# XXX LEARNING MODULE 1

XXX® Learning Module 1
The Respiratory Tract

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## Module Introduction

To function, body cells require oxygen ($O_2$). The respiratory system, which consists of air passages, pulmonary vessels, and the lungs, as well as breathing muscles, supplies fresh oxygen to the blood so that it can be distributed to the rest of the body tissues. The respiratory system also removes carbon dioxide ($CO_2$), a waste product of body processes. Air moves in and out of the lungs because of pressure changes as the diaphragm and other breathing muscles contract and relax. Normal breathing is mainly an involuntary process, controlled by respiratory centers in the brainstem.

This module reviews the respiratory system and explains how the system facilitates gas exchange in the body. Throughout the module, each section focuses on a specific area of respiratory function that is of particular relevance to chronic obstructive pulmonary disease (COPD).

In this module, you will meet Mike, a patient who we will follow throughout all the modules.

## Chapter 1: The Respiratory Tract

## Learning Objectives

- Explain the anatomy of the respiratory tract and related systems
- Describe the path that air follows throughout the respiratory tract
- Explain the process of gas exchange in the alveoli

## Overview of the Respiratory System

**Take a DEEPER breath!**

**View CD-ROM Option #1**

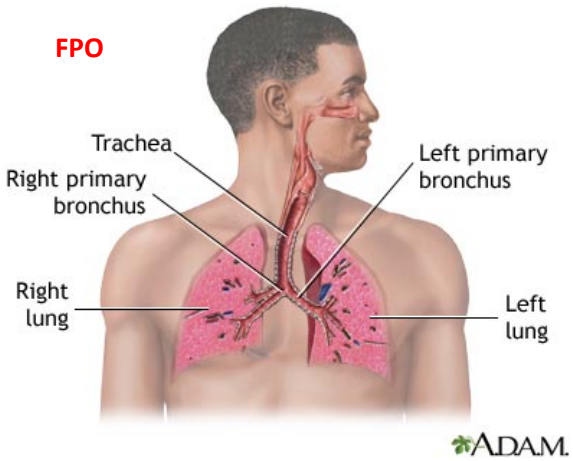
**Follow the Breath:**

**Tour of the Upper Respiratory Tract**

The respiratory system contains 2 major parts. The *upper respiratory tract* includes the nose (nasal cavity and sinuses), mouth, **larynx**, and **trachea**. The *lower respiratory tract* consists of the **lungs, bronchi**, and **alveoli**. The (Figure 1)

**[Tortora, 2009, pg 875, col 1, para 1]**

**Figure 1. Picture of Upper and Lower Respiratory Tract**




**[Medline Plus. http://www.nlm.nih.gov/medlineplus/ency/imagepages /9248.htm]**

**Breathing Basics: What Happens When You Breathe?**

***Take a breath…***

Humans breathe about 20,000 times a day.

[http://www.lungusa.org/your-lungs/]

**Take a DEEPER breath!**

**View CD-ROM Option #2**

**Follow the Breath:**

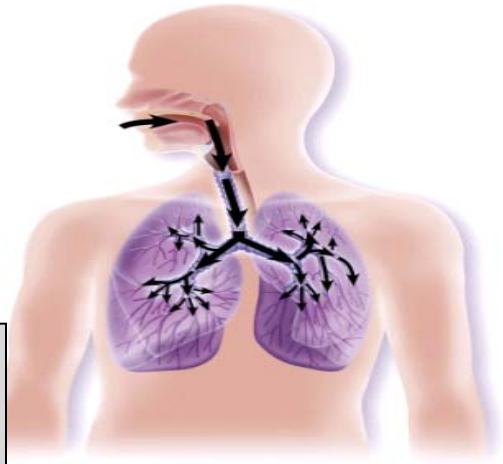
**Tour of the Lower Respiratory**

***Take a breath…***

Over a long period of time, breathing in cigarette smoke may damage the airways and air sacs, leading to COPD. COPD prevents airflow in and out of the lungs and can hinder gas exchange in the air sacs. **[Tortora 2009, pg 913]**

Breathing is a process we all take for granted. The main job of the respiratory system is to move fresh air into and get waste gases out of the body. The essential function of the lungs is to provide $O_2$ from the inhaled air to the **capillaries,** blood vessels embedded in the walls of the tiny air sacs called **alveoli,** and to exhale the $CO_2$ delivered from them. When taking a breath, air enters through the nasal passages, where it is filtered, heated, and humidified by the **paranasal sinuses**, membrane-lined cavities in the bones surrounding the nasal passages. The filtering process continues down through the throat, **larynx, trachea,** and **bronchi** to the lungs, each of which contains a "tree" of branching tubes that end in the **alveoli**, where gases diffuse into and out of the bloodstream in tiny vessels (Figure 2). Little thought is given to this process; breathing in and out takes place at the speed necessary for the demands of the activity—deeper breathing for chopping wood, faster breathing for playing racquet ball, and slower breathing while doing paperwork or reading a book. Most people don't realize they could go for weeks without food, days without water, but only a few minutes without oxygen.

**Figure 2. Pathway of Air Flow** FPO



***Take a breath…***

The exchange of gas takes place in the alveoli.

Air that is breathed in contains about 21% $O_2$.

**[Tortora 2009, pg 896, col 2, para4]**

Inside the alveoli, some of the $O_2$ dissolves in the surface moisture and passes through the thin lining of the blood vessel, where most of it is picked up by the hemoglobin of the red blood cells. At the same time, $CO_2$, most of which is carried in the blood plasma, passes into the lungs, where it is released as a gas ready to be breathed out. Excessive $CO_2$ or inadequate $O_2$ will trigger faster, deeper breathing.

**[Tortora 2009, pg889, col1, para 3; col2, para 1]**

**Lungs**

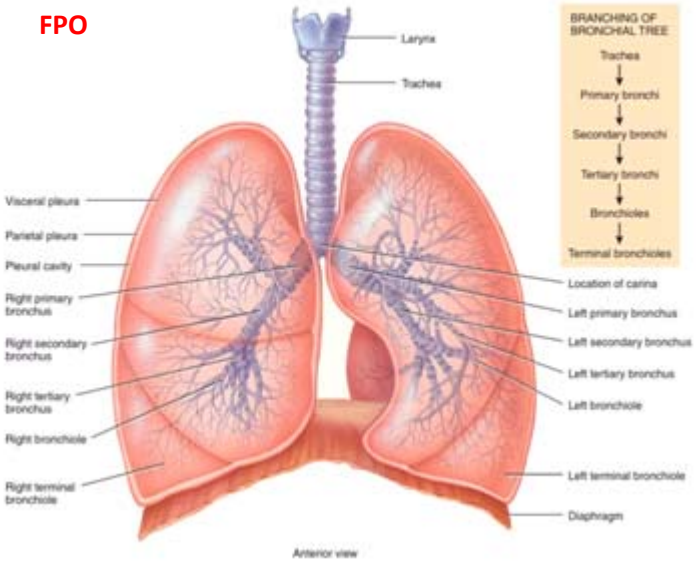
Lungs are part of an important group of organs and tissues working together to help breathing. The 2 lungs, 1 on the right and 1 on the left, serve as the body's major respiratory organs and are protected by the flexible rib cage. Together, the lungs form one of the largest organs in the body. The right lung is divided into 3 lobes, and the left into 2. The left lung is smaller than the right, as the heart takes up more room on the left. The lungs house a dense branching latticework of bronchial tubes that become progressively narrower (Figure

3). The 2 primary **bronchi**, which connect the lungs with the base of the **trachea**, are the largest tubes. **[Tortora, pg 884, Fig 23.7; pg 885, cols 1-2, para 1-3; pg 886, Fig 23.9]**

***Take a breath…***

Hiccups are caused when your diaphragm contracts suddenly. This interrupts your normal breathing pattern by making you draw in air sharply. The air passes over your vocal cords, making a hiccupping noise. Back in 1922, Charles Osborne of Iowa, had the longest attack of hiccups on record, 68 years for a grand total of 430 million hiccups. [http://soundmedicine.iu.edu/segment/139/redirect?seg=139]

**Figure 3: Branching of Bronchial Tree**




**[Tortora, pg 884, Fig 23.7]**

**Take a DEEPER breath!**

**View CD-ROM Option #3**

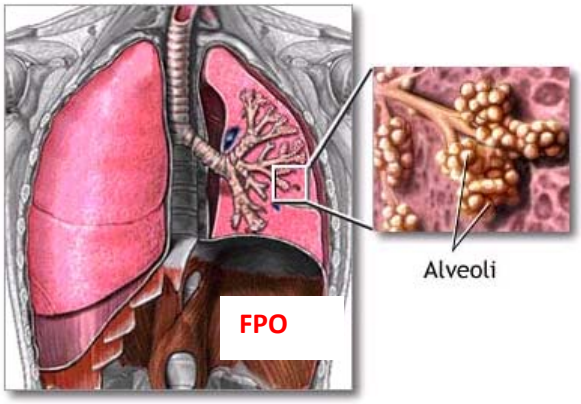
**Gas Exchange in the Alveoli**

Inside the lungs, the primary **bronchi** divide into secondary and tertiary **bronchi** and increasingly smaller branches known as **bronchioles**, to finally end in clusters of tiny air sacs, the **alveoli**, which number in the millions. Structurally, the **alveoli** are elastic, thin walled, and filled with air by the respiratory **bronchioles** (Figure 4). It is through the alveolar walls that $O_2$ diffuses from the inhaled air into the pulmonary bloodstream, and waste $CO_2$ is eliminated. The **alveoli** lie in clusters like bunches of grapes around the alveolar ducts, which then join together to form the **bronchioles** (Figure 4). The **bronchioles** link the alveolar ducts to the respiratory tract. The lungs also have blood vessels that comprise

the branches of the **pulmonary artery** and **veins**.

**[Tortora, pg 885, cols 1-2, para 1-3; pg 886, Fig 23.9]**

**Figure 4. Alveoli Clusters**




**[Medline Plus, pg 1]**

***Take a Breath…***

Multitasking

Your lungs aren't just for breathing. Have you ever tried speaking while breathing? Difficult, isn't it? That's because when you speak, your lungs push air out over the vocal cords in your neck, which makes them vibrate to create different sounds. Your lungs also allow you to cough and sneeze, keeping your air passages free from dust and mucus.

**Diaphragm**

The diaphragm, the main respiratory muscle, is a dome-shaped structure below the lungs that separates the chest cavity from the abdominal cavity. Its contraction and relaxation moves air in and out of the lungs. To draw air into the lungs, the chest cavity needs to expand. The muscles of the diaphragm contract, which causes it to flatten. At the same time, the **intercostal muscles,** located between the ribs, contract, lifting the ribs upward and outward. The pressure in the chest cavity is thus reduced, and the lungs expand, drawing in air via the mouth or nose. [Tortora, p892. Fig 23.14]

**Take a DEEPER breath!**

**View CD-ROM Option #4**

**Mechanics of Breathing**

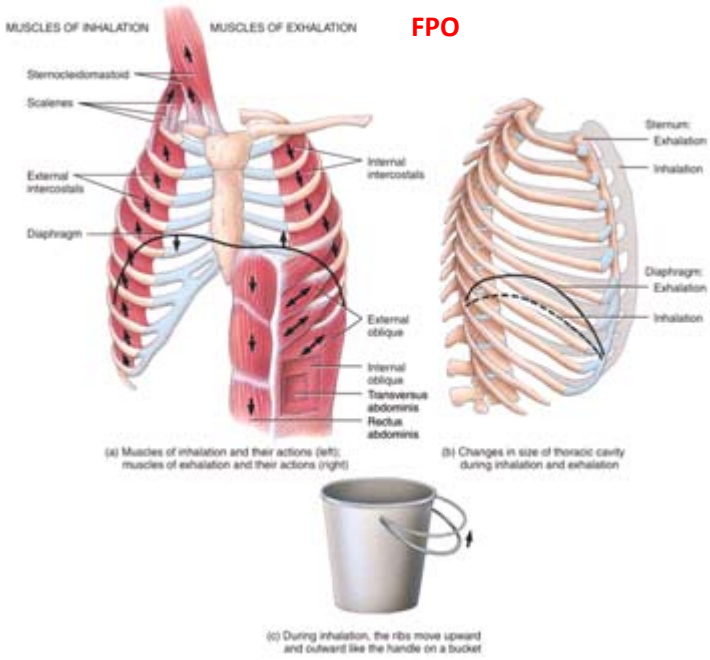
The rib muscles are also involved in **inhalation** and **exhalation** (Figure 4). When the **intercostal muscles** relax, the ribs fall downward and inward, and the lungs collapse, forcing the air out. At the same time, the diaphragm relaxes and is pulled up into the chest cavity (Figure 5). **[Tortora, pg 890, cols 1-2; 891, Fig 23.13 and cols 1,2; pg 892, fig 23.14, cols 1 and 2; pg 893, fig 23.15, col 1, para 1-2.]** The lungs remain partly filled even after **exhalation** because of an essential fluid secreted inside the **alveoli**. Known as **surfactant**, the fluid is produced by specialized cells and is composed of fatty proteins. It also appears to play a role in preventing lung infections. **[Tortora, p893, col 2, para 3]**

Breathing out requires no effort from the body unless we have a lung disease or are doing physical activity. Playing racquet ball, for example, demands contraction of the abdominal muscles and forcefully pushing the diaphragm against the lungs. This rapidly pushes out the air in the lungs.

***Take a breath…***

Our lungs are second only to the heart in their work rate: each lung expands and contracts between 12 and 20 times a minute to supply the body with the oxygen it needs and, just as important, to expel carbon dioxide.

**Figure 5: Inhalation and Exhalation**




**[Tortora, pg 891, Fig 23.13]**

## Progress Check #1

**1. What is the respiratory system?**

a) The body's system of nerves

b) The body's blood-transporting system

c) The body's breathing system

d) The body's immune system

e) The body's excretory system

**2. What important activity takes place in the lungs?**

a) Liquid waste is filtered from the blood

b) Food is digested

c) Hydrogen is eliminated

d) $CO_2$ is chemically converted to $O_2$

e) $O_2$ is exchanged for $CO_2$

**3. What primary muscle is associated with inhalation and exhalation?**

a) Trachea

b) Liver

c) Diaphragm

d) Lungs

e) Windpipe

**4. How many primary bronchial tubes branch off into the lungs?**

a) 2

b) 3

c) 4

d) None of the above

**5. In order to inhale, the size of the chest cavity must _____ and the pressure within the chest cavity must _____.**

a) decrease; increase

b) increase; increase

c) increase; decrease

d) decrease; decrease

e) stay the same; increase

## Chapter 2: Keeping the Respiratory Tract Healthy

### Learning Objectives

- Explain the process by which the respiratory tract stays healthy
- Describe the physiology behind pulmonary circulation

***Take a breath…***

Red blood cells carry oxygen around the body. When red blood cells are carrying oxygen, they are bright red, but when the oxygen is used up, they become dark red. As the cells in the body use up their oxygen, they release carbon dioxide into the blood. Because the body doesn't need carbon dioxide, you breathe it out.

The respiratory tract has a self-cleaning mechanism that helps it stay healthy. In the nose, the mucous membrane that lines the nasal cavity traps dust, dirt, and bacteria, the larger particles in the air. Hair like **cilia** that extend from the surface of cells covering the mucus membrane beat upward, carrying **mucus**, dust, and other trapped potential contaminants into the pharynx. This important protective mechanism is called the **mucociliary escalator**. Once in the pharynx, the **mucus** responsible for trapping foreign material, which is produced by the specialized **goblet cells**, can be swallowed, thus destroyed by stomach acid, or spit out. **Goblet cells** are found scattered among the epithelial lining of the respiratory tract—the **trachea**, **bronchus**, and larger **bronchioles**. **[Tortora 113, col 2, para1-2; p 114, col 2, para 2-3]** The importance of **goblet cells** will be described more thoroughly in Module 2 when we discuss diseases such as COPD.

Smoking inhibits the movement of **cilia** and destroys the **cilia** in the respiratory tract. Over time the body will not be able to remove the excess **mucus** and foreign debris in the respiratory tract, resulting in shortness of breath and breathing difficulties. **[Tortora, p910, col 1, para6; col 2, para 1]**

**Pulmonary Circulation: 2 Pumps in 1**

The cardiovascular system is composed of 2 functional systems. The right side of the heart and its blood vessels form the **pulmonary circuit**, which pumps blood to the lungs through the **pulmonary arteries** and back to the heart via the **pulmonary veins**. The left side of the heart and its vessels form the **systemic circuit**, which supplies blood to the body's cells and then back to the heart.

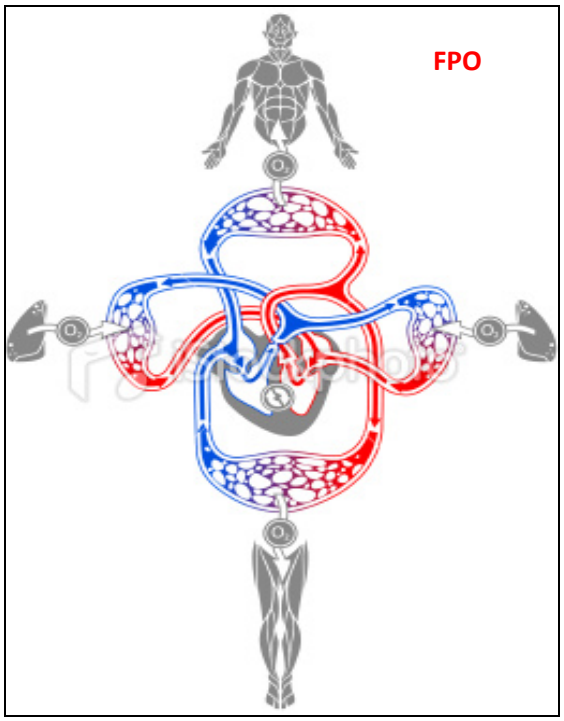
Passage of blood through the lungs, the pulmonary circulation, enables blood to pick up oxygen. The reoxygenated blood returns to the left side of the heart and is then pumped out again to the body tissues via the **systemic circuit** (Figure 6). The full circuit around the lungs and body takes only approximately 1 minute when the body is at rest. The heart pumps about 4—8 liters in 1 minute. That's an average of between 5760 and 11,520 liters per day. **[Tortora, pg 889, col 1, para 2; Merck Manual, pg 3, para 4, ln 1 -2]**

**Take a DEEPER breath!**

**View CD-ROM Option #5**

**Pulmonary Circulation**

**Figure 6: Blood Flow to Lungs and Body**




**[http://www.istockphoto.com/stock-illustration-6842615-circulatory-system.php]**

## Progress Check #2

**1. Reoxygenated blood returns to the _____.**

a) right side of the heart

b) left side of the heart

c) lungs

d) cilia

**2. Which cells produce mucus for the purpose of trapping foreign material?**

a) Bronchioles

b) Alveoli

c) Goblet

d) Capillaries

**3. _____ are mircroscopic, hair like cells responsible for moving foreign material away from the lungs in order to protect them.**

a) Bronchioles

b) Capillaries

c) Right and left primary bronchi

d) Cilia

**4. Blood is pumped to the entire body via the_____.**

a) lymph system

b) pulmonary circuit

c) alveoli

d) systemic circuit

**5. Blood is pumped from the heart to the lungs through the_____.**

a) pulmonary veins

b) pulmonary arteries

c) pulmonary capillaries

d) papillary muscle

## Chapter 3: Neurological Control of Respiration

### Learning Objectives

- Define the role of the autonomic nervous system in respiration
- Explain the difference between the sympathetic and the parasympathetic nervous system
- Describe non-respiratory functions of the lungs

Unlike energy, the body cannot store $O_2$, so we need to breathe air in and out of our lungs continuously. The rate and depth of breathing can be consciously modified, but the underlying need to breathe is controlled by involuntary centers in the **brainstem**. Our bodies respond to changes in $O_2$ and $CO_2$ levels automatically by adjusting our breathing, even without a conscious effort.

***Take a breath***

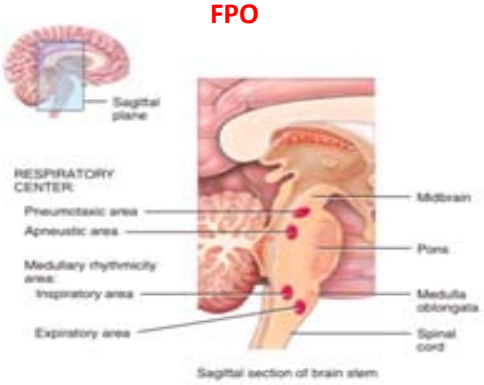
When a person engages in vigorous exercise, breathing becomes faster and deeper. Is it necessary to think about breathing faster and deeper, or is it an automatic response?

Breathing is controlled by contractions of the respiratory muscles including the **intercostal muscles** and **diaphragm**, all of which are controlled by nerve stimulations. The main area for respiratory muscle control is a portion of the brain called the respiratory control center, which is located in the **brainstem** and includes parts of the **medulla oblongata** and pons. (Figure 7) The **medulla** triggers respiratory muscle contraction for **inhalation** and relaxation for **exhalation**, and the

pons helps regulate the rhythm of normal breathing. **[Tortora pg 905-906, col2, para 2-3, Fig 23.24]**

**Figure 7: The Respiratory Center**

FPO




**[Tortora, pg 905; Fig 23.24]**

**Autonomic Nervous System**

Structured to enable immediate, involuntary responses, the **autonomic nervous system** (ANS) regulates internal body functions in order to maintain **homeostasis**, or inner balance/stability. The ANS is important in 2 situations: emergencies that cause stress and require us to fight or take flight and non-emergencies that allow us to rest and digest. The ANS regulates muscles, around blood vessels, in the skin, stomach, heart and glands. **[Tortora, pg 546, col 1, para 1]** These 2 functions are known as the **sympathetic** and **parasympathetic** divisions.

***Take a breath…***

It's a nice sunny day. Mike is walking in the park. Suddenly, an angry bear appears in his path. Does he stay and fight, *OR* does he turn and run away? These are the "fight or flight" responses. In these types of situations, the sympathetic nervous system is called into action and uses energy to increase the heart beat and slow down digestion.

***The 2 Divisions of the ANS***

The **sympathetic** and **parasympathetic** divisions of the ANS typically function in opposition to each other. The **sympathetic nervous system** originates in the spinal cord and is the excitatory system that prepares the body for stress. The **parasympathetic nervous system** maintains or restores energy. Although both divisions innervate many organs and structures, the numbers of **ganglia** (clusters of nerve cells where axons communicate in a synapse) are different. The activating chemicals, called neurotransmitters (Figure 8), and their effects, are also different. **[Tortora, pg 547, col 2, para 3; pg 548, col 1, para 1]**

***Take a breath…***

It is a nice, sunny day…You are walking in the park. You decide to relax on a park bench. This calls for "rest and digest" responses. Now is the time for the parasympathetic nervous to work to save energy. Your blood pressure decreases. Your heart beats slower. And digestion can start.

The ***sympathetic nervous system*** promotes a "flight or fight" response, corresponds with arousal and energy generation, and inhibits digestion. The sympathetic division is especially important in emergency situations when we might be required to either fight or take flight. It accelerates the heartbeat and dilates the bronchi to meet the oxygen demands of the active muscles. If you were running a race, for example, as you begin to move your body, your muscles begin to require more oxygen. Your heart speeds up to pump more blood, and your bronchi dilate to allow more oxygen to enter your lungs. The hormones epinephrine and **norepinephrine** from the **adrenal medulla** affect the body during stress. **Norepinephrine** raises heart rate and blood pressure; epinephrine stimulates carbohydrate metabolism. **[Tortora, pg 547, col 2, para 3; pg 548, Fig 15.1]**

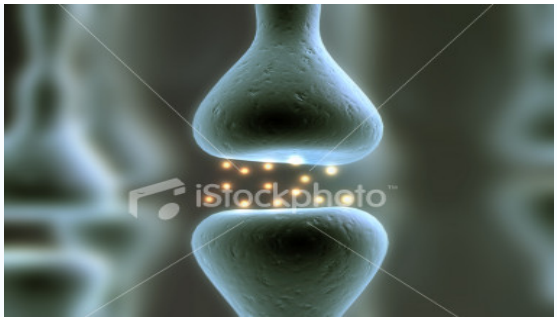
At the **effector organs**, **sympathetic ganglionic neurons** release **norepinephrine** (noradrenaline) along with other co-transmitters to act on **adrenergic receptors**. There are 2 main groups of **adrenergic receptors**: alpha and beta. Alpha receptors are located primarily in blood vessels and the brain, whereas beta receptors, including $\beta_1$ and $\beta_2$, are more prevalent in the lungs. When $\beta_2$ is stimulated, the **bronchioles** dilate. This

is the primary site of action of certain respiratory medications (eg, **beta agonists**), which we will learn more about in Module 3. When $\beta_2$ is blocked, bronchospasm may occur. **[Tortora, pg 559, col 1-2, Table 15.2]**

The ***parasympathetic nervous system*** promotes a "rest and digest" response, calms the nerves, and enhances digestion. It is mediated by the neurotransmitter acetylcholine. The **parasympathetic** division can be thought of as the "housekeeper" division, because it promotes all the internal responses that we associate with a relaxed state. For example, parasympathetic nerves cause the pupil of the eye to contract, promote digestion of food, slow heart rate, and decrease the strength of cardiac contraction. The neurotransmitter used by the **parasympathetic nervous system** is acetylcholine, which affects cholinergic receptors. **[Tortora, pg 548, col 1, para 1, Fig 15.1]** Anticholinergic medications, such as antihistamines, are used to decrease or balance acetylcholine activity.

**Figure 8. Neurotransmission Between Neurons**

**FPO**




http://www.istockphoto.com/stock-photo-2227524-receptor.php

**Other Functions of the Lung**

***Controlling blood pH***. We have already discussed the exchange of gas in the lungs and the fact that $CO_2$ is a waste product of the metabolism of $O_2$. As with all waste products, $CO_2$ is excreted into the blood. Then it is transported via the blood to the lungs, where it is eventually exhaled. $CO_2$ is slightly acidic, and it may accumulate in the bloodstream in certain disease states. This increase in the concentration of $CO_2$ in the blood causes the pH level of the blood to become more acidic. The goal of the body is to keep the pH "normal," so that if the blood becomes acidic, the speed and depth of breathing will increase in an attempt to blow off more $CO_2$ out of the body.

***Take a breath…***

What is blood pH?

Acidity and alkalinity are expressed on the pH scale, which ranges from 0 (strongly acidic) to 14 (strongly basic or alkaline). A pH of 7.0, in the middle of the scale, is neutral. Normal blood is slightly basic, with a pH range of 7.35 to 7.45. To function properly, the body maintains the pH of the blood close to 7.40.

**[Tortora, pg42, Fig. 2.12 and Col 1, para1, 2]**

For example, when a person engages in a sport like racquet ball, the heart rate, blood pressure, and cardiac output (the amount of blood pumped per heart beat) all increase. Blood flow to the heart, the muscles, and the skin increase. The body's metabolism becomes more active, producing $CO_2$ in the muscles. Breathing becomes faster and deeper to supply the oxygen required by this increased metabolism. On the other hand, if the body's pH is too basic, then the speed and depth of breathing will decrease in an attempt to retain $CO_2$ and bring the pH level back to normal. **[Tortora, pg 690, col 1-2, para 2-3]**

***Defending the body against infection and blockages.*** The lungs are also important in the body's defense against infection and other harmful environmental factors. Whereas the nose is the first line of defense against inhaled harmful materials, the lungs provide the second line of defense. Inhaled particles, such as smoke and pollution, or infectious agents, such as bacteria and viruses, pass through the mouth or nose and lodge in the lungs.

***Take a breath***

In asthma and COPD, mucus causes obstruction of the bronchioles and makes breathing more difficult.

Did you know that every time you smoke, you are paralyzing the cilia. This allows the mucus to build up and irritants to enter the lungs. **[Tortora 2009, pg 913, col 1, para1-4]**

**Mucus** functions to trap such inhaled agents and helps the white blood cells in the lungs to engulf and destroy the harmful materials. Coughing is the best way to clear **mucus** and other materials from the lungs. Remember that **cilia** in the larger airways beat forcefully to propel **mucus** and cells up the airways to be coughed out or swallowed—unless, of course, the **cilia** have been deactivated or destroyed, allowing thick **mucus** to accumulate and compromise lung function.

***Controlling blood pressure.*** Blood pressure is the force of the blood against the artery walls. High blood pressure (hypertension) and low blood pressure (hypotension) can both cause cardiovascular problems. As we have learned, breathing exchanges gases between the air outside and the **alveoli** in the lungs. Receptors in our bodies can detect any kind of changes concerning movement and pressure. If these receptors detect a rise in

blood pressure in the circulatory system, they encourage slower breathing. If blood pressure is low, the receptors tend to speed up the breathing rate. **[Tortora, pg 775, Fig 21.10, col 2, para 1; pg 776, col 1, para 1-2, col 2, par 1-2]**

## Progress Check #3

**1. Breathing is controlled by**

a) Changes in O2 and CO2 levels

b) Involuntary centers in the brainstem

c) Respiratory muscles

d) All of the above

**2. Normal blood is slightly _____ with a pH range of _____.**

**a) acidic; 12.0 to 14.5**

**b) alkaline; 7.35 to 7.45**

**c) acidic; 7.35 to 7.45**

**d) None of the above**

**3. What are the 2 divisions of the autonomic nervous system?**

a) Autonomic

b) Somatic

c) Parasympathetic

d) Sympathetic

e) Both c and d

**4. The _____system turns on in threatening situations.**

a) Somatic nervous system

b) Sympathetic nervous system

c) Parasympathetic nervous

d) Both the sympathetic and parasympathetic nervous systems

e) The autonomic nervous system


## Meet Mike

Mike is a 45-year-old, 5'10" tall, 190-pound builder. He has been physically active most of his life. Whether it's chopping wood for the fireplace, playing racquet ball with his kids or buddies, or working long hours in his construction business, Mike has never been afraid of physical activity. And, in fact, Mike hates being inactive; he could never be accused of being a couch potato. Mike sees his doctor regularly. Although he's had the normal amount of colds and occasional viruses over the years, Mike usually presents with fairly normal vital signs, including normal blood pressure readings and heart rate. In all respects, Mike is healthy. However, his doctor has been strongly encouraging him to quit smoking since he's been smoking since his teens. But Mike enjoys smoking his pack of cigarettes and is hesitant to quit, despite the fact that his dad, also a smoker, has been having some difficulty with his breathing lately. Mike is at his doctor's office today for his annual physical.

1. Mike's doctor listens to his chest and hears the air moving throughout his respiratory track. Describe the path through which the air is moving.
2. Mike's doctor asks him to take a deep breath. What is happening mechanically inside his chest when he breaths in deeply?
3. Mike's doctor listens to his heart for 1 minute. How many liters of blood have been pumped during this time?

4. Mike is very relaxed during the doctor's visit. What part of the autonomic nervous system is predominantly in control at this moment?

**Answers to Case Study:**

1. Air enters the nose and mouth and then passes through the larynx. From there, it moves onto the trachea into the bronchi until it reaches the alveoli.

   **[Tortora, pg 875, col 1, para 1]**

2. When drawing air into the lungs, the muscles of the diaphragm contract, causing it to flatten. The intercostal muscles of the ribs contract, lifting the ribs upward and outward. Finally, the lungs expand, allowing air to enter.

   **[Tortora, pg 890, cols 1-2]**

3. The heart pumps about 4 to 8 liters in 1 minute.

   **[Merck Manual, p3, para 4, ln 1 -2]**

4. The parasympathetic nervous system promotes a "rest and digest" response, calms the nerves, and enhances digestion.

   **[Tortora, pg 547, col 2, para 3; pg 548, col 1, para 1]**

## Module Summary

In this module, you have learned some important facts about the anatomy and physiology of the respiratory tract. Importantly, the airways form a network along which air travels to, from, and within the lungs, and the airways branch repeatedly, each branch narrowing until the end terminals—the **alveoli**—are reached. Critical to this process, the lungs reoxygenate the blood used by the tissues of the body and remove accumulated waste such as $CO_2$. You may not have realized just how complex the pulmonary circulation is, yet the full circuit of blood around the lungs and body takes only about 1 minute when the body is at rest. You have also learned that the respiratory system works hard to keep us healthy via the protective mucociliary escalator. Breathing is controlled by contractions of the respiratory muscles, which are controlled by nerve stimulations. Finally, you learned that the rate and depth of breathing can be consciously modified, but the underlying need to breathe is controlled by involuntary centers in the **brainstem**.

**Answer Key for All Progress Checks:**

To be inserted once brand/training review complete for ease of review.

## GLOSSARY

**Adrenal medulla**

The core of the adrenal gland. It is surrounded by the adrenal cortex; and produces epinephrine (adrenaline) and norepinephrine (noradrenaline)

**Adrenergic receptors**

Any of several reactive components of effector tissues, most of which are innervated by adrenergic postganglionic fibers of the sympathetic nervous system

**Agonist**

A drug that binds to a receptor of a cell and triggers a response by the cell

A drug that, by producing no biological effects, inhibits the action of another drug when both interact with the same cell receptors

**Alveoli**

Tiny thin-walled sacs found at the terminus of the bronchioles that are filled with air and where the exchange of $CO_2$ and $O_2$ takes place

**Autonomic nervous system**

A regulatory structure that helps people adapt to changes in their environment

**Brainstem**

The part of the brain connecting the forebrain and the spinal cord and connecting the midbrain, pons, and medulla oblongata

**Beta agonists**

Drugs that mimic sympathetic nervous system stimulation, producing relaxation and dilation of the bronchi (airways) to improve the flow of air into and out of the lungs

**Bronchiole**

A small airway that leads to areas of the lung and absorbs oxygen from the air

**Bronchus**

One of the large air tubes leading from the trachea to the lungs that convey air to and from the lungs (plural: bronchi)

**Capillary**

The smallest blood vessel found within the tissues of the body

**Cilia**

Microscopic hair like processes extending from the surface of a cell that are capable of rhythmic motion (singular: cilium)

**Effector organ**

Any muscle or gland that mediates overt behavior, that is, movement or secretion

**Exhalation**

The movement of air out of the bronchial tubes, through the airways, to the external environment during breathing

**Ganglia**

Nerve cell bodies located outside the brain and spinal cord (singular: ganglion)

**Goblet cells**

Any of the specialized epithelial cells found in the mucous membrane of the stomach, intestines, and respiratory passages that secrete mucus

**Homeostasis**

The processes whereby the internal environment of an organism tends to remain balanced and stable

**Inhalation**

The process of taking air into the lungs

**Intercostal muscles**

Muscles located between the ribs

**Larynx**

A special part of the body that functions as an airway to the lungs as well as providing us with a way of communicating (vocalizing)

**Medulla oblongata**

The lower portion of the brainstem, which directly controls breathing

**Mucus**

A slippery secretion produced by, and covering, mucous membranes

**Mucociliary escalator**

The non-immunological defense mechanism involving ciliary action and flow of **mucus** from **bronchioles**, through the bronchi and trachea to the larynx, by which particulate matter is removed from the respiratory tract

**Norepinephrine**

A neurohumoral transmitter for most postganglionic sympathetic fibers that is produced with epinephrine (adrenaline) in the adrenal medulla

**Paranasal sinus**

One of several air-filled cavities that is lined with **mucus** and is drained into the nasal cavity

**Parasympathetic nervous system**

A part of nervous system that slows the heart rate, increases intestinal and gland activity, and relaxes muscles

**Pulmonary artery**

Blood vessel that takes blood away from the heart to the lungs

**Pulmonary circuit**

Path of blood through vessels that take oxygen-poor blood to and oxygen- rich blood away from the lungs

**Pulmonary vein**

Blood vessel that that takes blood away from the lungs to the heart

**Surfactant**

Any of the agents that form a thin layer over the alveolar surfaces to help retain moisture

**Sympathetic ganglionic neuron**

A nerve cell responsible for the release of norepinephrine and other neurotransmitters that act on adrenergic receptors

**Sympathetic nervous system**

The branch of the **autonomic** nervous system that prepares the body for emergencies: for "fight or flight"

**Systemic circuit**

Part of the cardiovascular system that serves body parts other than the gas-exchanging surfaces in the lungs

**Trachea**

A tube-like portion of the breathing or respiratory tract that connects the voice box (larynx) with the bronchial parts of the lungs

## REFERENCES


Sound Medicine. The Longest Case of Hiccups? Indiana University School of Medicine.

http://soundmedicine.iu.edu/segment/139/redirect?seg=139.

Accessed December 10, 2009.

Cardiac catheterization. Merck Manual Online.

http://www.merck.com/mmpe/sec07/ch070/ch070b.html#sec07-ch070-ch070b-215. Accessed December 15, 2009.

Normal Lungs and Alveoli. Medline Plus: A Service of the US National Library of Medicine and the National Institutes of Health.

http://www.nlm.nih.gov/medlineplus/ency/imagepages/8675.htm. Accessed December 14, 2009.

Petty T. The Normal Lung. National Emphysema Foundation Web site.

http://www.emphysemafoundation.org/pulmonary-health/60-the-normal-lung.html. Accessed December 10, 2009.

Tortora, G, Derrickson B. *Principles of Anatomy and Physiology*. 12th ed. Hoboken, NJ: John Wiley & Sons; 2009.

How the lungs and respiratory system work. WebMD UK Limited and Boots UK Limited Web site.

http://www.webmd.boots.com/asthma/how-we-breathe. Accessed December 10, 2009.