Parts of respiratory system

The respiratory system is the network of organs and tissues that help you breathe. It includes your airways, lungs and blood vessels. The muscles that power your lungs are also part of the respiratory system. These parts work together to move oxygen throughout the body and clean out waste gases like carbon dioxide.

Features of the Human Respiratory System

The respiratory system in humans has the following important features:

- The energy is generated by the breakdown of glucose molecules in all living cells of the human body.
- Oxygen is inhaled and is transported to various parts and are used in the process of burning food particles (breaking down glucose molecules) at the cellular level in a series of chemical reactions.
- The obtained glucose molecules are used for discharging energy in the form of ATP- (adenosine triphosphate)

FUNCTION

The respiratory system has many functions. Besides helping you inhale (breathe in) and exhale (breathe out), it:

- Allows you to talk and to smell.
- Warms air to match your body temperature and moisturizes it to the humidity level your body needs.
- Delivers oxygen to the cells in your body.
- Removes waste gases, including carbon dioxide, from the body when you exhale.
- Protects your airways from harmful substances and irritants.

ANATOMY

The respiratory system has many different parts that work together to help you breathe. Each group of parts has many separate components.

Your airways deliver air to your lungs. Your airways are a complicated system that includes your:

- **Mouth and nose:** Openings that pull air from outside your body into your respiratory system. Humans have exterior nostrils, which are divided by a framework of cartilaginous structure called the septum. This is the structure that separates the right nostril from the left nostril. Tiny hair follicles that cover the interior lining of nostrils act as the body's first line of defence against foreign pathogens. Furthermore, they provide additional humidity for inhaled air.
- **Sinuses:** Hollow areas between the bones in your head that help regulate the temperature and humidity of the air you inhale.

Larynx

Two cartilaginous chords lay the framework for the larynx. It is found in front of the neck and is responsible for vocals as well as aiding respiration. Hence, it is also informally called the voice box. When food is swallowed, a flap called the epiglottis folds over the top of the windpipe and prevents food from entering into the larynx.

- **Pharynx (throat):** Tube that delivers air from your mouth and nose to the trachea (windpipe). The nasal chambers open up into a wide hollow space called the pharynx. It is a common passage for air as well as food. It functions by preventing the entry of food particles into the windpipe. The epiglottis is an elastic cartilage, which serves as a switch between the larynx and the oesophagus by allowing the passage of air into the lungs, and food in the gastrointestinal tract.
- **Trachea:** Passage connecting your throat and lungs. The trachea or the windpipe rises below the larynx and moves down to the neck. The walls of the trachea comprise C-shaped cartilaginous rings which give hardness to the trachea and maintain it by completely expanding. The trachea extends further down into the breastbone and splits into two bronchi, one for each lung.
- **Bronchial tubes:** Tubes at the bottom of your windpipe that connect into each lung. The trachea splits into two tubes called the bronchi, which enter each lung individually. The bronchi divide into secondary and tertiary bronchioles, and it further branches out into small air-sacs called the alveoli. The alveoli are single-celled sacs of air with thin walls. It facilitates the exchange of oxygen and carbon dioxide molecules into or away from the bloodstream.
- **Lungs:** Two organs that remove oxygen from the air and pass it into your blood. Lungs are the primary organs of respiration in humans and other vertebrates. They are located on either side of the heart, in the thoracic cavity of the chest. Anatomically, the lungs are spongy organs with an estimates total surface area between 50 to 75 sq meters. The primary function of the lungs is to facilitate the

exchange of gases between the blood and the air. Interestingly, the right lung is quite bigger and heavier than the left lung.

The functional units of respiration and are key to survival (each lung weighing approximately 1.1 kg). The structure of the lung is well suited for efficient exchange of respiratory gases.

- Through the airway and vascular trees, fresh gases and venous blood are delivered to and removed from a large alveolar capillary surface area.
- In an adult, inhaled air enters the trachea and is delivered to the alveoli with a surface area of ∼140 m2, roughly the size of a tennis court.
- Similarly, the pulmonary vascular tree begins as the main pulmonary artery and repeatedly bifurcates into arterioles and capillaries that cover 85–95% of the alveolar surface.
- An exceptionally thin membrane of only 1 μm separates the alveolar gas and blood compartments, allowing gases to diffuse rapidly between them.
- Due to the relatively large blood volume within the alveolar capillaries, blood flow slows and the transit time for blood increases, normally to 0.25–0.75 s, allowing more time for gas exchange.
- The fantastic design that allows this gas exchange within the thoracic cavity has been highlighted by comparing this engineering feat to that of folding a letter so that it fits into a thimble[6].
- Lungs are affected by a wide range of pathology that results in a diverse range of illnesses.
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From your lungs, your bloodstream delivers oxygen to all your organs and other tissues.

Muscles and bones help move the air you inhale into and out of your lungs. Some of the bones and muscles in the respiratory system include your:

- **Diaphragm:** Muscle that helps your lungs pull in air and push it out.
- **Ribs:** Bones that surround and protect your lungs and heart.

When you breathe out, your blood carries carbon dioxide and other waste out of the body. Other components that work with the lungs and blood vessels include:

- **Alveoli:** Tiny air sacs in the lungs where the exchange of oxygen and carbon dioxide takes place. Bronchioles end in tiny air sacs called alveoli, where the exchange of oxygen and carbon dioxide actually takes place. Each person has hundreds of millions of alveoli in their lungs.

The Thorax houses the bronchial tree, lungs, heart, and other structures.

- The top and sides of the thorax are formed by the ribs and attached muscles, and the bottom is formed by the diaphragm.
- The chest walls form a protective cage around the lungs and other contents of the chest cavity

The alveoli (singular: alveolus) are tiny hollow air sacs that comprise the basic unit of respiration.

Alveoli are found within the lung parenchyma and are found at the terminal ends of the respiratory tree, clustered around alveolar sacs and alveolar ducts. Each alveolus is approximately 0.2 mm in diameter. There are around 300 million to 1 billion alveoli in the human lungs, covering an area of 70 square metres.

- The alveolar walls are comprised of collagen and elastic fibres which facilitate expansion during inspiration and return to the original shape during expiration. There are numerous capillaries within the alveolar walls where gas exchange occurs. Pores of Kohn are also located within the walls.
- Alveoli contain two major types of epithelial cells. The most abundant, type 1 pneumocytes (95%) are squamous cells in which gas exchange occurs. The remaining 5%, type 2 pneumocytes, are granular cells which secrete surfactant. Surfactant is a lipoprotein with a high phospholipid content which reduces surface tension. This increases pulmonary compliance, prevents atelectasis and aids recruitment of collapsed airways.
- Alveolar macrophages are also located in the alveoli. They protect the alveoli from foreign material by engulfing it, including bacteria, dust and carbon particles[8].

Gas exchange occurs in the lungs between alveolar air and blood of the pulmonary capillaries. For effective gas exchange to occur, alveoli must be ventilated and perfused. Ventilation (V) refers to the flow of air into and out of the alveoli, while perfusion (Q) refers to the flow of blood to alveolar capillaries.

- Individual alveoli have variable degrees of ventilation and perfusion in different regions of the lung.
- Collective changes in ventilation and perfusion in the lungs are measured clinically using the ratio of ventilation to perfusion (V/Q).
- Changes in the V/Q ratio can affect gas exchange and can contribute to hypoxemia

- **Bronchioles:** Small branches of the bronchial tubes that lead to the alveoli.
- **Capillaries:** Blood vessels in the alveoli walls that move oxygen and carbon dioxide.
- **Lung lobes:** Sections of the lungs — three lobes in the right lung and two in the left lung.
- **Pleura:** Thin sacs that surround each lung lobe and separate your lungs from the chest wall.

Some of the other components of your respiratory system include:

- **Cilia:** Tiny hairs that move in a wave-like motion to filter dust and other irritants out of your airways.
- **Epiglottis:** Tissue flap at the entrance to the trachea that closes when you swallow to keep food and liquids out of your airway.
- **Larynx (voice box):** Hollow organ that allows you to talk and make sounds when air moves in and out.

Respiratory Tract

The respiratory tract in humans is made up of the following parts:

- **External nostrils** – For the intake of air.
- **Nasal chamber** – which is lined with hair and mucus to filter the air from dust and dirt.
- **Pharynx** – It is a passage behind the nasal chamber and serves as the common passageway for both air and food.
- **Larynx** – Known as the soundbox as it houses the vocal chords, which are paramount in the generation of sound.
- **Epiglottis** – It is a flap-like structure that covers the glottis and prevents the entry of food into the windpipe.
- **Trachea** – It is a long tube passing through the mid-thoracic cavity.

- **Bronchi** – The trachea divides into left and right bronchi.
- **Bronchioles** – Each bronchus is further divided into finer channels known as bronchioles.
- **Alveoli** – The bronchioles terminate in balloon-like structures known as the alveoli.
- **Lungs** – Humans have a pair of lungs, which are sac-like structures and covered by a double-layered membrane known as pleura.

Air is inhaled with the help of nostrils, and in the nasal cavity, the air is cleansed by the fine hair follicles present within them. The cavity also has a group of blood vessels that warm the air. This air then passes to the pharynx, then to the larynx and into the trachea.

The trachea and the bronchi are coated with ciliated epithelial cells and goblet cells (secretory cells) which discharge mucus to moisten the air as it passes through the respiratory tract. It also traps the fine bits of dust or pathogen that escaped the hair in the nasal openings. The motile cilia beat in an ascending motion, such that the mucus and other foreign particles are carried back to the buccal cavity where it may either be coughed out (or swallowed.)

Once the air reaches the bronchus, it moves into the bronchioles, and then into the alveoli.

Respiratory System Functions

The functions of the human respiratory system are as follows:

Inhalation and Exhalation

The respiratory system helps in breathing (also known as pulmonary ventilation.) The air inhaled through the nose moves through the pharynx, larynx, trachea and into the lungs. The air is exhaled back through the same pathway. Changes in the volume and pressure in the lungs aid in pulmonary ventilation.

Exchange of Gases between Lungs and Bloodstream

Inside the lungs, the oxygen and carbon dioxide enter and exit respectively through millions of microscopic sacs called alveoli. The inhaled oxygen diffuses into the pulmonary capillaries, binds to haemoglobin and is pumped through the bloodstream. The carbon dioxide from the blood diffuses into the alveoli and is expelled through exhalation.

Exchange of Gases between Bloodstream and Body Tissues

The blood carries the oxygen from the lungs around the body and releases the oxygen when it reaches the capillaries. The oxygen is diffused through the capillary walls into the body tissues. The carbon dioxide also diffuses into the blood and is carried back to the lungs for release.

The Vibration of the Vocal Cords

While speaking, the muscles in the larynx move the arytenoid cartilage. These cartilages push the vocal cords together. During exhalation, when the air passes through the vocal cords, it makes them vibrate and creates sound.

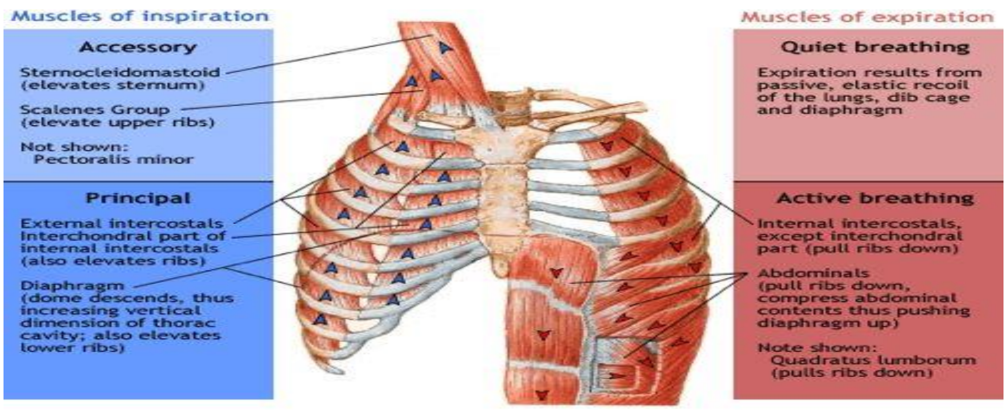
Olfaction or Smelling

During inhalation, when the air enters the nasal cavities, some chemicals present in the air bind to it and activate the receptors of the nervous system on the cilia. The signals are sent to the olfactory bulbs via the brain.

Respiration is one of the metabolic processes which plays an essential role in all living organisms. However, lower organisms like the unicellular do not "breathe" like humans – intead, they utilise the process of diffusion. Annelids like earthworms have a moist cuticle which helps them in gaseous exchange. Respiration in fish occurs through special organs called gills. Most of the higher organisms possess a pair of lungs for breathing.

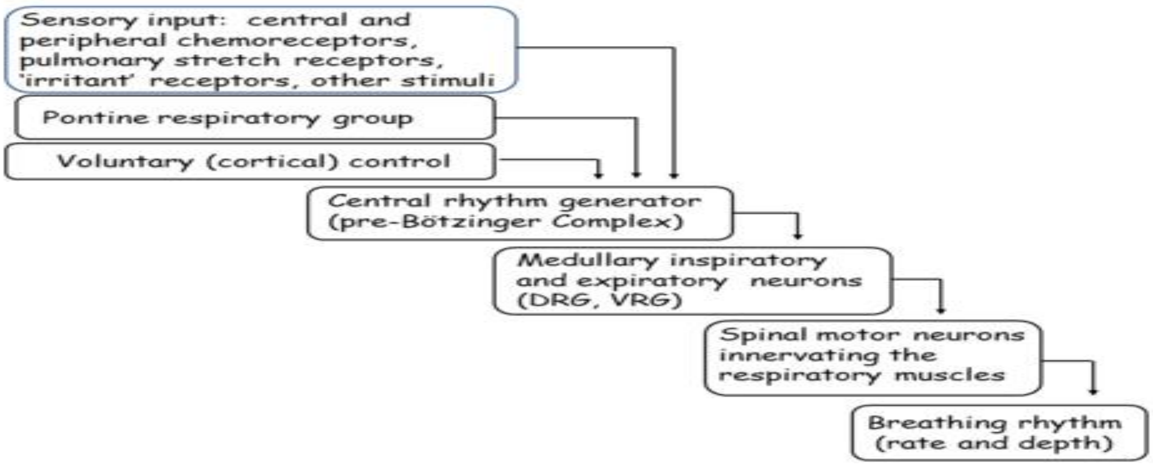
How the Respiratory System Works

The cells in our bodies need oxygen to stay alive. Carbon dioxide is a by-product of respiration. The lungs and respiratory system allow oxygen in the air to be taken into the body, while also letting the body get rid of carbon dioxide in the air breathed out.



- When you breathe in, the diaphragm moves downward toward the abdomen, and the rib muscles pull the ribs upward and outward (making the chest cavity bigger and pulling air through the nose or mouth into the lungs). See muscles of Respiration.
- In exhalation, the diaphragm moves upward and the chest wall muscles relax, which causes the chest cavity to get smaller and push air out of the respiratory system through the nose or mouth.
- With each inhalation, air fills a large portion of the millions of alveoli. Oxygen diffuses from the alveoli to the blood through the capillaries lining the alveolar walls. Once in the bloodstream, oxygen gets picked up by the hemoglobin in red blood cells. This oxygen-rich blood then flows back to the heart, which pumps it through the arteries to oxygen needy tissues throughout the body.
- In the capillaries of the body tissues, oxygen is freed from the hemoglobin and moves into the cells.
- Carbon dioxide produced moves out of the cells into the capillaries, where most of it dissolves in the plasma of the blood.
- Blood rich in carbon dioxide then returns to the heart via the veins.
- From the heart, this blood is pumped to the lungs, where carbon dioxide passes into the alveoli to be exhaled[1].

Control of Respiratory Rate



Breathing is an automatic and rhythmic act produced by networks of neurons in the hindbrain (the pons and medulla). Complex procedure see image R.

- The neural networks direct muscles that form the walls of the thorax and abdomen and produce pressure gradients that move air into and out of the lungs.
- The respiratory rhythm and the length of each phase of respiration are set by reciprocal stimulatory and inhibitory interconnection of these brain-stem neurons.

An important characteristic of the human respiratory system is its ability to adjust breathing patterns to changes in both the internal and the external environment.[10]

- Ventilatory rate (minute volume) is tightly controlled and determined primarily by blood levels of carbon dioxide as determined by metabolic rate.
- Chemoreceptors can detect changes in blood pH that require changes in involuntary respiration to correct.The apneustic (stimulating) and pnuemotaxic (limiting) centers of the pons work together to control rate of breathing.
- The medulla sends signals to the muscles that initiate inspiration and expiration and controls nonrespiratory air movement reflexes, like coughing and sneezing.

The motor cortex within the cerebral cortex of the brain controls voluntary respiration (the ascending respiratory pathway).

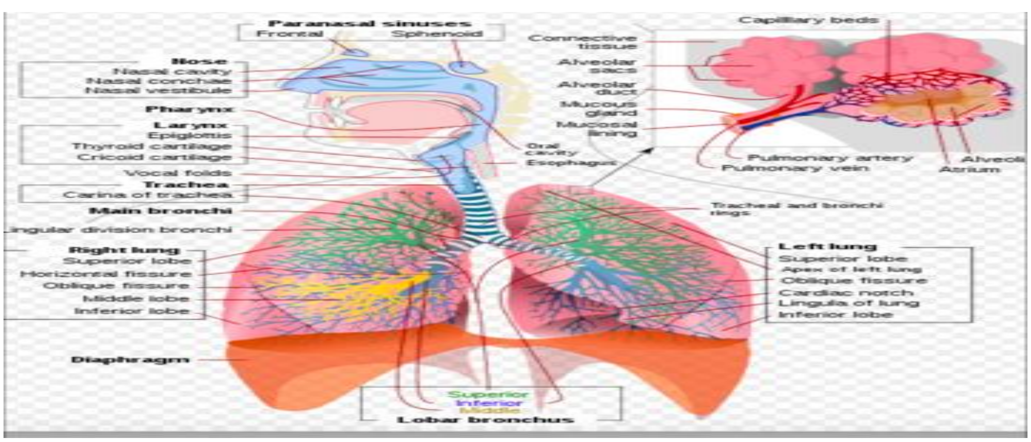
- Voluntary respiration may be overridden by aspects of involuntary respiration, such as chemoreceptor stimulus, and hypothalamus stress response.
- The phrenic nerves, vagus nerves, and posterior thoracic nerves are the major nerves involved in respiration.
- Voluntary respiration is needed to perform higher functions, such as voice control.

Lung Volumes and Lung Capacity

The lung capacities of different animals vary based on their activities. E.g., the lung capacity of cheetahs is much higher than humans. This is because they require a large amount of oxygen for their muscles that help them to run fast. The lung capacity of elephants is also higher due to their large body size.

A human lung can hold a maximum of six litres of air. The volume of air involved in the breathing process can be evaluated with the help of a spirometer. It is an equipment which is used to examine the total volume of air inhaled and exhaled by the lungs. It is also used in testing the pulmonary function.

The air in the lungs is measured in terms of lung volume and lung capacity. Lung volume measures the amount of air for inhalation or exhalation. Whereas, lung capacity measures how much air can be inhaled from the end of a maximal exhalation.



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Lung Volumes

The lung volume can be described by the following terms:

Tidal Volume

The tidal volume is the total amount of air inhaled or exhaled during regular respiration or relaxed breathing. Approximately 500 ml of air is utilized during normal respiration in a healthy man.

Inspiratory Reserve Volume

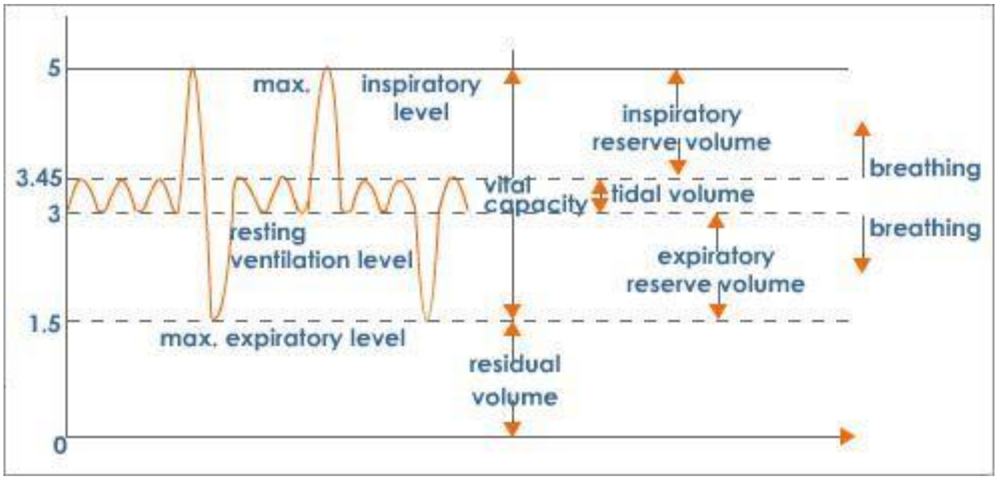
An inspiratory reserve volume is a supplementary volume, approximately ranging between 2500 to 3100 ml of air which could be effectively inhaled after the inspiration of a standard tidal volume.

Expiratory Reserve Volume

An expiratory reserve volume refers to the additional capacity of air which is about 1200 ml are that could be forcibly exhaled out after the expiration of a standard tidal volume.

Residual Volume/Reserve Volume

The residual volume is about the total volume of air around 1100 ml to 1200 ml residing in the lungs after the reserve volume is emitted or breathed out.



Lung Capacities

The lung capacities can be explained by the following terms:

Total Lung Capacity

The total lung capacity applies to the total volume of air-filled in the lungs after a forced inspiration. The lung capacity of a healthy man is estimated to be 6000 ml.

TLC = TV + ERV + IRV + RV

Vital Capacity

The vital capacity is the total volume of air that can be expired after a maximum inhalation or maximum air that a person can breathe in after forced expiration. It is an important measure of a person's respiratory health. A decreased vital capacity is an indication of restrictive lung disease where the lungs cannot expand completely. In the case of normal vital capacity, the improper functioning of lungs indicates obstructive lung disease where the lungs are blocked in the airways.

VC = TV + ERV + IRV

Inspiratory Capacity

The inspiratory capacity is the total volume of air that can be inspired which is about 3600 ml.

IC = TV + IRV

Functional Residual Capacity

The functional residual capacity is the total volume of air residing within the lungs after an exhalation process and it is about 2400 ml.

FRC = ERV + RV

The residing air present within the lungs which does not participate in gas exchange is located in the portion of the airways inside the bronchi and bronchioles and outside the alveoli.

Gaseous exchange

We are all well aware of the importance of oxygen for survival. Hence, one must also be familiar with the transportation, exchange, and regulation of necessary gases. In very small organisms, there is no need to have a separate transportation system for gases as all its cells are directly involved in the exchange of gases by diffusion. This diffusion is caused due to the differential partial pressure of the respiratory gases. Gases tend to move from a high-pressure area to a low-pressure one. Towards the end of the process, oxygen passes from the blood to tissue fluid and carbon dioxide from tissue fluid into the blood. But larger, multicellular organisms will definitely need a mechanism for the transport of gases for their different organs and tissues. Human beings fall into this category and have a well-developed system for the transportation of gases.

Exchange and Regulation of Gases

Exchange of gases in Humans

The transportation of gases is a very efficient process. Oxygen molecules get carried by the haemoglobin molecules of the red blood cells since it has a great affinity for oxygen. Each haemoglobin molecule binds to four molecules of oxygen. These oxygen molecules are picked up by haemoglobin and get transported by the blood to various tissues. As carbon dioxide is more soluble in water than oxygen, it is transported in the dissolved form in our blood, while some are also transported by haemoglobin. Not all of the carbon dioxide formed is expelled from the body as some of it reacts with water to form compounds useful for life processes.

Human bodies have mastered the art of catering to their needs. In other words, the human body knows when to increase the supply of oxygen and when to reduce it. To put this simply, it has learned the art of adaptation. This regulatory system that takes care of it is present in the medulla. The respiratory system happens to be extremely sensitive to the concentration of CO2 in the arterial blood. The decrease or increase of it is evident in the acceleration or slowing down of the respiration activity or in the change in rate and depth of breathing.

Three processes are essential for the transfer of oxygen from the outside air to the blood flowing through the lungs: ventilation, diffusion, and perfusion.

- Ventilation is the process by which air moves in and out of the lungs.
- Diffusion is the spontaneous movement of gases, without the use of any energy or effort by the body, between the alveoli and the capillaries in the lungs.
- Perfusion is the process by which the cardiovascular system pumps blood throughout the lungs.

The body's circulation is an essential link between the atmosphere, which contains oxygen, and the cells of the body, which consume oxygen. For example, the delivery of oxygen to the muscle cells throughout the body depends not only on the lungs but also on the ability of the blood to carry oxygen and on the ability of the circulation to transport blood to muscle. In addition, a small fraction of the blood pumped from the heart enters the bronchial arteries and nourishes the airways.