UNIT 5 RESPIRATION

Structure

5.1 INTRODUCTION

Respiration is the process which deals with the act of respiring or breathing, the act of taking in and giving out air, the aggregate of those processes by which oxygen is introduced into the system and carbon dioxide is removed. This unit will deal with the mechanism of respiration, the respiratory organs and their functions in the body.

Objectives

After studying this unit, you will be able to:

- illustrate the structure and functions of organs of respiratory system,
- describe the mechanics of respiration, and
- explain the regulation of breathing.

5.2 ORGANS OF THE RESPIRATORY SYSTEM

The respiratory system consists of various organs. They form a clear pathway for the air to enter and leave the lungs. The body needs a constant supply of oxygen from air and wants to dispose off carbon dioxide, produced as a waste product of cell metabolism. The blood transports oxygen from the lungs to the body cells and returns carbon dioxide from the cells to the lungs for excretion.

A number of organs are involved in the most crucial process of respiration. Can you name them? Well, the organs of the respiratory system are:

- the nose and the nasal cavity
- the pharynx
- the larynx
- the trachea
- two bronchi
- the bronchioles and small air passages, and
- two lungs and the pleura.

Figure 5.1 illustrates the major respiratory organs. Please note that the mouth isn't considered a "respiratory organ" because it is also a "digestive organ". All of the respiratory organs can be considered to be either upper or lower respiratory tract organs. So, the nose and mouth fit into the upper respiratory tract category, while the larynx down upto lungs, fit into the lower respiratory tract category.

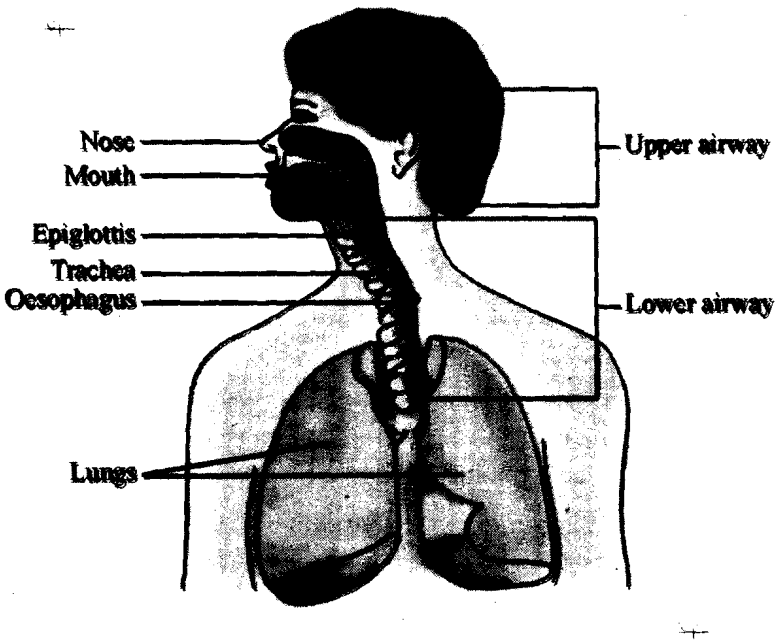

Figure 5.1: Major respiratory organs

Now, let us understand the structure and functions of each of these organs in the respiratory process. We shall begin with the nose and the nasal cavity.

5.2.1 The Nose and the Nasal Cavity

You would agree that one of the most prominent features of the face is the nose. The nose is the first of the respiratory organs through which we respire, i.e. inhale oxygen and exhale carbon dioxide. What are the functions of the nose? We all are familiar with the functions of the nose. The nose:

- acts as a respiratory passage through which the incoming air passes, and
- warms, moistens and filters the air. The air becomes warm as it passes through the nose. It is moistened by contact with the moist mucous. The air gets filtered because the dust particles and other impurities (in form of particulate matter) stick to the mucous. Hence, nose acts as a filter. The cilia of the mucous membrane waft mucous and the dust particles from the nose towards the throat.

The nose has two nostrils, which serve as the first passageways. The nose is lined with a ciliated epithelium. The air that enters our nostrils runs into a larger opening, called the *nasal cavity* (posterior to the nose). To the front of the nasal cavity is the nose, while

the back is continuous with the pharynx. The nasal cavity is important in warming and cleaning the air as it is inhaled. The olfactory epithelium lines this nasal cavity. The *olfactory epithelium* is a specialized epithelial tissue inside the nasal cavity that is involved in smell. The olfactory epithelium, in fact, is *a mucous membrane*, covered in mucus and ciliated at its apical edge. Any material in the air like dust and bacteria, which is not useful for our respiratory system, tends to get stuck in the mucus. Therefore, by having mucus coating, our olfactory epithelium, we are able to filter our air before taking it into the lungs. However, once materials begin to accumulate in the mucus, we have to clean the mucus out. That's where the cilia come in. All of the cilia on our mucous membrane sweep mucus toward our pharynx (throat). The mucus is thus moved along into the pharynx (where we swallow it) and new mucus is secreted to cover the mucus membrane.

So briefly we have looked at the structure and functions of the nose and the nasal cavity. Next, we shall read about the pharynx.

5.2.2 The Pharynx

Pharynx or the *airway of the respiratory system* is at the back of the throat, as can be seen in Figure 5.2, through which air passes when one inhales. It acts as a passageway for air from the nasal cavity and/or the mouth to the lungs via the larynx and the trachea, for food and liquids from the mouth to the esophagus. Let us study about its structure and functions.

Structure

The pharynx is a cone-shaped tubular section that extends from the mouth and the nasal cavities to the larynx, where it becomes continuous with the oesophagus. Hence, it is common to both respiratory system and digestive system. It is approximately 12 to 14 cm in length. The pharynx is divided into three parts as illustrated in Figure 5.2. These include:

- *the nasopharynx:* it is the part of the upper throat, which lies behind the nose. On its lateral wall are the two openings of the auditory tubes which lead from the nasopharynx to the middle ear. It is lined by a ciliated epithelium.
- *the oropharynx:* it is that part of the pharynx which lies above the oesophagus and is continuous with the mouth extending from below the level of the soft palate to the level of second cervical vertebra.
- *the laryngopharynx:* it is the lower part of the pharynx which extends from the oro-pharynx above and continues as the oesophagus below, i.e. from the level of the second to the sixth cervical vertebra.

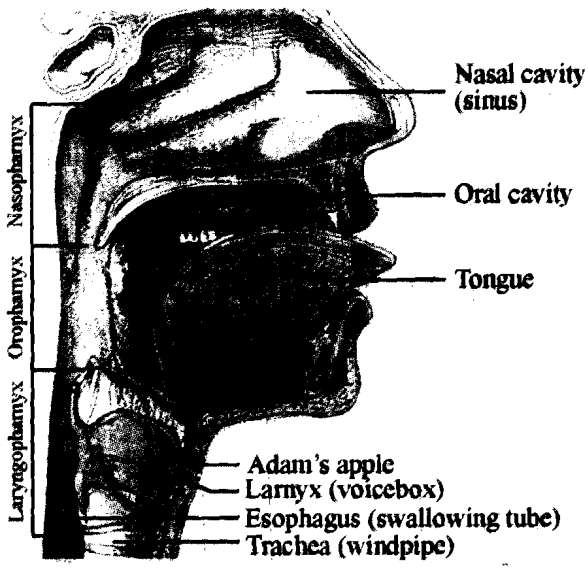

Figure 5.2: The three parts of the pharynx

Both oropharynx and laryngopharynx are lined by stratified squamous epithelium. The pharynx is composed of three layers of tissues. The *mucous membrane* lines the pharynx. The *intermediate layer* consists of fibrous tissue. The *muscle layer* is the outermost layer consisting of muscles known as the constrictor muscles of the pharynx.

What is the role of the pharynx in our body? Let's find out.

Functions

The functions are listed herewith:

- Both air and food pass through the pharynx.
- Air is further warmed up and moistened as it passes through the pharynx.
- As auditory tubes pass between the nasopharynx and middle ear, air passes through these tubes to the middle ear.

From the pharynx we move on to the larynx.

5.2.3 The Larynx

The larynx or *voice box* is an organ in the neck that plays a crucial role in speech and breathing. The larynx is the portion of the trachea that contains the vocal cords i.e. the voice box. It is the primary organ of voice production. The vocal cords are the upper opening into the windpipe (trachea), the passageway to the lungs. This structure also separates the airway from the breathing tube while swallowing by closing.

Until puberty, there is a little difference in the size of the larynx in males and females. But after puberty, there is a considerable enlargement in the males. What is the larynx made up of? Let's get to know its structure.

Structure

The larynx is a cylindrical grouping of cartilage, muscles and soft tissues attached to each other by ligaments and membranes which contains the vocal cords and the structures which help to produce sound. The framework of the larynx is made up of the thyroid cartilage as shown in Figure 5.3. The anterior portion of the thyroid cartilage can be easily felt in thin necks as the "Adam's apple". Try feeling this, in the neck.

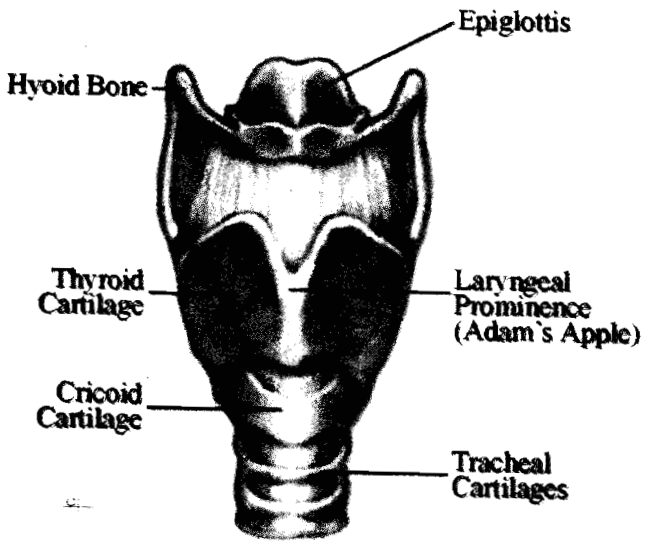

Figure 5.3: Structure of larynx

Coming to the vocal cords, these are the muscular bands covered by a thin layer called *mucosa*. There is a right and left cord, forming a "V" when viewed from above. The vocal cords extend from the root of the tongue to the trachea.

What is the role of larynx? Because of its location, the larynx has many functions to perform. These are listed next:

Functions

The larynx perform the following functions:

- Control of the airflow during breathing. It ensures the passage of air from the pharynx to the trachea.
- Protection of the airway. Air is filtered, moistened and warmed here.
- Production of sound for speech. It ensures voice production due to the presence of vocal cords.
- It facilitates swallowing of food.

Above the larynx, if you look carefully at Figure 5.3, you will see a flexible structure made up of cartilage called the *epiglottis*. When we swallow, the larynx, the epiglottis, and the vocal cords all close as much as possible to prevent food from getting into the lungs.

Next organ in the respiratory system is the *trachea*, about which we shall learn next.

5.2.4 The Trachea

The *trachea* better known as the *wind pipe,* is a continuation of the larynx. It is in the front of your neck and is very hard with tough rings around it. Feel the front of your neck. Can you feel your trachea?

It is the tube that extends from the oral cavity into the chest (the fifth thoracic vertebra), where it branches into 2 major bronchial tubes (right and left bronchi) as can be seen in Figure 5.4. Let us now study about its structure and composition.

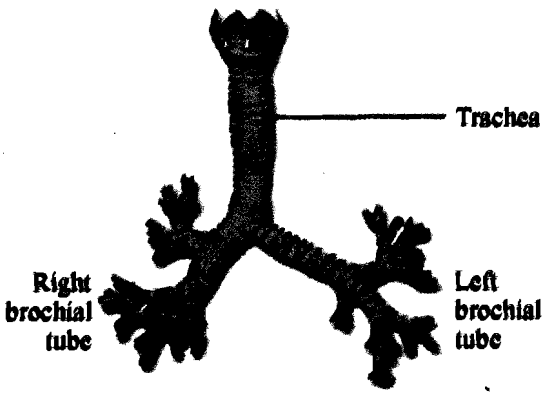

Figure 5.4: The trachea

Structure

Trachea is composed of C-shaped hyaline cartilages (a type of connective tissue) joined together by the muscle tissues that conveys inhaled air from the larynx to the bronchi.

The *outer surface* of the trachea is composed of a fibrous tissue and an elastic tissue. They enclose the cartilages. The *middle layer* is again composed of fibrous tissue lined with areolar tissue. It contains blood vessels, nerves and lymphatics. The *inner lining* is composed of ciliated epithelial cells and goblet cells. Goblet cells are the epithelial cells that secrete mucus.

Like the larynx, the trachea too performs the function of passage of air as highlighted in the functions herewith.

Functions

The trachea:

- ensures the passage of air from the larynx to the bronchi, and
- warms, moistens and filters the air as it passes through the trachea.

We have seen above that the trachea branches into the right and the left bronchi. Let us learn about the bronchi next.

5.2.5 The Bronchi

The trachea, as shown in Figure 5.4, is divided into left and right bronchi at about the level of 5th thoracic vertebra. Let us now study about the characteristic features and functions of the bronchi.

Structure

The bronchi are composed of less well-defined cartilages. The bronchi are lined with a ciliated epithelium.

The *right bronchus* is a wider and shorter tube. It is approximately 2.5 cm in length. After entering the right lung, it divides into three branches, as illustrated in Figure 5.4, one of which passes to each lobe. Each branch is subdivided into numerous small branches. The *left bronchus* is narrower and longer than the right. It is about 5 cm in length. After entering the lung, the left bronchus divides into two branches, one of which goes to each lobe. Each branch is then subdivided into numerous small branches. The further subdivisions of the bronchi will be considered in the next section. We shall look at the function performed by these bronchi, next.

Function

Air passes through the bronchi to reach the bronchioles. This is the main function of bronchi.

5.2.6 The Bronchioles and Smaller Air Passages

Bronchioles are the smaller branches or the sub-division of the bronchi, as illustrated in Figure 5.5, which connect to the alveoli or the air sacs. In simple terms, bronchiole is a tiny branch of air tubes in the lungs. Let us see now what is the structure and composition of these.

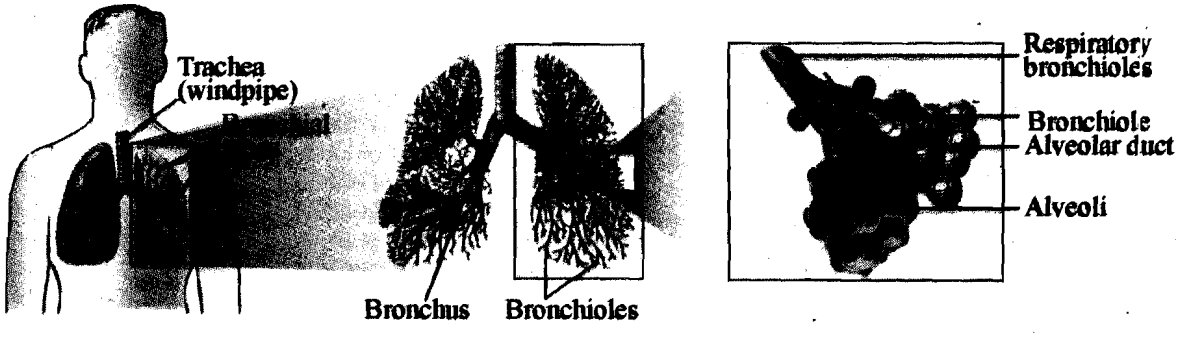

Figure 5.5: The bronchioles and the alveoli

Structure

The bronchioles have a diameter of about 1 mm. The bronchioles contain no cartilage. They are composed of muscle tissue, fibrous tissue and elastic tissue with the innermost

lining of ciliated columnar epithelium. As the tubes become smaller, the columnar epithelial cells are replaced by a single layer of flattened epithelial cells. Fibrous tissue and muscle tissue disappears.

The minute bronchioles, known as the *terminal bronchioles* divide to form *respiratory bronchioles*. These respiratory bronchioles again divide to form *alveolar ducts*. The alveolar ducts open into minute sac-like structure called as *alveoli*, as shown in Figure 5.5, in which the exchange of oxygen and carbon dioxide takes place. In the alveoli, interchange of gases takes place between the air in the alveoli and the blood in the capillaries.

Like the bronchi, the function of the bronchioles is also to aid in air passage.

Next, let us get to know about the lungs.

5.2.7 The Lungs and the Pleura

Lungs are a pair of two spongy organs, as can be seen in Figure 5.5, contained within the chest and are responsible for the respiration and the delivery of oxygen into the bloodstream.

Let us get to know the structure of this important organ.

Structure of lungs

There are two lungs in our body. They are situated in the thoracic cavity separated from each other by the heart. They extend from the root of the neck above to the diaphragm below as can be seen in Figure 5.6. Diaphragm is a dome-shaped muscle that works with our lungs to allow us to inhale (breathe in) and exhale (breathe out) air. Lungs are roughly conical in shape, as can be seen in Figure 5.6.

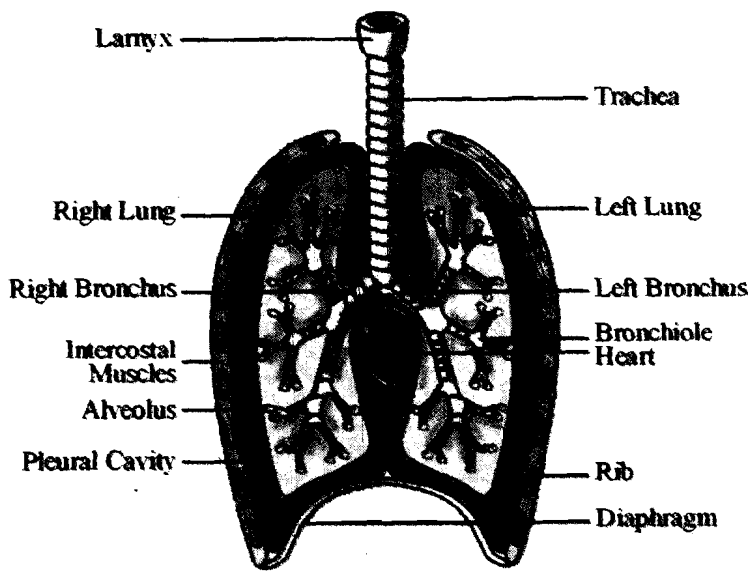

Figure 5.6: The lungs and the pleura

Look at Figure 5.7. You would have noticed that the right lung is divided into three distinct lobes: superior (upper), middle and inferior (lower). The left lung is divided into two lobes: superior (upper) and inferior (lower).

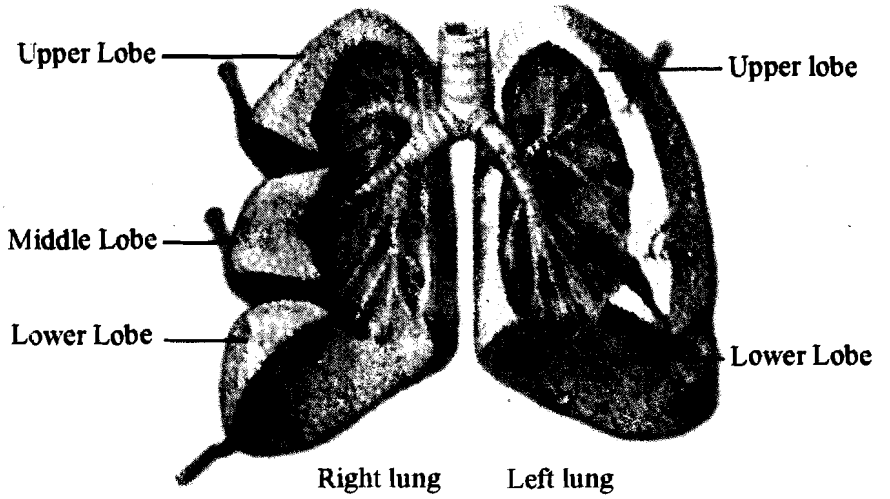

Figure 5.7: Structure of the lungs

The lungs are composed of the bronchi, bronchioles, alveolar ducts and alveoli as you have seen in Figure 5.6. We learnt that in chest cavity, the trachea splits into two small tubes called bronchi. Each bronchus then divides again into still smaller tubes called bronchioles, and finally end in the grapelike clusters of alveolar sacs. There are around 70 million alveoli in each lung. These are the tiny air sacs. It is here that oxygen enters the blood and carbon dioxide leaves it. The alveolar sacs are surrounded by a dense network of pulmonary capillaries, which are minute branches of the pulmonary artery transporting venous blood to the lungs.

The bronchioles, alveolar ducts and alveoli constitute the *lobules* of the lungs. These lobules are separated by areolar elastic tissue. Surrounding the lungs are two thin membranes known as the *pleura*, the space between the two layers is known as the *pleural cavity* as can be seen in Figure 5.6. We shall learn about the pleura in greater details in a little while from now.

In Unit 4, we learnt that the pulmonary artery, that is, a blood vessel delivering oxygen-poor blood from the right ventricle to the lungs, divides into left and right branch. The left branch supplies deoxygenated blood to the left lung and the right branch supplies deoxygenated blood to the right lung. The branches of pulmonary artery are again divided into many branches. They ultimately form a capillary network in the walls of the alveoli. The exchange of gases takes place between the air in the alveoli and blood in the capillaries. The pulmonary capillaries join up to form two main pulmonary veins which convey oxygenated blood to the left atrium of the heart.

Having understood the structure of the lungs, it would not be difficult to visualize the functions of the lungs. The functions are listed next.

Functions of lungs

The main functions of lungs include:

- exchange of gases (O_2 and CO_2) between the alveoli of lungs and capillary network around them, and
- expand to take in air and then contract to expel it.

Now let us get a deeper insight into the structure and function of pleura. Pleura, as seen in Figure 5.6, is *a membrane surrounding the outer surface of the lungs and the inner surface of the chest wall and the diaphragm.* Let us see what it is composed of.

Structure of Pleura

The serous membrane that covers the lung and the wall of the chest cavity to protect and cushion the lungs is called the *pleura.* The *pleura* are composed of flattened epithelial cells. Pleura are composed of two layers of membrane. These are:

- The *parietal pleura:* It lines the walls of the chest cage and covers the upper surface of the diaphragm. It lines the ribs, sternum, costal cartilages and the internal intercostal muscles and covers the superior surface of the diaphragm.
- The *visceral pleura:* It is firmly attached to the lung itself, completely covering its surfaces and passing into the fissures which divides the lung into lobes.

In the normal condition, the parietal pleura and the visceral pleura are in close contact. There is a *potential space* between the two layers termed as *pleural cavity* shown in Figure 5.6. This space is filled with a serous fluid secreted from the epithelial cells of the membrane. This fluid prevents friction between these two layers. Interpleural pressure helps in the expansion of the lungs and is always negative.

With this, we come to an end of our study of the different organs of the respiratory system. Let us take a break here and recapitulate what we have learnt so far.

Check Your Progress Exercise 1

1) List the organs involved in the process of respiration.

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2) Differentiate between the bronchi and bronchioles.

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3) Discuss the functions of the following organs:

a) Nose

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b) Larynx

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c) Lungs

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4) Fill in the blanks:

i) The exchange of gases between blood and lungs is referred to as ..... respiration and between blood and cells is called as..... respiration.

ii) The three parts of pharynx are ....., ... and .....

iii) The cartilages present in the larynx are ....., ... and ..... .

iv) The epithelial cells that secrete mucus are ..... cells.

v) The membrane that covers the lungs and the wall of chest cavity to protect lungs is .....

5.3 THE MECHANICS OF RESPIRATION

The process of respiration can be well understood by studying the mechanics of respiration. This can be explained through a respiratory cycle which consists of three phases:

a) *Inspiratory phase:* In inspiratory phase, there is an inhalation of air. It is an active process because it is the result of muscle contraction. It is partly voluntary and partly involuntary.

b) *Expiratory phase:* In expiratory phase, there is an exhalation of air. It is a passive process because in this phase, the diaphragm and the intercostal muscles relax and the lungs recoil.

c) *Pause:* After expiration, there is a short pause.

Have you ever thought how the respiration cycle is performed? Well, it is performed with the help of the muscles. The muscles involved in respiration include *intercostal muscles* (external and internal intercostal muscles), *the diaphragm* and the *abductor muscles* in the larynx. Let us study how each of these muscles help in respiration. We shall begin with the intercostal muscles.

A) *The intercostal muscles:* Look at Figure 5.6. Can you spot the intercostal muscles? Yes, there are 11 pairs of intercostal muscles. The intercoastal muscles are the muscles between the ribs which contract during inspiration to increase the volume of the chest cavity. They are located in the spaces between the ribs. They are arranged in two layers called the *external intercostal muscles* and the *internal intercostal muscles*.

- The external intercostal muscle fibres extend in a downward and forward direction from the lower border of the rib above to the upper border of the rib below.
- The internal intercostal muscle fibres extend in a downward and backward direction from the lower border of the rib above to the upper border of the rib below. They cross the external intercostal muscle fibres at right angles. The intercostal muscles are stimulated to contract by intercostal nerves.

During inspiration, the intercostal muscles contract. They move upwards and outwards causing enlargement of the thoracic cavity as shown in the Figure 5.8.

During expiration, the volume of thoracic cavity is decreased by relaxation of diaphragm and intercostal muscles which results in increase in thoracic pressure and pressure of lungs. As a result, air is expired from lungs to the atmosphere.

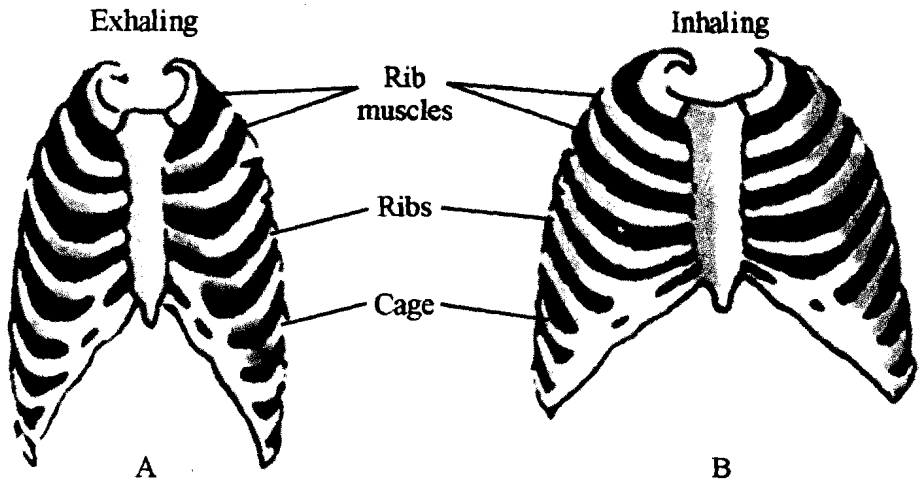

Figure 5.8: The exhaling and inhaling process

Next, let us see what the structure of diaphragm is and what is the role of diaphragm muscles in the respiratory process.

B) *The diaphragm:* The diaphragm is *a muscular membranous partition separating the abdominal and thoracic cavities* (refer to Figure 5.6) and functioning in respiration. It consists of a central tendon from which the muscle fibres radiate.

When the diaphragm contracts, its muscle fibres shorten and the central tendon is pulled downwards. Thus, the thoracic cavity is enlarged in length. The diaphragm is supplied by *phrenic nerves.* Phrenic nerves are *a pair of nerves that arises from cervical spinal roots and passes down the thorax to innervate the diaphragm and control breathing.*

The muscles of the diaphragm and the intercostal muscles contract simultaneously. Thus, the thoracic cavity is enlarged in all directions (antero-posterior and vertical).

Next, let us study about the third set of muscles involved in respiration, i.e., abductor muscles.

C) *Abductor muscles:* Abductor muscle is *a muscle that serves to draw a part out, or from the median line* (as the abductor oculi, which draws the eye outward). Abductor muscles in the larynx contract in the beginning of inspiration, pulling the vocal cords apart. The epiglottis is opened. Epiglottis, as you already know, is *the vocal apparatus of the larynx*, the true vocal folds and the space between them where the voice tone is generated. But during the stage of swallowing, contraction of the abductor muscles closes the epiglottis and prevents the aspiration of food into the lungs.

So you can visualize how important these three muscles, described above, are in the process of respiration. The three muscles, together, help in the respiration process. Next, let us study what are the changes that take place in the lungs during the process of respiration.

Changes in lungs during respiration: In inspiration (when we breathe in air), the thoracic cavity (i.e. the cavity in the vertebrate body enclosed by the ribs between the diaphragm and the neck and containing the lungs and heart) is increased by the simultaneous contraction of intercostal muscles and the diaphragm.

The parietal pleura (the part of pleura attached to the inner wall of the thorax and to the diaphragm) moves with the walls of the thorax and the diaphragm. The visceral pleura (the part of pleura attached to the lungs) follows the parietal pleura. This reduces the pressure in the pleural cavity to a level considerably lower than the atmospheric pressure. The lungs are stretched and pressure within the alveoli is reduced. This causes the air to come to the lungs in an attempt to equalize the atmospheric and alveolar air pressure.

During expiration (when we breathe out), when the diaphragm and the intercostal muscles relax, the thoracic cavity is reduced in size. The lungs recoil and expiration occurs.

The discussion above focussed on the mechanics of breathing. Do you know what is the normal rate of breathing in adults ? Read the next section and find out.

The rate and depth of breathing: Do you know what the normal rate of breathing in adults is and what are the factors on which it depends? Well, the normal rate of respiration in adults is 14 -18 per minute. The rate and depth of breathing vary depending upon the health, physical activity and emotional state of the individual. The amount of air which enters or leaves the lungs varies in association with the changes in the depth of respiration.

In normal breathing, the intercostal muscles and the diaphragm are involved, but in deep breathing, *accessory muscles* of respiration are involved. These muscles include *sterno-mastoid*, the *pectoralis major* (a skeletal muscle that adducts and rotates the arm) and the *platysma* (either of the two broad muscles located on the either side of the neck and innervated by the facial nerve, it extends from the lower jaw to clavicle and is involved in the movement of the mouth and jaw). Contraction of these muscles increases the capacity of the thoracic cavity.

In this section, we have learnt about the mechanics of respiration. We have seen how the air passes in and then exhaled out. During this process, there is volume of air in the lungs, what we call *pulmonary volumes*. Let us read more about this concept and the terminology used in this context.

5.4 PULMONARY VOLUMES

Pulmonary volumes are *the volume of gases in lungs under different conditions of respiration.* There are different terms associated with each of these conditions. Let us get to know them.

- *Tidal Volume (TV):* It is the volume of air that is taken in or given out during quiet breathing. The volume is about 500 ml.
- *Inspiratory Reserve Volume (IRV):* It is the volume of air that can be taken in by forceful inspiration over and above the tidal volume. It varies from 2000 to 3,300 ml.
- *Inspiratory Capacity (IC):* It is the tidal volume and the volume of air taken during maximum inspiratory effort. It is about 3500 ml.
- *Expiratory Reserve Volume (ERV):* It is the volume of air that can be breathed out by forced expiration after normal expiration. It is about 1000 ml.
- *Residual Volume (RV):* It is the volume of air that remains in the lungs after maximal expiration. The average volume is about 1200 ml.
- *Functional Residual Capacity (FRC):* It is the volume of air or gas remaining in the lungs after a normal expiration. It varies from 2500 ml to 3000 ml. It is the sum of the residual volume and expiratory reserve volume.
- *Total Lung Volume (TLV) or Total Lung Capacity (TLC):* It is the volume of air remaining in the lungs after a maximal inspiration. It is the sum of the vital capacity and residual volume. It is about 5000 ml to 6000 ml

- *Vital Capacity (VC):* It is the volume of air that can be breathed out by forced expiration, after taking forced inspiration. It is about 4800 ml in males and 3100 ml in females.
- *Dead Space:* It is the amount of air locked up in the respiratory passages, i.e. the pharynx, trachea and bronchi. The air in these spaces is not available for gaseous exchange. It is called as *anatomical dead space* or in other words, it is the volume of the conducting airways from the external environment (at the nose and mouth) down to the level at which the inspired gas exchanges oxygen and carbon dioxide with pulmonary capillary blood. The volume of the dead space amounts to about 150 ml.

The terms defined above are general terms and you would come across these terms during your study and practice of dietetics.

Next, after learning about the process of respiration, we shall move on to studying about the interchange of gases within the lungs.

5.5 INTERCHANGE OF GASES WITHIN THE LUNGS

The interchange of gases within the lungs takes place between the process of inspiration and expiration. You already know that the act of inhaling, the drawing in of air (or other gases) as in breathing is inspiration. On the other hand, the act or process of breathing out, or forcing air from the lungs through the nose or mouth is expiration.

This exchange of gases occurs between the blood in the capillary network which surrounds the alveoli and the air in the alveoli of lungs. Alveoli, you learnt earlier, are *a small sac-like structural unit of the lung where oxygen is exchanged for carbon dioxide.*

In physical chemistry, you have studied that gases always exert pressure upon the wall of their container and gases always tend to diffuse from a higher partial pressure to a lower partial pressure i.e. down the concentration gradient. Air, as you might already know, is a mixture of gases. Its approximate composition is given in Table 5.1.

Table 5.1: Composition of air

Constituents of Air	Percentage
Oxygen	21
Carbon dioxide	0.04
Nitrogen	78
Other gases	1

Each one of the above mentioned gases found in the air exerts a part of total pressure. This depends upon its concentration in the mixture. The proportion of total pressure provided by each gas is called its *partial pressure*. If the atmospheric pressure at sea level is 760 mm mercury (mm Hg) then,

$$\text{Partial pressure of oxygen } (pO_2) = \frac{21}{100} \times 760 = 160 \text{ mm Hg}$$

$$\text{Partial pressure of carbon dioxide } (pCO_2) = \frac{0.04}{100} \times 760 = 0.3 \text{ mm Hg}$$

and so on.

During inspiration and expiration, the lungs and respiratory passages are always filled up with air. The inspired air is mixed with the air in the lungs and the net result

is that the pO_2 and pCO_2 remain fairly constant. Oxygen diffuses from the alveoli to the blood. Carbon dioxide diffuses from the blood to the alveoli. The blood in the capillaries flows slowly. Oxygen and carbon dioxide get sufficient time to interchange. By this mechanism, oxygen is absorbed in blood and carbon dioxide is removed from the blood. The composition of expired and inspired air is therefore different as highlighted in Table 5.2.

Table 5.2: Approximate composition of expired and inspired air

	Inspired air (%)	Expired air (%)
Oxygen	21	17
Carbon dioxide	0.04	4.404
Nitrogen	78	78
Inert gases	1	1

Next, let us look at the various routes of oxygen and carbon dioxide transport. Let us start with transport of oxygen.

5.5.1 Transport of Oxygen

You may recall reading earlier that oxygen is carried in two ways by the blood – by the plasma and by the red blood cells. Let us learn how.

- *By Plasma:* At a tension of 100 mm Hg, 0.3 ml oxygen is dissolved in every 100 ml of blood. This small volume is negligible as far as the oxygen supply to the tissues is concerned, but is important in determining the oxygen tension gradient from the plasma to the tissues, upon which diffusion depends.
- *By Red Blood Cells:* Oxygen combines with haemoglobin, i.e., the red pigment in red blood cells. It combines with oxygen in the lungs, transports it around the body and releases the oxygen to cells that need it to form oxyhaemoglobin. Haemoglobin, you may already know, is a protein made up of 4 subunits, each of which contains a heme moiety attached to a polypeptide chain. Heme, is a complex made up of a porphyrin and one atom of ferrous iron. Each of the 4 iron atoms can bind reversibly one oxygen molecule. The iron remains in the ferrous form and the resulting combination with oxygen is known as *oxygenation.* The entire process can be represented as:

$$Hb_4 + O_2 \rightarrow Hb_4O_2$$

$$Hb_4O_2 + O_2 \rightarrow Hb_4O_4$$

$$Hb_4O_4 + O_2 \rightarrow Hb_4O_6$$

$$Hb_4O_6 + O_2 \rightarrow Hb_4O_8$$

Hb_4 stands for haemoglobin and O_2 stands for oxygen.

The tension of oxygen in the arterial blood is about 90 -100 mm Hg and oxygen tension in the tissues is less than 40 mm Hg. When the arterial blood passes through the tissues, it carries oxyhaemoglobin. As the oxygen tension in the tissues is much lower, oxygen tension in the arterial blood falls. The oxyhaemoglobin in the red blood cells is exposed to low tension of oxygen, it dissociates and oxygen leaves the blood stream and enters the tissue. The equilibrium of oxyhaemoglobin and nonbonded haemoglobin at various partial pressures can be best studied through a *oxygen dissociation curve,* discussed next.

Oxygen dissociation curve: When different partial pressures of oxygen are plotted against the amount of oxyhaemoglobin formed or dissociated, the *sigmoid curve* is obtained, as shown in Figure 5.9 which is called as *oxygen dissociation curve.*

The oxygen dissociation curve is a graph (Figure 5.9) that shows the percent saturation of haemoglobin at various partial pressures of oxygen. The purpose of an oxygen dissociation curve is to show the equilibrium of oxyhaemoglobin and nonbonded haemoglobin at various partial pressures. At high partial pressures of oxygen, usually in the lungs, haemoglobin binds to oxygen to form oxyhaemoglobin. When the blood is fully saturated, all the erythrocytes are in the form of oxyhaemoglobin. As the erythrocytes travel to tissues deprived of oxygen, the partial pressure of oxygen will decrease. Consequently, the oxyhaemoglobin releases the oxygen to form haemoglobin.

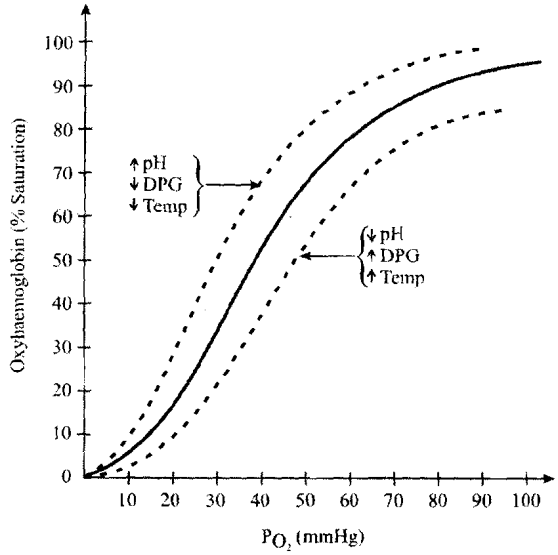

Figure 5.9: Oxygen dissociation curve

The degree of oxygen dissociation depends upon the oxygen tension, carbon dioxide tension, hydrogen ion concentration, strength of haemoglobin solution and temperature.

Oxygen dissociation curve is shifted towards the right during the rise of temperature or increase in the red cells of 2, 3 – diphosphoglycerate (DPG) or the fall of plasma pH, with the dicrease in pH showing decreased affinity of haemoglobin for oxygen as can be seen in Figure 5.9.

Foetal haemoglobin (haemoglobin in the foetus) has got a greater affinity for oxygen than the adult haemoglobin at low pO_2. So, the oxygen dissociation curve of foetal haemoglobin is shifted towards the left.

Now, let us look at the other aspect i.e. the transport of carbon dioxide.

5.5.2 Transport of Carbon Dioxide

Carbon dioxide is carried in the blood in three ways – in solution, in combination with protein, and as bicarbonate. We shall look at each of these mechanisms one by one.

- *In solution*: Carbon dioxide is a more soluble gas than oxygen. Its amount in solution is proportional to the tension. At a tension of 40 mm Hg, 3 ml carbon dioxide dissolves in every 100 ml blood. Carbon dioxide in solution forms carbonic acid, which ionizes at blood pH into hydrogen and bicarbonate ions as shown herewith.

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

- *In combination with protein*: Carbon dioxide forms a neutral carbamino compound with haemoglobin. It combines with the haemoglobin in the red blood cell at a different site from that at which the oxygen combines. The oxygen combines with the iron haem radical, the carbon dioxide combines with the amine group of the protein forming carbamino groups with fully reduced haemoglobin. 8 ml of carbon dioxide is carried as carbamino by 100 ml of blood.

- *As bicarbonate*: The maximum portion of carbon dioxide in the blood is in the form of bicarbonate – sodium bicarbonate in the plasma and potassium bicarbonate in the red blood cells.

As the blood passes through the capillaries, bicarbonate (HCO_3^-) ions diffuse into the plasma. The protein anions cannot cross the cell membrane, sodium and potassium do not diffuse freely. Electrochemical neutrality is maintained by diffusion of chloride into the red cells. This phenomenon is known as *chloride shift.*

In the arterial blood, 3 ml carbon dioxide percent are in solution, 3 ml as carbamino and 42 ml as bicarbonate, making a total 48 ml carbon dioxide in blood. So the blood leaves the lungs and arrives at the tissues carrying 48 ml carbon dioxide per 100 ml of blood at a tension of 40 mm Hg. It leaves the tissue and arrives at the lungs carrying 52 ml carbon dioxide per 100 ml of blood at a tension of 46 mm Hg. The three forms of carbon dioxide are carried by the blood and they interact to form the total *carbon dioxide* (CO_2) *dissociation curve* as shown in Figure 5.10. The *carbon dioxide dissociation curve* is plotted as carbon dioxide absorbed in 100 ml of blood against the partial pressure of carbon dioxide.

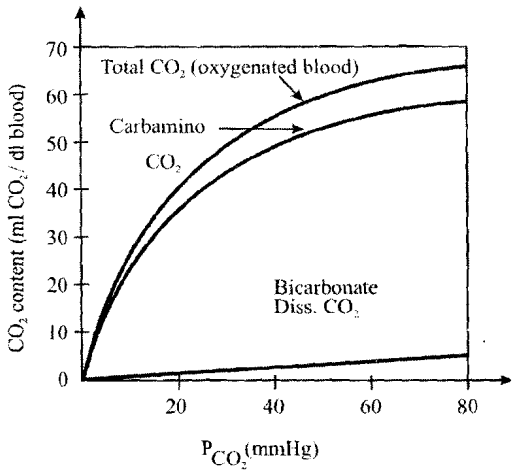

Figure 5.10: Carbon dioxide dissociation curve

As the carbon dioxide tension is increased, the total amount of carbon dioxide taken up by blood also rises. At any given carbon dioxide tension, the reduced blood takes up larger amount of carbon dioxide than oxygenated blood.

Check Your Progress Exercise 2

1) Fill in the blanks:

   i) The muscles involved in the process of respiration are ....., ... and ..... muscle.

   ii) The nerves that control breathing are ..... .

   iii) A muscle that pulls apart the vocal cords is referred to as ....muscle.

   iv) Small sac-like structural unit of the lung where oxygen is exchanged for carbon dioxide is ..... .

   v) Oxygen is transported in our body by .....and ..... .

2) Explain the mechanics of respiration.

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3) List the changes that occur in lungs during respiration.

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4) Explain the following terms:

i) Chloride shift

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ii) Oxygen dissociation curve

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5.6 REGULATION OF RESPIRATION

We have studied the process of respiration above. You would have realized that it is a rhythmic process. The basic rhythm of breathing is controlled by respiratory centers located in the *medulla* and *pons* of the brainstem. Pons is *a neural structure linking the medulla oblongata and the cerebellum with the mid brain* as can be seen in Figure 5.11. Medulla is *a white fatty substance that forms a medullary sheet around the axis cylinder of some nerve fibres*. Within the medulla, a paired group of neurons known as the *inspiratory center* or the dorsal respiratory group, sets the basic rhythm by automatically initiating inspiration. The inspiratory center sends nerve impulses along the phrenic nerve to the diaphragm and along the intercostal nerves to the external intercostal muscles which continue for a period of about 2 seconds. This stimulates the inspiratory muscles to contract, initiating inspiration. The inspiratory center causes the phrenic nerve to stop firing for about 3 seconds, which allows the muscles of respiration to relax. The elastic recoil of the lungs and chest wall leads to expiration.

The rhythmic process of respiration is a well-coordinated and regulated activity. The control of respiration is partly neural and partly chemical. Neural and chemical controls are linked together. Let us study about each of these controls. We shall begin with the neural control or the nervous control over the respiratory process.

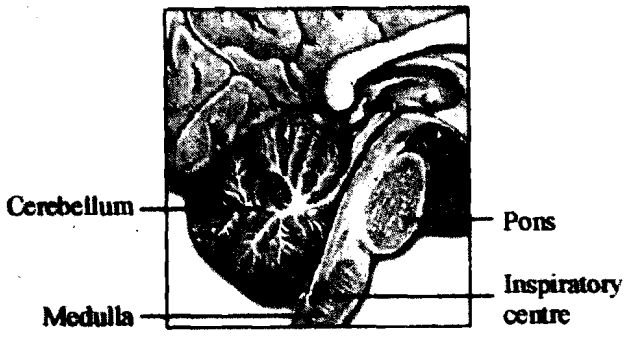

Figure 5.11: Structures of pons and medulla

5.6.1 Neural Control of Respiration

Neural control of respiration originates in the respiratory center, as you learnt above, and signals are transmitted through the *phrenic nerves* to excite the diaphragm. This excitation produces contraction of the diaphragm, expansion of the chest wall and lung, and an increase in airway pressure, flow and volume. Direct monitoring of the phrenic nerve is not possible, but the neural method monitors electrical signals to the diaphragm. These signals represent neural drive to the diaphragm and are a proxy for phrenic nerve activity.

There are two neural mechanisms which control respiration:

1) Voluntary system
2) Automatic system

What are these systems? Let's find out.

1) *Voluntary system:* The centre for the voluntary system is located in the *cerebral motor cortex*, i.e., a part of the brain that is situated in frontal lobe. The cerebral motor cortex in the precentral gyrus consists of a collection of nerve cell bodies. We will learn about this region later in Unit 9. The cerebral motor cortex sends impulses to the respiratory motor neurons via the corticospinal tracts (CST). The CST is a direct link from cerebral cortex to the spinal cord and is involved with the precise and skilled movements of the extremities (hand and foot). It deals with the contraction of individual muscles and is the pathway for the selection of the prime movers for any muscular activity.

2) *Automatic system:* The automatic centres are located in the medulla and the pons. The motor out flow from this system goes to the respiratory motor neurons located in the lateral and ventral portions of the spinal cord, which is a part of the central nervous system extending from the base of the skull through the vertebrae of the spinal column. It is continuous above with the brain stem and is involved in carrying the information from the body's nerves to the brain and signals from the brain to the body.

Now let us get to know more about the centres and their functions in regulating the mechanism of respiration.

- *Medullary centre:* The respiratory centre is a collection of highly specialized cells situated in the medulla oblongata which are essential to normal respirations. There are two groups of neurons – the *dorsal group* and the *ventral group* as you can see in Figure 5.12. The dorsal respiratory group is the source of rhythmic drive to

the phrenic neurons. The ventral group has two divisions – the *cranial division* and the *caudal division.* The cranial division is made up of neurons that innervate the accessory muscles of respiration. The caudal division is made up of neurons that provide the inspiratory and expiratory drive to the motor neurons supplying the intercostal muscles.

The respiratory centre consists of two main parts – *inspiratory centre and the expiratory centre.* The inspiratory centre is dominant. A *reciprocal relationship* exists between these two parts. When the inspiratory muscles are active, expiratory muscles are inhibited.

The respiratory centre initiates nerve impulses which pass out from the brain in the phrenic nerves to the diaphragm and intercostal nerves to the intercostal muscles. These impulses stimulate the muscles to contract. This increases the capacity of the thoracic cavity and inspiration occurs. A second group of neurons in the medulla, the expiratory center appears to function mainly during forced expiration, stimulating the internal intercostal and abdominal muscles to contract.

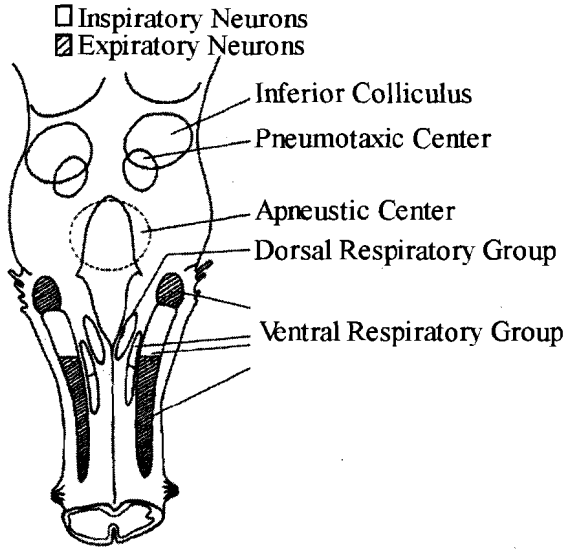

Figure 5.12: The medullary centre

- *Pontine centre:* The rhythmic discharge of the neurons in the respiratory centre is modified by centers in the pons (apneustic and pneumotaxic centre) as seen in the Figure 5.11). Activity in these centers determines the depth of inspiration.

If the vagus nerves and the inferior portion of the pons (connection between these two pontine centers) are destroyed, the inspiratory neurons discharge continuously and there is a sustained contraction of the inspiratory muscles. This arrest of respiration in inspiration is called *apneusis*. The area in the pons responsible for apneusis is called the *apneustic centre*. The area in the pons that prevents apneusis is called *pneumotaxic centre*. This area is situated in the upper pons as you would have noticed in the Figure 5.12. It controls the exaggerated activity of the apneustic centre and produces a rhythmical respiratory activity.

The exact function of the pontine respiratory centre is not clear. But they determine the depth and make the rhythmic discharge of the medullary neurons smooth and regular.

There are certain other factors which are involved in the nervous regulation of respiration. Let us have a look at each of these.

Role of other factors

- *The vagus nerve:* The rhythm and depth of respiration are controlled by the reflexes from the vagus nerve. When the lungs are inflated, there is an arrest of inspiration.

When lungs are deflated, the opposite effect is observed. This reflex is called *'Hering-Breuver reflex'*. When both the vagus nerves are cut, respiration becomes slow. But if the central cut end of the vagus nerve is stimulated, then the respiration becomes more or less normal. From this experiment, it can be suggested that sensory impulses through the vagus nerve help to make the respiration normal.

It was also observed that if the vagus nerve were cooled to 0 °C, inflation of lungs did not cause inhibition of respiration. But if vagus nerve was warmed, inflation of lungs did not inhibit the respiration. This later effect is called paradoxical *reflex of head.*

- *Vasomotor centre and cardio-inhibitory centre:* The vasomotor centre (in the medulla ablongata) excites the respiratory centre. The pulmonary ventilation is increased. The factors which stimulate respiration may excite the vasomotor centre simultaneously. Cardio-inhibitory (which restrains the action of heart) centre inhibits the respiratory centers. Hence, during respiration, heart rate and BP may vary. During inspiration, there is usually a rise in the heart rate and BP.

- *Reflex actions:* Certain reflex actions are associated with the respiratory process. These are:

1) *Cough reflex:* Cough reflex causes cough due to irritation of some receptors in tracheo-bronchial tree. It is a protective reflex. The irritation may occur in the vagal sensory nerve endings of the larynx, trachea etc. Chemically induced coughing occurs due to inhalation of gas. Cough, either mechanically or chemically induced, is a sudden forcible *expiratory act.*

2) *Hiccup:* It is also a reflex associated with stimulation of sensory endings in the gastrointestinal tract or other tissue through irritation. It is a sharp sound of *inhalation* with spasm of the epiglottis and diaphragm.

3) *Sneezing:* This reflex is an involuntary, sudden, violent and audible *expulsion of air* through the mouth and nose. Usually irritation of the nasal mucosa produces this reflex.

4) *Yawning:* It is a *deep inspiration* drawn through open mouth. Low oxygen tension in the blood may be the cause of yawning.

From our discussion above, it must be clear that conveyor system (central vascular system) and ventilatory system (lungs) work in harmony to provide nutrients and gases (O_2 and CO_2) to tissues/cells for their metabolism and energy expenditure.

Next, let us learn about the chemical control of respiration.

5.6.2 Chemical Control of Respiration

Let us now focus on the chemical control of respiration. But before that, let's get to know which chemicals are involved in this process.

The main chemical factors which influence the respiratory centers are the tension of *carbon dioxide* and *oxygen* in blood. In the *carotid body* (a clump of large polyhedral cells richly supplied with the blood vessels and nerves situated near the carotid bifurcation on each side) and in the aortic bodies (cells in the walls of the arch of aorta), cells are sensitive to *carbon dioxide excess* (increased pCO_2) and *oxygen lack* (decreased pO_2). When carotid body and aortic body are stimulated, impulses pass to the respiratory centre in the medulla, through the branches of vagus and glossopharyngeal nerves and stimulate respiration. Figure 5.13 illustrates the carotid and aortic bodies and the nerves.

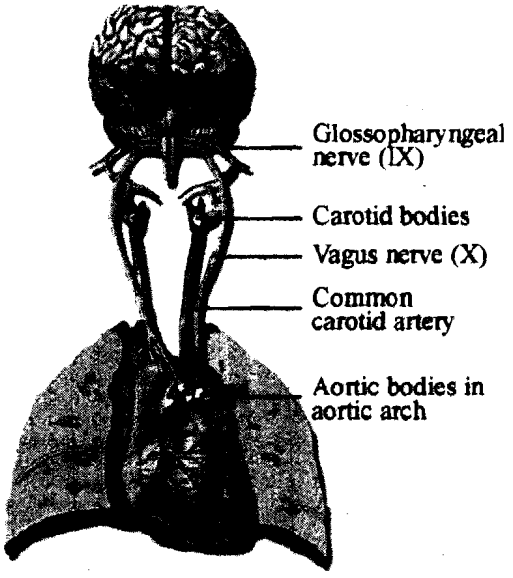

Figure 5.13: The carotid and aortic bodies and the nerves

Changes of carbon dioxide tension, oxygen tension and hydrogen ion concentration affect respiration. The effects of these changes are discussed below:

- *Effect of carbon dioxide tension:* The accumulation of carbon dioxide in blood is the most important stimulus for respiration. A slight rise in carbon dioxide in the inspired air increases the rate and depth of respiration. How? Increased carbon dioxide levels in the arterial blood result in decreased blood pH, which stimulates the peripheral sensory receptors (chemoreceptors). They respond by sending more nerve impulses to the respiratory centers, which stimulate the respiratory muscles, causing faster and deeper breathing. More carbon dioxide is exhaled, which drives the chemical reaction to the left and returns the pCO_2 and pH to normal levels.

  Thus, the total pulmonary ventilation is increased and adjusted and alveolar carbon dioxide remains constant. But if the percentage of carbon dioxide in the inspired air is above 5%, then the adjustment fails. Accumulation of carbon dioxide in the blood leads to *acidosis* (an excessive acidity of the body fluids due to either an accumulation of acids or a loss of bicarbonate i.e., the hydrogen ion concentration is increased and thus the pH is decreased).

  Respiratory acidosis occurs when the lungs fail to eliminate sufficient amount of carbon dioxide. In this, the excess carbon dioxide combines with water to form carbonic acid, which increases the acidity of the blood. This may be due to the changes in lungs which prevent normal gas exchange, depression of the respiratory centre by drugs or respiratory obstruction.

- *Effect of hydrogen ion concentration:* During acidosis when there is an excess retention of carbon dioxide in the body, the rate of respiration increases and the body tries to eliminate more carbon dioxide. As more carbon dioxide passes out of blood stream into the lungs, the hydrogen ion concentration of blood is lowered.

  During alkalosis, rate of respiration decreases and the body tries to increase carbon dioxide tension. As more carbon dioxide is accumulated, hydrogen ion concentration of the blood is increased.

- *Effect of oxygen tension:* The respiratory system is much more sensitive to carbon dioxide excess than to the oxygen deficiency. If oxygen tension in the inspired air can be reduced to 13%, there are no appreciable changes on respiration. If it is less than 10%, then there is a feeling of discomfort and uneasiness.

Having gone through the discussion above, you would have got a clear idea about the neural and chemical control of respiration.

Next, we shall look at the internal respiration.

5.7 INTERNAL RESPIRATION

What do you understand by the term 'internal respiration'? Well, the interchange of gases between the blood and cells of the body is *internal respiration.*

The exchange of gases between the blood and tissues takes place between the *arterial end* of the capillaries and the tissue fluid. The process involved is termed as *diffusion.* Diffusion occurs from a higher concentration of oxygen in the blood to a lower concentration in the tissue fluid.

Oxygen is dissolved in the plasma and is carried from the lungs to the tissues. Oxygen combines with haemoglobin to form oxyhaemoglobin. Oxyhaemoglobin breaks up easily to liberate oxygen. Tissue cells need a constant supply of oxygen. Hence, diffusion of oxygen from the blood to the tissue fluid and then to the cells is continuous. The active cells receive more oxygen. When the cells become very active, there is a higher concentration of carbon dioxide. This helps in the release of oxygen from oxyhaemoglobin more rapidly.

Carbon dioxide is one of the waste products of carbohydrate and fat metabolism. The mechanism by which carbon dioxide is transferred from the cells into the blood is diffusion which occurs at the venous end of the capillaries.

Certain adjustments need to be made inside our body, to cope up with the varying environmental conditions. We shall learn about these adjustments next.

5.8 RESPIRATORY ADJUSTMENTS

Certain adjustments need to be made inside our body as well, to cope up with the varying environmental conditions, as well as, abnormal and normal conditions. Let us see what kind of respiratory adjustments are made in our body. Some of the common terms related to it are explained herewith.

- *Fatigue:* Fatigue means a state of decreased efficiency due to prolonged exertion. It may occur due to sustained muscle contraction. The muscles become ischemic. Fatigue may also occur due to acidosis on the brain.
- *Hypoxia:* Hypoxia is the oxygen deficiency at the tissue level below the physiological level. There are four types of hypoxia. Let's get to know them.
    a) Hypoxic hypoxia: It is a hypoxia resulting from defective oxygenation of the blood in the lungs. It is a problem in high altitudes where pO_2 of the arterial blood is reduced. It may also occur as a complication of pneumonia.
    b) Anaemic hypoxia: It is a type of hypoxia due to anaemia where the arterial pO_2 is normal but the amount of haemoglobin available to carry oxygen is reduced.
    c) Stagnant or ischemic hypoxia: It is a hypoxia resulting from slow peripheral circulation (such as follows congestive cardiac failure). In this, the blood flow to the tissues is so low that an adequate amount of oxygen is not delivered to it, inspite of having a normal pO_2 and haemoglobin concentration. The liver and the brain are damaged by stagnant hypoxia in congestive heart failure.

d) Histotoxic hypoxia: It is a type of hypoxia in which due to the action of a toxic agent oxidative enzymes are poisoned hence the tissue cells cannot utilize oxygen supplied to them. Cyanide poisoning is one of the causes.

- *Dyspnoea:* Shortness of breath or dyspnoea is a feeling of difficult or labored breathing that is out of proportion to the patient's level of physical activity. In other words, the term also means distressed breathing and the subject is conscious of shortness of breath.
- *Hyperpnoea:* It is a term for an increase in the rate and depth of respiration. The cause of hyperpnoea may be voluntary or due to impulses from the hypothalamus.
- *Orthopnoea*: Dyspnoea occurs even at rest in severe cardiac congestive failure. This condition is called orthopnoea.
- *Tachypnoea:* It is a rapid, shallow breathing.
- *Apnoea:* Apnoea means cessation of breathing. Temporary apnoea may be seen in low carbon dioxide tension in blood. During swallowing, there is a temporary apnoea.
- *Cyanosis:* Cyanosis is a physical sign causing bluish discoloration of the skin and mucous membranes. Cyanosis is caused by a lack of oxygen in the blood capillaries containing more than 5 g of reduced haemoglobin in 100 ml of blood. Cyanosis is associated with the cold temperatures, heart failure, lung diseases and smothering. It is seen in infants at birth as a result of heart defects, respiratory distress syndrome, or lung and breathing problems. If the blood does not absorb enough oxygen during its passage through the lungs, then the arterial blood appears bluish in color.
- *Acclimatization:* A compensatory respiratory adjustment at moderately high altitudes is called acclimatization. If you were to visit places like Leh (Ladakh) you would be told that you would need some time to acclimatize.

  At very high altitudes, the alveolar pO_2 may fall to 40 millimeters of mercury and haemoglobin will be only 75% saturated. At this point, increased ventilation will make a dramatic difference in the amount of oxygen loaded into the blood.

  At high altitudes, there are not only changes in respiration but also changes in blood and circulation, in kidney.
- *Pneumothorax:* It is a collection of air or gas in the chest or pleural space that causes a part or all of a lung to collapse. Due to the rupture of chest wall, when air is admitted to the pleural space, the lining on the affected side is collapsed.
- *Emphysema:* Emphysema is a chronic respiratory disease where there is an over-inflation of the air sacs (alveoli) in the lungs, causing a decrease in the lung function, and often, breathlessness. In this, the lungs lose their elasticity in degenerative pulmonary disease. The walls between the alveoli breakdown so that the alveoli are replaced by large air sacs. Because of uneven alveolar ventilation, severe hypoxia develops.
- *Asphyxia:* Improper aeration of blood produces a series of pathological manifestation and ultimately death. The symptoms are collectively called asphyxia. There is a pronounced stimulation of respiration with violent respiratory efforts. Blood pressure and heart rate rise.
- *Hypercapnia:* It is the retention of carbon dioxide in the body. There is a depression of the central nervous system.
- *Hypocapnia:* During hyperventilation, the arterial pCO_2 falls. This condition is called hypocapnia.
- *Oxygen toxicity:* Exposure to oxygen at increased pressure can produce a marked increase in the dissolved oxygen in blood. It produces toxic effects on the respiratory system. The respiratory passages become irritated. There is nasal congestion, sore throat and coughing.

An exhaustive list of respiratory adjustments has been presented above. These respiratory adjustment terms you may have heard some time or the other. Now you know what they mean.

You may have also come across the term *artificial respiration.* What is it? The last section in this unit talks about artificial respiration.

5.9 ARTIFICIAL RESPIRATION

An artificial respiration needs to be given in the cases where the respiratory muscles are not able to provide an adequate ventilation of the lungs. The artificial respiration may be given either by equipment or manually.

Whatever be the technique of artificial respiration, the first essential step is to establish and maintain a clear airway from the nose or mouth to the lungs. Let us see how one can be given artificial means of respiration by the use of equipments.

- *Artificial respiration by an equipment*

The equipments which aid in artificial respiration include:

a) *Cabinet respiration:* Such an apparatus is used when the respiratory muscles are paralyzed by an injury or an infection. A cabinet respirator consists of a box in which the patient is placed with his head outside and an air-tight seal around his neck. Respiratory movements are brought about by lowering and raising the pressure in the box.

b) *Intermittent positive pressure lung inflation:* When medulla is affected, the cough reflex may be lost. To prevent secretions entering the lungs, a tube is inserted into the trachea. This tube is connected to a positive pressure pump which inflates the lungs by blowing air into them. Alternatively, a negative pressure may be incorporated so that the expired air is sucked.

Next, we move on to the manual methods of respiration.

- *Artificial respiration by manual methods*

The manual methods used for artificial respiration include:

a) *Mouth to mouth respiration:* If no instrument is available, one's own lung may be used as a positive pressure pump. Air may be blown into the lungs of the subject by way of his mouth or nose. This is known as mouth to mouth artificial respiration as shown in Figure 5.14. This is one of the most important and practical methods.

b) *External cardiac massage:* If respiration stops, then after a short time the heart will also stop beating due to oxygen lack. If the heart is still beating, external cardiac massage is not employed. If the heart stops beating, respiration will stop. In such cases, external cardiac massage is given to restore the circulation of blood.

Check Your Progress Exercise 3

1) Fill in the blanks:

   i) The reflex actions associated with breathing are ....., ..., ... and ..... .

   ii) The chemical factors influencing the respiratory centers are ..... and ..... .

   iii) Combination of excess CO_2 with water to form carbonic acid, which increases the acidity of the blood is called ..... .

   iv) A compensatory respiratory adjustment at moderately high altitude is called ..... .

   v) Bluish discolouration of the skin and mucous membranes is called as ..... .

2) Name the two neural mechanisms that control the respiratory process? Explain how does voluntary system helps to control the process of respiration?

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3) Define the following terms:

   i) Hypoxia

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   ii) Emphysema

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5.10 LET US SUM UP

In this unit, we studied about the organs and the mechanism involved in the respiration process. The respiratory system consists of lungs and a series of air passages. They form a pathway for oxygen to enter and carbon dioxide to leave the lungs.

We learnt that respiration ensures an adequate intake of oxygen from the environment for the oxidative processes of the body. It also ensures the removal of carbon dioxide to maintain a constant hydrogen ion concentration in the blood.

Then we learnt about the cycle of respiration, which consists of inspiration, expiration and a pause. Inspiration, as you now know, means inhalation of air and expiration means exhalation of air. The main muscles involved in respiration are the diaphragm, intercostal muscles and abductor muscles.

Then, finally we saw that the regulation of respiration is partly chemical and partly nervous. These two systems, as you would have realized, are closely linked. Between the process of inspiration and expiration, interchange of gases takes place between the blood and the capillary network surrounding the alveoli and the air in the alveoli of the lungs.

Finally we had a look at the artificial methods of respiration using both equipments and manual methods.

5.11 GLOSSARY

Acclimatization : the process of becoming accustomed to a new environment.

Apnoea : cessation of breathing.

Asphyxia : it is produced by occlusion of the airway (strangulation, drowning) accute hypercapnia and hypoxia develop together.

Cartilage : a connective tissue that covers the ends of bones in a joint.

Cyanosis : a bluish coloration of skin and mucus membrane due to excessive reduced haemoglobin in blood.

Diaphragm : a thin dome-shaped skeletal muscle that separates the thoracic and abdominal cavities.

Dyspnoea : difficult breathing.

Hypercapnia : excessive carbon dioxide in blood.

Hyperpnoea : an abnormal increase in depth and rate or respiration.

Hypocapnia : the deficiency of carbon dioxide in blood.

Hypoxia : reduction of oxygen supply to a tissue.

Pharynx : a cone-shaped tubular section of the alimentary canal that extends from the mouth and the nasal cavities to the larynx, where it becomes continuous with the oesophagus.

5.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) The organs involved in the process of respiration are nose and nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles and two lungs.

2) The bronchi are composed of well-defined cartilages and are lined with a ciliated epithelium while the bronchioles contain no cartilage and are composed of muscle tissue, fibrous tissue and elastic tissue with the innermost lining of ciliated columnar epithelium.

3) a) The nose, acts as a respiratory passage through which the incoming air passes, and warms, moistens and filters the air. The air becomes warm as it passes through the nose. It is moistened by contact with the moist mucous. The air gets filtered because the dust particles and other impurities (in the form of particulate matter) stick to the mucous.

b) The larynx:

- controls the airflow during breathing and ensures the passage of air from the pharynx to the trachea.
- protects the airway. Air is filtered, moistened and warmed here.
- produces sound for speech and this ensures voice production due to the presence of vocal cords, and
- facilitates swallowing of food.

c) The lungs exchange gases (O_2 and CO_2) between the alveoli of lungs and capillary network around them; and expand to take in air and then contract to expel it.

4) i) internal, external

ii) nasopharynx, oropharynx and laryngopharynx

iii) thyroid, cricoid, tracheal

iv) goblet

v) pleura

Check Your Progress Exercise 2

1) i) intercostal, diaphragm and abductor

ii) phrenic

iii) abductor

iv) alveoli

v) plasma, RBC

2) The mechanics of respiration can be explained through a respiratory cycle consisting of 3 phases:

a) Inspiratory phase: In this, there is an inhalation of air. It is contraction. It is partly voluntary and partly involuntary.

b) Expiratory phase: In this, there is an exhalation of air. It is a passive process in which the diaphragm and the intercostal muscles relax and the lungs recoil.

c) Pause: After expiration, there is a short pause.

3) Respiration is a process including both inspiration and expiration. In inspiration, the thoracic cavity is increased by the simultaneous contraction of intercostal muscles and the diaphragm. The parietal pleura moves with the walls of thorax and diaphragm. The visceral pleura follows the parietal pleura, which reduces the pressure in the pleural cavity to a level considerably lower the atmospheric pressure.

The lungs are stretched and pressure within the alveoli is reduced. This causes the air to come to the lungs in an attempt to equalize the atmospheric and alveolar air pressure. During expiration, the thoracic cavity reduces in size. The lungs recoil and expiration occurs.

4) i) A phenomenon in which the bicarbonate ions diffuse into the plasma as the blood passes through the capillaries is referred to as chloride shift.

ii) When different partial pressures of oxygen are plotted against the amount of oxyhaemoglobin formed or dissociated, the sigmoid curve obtained is called as oxygen dissociation curve.

Check Your Progress Exercise 3

1) i) cough; hiccup; sneezing; yawning

ii) CO_2 and O_2

iii) respiratory acidosis

iv) acclimatization

v) cyanosis

2) The two neural mechanisms which control respiration are: Voluntary system and Automatic system.

The centre for the voluntary system is located in the cerebral motor cortex. It sends impulse to the respiratory motor neurons via the corticospinal tracts (CST). It deals with the contraction of individual muscles and is the pathway for the selection of the prime movers for any muscular activity.

3) i) The deficiency of oxygen at the tissue level below the physiological level is referred to as hypoxia.

ii) Emphysema is a chronic respiratory disease where there is an over-inflation of the alveoli in the lungs, causing a decrease in lung function, and often breathlessness.