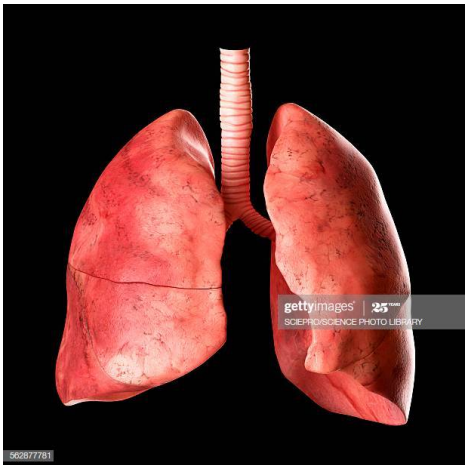
THE RESPIRATORY SYSTEM



Introduction

Respiratory System is crucial to every human being. Without it, we would cease to live outside of the womb. Let us begin by taking a look at the structure of the respiratory system and how vital it is to life. During inhalation or exhalation air is pulled towards or away from the lungs, by several cavities, tubes, and openings.

The organs of the respiratory system make sure that oxygen enters our bodies and carbon dioxide leaves our bodies.

The respiratory tract is the path of air from the nose to the lungs. It is divided into two sections: **Upper Respiratory Tract** and the **Lower Respiratory Tract**. Included in the upper respiratory tract are the **Nostrils**, **Nasal Cavities**, **Pharynx**, **Epiglottis**, and the **Larynx**. The lower respiratory tract consists of the **Trachea**, **Bronchi**, **Bronchioles**, and the **Lungs**.

As air moves along the respiratory tract it is warmed, moistened and filtered.

Functions

In this chaper we will discuss the four processes of respiration. They are:

1.**BREATHING** or ventilation

2.**EXTERNAL RESPIRATION**, which is the exchange of gases (oxygen and carbon dioxide) between inhaled air and the blood.

3.**INTERNAL RESPIRATION**, which is the exchange of gases between the blood and tissue fluids.

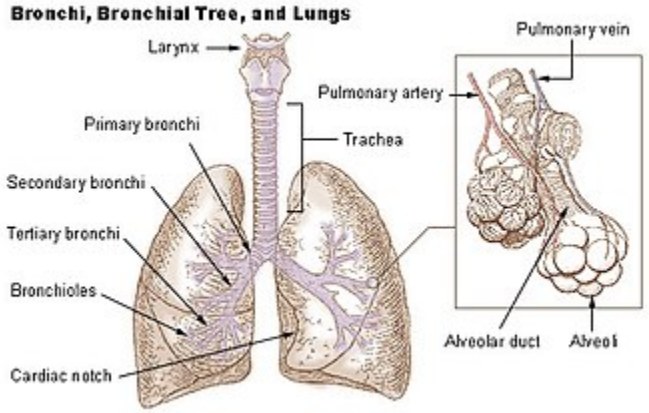
4.CELLULAR RESPIRATION

In addition to these main processes, the respiratory system serves for:
REGULATION OF BLOOD pH, which occurs in coordination with the kidneys, and as a

For: B Sc Hons. Biotechnology 4 Semester Paper 4 Human Physiology

DEFENSE AGAINST MICROBES

Breathing and Lung Mechanism



Ventilation is the exchange of air between the external environment and the alveoli. Air moves by bulk flow from an area of high pressure to low pressure. All pressures in the respiratory system are relative to atmospheric pressure (760mmHg at sea level). Air will move in or out of the lungs depending on the pressure in the alveoli. The body changes the pressure in the alveoli by changing the volume of the lungs. As volume increases pressure decreases and as volume decreases pressure increases. There are two phases of ventilation; inspiration and expiration. During each phase the body changes the lung dimensions to produce a flow of air either in or out of the lungs.

The body is able to change the dimensions of the lungs because of the relationship of the lungs to the thoracic wall. Each lung is completely enclosed in a sac called the pleural sac. 2 structures contribute to the formation of this sac. The parietal pleura is attached to the thoracic wall where as the visceral pleura is attached to the lung itself. In-between these two membranes is a thin layer of intrapleural fluid. The intrapleural fluid completely surrounds the lungs and lubricates the two surfaces so that they can slide across each other. Changing the pressure of this fluid also allows the lungs and the thoracic wall to move together during normal breathing. Much the way two glass slides with water in-between them are difficult to pull apart, such is the relationship of the lungs to the thoracic wall.

The rhythm of ventilation is also controlled by the "Respiratory Center" which is located largely in the medulla oblongota of the brain stem. This is part of the autonomic system and as such is not controlled voluntarily (one can increase or decrease breathing rate voluntarily, but that involves a different part of the brain). While resting, the respiratory center sends out action potentials that travel along the phrenic nerves into the diaphragm and the external intercostal muscles of the rib cage, causing inhalation. Relaxed exhalation occurs between impulses when the muscles relax. Normal adults have a breathing rate of 12-20 respirations per minute.

The Pathway of Air

By : Dr. Santosh Thakur, Lecturer, S.S. In Zoology and Biotechnology, Vikram University, Ujjain

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When one breathes air in at sea level, the inhalation is composed of different gases. These gases and their quantities are Oxygen which makes up 21%, Nitrogen which is 78%, Carbon Dioxide with 0.04% and others with significantly smaller portions.

In the process of breathing, air enters into the nasal cavity through the nostrils and is filtered by coarse hairs (**vibrissae**) and mucous that are found there. The vibrissae filter macroparticles, which are particles of large size. Dust, pollen, smoke, and fine particles are trapped in the mucous that lines the **nasal cavities** (hollow spaces within the bones of the skull that warm, moisten, and filter the air). There are three bony projections inside the nasal cavity. The **superior, middle, and inferior nasal conchae**. Air passes between these chonchae via the nasal meatuses.

Air then travels past the nasopharynx, oropharynx, and laryngopharynx, which are the three portions that make up the pharynx. The **pharynx** is a funnel-shaped tube that connects our nasal and oral cavities to the larynx. The **tonsils** which are part of the lymphatic system, form a ring at the connection of the oral cavity and the pharynx. Here, they protect against foreign invasion of antigens. Therefore the respiratory tract aids the immune system through this protection. Then the air travels through the **larynx**. The larynx closes at the epiglottis to prevent the passage of food or drink as a protection to our trachea and lungs. The larynx is also our voicebox; it contains vocal cords, in which it produces sound. Sound is produced from the vibration of the vocal cords when air passes through them.
The **trachea**, which is also known as our windpipe, has ciliated cells and mucous secreting cells lining it, and is held open by C-shaped cartilage rings. One of its functions is similar to the larynx and nasal cavity, by way of protection from dust and other particles. The dust will adhere to the sticky mucous and the cilia helps propel it back up the trachea, to where it is either swallowed or coughed up. The **mucociliary escalator** extends from the top of the trachea all the way down to the **bronchioles**, which we will discuss later. Through the trachea, the air is now able to pass into the bronchi.

Inspiration

Inspiration is initiated by contraction of the diaphragm and in some cases the intercostals muscles when they receive nervous impulses. During normal quiet breathing, the phrenic nerves stimulate the diaphragm to contract and move downward into the abdomen. This downward movement of the diaphragm enlarges the thorax. When necessary, the intercostal muscles also increase the thorax by contacting and drawing the ribs upward and outward.

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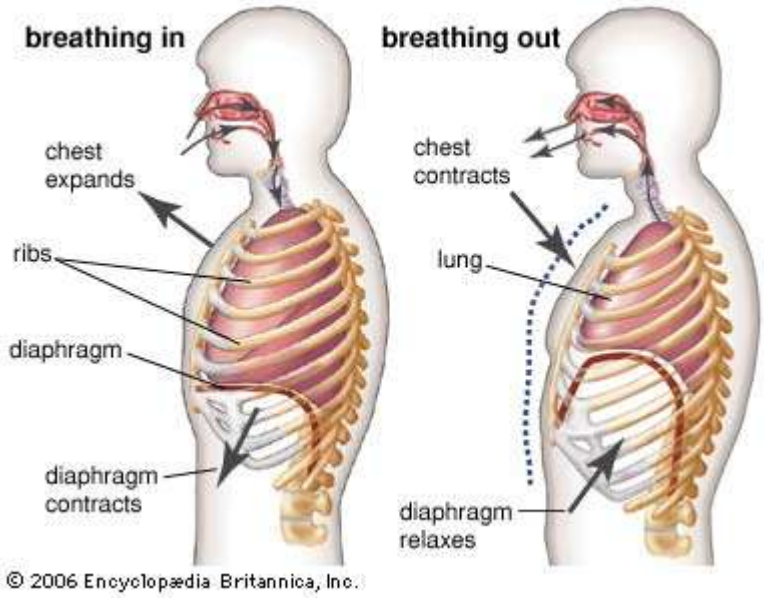


Expiration

During quiet breathing, expiration is normally a passive process and does not require muscles to work. When the lungs are stretched and expanded, stretchy receptors within the alveoli send inhibitory nerve impulses to the medulla oblongata, causing it to stop sending signals to the rib cage and diaphragm to relax and rise. This elastic recoil causes the lungs and chest cavity to shrink and increase the air pressure within the lungs. This increased positive air pressure pushes the air out of the lungs. Expiration happens as the diaphragm relaxes. Although the respiratory system is primarily under involuntary control, and regulated by the medulla oblongata, we have some voluntary control over it also. This is due to the higher brain function of the cerebral cortex.

When under physical or emotional stress, more frequent and deep breathing is needed, and both inspiration and expiration will work as active processes. Additional muscles in the rib cage forcefully contract and push more air out of the lungs. (This cannot occur during rest.) In addition to deeper breathing, when coughing or sneezing we exhale forcibly. Our abdominal muscles will contract suddenly (when there is an urge to cough or sneeze), raising the abdominal pressure. The rapid increase in pressure pushes the relaxed diaphragm up against the pleural cavity. This causes air to be forced out of the lungs.

Respiratory System: Upper and Lower Respiratory Tracts

For the sake of convenience, we will divide the respiratory system in to the upper and lower respiratory tracts:

Upper Respiratory Tract

The upper respiratory tract consists of the nose and the pharynx. Its primary function is to receive the air from the external environment and filter, warm, and humidify it before it reaches the delicate lungs where gas exchange will occur.

Air enters through the nostrils of the nose and is partially filtered by the nose hairs, then flows into the nasal cavity. The nasal cavity is lined with epithelial tissue, containing blood vessels, which help warm the air; and secrete mucous, which further filters the air. The endothelial lining of the nasal cavity also contains tiny hairlike projections, called cilia. The *cilia* serve to transport dust and other foreign particles, trapped in mucous, to the back of the nasal cavity and to the pharynx. There the mucus is either coughed out, or swallowed and digested by powerful stomach acids. After passing through the nasal cavity, the air flows down the pharynx to the larynx.

Lower Respiratory Tract

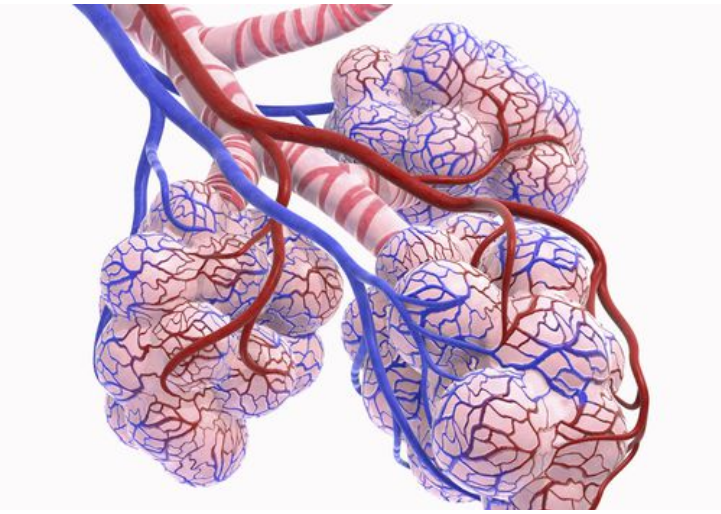
The lower respiratory tract starts with the larynx, and includes the trachea, the two bronchi that branch from the trachea, and the lungs themselves. This is where gas exchange actually takes place.

Larynx

The larynx (plural larynges), colloquially known as the voice box, is an organ in our neck involved in protection of the trachea and sound production. The larynx houses the vocal cords, and is situated just below where the tract of the pharynx splits into the trachea and the esophagus. The larynx contains two important structures: the epiglottis and the vocal cords.

The epiglottis is a flap of cartilage located at the opening to the larynx. During swallowing, the larynx (at the epiglottis and at the glottis) closes to prevent swallowed material from entering the lungs; the larynx is also pulled upwards to assist this process. Stimulation of the larynx by ingested matter produces a strong cough reflex to protect the lungs. Note: choking occurs when the esophagus fails to cover the trachea, and food becomes lodged in our windpipe.

The vocal cords consist of two folds of connective tissue that stretch and vibrate when air passes through them, causing vocalization. The length the vocal cords are stretched determines what pitch the sound will have. The strength of expiration from the lungs also contributes to the loudness of the sound. Our ability to have some voluntary control over the respiratory system enables us to sing and to speak. In order for the larynx to function and produce sound, we need air. That is why we can't talk when we're swallowing.



Homeostasis and Gas Exchange

Homeostasis is maintained by the respiratory system in two ways: gas exchange and regulation of blood pH. Gas exchange is performed by the lungs by eliminating carbon dioxide, a waste product given off by cellular respiration. As carbon dioxide exits the body, oxygen needed for cellular respiration enters the body through the lungs. ATP, produced by cellular respiration, provides the energy for the body to perform many functions, including nerve conduction and muscle contraction. Lack of oxygen affects brain function, sense of judgment, and a host of other problems.

Gas Exchange

Gas exchange in the lungs is between the alveolar air and the blood in the pulmonary capillaries. This exchange is a result of increased concentration of oxygen, and a decrease of C02.

External Respiration

External respiration is the exchange of gas between the air in the alveoli and the blood within the pulmonary capillaries. A normal rate of respiration is 10-20 breaths per minute. In external respiration, gases diffuse in either direction across the walls of the alveoli. Oxygen diffuses from the air into the blood and carbon dioxide diffuses out of the blood into the air. Most of the carbon dioxide is carried to the lungs in plasma as bicarbonate ions (HCO3-). When blood enters the pulmonary capillaries, the bicarbonate ions and hydrogen ions are converted to carbonic acid (H2CO3) and then back into carbon dioxide (CO2) and water. This chemical reaction also uses up hydrogen ions. The removal of these ions gives the blood a more neutral pH, allowing hemoglobin to bind up more oxygen.

Internal Respiration

Internal respiration is the exchanging of gases at the cellular level.

Right and Left Lungs

The **Right Primary Bronchus** is the first portion we come to, it then branches off into the **Lobar (secondary) Bronchi**, **Segmental (tertiary) Bronchi**, then to the **Bronchioles** which have little cartilage and are lined by simple cuboidal epithelium (See fig. 1). The bronchi are lined by pseudostratified columnar epithelium. Objects will likely lodge here at the junction of the Carina and the Right Primary Bronchus because of the vertical structure. Items have a tendency to fall in it, where as the Left Primary Bronchus has more of a curve to it which would make it hard to have things lodge there.

The **Left Primary Bronchus** has the same setup as the right with the lobar, semental bronchi and the bronchioles.

The lungs are attached to the heart and trachea through structures that are called the **roots of the lungs**. The roots of the lungs are the bronchi, pulmonary vessels, bronchial vessels, lymphatic vessels, and nerves. These structures enter and leave at the **hilus** of the lung which is "the depression in the medial surface of a lung that forms the opening through which the bronchus, blood vessels, and nerves pass" (medlineplus.gov).

There are a number of **terminal bronchioles** connected to **respiratory bronchioles** which then advance into the **alveolar ducts** that then become **alveolar sacs**. Each bronchiole terminates in an elongated space enclosed by many air sacs called **alveoli** which are surrounded by blood capillaries. Present there as well, are **Alveolar Macrophages**, they ingest any microbes

that reach the alveoli. The **Pulmonary Alveoli** are **microscopic**, which means they can only be seen through a microscope, membranous air sacs within the lungs. They are units of respiration and the site of gas exchange between the respiratory and circulatory systems.

Lung Capacity

The normal volume moved in or out of the lungs during quiet breathing is called **tidal volume**. When we are in a relaxed state, only a small amount of air is brought in and out, about 500 mL. You can increase both the amount you inhale, and the amount you exhale, by breathing deeply. Breathing in very deeply is **Inspiratory Reserve Volume** and can increase lung volume by 2900 mL, which is quite a bit more than the tidal volume of 500 mL. We can also increase expiration by contracting our thoracic and abdominal muscles. This is called **expiratory reserve volume** and is about 1400 ml of air. **Vital capacity** is the total of tidal, inspiratory reserve and expiratory reserve volumes; it is called vital capacity because it is vital for life, and the more air you can move, the better off you are. There are a number of illnesses that we will discuss later in the chapter that decrease vital capacity. Vital Capacity can vary a little depending on how much we can increase inspiration by expanding our chest and lungs. Some air that we breathe never even reaches the lungs! Instead it fills our nasal cavities, trachea, bronchi, and bronchioles. These passages aren't used in gas exchange so they are considered to be **dead air space**. To make sure that the inhaled air gets to the lungs, we need to breathe slowly and deeply. Even when we exhale deeply some air is still in the lungs,(about 1000 ml) and is called **residual volume**. This air isn't useful for gas exchange. There are certain types of diseases of the lung where residual volume builds up because the person cannot fully empty the lungs. This means that the vital capacity is also reduced because their lungs are filled with useless air.

Upper Respiratory Tract Infections

The upper respiratory tract consists of our nasal cavities, pharynx, and larynx. Upper respiratory infections (URI) can spread from our nasal cavities to our sinuses, ears, and larynx. Sometimes a viral infection can lead to what is called a secondary bacterial infection. **"Strep throat"** is a primary bacterial infection and can lead to an upper respiratory infection that can be generalized or even systemic (affects the body as a whole). Antibiotics aren't used to treat viral infections, but are successful in treating most bacterial infections, including strep throat. The symptoms of strep throat can be a high fever, severe sore throat, white patches on a dark red throat, and stomach ache.

Sinusitis

An infection of the cranial sinuses is called **sinusitis**. Only about 1-3% of URI's are accompanied by sinusitis. This "sinus infection" develops when nasal congestion blocks off the tiny openings that lead to the sinuses. Some symptoms include: post nasal discharge, facial pain that worsens when bending forward, and sometimes even tooth pain can be a symptom. Successful treatment depends on restoring the proper drainage of the sinuses. Taking a hot shower or sleeping upright can be very helpful. Otherwise, using a spray decongestant or sometimes a prescribed antibiotic

will be necessary.

Otitis Media

Otitis media in an infection of the middle ear. Even though the middle ear is not part of the respiratory tract, it is discussed here because it is often a complication seen in children who has a nasal infection. The infection can be spread by way of the '*auditory (Eustachian) tube* that leads form the nasopharynx to the middle ear. The main symptom is usually pain. Sometimes though, vertigo, hearing loss, and dizziness may be present. Antibiotics can be prescribed and tubes are placed in the eardrum to prevent the buildup of pressure in the middle ear and the possibility of hearing loss.

Tonsillitis

Tonsillitis occurs when the tonsils become swollen and inflamed. The tonsils located in the posterior wall of the nasopharynx are often referred to as adenoids. If you suffer from tonsillitis frequently and breathing becomes difficult, they can be removed surgically in a procedure called a tonsillectomy.

Laryngitis

An infection of the larynx is called laryngitis. It is accompanied by hoarseness and being unable to speak in an audible voice. Usually, laryngitis disappears with treatment of the URI. Persistent hoarseness without a URI is a warning sign of cancer, and should be checked into by your physician.

Lower Respiratory Tract Disorders

Lower respiratory tract disorders include infections, restrictive pulmonary disorders, obstructive pulmonary disorders, and lung cancer.

Lower Respiratory Infections

Acute bronchitis

An infection that is located in the primary and secondary bronchi is called bronchitis. Most of the time, it is preceded by a viral URI that led to a secondary bacterial infection. Usually, a nonproductive cough turns into a deep cough that will expectorate mucus and sometimes pus.

Pneumonia

A bacterial or viral infection in the lungs where the bronchi and the alveoli fill with a thick fluid. Usually it is preceded by influenza. Symptoms of pneumonia include high fever & chills, with headache and chest pain. Pneumonia can be located in several lobules of the lung and obviously, the more lobules involved, the more serious the infection. It can be caused by a bacteria that is usually held in check, but due to stress or reduced immunity has gained the upper hand.

Restrictive Pulmonary Disorders

Pulmonary Fibrosis

Vital capacity is reduced in these types of disorders because the lungs have lost their elasticity. Inhaling particles such as sand, asbestos, coal dust, or fiberglass can lead to **pulmonary fibrosis**,

a condition where fibrous tissue builds up in the lungs. This makes it so our lungs cannot inflate properly and are always tending toward deflation.

Asthma

Asthma is a respiratory disease of the bronchi and bronchioles. The symptoms include wheezing, shortness of breath, and sometimes a cough that will expel mucus. The airways are very sensitive to irritants which can include pollen, dust, animal dander, and tobacco. Even being out in cold air can be an irritant. When exposed to an irritant, the smooth muscle in the bronchioles undergoes spasms. Most asthma patients have at least some degree of bronchial inflammation that reduces the diameter of the airways and contributes to the seriousness of the attack. While asthma is not curable, it IS treatable.