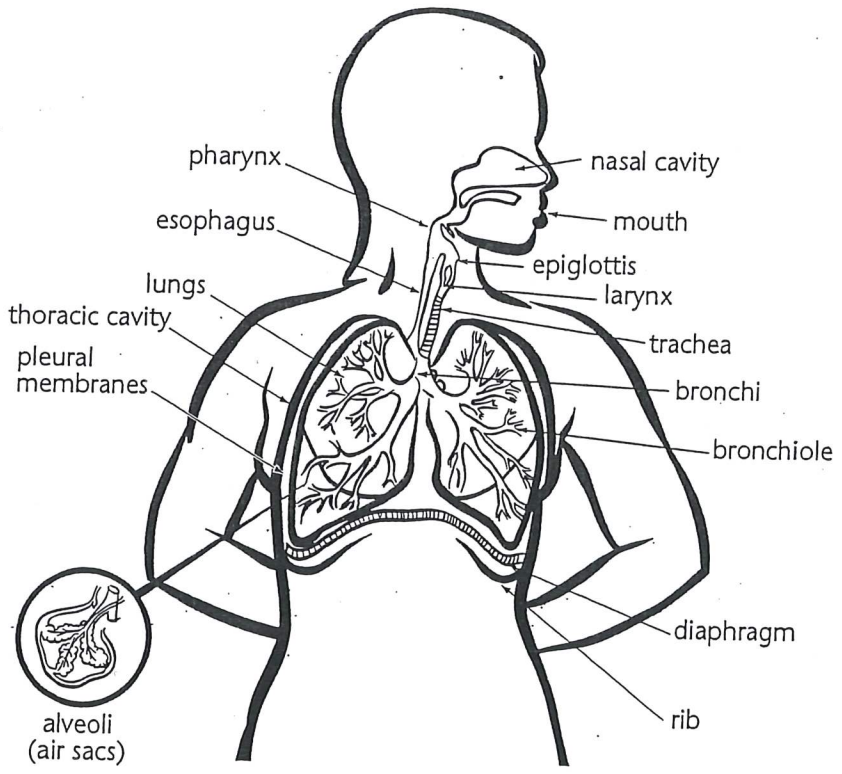
~~Section 3.4~~ Unit 10
Respiratory System

Section Overview

All the cells in your body require oxygen. Without it, they couldn't move, build, reproduce, and turn food into energy. In fact, without oxygen, they and you would die! How do you get oxygen? From breathing in air which your blood circulates to all parts of the body.

This section discusses how the respiratory system functions to enrich our bodies with oxygen.

You may want to check with your local teacher to see about an optional assignment for this section. If your local teacher purchased the Teacher's Guide to this course they will have the optional assignment information.



Lesson 3.4A
The Anatomy of the Respiratory System

Overview

At rest, the body moves 10 litres of air into and out of the lungs every minute. This movement of air into and out of the lungs is called breathing. The human lungs contain 300 million alveoli with a surface area forty times greater than that of the skin. The alveoli are responsible for the exchange of oxygen and carbon dioxide between the lungs and the blood. This lesson introduces the anatomy of the respiratory system and the functions of each individual organ.

Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod3.html

The Anatomy of the Respiratory System

The **respiratory system** is responsible for the process of breathing, and it cooperates with the circulatory system in the process of respiration. Breathing involves the organs of the respiratory tract. These organs transport oxygen-rich air to the blood in the capillaries of the alveoli and remove carbon dioxide and water taken to the lungs from the tissues.

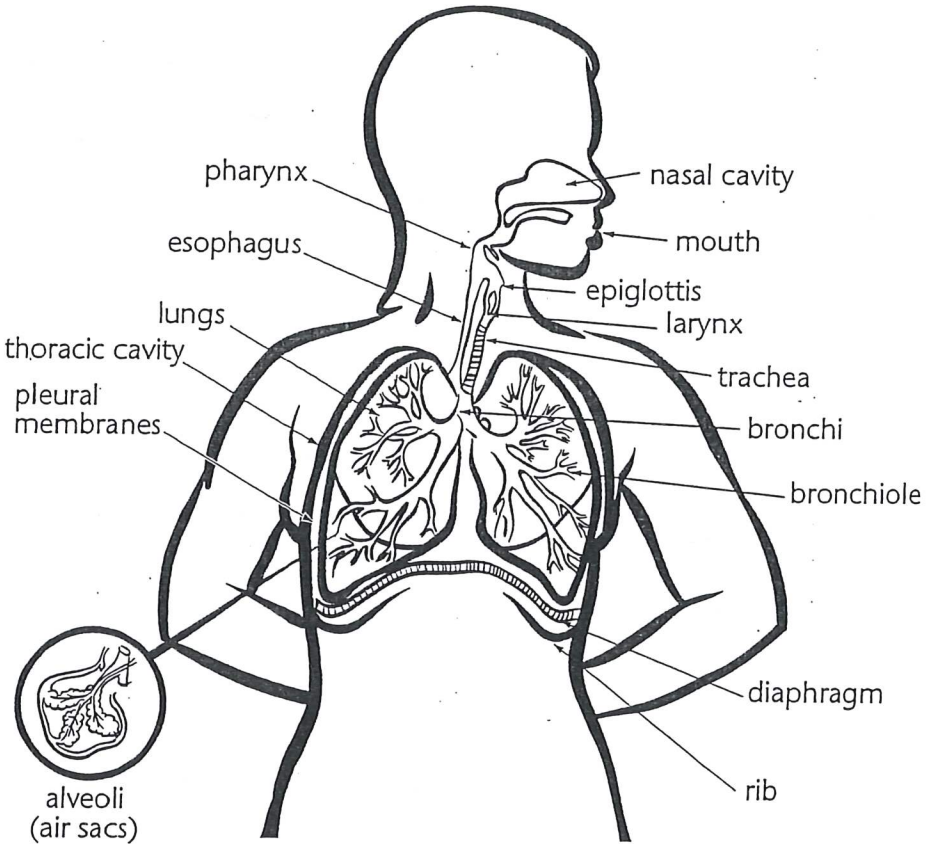
There are three types of respiration. **External respiration** exchanges oxygen and carbon dioxide in the alveoli of the lungs. **Internal respiration** is the exchange of gases between the capillaries and the tissue fluid. In cellular respiration, cells use oxygen to burn glucose to produce ATP energy and the waste products carbon dioxide and water.

Both the mechanism of breathing and external and internal respiration are discussed as separate lessons in this unit.

If you have access to the Internet, go to the *Biology 12 Web site* to check out further online resources.

Structure and Functions of the Respiratory System

The following diagram illustrates the structure and functions of the respiratory system. Refer also to Figure 15.1 on page 286 of your *Inquiry Into Life* textbook.



The Nasal Cavity — Air from outside the body passes through two nostrils or nares and into the nasal cavities. Ciliated cells in the upper parts of the nasal cavities are odour receptors and are responsible for the sense of smell.

Pharynx or Throat — The pharynx is a common passage way for both the respiratory and digestive systems.

Larynx or Voice Box — The larynx, a structure located below the epiglottis, acts as a passageway for air between the pharynx and trachea. The larynx contains the vocal cords.

Trachea or Windpipe — The trachea lies in front of the esophagus and directs air between the larynx and the bronchi. The trachea consists of a number of cartilaginous rings stacked on top of each other. These rings prevent the trachea from collapsing when the pressure in the thoracic cavity decreases during inhalation.

Bronchi (one is a bronchus) — The bronchi branch off the trachea and supply air to the lungs. Each main bronchus branches into many secondary bronchi that have smaller diameters, thinner walls, and less cartilage for support. Secondary bronchi lead to the smaller tubes called bronchioles.

Bronchioles — Bronchioles, the smallest tubes within the lungs, carry air to the alveoli. Each bronchiole supplies air to a lobule within the lung. Each lobule contains many alveoli.

Thoracic Cavity — The thoracic cavity is the enclosed space within the ribcage. The diaphragm is at the bottom of the thoracic cavity. This cavity allows breathing to take place, and it protects the heart, large blood vessels, and other vital organs.

Diaphragm — The diaphragm is a dome-shaped muscle that separates the thoracic cavity and abdominal cavity. When the diaphragm contracts, the muscles shorten and flatten out the dome-shaped diaphragm, increasing the volume of the thoracic cavity and pushing down on the abdomen.

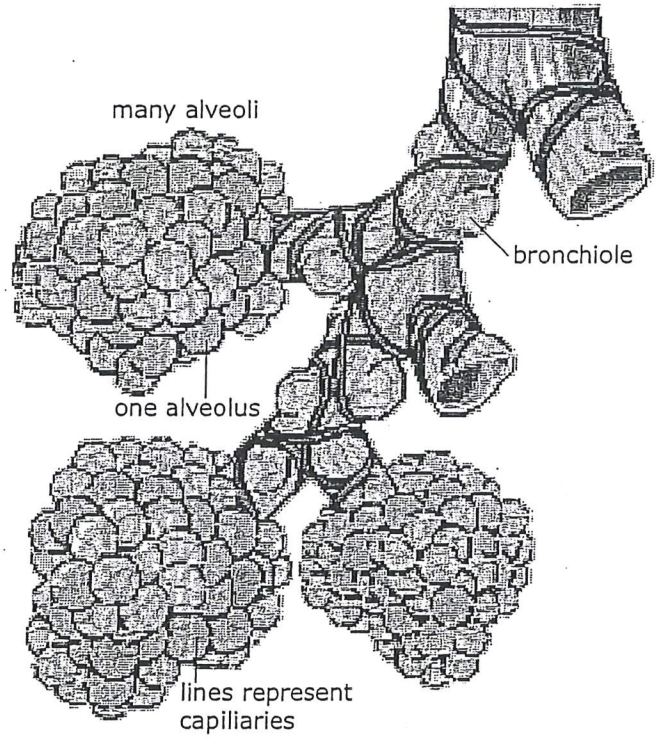
Ribs — The ribs are bones attached to the spine and sternum. They form the structure of the thoracic cavity. Intercostal muscles between the ribs contract to pull the ribs up and out during inhalation and relax during exhalation.

Pleural Membranes — The pleural membranes are made up of two layers that lie between the lungs and the chest wall. The inner membrane encases the lungs, and the outer membrane adheres to the chest wall. A thin layer of fluid between the two membranes prevents friction and allows easy movement between the lungs and chest wall. The complete seal and the low pressure between these layers prevent the lungs from collapsing.

Alveoli (one is an alveolus) — Alveoli are the air sacs within the lungs. They have thin walls made of simple squamous epithelial cells and are surrounded by blood capillaries (another layer of simple squamous epithelium). Gas exchange occurs in the alveoli. Oxygen gas is in higher concentration in the alveoli than in the blood and so it diffuses into the blood through this thin layer of cells. Carbon dioxide is in higher concentration in the blood than in the alveoli, so it diffuses into the alveoli through this thin layer. The inner surface of the alveolus is covered in a thin lipoprotein layer called pulmonary surfactant. This layer prevents the alveoli from collapsing during exhalation.

Alveoli Structure and Function

Bronchiole With Alveoli



This is the site of external respiration—the exchange of gases between the alveoli and blood capillaries.

The following table summarizes the alveoli structure and its function.

Alveoli Structure and Function Summary	
Structural Component	**Functional Benefit**
Alveoli are arranged in grape-like clusters	Greatly increases surface area for gas exchange
Thin walls—one cell thick	Increases rate of diffusion of oxygen and carbon dioxide between alveoli and blood
Densely covered with blood capillaries	Large contact area between alveoli and blood supply
Inner walls are lined with pulmonary surfactant	Lowers the surface tension within the alveoli and prevents them from collapsing
Walls of alveoli are moist	Aids rate of diffusion of gases
Alveoli contain stretch receptors	Prevents alveoli from over-filling with air and causing damage to the thin walls.

The Roles of Cilia and Mucus

Cilia are short hair-like structures made of microtubules (9 + 2 arrangement) that are able to produce movement. In the respiratory system, cilia are found on the ciliated columnar epithelial cells that line the tubes of the lungs. The movement of the cilia sweeps mucus and debris out of the lungs. The tubes of the lungs also contain mucus-producing goblet cells similar to those of the digestive system. Foreign particles in air, such as dust, are trapped by the mucus and swept by the cilia out of the airway into the throat where they are coughed up or swallowed.

Chemicals in cigarette smoke are known to reduce the activity and even permanently disable cilia in the respiratory tract. Read page 299 in your textbook for information related to smoking and lung health. Please don't smoke.

If you have access to the Internet, go to the *Biology 12 Web site* to check out the effects of cigarette smoking on the respiratory system.

Guided Practice 3.4A 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

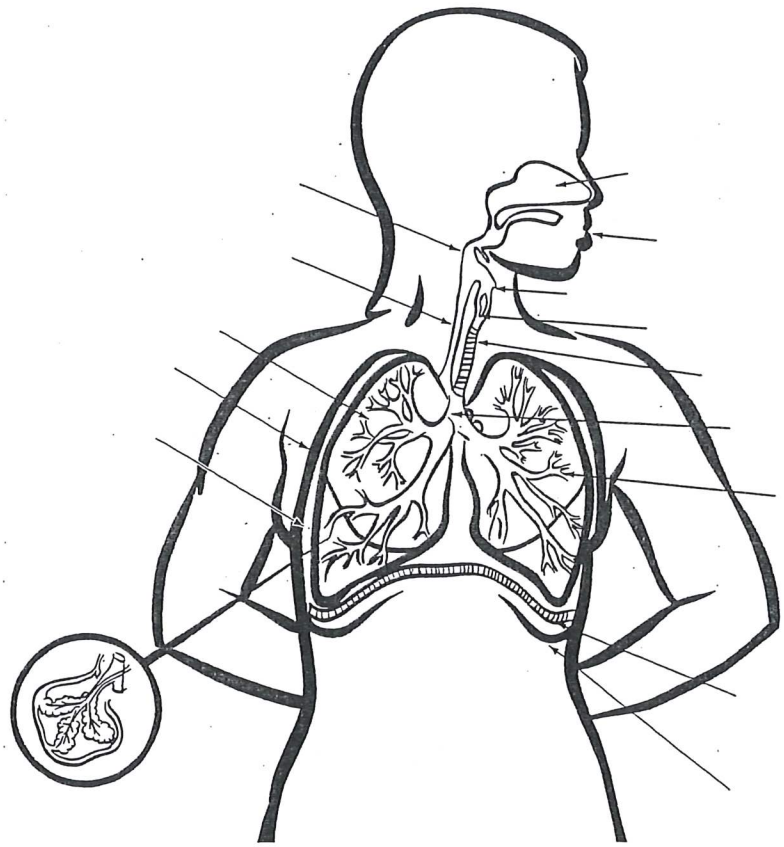
Vocabulary terms to know for this lesson:

- alveoli
- bronchi
- bronchioles
- cilia
- diaphragm and ribs
- larynx
- mucus
- nasal cavity
- pharynx
- pleural membranes
- respiration
- respiratory tract
- thoracic cavity
- trachea

Guided Practice 3.4A 2

Written Response

1. Label this diagram of the respiratory tract and provide functions for each structure identified.



Structure	Function
Nasal cavity	
Pharynx or throat	
Larynx or voice box	
Trachea or windpipe	
Bronchi (one is a bronchus)	
Bronchioles	
Thoracic cavity	
Diaphragm	
Ribs	
Pleural membranes	
Alveoli (one is an alveolus)	
Lungs	
Esophagus	
Mouth	

2. Draw a flow chart with arrows to describe the path of air flow from the nose to the alveoli during inspiration.

3. Complete the following table by outlining the structures of the alveoli that make it well suited to its function.

Structural Component	Functional Benefit

4. Describe how debris and particles in the air are removed from the lungs by mucus and cilia.

Summary

Completing this lesson has helped you to:

- identify the structures of the respiratory system in a diagram
- describe the function of each structure in the respiratory system
- list the enzyme, substrate, product, source gland, site of action, and pH for each digestive reaction
- understand how the alveolus is well suited for gas exchange
- describe how mucus and cilia keep the airways clean

Lesson 3.4B
Breathing

Overview

Humans breathe 15 to 20 times per minute. This lesson discusses how breathing takes place, and outlines the mechanisms and structures involved.

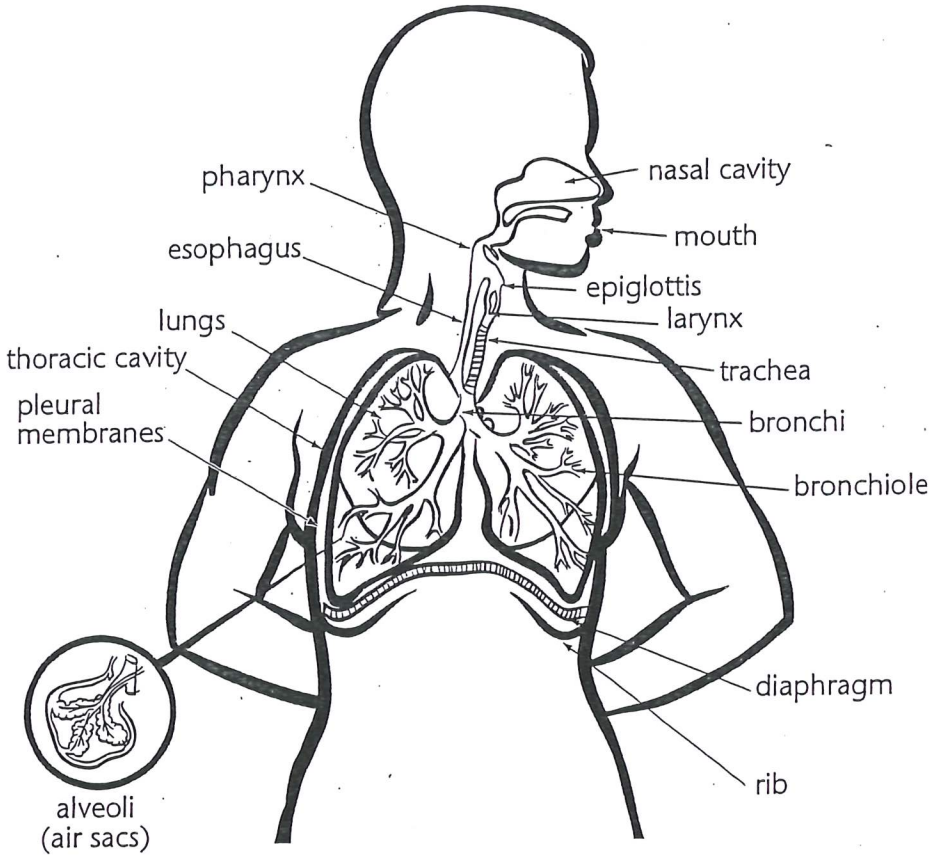
Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod3.html

Breathing

The organs of respiratory system are responsible for the process of breathing. These organs work to provide oxygen rich air to the blood in the capillaries of the alveoli and remove carbon dioxide and water returned to the lungs from the tissues. The respiratory system also cooperates with the circulatory system in the process of respiration.

The following diagram illustrates the structure and functions of the respiratory system. Refer also to Figure 15.6 on page 292 of your *Inquiry Into Life* textbook.



At rest, we breathe about 20 times a minute and exchange about 500 millilitres of air with each breath. This is called the tidal volume.

The lungs, diaphragm, ribs and intercostal muscles, and the pleural membranes work together to perform the processes of inhalation and exhalation. These processes are controlled by the brain's breathing centre in the medulla oblongata, which responds directly to the levels of carbon dioxide and hydrogen ion (acid) in the cerebrospinal fluid.

The respiratory centre also receives signals from receptors in the aorta and carotid arteries that respond to increased levels of carbon dioxide and low levels of oxygen.

The breathing centre stimulates the diaphragm and intercostal muscles to create conditions of lower or higher pressure within the thoracic cavity. If the pressure in the thoracic cavity is lowered, air is at higher pressure in the environment and rushes into the lungs. This is called negative pressure breathing. If the pressure in the thoracic cavity is raised above the air pressure in the environment, air rushes out of the lungs. To equalize pressure, air will move from areas of high pressure to areas of low pressure.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.4B Breathing to see an animation on breathing and answer questions about it.

Control of Breathing

Breathing is controlled by the respiratory centre of the brain, so it normally occurs automatically. The respiratory centre is located in **medulla oblongata** (the brain stem) and is part of the autonomic nervous system. The respiratory or breathing centre receives and responds to impulses from several sources, including other parts of the brain, **stretch receptors** in the walls of the alveoli, and chemoreceptors in the aorta and carotid arteries. Central chemoreceptors, located in the medulla oblongata, respond to changes in hydrogen ion concentration and the partial pressure of carbon dioxide in the cerebrospinal fluid.

The respiratory centre senses changes in blood chemistry and receives signals from receptors located in the aorta and carotid arteries. The respiratory centre does not sense when oxygen levels are low. Instead it senses when carbon dioxide or acid levels increase. If levels of carbon dioxide or acid become too high, the respiratory centre will increase the rate of breathing until levels of carbon dioxide and acid return to acceptable levels.

The chemoreceptors in the aorta (**aortic bodies**) and the carotid arteries (**carotid bodies**) also monitor the blood chemistry and detect unacceptably high levels of carbon dioxide. These chemoreceptors do detect low oxygen levels, and stimulation of the respiratory centre by these receptors increases the rate and depth of breathing. Oxygen levels have very little influence during normal breathing.

Although breathing is automatic, you can consciously alter or stop breathing, if only for a limited time. This is possible because other parts of the brain send inhibitory messages to the breathing centre. For a short period of time, these messages block the excitatory signals to the muscles used to breathe. When carbon dioxide levels become high enough, the stimulus to breathe overrides the inhibitory signals coming from other parts of the brain. Breathing resumes, even though other parts of the brain are sending instructions not to breathe.

Mechanism of Inhalation

Inhalation or **inspiration** is the active phase of breathing that results in air flow to the lungs.

Here's how the process works:

- air is exhaled from the lungs, which increases levels of carbon dioxide and hydrogen ions (products of cellular respiration) in the blood
- this change is detected by the brain's respiratory centre in the medulla oblongata
- the respiratory centre sends a signal via the nervous system, causing the muscles of the diaphragm and the intercostal muscles of the rib cage to contract
- contraction of the diaphragm causes it to shorten and lower, and that increases the volume of the thoracic cavity
- contraction of the intercostal muscles lifts the ribs up and out, further increasing the volume of the thoracic cavity
- as the volume of the thoracic cavity increases, the fluid between the pleural membranes creates surface tension that lets the membranes move with the ribs
- the increased volume of the **thoracic cavity** results in decreased air pressure within the lungs

- air in the environment is at higher pressure than in the lungs, so it moves into the lungs to equalize the pressure
- this brings oxygen-rich air (air is 20% oxygen) to the alveoli
- oxygen in the alveoli diffuses into the blood capillaries

Mechanism of Exhalation

Exhalation or **expiration** is the process of air flow out of the lungs.

Here's how the process works:

- as air is inhaled, the alveoli fill up
- **stretch receptors** in the alveoli signal the brain's respiratory centre in the medulla oblongata to stop sending signals to the diaphragm and intercostal muscles; this type of signal is called negative feedback
- the muscles of the diaphragm relax and lengthen into a dome shape, decreasing the volume of the thoracic cavity
- the intercostal muscles of the rib cage relax, and the ribs move downward and inward, decreasing the volume of the thoracic cavity
- the decreased volume of the thoracic cavity results in increased pressure within the lungs
- air is forced out into the environment to equalize pressure
- as air exits the lungs, the surfactant that lines the alveoli and the decreased pressure between the pleural membranes prevents the alveoli from collapsing
- this air movement carries water vapour and carbon dioxide gas out of the lungs

The rôle of the pleural membranes in keeping the lungs inflated is demonstrated when a penetrating injury allows outside air into the thoracic cavity, causing the lungs to collapse.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.4B Breathing for information about inspiration and expiration. You will also find a site to work through a case study relating to asthma.

Guided Practice 3.4B 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- alveoli
- aortic and carotid bodies
- breathing
- carbon dioxide
- diaphragm
- exhalation
- hydrogen ions
- inhalation
- intercostal muscles
- medulla oblongata
- oxygen
- respiratory centre
- stretch receptors
- thoracic cavity

Guided Practice 3.4B 2
Written Response

1. Describe the mechanics of inhalation.
2. Describe the mechanics of exhalation.
3. What is the name of the centre in the brain that controls breathing? Where is this centre located?
4. What type of receptors gather information on blood chemistry for the control of breathing? Where are these receptors located in the body? Which chemicals are monitored by these receptors?
5. Which receptors control the depth of breathing? What type of feedback do these receptors provide for the regulation of breathing?

Summary

Completing this lesson has helped you to:

- list the respiratory structures involved in breathing
- understand how blood gases signal the respiratory control centre to stimulate breathing
- describe the steps involved in inhalation
- describe the steps involved in exhalation

Lesson 3.4C
Internal and External Respiration

Overview

The respiratory system is responsible for the process of breathing, and it cooperates with the circulatory system in the process of respiration. Respiration includes external respiration (the exchange of oxygen and carbon dioxide in the alveoli of the lungs), internal respiration (the exchange of gases between the capillaries and the tissue fluid), and cellular respiration (cells using oxygen to burn glucose to produce ATP energy and the waste products carbon dioxide and water). In summary, internal respiration takes place in the tissues and external respiration occurs in the lungs.

Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Media CD*

Internal and External Respiration

Respiration provides oxygen to cells for the process of cellular respiration. Cellular respiration occurs in the mitochondria of cells and produces ATP energy for cellular processes. During cellular respiration, glucose and oxygen (nutrients) are converted to carbon dioxide and water (wastes). With the help of the circulatory system, respiration also removes those waste products.

This lesson deals with gas exchange between the alveoli and blood capillaries of the lungs (external respiration), and with gas exchange between the blood capillaries of the body and the tissue fluid surrounding cells (internal respiration). Before you continue, you may want to review the lessons that cover alveolar structure and function, and capillary tissue-fluid exchange.

See Figure 15.8 on page 295 of your *Inquiry Into Life* textbook for a summary diagram of these processes.

Blood transports oxygen, carbon dioxide, and water between the lungs and the cells of the body. Oxygen is carried by hemoglobin molecules (Hb—actually called deoxyhemoglobin when no oxygen is attached) inside red blood cells that form oxyhemoglobin (HbO_2).

Carbon dioxide is mainly transported in blood plasma in the form of bicarbonate ion, with some carbon dioxide molecules attached to hemoglobin as carbaminohemoglobin ($HbCO_2$). A small amount of carbon dioxide gas dissolves directly in the plasma. Hydrogen ions attach to hemoglobin forming reduced hemoglobin (HHb).

If you have access to a computer and the *Biology 12 Media CD*, go to *How We Breathe* now.

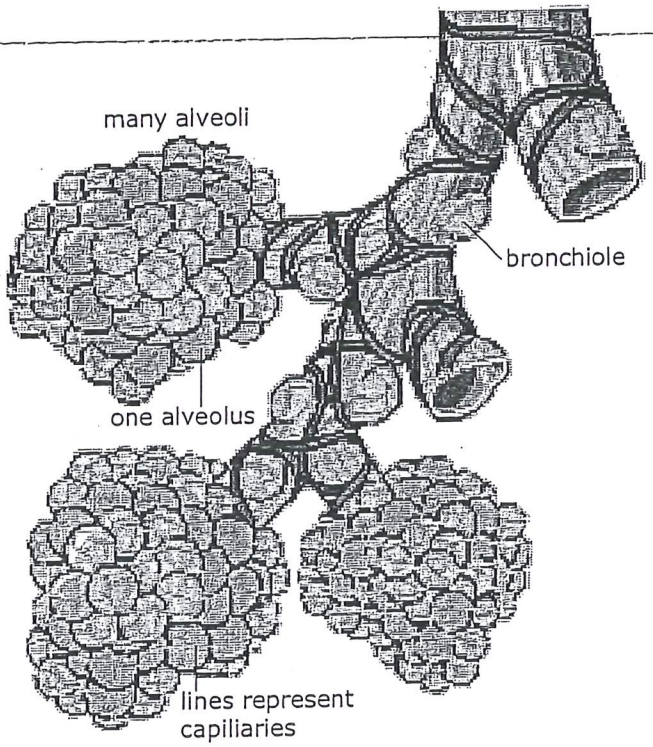
Go to your:

Biology 12 Media CD > Module 3 > How We Breathe.

External Respiration

External respiration occurs in the alveoli. The reactions that occur in the lungs are aided by the lower temperature and higher pH found there. The reactions are summarized below.

Bronchiole With Alveoli



This is the site of external respiration—the exchange of gases between the alveoli and blood capillaries.

External Respirations (Reactions)

$$Hb + O_2 \rightarrow HbO_2$$

$$HbCO_2 \rightarrow Hb + CO_2$$

$$HHb \rightarrow Hb + H^+$$

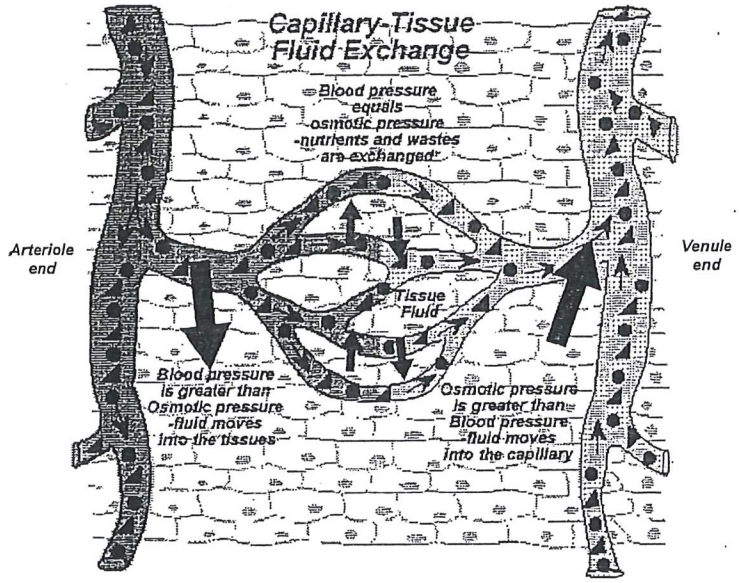
$$H^+ + HCO_3^- \xrightarrow[anhydrase]{carbonic} H_2O + CO_2$$

See page 294 of your *Inquiry Into Life* textbook for the chemical reactions involved in external respiration.

Blood that is low in oxygen will pick up oxygen as it diffuses from the alveoli (where it is in high concentration) into the blood capillaries (where it is in low concentration). Hydrogen ions are released from reduced hemoglobin and to combine with bicarbonate ions to form carbonic acid. An enzyme called **carbonic anhydrase** helps convert the carbonic acid into carbon dioxide and water, which diffuse into the alveoli. The small amount of carbon dioxide found as carbaminohemoglobin also diffuses into the alveoli.

Internal Respiration

Internal respiration occurs in the capillary beds of the tissues. The reactions that occur in the tissues are aided by the higher temperature and lower pH found there. The reactions are summarized below.



Internal Respirations Reactions

$$Hb + O_2 \rightarrow HbO_2$$

$$HbCO_2 \rightarrow Hb + CO_2$$

$$HHb \rightarrow Hb + H^+$$

$$H^+ + HCO_3^- \xrightarrow[anhydrase]{carbonic} H_2O + CO_2$$

See page 294 of your *Inquiry Into Life* textbook for the chemical reactions involved in internal respiration. While there, look at Figure 15.8 on page 295 for a visual focus on both internal and external respiration.

Oxygen in the blood diffuses into the tissues. Water and carbon dioxide diffuse from the tissues into the blood, where they form carbonic acid. Carbonic acid in the blood is converted into bicarbonate ions and hydrogen ions by the enzyme carbonic anhydrase. Bicarbonate ions are transported in plasma to the lungs, and hydrogen ions combine with hemoglobin to form reduced hemoglobin in red blood cells. Smaller amounts of carbon dioxide combine with hemoglobin to form carbaminohemoglobin in red blood cells, and are returned to the lungs in this form. Small amounts of carbon dioxide can also dissolve directly in plasma.

If you have access to a computer and the *Biology 12 Media CD*, go to *Racing Respiration* now.

Go to your:

Biology 12 Media CD > Module 3 > Racing Respiration.

Guided Practice 3.4C 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- alveoli
- bicarbonate ions
- capillaries
- carbaminohemoglobin
- carbon dioxide
- carbonic anhydrase
- chemical equations for internal and external respiration
- external respiration
- internal respiration
- oxygen
- oxyhemoglobin
- pH
- reduced hemoglobin
- temperature

Guided Practice 3.4C.2
Written Response

1. How does oxygen move from across the walls of the alveoli and the capillaries and into the blood? In which form is oxygen transported in the blood to the tissues?

2. Carbon dioxide is transported from the tissues to the lungs, primarily in plasma. In what form is carbon dioxide found in plasma? Name the enzyme that aids the conversion of carbon dioxide in the tissues and in the lungs. How does hemoglobin help with carbon dioxide transport? List two other ways that smaller quantities of carbon dioxide are transported in the blood.

3. List three major differences between internal and external respiration.

4. Summarize the chemical reactions that describe internal and external respiration. Include the location where the reactions occur and the relative pH and temperature at each location.

Summary

Completing this lesson has helped you to:

- understand the differences between external, internal, and cellular respiration
- describe the role of hemoglobin in gas exchange
- list the reactions that describe external respiration occurring in the alveoli
- list the reactions that describe internal respiration occurring in the capillary bed of the tissues