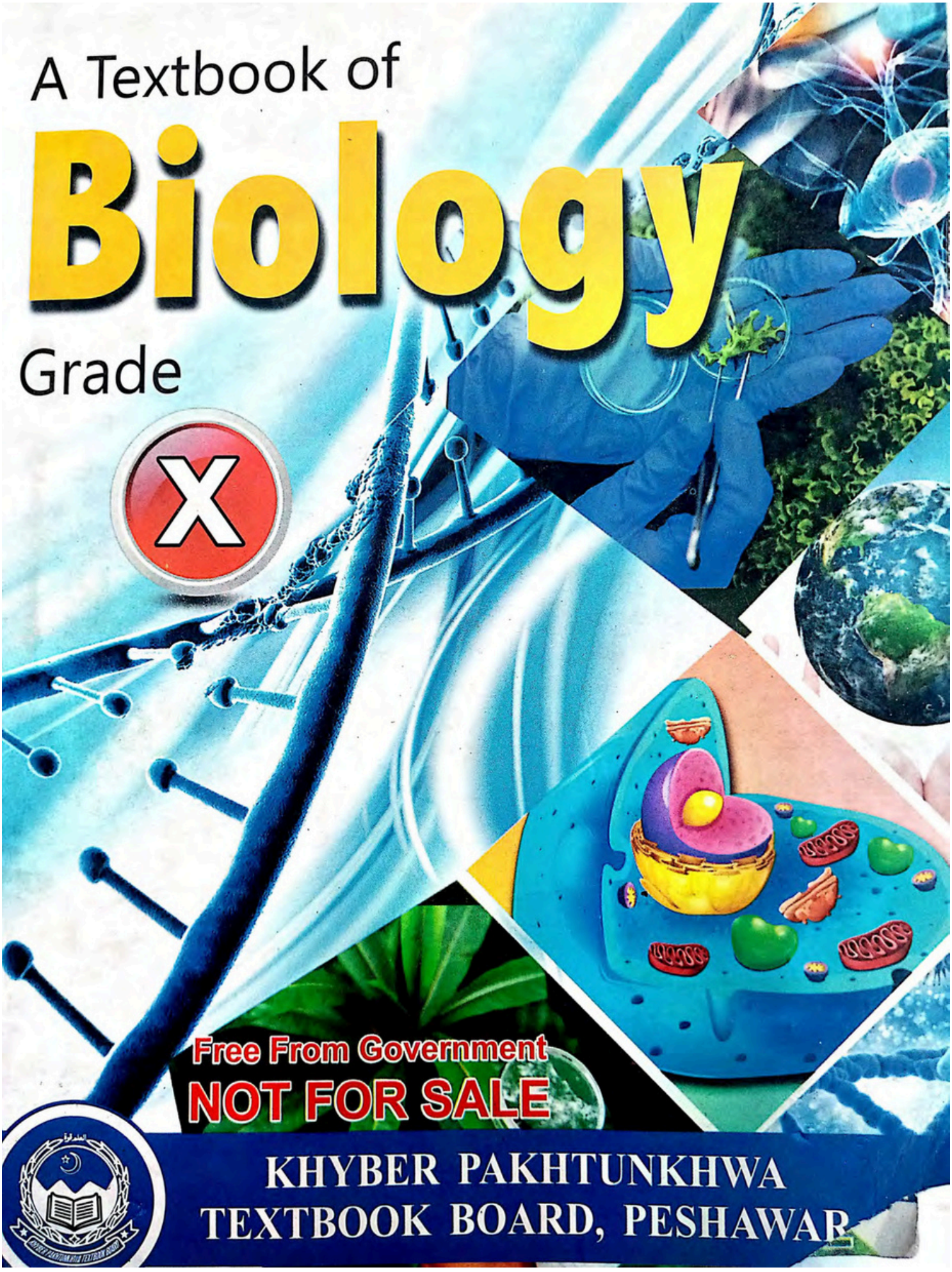
A Textbook of

Biology

Grade

X



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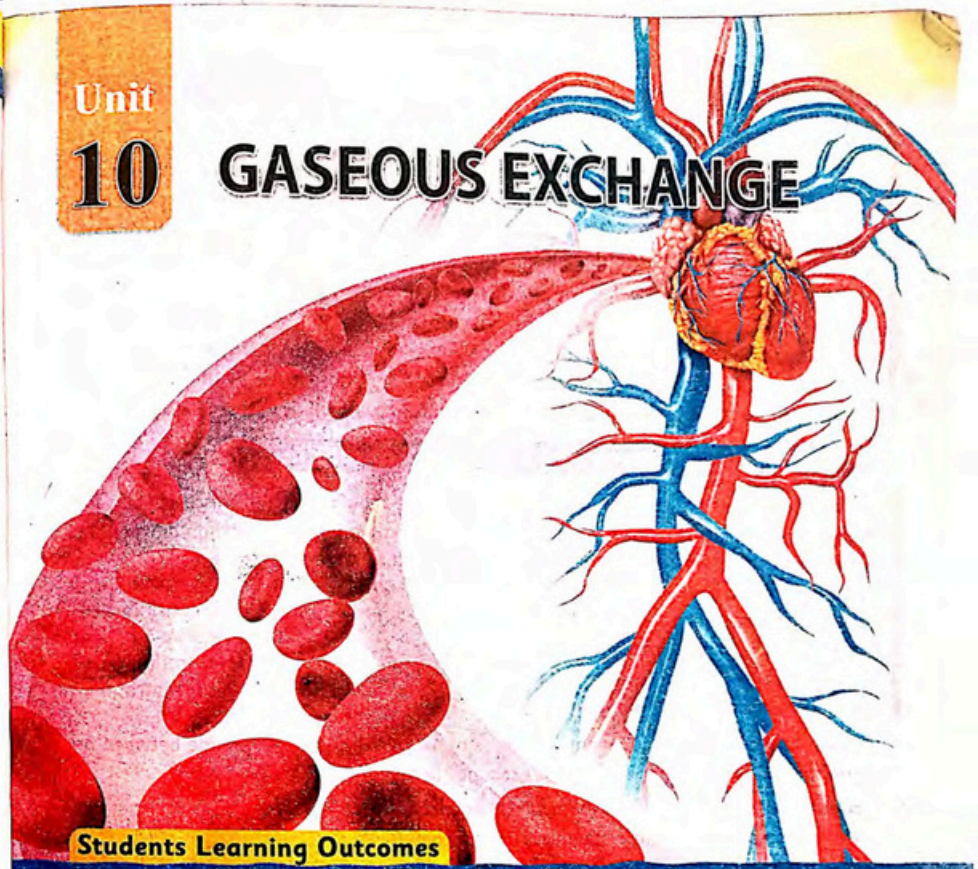
TEXTBOOK BOARD, PESHAWAR

CONTENTS

Unit 10

GASEOUS EXCHANGE



Students Learning Outcomes

The students will be able to:

- Differentiate among respiration, gas exchange and breathing.
- Describe the process of gaseous exchange in plants by comparing photosynthesis and respiration.
- Describe the role of the parts of the air passageway and of the lungs.
- Describe the mechanism of breathing in term of movements of ribs and diaphragm.
- State the rate of breathing at rest and after exercise.
- Differentiate between the composition of inspired and expired air.
- Describe briefly diseases related to the respiratory system like bronchitis, emphysema, pneumonia, asthma, and lung cancer.
- Describe the biological consequences of smoking in relation to the lungs and circulatory system.

Introduction

All living organisms need energy to perform their life sustaining activities. We already know that the ultimate source of energy for life is sunlight. Photosynthetic organisms capture sunlight (recall photosynthesis from Unit 7) and prepare energy rich organic molecules (food) by utilising carbon dioxide and water. Oxygen is released as a bye product of photosynthesis. Respiration takes place in all organisms. During respiration they utilise oxygen to break down organic molecules into carbon dioxide and water to release energy (recall respiration from Unit 7). In this unit we will study how organism give and take the gases (carbon dioxide and oxygen) which are needed for photosynthesis and respiration. We will also study the human respiratory system and its common diseases in detail.

10.1 Respiration, Gaseous Exchange and Breathing

Respiration is an energy releasing process at the cellular level. In this process, food molecules (e.g. glucose) are broken down into simpler compounds like carbon dioxide and water with the release of energy. We know that for aerobic respiration, oxygen is required for the complete oxidation of food molecules while CO_2 is released as a by product. It means that all organisms need to take O_2 from the environment (air or water) for respiration. They also need to release CO_2 into the environment.

Recalling

Diffusion is a process in which molecules move from a region of higher concentration to a region of lower concentration.

Gaseous exchange means the exchange of oxygen and carbon dioxide between an organism and its environment. Gaseous exchange occurs by diffusion.

Breathing is the physical process in which animals move air into and out of their body. It is done to get oxygen from air and to release carbon dioxide in it. In higher animals, lungs are the organs of breathing. In breathing, fresh air is made available to the respiratory surface of the lung for gaseous exchange. As fresh air has a higher concentration of oxygen than is present in the blood, therefore, it diffuses into the blood. At the same time, the concentration of carbon dioxide is higher in the blood, so it is diffuses into the lungs and is expelled out by the process of breathing.

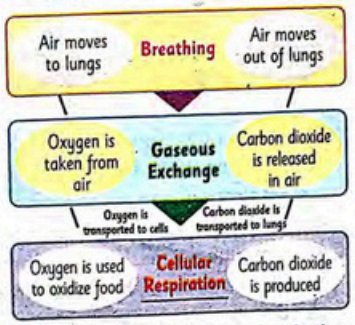


Fig.10.1 Relationship between respiration, gaseous exchange and breathing.

10.2 Gaseous Exchange in Plants

During the daytime, all plant cells are carrying out respiration. The green parts (leaves) of plants are also carrying out photosynthesis. For photosynthesis, the leaves use carbon dioxide which is produced during respiration. They also take carbon dioxide from the environment. For respiration, leaves use oxygen which is produced during photosynthesis. During respiration, they release carbon dioxide which is used in photosynthesis. So, during daytime leaves are taking carbon dioxide from the environment and releasing oxygen in it.

During the night, all cells are carrying out respiration while there is no photosynthesis. So, the cells get oxygen from the environment and release carbon dioxide.

In plants, the gaseous exchange between the body and the environment occurs through the surface. The outer surface of the root, stem and leaves is called the **epidermis**. This layer allows the exchange of gases between the inner cells and the environment. At some parts a thick cuticle is present over the epidermis. It also allows the exchange of gases.

In leaves and young stems, the epidermis has small pores called **stomata**. In these parts, the air moves in and out through the stomata. Inside the body, gaseous exchange occurs between the cells and air. In woody stems, the entire surface is covered by bark. Gaseous exchange cannot occur through bark. The bark contains special pores called **lenticels**, which allow the gaseous exchange with the environment.

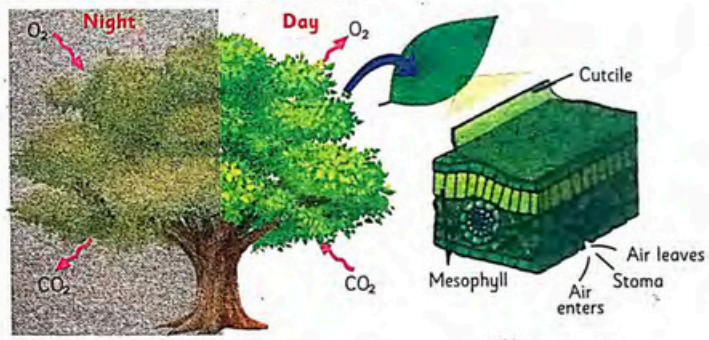


Fig.10.2 (a). Gaseous exchange in plants; (b). Gaseous exchange in a leaf.

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Effects of Tilling

You might have seen the farmers and gardeners tilling the soil. Tilling helps soil drainage and aeration.

It creates air spaces between soil particles. These spaces in turn allow better exchange of gases between roots and the air.

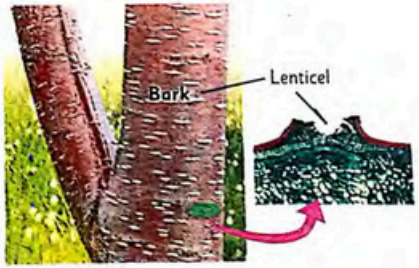

Fig.10.3 Lenticels in a bark

10.3 Gaseous Exchange in Humans

Humans have an efficient respiratory system adopted well for the terrestrial mode of life. This system ensures a smooth exchange of gases between the environment and the human body. This system can be divided into two main components which are: air passageway and lungs.

a). Air Passageway

When air enters the body, it passes through connected tubes to reach the lungs. After gaseous exchange, air moves from the lungs to the outside through the same connected tubes. These connected tubes are collectively called the air passageway. It consists of nostrils and nasal cavities, pharynx, larynx, trachea, bronchi and bronchioles.

Two openings or **external nostrils** lie on the ventral side of the head. They allow the air from the outside into two **nasal cavities**. Here the air is warmed, moistened and dust freed by the hairs and the mucous membrane of the nasal cavity.

For Your Information

We should breathe through the nose and not through the mouth to keep ourselves healthy.

The nasal cavities lead into the **pharynx** which is about a 4.5 inches long muscular passage. It is also lined by the mucous membrane.

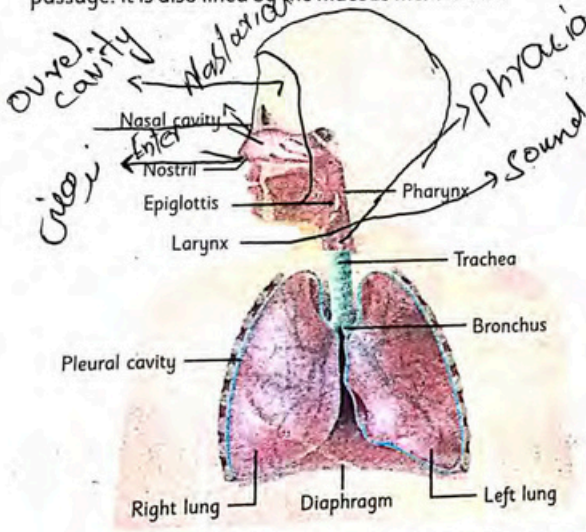

Fig. 10.4 General Outline of the Air Passageway and Lungs

For Your Information

The pharynx contains tonsils and adenoids, which are organs of lymphatic tissue used to trap and filter microorganisms.

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The air moves from the pharynx into the **larynx** or voice box. It surrounds the upper part of the trachea. The cavity of the larynx is also lined by the mucous membrane. At the back of the pharynx are two passages, one opens into the esophagus on the dorsal side and the other opens through the **glottis** into the trachea on the ventral side. The glottis is guarded by a lid like structure called the epiglottis.

Tidbit

Why is it advised to breathe through the nose and not through the mouth?

The larynx opens into the **trachea** or wind pipe. It is a tubular structure. It lies ventral to the esophagus and extends to the chest cavity or thorax. The inner surface of the trachea is ciliated and secretes mucus. This helps to filter, moisten and warm the incoming air. The trachea has 16 to 20 C-shaped **cartilaginous rings** which prevent it from collapsing and keep the passage of air open.

Recalling

Transpiration is the loss of water from a plant surface in the form of vapours.

Inside the thorax, the trachea divides into two branches called **bronchi**. Each bronchus enters the lung on its own side. The bronchi also possess the cartilaginous rings but smaller than those of the trachea. Each bronchus, on entering the lungs, divides and sub-divides progressively into smaller bronchi. When the smaller bronchi attain the diameter of one millimeter or less, then they are called **bronchioles**. Bronchioles have no cartilage.

Each bronchiole ends in a duct. The duct opens in a cluster of pouches, which resemble bunches of grapes. Each pouch is microscopic structure and is called **alveolus** (plural: Alveoli). The alveoli are thin-walled and provide the surface for gaseous exchange. Their walls are covered with a network of blood capillaries where gaseous exchange occurs.

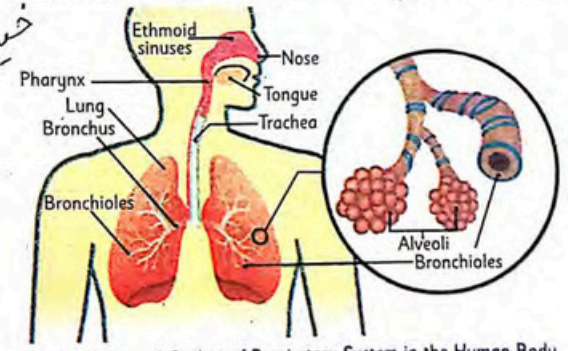


Fig. 10.5 General Outline of Respiratory System in the Human Body.

b). Lungs

The lungs are placed in the chest cavity. From above and sides, lungs are enclosed by the chest wall, while there is a thick muscular structure called the **diaphragm** below the lungs.

Each lung is enclosed in a double membrane called **pleura**. It contains a **pleural fluid**. This fluid makes the movements of the lungs (expansion and contraction) easy.

10.3.1 Mechanism of Breathing

Breathing consists of two phases, the taking in of air called inspiration and letting out of air called expiration. These two phases take place continuously one after the other. Air moves in when the air pressure in the lungs is lower than the pressure outside the body and it moves out when the pressure in the lungs is greater than the atmospheric pressure.

For Your Information

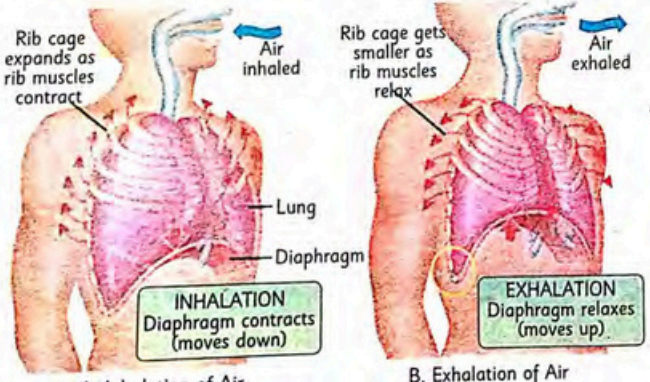
The thorax or chest-cavity is bound by the ribs and muscles at the sides, by the sternum (or chest bone) on the ventral side, by the backbone on the dorsal side and by the diaphragm at the posterior end. The diaphragm is a dome-shaped sheet of skeletal muscles. The muscles in between the ribs are called intercostal muscles.

a) Inspiration: During inspiration, the volume of the chest cavity increases and the pressure in the lungs decreases. It happens due to two reasons.

- The muscles of the diaphragm contract, so it becomes flat instead of its domed position.
- The intercostal muscles present between the ribs, contract. Due to their contraction, the ribcage expands.

Due to these movements the volume of the chest cavity increases and so pressure on the lungs decreases. As a result, the atmospheric air rushes in to the lungs through the air passageway.

b) Expiration: During this process, the muscles of the ribs and the diaphragm relax. The ribcage goes down to its original position whereas the diaphragm becomes dome-shaped. The volume of the chest cavity is decreased. It increases the pressure on the lungs to expel the air out.



A. Inhalation of Air B. Exhalation of Air

Fig.10.6 Mechanism of Breathing in Humans

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10.3.2 Gaseous exchange in Lungs

We know that the alveoli are very thin-walled and have a network of blood capillaries. So they are an excellent site for gaseous exchange. The blood which enters these capillaries has a low oxygen concentration whereas the inhaled air present in the alveoli has a higher oxygen concentration. Therefore, oxygen from the alveoli diffuses into the capillaries. Similarly, the carbon dioxide concentration in the blood present in the capillaries is more than that of the alveoli. Therefore carbon dioxide diffuses out of the blood and into the alveoli.

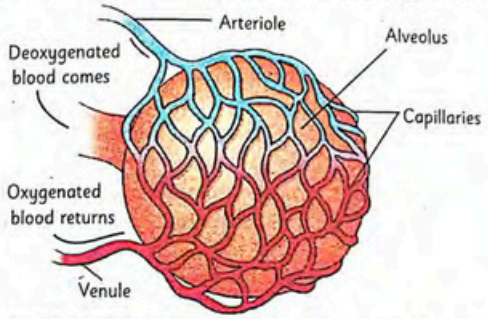

Fig.10.7 Blood circulation in the lungs (around an alveolus)

Tidbit

The size of the lungs of any organism is related to the activities and body form of that organism. Cheetah and elephant have large lungs. What do you think why they have large lung sizes?

10.4 Biological Consequences of Smoking

Smokers have a much higher risk of developing life threatening diseases. The most crucial risk of smoking is cancer in the lungs, kidneys, oral cavity, larynx, breast, bladder, oesophagus, pancreas and stomach.

Tobacco smoke contains over 4,000 different chemicals. Out of these, there are more than 69 known **carcinogens** (cancer causing chemicals). The effects of some chemicals found in cigarettes are given below.

The majority of the particulate matter inhaled by a smoker is composed of **tar**. Within tar, there are many carcinogens. Tar in its solid form also stains the teeth and

Bad Social Effects of Smoking

Breathing of smoke-laden air by nonsmokers is known as **passive smoking**. The majority of the nonsmokers are allergic to cigarette smoke as it produces irritation in their eyes and throats. They can also develop cancer by continuously living in an environment polluted with cigarette smoke. Moreover, people tend do not like the company of cigarette smokers due to the bad smell that comes from their mouth. For this reason there are separate zones in public places such as offices, hotels and restaurants for smokers. The Government has banned smoking at public places and on public transport.

fingers of smokers. It can also stain and damage the lung tissue. Tar also increases the production of mucous and phlegm.

Nicotine has many harmful effects such as increased heart rate and blood pressure, constriction in the blood vessels, damage to the muscles, and disturbance in hormonal systems and metabolism. Nicotine can also increase platelet stickiness in the blood which can cause blockage and cause coronary diseases.

For Your Information

The World Health Organization has called the governments to stop tobacco advertisements to prevent young people to start smoking.

(Reference: Document number: WHO/NMH/PND/13.1)

Carbon monoxide is formed when a cigarette is lit. It combines with red blood cells and prevents oxygen transportation. When carbon monoxide enters the air ways, it stays along with other toxic chemicals contained in cigarette smoke. These toxins cause inflammation, impair lung functions, and increase the risk of lung diseases.

Benzene is a major component of cigarettes. It is a carcinogen and causes blood cancer (leukaemia). Similarly, **formaldehyde** present in cigarettes causes cancers and respiratory, skin and gastrointestinal problems.

Thirty different **metals** are also found in cigarette smoke, many of which have been linked to cancer. A few of the metals found are; Arsenic, Nickel, Cadmium, Chromium, and Lead. **Radioactive compounds** are also found in cigarettes, all of them are carcinogens.

Fig. 10.8 Some of the Contents of a Cigarette

10.4.1 Effect of Exercise on the Rate of Breathing

Under resting condition the rate of breathing is **15-20 times per minute**. During exercise this rate increases instantly. This is due to the fact that more oxygen is required for the oxidation of glucose molecules to get more energy. As a result of this, more CO_2 is produced which thus accumulates in the blood.

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When this blood reaches the brain, the medulla **(breathing centre)** detects more carbon dioxide in the blood and sends nerve impulses to the diaphragm and rib muscles at greater speed. So the speed of contraction and relaxation of these muscles increases. It increases the rate and depth of breathing. During exercise, the breathing rate increases up to **30-40 times per minute**.

Proper Ventilation for Healthy Living

A home ventilation system is used to maintain a healthy living environment by supplying fresh air inside the home while at the same time removing stale and polluted air. Home ventilation also helps to maintain proper humidity levels. With insufficient home ventilation, pollutants can build up and become very concentrated. Proper home ventilation can help reduce allergy and asthma symptoms and help ease other respiratory disorders.

Air components	Inspired Air	Expired Air
Oxygen	21%	16%
Carbon dioxide	0.04%	4%
Water vapours	Variable	Saturated
Temperature	Variable	38 °C

Table 10.1 Composition of Inspired and Expired Air

Activities

Morning walk is traditionally considered beneficial for health. Analyse this sentence in the context of better gaseous exchange.

10.5 Respiratory Disorders

Sometime the normal functioning of the respiratory system is disrupted due to certain factors which can lead to serious respiratory disorders. Some of these disorders are discussed below.

1. Bronchitis

When the lining of the bronchi or bronchioles becomes inflamed or infected, this condition is called bronchitis. Bronchitis reduces the amount of air that can flow and causes formation of mucus in the airways. Bronchitis is caused by viruses, bacteria, and their particles that irritate the bronchial tubes.

Short-term bronchitis resolves without treatment in two weeks. If conditions do not improve, the patient is given medicines. Antibiotics are used when bronchitis is due to bacterial infection. When bronchitis is due to viral infection, anti-viral medicines are used. Coughing helps to remove irritants from the bronchi.

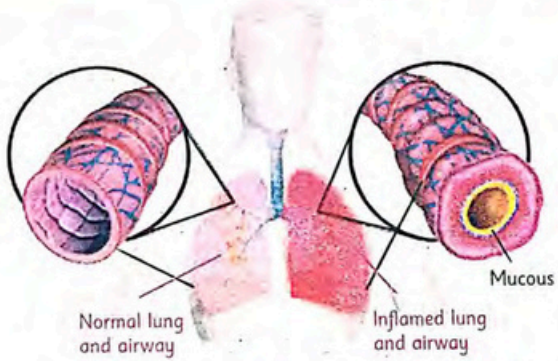

Fig.10.9 Mucous in air ways accumulates and causes bronchitis

2. Emphysema

This is a severe type of lung disease in which due to extensive cough walls of the alveoli are damaged. Environmental pollution can cause emphysema. Cigarette smoke is the most common cause. The effects of emphysema are permanent and irreversible, however if smoking is stopped, further damage might be reduced.

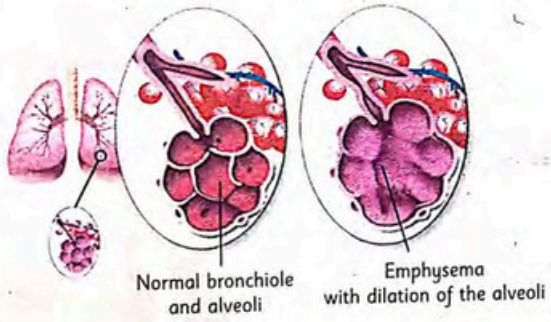

Fig.10.10 Emphysema

3. Pneumonia

Pneumonia is an inflammation in the lungs, due to infection in the alveoli. Due to pneumonia, the alveoli are filled with pus. It is caused by bacteria, viruses or fungi. General symptoms of pneumonia are cold (upper respiratory infection, for example, sneezing sore throat, cough), which

For Your Information

Pneumonia can be transmitted by breathing in air with small droplets. These droplets get into the air when an infected person (having these germs) coughs or sneezes.

are then followed by high fever (sometimes as high as 104 °F) shaking chills, and a cough with sputum production.

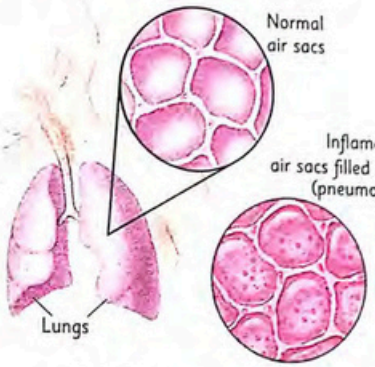

Fig. 10.11 Pneumonia in Human Beings

4. Asthma

Asthma is the inflammation (swelling) in the walls of the bronchi and bronchioles. During an attack of asthma, the walls of the bronchi and bronchioles swell and their inner passage is reduced. It results in shortness of breath. The patient experiences recurring attacks of shortness of breath, wheezing (whistling sound when breathing out), coughing and chest tightness.

The most common reason for asthma is the sensitivity to **allergens** (allergy causing factors e.g. pollens, cold, smoke or other chemicals in the air). When asthma patients inhale such allergens, they may suffer an attack of the symptoms of asthma.

Asthma patients are given short-term treatments. They use medicines which contain chemicals to dilate the bronchioles. Such **"bronchodilators"** are given in the form of inhalers.

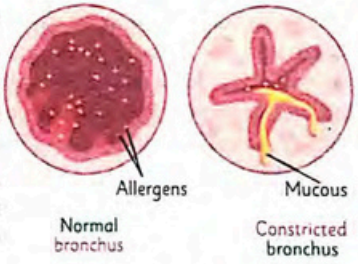

Fig.10.12 Asthma

5. Lung Cancer

Lung cancer is also a respiratory disease, which is more common in men than in women. The most common causes are smoking, industrial carcinogens and air pollution. Symptoms of lung cancer are cough with sputum, breathlessness and pleural chest pain.

The main causes of any cancer are carcinogens (such as those in tobacco smoke), ionising radiation and viral infection. Smoking is the main contributor to lung cancer. Cigarette smoke contains over 69 known carcinogens (cancer causing chemicals).

In its early stages, lung cancer does not show any symptoms. However, in the advance stage when it has fully spread, it is very painful and incurable and becomes fatal. The patient of lung cancer is given one or more treatments, including surgery, chemotherapy, and radiation therapy.

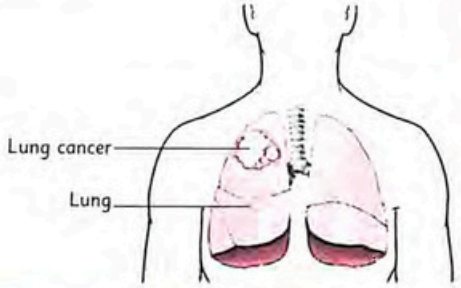

Fig.10.13 Lung cancer

Science, Technology and Society

Artificial Ventilators

Mechanical ventilation is a form of artificial respiration that uses a breathing machine (mechanical ventilator) to assist patients with breathing. It is used when the lungs are not functioning properly. A breathing machine pushes air into the lungs. It includes controls to adjust the rate and size of each breath. It also humidifies, warm and moisten the air going into the lungs. It has special tubing for the air to pass through, and to trap unused moisture from the tubing. The breathing machine ensures that adequate oxygen gets into the blood stream and carbon dioxide is exhaled.

Science, Technology and Society

Dangers of breathing in exhausts of fossil fuels

You might have experienced a very irritating condition while standing right in the middle of a traffic jam. Exhausts of all sorts are attacking your nose and your entire respiratory system. Fossil fuel contains a lot of harmful compounds which are dangerous for our health. For example, fossil fuel exhaust contains carbon monoxide, nitrogen oxide, carbon dioxide, formaldehyde and soot. Those who breathe in such exhaust have an increased risk of lung cancer. There is also a risk of non-cancerous breathing conditions, especially asthma.

Key Points

- For aerobic respiration, oxygen is required for the complete oxidation of food molecules while carbon dioxide is released as a by product.
- Gaseous exchange means the exchange of oxygen and carbon dioxide between an organism and its environment.
- Breathing is the physical process in which animals take air in and out of their body, to get oxygen from this air and to release carbon dioxide in it.
- In plants, the gaseous exchange between the body and the environment occurs through the general surface, stomata and lenticels.
- The air passageway consists of nostrils, nasal cavities, pharynx, larynx, trachea, bronchi and bronchioles.
- Through external nostrils, air enters into two nasal cavities, from where it goes into the pharynx and then into larynx or voice box.
- The larynx opens into the trachea or wind pipe which divides into two bronchi. Each bronchus enters the lungs on its own side and divides and sub-divides into smaller bronchi and finally into bronchioles. Each bronchiole end at a duct which opens in a cluster of alveoli.
- The alveoli are very thin-walled and provide the surface for gaseous exchange. Their walls are covered with a network of blood capillaries where gaseous exchange occurs.
- Each lung is enclosed in a double membrane called pleura which contains a pleural fluid.
- During inspiration, the muscles of the diaphragm contract, so it becomes flat. The intercostal muscles also contract, so the ribcage expands. In this way the volume of chest cavity increases, pressure on the lungs decreases and so the atmospheric air rushes in to the lungs.
- During expiration, the muscles of the ribs and the diaphragm relax. In this way, the volume of the chest cavity is decreased, pressure on lungs is increased and so the air is expelled out. Smokers have a much higher risk of developing life threatening diseases.
- Tobacco smoke contains more than 69 known carcinogens.
- Tobacco contains tar which has many carcinogens. It also stains and damages the lung tissue.
- Nicotine has many harmful effects such as increased heart rate and blood pressure, constriction in the blood vessels, damage to the muscles, disturbance in hormonal system and metabolism.
- Carbon monoxide is formed when a cigarette is lit. It combines with red blood cells and prevents oxygen transportation.
- Benzene (major component of cigarettes) is a carcinogen and causes blood cancer (leukaemia).
- Under resting condition the rate of breathing is 15-20 times per minute. During exercise this rate increases up to 30-40 times per minute.
- When the lining of bronchi or bronchioles becomes inflamed or infected, the condition is called bronchitis.
- In emphysema, the walls of the alveoli are damaged and the patient feels difficulty in breathing (shortness of breath). Pneumonia is an inflammation in the lungs, due to infection in the alveoli.

Exercise

A. Select the correct answer.

1. The correct order of the structures involved in the flow of air in the human body is:
   a. Pharynx — Trachea — Larynx — Bronchi — Bronchioles
   b. Larynx — Pharynx — Trachea — Bronchioles — Bronchi
   c. Trachea — Pharynx — Larynx — Bronchi — Bronchioles
   d. Pharynx — Larynx — Trachea — Bronchi — Bronchioles
2. Food is prevented from entering into the Larynx by:
   a. Glottis b. Epiglottis c. Vocal cards d. Internal nostrils
3. Oxygen from the lungs enter into the blood due to:
   a. Diffusion b. Less affinity of O_2 for air
   c. Higher affinity of CO_2 for air d. Osmosis
4. Which part of the air passageway is also called the windpipe?
   a. Bronchus b. Alveolus c. Larynx d. Trachea
5. In which disease are the walls of the alveoli are broken?
   a. Pneumonia b. Bronchitis c. Emphysema d. Asthma
6. The diaphragm is flat, the ribs move out; this occurs during:
   a. Expiration b. Inspiration c. Lungs expansion d. Breathing
7. The chest cavity is separated from the abdominal cavity by a muscle called:
   a. Larynx b. Trachea c. Bronchus d. Diaphragm
8. Respiration at cellular level is known as:
   a. Breathing b. Ventilation c. Oxidation d. Inhalation
9. High fever, cold and cough with sputum production are symptoms of:
   a. Emphysema b. Asthma c. Pneumonia d. Bronchitis
10. Chemotherapy is a treatment of:
    a. Emphysema b. Bronchitis c. Asthma d. Lung cancer

B. Write short answers to the following questions.

1. Why do plants not need a specialised respiratory system?
2. Differentiate between the terms "respiration" and "breathing".
3. How are the surface area of leaves and lungs important for gaseous exchange?
4. What is the function of the cartilage present in the walls of the trachea and bronchi?

5. What is a diaphragm and what is its role in breathing?
6. What are carcinogens? Name any two carcinogens present in tobacco.
7. Compare the composition of inhaled and exhaled air.

C. Write detailed answers to the following questions:

1. The gaseous exchange in plants is important for photosynthesis and respiration. Explain the types of gases exchanged and its mechanism.
2. Describe the mechanism of breathing in human beings.
3. Draw a diagram of the air passage in the human body and describe the role of different parts in the flow of air through it.
4. What are the causes of respiratory disorders such as bronchitis, pneumonia and lung cancer?

Activities

1. Investigate the effect of light on the net gaseous exchange from a leaf, by using bicarbonate as the indicator.
2. Investigate the breathing rate at rest and after exercise.
3. Find out how much air a person can take into his lungs.
4. Demonstrate through experiment, that carbon dioxide is exhaled during respiration.