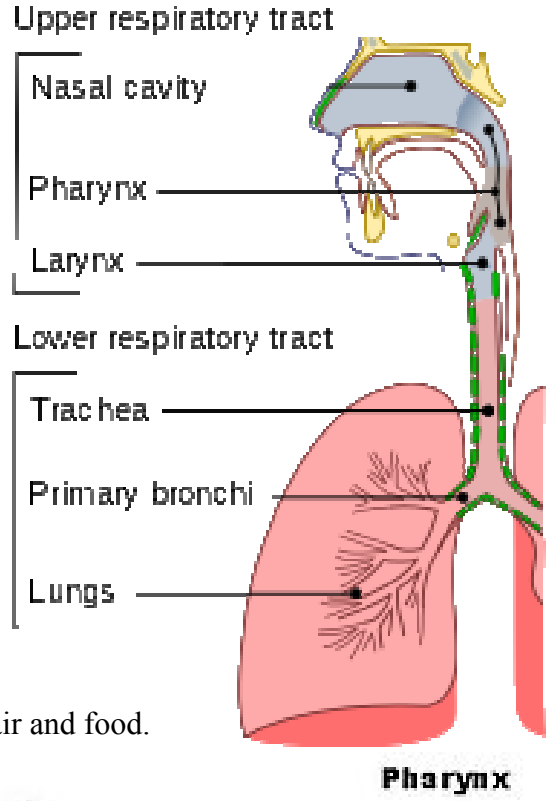
RESPIRATORY SYSTEM

1. The respiratory system, also called the gas exchange system, is the body getting rid of carbon dioxide and taking in oxygen.
2. Carbon dioxide, a waste product, goes out of the body. Oxygen, which the body needs, comes in. The lungs are the main organ to do this.

The first step in this process is breathing in air, or inhaling. Inhalation means bringing air rich in oxygen into the body. Exhalation means giving out air rich in carbon dioxide from the body. The second step is gas exchange in the lungs where oxygen is diffused into the blood and the carbon dioxide diffuses out of the blood. The third process is cellular respiration, which produces the chemical energy that the cells in the body need, and carbon dioxide. Finally, the carbon dioxide from cellular respiration is breathed out of body from the lungs.

Structure

The respiratory tract is divided into two sections: the upper airways and the lower airways. These two sections are separated by the vocal cords.



The nose and nasal cavity

The upper respiratory tract starts with the nose and the nasal cavity. When a person breathes in through the nose, the air goes into the nasal cavity. The nasal cavity is lined with mucous and little hairs called cilia. These help filter things like dust out of the air a person breathes. The nasal cavity also warms the air.

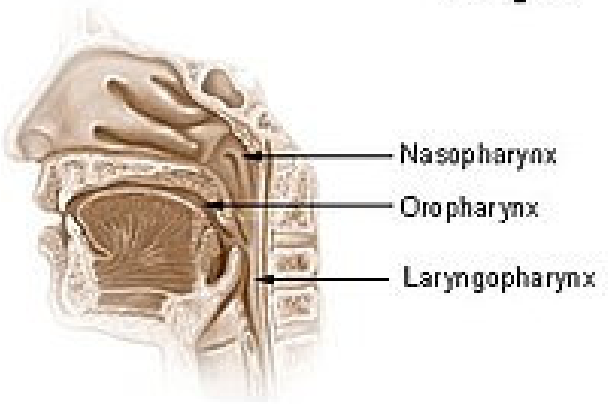
The pharynx

The parts of the pharynx

Next is the pharynx. The pharynx is a common pathway for air and food.

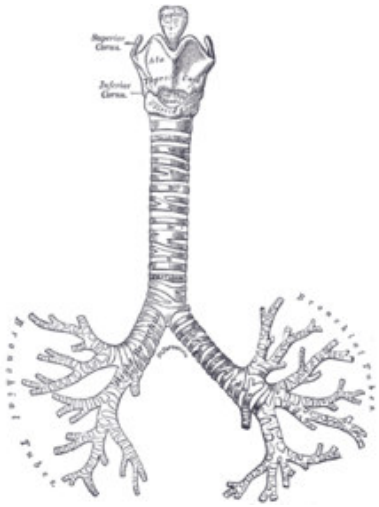
When a person breathes in, air goes through the pharynx on its way to the lungs. When a person eats, food passes through the pharynx on its way to the digestive system. There are three parts to the pharynx:

1. The nasopharynx ends around the uvula.
2. The oropharynx goes from the uvula to the base of the tongue.



3. The laryngopharynx (or hypopharynx) ends by splitting off into two tubes. These are the trachea and the esophagus. The trachea is in the front of the throat, and carries air toward the lungs. The esophagus is in the back of the throat, and carries food toward the digestive system.

The larynx



Drawing showing the larynx (at the top); the trachea (the straight tube), which splits into the mainstem bronchi; and the smaller bronchi that branch off the mainstem bronchi

The next part of the upper airways is the larynx. The larynx is sometimes called the "voice box" because it has the vocal cords in it, making it possible to speak. The larynx also protects the trachea. Important parts of the larynx include:

- The epiglottis: This is a leaf-shaped piece of cartilage which drops to protect the trachea when a person swallows food. This keeps the food from going down the trachea and into the lungs.
- The thyroid cartilage (Adam's apple)
- The vocal cords

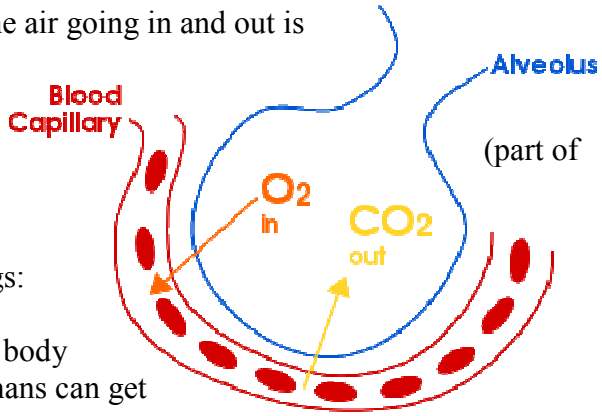
The larynx continues in the lower airways. Important parts of the larynx that are in the lower airways include:

- The cricoid cartilage: This is a ring of cartilage which anchors the trachea. The trachea begins at the cricoid cartilage.
- The trachea: This is a tube made of smooth muscle which brings air to the lungs. Because it is made of muscle, the trachea needs cartilage, which is stronger than muscle, to protect it. After the cricoid cartilage, many C-shaped pieces of cartilage surround the trachea to protect it and anchor it.

The bronchi

The trachea then splits into the two main bronchi. This split happens at a place called the carina, which is behind the middle of the sternum (breastbone). The bronchi are two tubes which carry air into the lungs. The main bronchi then split into smaller and smaller bronchi, which reach out into all the parts of the lungs like tree branches. Finally, the smallest bronchi, called bronchioles, end in the alveoli.

Breathing is moving air in and out of the lungs. The air going in and out is called *breath*. If a person cannot breathe, they will die. Gas exchange in humans. Oxygen and carbon dioxide switch places between a capillary (part of the bloodstream) and an alveolus (an air sac in the lungs).



Breathing helps people do two very important things:

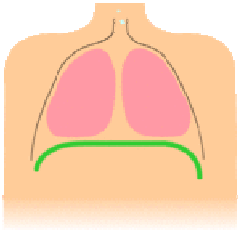
1. Get oxygen into the body. Every part of the body needs oxygen to survive. The only way humans can get oxygen is to breathe it in.
2. Get carbon dioxide (CO_2) out of the body. When the body makes energy, carbon dioxide gets left over. The body needs to get rid of extra carbon dioxide, because too much of it is poisonous. The only way humans can get rid of carbon dioxide is to breathe it out.

When a person breathes in, they bring air into their lungs. Air has oxygen in it. The oxygen goes from the lungs into the person's bloodstream. When oxygen goes into the bloodstream, extra carbon dioxide comes out and goes into the lungs. This is called gas exchange: basically, oxygen and carbon dioxide are changing places. Oxygen is now in the bloodstream, which can carry that oxygen around to every part of the body. Also, carbon dioxide is now in the lungs, where it can be breathed out.

Adults breathe about 18 times a minute, which is more than 25,000 times a day. Children breathe even faster.

Breathing muscles

For a person to breathe, certain muscles have to contract (get tighter) and relax at the right times. The special groups of neurons in the medulla tell these breathing muscles when to contract (which makes a person breathe in) and when to relax (which makes a person breathe out).There are a few main groups of muscles that control breathing.



Animation of how the diaphragm (in green) works

The diaphragm is the main muscle that controls breathing. It is a sheet of muscle that runs along the bottom of the rib cage. When the diaphragm is relaxed, it is shaped like a dome (like a half circle). When the medulla tells the diaphragm to make the body breathe in, the diaphragm pulls down and straightens out. This creates more room inside the chest, and more room for the lungs to fill up with air. Air comes into the lungs (this is inhalation). When it is time to breathe out, the diaphragm relaxes again and air leaves the lungs.[3]

About 60% - 70% of a person's ability to breathe comes from the diaphragm.

The diaphragm is controlled by a special set of nerves called the phrenic nerves. The medulla tells the diaphragm when to contract by sending messages through the phrenic nerves. Because the diaphragm is so important for breathing, the phrenic nerves are very well protected in the body. They are at the very top of the spinal cord, near the neck.

The intercostals (Rib muscles)
The intercostal muscles run between each rib. When a person needs to breathe in, these muscles contract and pull the ribs upward. This creates more room inside the chest for the lungs to fill.

When a person is resting, the about 30% to 40% of their ability to breathe comes from the intercostal muscles.

The intercostal muscles are controlled by the intercostal nerves. The medulla tells the intercostals when to contract by sending messages through these nerves. The intercostal nerves are not as well protected as the phrenic nerves. The intercostal nerves run along the thoracic spine (which is in the upper to middle back) and connect to the intercostal muscles. This means that if a person injured their thoracic spine, they might not be able to use their intercostal muscles. They would then lose 30% to 40% of their ability to breathe. However, since the nerves that control the diaphragm are much farther up in the spine and better protected, the person would still be able to use their diaphragm to breathe. They would still have 60% to 70% of their ability to breathe.[6]

Accessory muscles

Accessory muscles are muscles that a person uses only when they need extra help breathing. Sometimes this is normal. For example, if a person has just done a lot of exercise, they may need extra oxygen. The medulla will tell the accessory muscles to kick in, to make it easier for the person to lift their chest to create more room for the lungs to fill. The most important accessory muscles are the muscles in the chest, abdomen, and neck.

However, if a person has to use accessory muscles to breathe while they are resting, this is a sign that they are not getting the oxygen their body needs. They may need medication, extra oxygen given through a mask, or even emergency medical treatment to help them breathe normally. For example, people with asthma or chronic obstructive pulmonary disease (COPD) often use an inhaler when they have trouble breathing. The inhaler puffs a medicine like albuterol down into the windpipe and into the lungs. This makes the air passages wider and helps the person breathe better than they could before.

Breathing Mechanism

Breathing is the first step in respiration. For respiration to happen, the body needs a constant supply of oxygen, which is done by breathing. Inhalation is the breathing in of air. To inhale, the lungs expand, decreasing the air pressure in the lungs. This is caused by two actions. The diaphragm (a sheet of muscular tissue that separates the lungs from the abdomen) is pulled

downward. Also the muscles between the ribs contract to expand the chest. Both of these actions expand the lungs. To fill the enlarged lungs, air from outside at higher pressure comes rushing into the area of low pressure in the lungs. Air first passes through the nose and mouth, then through the larynx (voice box), then down the trachea (windpipe), and into the lungs and comes out.

The lungs are made of many tubes or branches. As air enters the lungs, it first goes through branches called the bronchi, then through smaller branches called bronchioles, and finally into the air sacs. Gas exchange occurs in the air sacs where oxygen is exchanged with carbon dioxide. The carbon dioxide in the air sacs now need to be exhaled, or breathed out. In the reverse process to inhaling, the diaphragm and the rib muscles relax, causing the lungs to be smaller. As the air pressure in the lungs is greater when the lungs are smaller, air is forced out. The exhaled air has a high concentration of carbon dioxide and a low concentration of oxygen. The maximum volume of air that can be breathed in and breathed out is called the vital capacity of the lungs and is up to five liters.

Lung volumes and capacity

Lung volumes are also known as respiratory volumes. It refers to the volume of gas in the lungs at a given time during the respiratory cycle. Lung capacities are derived from a summation of different lung volumes. The average total lung capacity of an adult human male is about 6 litres of air. Lung volumes measurement is an integral part of pulmonary function test. These volumes tend to vary, depending on the depth of respiration, ethnicity, gender, age, body composition and in certain respiratory diseases. A number of the lung volumes can be measured by Spirometry- Tidal volume, Inspiratory reserve volume, and Expiratory reserve volume. However, measurement of Residual volume, Functional residual capacity, and Total lung capacity is through body plethysmography, nitrogen washout and helium dilution technique.

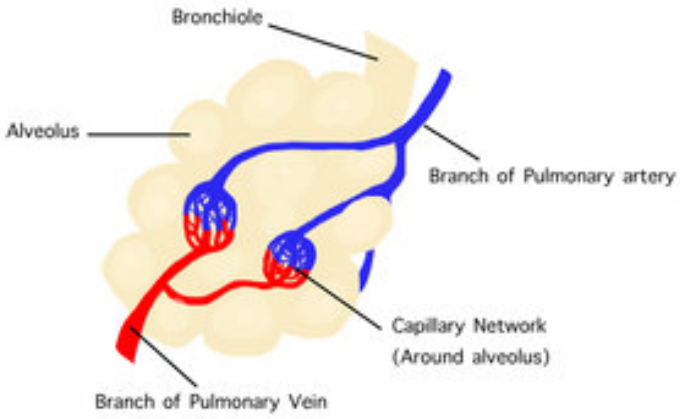
Lung Volumes

- **Tidal Volume(TV):** It is the amount of air that can be inhaled or exhaled during one respiratory cycle This depicts the functions of the respiratory centres, respiratory muscles and the mechanics of the lung and chest wall. The normal adult value is 10% of vital capacity (VC), approximately 300-500ml (6-8 ml/kg) but can increase up to 50% of VC on exercise
- **Inspiratory Reserve Volume(IRV)**: It is the amount of air that can be forcibly inhaled after a normal tidal volume.IRV is usually kept in reserve, but is used during deep breathing. The normal adult value is 1900-3300ml.
- **Expiratory Reserve Volume(ERV):** It is the volume of air that can be exhaled forcibly after exhalation of normal tidal volume. The normal adult value is 700-1200ml. ERV is reduced with obesity, ascites or after upper abdominal surgery.

- **Residual Volume(RV):** It is the volume of air remaining in the lungs after maximal exhalation. Normal adult value is averaged at 1200ml(20-25 ml/kg) .It is indirectly measured from summation of FRC and ERV and cannot be measured by spirometry.

Gas exchange

The inhaled air goes down to the air sacs at the end of each bronchiole. The air sacs are called alveoli — they have a large surface area, and are moist, thin, and close to a blood supply. The inhaled air has a much greater concentration of oxygen than carbon dioxide whilst the blood flowing to the lungs has a more carbon dioxide than oxygen. This creates a concentration gradient between the air in the air sacs and the blood, meaning there is more oxygen in the air than the blood.



As the membrane, oxygen can easily diffuse in and out. Oxygen at high concentration in the air sacs diffuses into the blood where oxygen concentration is low, and carbon dioxide at high concentration in the blood diffuses into the air sacs where carbon dioxide concentration is low. The oxygen in the blood enters the circulatory system and is used by the cells in the body. The carbon dioxide in the air sacs are exhaled out of the body.

Function

The airways' job is to bring air to the lungs, so it can get to the alveoli. At the alveoli, a very important process called "gas exchange" takes place. Oxygen from the air breathed into the lungs goes into the blood. The blood can then carry oxygen to every part of the body through the bloodstream. During gas exchange, carbon dioxide goes from the blood into the lungs, so it can be breathed out. If this exchange of gases did not happen, the body would not get enough oxygen to stay alive, and would also get poisoned by carbon dioxide.

Regulation of breathing breathing

A part of the brainstem called the medulla oblongata controls breathing. Groups of neurons in the medulla tell the breathing muscles when to breathe in, when to breathe faster, and when to breathe slower. The brainstem measures how much carbon dioxide is in a person's blood. If there is too much carbon dioxide, the medulla tells the body to breathe faster. This helps the person breathe out the extra carbon dioxide. Once the amount of carbon dioxide in the blood is normal again, the medulla tells the body to breathe slower again.

The body also measures the amount of oxygen in the blood. If there is not enough oxygen in the blood, the medulla will tell the body to breathe faster, to take in more oxygen. Once there is enough oxygen in the blood, the medulla will tell the body to breathe slower again.

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