15

The Respiratory System

FOCUS: The respiratory system consists of the nasal cavity, pharynx, larynx, trachea, and lungs. The diaphragm and thoracic wall muscles change the volume of the thoracic cavity, producing pressure gradients responsible for the movement of air into and out of the lungs. Oxygen is mostly transported bound to hemoglobin, and most carbon dioxide is transported as bicarbonate ions. Respiration is controlled by centers in the brain. The most important regulators of resting respiration are blood carbon dioxide and pH levels, although low blood oxygen levels can increase respiration. Respiration during exercise is mostly determined by the cerebral motor cortex and by feedback from proprioceptors.

CONTENT LEARNING ACTIVITY

Nose and Nasal Cavity

"*Air enters the external nares and passes through the nasal cavity into the pharynx.*"

Match these terms with the correct statement or definition:

Conchae	Internal nares
Epithelium	Nasal septum
External nares	Nasolacrimal duct
Hard palate	Paranasal sinuses

_____ 1. Posterior openings from the nasal cavity into the pharynx.

_____ 2. Divides the nasal cavity into right and left parts.

_____ 3. Bony ridges on the lateral walls of the nasal cavity.

_____ 4. Air-filled spaces within bones that connect to the nasal cavity; reduce skull weight and act as resonating chambers.

_____ 5. Brings tears from the eyes into the nasal cavity.

_____ 6. Produces mucus that traps debris in the air; moves mucus to the pharynx.

 The nasal cavity filters, humidifies, and warms air.

Pharynx

"*The pharynx is the common passageway of both the digestive and respiratory systems.*"

Match these terms with the correct statement or definition:

Laryngopharynx
Nasopharynx
Oropharynx
Soft palate
Uvula

_____ 1. The superior part of the pharynx.

_____ 2. These two structures prevent swallowed materials from entering the nasopharynx.

_____

_____ 3. The auditory tubes open into this part of the pharynx.

_____ 4. Extends from the uvula to the epiglottis; the oral cavity opens into it.

_____ 5. Connects to the esophagus.

Larynx

"*The larynx is the site of voice production.*"

A. Match these terms with the correct statement or definition:

Arytenoid cartilage
Corniculate cartilage
Cricoid cartilage
Cuneiform cartilage
Epiglottis
Thyroid cartilage
Vestibular folds
Vocal folds

_____ 1. Largest, unpaired cartilage of the larynx; the Adam's apple.

_____ 2. Unpaired cartilage; covers opening into larynx during swallowing.

_____ 3. Three paired cartilages.

_____

_____

_____ 4. Ligaments that close together to prevent materials from entering the larynx.

_____ 5. Vibrate to produce sound; the true vocal cords.

 Laryngitis is an inflammation of the mucous membranes covering the true vocal cords.

B. Match these terms with the correct parts labeled in figure 15.1

Conchae
Epiglottis
External naris
Hard palate
Internal naris
Laryngopharynx
Larynx
Nasopharynx
Oropharynx
Soft palate
Thyroid cartilage
Trachea
Uvula
Vestibular fold
Vocal fold

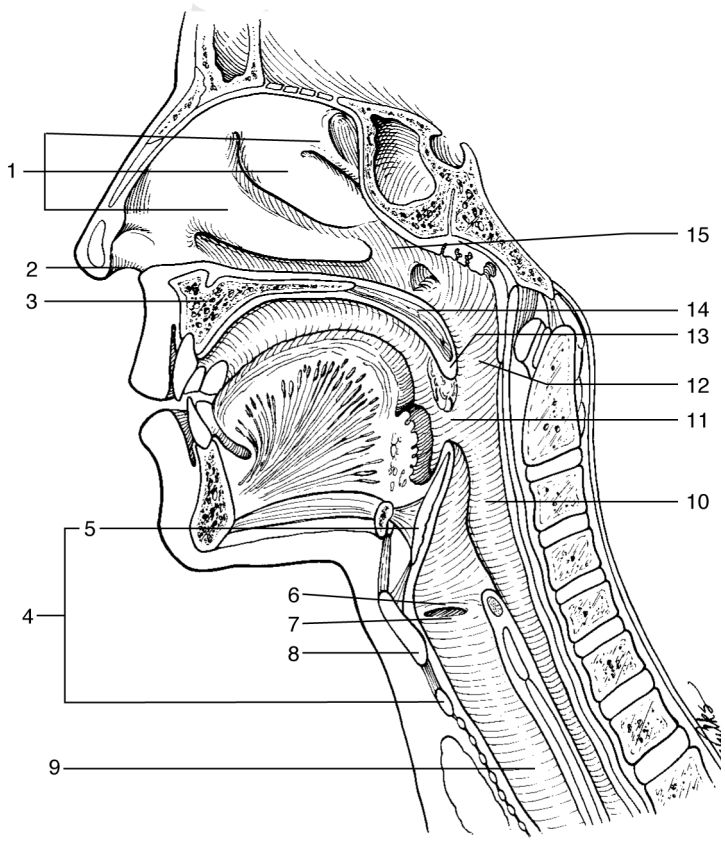

Figure 15.1

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____

Trachea and Bronchi

"*The trachea and bronchi serve as passageways for air between the larynx and lungs.*"

Match these terms with the correct statement or definition:

Primary bronchi
Trachea

_____ 1. Extends from the larynx and divides to form two tubes; supported by C-shaped cartilages.

_____ 2. During swallowing, the esophagus pushes into this tube.

_____ 3. Tubes that supply each lung.

Lungs

"*The lungs are the principal organs of respiration.*"

A. Match these terms with the correct statement or definition:

Alveolar ducts
Alveoli
Bronchopulmonary segments
Lobes
Secondary bronchi
Terminal bronchioles
Tertiary bronchi

_____ 1. Parts of the lung separated by deep fissures on the surface of the lungs.

_____ 2. Sections of lung separated by connective tissue but not visible as surface fissures.

_____ 3. Tubes that supply the lobes of the lungs.

_____ 4. Tubes that supply the bronchopulmonary segments.

_____ 5. Tubes that supply the respiratory bronchioles.

_____ 6. Tubes formed by the subdivision of the respiratory bronchioles.

_____ 7. Place where most gas exchange takes place (some exchange takes place in the alveolar ducts and respiratory bronchioles).

B. Match these terms with the correct parts labeled in figure 15.2:

Alveolar ducts
Alveoli
Primary bronchi
Respiratory bronchiole
Secondary bronchi
Terminal bronchiole
Tertiary bronchi
Trachea

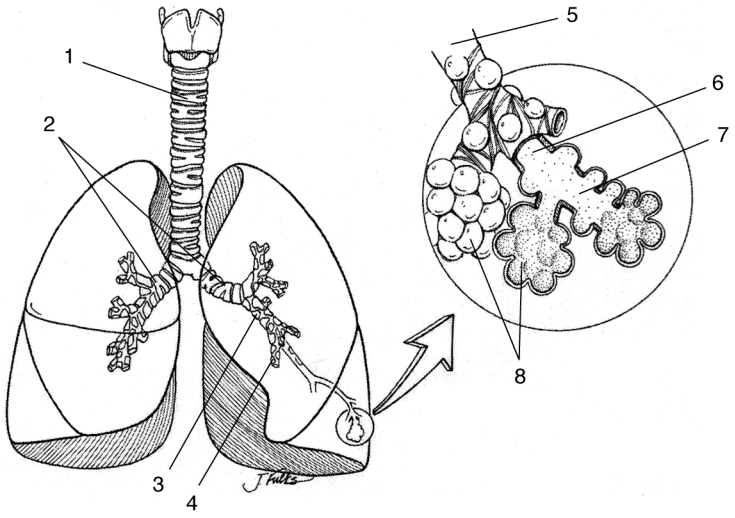

Figure 15.2

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Pleural Cavities

"*Each lung is surrounded by a separate pleural cavity.*"

Match these terms with the correct statement or definition:

Parietal pleura
Pleural cavity
Pleural fluid
Thoracic cavity
Visceral pleura

_____ 1. Cavity that contains the lungs and the pleural cavities.

_____ 2. Cavity formed by membranes; surround the lungs.

_____ 3. The part of the pleural membrane that is in contact with the lungs.

_____ 4. The pleural cavity contains a thin film of this substance which acts as a lubricant.

Pleurisy is an inflammation of the pleural membranes.

Lymphatic Supply

"*The lungs have two lymphatic supplies.*"

Match these terms with the correct statement or definition:

Deep lymphatic vessels
Superficial lymphatic vessels

_____ 1. Located deep to the visceral pleura.

_____ 2. Follows the bronchi, but does not supply alveoli.

Phagocytic cells pick up carbon particles and other debris from inspired air and move it to the lymphatic vessels.

Changing Thoracic Volume

"*Muscles associated with the ribs are responsible for breathing.*"

Match these terms with the correct statement or definition:

Diaphragm
Muscles of inspiration
Muscles of expiration

_____ 1. Includes the diaphragm and muscles that elevate the ribs and sternum.

_____ 2. Muscles that depress the ribs and sternum.

_____ 3. Responsible for most of the change in thoracic volume during breathing.

_____ 4. Expiration during quite breathing occurs when these muscles relax and the elastic recoil of the thorax and lungs decreases thoracic volume.

Pressure Changes and Air Flow

"*Changes in air pressure, produced by the muscles of respiration, result in air flow.*"

A. Using the terms provided, complete these statements:

Decreases	Lower
Higher	Pressure
Increases	Volume

The flow of air into and out of the lungs is governed by two physical principles:

1. Changes in volume result in changes in pressure. As the volume of a container increases, the pressure within the container (1), and as the volume of a container decreases, the pressure within the container (2).
2. Air flows from areas of (3) pressure to areas of (4) pressure.

The muscles of respiration cause changes in thoracic (5), and changes in thoracic volume cause changes in (6) that result in air flow.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

B. Using the terms provided, complete these statements:

Alveolar pressure	Into
Atmospheric pressure	Less than
Equal to	Out of
Greater than	

The air pressure within the alveoli is called (1), and the air pressure outside the body is called (2). At the end of expiration, alveolar pressure is (3) atmospheric pressure and there is no movement of air into or out of the lungs. During inspiration, alveolar volume increases, causing alveolar pressure to become (4) atmospheric pressure. Because of this pressure difference, air moves (5) the lungs. At the end of inspiration, alveolar pressure is (6) atmospheric pressure and there is no movement of air into or out of the lungs. During expiration, alveolar volume decreases, causing alveolar pressure to become (7) atmospheric pressure. Because of this pressure difference, air moves (8) the lungs.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Lung Recoil

"*Passive recoil of the thorax and lungs decreases thoracic and lung volumes.*"

A. Match these terms with the correct statement or definition:

Elastic fibers
Pleural pressure
Surface tension of alveolar fluid
Surfactant

_____ 1. Two factors that cause the lungs to recoil.

_____

_____ 2. A mixture of lipoproteins produced by the epithelium of the alveoli; reduces surface tension.

_____ 3. Two factors that keep the lungs from collapsing.

_____

B. Using the terms provided, complete these statements:

Collapse
Expand
Lung recoil
Pleural fluid

When pleural pressure is less than alveolar pressure, the alveoli (1). Pleural pressure is normally less than alveolar pressure because of a "suction effect" produced by (2). The visceral and parietal plurae are not pulled apart by lung recoil because they are held together by (3). When pleural pressure is sufficiently low, lung recoil is overcome and the alveoli (4).

1. _____
2. _____
3. _____
4. _____

Respiratory distress syndrome results when newborns do not manufacture enough surfactant and the lungs tend to collapse. Pneumothorax, the entry of air into the pleural cavity, can also cause lung collapse.

Changing Alveolar Volume

"*Changing alveolar volume results in air movement into and out of the lungs.*"

Match these terms with the correct statement or definition:

Decreases
Increases

_____ 1. Effect of increased thoracic volume on pleural pressure.

_____ 2. Effect of increased lung recoil on pleural pressure.

_____ 3. Effect of decreased pleural pressure on alveolar volume.

_____ 4. Effect of increased alveolar volume on alveolar pressure.

_____ 5. Effect of decreased alveolar pressure on air movement into the lungs.

Pulmonary Volumes and Capacities

"*A spirometer is a device for measuring the volumes of air that move into and out of the lungs.*"

A. Match these terms with the correct statement or definition:

Expiratory reserve volume
Forced expiratory vital capacity
Inspiratory reserve volume
Pulmonary capacity
Pulmonary volumes
Residual volume
Tidal volume
Vital capacity

_____ 1. Examples are tidal volume, inspiratory reserve volume, expiratory reserve volume, and residual volume.

_____ 2. Volume of air inspired or expired by quiet breathing.

_____ 3. Volume of air in lungs after maximum expiration.

_____ 4. Sum of two or more pulmonary volumes.

_____ 5. Sum of the inspiratory reserve volume, tidal volume, and expiratory reserve volume.

_____ 6. After a person inspires maximally, the rate at which lung volume changes when he exhales maximally and as rapidly as possible.

B. Match these terms with the correct parts labeled in figure 15.3:

Expiratory reserve volume
Inspiratory reserve volume
Residual volume
Tidal volume
Vital capacity

1. _____
2. _____
3. _____
4. _____
5. _____

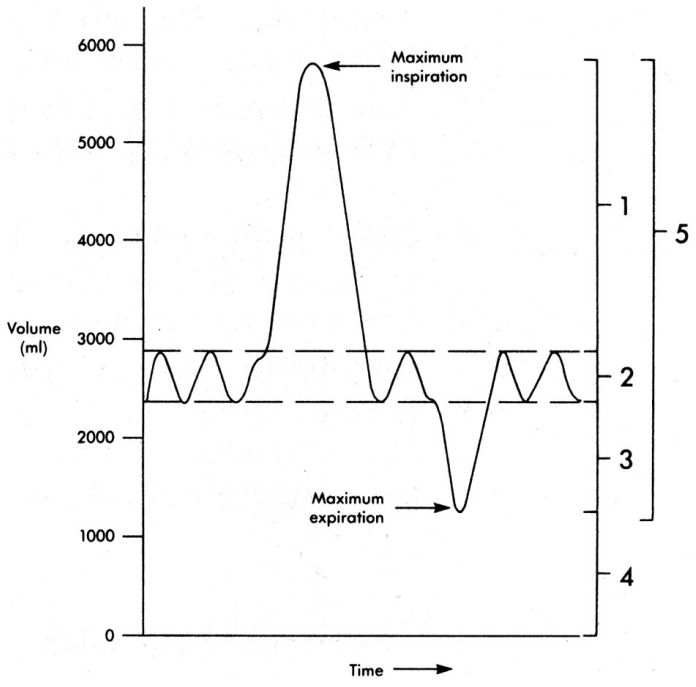

Figure 15.3

Gas Exchange

"*Gas exchange takes place across the respiratory membrane.*"

A. Match these terms with the correct parts labeled in figure 15.4:

Alveolar fluid
Alveolar epithelium
Basement membrane of alveolar epithelium
Basement membrane of capillary endothelium
Capillary endothelium
Interstitial space

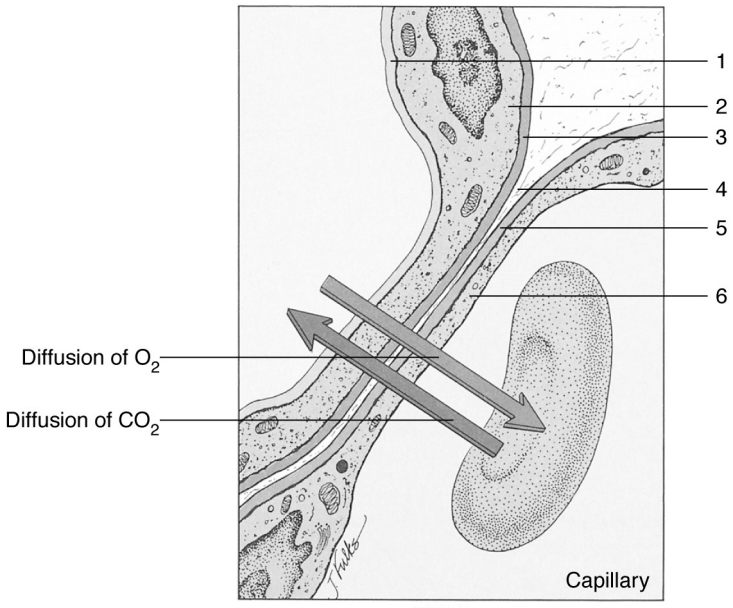

Figure 15.4

1. _____ 3. _____ 5. _____

2. _____ 4. _____ 6. _____

B. Match these terms with the correct statement or definition:

Dead space
Decreases
Higher
Increases
Lower
Partial pressure

_____ 1. Volume of respiratory passageways in which no gas exchange between air and blood occurs.

_____ 2. The effect on gas exchange when the respiratory membrane becomes thicker; an example is pulmonary edema.

_____ 3. The effect on gas exchange when the surface area of the respiratory membrane decreases; an example is emphysema.

_____ 4. The pressure exerted by a gas in a mixture of gases.

_____ 5. The effect on gas exchange when the difference in partial pressures for a gas across the respiratory membrane increases.

_____ 6. Effect on gas exchange of increasing ventilation rate.

_____ 7. The partial pressure of oxygen in blood compared to the partial pressure of oxygen in tissues.

_____ 8. The partial pressure of carbon dioxide in blood compared to the partial pressure of carbon dioxide in tissues.

Oxygen and Carbon Dioxide Transport in the Blood

"*Oxygen is transported bound to hemoglobin; carbon dioxide is mostly transported as bicarbonate ion.*"

A. Using the terms provided, complete these statements:

High	Oxyhemoglobin
Low	Plasma

The molecule formed when oxygen combines with hemoglobin is (1). About 98.5% of oxygen is transported as (2). The remaining 1.5% of oxygen is transported dissolved in (3). More oxygen is released from oxyhemoglobin when the partial pressure of oxygen in tissues is (4), the partial pressure of carbon dioxide is (5), the pH is (6), and the temperature in the tissues is (7). These conditions are found in skeletal muscle during exercise, and ensure maximal release and delivery of oxygen to the muscle cells.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

B. Using the terms provided, complete these statements:

Bicarbonate ion	Decreases
Blood proteins	Hydrogen ions
Carbonic anhydrase	Increases
Carbonic acid	Plasma

About 7% of carbon dioxide is transported by (1), 23 % by (2) (primarily hemoglobin), and 70% as (3). The enzyme (4) inside erythrocytes catalyzes the reaction between carbon dioxide and water to form (5). This substance dissociates to form (6) and bicarbonate ions. Carbon dioxide has an important effect on the pH of blood. When carbon dioxide levels increase, hydrogen ion levels increase, and blood pH (7).

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

Rhythmic Ventilation

"*The generation of the basic rhythm of ventilation is controlled by neurons within the medulla oblongata.*"

A. Match these terms with the correct statement or definition:

Dorsal respiratory groups
Medullary respiratory center
Pontine respiratory group
Ventral respiratory groups

_____ 1. Consists of two dorsal respiratory groups and two ventral respiratory groups.

_____ 2. Primarily responsible for stimulating contraction of the diaphragm.

_____ 3. Controls the external intercostal, internal intercostal, and abdominal muscles.

_____ 4. Appears to play a role in switching between inspiration and expiration.

B. Using the terms provided, complete these statements:

Fewer
More
Pontine
Stretch receptors
Threshold

1. _____
2. _____
3. _____
4. _____

Inspiration begins when the input from many sources, such as from receptors that monitor blood gas levels or body movements, reach a _(1)_. Once inspiration begins, _(2)_ inspiratory neurons are gradually activated, resulting in the stimulation of the muscles of inspiration for approximately 2 seconds. Neurons responsible for stopping inspiration receive input from the neurons stimulating respiration, the _(3)_ respiratory group, and _(4)_ in the lungs. When the input to these neurons exceeds threshold, inspiration stops.

Modification of Ventilation

"*Although the medullary neurons establish the basic rate and depth of respiration, their activities can be influenced by input from other parts of the brain and by input from peripheral receptors.*"

A. Match these terms with the correct statement or definition:

Cerebral cortex
Hering-Breuer reflex

_____ 1. Part of the brain that is able to consciously or unconsciously change the rate or depth of respiration, such as talking or holding one's breath.

_____ 2. Limits the degree to which inspiration proceeds and prevents overinflation of the lungs.

B. Match these terms with the correct statement or definition:

Carbon dioxide
Carotid and aortic body chemoreceptors
Decreases
Increases
Medullary chemoreceptors
Oxygen

_____ 1. This substance is the major regulator of respiration because of its effect on pH.

_____ 2. The effect of an increase in blood carbon dioxide on blood pH.

_____ 3. The effect of a decrease in blood pH on respiration.

_____ 4. Primarily responsible for detecting changes in blood pH.

_____ 5. Primarily responsible for detecting changes in blood oxygen.

_____ 6. Effect of greatly decreased blood oxygen levels on respiration.

Effect of Exercise on Ventilation

"*No one factor can account for all the respiratory changes occurring during exercise.*"

Match these terms with the correct statement or definition:

Anaerobic threshold
Decreases
Increases
No significant change

_____ 1. Effect of action potentials, traveling from collateral fibers of motor pathways, on breathing rate during exercise.

_____ 2. Effect of stimulation of proprioceptors on respiratory rate during exercise.

_____ 3. Changes in <u>average</u> arterial oxygen, carbon dioxide, and pH values during exercise.

_____ 4. The highest level of exercise that can be performed without causing a significant change in blood gases and pH.

Respiratory Adaptations to Training

"*The cardiovascular and respiratory systems become more efficient with training.*"

Match these terms with the effect produced by training:

Decreases
Increases
No change

_____ 1. The change in vital capacity.

_____ 2. The change in tidal volume at rest and during submaximal exercise.

_____ 3. The change in tidal volume during maximal exercise.

_____ 4. The change in respiratory rate during maximal exercise.

_____ 5. The change in minute ventilation during maximal exercise.

QUICK RECALL

1. List 5 functions of the respiratory system.

2. Trace the path of inspired air from the trachea to the alveoli by naming the structures through which the air passes.

3. Describe the relationship between the tracheobronchial tree and the lungs and the parts of the lungs.

4. Describe the relationship between the volume and the pressure of a gas in a closed container.

5. List two factors that tend to cause the lungs to recoil and two factors that prevent the alveoli from collapsing.

6. List the four pulmonary volumes and define vital capacity.

7. List the six layers of the respiratory membrane.

8. List two ways oxygen is transported in the blood, and state their relative importance.

9. List three ways that carbon dioxide is transported in the blood, and indicate their relative importance.

10. Describe the chemical events that result in a decrease in blood pH when blood carbon dioxide levels increase.

11. List three chemical factors that influence respiration, the location in the body where the levels of these chemicals are monitored, and the changes of these chemicals that cause an increase in respiration rate.

12. Name the factors that have the greatest effect on the regulation of respiration at rest and during exercise.

WORD PARTS

Give an example of a new vocabulary word that contains each word part.

WORD PART	MEANING	EXAMPLE
bronch-	windpipe	1. _____
pleur-	the side	2. _____
-pharyn-	the throat	3. _____
oro-	the mouth	4. _____
-spire	breathe	5. _____
pneumo-	lungs	6. _____

MASTERY LEARNING ACTIVITY

Place the letter corresponding to the correct answer in the space provided.

_____ 1. The nasal cavity
a. warms and humidifies air.
b. is divided into left and right parts by the hard palate.
c. contains the openings to the auditory tubes.
d. all of the above

_____ 2. The nasopharynx
a. is closed off by the epiglottis when materials are swallowed.
b. opens into the oral cavity.
c. has openings from the paranasal sinuses.
d. contains the pharyngeal tonsils.

_____ 3. The larynx
a. connects the pharynx to the esophagus.
b. has one unpaired cartilage.
c. has C-shaped cartilages.
d. contains the vestibular folds.

_____ 4. During an asthma attack, the patient has difficulty breathing because of constriction of the
a. trachea.
b. bronchi.
c. bronchioles.
d. alveoli.

_____ 5. The parietal pleura
a. covers the surface of the lungs.
b. lines the walls of the thoracic cavity.
c. separates the bronchopulmonary segments from each other.
d. is the membrane across which gas exchange occurs.

_____ 6. During quiet expiration,
a. the diaphragm moves inferiorly.
b. the external intercostal muscles contract.
c. the thorax and lungs passively recoil.
d. all of the above

_____ 7. During inspiration,
a. pleural pressure is greater than alveolar pressure.
b. alveolar volume increases.
c. alveolar pressure is greater than atmospheric pressure.
d. all of the above

_____ 8. The lungs do not normally collapse because of
a. surfactant.
b. elastic recoil of lung tissue.
c. surface tension of alveolar fluid.
d. all of the above

_____ 9. Immediately after the creation of an opening through the thorax into the pleural cavity,
a. air flows into the pleural cavity through the hole.
b. air flows out of the pleural cavity through the hole.
c. air neither flows out nor in through the hole.
d. the lung protrudes through the hole.

_____10. A patient expires normally; then, using forced ventilation, he blows as much air as possible into a spirometer. This measures the
a. inspiratory reserve.
b. expiratory reserve.
c. residual volume.
d. tidal volume.
e. vital capacity.

_____11. Given the following lung volumes:
1. tidal volume = 500 mL
2. residual volume = 1000 mL
3. inspiratory reserve = 2500 mL
4. expiratory reserve = 1000 mL
5. dead space = 1000 mL

The vital capacity is
a. 3000 mL.
b. 3500 mL.
c. 4000 mL.
d. 5000 mL.
e. 6000 mL.

_____12. Which of the following layers must gases cross to pass from the alveolus to the blood within the alveolar capillary?
a. simple squamous epithelium
b. basement membrane
c. thin interstitial space
d. thin layer of alveolar fluid
e. all of the above

_____13. Which of the following increases the rate of gas exchange across the respiratory membrane?
a. increase the thickness of the respiratory membrane
b. decrease the surface area of the respiratory membrane
c. increase the partial pressure difference across the respiratory membrane
d. all of the above

_____14. Carbon dioxide is mostly transported in the blood
a. dissolved in plasma.
b. bound to blood proteins, primarily the globin portion of hemoglobin.
c. within bicarbonate ions.
d. bound to the heme portion of hemoglobin.

_____15. The partial pressure of carbon dioxide in the venous blood is less than in the
a. fluid of the tissue spaces.
b. air of the alveoli.
c. arterial blood.
d. all of the above

_____16. Concerning the regulation of respiration,
a. the medullary respiratory center stimulates the muscles of respiration.
b. the pontine respiratory group plays a role in switching between inspiration and expiration.
c. inspiration begins when the input from many sources reaches threshold
d. the cerebral cortex can regulate respiration.
e. all of the above

_____17. The Hering-Breuer reflex
a. increases the volume of inspired air.
b. increases the volume of expired air.
c. occurs in response to increased carbon dioxide levels in the blood.
d. occurs in response to stretch of the lungs.
e. stimulates the respiratory center.

_____18. Blood oxygen levels
a. are more important than carbon dioxide levels in the regulation of respiration.
b. need to change only slightly to cause a change in respiration.
c. are monitored primarily by chemoreceptors in the carotid and aortic bodies.
d. all of the above

_____19. During exercise, respiration rate and depth increase primarily because of
a. increased blood carbon dioxide levels.
b. decreased blood oxygen levels.
c. decreased blood pH
d. input to the respiratory center from the cerebral motor cortex and from proprioceptors.

_____20. In response to exercise training,
a. tidal volume at rest does not change.
b. minute ventilation during maximal exercise increases.
c. the brain learns to match ventilation to exercise intensity.
d. all of the above

FINAL CHALLENGES

Use a separate sheet of paper to complete this section.

1. Marty Blowhard used a spirometer with the following results:
   a. After a normal inspiration, a normal expiration was 500 mL.
   b. Following a normal expiration, he was able to expel an additional 1000 mL.
   c. Taking as deep a breath as possible, then forcefully exhaling all the air possible, yielded an output of 4500 mL.

   On the basis of these measurements, what is Marty's inspiratory reserve?

2. One technique for artificial respiration is the back-pressure arm-lift method, which is performed with the victim lying face down. The rescuer presses firmly on the base of the scapula for several seconds, then grasps the arms and lifts them. The sequence is then repeated. Explain why this procedure results in ventilation of the lungs.

3. Another technique for artificial respiration is mouth-to-mouth resuscitation. The rescuer takes a deep breath, blows air into the victim's mouth, and lets air flow out of the victim. The process is repeated. Explain the following: (1) Why do the victim's lungs expand; (2) why does air move out of the victim's lungs; and (3) what effects do the partial pressure of oxygen and carbon dioxide of the rescuer's air have on the victim?

4. Predict what would happen to a baby's tidal volume if the phrenic nerves were damaged; if the spinal nerves to the intercostal muscles were damaged; and if the nerves supplying stretch receptors in the lungs were damaged.

5. You and your physiology instructor are trapped in an overturned ship. To escape you must swim underwater a long distance. You tell your physiology instructor it would be a good idea to hyperventilate before making the escape attempt. Your instructor calmly responds, "What good would that do? By the time blood passes through the pulmonary capillaries all the hemoglobin molecules have combined with oxygen. That is, hemoglobin is carrying as much oxygen as it can." What would you do and why?