process of respiration. Either eminently respirable air is changed in the lungs to chalky acid air; or an exchange takes place, the eminently respirable air being absorbed, and an almost equal volume of chalky acid air being given up to the air from the lungs. He had to admit that there were strong grounds for believing that eminently respirable air did combine with the blood to produce the red colour.



fig-2: Priestley

Lavoisier's findings lead way to several other researchers.

- Which gas do you think is Lavoisier talking about when he says chalky acid gas?
- Which gas according to him is respirable air?
- What steps in the process of respiration does Lavoisier mention as an inference of his experiments?

A few lines from a textbook of Human Physiology, written by a renowned chemist, John Daper around mid-19th century goes like this..

“The chief materials which a living being receives are matter that can be burnt, water and oxygen gas; and out of the action of these upon one another, all the physical phenomena of its life arise. What the body expels out is water, oxide of carbon, phosphorous, sulphur and others.”

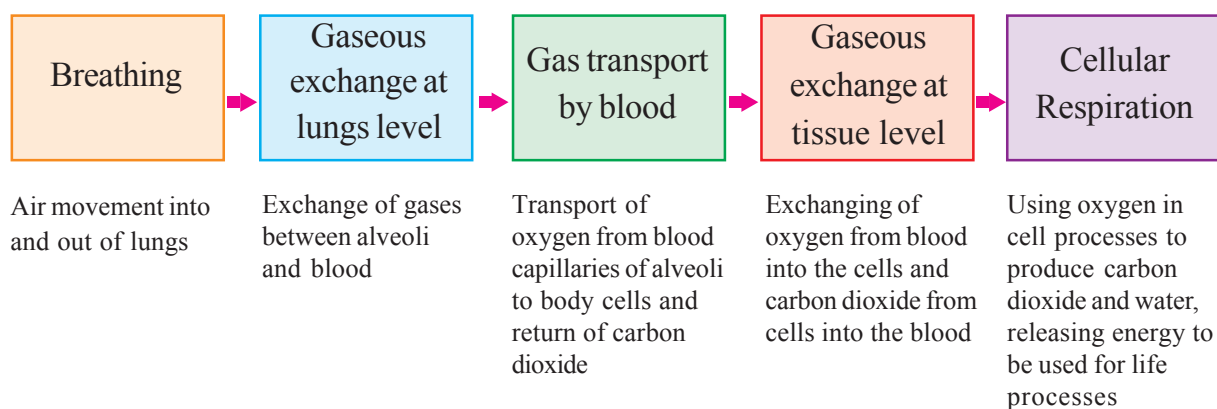
Thus, we can see that the role of major compounds and elements in the process of respiration was known by mid19th century. The events involved were not very clearly understood, but, people believed that there was some relationship of the heat produced in the body and the process of respiration.

- It is a common observation that our breath is warmer than the air around us; does respiration have anything to do with this?

Let us study the events involved in respiration in human beings to figure it out.

Events / Steps in Respiration

There are no strict demarcations of events involved in the process of respiration. It is a very complex process of several biochemical and physical processes. But for a general understanding on what goes on, we shall study under the following heads.



Breathing

In the previous classes we did experiments to find out what was there in the air we breathe out.

We had seen that in a set up with lime water, it turned milky white fast as we breathe out into it as compared to a similar set up in which normal air was passed with the help of a syringe or pichkari in lime water. (Experimental set up to test the presence of Carbon dioxide in exhaled air). Arrange apparatus as shown in figure and try to do the experiment once again to find out what happens.

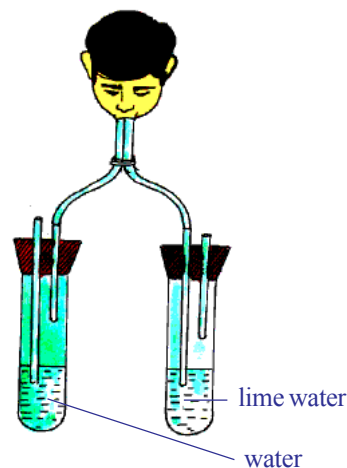


fig-3: Respiratory gases

- *What does this experiment indicate?*
- *Which gas turns lime water milky?*
- *Which gas do you think might be present in greater quantities in the air we breathe out as compared to air around us?*
- *We are also aware of the fact that water vapor deposits on a mirror if we breathe out on it.*
- *Where does this water vapor come from in exhaled air?*

We shall have to study the pathway of air in our body through our respiratory system and the mechanism of breathing in respiration to find out how the exhaled air comes out (Fig showing the respiratory system/pathway). By “respiratory system” we usually mean the passages that transport air to the lungs and to the microscopic air sacs in them, called alveoli (where gases are exchanged between them and blood vessels) and vice versa.

Pathway of air

Let us observe the pathway of air from nostril to alveolus.

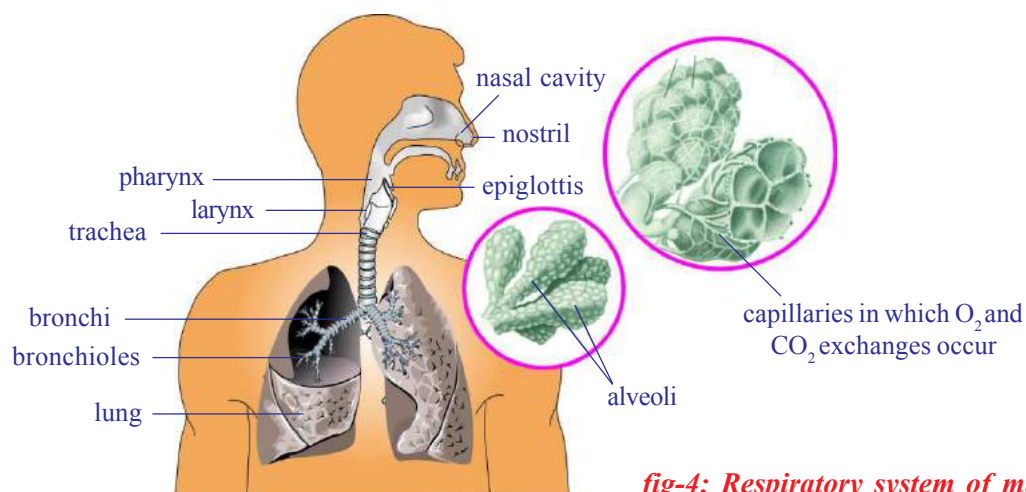










fig-4: Respiratory system of man

Nostrils: 	Air usually enters the body through the nostrils
Nasal cavity: 	Air is filtered. The moist surface of the lining of the nasal cavity, and the hairs growing from its sides, remove some of the tiny particles of dirt in the air. In addition, as the inhaled air passes through the nasal cavity, its temperature is brought close to that of the body, and it takes up water vapour so that it becomes more moist than before.
Pharynx: 	Warming and moistening goes on in this common passage of digestive and respiratory system. Epiglottis, a flap like muscular valve controls movement of food and air towards their respective passages.
Larynx: 	This stiff box contains our vocal cords. When air passes out of the lungs and over the vocal cords, it causes them to vibrate. This produces sounds on the basis of our speech, song etc.
Trachea: 	Wind pipe channeling air to lungs. Touch your neck to feel the tube like structure.
Bronchus: 	At its lower end the trachea or the wind pipe divides into two bronchi-one leading to each lung.
Bronchioles: 	Each bronchi is further divided into smaller and smaller branches called bronchioles.
Alveolus: 	These finally terminate in clusters of air sacs called alveoli in the lungs which are very small and numerous. Gaseous exchange takes place here as blood capillaries take up oxygen and expel carbon dioxide.
Blood:	Carries oxygen, collects CO ₂ to each and every cell of the body.

The whole passage from nostrils to alveolus is moist and warm.



Do you know?

The interior of lung is divided into millions of small chambers, thus tremendously increasing the moist surface available for transfer of gases between air and blood. The linings of the lungs are much folded and so their total surface is enormous. If all alveoli of our lungs are spread out they will cover an area of nearly 160 m².



Think and discuss

- What will happen if the respiratory tract is not moist?
- Are both lungs similar in size?
- Why alveolus are so small and uncountable in number?

Epiglottis and passage of air

From the nasal cavity, the air goes into the pharynx. There is a tricky problem here. From the pharynx there are two passages, beginning with nearly same opening and ending into separate ones, one to the lungs and one to the stomach. It is important that air goes into one and food into the other. It is also important that food *does not* enter the tube through which air goes into the lungs. The traffic is kept properly

channeled by a flap like valve, the **epiglottis** that protects the tube to the lungs, arresting entry of food. Observe the following figures and discuss in your class how epiglottis works while breathing or swallowing

This valve is partly closed when we swallow food; it deflects food down to the stomach and keeps it out of the trachea or wind pipe which is the route to the lungs. The epiglottis opens more widely when we take a breath, and air enters the lungs. Nervous regulation is important in guiding the function of epiglottis and passage of food and air. Let us try to do an activity to feel what happens when we swallow food.

- *Why we are advised not to talk while eating food ?*

Activity-1

Keep your palm around an inch away from your nose, feel you are breathing out, do not remove it until you have finished the activity. Breathe steadily for 1-2 minutes. Now take a piece of any fruit, chew and before swallowing it keep the fingers of the other palm on your neck, now swallow it.

- *What did you notice? What happens to your breath as you try to swallow?*

Epiglottis diverts air to lungs



fig-5(a): Breathing

Epiglottis diverts food mass away from opening of larynx



fig-5(b): Swallowing

- What is helping you to swallow without deflecting it to the wind pipe?

Mechanism of respiration in human beings

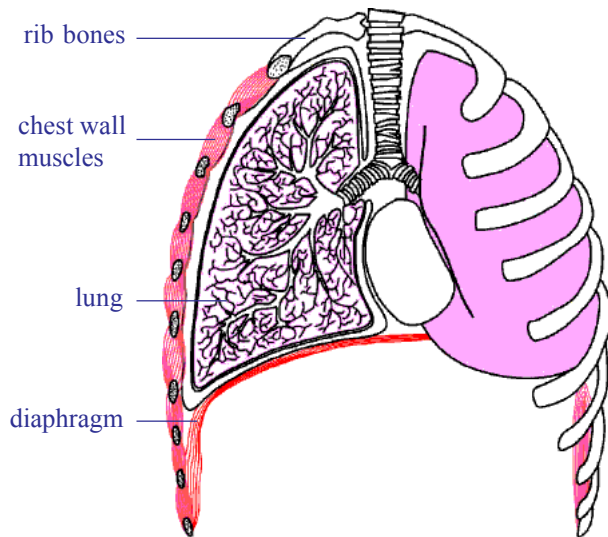


fig-6: Movement of diaphragm

We know that breathing is the process of inhaling and exhaling. The organs involved are mainly the lungs. You can't see your lungs, but it's easy to feel them in action. Put your hands on your chest and breathe in very deeply. You will feel your chest getting slightly bigger. Now breathe out the air, and feel your chest return to its regular size. You've just felt the power of your lungs! The lungs themselves can neither draw in air nor push it out. Instead, the chest wall muscles and another flexible

flattened muscle called **diaphragm** helps the lungs in moving air into and out of them. See how the diaphragm works in the figure.

- What is the role of diaphragm and ribs in respiration? Are both active in man and woman?

The chest wall is made up of ribs, muscles, and the skin. The ribs are attached at an angle to the spine (if you run your finger along one of your ribs, you will notice that it extends downward from the spine). When we inhale, the chest wall moves up and expands. This causes an increase in the volume of the chest cavity.

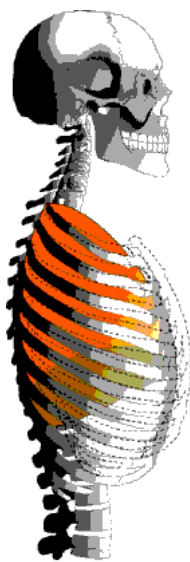


fig-7: Movement of rib cage during inhalation, exhalation

The diaphragm may be imagined as the 'floor' if you think of the chest cavity as a "room." When the diaphragm is relaxed when we breathe out, it is in the shape of a dome with the convex side of the dome extending into the chest cavity. When the diaphragm contracts during inhalation it flattens out a bit or the dome moves downward. As a result, the volume of the chest cavity is increased.

When the diaphragm flattens and the volume of the chest cavity is increased, its internal pressure decreases and the air from the outside rushes into the lungs. This is **inspiration** (inhalation).

Then the reverse occurs. The chest wall is lowered and moves inward, and the diaphragm relaxes and assumes its dome shape. These changes increase the pressure on the lungs; their elastic tissue contracts and squeezes the air out through the nose to the external atmosphere. This is **expiration** (exhalation).

? Do you know?

Our lungs are spongy in nature. They are not of the same size. The lung towards left is slightly smaller making space for your heart! Lungs are protected by two membranes called pleura. A fluid filled between these membranes protects the lungs from injury and also aid in the expansion of the spongy and elastic lung muscle, as they slide one over the other.

You must have noticed that your own breathing is slow and shallow when you are at rest. It is deeper and faster when you exercise hard. Indeed, patterns of breathing show a great range, for they are coordinated with moment-by-moment needs of the body for supply of oxygen and removal of carbon dioxide.

What other situations affect your breathing?

It has been found that all movements of breathing stop at once when the nerves leading from the brain to the respiratory muscles are cut.

- *What can be concluded from this?*
- *What happens during the process of breathing?*
- *Which gas needs to be removed from our body during exhalation? Where does the extra amount of gas come from?*
- *What is the composition of inhaled air?*
- *When exhaled air is compared with inhaled air, is there any difference in composition?*

Gaseous Exchange (alveoli to capillaries)

Gaseous exchange takes place within the lungs by diffusion from the alveoli to blood capillaries and vice versa. The carbon dioxide in the blood is exchanged for oxygen in the alveoli. These tiny air sacs in the lungs are numerous and only one cell thick. They are surrounded by capillaries that are also only one cell thick. Blood, dark red in colour flows from the heart through these capillaries and collects oxygen from the alveoli. At the same time, carbon dioxide passes out of the capillaries and into the alveoli. When we breathe out, we get rid of this carbon dioxide. The bright red, oxygen-rich blood is returned to the heart and pumped out to all parts of the body.

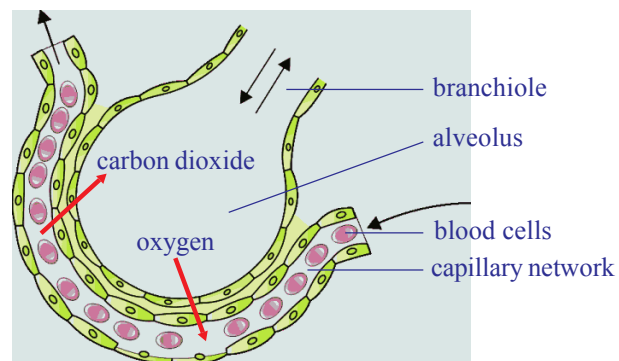
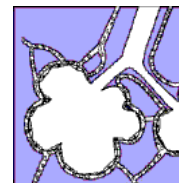


fig-8: Diffusion path way for gaseous exchange between lung and blood capillaries

As a result of gaseous exchange, the composition of inhaled and exhaled air is different. See the table given below. Approximate values are given in the table

- *Why does the amount of Oxygen vary between exhaled and inhaled air?*

Gas	% in inhaled air	% in exhaled air
Oxygen	21	16
Carbon dioxide	0.04	4
Nitrogen	79	79

- *What has raised the percentage of carbon dioxide in exhaled air?*

? Do you know?

The total lung capacity of human being is nearly 5800ml. Normally at rest who inhale or exhale approximately 500ml of air. 120ml of air remains in lungs after complete exhalation. Recall the activity of lung capacity performed by you in class VII in the chapter ‘Respiration in Organisms’.

Transportation of gases

We know that air is a mixture of gases, that fills the lungs and the alveoli when that enters our body. The relative amount of different gases in air and their combining capacity with haemoglobin and other substances in blood determine their transport via blood in the body.

When oxygen present in the air is within normal limits (around 21%) then almost all of it is carried in the blood by binding to haemoglobin, a protein (quite like chlorophyll, the only major difference being it has iron in place of magnesium as in chlorophyll) present in the red blood cells. As oxygen is diffused in the blood, it rapidly combines with the haemoglobin to form oxyhaemoglobin. Not only haemoglobin can combine with oxygen, but the reverse can also happen to yield a molecule of haemoglobin and oxygen.

Carbon dioxide is usually transported as bicarbonate, while some amount of it combines with haemoglobin and rest is dissolved in blood plasma. Study the following equation for better understanding.



? Do you know?

If haemoglobin is exposed to air at sea level, nearly every molecule combines with oxygen to form oxyhaemoglobin. At a height of 13 km (about 8 miles) above sea level, the concentration of oxygen is much lower about one fifth at sea level.

Under these conditions only about half as many molecules of oxygen combine with haemoglobin to form oxyhaemoglobin. This is important, because blood cannot carry enough oxygen to the tissues if haemoglobin is combined with few oxygen molecules. In fact, human life is impossible at such an altitude without a supplementary supply of oxygen. Provision for such a supply is built into modern aircraft, which have pressurized cabins that maintain an enriched air supply. When we go deep into the sea we will face another type of problems.



fig-9: Mountaneer

Gaseous exchange (capillaries to cells and back)

In the capillaries over the tissues, haemoglobin meets a very different environment. The tissue cells are continually using oxygen, hence, the concentration of oxygen is quite low in them. It might be only one third of that in the lungs. As the concentration of oxygen is so low, oxyhaemoglobin releases the oxygen molecule that enters the cells. In the reactions that occur within cells in our bodies, carbon dioxide and water are produced and energy is released to be used up for different purposes.

Cellular respiration

The term cellular respiration refers to the pathway by which cells release energy from the chemical bonds of food molecules that enter them. It provides that energy for the essential processes of life. So living cells must carry out cellular respiration. It can be in the presence of oxygen that is ‘aerobic respiration’ or in its absence that is ‘anaerobic respiration (fermentation)’. Cellular respiration in prokaryotic cells like that of bacteria occurs within the cytoplasm. In eukaryotic cells cytoplasm and mitochondria are the sites of the reactions. The produced energy is stored in mitochondria in the form of ATP. That is why mitochondria are called “power houses of cell”.

The exact chemical details of the breakdown of sugar or other foods within a living cell does not take place as a single reaction, but occurs in a series of small steps.

How does this affect the energy release? As the change in the chemical nature of the molecule from one stage to the next is slight, in any step small amount of energy is released. The complete breakdown of a sugar molecule with the release of all its available energy

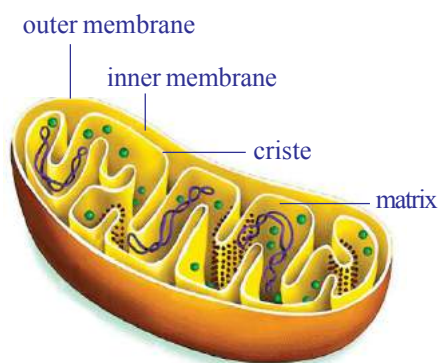


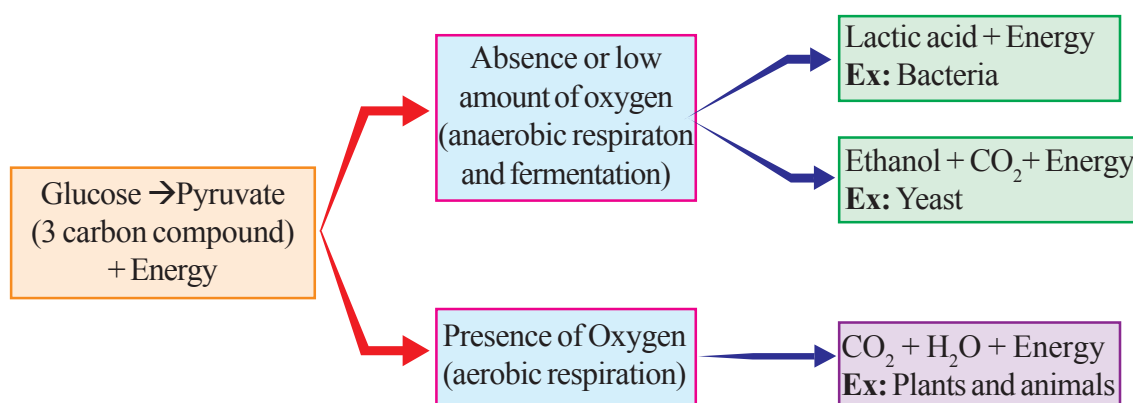
fig-10: Mitochondria

involves a series of different chemical reactions.

From the breakdown of glucose the energy is released and stored up in a special compound, known as ATP (adenosine triphosphate). It is a small parcel of chemical energy. The energy currency of these cells is ATP an energy rich compound that is capable of supplying energy wherever needed within the cell. Each ATP molecule gives 7200 calories of energy. This energy is stored in the form of phosphate bonds. If the bond is broken the stored energy is released.

- *Do cells of alveoli or lungs also require oxygen to carry out cellular respiration? Why/Why not?*

In short, at cellular level we could have the following pathways starting with glucose (It is one example, remember that there are other components of food as well).



? Do you know?

Glucose is the most commonly used sugar for deriving energy in plants, animals and in microorganisms. In all these organisms the glucose is oxidized in two stages. In the first stage it is converted into two molecules of pyruvic acid. In the second stage if oxygen is available pyruvic acid is oxidized to CO₂ and water, large amount of energy is released. If oxygen is inadequate or not utilised pyruvic acid is converted into either ethanol or lactic acid and very little amount of energy (nearly one tenth of that is produced with adequate amount of oxygen) is released.

Can energy be released without oxygen?

- *After undergoing strenuous exercise we feel pain in muscles, does adequate oxygen reach the muscles?*
- *What is being formed in the muscles?*

When you sprint a hundred yards, you do a considerable amount of muscular work. But you do not start a race by standing on the track and panting for a few minutes to stoke up with oxygen first. In fact you can run the race with very little extra breathing. The fastest sprinters do not breathe at all when running a hundred yards. After you have reached the destiny, however, you feel very different. Depending on your state of training, and on how hard you ran, you will pant for some minutes after the race, until your breathing gradually returns to normal.



fig-11: Athlete (Strenuous exercise)

These facts could be linked up with what we have learned so far about ATP. It might be that the race was run on the energy produced when the ATP already present in your muscles was being converted to ADP. Unfortunately this pleasantly simple idea is inadequate, because we only carry sufficient ATP in a muscle to last for about half a second when doing vigorous exercise. There must be some other explanation for the way in which we can produce energy first and then use up oxygen later.

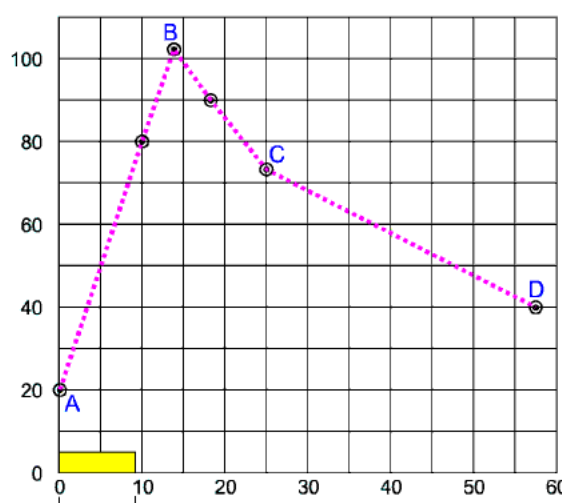
One approach in the study of this problem was to analyze the blood of a person during and after exercise. For obvious reasons the athlete taking part in the experiment had to stay still where the apparatus was. He pedaled a stationary bicycle, or ran on a tread mill (belt moving as fast backwards as the athlete moved forwards). Some results are shown in the graph. Vigorous exercise lasted for nine minutes (shown by the bar at the base of the diagram) and regular blood samples were taken and analyzed. One particular compound in the blood, lactic acid, was found to vary greatly in its concentration as you can see from the graph.

Observe the graph of lactic acid accumulation in the muscles of an athlete and answer the following questions.

(Graph showing varying amount of lactic acid in the muscles)

x - axis = Time in minutes

y - axis = Concentration of lactic acid in blood mg/cm^3



Graph showing effects of vigorous exercise on the concentration of lactic acid in blood.

- a. What was the concentration of lactic acid in the blood to start with?
- b. What was the greatest concentration reached during the experiment?
- c. If the trend between points C and D were to continue at the same rate, how long might it take for the original lactic acid level to be reached again? (Hint: extend the line CD until it reaches the starting value.)
- d. What does high level of lactic acid indicate about the condition of respiration?

Accumulation of lactic acid results in muscular pain. If we take walk, brisk walk, slow jogging, running for same distance we feel that there an increase in pain levels this is because of lactic acid accumulation.

It seems as if the lactic acid was being produced rapidly by the active muscles, and then only gradually removed from the blood after exercise. What is surprising is that the athlete needs a great length of time to recover. The simplest explanation we can produce at this stage is that the sugar in the working muscles was being changed to lactic acid. The energy stored in lactic acid molecules is less than that in sugar molecules, and if the acid comes from the sugar then the energy released could be used to rebuild ATP from ADP and phosphate.

During a 100 m race a well-trained athlete can hold his breath all the time it is not until afterwards that he pants. In this case, the muscles are using the energy released during the anaerobic breakdown of glucose. It is not until afterwards that the athlete obtains the oxygen needed in order to remove the lactic acid. Therefore, when we under-take strenuous exercise we build up what is called an **oxygen debt** which has to be repaid later. In a longer race athletes have to breathe all the time, so some lactic acid is removed while they are running, and they can go on for longer before becoming exhausted. The presence of lactic acid in the blood is the main cause of muscle fatigue, but if the body is rested for long enough the tiredness goes.

Anaerobic respiration

We have found that living things produce carbon dioxide and give out energy. If these processes are caused by an oxidation process, what happens if the oxygen supply is cut off? If human muscles can go on releasing energy when they are short of oxygen, what can cells of other living organisms do?

Let us find out by doing some experiments.



Lab Activity

Some experiments with yeast

To test this idea we can see whether it is possible to detect any rise in temperature and the production of carbon dioxide, when living organisms are kept away from a supply of oxygen.

Yeast grows rapidly if it is supplied with glucose in solution. Indeed, wild yeasts are normally found growing on the skins of fruits like grapes and apples, from which they derive their food supplies. Our immediate problem is to remove the oxygen from the glucose solution and yeast.

1. You can remove dissolved oxygen from glucose solution by heating it for a minute, and then cooling it without shaking. Now put in some yeast; the supply of oxygen from the air can be cut off by pouring one centimetre layer of liquid paraffin on to the mixture.
2. If you wish to check that the oxygen has been removed from the mixture, add a few drops of diazine green (Janus Green B) solution to the yeast suspension before you pour the liquid paraffin (wax) over it. This blue dye turns pink when oxygen is in short supply around it.
3. Arrange for any gas produced by the yeast to escape through a wash bottle containing bicarbonate/indicator solution (or lime water).

We have not described any control experiments try working them out for yourself. You may prefer to carry out the 'carbon dioxide production' part of the experiment on a smaller scale, using test tubes. If you do, then warm them to about 37° C in order to speed up the test.

- *What happens when a baker prepares a dough by mixing yeast in it?*

Fermentation

Let us recall maida dough and yeast powder activity that you performed in class VIII in the chapter 'The story of microorganisms'. Why volume of the dough has increased? Which gas released in that reaction?

If yeast and sugar solution are left to stand without oxygen for some days, they develop a characteristic smell, caused by production of new compound called ethanol, which has been manufactured by the yeast from

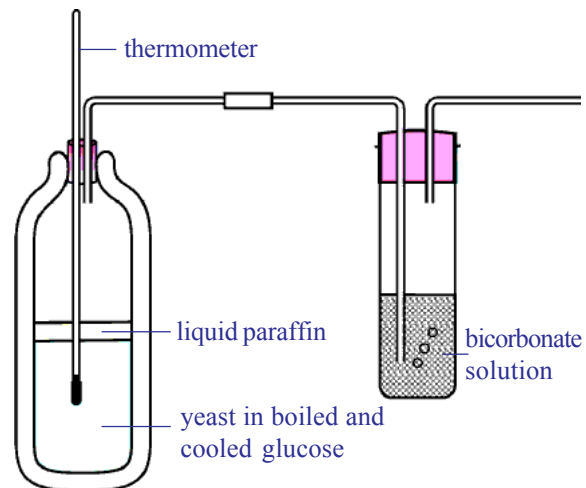


fig-12: Testing for production of heat and CO₂ under anaerobic respiration

the sugar. The same type of smell you can notice from preserved idly, dosa dough at your home. But not in refrigerator. The ethanol can be separated from the yeast-glucose mixture by the process of fractional distillation since ethanol boils at a lower temperature (70°C) than the sugar solution. Collect information about fractional distillation with the help your teacher.

Quite like aerobic respiration this is a process of producing energy when there is no supply of oxygen.

- *Respiration is an energy releasing pathway, do you agree? Justify your answer.*

Respiration versus combustion

Lavoisier around the late 18th century, through a series of carefully performed experiments, came to the opinion that respiration was a process like combustion. He wrote in a compilation in 1783, “respiration is a combustion process. It is a very slow process and here oxygen is not only combines with carbon but also with hydrogen.” Robinson also stated that respiration is a type of combustion and combustion is the source of heat in animals.

Activity-2

Observing changes during combustion of sugar

Arrange apparatus as shown in the figure and heat it over a flame. Does it melt? What happen if you heat for somemore time?

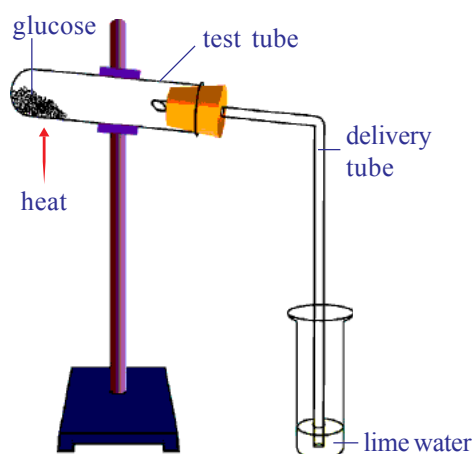


fig-13: CO_2 - a by product of energy release

When glucose burns, carbon dioxide and water are produced and energy is released as heat.

We know that combustion of glucose gives us carbon dioxide, water and energy while from the respiratory equation we get the same products. But essentially the processes must differ due to following reasons.

1. Glucose must be burnt at high temperature in the laboratory to liberate energy, if it happened in our cells, all cells would be burnt.
2. Once glucose starts burning we can't stop the process easily, but living cells are able to exercise control over the sort of burning of glucose in the presence of oxygen.

3. Water normally stops combustion from taking place while cells contain a lot of water and respiration still goes on.

What can you conclude from this?

Heat production by living organisms

Heat production was a feature of burning glucose or sugar as you observed earlier. Living animals and plants usually produce energy in the form of heat.

We feel warm when we wear sweater in winter season. We know that sweater prevents loss of heat energy produced by the body. Does this suggest any way in which our bodies lose heat to the surroundings?

- *What are the other ways in which our body loses heat?*

Heat is constantly lost from the body surface thus it must be continuously generated within our bodies to replace what has been lost to keep the body temperature constant.

- *Is the rate of heat production always the same?*

In the course of vigorous activity, a greater amount of heat is generated. We know that we feel hot after some form of strenuous exercise such as running.

During cellular respiration energy is released. Some part of energy is stored in the form of ATP. Some part of energy is utilised in our day to day life activities. And the excess amount of energy is released in the form of heat. But in case of vigorous activity like running we need more amount of energy. For this the rate of respiration is increased. So heat is also released in excess quantity. That's why we feel warm. If the oxygen is not sufficient during vigorous exercise muscles start anaerobic respiration. Hence, lactic acid is formed. We know that accumulation of lactic acid causes pain in muscle. We reach normal position after some rest. Deep breath helps us to restore energy in our body. Refer in annexure about Yoga Asanas.

Evolution in gases exchanging system

Exchange of gases is a common life process in all living organisms, but it is not same in all. Single celled organisms Amoeba or multicellular organisms like Hydra and Planarians obtain oxygen and expel carbon dioxide directly from the body by the process of diffusion. In other multicellular animals special organs are evolved. Animals either terrestrial or aquatic adopted to different types of respiration and possess different types of respiratory organs mostly depending on the habitat in which they live. Body size, availability of water and the type of their circulatory system

are some of the reasons for the animals to develop different types of respiratory organs.

We will see tracheal respiratory system in insects like cockroach, grasshopper etc. Tracheal respiratory system consists of series of tubes called trachea. This is divided into fine branches called tracheoles which carry air directly to the cells in the tissues.

Some aquatic animals like fishes have developed special organs for respiration which are known as gills or branchiae. Blood supplied to gills through capillaries which have thin walls which gases are exchanged. This is called branchial respiration. Fish keeps its mouth open and lowers the floor of the oral cavity. As a result water from outside will be drawn into the oral cavity. Now the mouth is closed and the floor of the oral cavity is raised. Water is pushed into the pharynx and is forced to gill pouches through internal branchial apertures. Gill lamellae are bathed with water and gas exchange takes place.

Respiration through skin is called cutaneous respiration. Frog an amphibian can respire through cutaneous and pulmonary respiration processes. Terrestrial animals like reptiles, birds and mammals, respire through lungs. Ask your teacher how crocodiles and dolphins respire?

Respiration in Plants

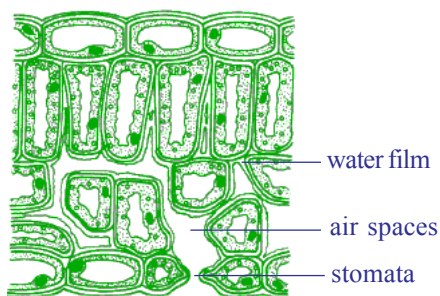


fig-14: Leaf as a respiratory organ

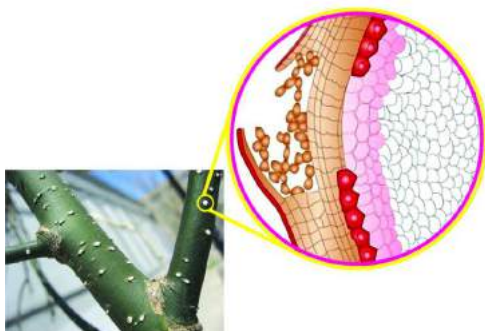


fig-15: Lenticells on stem

You already know about stomata in leaf where gaseous exchange takes place in plants. There are other areas on the plant body as well through which gaseous exchange take place like surface of roots, lenticels on stem etc. (Fig showing stomata and lenticels). Some plants have specialized structures like breathing roots of mangrove plants as well as the tissue in orchids that produces oxygen is also required by plants to produce energy and carbon dioxide is released. But CO_2 is required elsewhere in the plants try to identify them.

Conduction within the plant

The stomatal openings lead to a series of spaces between the cells inside the plant. Which form a continuous network all over the plant. The spaces are very large in the leaves, much smaller in other parts of the plant. The air spaces are lined with water where the oxygen is dissolved in this and passes

through the porous cell walls into the cytoplasm. Here the sugar is broken down into carbon dioxide and water with the liberation of the energy. The carbon dioxide passes out into the air spaces by a similar method.

The whole system works by diffusion; as the oxygen is used up by the cells a gradient develops between the cells and the air in the spaces. Similarly between the air in the spaces and the air outside the stomata and lenticels, so oxygen passes in. In the same way, as more carbon dioxide is released by the cells a gradient occurs in the reverse direction and it passes out to the environment.

Aeration of roots

Most plants can aerate their roots by taking in the oxygen through the lenticels or through the surface of their root hairs (as their walls are very thin). They obtain oxygen from the air spaces existing between the soil particles. But, plants which have their roots in very wet places, such as ponds or marshes, are unable to obtain oxygen. They are adapted to these water-logged conditions by having much larger air spaces which connect the stems with the roots, making diffusion from the upper parts much more efficient.



fig-16: Aerial roots

The most usual adaptation is to have a hollow stem. Next time when you are by a pond or marsh cut the stems of some of the plants which are growing there and see how many are hollow compared with a similar number of species of plants growing in normal soil. The problem of air transport is more difficult for trees and not many survive with their roots permanently in water. An exception is the mangrove tree of the tropics which forms aerial roots above the soil surface and takes in oxygen through these roots.

To know more about respiration in plants we should perform the following activities.

Activity-3

Take a handful of moong or bajra seeds. Soak the seeds in water a day before to perform your experiment. Keep these soaked seeds in a cloth pouch and tie with a string tightly. Keep the cloth pouch in a corner of your class room. Next day collect the sprouts/germinated seeds from the pouch, keep it in a glass bottle/plastic bottle(around 200 ml capacity). Take a small injection bottle, fill three fourth of the bottle

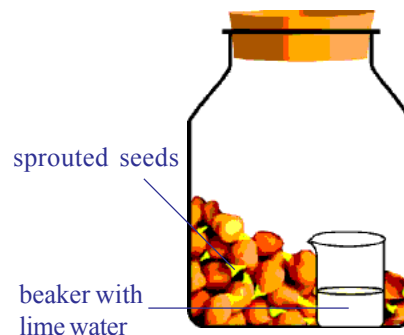


fig-17: Evolved CO₂ in respiration

with lime water. Tie a thread to the mouth of the small bottle; insert it in the bottle carefully and let it hang by the thread. Close the plastic bottle tightly. Make a similar set with unsprouted seeds. Keep this set undisturbed for one or two days. During this time observe the color of lime water in both the sets. In which set does the color change faster? Why?

Activity-4

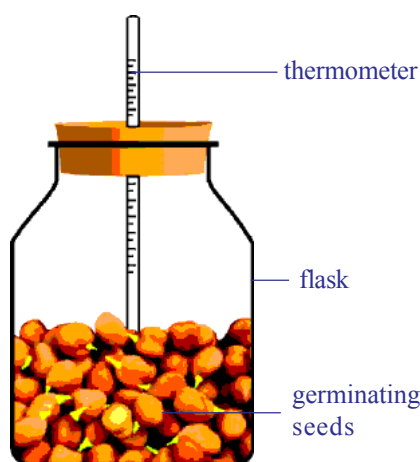


fig-18: Heat evolved during respiration

Take sprouts which were prepared for above activity in a thermos flask. Remove the lid and prepare a cork (with thermocol, or rubber or any other material) through which you can bore a hole to insert a thermometer. Take care that the bulb of the thermometer should dip in the sprouts. Close the flask with this tight fitting cork. Record the temperature every two hours. You are advised to do this for at least 24 hours.

- Make a graph by using your observations.
- *Is there any increase in temperature?*
- *Does the temperature increase steadily or does it abruptly increase at a time of the day?*
- *Where does the heat come from?*

Photosynthesis versus Respiration

Plants carry out photosynthesis, which means that they produce their own food from atmospheric CO_2 using light energy from the sun. This process is a complex series of steps involving the conversion of light energy into chemical energy, which is then used to synthesize sugars from carbon dioxide. This is a process of synthesis or an anabolic process which occurs in the chloroplasts.

The equation below summarizes the photosynthetic process



Once produced, the sugars can then be used for the process of respiration to provide energy to run all life processes.

Respiration as we know is not just the exchange of gasses. It is the process of breakdown of complex food molecules or a catabolic process to produce chemical or potential energy.

This can be summarized by the equation



Photosynthesis and respiration appear to be opposing reactions, but both have very different biochemical pathways and are essential for a plant's metabolism.

Photosynthesis takes place in the chloroplast to produce sugars, starch and other carbohydrates for the plant's metabolic needs. Cellular respiration occurs in mitochondria where these carbohydrates are "burned" to produce chemical energy to function at the cellular level. During day time, the rate of photosynthesis is usually higher than that of respiration while at night it is just reverse in most plants. Temperature, humidity, light intensity etc. seem to affect the ratio of photosynthesis and respiration in plants.



Key words

Aerobic respiration, Anaerobic respiration, Alveoli, Trachea, Bronchi, Bronchioles, Epiglottis, Pyruvate, Anabolic, Catabolic.



What we have learnt

- By "respiratory system" we usually mean the passages that transport air to the lungs and to the microscopic air sacs in them, called alveoli (where gases are exchanged) and vice versa.
- The term 'respiration' refers to the whole chain of processes from the inhalation of air to the use of oxygen in the cells.
- Lavoisier found that the air that we breathe out precipitated lime water while that after heating metal did not. He also found that something even beyond lungs occurred to produce carbon dioxide (he knew it as fixed air) and body heat.
- Air passes from nostrils to nasal cavity to pharynx, larynx, trachea, and bronchi, bronchioles to alveoli and blood and back through the same route.
- Gas exchange in the lungs takes place in the tiny air sacs called alveoli in the lungs. The lungs have millions of alveoli and each lies in contact with capillaries. Oxygen and carbon dioxide diffuse readily across a combination of the alveolar wall, the capillary wall and a thin layer that lies between them.
- Diaphragm is a muscular tissue present at the floor of the chest cavity.
- During inspiration (inhalation) the volume of the chest cavity is increased as the diaphragm contracts and dome flattens out, its internal pressure decreases and the air from the outside rushes into the lungs.

sides, remove some of the tiny particles of dirt in the air. In addition, as the inhaled air passes through the nasal cavity, its temperature is brought close to that of the body, and it takes up water vapor so that it becomes more moist than before.

- Pharynx is a common passage of digestive and respiratory system. Epiglottis, a flap like muscular valve controls movement of air and food towards their respective passages.
- Larynx is a stiff box like structure containing our vocal cords. When air passes out of the lungs and over the vocal cords, it causes them to vibrate. This produces sounds on the basis of our speech, song etc.
- Trachea is the wind pipe channeling air to lungs.
- At its lower end the trachea or the wind pipe divides into two bronchi-one leading to each lung.
- The bronchi divide into smaller and smaller branches called bronchioles.
- These finally terminate in clusters of air sacs called alveolus in the lungs which are very small and numerous. Gaseous exchange takes place here as blood capillaries take up oxygen and expel carbon dioxide here.
- Aerobic respiration occurs in adequate supply of air producing a lot of energy, carbon dioxide and water.
- Anaerobic respiration and fermentation occurs in inadequate supply or absence of oxygen to produce energy.
- Cells may resort to the breakdown of 3 carbon compound, pyruvate, aerobically or anaerobically depending upon the availability of oxygen. Usually in multicellular organisms cells fail to carry on the process of anaerobic respiration for long.
- Respiration is not essentially a process of combustion differ due to following reasons
 - Glucose must be burnt at high temperature in the laboratory to liberate energy, if it happened in our cells, all cells would be burnt.
 - Once glucose starts burning we can't stop the process easily, but living cells are able to exercise control over the sort of burning of glucose in the presence of oxygen.
 - Water normally stops combustion from taking place while cells contain a lot of water and respiration still goes on.
- Photosynthesis and respiration appear to be opposing reactions, but both have very different biochemical pathways and are essential for a plant's metabolism.
- Photosynthesis takes place in the chloroplast to produce sugars, starches and other carbohydrates for the plant's metabolic needs.
- Cellular respiration occurs in mitochondria where mainly these carbohydrates are "burned" to produce chemical energy to do work at the cellular level.



Improve your learning

- Distinguish between (AS1)
 - inspiration and expiration
 - aerobic and anaerobic respiration
 - respiration and combustion
 - photosynthesis and respiration
- State two similarities between aerobic and anaerobic respiration.(AS1)
- Food sometimes enters the wind pipe and causes choking. How does it happen?(AS1)
- Why does the rate of breathing increase while walking uphill at a normal pace in the mountains? Give two reasons.(AS1)
- Air leaves the tiny sacs in the lungs to pass into capillaries. What modification is needed in the statement?(AS1)
- Plants photosynthesize during daytime and respire during the night. Do you agree to this statement? Why? Why not?(AS1)
- Why does a deep sea diver carry oxygen cylinder on her back?(AS1)
- How are alveoli designed to maximize the exchange of gases?(AS1)
- Where will the release of energy from glucose in respiration take place? Mala writes lungs while Jiya writes muscles. Who is correct and why?(AS1)
- What is the role of epiglottis and diaphragm in respiration?(AS1)
- How gases exchange takes place at blood level?(AS1)
- Explain the mechanism of gasses exchange at branchiole level.(AS1)
- After a vigorous exercise or work we feel pain muscles. What is the relationship between pain and respiration?(AS1)
- Raju said stem also respire along with leaves in plants. Can you support this statement? Give your reasons.(AS1)
- What happen if diaphragm is not there in the body?(AS2)
- If you have a chance to meet pulmonologist what questions your going to clarify about pulmonary respiration?(AS2)
- What procedure you followed to understand anaerobic respiration in your school laboratory?(AS3)
- What are your observations in combustion of sugar activity?(AS3)
- Collect information about cutaneous respiration in frog. Prepare a note and display them in your classroom.(AS4)
- Collect information about respiratory diseases (because of pollution, tobacco) and discuss with your classmates.(AS4)
- What is the pathway taken by air in the respiratory system? Illustrate with a labelled diagram.(AS5)
- Draw a block diagram showing events in respiration. Write what you understood about cellular respiration.(AS5)

23. How you appreciate the mechanism of respiration in our body?(AS6)
24. Prepare an article on enaerobic respiration to present school symposium.(AS7)
25. Prepare a cartoon on discussion between haemoglobin and chlorophyll about respiration.(AS7)

Fill in the blanks

1. Exhaled air contains _____ and _____.
2. A flap like muscular valve controls movement of air and food is _____.
3. Energy currency of the cell is called _____.
4. Lenticells are the respiratory organs exists in _____ part of plant.
5. Mangroove trees respire with their _____.

Choose the correct answer

1. We will find vocal cords in ()
 a) larynx b) pharynx c) nasal cavity d) trachea
2. Cluster of air sacs in lungs are called ()
 a) alveolus b) bronchi c) braonchioles d) air spaces
3. Which of the following is correct ()
 a) the diaphragm contracts - volume of chest cavity increased
 b) the diaphragm contracts - volume of chest cavity decreased
 c) the diaphragm expands - volume of chest cavity increased
 d) the diaphragm expands - volume of chest cavity decreased
4. Respiration is a catabolic process because of ()
 a) breakdown of complex food molecules b) conversion of light energy
 c) synthesis of chemical energy d) energy storage
5. Energy is stored in ()
 a) nucleus b) mitochondria c) ribosomes d) cell wall



Annexure

Pranayama - The art of breathing

It is wonder to know that only human beings have to learn how to breath. Our lungs are devided into lobes. At each breath we will inhale or exhale only 500ml of air. Where as our lung capacity is approximately 5800ml. So most of the time breathing takes place in the upper lobes only. This means we are not using our lungs to their fullest capacity. Even after complete expiration approximately 1200ml of air remains in our lungs. So we can make use of 4600ml of lung capacity for breathing.



The indian ayurvedic physician. Patanjali developed a scientific breathing practice called *Yogabyasa*. Maharshi Patanjali proposed a theory called Astanga yoga. He was introduced 195 yogic principles in eight divisions. 1. Yama (Social disipline), 2. Niyama (Individual disipline), 3. Asana (Body posture), 4. Pranayama (Expansion of vital energy), 5. Prathyahara (With drawal of senses), 6. Dharana (Consontration), 7. Dhyana (Meditation), 8. Samadi (Self rialisation).

The art of breathing in *Yogabyasa* is called *Pranayama* prana means gas, ayama means journey. In Pranayama practice air is allowed to enter three lobes of lungs inorder to increase the amount of oxygen to defuse into blood. Deep breaths in Pranayama helps us to reduce breathings per minute form 20-22 to 15. Because of these deep breaths more amount of oxygen available to brain and tissues of the body will be more active. It is very important to practice Pranayama regularly to make our life healthy and active. All people irrespective of age and sex should practice Pranayama under the guidance of well trained Yoga Teacher to improve the working capacity of lungs.