

Respiratory Organs

What happens when our body does not get enough oxygen? We feel breathless, tired, uneasy and can even become unconscious in extreme cases! Why do you think this happens? This is because oxygen is extremely important for producing energy. The respiratory organs are responsible for this process. Let's study about these essential organs in our body.

Different Respiratory Organs

Different animals have different respiratory organs based on their habitat and body organization. Invertebrates like sponges and flatworms breathe through simple diffusion over their body surface. Earthworms use their cuticle while insects use a network of tubes. Most aquatic animals use specialized structures called 'gills' whereas most terrestrial creatures use structures called 'lungs'.

Did you know that frogs can breathe through their moist skin too? Among vertebrate animals, fishes breathe through gills; while birds, reptiles, and mammals use lungs to breathe. Mammals respire using a

well developed respiratory system. Let's learn about the human respiratory organs in more detail.

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- [Mechanism of Breathing](#)
- [Exchange and Transport of Gases](#)
- [Regulation of Respiration](#)
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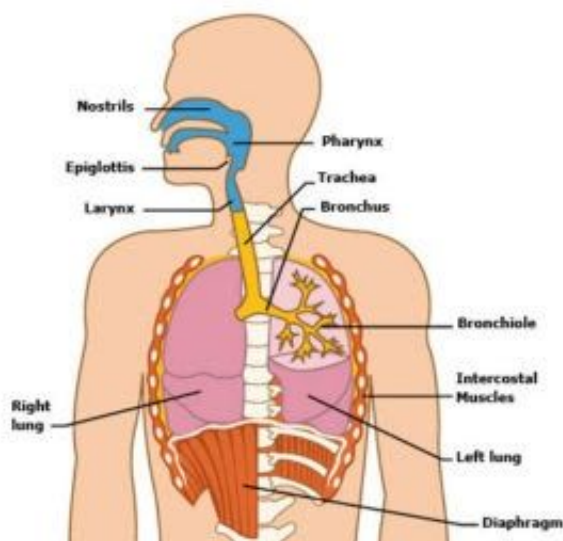
Human Respiratory System

The human respiratory system has the following parts:

- We take in oxygen from the atmosphere with our nostrils. The nostrils open into the nasal chamber through a nasal passage. This chamber then opens into the pharynx, a part of which is the common passageway for air and food.
- The pharynx opens into the trachea through the larynx. The larynx is a box-like structure made of cartilage that helps to produce sound and is, therefore, called the 'sound box'. A cartilaginous structure called epiglottis prevents the entry of food into the larynx. Trachea, on the other hand, is a tube that

divides at the 5th thoracic vertebra into the left and right primary bronchi.

- Each bronchus divides multiple times to give rise to secondary and tertiary bronchi which ultimately gives rise to thin, terminal structures called bronchioles.
- The terminal bronchioles then give rise to a number of vascular bag-like structures called alveoli which have very thin walls.

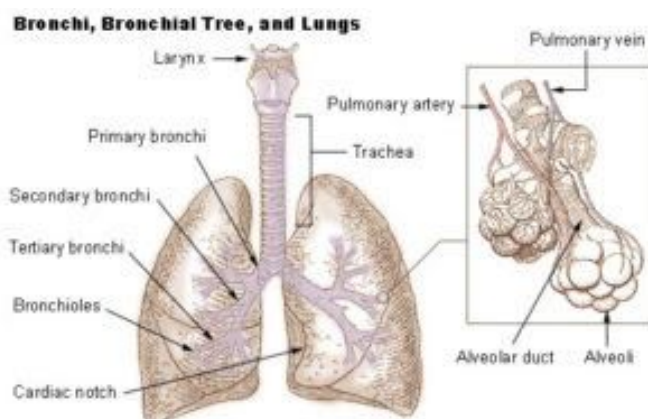


Parts of the human respiratory system.

This network consisting of bronchi, bronchioles, and alveoli forms the lung. Let's learn in more detail about the lungs.

Lungs

Humans have two lungs (right and left) that are covered by a double-layered covering pleura. The layers contain pleural fluid in the middle that helps to reduce friction on the lung surface. The inner pleural membrane is in close contact with the lung whereas the outer membrane is in contact with the thoracic lining.



Parts of the human lung. (Source: Wikimedia Commons)

In our body, the lungs are situated in an air-tight chamber called the thoracic chamber. This chamber consists of the vertebral column at the back, sternum in the front, ribs on the sides and diaphragm on the lower side. This setup of the lungs is such that any change in the

volume of the thoracic cavity will affect the lung cavity. This is very important for respiration.

Functions of the Respiratory Organs

In terms of function, the respiratory system has the following two parts:

1) Conducting part – This is the part from the nostrils to the terminal bronchioles. The conducting part has the following functions –

- Transport atmospheric air to the alveoli.
- Clear the air from foreign particles.
- Humidify the air.
- Bring the air to body temperature.

2) Respiratory/Exchange part – This part includes the alveoli and their ducts. Here, actual diffusion of oxygen and carbon dioxide between blood and atmospheric air happens.

Steps Involved in Respiration

- Breathing in of atmospheric air and breathing out of CO₂ produced in the alveoli.

- Diffusion of O_2 and CO_2 across the membrane of alveoli.
- Transport of gases across the body by the blood.
- Exchange of O_2 and CO_2 between blood and tissues.
- Cellular respiration which involves the use of O_2 by cells for catabolic reactions and release of CO_2 .

Solved Example For You

Q: The deficiency of which of the following factors causes 'Hypoxia'?

- O_2
- Water
- CO_2
- Vitamins

Solution: The answer is 'a'. Hypoxia is a condition where the body or a part of the body does not get enough oxygen supply.

Mechanism of Breathing

Do any of us have to think too much or make a lot of effort while breathing? No, right? It comes naturally to us the moment we are

born. But, did you know that while **breathing**, an act that seems simple to us, our **respiratory system** performs a lot of work! Our respiratory system is made of organs and muscles that help make this process smooth and easy. Let's learn how this system works.

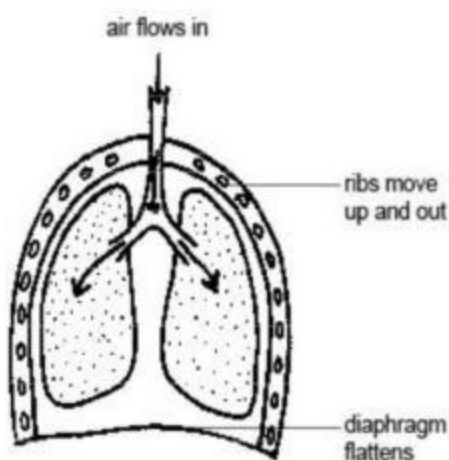
Mechanism Of Breathing

The respiratory system goes through two stages – Inspiration and Expiration. Let's understand what happens during these two stages. During inspiration, atmospheric air is drawn in while during expiration, air is expelled out. This movement of air in and out of the **lungs** is due to a pressure gradient between the atmosphere and the lungs.

If the pressure in the lungs is lower than the atmospheric pressure, then inspiration can take place. On the other hand, if the pressure in the lungs is higher than that of the atmosphere, then expiration takes place. This pressure gradient is due to the diaphragm and a special set of muscles in the respiratory system – the internal and external intercostals that are situated between the ribs.

Inspiration

What causes inspiration? The contraction of the diaphragm increases the volume of the thoracic chamber in the front and back. This volume is further increased by the contraction of external intercostal muscles which lifts up the ribs and sternum. Increase in the thoracic volume increases the pulmonary volume such that the intrapulmonary pressure is less than the atmospheric pressure. This forces the air to move from outside into the lungs i.e. inspiration.

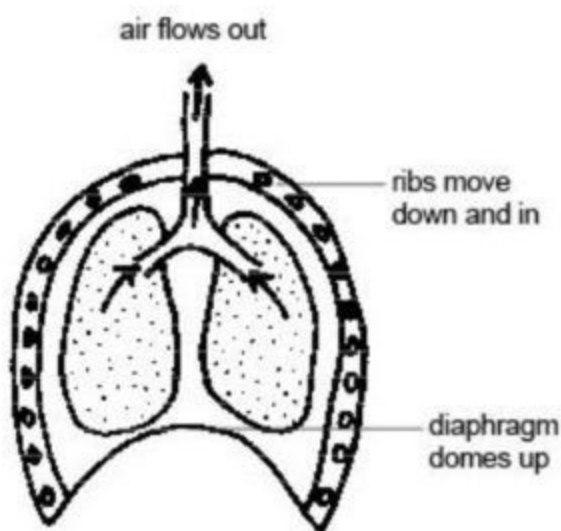


Process of inspiration (Source: Wikimedia Commons)

Expiration

How does expiration happen? When the diaphragm and the intercostal muscles relax, the ribs and sternum return to their normal positions. This reduces the thoracic volume and consequently, the pulmonary

volume. This makes the intra-pulmonary pressure higher than the atmospheric pressure causing the release of air from the lungs i.e. expiration.



Process of expiration (Source: Wikimedia Commons)

Additional muscles in the abdomen help to increase the strength of inspiration and expiration. The average rate of respiration of a healthy human is 12-16 breaths/minute. We can estimate the volume of air during breathing movements using a Spirometer. It helps to clinically assess pulmonary function.

Respiratory Volumes And Capacities

During clinical assessments, the following terms are used to describe respiratory volumes and capacities.

- **Tidal Volume (TV):** It is the volume of air inspired or expired during normal breathing. A healthy human can inspire or expire approximately 6000 to 8000 ml of air/minute. Therefore, the tidal volume is approximately 500 ml per inspiration.
- **Inspiratory Reserve Volume (IRV):** This refers to the additional volume of air a person can forcefully inspire. It is approximately 2500-3000 ml.
- **Expiratory Reserve Volume (ERV):** This refers to the additional volume of air a person can forcefully expire. It is approximately 1000-1100 ml.
- **Residual Volume (RV):** This is the volume of air that remains in the lungs even after a forcible expiration. This is approximately 1100-1200 ml.

The pulmonary capacities used in clinical assessment are derived by adding a few respiratory volumes described above.

- **Inspiratory Capacity (IC):** This is the volume of air a person can inspire after a normal expiration. It is the sum of tidal volume and inspiratory reserve volume ($TV + IRV$).
- **Expiratory Capacity (EC):** This refers to the volume of air a person can expire after a normal inspiration. It is the sum of tidal volume and expiratory reserve volume ($TV + ERV$).
- **Functional Residual Capacity (FRC):** This is the volume of air that remains in the lungs following a normal expiration. It is the sum of expiratory reserve volume and residual volume ($ERV + RV$).
- **Vital Capacity (VC):** It is the maximum volume of air a person can breathe out, following a forced inspiration. It is the sum of inspiratory and expiratory reserve volume and tidal volume ($IRV + ERV + TV$).
- **Total Lung Capacity:** It refers to the total volume of air the lungs can accommodate after a maximal inspiration. It is the sum of all the lung volumes ($TV + RV + IRV + ERV$) or vital capacity + residual volume ($VC + RV$).

A Solved Example For You

Q: If the tidal volume is 500 ml and the expiratory reserve volume is 1100 ml, what is the expiratory capacity?

- a. 1100 ml
- b. 500 ml
- c. 1600 ml
- d. 1500 ml

Solution: The answer is 'c'. The expiratory capacity is tidal volume + expiratory reserve volume. Therefore, it is $500 + 1100 = 1600$ ml.

Exchange and Transport of Gases in Lungs

Gas exchange is the process that occurs between **oxygen** and **carbon dioxide**. Oxygen is passed from the lungs to the bloodstream and carbon dioxide is eliminated from the bloodstream to the lungs.

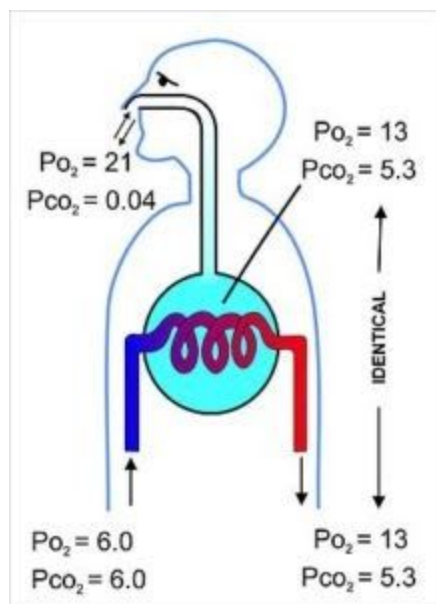
Exchange of Gas takes place in lungs between the alveoli and capillaries which are tiny blood vessels, placed at the walls of alveoli.

The rate of diffusion depends on the thickness of the biological membrane which forms the boundary between the external

environment and organisms. Let's learn more about how this gas exchange and transport take place.

Exchange Of Gases

Although the primary sites of gas exchange are the alveoli, exchange of O_2 and CO_2 also happens between blood and tissues. Gas exchange at these sites happens by simple diffusion based on a concentration/pressure gradient. The rate of diffusion depends not only on the solubility of gases but also on the thickness of the membranes involved in gas exchange.



Partial **pressure** is the pressure that comes from an individual gas in a **mixture** of gases. It is represented as pO_2 for oxygen and pCO_2 for carbon dioxide. The table below shows the partial pressures of these gases in the atmospheric air and different sites of gas exchange.

Respiratory Gas	Atmospheric air	Alveoli	Blood	Blood	Tissues
			(Deoxygenated)	(Oxygenated)	
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

The data in the above table clearly shows that there is a concentration gradient for O_2 from the alveoli to blood and blood to **tissues**.

Similarly, CO_2 has a concentration gradient in the opposite direction i.e. from tissues to blood and blood to the alveoli. The amount of CO_2 that can diffuse through a membrane is much higher than that of O_2 since the solubility of CO_2 is 20-25 times higher than that of O_2 .

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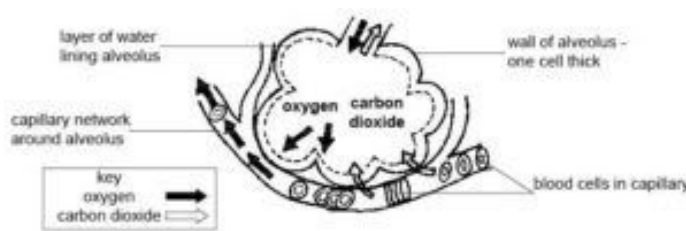
- [Respiratory Organs](#)
- [Mechanism of Breathing](#)
- [Regulation of Respiration](#)
- [Disorders of Respiratory System](#)

Diffusion Membrane

The diffusion membrane has three layers –

- The thin squamous epithelium of the alveoli.
- The endothelium containing alveolar capillaries.
- The basement substance between the epithelium and endothelium.

The total thickness of the diffusion membrane is less than a millimeter. All these factors in our body make it easy for the diffusion of O₂ from alveoli to tissues and that of CO₂ from the tissues to alveoli.



Cross section of an alveolus (Source: Wikimedia Commons)

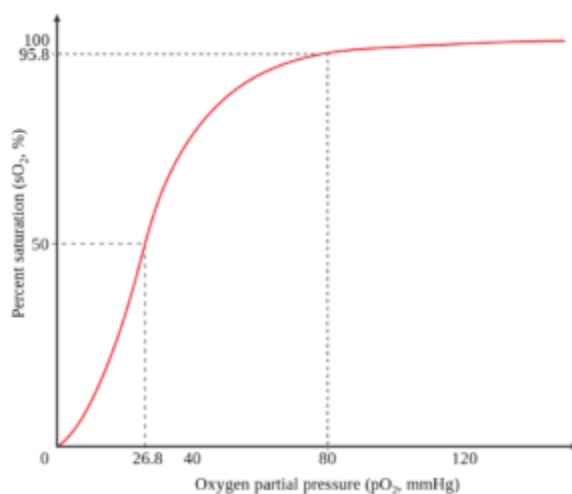
Transport Of Gases

The transport of O_2 and CO_2 happens through blood. The RBCs in the blood carry 97% of O_2 while plasma carries the remaining 3% of O_2 in a dissolved state. In case of CO_2 , the RBCs carry about 20-25%, plasma carries 7% of CO_2 in a dissolved state while the remaining 70% is carried as bicarbonate.

Transport Of Oxygen

O_2 binds reversibly to haemoglobin in blood to give oxyhaemoglobin. Haemoglobin is a red coloured pigment in the RBCs that contains iron. A maximum of 4 molecules of O_2 can bind to a **molecule** of haemoglobin. The partial pressure of O_2 is the primary factor that affects this binding. Other factors that can influence this binding are partial pressure of CO_2 , temperature and hydrogen **ion** concentration.

When we plot the percent of saturation of haemoglobin with O_2 against pO_2 , we get a sigmoid curve. This curve is the 'Oxygen Dissociation Curve' and is useful in studying the effects of H^+ concentration, pCO_2 etc, on the binding of O_2 with haemoglobin.



Oxygen Dissociation Curve (Source: Wikimedia Commons)

In the alveoli, there is high pO_2 , low pCO_2 , low temperature, and low H^+ concentration. These conditions are favourable for the formation of oxyhemoglobin. However, in the tissues, there is low pO_2 , high pCO_2 , high temperature, and high H^+ concentration which is favourable for the dissociation of O_2 from oxyhemoglobin.

This shows that O_2 binds to haemoglobin on the lung surface and gets dissociated in the tissues. Under normal physiological conditions,

every 100 ml of oxygenated blood delivers about 5 ml of O₂ to the tissues.

Transport Of Carbon Dioxide

Apart from O₂, haemoglobin also carries about 20-25% of CO₂, as carbamino-haemoglobin. This binding is primarily related to the partial pressure of CO₂, however, pO₂ is also a major factor that affects this binding. In the tissues, when the pCO₂ is high and pO₂ is low, more binding of CO₂ takes place. On the other hand, when pCO₂ is low and pO₂ is high in the alveoli, CO₂ dissociates from carbamino-haemoglobin formed in the tissues and is released in the alveoli.

The **enzyme** – carbonic anhydrase is present in high concentration in the RBCs. Small amounts of this enzyme are also present in plasma. This enzyme catalyzes the following reaction in both directions:



The partial pressure of CO₂ is high in the tissues due to catabolism. Here, CO₂ diffuses into the blood (plasma and RBCs) and gives rise to HCO₃⁻ and H⁺. The reaction takes place in the opposite direction in

the alveoli where the $p\text{CO}_2$ is low, leading to the formation of CO_2 and H_2O . Thus, at the tissue level, CO_2 is trapped as bicarbonate, transported to the alveoli and released as CO_2 . Under normal physiological conditions, every 100 ml of deoxygenated blood delivers about 4 ml of CO_2 to the alveoli.

Solved Example For You

Q: Which of the following factors is not favourable for oxyhaemoglobin formation in the alveoli?

- a. Low $p\text{CO}_2$
- b. High $p\text{O}_2$
- c. High H^+ concentration.
- d. Low temperature

Solution: The answer is 'c'. Formation of oxyhemoglobin requires low H^+ concentration.

Regulation of Respiration

What is respiration? Do humans have the ability to regulate their breathing? Yes, they do! Human beings can control their respiration to

suit the demands of the body [tissues](#). Which body system do you think is responsible for this regulation? It is the [nervous system](#). Special centres in the nervous system called ‘The respiratory centres of the brain’ regulate different aspects of respiration. Let’s learn about how these centres regulate respiration.

Respiration Centres Of The Brain

The neuronal signals transmitted between respiratory centres of the brain and the [muscles](#) in the chest and diaphragm modulate respiration. There are three main centres of the brain that regulate breathing. They are present in the medulla and the pons region of the brain. They regulate breathing by stimulating the contraction of the intercostal muscles and the diaphragm. Let’s take a closer look at these different centres.

Browse more Topics under Breathing And Exchange Of Gases

- [Respiratory Organs](#)
- [Mechanism of Breathing](#)
- [Exchange and Transport of Gases](#)
- [Disorders of Respiratory System](#)

In Medulla

Respiratory Rhythm Centre

Inspiration is followed by expiration, thus creating a regular, oscillating cycle of **breathing**. This is the respiratory rhythm. A special centre in the medulla region of the brain is primarily responsible for regulating respiratory rhythms. This is the 'Respiratory Rhythm Center'. This centre produces rhythmic nerve impulses that contract the muscles responsible for inspiration (diaphragm and external intercostal muscles).

Normally, expiration happens when these muscles relax. However, in case of rapid breathing, this centre stimulates the muscles responsible for expiration (internal intercostal muscles and abdominal muscles).

In The Pons

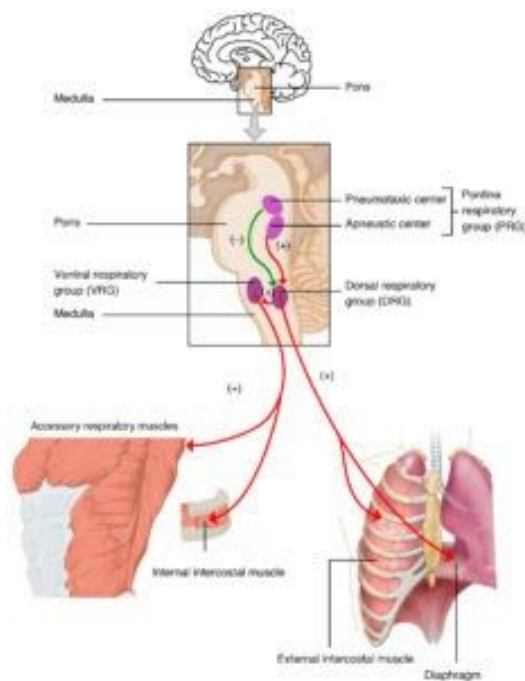
Pneumotaxic Centre

This centre regulates the functions of the respiratory rhythm centre. It controls both the rate and pattern of breathing. The pneumotaxic centre can send neural signals to reduce the duration of inspiration, thereby affecting the rate of respiration. The actions of this centre prevent the lungs from over-inflating.

It also regulates the amount of air that the body takes in, in a single breath. If this centre is absent, it increases the depth of breathing and decreases the respiratory rate. It performs the opposite function of the Apneustic centre described below.

Apneustic Centre

This centre promotes inspiration by constantly stimulating the neurons in the medulla region. It sends signals that oppose the action of the signals from the pneumotaxic centre. It sends positive signals to the neurons that regulate inspiration, thereby **controlling** the intensity of breathing.



There also exists a chemosensitive area in the brain stem adjacent to the respiratory rhythm centre. It is highly sensitive to CO₂ and hydrogen **ions**. Increase in CO₂ and H⁺ ions activate this centre, which in turn signals the rhythm centre to adjust the respiratory process and eliminate these substances.

In addition to respiratory centres, there are certain receptors also that can detect changes in CO₂ and H⁺ ion concentration and send signals to regulate breathing. Some of these are chemoreceptors located in the medulla, aortic arch, and carotid artery whereas some are receptors in the walls of bronchi and bronchioles.

Some factors that affect the rate of **respiration** are:

- **Temperature**
- CO₂ concentration
- **Water**
- **Light**

A Solved Example For You

Q: Which respiratory centres work against each other and together control the rate of respiration?

- a. Pneumotaxic centre and Apneustic centre
- b. Apneustic centre and Rhythm centre
- c. Pneumotaxic centre and Rhythm centre
- d. Chemosensitive area and Apneustic centre

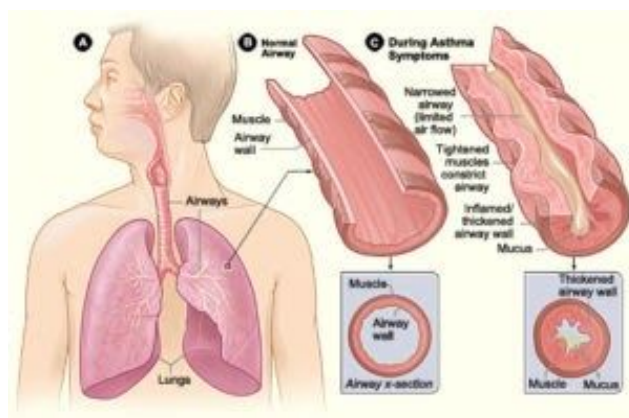
Solution: The answer is 'a'. The Pneumotaxic centre prevents over-inflation of the lungs, while the apneustic centre promotes over-inflation, thus controlling the rate of respiration.

Disorders of Respiratory System

We take our ability to breathe and our lungs for granted. But, did you know that respiratory diseases are leading causes of death around the world? Diseases such as bronchitis, asthma, tuberculosis etc, are on the rise worldwide. The rising level of pollution is one of the major reasons for this. Let's try to learn what are some of the common respiratory diseases and how it affects people.

Asthma

Asthma is a condition where a person finds it difficult to breathe due to inflammation of the bronchi and bronchioles. Common symptoms of asthma are wheezing, dry cough and shortness of breath. Multiple factors such as infection, pollution, allergic reactions etc. can trigger an asthmatic attack. Usually, asthma starts in childhood and carries on into adulthood. However, some people in their 60s or 70s can develop asthma. This is adult-onset asthma.



Asthmatic attack (Source: Wikimedia Commons)

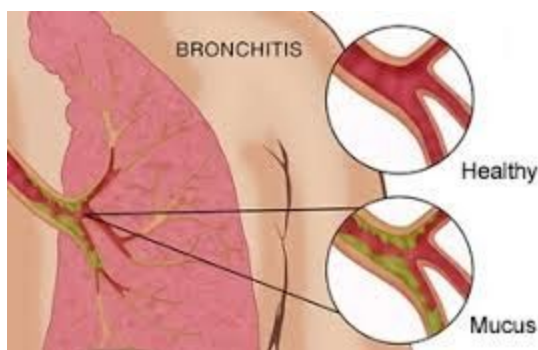
Chronic Obstructive Pulmonary Disease

Chronic Obstructive Pulmonary Disease (COPD) is a term that describes multiple respiratory diseases that cause breathlessness or affect normal exhalation. It is a serious disease where the symptoms include coughing up sputum (mucus from the lungs) and shortness of

breath. COPD can be tricky to diagnose because it can develop without any visible symptoms for a long time or the symptoms can be mistaken for the normal process of ageing. Cigarette smoking is one of the major causes of COPD.

Bronchitis

Chronic bronchitis is a form of COPD characterized by chronic coughing. Patients usually cough up sputum in the morning. Acute bronchitis, on the other hand, is not a long-term disease but is due to a viral or bacterial infection. Therefore, it is treatable with antibiotics and the symptoms subside once the infection is gone.

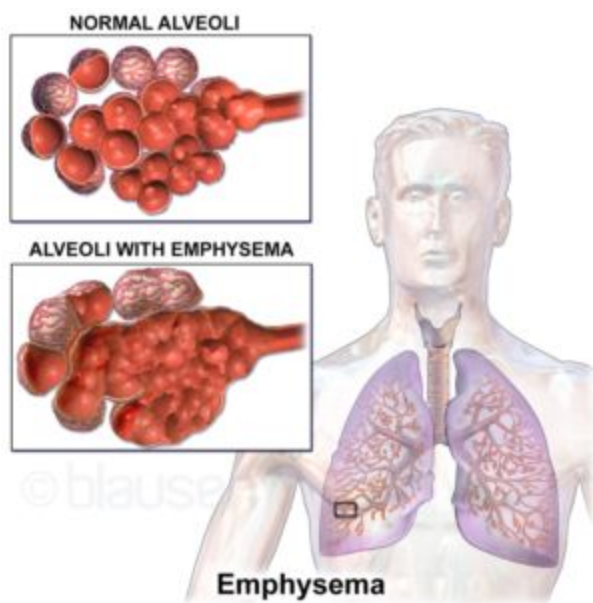


Bronchitis (Source: healthlifemedia.com)

Emphysema

It is another form of COPD and is a serious respiratory problem.

Cigarette smoking is a major cause which damages the alveolar walls thereby, decreasing the respiratory surface. It develops slowly over the years. Patients with emphysema have trouble exhaling air from their lungs. In extreme cases, there is respiratory failure and the need for extra oxygen to help with [breathing](#).

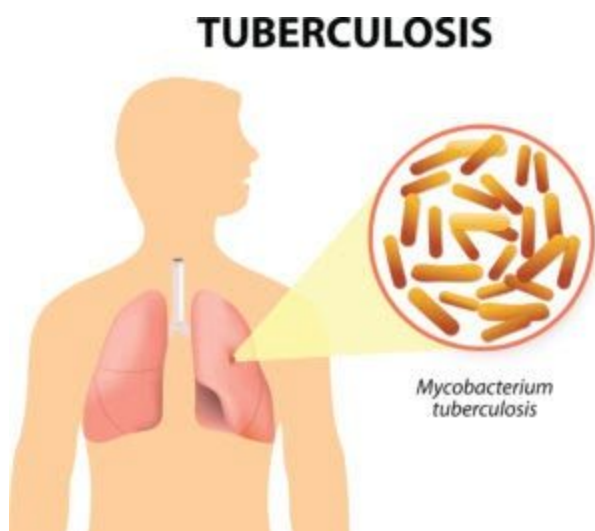


Emphysema (Source: Wikimedia Commons)

Tuberculosis

The bacterium *Mycobacterium tuberculosis* usually causes this infectious disease. Tuberculosis (TB) usually affects the lungs, but it can also affect other body parts. It spreads through the air when people

with active TB sneeze, cough, speak or spit. Most TB infections are symptomless and are called latent tuberculosis. 10% of these infections progress to active disease, which if not treated, can be fatal. Typical symptoms of TB include chronic cough with blood in the sputum, weight loss, fever and night sweats.



Tuberculosis (Source: allencountyhealth.com)

Obstructive Respiratory Disorders

These are disorders due to the working conditions of a certain occupation. In industries that involve stone-breaking or grinding, a lot of dust is generated which the body's defence system cannot handle. Prolonged exposure to this dust causes inflammation leading to fibrosis (excess fibrous tissue) that results in serious lung damage.

Workers in these industries can prevent this by wearing protective masks.

Other major respiratory diseases involve pneumonia, cystic fibrosis, and lung cancer. Therefore, some measures that we can take to reduce the occurrence of these diseases are to stop smoking and reduce environmental pollution.

Learn [Respiratory Organs](#) here in detail.

Solved Example For You

Q: Which of the following respiratory diseases is not due to a viral/bacterial infection?

- a. Acute bronchitis
- b. Emphysema
- c. Tuberculosis
- d. Asthma

Solution: The answer is ‘b’. Cigarette smoke is the major trigger of emphysema.