SBI3U-C

Lesson 10

The Human Respiratory System

Introduction

The primary function of the respiratory system is to supply the blood with oxygen to deliver to all parts of the body. The respiratory system does this through breathing. When we breathe, we inhale oxygen (O_2) and exhale carbon dioxide (CO_2). This exchange of gases is the respiratory system's means of getting oxygen to the blood.

The health of our lungs and entire respiratory system is affected by the quality of the air we breathe. In addition to oxygen, this air contains other substances such as pollutants, which can be harmful. Exposure to chemicals by inhalation can negatively affect our lungs and other organs in the body. The health effects caused by air pollutants may range from subtle biochemical and physiological changes to difficulty breathing, wheezing, coughing, and aggravation of existing respiratory and cardiac conditions.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
What is Respiration?	¼
Structure of the Human Respiratory System	½
How the Human Respiratory System Works	½
Activity: Measuring Lung Capacity	1
What Can Affect Lung Function?	½
Writing a Science Article Summary	1
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- use appropriate terminology related to animal anatomy
- explain the anatomy of the respiratory system and the process of ventilation and gas exchange from the environment to the cell (for example, the movement of oxygen from the atmosphere to the cell; the roles of ventilation, hemoglobin, and diffusion in gas exchange)
- use a spirometer to measure lung capacity
- learn to analyze the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

What is Respiration?

Respiration, or breathing, is the process by which O_2 is taken in from the external environment. Breathing involves both inhalation (air moving in) and exhalation (air moving out). The movement of air allows the body to take in the oxygen it needs for cellular activities and remove CO_2, which is a waste product of cellular respiration. The exchange of O_2 and CO_2 occurs in the lungs.

The respiratory system and circulatory system are linked; that is, blood carries the oxygen from the lungs to all the cells of the body. External respiration is the exchange of gases across the respiratory surface, between air sacs called alveoli and the blood. The respiratory surface is where oxygen diffuses into the organism and CO_2 diffuses out of the organism. The surface must be moist in order for diffusion to occur.

Internal respiration is the exchange of gases between the blood and the individual cell in the tissue. Oxygen diffuses out of the blood and CO_2 diffuses into the blood. This exchange makes it possible for cellular respiration to occur.

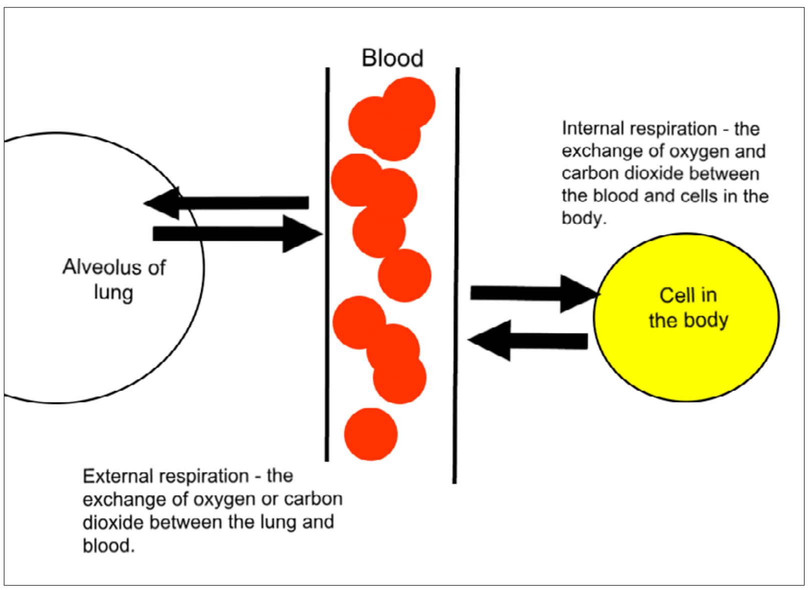

Figure 10.1: Diagram showing internal and external respiration

Cellular respiration occurs at the cellular level in the cytoplasm and mitochondria, and it needs to occur in every cell. It is the process of oxidizing food molecules, like glucose, into CO_2 and water. The energy released is captured in the form of adenosine-5′-triphosphate (ATP) for use by all the energy-consuming activities of the cell. To support the process of cellular respiration, the digestive system supplies glucose, and the respiratory system supplies oxygen and the ability to remove CO_2.

In summary, when you breathe in oxygen, it goes into your lungs, where it crosses into the blood (external respiration). From the blood, it travels through the body and into a body cell (internal respiration). The cell then uses this oxygen to covert glucose into energy (cellular respiration). This process creates carbon dioxide as a waste product, which goes from the body cell into the blood, then from the blood into the lungs where it is exhaled.

Importance of Maintaining Healthy Respiration

Cities with high levels of air pollutants carry the danger of exposing individuals living within them to the possibility of developing asthma, pneumonia, and other lower respiratory infections. Despite the variety of regulations enacted to reduce air pollution since the 1970s, many North Americans still live in areas that are exposed to unsafe levels of one or more major air pollutants. Those pollutants include ozone, particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, and lead. Because children are outdoors more often and breathe more for their size than adults, they are more susceptible to the dangers of air pollution.

Support Questions

24. Match the type of respiration with the correct definition. Suggested answer

Type of respiration	Definition
1. Cellular respiration	A. The exchange of gases between the blood and the individual cell in the tissue
2. Internal respiration	B. The process in which oxygen is taken in from the external environment
3. External respiration	C. The exchange of gases across the respiratory surface between the alveoli and the blood
4. Breathing	D. The process of oxidizing food molecules, like glucose, to produce CO_2 and water

25. How does oxygen get from the atmosphere to the cell? Suggested answer

Structure of the Human Respiratory System

Each day, we breathe about 20 000 times. All of this breathing could not happen without the respiratory system, which includes the nose, throat, larynx, trachea, and lungs (Figure 10.2). Air enters through the nostrils, where it is warmed and cleaned by small hairs that act like filters to remove dust and other particles. As air passes through the nasal cavity, the cilia (tiny hair-like projections) on the nasal cavity's epithelial lining further filter and moisten the air. The air then passes through the back of the mouth, crossing the path of food as it enters the larynx, or voice box. The air then passes down the trachea, through the two tubes called bronchi, each of which is attached to a lung, then into the lungs. Human lungs are located in the chest, or thoracic cavity. The thoracic cavity is bounded on its side by the ribs and inter-costal muscles, and on the bottom by a thick layer of muscle, the diaphragm, which separates the thoracic cavity from the abdominal cavity.

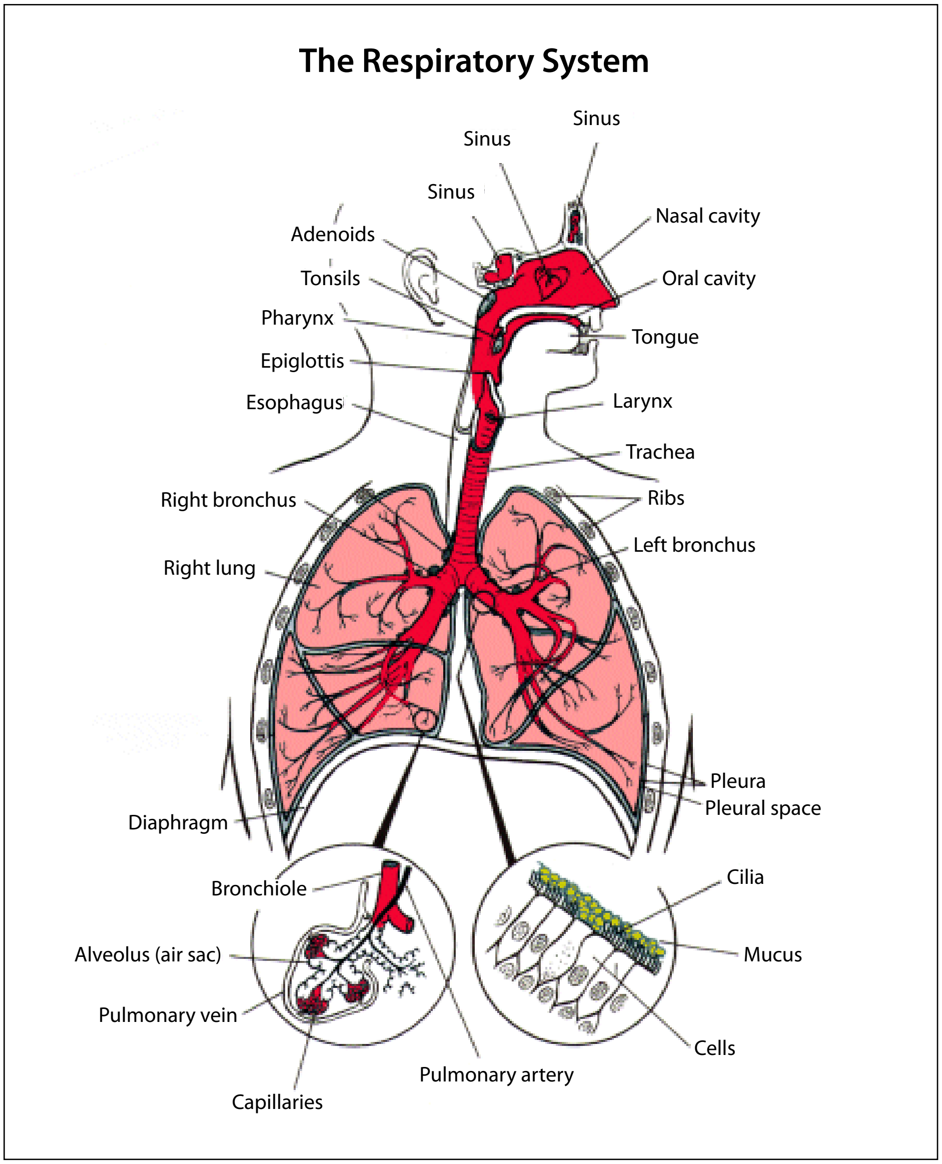

Figure 10.2: The human respiratory system, showing expanded views of the alveolous (bottom left) and the lining of the bronchus (bottom right)

Source: lung.ca

Although we cannot see it, the air we breathe is made up of several gases. The oxygen concentration in the air we breathe is 21% and is the most important gas for keeping us alive because body cells need it for energy and growth. Without oxygen, the body's cells would die.

Respiratory Structures above the Thoracic Cavity

The Nasal and Oral Cavity

Air can enter the body through the nose or mouth. The nose serves three purposes: it warms, filters, and moistens the air before it reaches the lungs. This will not occur if you breathe through your mouth. (Mouth breathing provides a larger portal for air entry in to the trachea, making the work of breathing during exercise easier, however, it will not be warmed, filtered or moistened as well as if you were to breathe through your nose.)

The nasal cavity (also called the nasopharynx) is lined with mucous membranes, which contain many folds to provide a large surface area. This facilitates temperature and moisture control. Cells in the nasal cavity secrete a sticky fluid called mucus that traps dust, particulate matter (such as pollen), bacteria, and other particles in the air. The mucus also helps moisten the air, making it more comfortable to breathe. Under the mucous membrane, there are a large number of capillaries. The blood within these capillaries helps warm the air as it passes through the nose. One of the reasons you get a runny nose in cold weather is because the nasal tissue releases large quantities of fluid in an attempt to warm and moisten the cold, dry air.

The nasal cavity is also lined with cilia, which move back and forth during breathing, pushing any foreign matter (such as dust) either toward the nostrils, where it is blown out, or toward the pharynx, where it travels through the digestive system and is excreted with the rest of the body's waste.

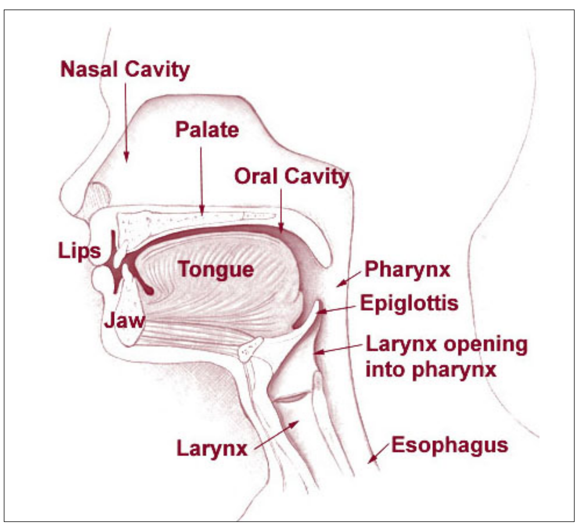

Figure 10.3: Diagram of the nasal and oral cavities

The Pharynx

The nasal cavity and the mouth—the two openings of the airway—meet at the pharynx, or throat, located at the back of the nose and mouth. The pharynx is part of the digestive system as well as the respiratory system because it carries both food and air. At the bottom of the pharynx, the pathway divides in two. One passageway is for food (the esophagus, which leads to the stomach), the other for air (the trachea). The epiglottis, a small flap of tissue, covers the air passage when we swallow, keeping food and liquid from going into the lungs. When air enters the esophagus, it collects and is removed by the process of eructation (burping). When food goes into the trachea instead of the esophagus, coughing occurs to help dislodge the particle of food. Choking may result if the food particle does not dislodge.

The Larynx

The larynx, or voice box, is the uppermost part of the air passage. This short tube contains a pair of muscles called the vocal cords, one on each side of the tube, which vibrate to make sounds, enabling humans to speak and sing. The larynx goes directly into the trachea or windpipe.

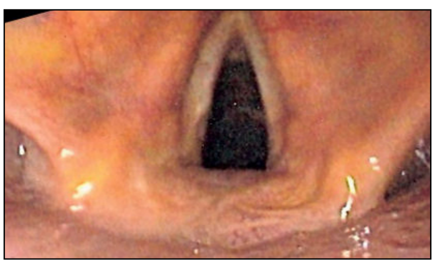

Figure 10.4: Photograph of a human larynx taken during endoscopy

The Trachea

The trachea is a tube approximately 12 centimetres in length and 2.5 centimetres wide. It extends downward from the base of the larynx. It lies partly in the neck and partly in the chest cavity. The walls of the trachea are strengthened by stiff rings of cartilage, which keep it open so air can flow through on its way to the lungs. Like the nasal cavity, the trachea is also lined with cilia, which sweep fluids and foreign particles out of the airway so they stay out of the lungs. Usually, the cilia move mucus and trapped foreign matter to the pharynx where it is normally swallowed.

Respiratory Structures within the Thoracic Cavity

The Lungs

The chest cavity, or thoracic cavity, is an airtight system that houses the bronchi, bronchioles, 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 a large muscle called the diaphragm. The chest walls and ribs form a protective cage around the lungs and other contents of the chest cavity.

The lungs are located on either side of the heart in the thoracic cavity. The upper part of the lung near the collarbone, or clavicle, is called the apex; the broad lower part is called the base. The base of each lung rests on the diaphragm.

Lung tissue is porous and spongy due to the tremendous amount of air sacs that it contains. The right lung is larger and broader than the left lung due to the shape and location of the heart. The right lung is also shorter due to the diaphragm's upward displacement to accommodate the liver. The right lung has three lobes; the left lung has only two.

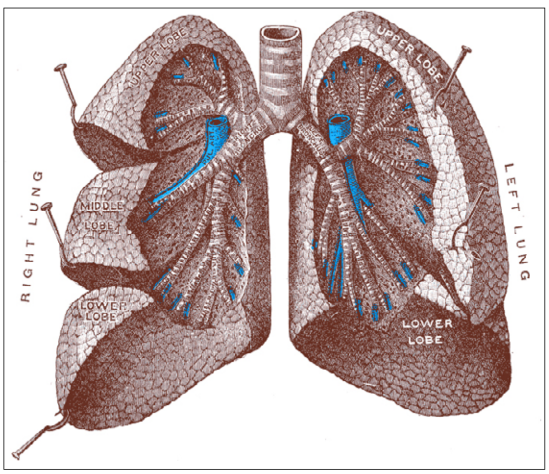

Figure 10.5: Drawing showing the structure of the lungs

Bronchi and Bronchioles

At its bottom end, the trachea divides into left and right air tubes called bronchi, which connect to the lungs. Within the lungs, the bronchi branch into smaller bronchi, then into even smaller tubes called bronchioles. The bronchioles divide and then subdivide. By doing this, their walls become thinner and have less and less cartilage. Bronchioles, which are as thin as a strand of hair, end in tiny air sacs called alveoli, which is where the exchange of oxygen and CO_2 takes place (see below). The network of bronchi, bronchioles and alveoli within the lungs is known as the bronchial tree.

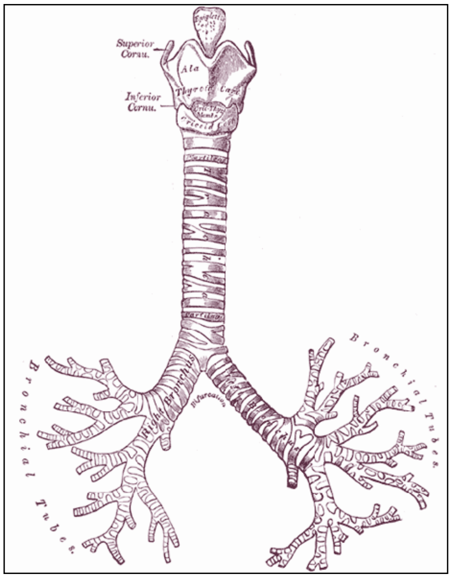

Figure 10.6: Drawing of the bronchi branching in to smaller and smaller tubes

The bronchi not only provide the passageway for air to the lungs, they also serve a cleaning function: they are lined with ciliated cells that secrete mucus to trap foreign particles (Figure 10.2 expanded view, bottom right). These cells then carry the particles upward to the mouth where they can be swallowed. It is estimated that every person swallows, on average, about 946 mL (almost 1 litre) of this mucus every day!

The Alveoli

Each bronchiole ends in a tiny air chamber that looks like a bunch of grapes, composed of many cup-shaped cavities known as alveoli (Figure 10.7).

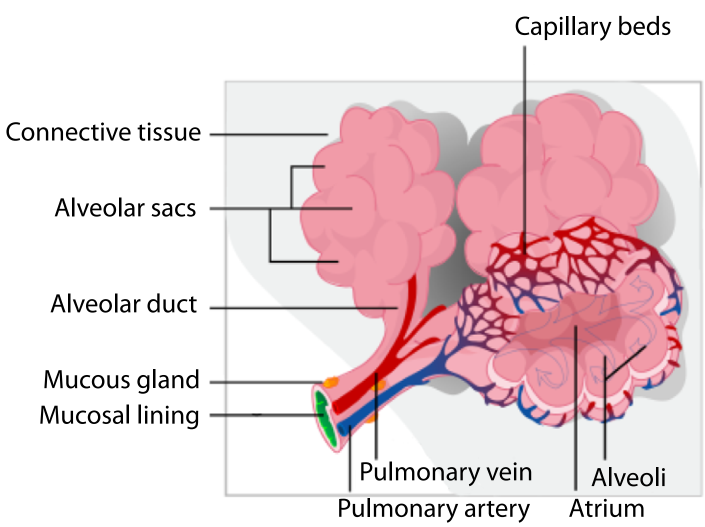

Figure 10.7: Image showing the structure of the alveoli

Each individual cavity is known as an alveolus. The walls of the alveoli, which are only about one cell thick, are the respiratory surface. They are thin and moist, and are surrounded by capillaries (tiny blood vessels). The exchange of oxygen and CO_2 between blood and inhaled air occurs through these walls. CO_2 diffuses from the red blood cells, through the capillary walls, into the alveoli. CO_2 leaves the alveoli through the nose and mouth. The opposite process occurs with oxygen, which diffuses from the alveoli into the capillaries, and from there into the red blood cells.

It is estimated that each lung contains about 150 million alveoli, with a total surface area of about 70 m^2. The gas exchange occurring in the lungs would not be nearly as large if the lungs were hollow bags. The inner walls of the alveoli are covered with a lipid-based material known as a surfactant. This surfactant helps to stabilize the alveoli, preventing their collapse. The absence of this surfactant would cause the alveoli to behave in a similar way to a plastic bag that is wet on the inside—its walls would stick together, preventing it from expanding to its full capacity.

When cigarette smoke is inhaled, about one-third of the smoke particles will remain within the alveoli, damaging the alveoli walls. Smoking causes a reduction in the working area of the respiratory surface and flexibility, leading to the disease called emphysema. Emphysema is a condition in which the alveoli lose their elasticity and crack or explode, thus decreasing the surface area for gas exchange.

The Diaphragm and Pleura

The lungs contain elastic tissues that allow them to inflate and deflate without losing shape. Lungs are connected to the diaphragm and to the walls of the thorax by the pleura. The parietal pleura line the chest wall; the visceral pleura are actually on the surface of the lungs. Between the two pleural membranes is a fluid that prevents friction and keeps the two membranes together during breathing.

The lungs are not able to inflate and deflate on their own. Breathing requires the use of the diaphragm, which is the major muscle of respiration. It is a large, dome-shaped muscle located below the lungs that contracts rhythmically and continually, and most of the time, involuntarily. Upon inhalation, the diaphragm contracts and flattens, and the chest cavity enlarges. This contraction creates a vacuum, which pulls air into the lungs. Upon exhalation, the diaphragm relaxes and returns to its domelike shape, and air is forced out of the lungs.

Recommended activity:

Do an Internet search using the terms “inhalation exhalation animation” and watch a video about the respiratory system.

The diaphragm almost always works perfectly, except when it becomes irritated. When this happens, it pulls down in a jerky way, which makes you suck air into your throat suddenly. When the air rushing in hits your voice box, you are left with a hiccup.

Support Questions

26. Draw and label the following structures of the respiratory system: trachea, lungs, right and left bronchus, bronchioles, and diaphragm. Suggested answer

27. What is the function of cilia in the respiratory system? Suggested answer

28. In the lungs, where does gas exchange occur? Suggested answer

How the Human Respiratory System Works

Gas Exchange and the Process of Diffusion

Gas exchange and breathing are two different processes. The main function of the respiratory system is gas exchange. This refers to the process of oxygen (O_2) and carbon dioxide (CO_2) moving between the lungs and blood. Efficient gas exchange can only occur if the alveoli are flushed regularly with fresh air.

Air moves in and out of the lungs every time a breath is taken. Thousands of capillaries line the lungs. Their function is to pick up the incoming oxygen. Red blood cells contain a protein called hemoglobin, which has binding sites for O_2 and CO_2. As O_2 enters the bloodstream, CO_2 leaves, exiting through the alveoli.

Each alveolus is lined with a thin layer of tissue and fluid, which is essential for the diffusion of O_2 and CO_2, because a gas must dissolve in a liquid in order to enter or leave a cell. In the tiny capillaries, oxygen is freed from hemoglobin and moves into the cells (Figure 10.8). Carbon dioxide, which is produced during the process of cellular respiration, diffuses out of these cells into the capillaries; most of it is then dissolved in the plasma of the blood. Blood rich in CO_2 then returns to the heart via the veins. From the heart, this blood is pumped to the lungs, where CO_2 passes into the alveoli to be exhaled.

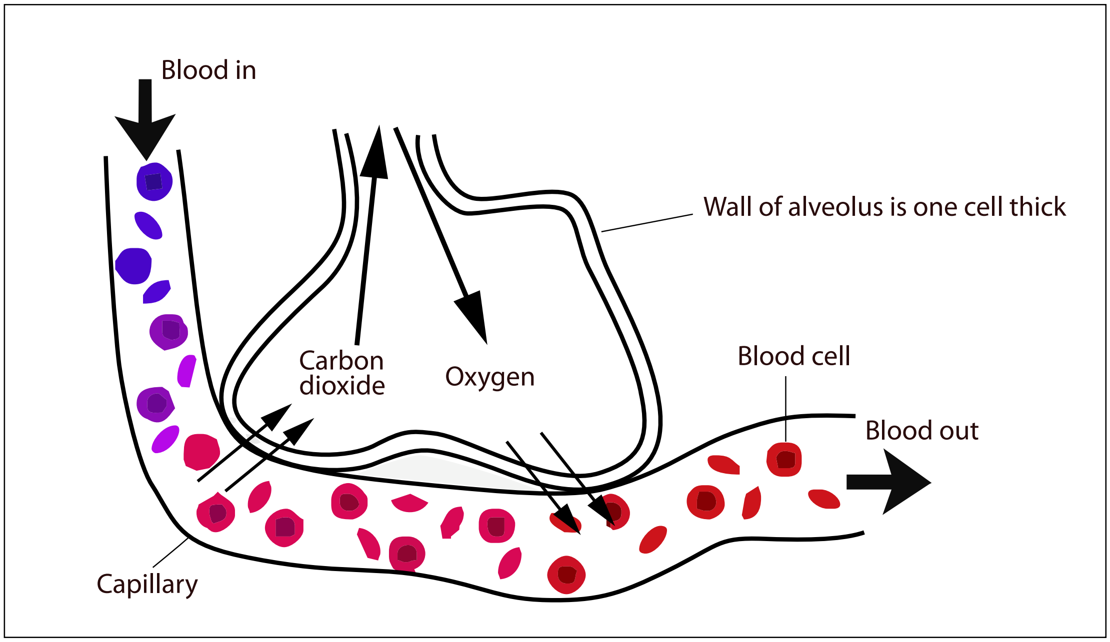

Figure 10.8: Cross-section of an alveolus

Diffusion is the process by which molecules of a given substance move from an area of relatively high concentration to an area of lower concentration. The exchange of gases (O_2 and CO_2) between the alveoli and the blood occurs by simple diffusion: O_2 diffusing from the alveoli into the blood, and CO_2 from the blood into the alveoli. Since diffusion requires an unequal distribution of gas molecules, the concentration of O_2 in the alveoli must be kept at a higher level than in the blood, and the concentration of CO_2 in the alveoli must be kept at a lower lever than in the blood. This is accomplished by continuously bringing fresh air (with lots of O_2 and little CO_2) into the lungs and the alveoli through the breathing process.

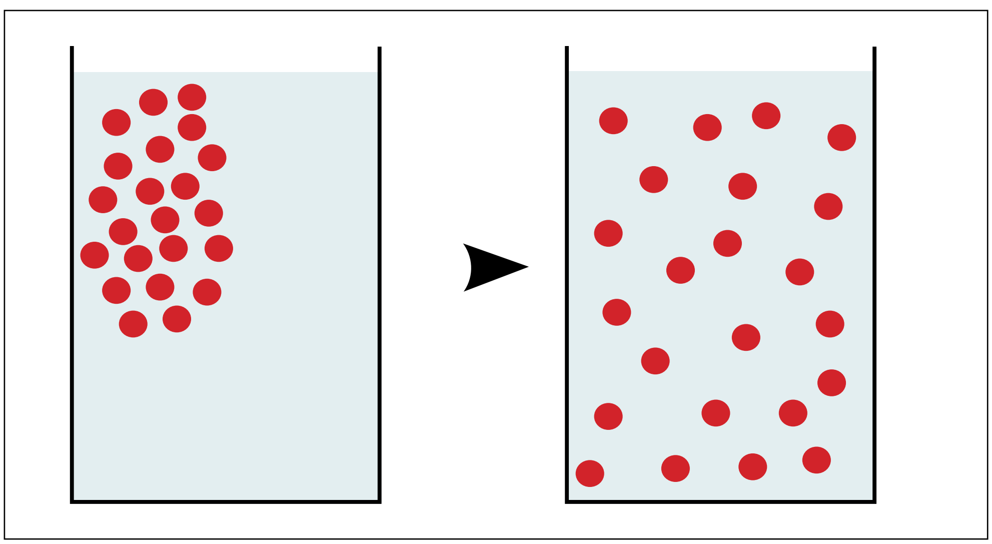

Figure 10.9: Diagram showing how molecules spread out evenly as diffusion takes place

The Breathing Process

Breathing is a cyclic repetition of inhalation (also called inspiration) and exhalation (also called expiration). During inhalation, the thoracic cavity enlarges, and the lungs fill with air. During exhalation, air is pushed out of the lungs, and the thoracic cavity decreases in size. The average person takes 12 to 16 breaths each minute. Air moves in and out of the lungs because of changes of pressure within the thorax, due to the action of the diaphragm. Gases (O_2 and CO_2) move from areas of high pressure to areas of lower pressure. When the internal pressure of the thoracic cavity is less than atmospheric pressure outside of the mouth, gas is drawn inwards in inhalation. When the opposite is true, gas moves outwards, resulting in exhalation.

The diaphragm, therefore, plays a lead role in breathing. When we breathe in, the diaphragm moves downward, toward the abdomen, and the rib muscles pull the ribs upward and outward, enlarging the chest cavity and pulling air in through the nose or mouth. Air pressure in the chest cavity and lungs is reduced, and because gas flows from areas of high pressure to low pressure, air from the environment flows through the nose or mouth into the lungs. When we breathe out, the diaphragm moves upward, forcing the chest cavity to get smaller, and pushing the gases in the lungs up and out through the nose and mouth. Air pressure in the lungs is increased, so air flows from the lungs, through the nose or mouth, up and out of the respiratory system back into the environment.

Breathing Rate

A respiratory control centre in the medulla oblongata, at the base of your brain, controls your breathing. This centre sends ongoing signals down your spine to the nerves of the muscles involved in breathing. Muscular contraction and relaxation controls the rate of expansion and contraction of the lungs. These muscles are stimulated by nerves that carry messages from the medulla.

Two systems control breathing: an automatic response and a voluntary response. Both are involved in holding your breath. Although an automatic breathing regulation allows you to breathe while you sleep, it sometimes malfunctions. In adults, sleep apnea involves stoppage of breathing for as long as 10 seconds, which can happen in some individuals as often as 300 times per night. In newborns, a malfunction of the automatic response may result in SIDS (sudden infant death syndrome).

Specialized nerve cells within the aorta and carotid arteries of the heart called peripheral chemoreceptors monitor the O_2 concentration of the blood and provide feedback to the respiratory control center. If the O_2 concentration in the blood decreases, they tell the respiratory center to increase the rate and depth of breathing. Peripheral chemoreceptors also monitor the CO_2 concentration in the blood. If the CO_2 concentration gets too high, then the chemoreceptors signal the respiratory center to increase the rate and depth of breathing. The increased rate of breathing returns the CO_2 concentration to normal, and the breathing rate then slows down. Stretch receptors in the lungs and chest wall monitor the amount of stretch in these organs. If the lungs become over-inflated (stretch too much), they signal the respiratory center to exhale and inhibit inspiration. This mechanism prevents damage to the lungs that would be caused by over-inflation.

Nerve cells in the airways also sense the presence of unwanted substances such as pollen, dust, noxious fumes, water, or cigarette smoke. These cells then signal the respiratory center to contract the respiratory muscles, causing you to sneeze or cough. Coughing and sneezing cause air to be rapidly and violently exhaled from the lungs and airways, removing the offending substance.

A question often asked by biology students is “Does air exhaled from someone else’s mouth really provide enough oxygen to save an unconscious person through mouth-to-mouth resuscitation?” The air we breathe in contains approximately 21% O_2 and 0.04% CO_2. Because O_2 is used to produce energy, and CO_2 is a waste by-product of producing energy, the air we breathe out will contain less O_2 and more CO_2 than the air we breathe in. As it turns out, however, the air we exhale contains approximately 3% CO_2 and 17% O_2, which is more than enough oxygen to supply the needs of a victim requiring mouth-to-mouth resuscitation—and carbon dioxide levels only become toxic above levels of 5%.

Support Questions

29. The average human takes about one breath every five seconds. Calculate how many breaths the average human would take in 20 minutes. Suggested answer

30. Explain how mouth-to-mouth resuscitation provides sufficient oxygen to an unconscious person. Suggested answer

Activity

Now watch this animated tutorial called Gas Exchange in Lungs, Alveoli and Human Cells.

Lung Capacity and Respiratory Volumes

Lung capacity is the amount of space available in the lungs to store air. Respiratory volumes are the actual amounts of air inhaled, stored, and exhaled from the lungs at any given time. Both measurements are expressed in millilitres (mL), although they can also be expressed in litres (L) or cubic centimetres (cm^3). (Note: one mL is equal to one cm^3.) A spirometer is a medical device used to measure respiratory volumes (Figure 10.10). There are many types of spirometers and, as you will see, you can even make one out of a balloon.

Figure 10.10: A type of spirometer used to measure lung capacity. The patient blows into the tube on the right and the volume of air exhaled is measured by the graduated cylinder.

Lung capacities differ with age, sex, body frame, and aerobic fitness. Measuring your lung capacity can help you determine how much stamina you have available to go about your daily routine, including sports and other activities. Usually, you need about one-third of your lung capacity to carry out routine tasks that do not require exertion. It is also possible for you to increase your lung capacity through regular exercise. Your lung capacity may be affected by certain disorders such as asthma and emphysema. Cigarette smoking will give you noticeable signs of emphysema after only three years of use. Such things as altitude, the position your body is in, air temperature, weather conditions, and air pollution may also affect lung capacity.

Lung capacity can be measured several ways:

Tidal Capacity

Tidal capacity is the amount of air your lungs can hold during normal breathing; in other words, the amount of air moved in and out of the body in one breath. This amount of air supplies enough O_2 for a person who is resting. The amount of air that enters the lungs during normal inhalation at rest is known as the tidal volume. The same amount leaves the lungs during exhalation. The average tidal volume is 500 mL.

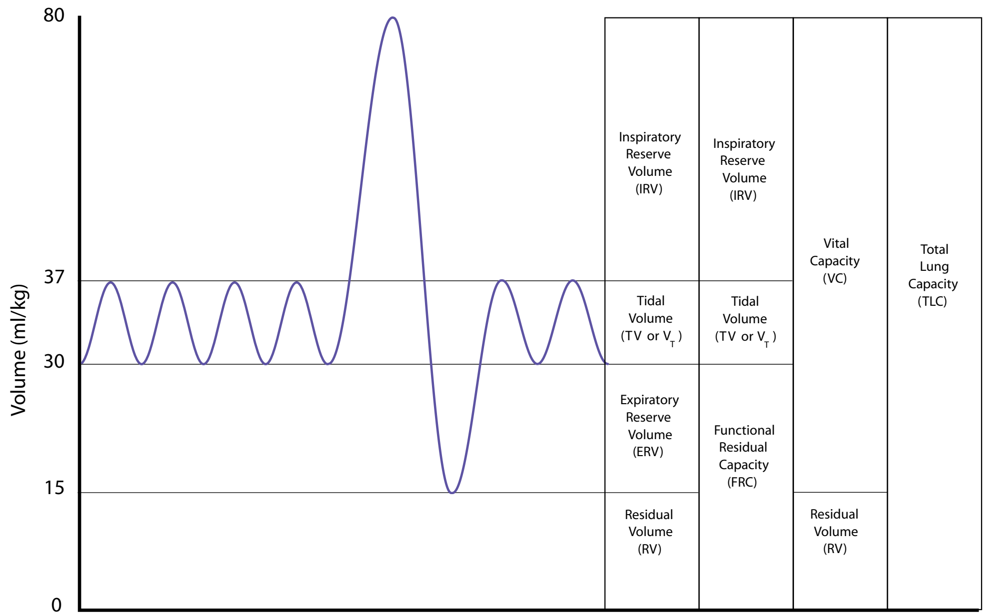

Figure 10.11: Graph comparing the different lung volumes

Reserve Volumes

The amount of extra air (beyond tidal volume) inhaled during a deep breath is known as the inspiratory reserve volume. This can be as high as 3000 mL. The expiratory reserve volume is the amount of extra air (beyond tidal volume) exhaled during a forceful breath out.

Vital Capacity

Vital capacity is the total amount of air that can be exhaled in one breath; in other words, the maximum amount of air that can be forcibly exhaled after breathing in as much as possible. This volume of air can be up to ten times more than you would normally exhale.

Residual Capacity

Residual capacity is the amount of room left in the lungs after a deep exhalation. The actual amount of air left in the lungs following a maximal exhalation is known as the residual volume. There must always be some air remaining in the lungs to prevent them from collapsing.

Total Lung Capacity

Total lung capacity is the total amount of air the lungs can hold; in other words, the amount of air in the lungs after a deep inhalation. It is equivalent to the vital capacity plus the residual capacity. The average total lung capacity is 6000 mL.

Anatomical Dead Space Air

Some amount of air remains behind in the various parts of the respiratory tract. The air in the trachea, bronchi and bronchioles (where no diffusion occurs) is called anatomical dead space air, and always consists of the last bit of air to be exhaled from the previous exhalation. When 500 mL of air is inhaled and 150 mL occupies anatomical dead space—in other words, it does not reach the alveoli—only 350 mL of the inhaled air is available for gas exchange. The other 150 mL of air is stale, and is depleted of O_2.

Activity: Measuring Lung Capacity

Purpose

To measure your lungs' tidal capacity and vital capacity using a homemade spirometer

Materials

- 1 round balloon
- 1 metric ruler
- 1 friend or family member

Procedure

Note: if you are unable to do this activity, you can use the sample data provided in the Suggested Answers to Support Questions for Lesson 10.

1. Measure your tidal capacity.
   a) Stretch a round balloon several times so that it will be easier to blow into it.
   b) Inhale normally, then exhale normally into the balloon. You want to capture the amount of air found in a normal breath.
   c) Pinch the end of the balloon and measure its diameter (Figure 10.12). Record your measurement in Table 10.1 under the heading Tidal Capacity—Balloon Diameter.
   d) Repeat steps b) and c) four more times, for a total of five measurements.

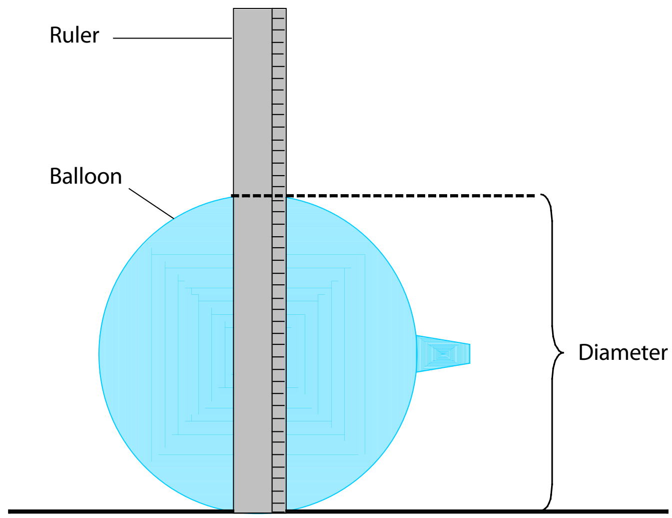

Figure 10.12: How to measure the diameter of the balloon

2. Measure your vital capacity.

    a) Stretch a round balloon several times to stretch it out.

    b) This time, inhale as much air as you can get into your lungs, then exhale as much air as you can into the balloon. You want to capture the amount of air found in your maximum-sized breath.

    c) Pinch the end of the balloon and measure its diameter. Record your measurement in Table 10.1 under the heading Vital Capacity—Balloon Diameter.

    d) Repeat steps b) and c) four more times, for a total of five measurements.

3. Convert your results to units of volume.

    Use the graph in Figure 10.13, below, to convert the round balloon diameters (in centimetres) to the approximate volume for tidal and vital capacity (in cubic centimetres). For example, if the tidal capacity balloon diameter was 10 cm, then the volume would be approximately 500 cm^3. Record these measurements in Table 10.1 in the Volume of Air column under the appropriate heading.

4. Calculate the average diameter.

    Calculate the average diameter for tidal capacity and vital capacity. To calculate the average diameter for five trials, add the five individual trial values together, then divide the sum by 5. The answer will be the average, or mean, trial value. For example:

    Trial 1: 14.0 cm

    Trial 2: 13.5 cm

    Trial 3: 13.8 cm

    Trial 4: 14.1 cm

    Trial 5: 14.2 cm

    Sum = (14 + 13.5 + 13.8 + 14.1 + 14.2) = 69.6

Average = 69.6 ÷ 5 = 13.92 cm.

Therefore, the average diameter for the five trials is 13.92 cm.

5. Repeat steps 1 to 4 of this procedure for a friend or family member.

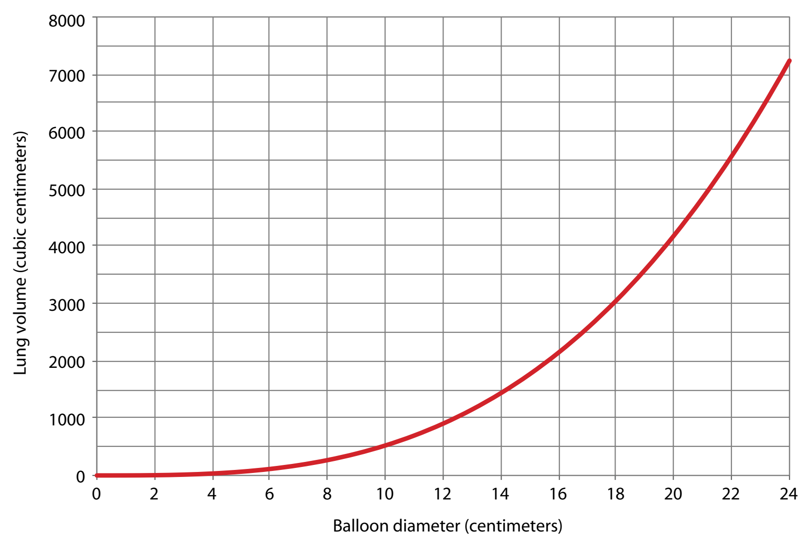

Figure 10.13: Converting balloon diameters to volume

Your results	Tidal capacity		Vital capacity	
Trial	**Balloon diameter (cm)**	**Volume of air (cm^3)**	**Balloon diameter (cm)**	**Volume of air (cm^3)**
1				
2				
3				
4				
5				
Average				

Friend or family member's results	Tidal capacity		Vital capacity	
Trial	Balloon diameter (cm)	Volume of air (cm^3)	Balloon diameter (cm)	Volume of air (cm^3)
1				
2				
3				
4				
5				
Average				

Table 10.1: Tidal and vital capacity measurements

Support Questions

31. What is meant by total lung capacity? Suggested answer

32. Compare your data to the data for your friend or family members. If you do not have your own data, you can use the sample data provided in the Suggested Answer to make a comparison. How can you account for the differences in the two tables? Suggested answer

33. How might an athlete's vital capacity compare to that of a non-athlete? Assume both are males of the same height, age, and mass. Explain your reasoning. Suggested answer

What Can Affect Lung Function?

We breathe about 20 000 times each day, inhaling about 16 kilograms of air—six times more than the food and drink we consume. Several factors can affect lung function, including air pollution, smoking, elevation, and exercise.

Air Pollution

Many of us breathe dirty urban air laden with particulates, carbon monoxide, and other substances that are damaging to the respiratory system. Our lungs have a variety of defense mechanisms to help protect themselves.

Filtration

The hairs inside the nostrils and the ciliated mucous lining in the nose and pharynx act as filters that trap foreign particles in inhaled air, preventing them from reaching the lungs.

Bronchial Constriction

Bronchial constriction is one of the most rapid defenses against breathing in dirty air. In this process, the bronchial tubes become narrower, and inhaled particles are more likely to land on the sticky mucous lining. As a result of this constriction, however, less air can pass through the lungs, decreasing the amount of O_2 being supplied to the body's cells. Chain-smokers remain in a state of chronic bronchial constriction.

Macrophages

Because the alveoli are not equipped with mucus or ciliated cells, foreign particles that make their way into the alveoli are engulfed and "eaten" by specialized white blood cells called macrophages. If there are too many foreign particles present because of air pollution, there may be a buildup of macrophages. These can accumulate in the lymph tissue of the lungs, causing inflammation and illness.

Smoking

The respiratory system cannot deal with tobacco smoke very well. Tobacco smoke contains 4000 different substances. Some of the most hazardous compounds are tar, nicotine, carbon monoxide (CO), cadmium, nitrogen dioxide, and hydrogen sulfide. Smoking stops the cilia from moving. Just one cigarette slows their motion for about 20 minutes. The tobacco smoke increases the amount of mucus in the air passages. When smokers cough, their body is attempting to get rid of the extra mucus.

The alveoli fill up with air when we breathe in, and deflate when we breathe out. In healthy lungs, the alveoli are springy and spongy, and the passageways that lead to the alveoli are unobstructed, wide and open. In unhealthy lungs—mainly smokers' lungs—the air passages are partially blocked, inflamed, or narrowed, and the alveoli are damaged, gradually becoming looser, saggy, and out of shape. The lungs' elasticity is destroyed; this is what makes the expansion and contraction of the lungs less efficient, and breathing more laboured and more frequent.

Smokers' lungs usually have dark spots corresponding to the areas containing tar and nicotine. The tar in cigarette smoke can be particularly damaging, as prolonged exposure can lead to the narrowing of the bronchioles and destruction of the lungs' protection and filter system. The cilia of the lungs get coated with tar, so the lungs cannot clean themselves and the smoker develops smoker's hack, a persistent cough that is a reaction to dirty lungs. Quitting smoking will reverse this effect. The cilia will recover, and the harmful substances will start to be cleaned out of the lungs more efficiently, eventually removing all traces of smoke particles from them. The process can be reversed as long as the smoker has not already developed chronic obstructive pulmonary disease, a condition that severely affects the lungs and respiratory system.

People that smoke are highly susceptible to emphysema. There is also a strong link between cigarette smoking and lung cancer. The smoking-related cancers—lung, mouth, lip, tongue, throat, larynx, pancreas, esophagus, and pharynx—have all seen marked increases over the twentieth century.

Second-hand smoke may be just as dangerous. Some studies suggest that smokers develop immunity to smoke that non-smokers do not. Across Canada, about 3000 people die each year from exposure to second-hand smoke.

The Human Body at Higher Elevations

Our bodies are adapted to perform optimally at sea level. As you climb higher, the proportion of each gas in the air stays the same but, because of lower pressure, the gas expands—making the air "thinner." Therefore, each breath at high altitudes actually brings in less O_2 than at sea level. A low level of O_2 delivered to the cells of the body produces a condition called hypoxia.

Immediate responses to these low levels of O_2 include rapid and deeper breathing as well as increased heart rate. Other body responses to this stress, called chronic responses or acclimatization, take longer to develop. People living at high altitudes acclimatize in several ways to help them function at high altitudes, including

- increased production of red blood cells (which can take up to two months to mature);
- improved circulation to body tissues (20–30% of the body's capillary system is normally not used, but at high altitudes all the capillaries are used to deliver O_2 to tissues);
- increased pulmonary blood pressure;
- increased mitochondrial density; and
- increased muscle myoglobin.

At the peak of Mount Everest, the maximum amount of O_2 that can be extracted from the air and delivered to the cells is only 30 to 40% of sea level readings; therefore, doing work at high altitudes is indeed much more difficult than at sea level, even with acclimatization.

Effect of Exercise

A person's vital capacity is greatly affected by their daily activities. Smoking or inactivity decrease the vital capacity by reducing the ability to exchange O_2 for CO_2. Regular exercise increases the body's need for O_2 and leads to numerous and varied physiological changes that are beneficial from a health standpoint, including

- improved cardio-respiratory function;
- improved skeletal muscle function;
- higher bone density;
- higher levels of high-density lipoprotein cholesterol (the so-called "good" cholesterol);

- lower blood pressure;
- decreased insulin need and improved glucose tolerance;
- enhanced performance at physical activities; and
- many psychological benefits.

Improved cardio-respiratory function means that the body is able to perform exercise much more efficiently. Exercises to improve cardio-respiratory function include swimming or middle- to long-distance running, whereby your heart rate is increased consistently but not intensively for long periods of time. This means respiration is more laboured than usual, and the lungs are forced to expand in order to cope with the increased workload to ensure your muscles receive oxygen more quickly. These exercises have been shown to increase the lungs' vital capacity.

In general, however, regular exercise does not substantially change measures of pulmonary function such as total lung capacity and vital capacity. One of the biggest differences between an athlete and a non-athlete concerns the heart's ability to pump blood and, consequently, deliver oxygen to working muscles.

Support Questions

34. Match the term to the definition.

Suggested answer

Term	Definition
1. Tidal volume	A. The amount of extra air inhaled (above tidal volume) during a deep breath
2. Inspiratory reserve volume	B. The last bit of air to be exhaled from the previous exhalation, which is depleted of O2
3. Expiratory reserve volume	C. The amount of air left in the lungs following a maximal exhalation
4. Residual volume	D. The most air you can exhale after taking the deepest breath
5. Vital capacity	E. The amount of extra air exhaled (above tidal volume) during a forceful breath out
6. Anatomical dead space air	F. The amount of air which enters the lungs during normal inhalation at rest

Writing a Science Article Summary

In this section, you will be asked to write a summary of a science article. To do this, you must answer the following four questions. In this course, we call these the four questions of research.

1. What was done?
2. Why was it done?
3. What was found?
4. What does it all mean?

Read the following article from the USC News called *Smog May Cause Lifelong Lung Deficits* and answer the questions at the end.

Support Questions

35. What was done? Suggested answer

36. Why was it done? Suggested answer

37. What was found? Suggested answer

38. What does it all mean? Suggested answer

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(17 marks)

29. During mouth-to-mouth resuscitation, exhaled air is forced into the victim's trachea. Exhaled air contains a higher level of CO_2 than atmospheric air. Would the higher level of CO_2 create problems for the victim, or would the exhaled air be beneficial? Explain. **(4 marks)**

30. Describe the journey of a carbon-dioxide molecule from an alveolus to the outside world. Describe the seven structures it passes along its way out of the body. Start your answer with carbon dioxide (CO_2) diffusing out of the blood into the alveoli. **(7 marks: 1 mark for each structure in the proper sequence)**

31. Consider the table below.

Person	Breathing rate (breaths per minute)	O_2 content in the blood (mL O_2 per 100 mL blood)
A	24	6
B	19	14
C	12	22
D	15	20

a) Which person is probably a smoker? Explain. **(3 marks)**

b) Which person is probably an athlete? Explain. **(3 marks)**

Now go on to Lesson 11. Send your answers to the Key Questions to the ILC when you have completed Unit 3 (Lessons 9 to 12).