

2

## HUMAN RESPIRATORY SYSTEM



### Students Learning Outcomes

**After studying this chapter, students will be able to:**

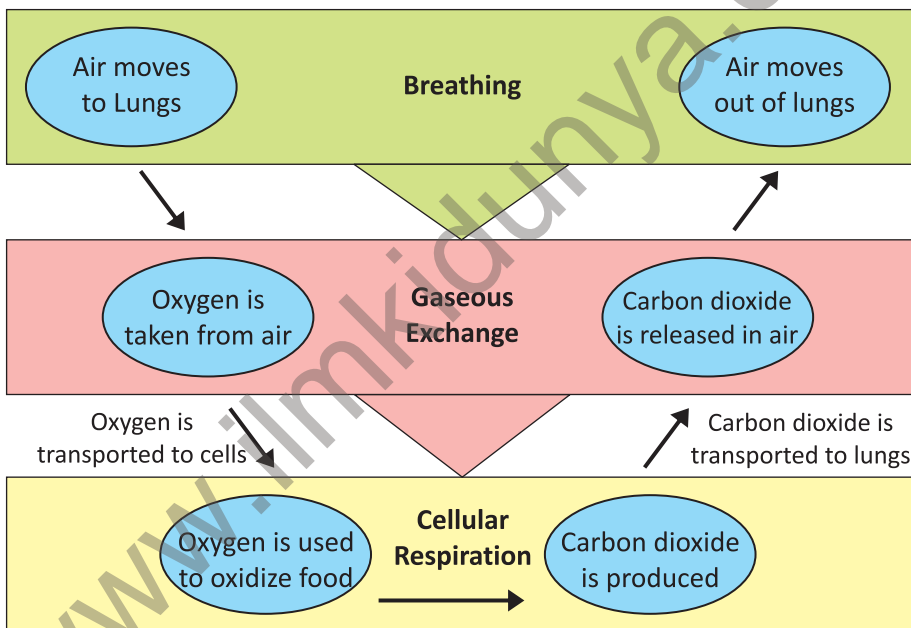
- Describe the roles of the parts of the air passageway and lungs.
- Describe the mechanism of breathing in terms of movements of ribs and diaphragm.
- Differentiate between the composition of inspired and expired air.
- Discuss briefly diseases related to respiratory system like bronchitis, emphysema, pneumonia, asthma, and lung cancer.

Organisms get energy by doing **cellular respiration**. It is the process in which cells oxidize food (glucose) and get energy. For this purpose, organisms need to carry oxygen to the cells and to remove carbon dioxide from the cells. **Gaseous exchange** is the process in which oxygen present in the inhaled air (in lungs) moves into blood, and carbon dioxide from the blood moves into the air to be exhaled. For gaseous exchange, animals do breathing.

In aerobic respiration, oxygen is utilized while carbon dioxide and water are produced.

## Breathing

**Breathing** is the process in which animals move air in and out of their body. It is done to get oxygen from air and to release carbon dioxide in it. Breathing and respiration are not the same processes. Respiration is a chemical process while breathing is a physical process. Breathing helps in gaseous exchange. Gaseous exchange, in turn, helps in respiration.



**FIGURE 2.1:** Relationship between respiration, gaseous exchange and breathing

## 2.1 HUMAN RESPIRATORY SYSTEM

Respiratory system is responsible for breathing and gaseous exchange. The human respiratory system consists of two major parts i.e., air passageway and lungs.

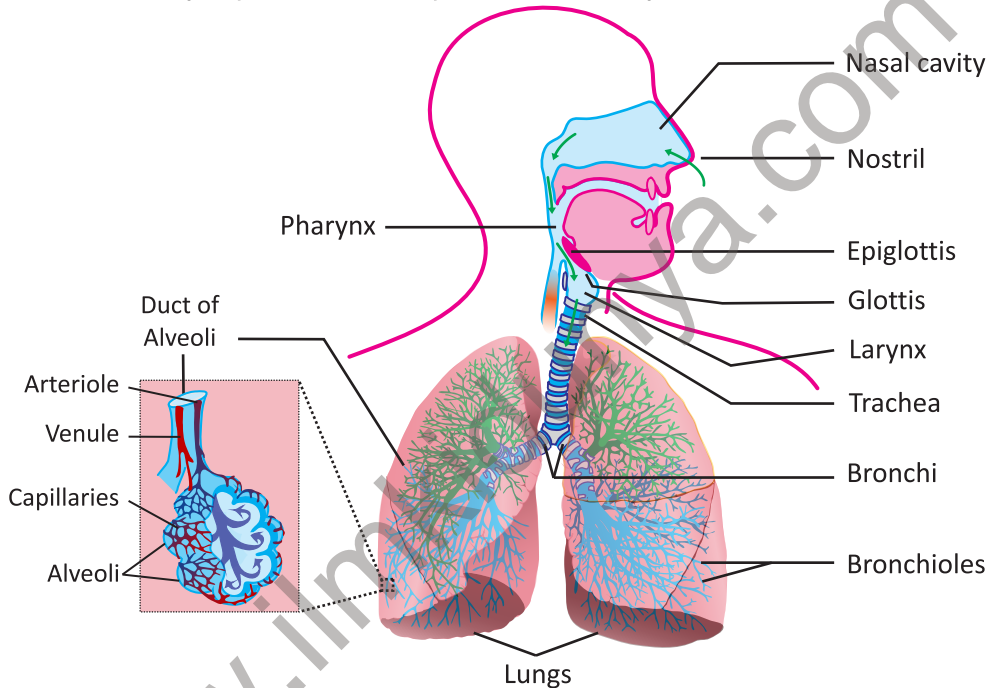
### A. The Air Passageway

When air enters the body, it passes through connected tubes to reach the

lungs. After gaseous exchange, air moves from the lungs to outside through the same connected tubes. These connected tubes are collectively called air passageway. It consists of the following parts.

### 1. Nostrils and Nasal cavity

The nasal cavity is made up of two narrow cavities between nostrils and pharynx. Air enters the nasal cavity through nostrils. **Fine hairs** in nasal cavity filter the incoming air by trapping large dust particles. **Mucus** on the walls of nasal cavity traps small dust particles. Mucus also warms the air and keeps its temperature nearly equal to the temperature of body.



**FIGURE 2.2: The air passageway and the lungs**

### 2. Pharynx

Nasal cavity opens into pharynx. At the floor of pharynx there is an opening called **glottis**. It opens in larynx. The glottis is guarded by a flap called **epiglottis**. It prevents food and liquid from entering the windpipe and lungs.

#### Recalling:

Pharynx is a common passage for food to oesophagus and for air to larynx.

### 3. Larynx

It is a box present between pharynx and trachea. Larynx is also called the **voice box**. Two fibrous bands called vocal cords are

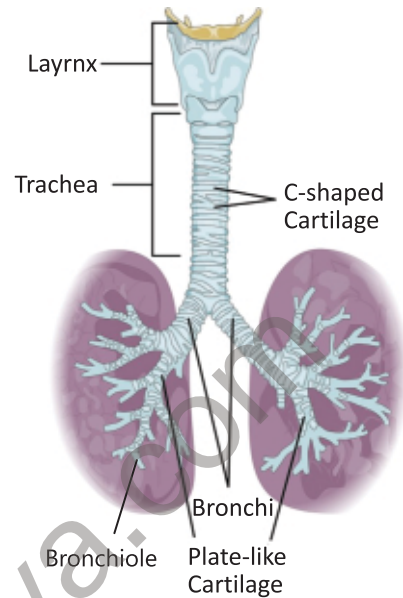
The vibrations of vocal cords and the movements of lips, cheeks, tongue and jaws produce specific sounds which result in speech.

attached to the inner walls of larynx. The vibrations of vocal cords produce sounds.

#### 4. Trachea and Bronchi

Trachea (windpipe) is a 12 cm long tube attached with larynx. It ends in two branches called **bronchi** (*singular*: bronchus). Each bronchus enters into the lung of its side.

The inner walls of trachea and bronchi are lined with mucus and cilia. Mucus traps fine dust particles and bacteria. Cilia move these particles and mucus upwards to the pharynx. In the walls of trachea, **C-shaped cartilages** are present. While the walls of bronchi have plate-like cartilages. These cartilages prevent trachea and bronchi from collapsing even when there is no air in them.



**FIGURE 2.3: Cartilage in Trachea and Bronchi**

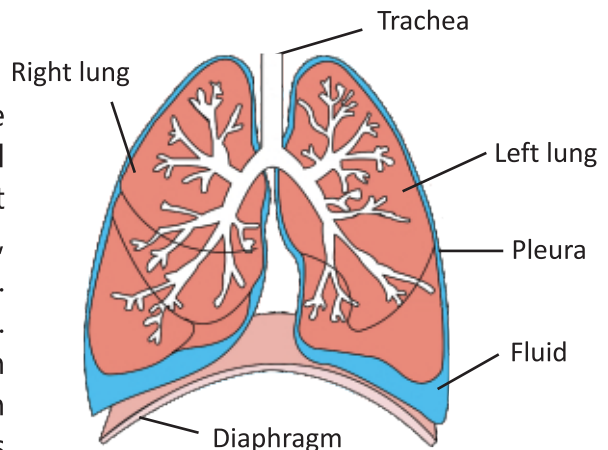
The chest wall is made up of 12 pairs of ribs and the rib muscles called **inter-costal muscles**.

#### 5. Bronchioles and Alveoli

Inside lungs, both bronchi continue to divide into very small tubes called bronchioles. As the branching continues, the amount of cartilage in the walls decreases. Cartilage is absent in the smallest bronchioles. Each bronchiole ends at an alveolar duct. This duct opens into a cluster of pouches. These thin-walled pouches are called alveoli (*singular*: alveolus). Each alveolus is surrounded by blood capillaries. When air reaches alveoli, oxygen moves from the air into blood, and carbon dioxide passes out of blood into the air in the alveoli.

#### B. The Lungs

There is a pair of lungs in the thoracic cavity. From above and sides, lungs are enclosed by the chest wall. A thick muscular structure, called **diaphragm** below lungs. Lungs are spongy and elastic organs. The left lung is slightly smaller than the right lung. There are two lobes in the left lung while right lung has three lobes. Lungs are enclosed

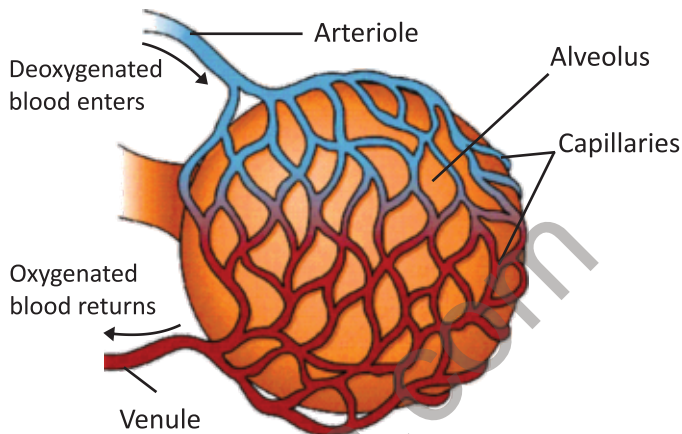


**Figure 2.4: Lungs**

in a double membrane called **pleura**. Its inner layer is attached to the surface of the lungs while the outer layer lines the inner surface of the chest wall and the diaphragm. It contains a **pleural fluid** for reducing friction between lungs and the chest wall.

### Blood Circulation in Lungs

Pulmonary artery carries deoxygenated blood from heart to lungs. Inside each lung, the pulmonary artery divides into smaller arterioles. The arterioles divide further and make capillaries around the alveoli. After surrounding the alveoli, the capillaries join to form venules. The venules join to form pulmonary vein which carries oxygenated blood back to heart.



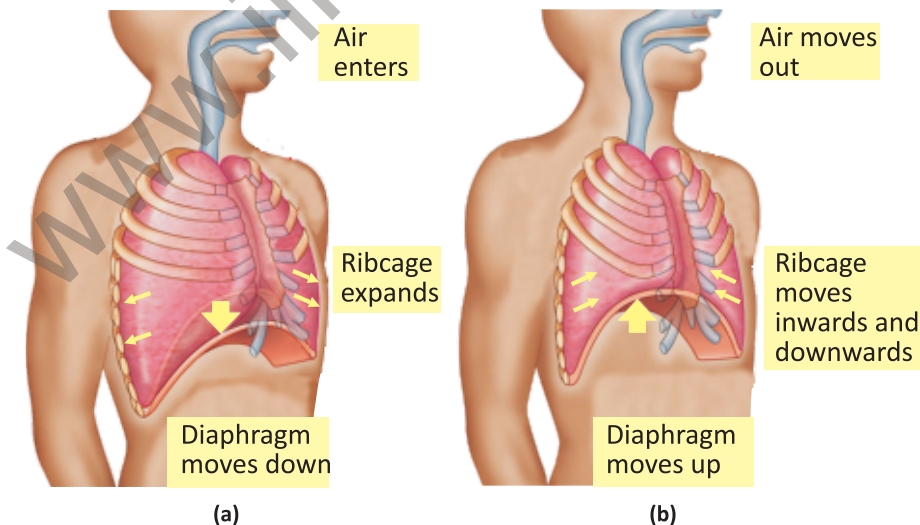
**Figure 2.5: Blood circulation in lungs (around an alveolus)**

## 2.2 THE MECHANISM OF BREATHING

Breathing is a physical process in which air is taken into the lungs and expelled out the lungs. There are two steps of respiration.

### 1. Inhalation (inspiration)

Inhalation means intake of air to the lungs. The following events occur



**Figure 2.6: Breathing; (a)- Inhalation (b)- Exhalation**

during inhalation;

The **intercostal muscles** (muscles located between the ribs) contract for the upward and outward movement of ribcage. At the same time, **diaphragm** also contracts and moves down. These two contractions increase the volume of the chest. So, pressure inside the chest is reduced and air is moved into lungs.

## 2. Exhalation (expiration)

Exhalation means moving the air out of the lungs. The following events occur during exhalation;

The **intercostal muscles** relax to move ribcage inwards. At the same time **diaphragm** also relaxes and moves up. These two movements decrease the volume of the chest. So, pressure inside the chest increases and air is forced out.

We lose half a litre of water a day through breathing. This is the water vapour we see when we breathe onto glass.

## The Rate of Breathing

Humans breathe **16 -20 times per minute** in normal conditions i.e., at rest. During exercise or hard job, muscles carry out cellular respiration at greater rate. So, more carbon dioxide is produced. The respiratory centre in brain detects greater concentration of carbon dioxide in blood. It sends messages to the muscles of ribs and diaphragm at greater speed. The speed of contraction and relaxation of these muscles increases. So, the breathing rate increases up to 30-40 times per minute.

## Composition of the Inhaled and the Exhaled Air

Feature	Inspired Air	Expired Air
Oxygen %age	21	16
Carbon dioxide %age	0.04	4
Nitrogen %age	79	79
Water vapours	Variable	Saturated
Temperature	Variable	Almost equal to body temperature
Dust particles	Variable	Almost none

## 2.3 RESPIRATORY DISORDERS

### 1. Bronchitis

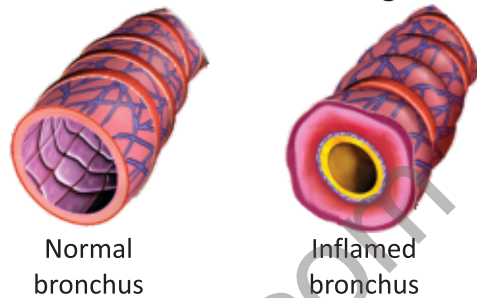
Bronchitis means inflammation (swelling) in bronchi or bronchioles. In

bronchitis, the inner space of bronchioles decreases. It may be short term i.e., acute (1-2 weeks) or long-term i.e., chronic (3months to 2 years). In chronic bronchitis, mucus-producing cells in the walls of bronchi increase in number. Thus, there is thick mucus in bronchi. It obstructs breathing.

**Causes:** Infections by viruses or bacteria and chemical irritants (e.g., tobacco smoke).

**Symptoms:** Coughing, wheezing, fever, chills and shortness of breath.

**Treatment:** Medications (cough suppressants) to ease breathing, antibiotics (if it is due to bacterial infection), antiviral medicines (if it is due to viral infection), avoiding irritants like smoke and pollution.



**Figure 2.7: Normal and inflamed bronchi**

## 2. Emphysema

In emphysema, the inner walls of alveoli become weak and then rupture. Thus, one larger air space is created instead of many small ones. So, the space for gaseous exchange decreases and the patient cannot breathe properly.

**Causes:** Long-term exposure to irritants in air e.g., tobacco smoke, chemical fumes and other air pollutants.

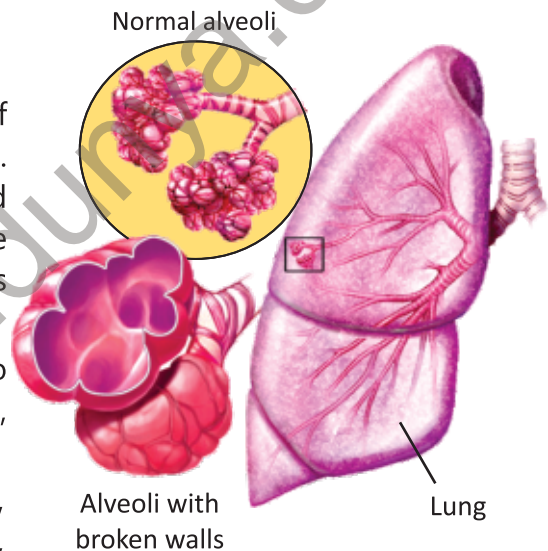
**Symptoms:** Shortness of breath, chronic cough (with or without mucus), wheezing and chest tightness.

**Treatment:** Medicines to relieve cough and breathing problems. Emphysema cannot be cured completely.

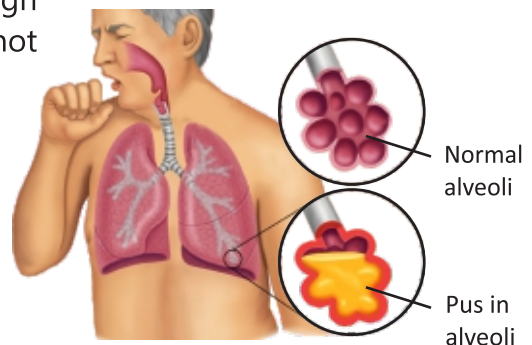
## 3. Pneumonia

Pneumonia is an inflammation in the lungs, due to infection in alveoli. These are filled with pus.

**Causes:** Infections by bacteria, viruses and fungi.



**Figure 2.8: Emphysema**



**Figure 2.9: Pneumonia**

**Symptoms:** The pneumonia patient suffers from high fever, chills, shortness of breath, and cough with sputum.

**Treatment:** Bacterial pneumonia is treated by using antibiotics. The viral and fungal pneumonia are treated by using antiviral and antifungal drugs respectively. Bacterial vaccines are also available to prevent bacterial pneumonia.

#### 4. Asthma

It is an inflammation of bronchi in which bronchi and bronchioles swell and are constricted.

**Symptoms:** Recurring attacks of shortness of breath, wheezing (whistling sound when breathing out), coughing and chest tightness.

**Causes:** Allergens (dust mites, pollen, mold, and pet dander), air pollutants (smoke, chemical fumes, and strong fragrances), weather changes, especially cold air, genetic factors (family history of asthma or allergies).

**Treatment:** Medicines (bronchodilators) to dilate bronchioles during asthma attack.

#### 5. Lung Cancer

Cancer means uncontrolled increase in the number of cells in any part of the body. When the masses of non-functional cells are formed in lungs, it is called lung cancer. It is the most common cancer in the whole world.

**Causes:** Carcinogens (such as those in tobacco smoke), ionizing radiation, viral infection. Passive smoking i.e., the inhalation of smoke from another's smoking is also a cause of lung cancer. The smoke from the upper burning portion of cigarette is

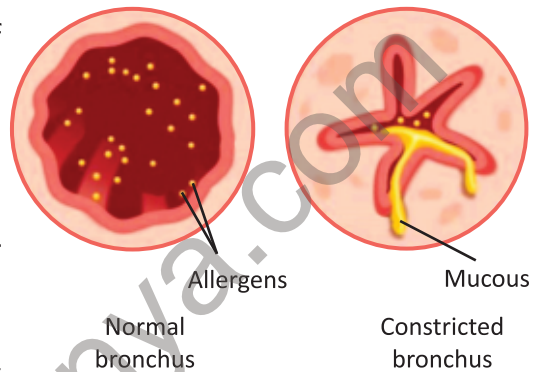


Figure 2.10: Asthma

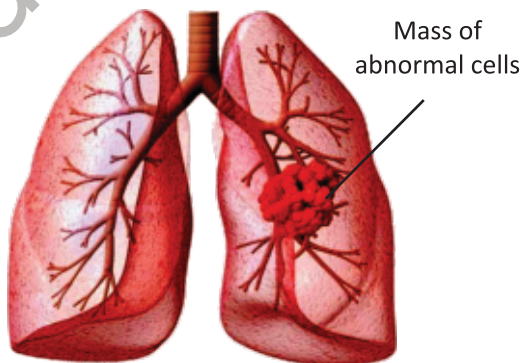


Figure 2.11: Lung cancer

Lung cancer is the most frequently diagnosed cancer globally, accounting for about 12.4% of all new cancer cases. In the world, it causes more than 1.5 million deaths annually.

In Pakistan, lung cancer accounts for about 5.1% of all new cancer cases annually. There are about 22,000 new lung cancer cases each year.

**Source:** World Health Organization

more dangerous than smoke exhaled by the smoker.

**Symptoms:** The most common symptoms are shortness of breath, coughing (including coughing up blood), and weight loss.

**Treatment:** The patient of lung cancer is given one or more treatments, including surgery, chemotherapy, or radiation therapy.

### Effects of Smoking

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

Tobacco smoke contains over 4,000 different chemicals e.g., nicotine and carbon monoxide. Out of these, there are more than 69 known **carcinogens** (cause cancer in humans). For example: tar and benzene etc.

- **Nicotine** is the major component of cigarettes. It damages many tissues including brain. It also hardens the walls of arteries and results in heart problem.

- **Carbon monoxide** is produced when tobacco is burnt during smoking. It is a poisonous gas. It combines with RBCs and prevents oxygen transport.

- **Tar** is present in cigarettes in the form of solid particles. When it is inhaled along with smoke, it is deposited in lungs. It reduces the surface area for gaseous exchange.
- **Benzene** is a major component of cigarettes. It is a carcinogen and

Non-smokers who inhale the smoke of others have 30% more chances of heart diseases and lung cancer.



**FIGURE 2.12:** Effect of smoking on lungs

In Pakistan, 12% of adults do smoke. 7.6% of all deaths in Pakistan are caused by tobacco use.

**Vaping** refers to inhaling vapor produced by an e-cigarette. These devices heat a liquid, which may contain nicotine, flavours, and other chemicals.

Many young people are attracted to vaping. They believe it a safer alternative to cigarettes, though this is not true.

Vaping can cause lung inflammation and lung injury. Nicotine and other chemicals in vape increase heart rate and blood pressure, contributing to heart disease.

causes blood cancer (leukaemia). Similarly, **formaldehyde** present in cigarettes causes cancers, respiratory, skin and gastrointestinal problems.

- **Ammonia** frees nicotine from tobacco turning it into a gas. It is poisonous for the body.
- There are many other **irritants** in cigarettes. These irritants damage the air passageways (respiratory tract) and cause many respiratory diseases, including cancer.

### Other Effects of Smoking

Smoking also increases blood cholesterol levels, blood pressure. It weakens blood vessels. Smoking causes the staining of teeth and bad breath. Tooth loss is 2 to 3 times higher in smokers than in non-smokers. Smoking increases the risk of tuberculosis by two to four times, and of pneumonia by four times.

The World **No Tobacco Day** is celebrated on the 31<sup>st</sup> of May every year.



## EXERCISE

### A. Select the correct answers for the following questions.

1. **Breathing means;**
  - a) Breakdown of C-H bonds to produce energy
  - b) Movements that take air in and out of body
  - c) Getting oxygen from the air and removing carbon dioxide
  - d) Transport of oxygen through blood to different parts of the body
2. **Which path does air take immediately after passing through the larynx?**
  - a) Pharynx
  - b) Bronchi
  - c) Trachea
  - d) Alveoli
3. **Why are alveoli surrounded by capillaries?**
  - a) To absorb water
  - b) To exchange gases
  - c) To produce mucus
  - d) To trap dust particles
4. **Which feature of alveoli helps in rapid gas exchange?**
  - a) Thick walls
  - b) Large diameter
  - c) Moist surface
  - d) Strong muscles
5. **Which action increases lung volume during breathing?**
  - a) Relaxing the diaphragm
  - b) Contracting intercostal muscles
  - c) Closing the trachea
  - d) Stiffening alveolar walls

6. Inhaled air contains 21% oxygen. What is its percentage in exhaled air?  
a) 0%                      b) 16%                      c) 21%                      d) 42%
7. Which factor controls the breathing rate?  
a) Carbon dioxide in blood                      b) Oxygen in blood  
c) Carbon dioxide in muscles                      d) Oxygen in muscles
8. The walls of alveoli are broken in:  
a) Pneumonia                      b) Bronchitis                      c) Emphysema                      d) Asthma
9. Smoking leads to lung cancer by:  
a) Increasing oxygen uptake  
b) Promoting uncontrolled cell division  
c) Slowing down healing  
d) Enlarging the trachea
10. Which chemical in cigarette smoke directly leads to addiction?  
a) Carbon monoxide                      b) Tar                      c) Nicotine                      d) Formaldehyde

### B. Write short answers.

1. Differentiate between gaseous exchange and breathing.
2. Differentiate between breathing and cellular respiration.
3. What is the function of cartilages present in the walls of trachea and bronchi?
4. What is the average breathing rate in human at rest and during exercise?
5. How does the structure of alveoli maximize gas exchange?
6. List the symptoms, causes, and treatments of bronchitis.
7. Mention the symptoms and treatments of emphysema.
8. What are carcinogens? Name any two carcinogens present in cigarettes.
9. Complete the following table:

Feature	Inspired Air	Expired Air
Oxygen	21%	
Carbon dioxide		4%
Nitrogen	79%	

### C. Write answers in detail.

1. Explain the process of inhalation and exhalation step by step.
2. Write a short note on the major parts of the human air passageway.

3. Describe the functions and locations of the bronchus, trachea, and alveoli.
4. What are the possible causes of lung cancer? Explain the harmful effects of smoking apart from lung cancer.

**D. Inquisitive Questions**

1. What can happen to breathing if diaphragm stops working properly?
2. Why is it dangerous when smoke particles settle inside lungs?
3. Why does the trachea has C-shaped cartilage rings while bronchioles do not have them?
4. During asthma attacks, patients feel harder to exhale than to inhale. Why is it so?

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