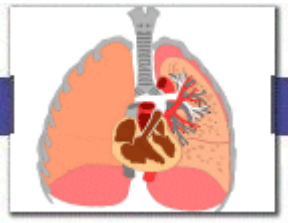


PARTNERS IN ASSISTIVE TECHNOLOGY TRAINING AND SERVICES

Significant Body Systems

PATTS

Contents:

Pulmonary/ Respiratory System

Introduction

Respiration is the act of breathing:

- inhaling (inspiration): muscle contraction, which lifts the ribs and pulls them outward, increases lung volume, allowing air to rush in (inspired air contains 21% oxygen and essentially no carbon dioxide)

  Audio recording: Lung Sounds
- exhaling (expiration) - muscle relaxation decreases lung volume and the air passively flows out (expired air contains 16% oxygen and 4.5% carbon dioxide)

The **respiratory system** functions to deliver the oxygen to the blood -- the transport medium of the cardiovascular system -- and to remove oxygen from the blood. The actual exchange of oxygen and carbon dioxide occurs in the lungs.

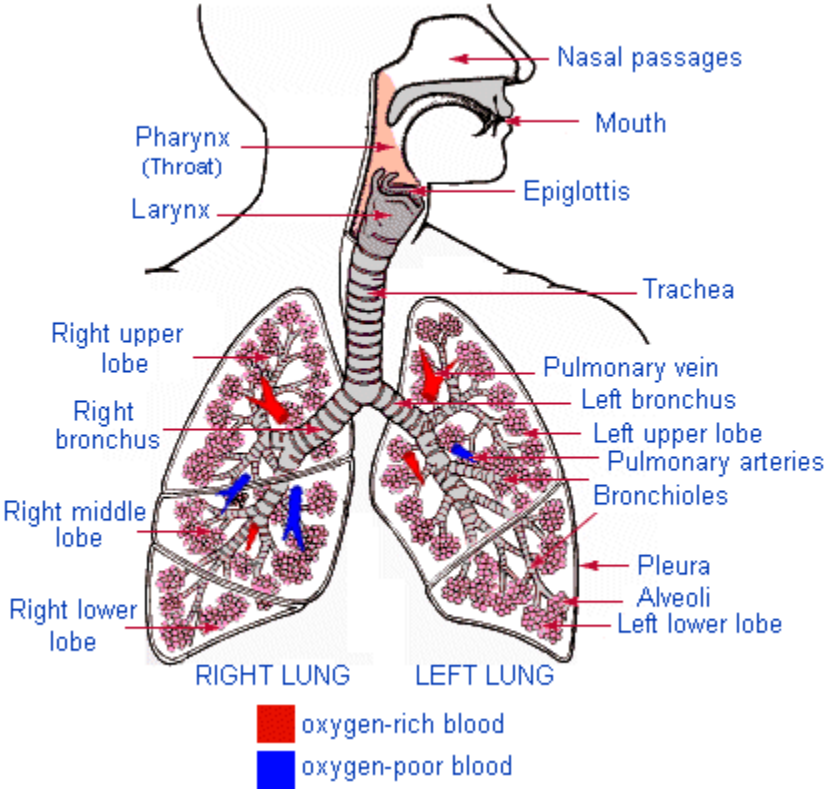
The respiratory centers in the brain stem (pons and medulla) control respiration's rhythm, rate, and depth. Primary controlling factors include 1) the concentration of carbon dioxide in the blood (high CO_2 concentrations initiate deeper, more rapid breathing) and 2) air pressure within lung tissue. Expansion of the lungs stimulates nerve receptors (vagus nerve X) to signal the brain to "turn off" inspiration. When the lungs collapse, the receptors give the "turn on" signal, termed the *Hering-Breuer inspiratory reflex*. Other regulators are: 3) an increase in blood pressure, which slows down respiration; 4) a drop in blood acidity, which stimulates respiration; and 5) a sudden drop in blood pressure, which increases the rate and depth of respiration. Voluntary controls -- "holding one's breath" -- can also affect respiration, but not indefinitely. Carbon dioxide build-up soon forces an automatic start-up.

Anatomy of the Respiratory System

Animation: Action of the diaphragm

The respiratory system consists of two tracts: The **upper** respiratory tract includes the nose (nasal cavity, sinuses), mouth, larynx, and trachea (windpipe). The **lower** respiratory tract includes the **lungs**, **bronchi**, and **alveoli**.

Click image for more detail.



The two lungs, one on the right and one on the left, are the body's major respiratory organs. Each lung is divided into **upper** and **lower lobes**, although the upper lobe of the right lung contains a third subdivision known as the **right middle lobe**. The right lung is larger and heavier than the left lung, which is somewhat smaller in size because of the predominately left-side position of the heart.

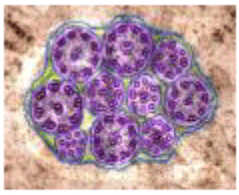
A clear, thin, shiny coating -- the pleura -- envelopes the lungs. The inner, visceral layer of the pleura attaches to the lungs; the outer, parietal layer attaches to the chest wall (thorax). Pleural fluid holds both layers in place, in a manner similar to two microscope slides that are wet and stuck together. The lungs are separated from each other by the **mediastinum**, an area that contains the heart and its large vessels, the **trachea** (windpipe), esophagus, thymus, and lymph nodes. The diaphragm, the muscle that contracts and relaxes in breathing, separates the thoracic cavity from the abdominal cavity.

Air Distribution

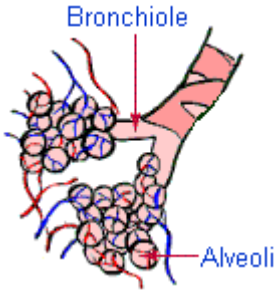
On inspiration, air enters the body through the nose and the mouth. Nasal hairs and mucosa (mucus) filter out dust particles and bacteria and warm and moisten the air. Less warming, filtering, and humidification occur when air is inspired through the mouth.

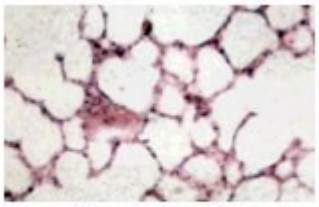
Air travels down the throat, or pharynx, where two openings exist, one into the **esophagus** for passage of food, and the other into the **larynx** (voice box) and **trachea** (windpipe) for continued airflow. When food is swallowed, the opening of the larynx (the epiglottis) automatically closes, preventing food from being inhaled. When air is inspired, the walls of the esophagus are collapsed, preventing air from entering the stomach. The larynx, which also contain the vocal cords, is lined with mucus that further warms and humidifies the air.

Air continues continues down the trachea, which branches into the right and left bronchi. The main-stem bronchi divide into smaller bronchi, then into even smaller tubes called **bronchioles**. The bronchial structures contain hair-like, epithelial projections, called **cilia**, that beat rythmically to sweep debris out of the lungs toward the pharynx for expulsion. Once in the bronchioles, the air is at body temperature, contains 100% humidity, and is (hopefully) completely filtered.



Cilia with Microtubules
© Dennis Kunkel, used with permission.





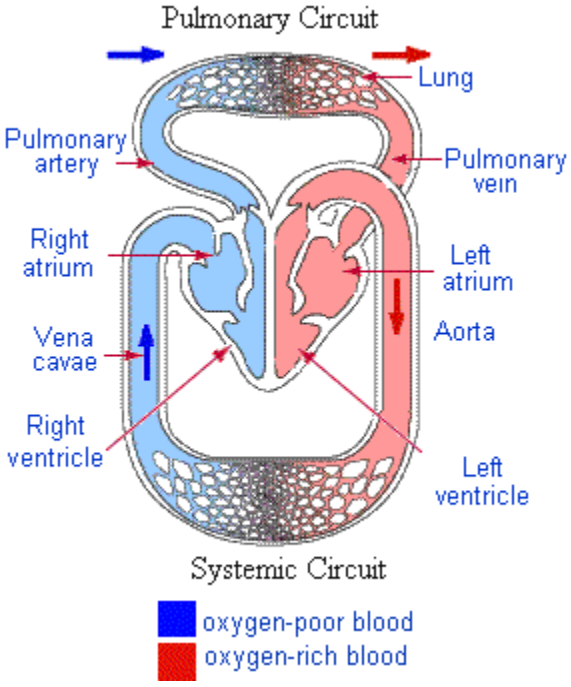
Lung alveoli
© Marjorie Thompson

Bronchioles end in air sacs called **alveoli** -- small, thin-walled "balloons," arranged in clusters. When you breathe in, enlarging the chest cavity, the "balloons" expand as air rushes in to fill the vacuum. When you breathe out, the "balloons" relax and air moves out of the lungs. It is at the alveoli that gas exchange occurs. Tiny blood vessels, capillaries, surround each of the alveoli. On inspiration, the concentration of dissolved oxygen is greater in the alveoli than in the capillaries. Oxygen, therefore, diffuses across the alveolar walls into the blood plasma. In the reverse process, carbon dioxide concentration is greater in the blood than the alveoli, so it passes from the blood into the alveoli and is ultimately breathed out.

As oxygen diffuses into the plasma, hemoglobin in the red blood cell picks up the oxygen, permitting more to flow into the plasma. The oxygen-carrying capacity of hemoglobin allows the blood to carry over 70 times more oxygen than if the oxygen were simply dissolved in the plasma alone. Therefore, the total oxygen uptake depends on: 1) the difference in oxygen concentration between the blood and alveoli, 2) the healthy functioning of the alveoli, and 3) the rate of respiration.

Pulmonary Circulation

The pulmonary circulatory circuit describes the process whereby oxygen and carbon dioxide are delivered to and from the lungs. Oxygen-poor blood travels to the right atrium via the inferior and superior vena cavae, then to the right ventricle. The right ventricle subsequently pumps the blood into the pulmonary artery, which branches to the right and left lungs. The pulmonary arteries subdivide until reaching the arteriole, then capillary levels. After gas exchange, the capillaries recombine to form venules and veins. Ultimately two right and two left pulmonary veins carry oxygen-rich blood to the heart for distribution, via the aorta/systemic circuit, to the rest of the body.



Lung Volumes/ Capacities

Measuring lung capacity using a spirometer.

The air that the lungs can hold can be divided into smaller designations called "volumes."

The amount of air a person breathes in and out at rest is called the **Tidal Volume** (Vt about 500ml). During such breathing, a person could actually take in more air or blow more out. The additional amount a person could inhale, such as during maximum physical activity, is called the **Inspiratory Reserve Volume** (IRV 3,000 ml). The additional amount a person could exhale is called the **Expiratory Reserve Volume** (ERV 1,000 ml). The **Residual Volume** (RV) is the amount of air that stays in the lung even after maximum expiration.

"Capacities" are combinations of two or more volumes.

- The **Total Lung Capacity** (TLC) is the total amount of air the lungs can contain: **TLC = RV + ERV + Vt + IRV**
- The **Vital Capacity** (VC) is the total amount of air the person can breathe in and out: **VC = ERV + Vt + IRV**
- **Functional Residual Capacity** (FRC) is the total amount of air left in the lungs at the end of a normal exhalation: **FRC = RV + ERV**

To Learn More

Web resources:

- The InnerBody: Anatomy Tutorials - Lungs
- Respiratory System (American Lung Association)
- National Heart, Lung, and Blood Institute
- Visible Human Project

Acknowledgments:

1. Joel DeLisa and Walter C. Stolov, "Significant Body Systems," in: *Handbook of Severe Disability*, edited by Walter C. Stolov and Michael R. Clowers. US Department of Education, Rehabilitation Services Administration, 1981, pages 41-45.
2. Catherine Parker Anthony and Gary A. Thibodeau, *Textbook of Anatomy & Physiology*. St. Louis: Mosby, 1983, pages 498-548.
3. Anatomy Clipart (Designs4Free)
4. Dennis Kunkel, Electron Microscopy Gallery
5. Marjorie Thompson, BIO 189, Slide Show, Brown University School of Medicine.