

The Respiratory System

Objectives

Functional Anatomy of the Respiratory System

1. List the structures and functions of the nose, nasal cavity, and paranasal sinuses.
2. Describe the structures of the pharynx, larynx, and trachea.
3. Explain the structure of the lungs and the vascular and neural networks that supply them.
4. Discuss the relationship of the pleurae to the lungs and thoracic wall, and their functional importance.

Mechanics of Breathing

5. Define intrapulmonary and intrapleural pressure.
6. Describe pulmonary ventilation and the relationships between pressure and volume changes as they apply to the lungs.
7. Identify the events of quiet and forced inspiration, and passive and forced expiration.
8. Discuss the effects of airway resistance, alveolar surface tension, and lung compliance on pulmonary ventilation.
9. List and define the respiratory volumes and capacities.
10. Distinguish between obstructive and restrictive respiratory disorders, and describe the role of pulmonary function tests in distinguishing between them.
11. Name the nonrespiratory air movements.

Basic Properties of Gases

12. Define Dalton's law of partial pressures, and relate it to atmospheric gases.
13. Explain Henry's law, and describe its importance to gas exchange in the lungs.

Composition of Alveolar Gas

14. Compare the composition of alveolar gases to atmospheric gases.

Gas Exchanges Between the Blood, Lungs, and Tissues

15. Define external respiration and pulmonary gas exchange, and describe the factors that affect exchange.

Transport of Respiratory Gases by Blood

16. Describe how oxygen and carbon dioxide are carried in the blood, and explain the role of hemoglobin.

Control of Respiration

17. List the neural structures that control respiration, and the factors that affect rate and depth of respiration.

Respiratory Adjustments

18. Explain the adjustments to respiration that occur in response to exercise and increased altitude.

Homeostatic Imbalances of the Respiratory System

19. Identify the characteristics of chronic obstructive pulmonary disorders, asthma, tuberculosis, and lung cancer.

Developmental Aspects of the Respiratory System

20. Describe the events of development and growth of the respiratory system.
21. List the changes that occur in the respiratory system with age.

Suggested Lecture Outline

I. Functional Anatomy of the Respiratory System (pp. 831–846; Figs. 22.1–22.11; Table 22.1)

- A. The Nose and Paranasal Sinuses (pp. 831–835; Figs. 22.1–22.3)
 1. The nose provides an airway for respiration; moistens, warms, filters, and cleans incoming air; provides a resonance chamber for speech; and houses olfactory receptors.
 2. The nose is divided into the external nose, which is formed by hyaline cartilage and bones of the skull, and the nasal cavity, which is entirely within the skull.
 3. The nasal cavity consists of two types of epithelium: olfactory mucosa and respiratory mucosa.
 4. The nasal cavity is surrounded by paranasal sinuses within the frontal, maxillary, sphenoid, and ethmoid bones that serve to lighten the skull, warm and moisten air, and produce mucus.
- B. The Pharynx (p. 835; Fig. 22.3)
 1. The pharynx connects the nasal cavity and mouth superiorly to the larynx and esophagus inferiorly.
 - a. The nasopharynx serves as only an air passageway, and contains the pharyngeal tonsil, which traps and destroys airborne pathogens.
 - b. The oropharynx is an air and food passageway that extends inferiorly from the level of the soft palate to the epiglottis.
 - c. The laryngopharynx is an air and food passageway that lies directly posterior to the epiglottis, extends to the larynx, and is continuous inferiorly with the esophagus.
- C. The Larynx (pp. 835–838; Figs. 22.3–22.5)
 1. The larynx attaches superiorly to the hyoid bone, opening into the laryngopharynx, and attaches inferiorly to the trachea.
 2. The larynx provides an open airway, routes food and air into the proper passageways, and produces sound through the vocal cords.
 3. The larynx consists of hyaline cartilages: thyroid, cricoid, paired arytenoid, corniculate, and cuneiform; and the epiglottis, which is elastic cartilage.
 4. Vocal ligaments form the core of mucosal folds, the true vocal cords, which vibrate as air passes over them to produce sound.
 5. The vocal folds and the medial space between them are called the glottis.
 6. Voice production involves the intermittent release of expired air and the opening and closing of the glottis.
 7. Valsalva's maneuver is a behavior in which the glottis closes to prevent exhalation and the abdominal muscles contract, causing intra-abdominal pressure to rise.
- D. The trachea, or windpipe, descends from the larynx through the neck into the mediastinum, where it terminates at the primary bronchi (pp. 838–840; Fig. 22.6).
- E. The Bronchi and Subdivisions: The Bronchial Tree (pp. 840–842; Figs. 22.7–22.8)
 1. The conducting zone consists of right and left primary bronchi that enter each lung and diverge into secondary bronchi that serve each lobe of the lungs.

2. Secondary bronchi branch into several orders of tertiary bronchi, which ultimately branch into bronchioles.
 3. As the conducting airways become smaller, the supportive cartilage changes in character until it is no longer present in the bronchioles.
 4. The respiratory zone begins as the terminal bronchioles feed into respiratory bronchioles that terminate in alveolar ducts within clusters of alveolar sacs, which consist of alveoli.
 - a. The respiratory membrane consists of a single layer of squamous epithelium, type-I cells, surrounded by a basal lamina.
 - b. Interspersed among the type-I cells are cuboidal type-II cells that secrete surfactant.
 - c. Alveoli are surrounded by elastic fibers, contain open alveolar pores, and have alveolar macrophages.
- F. The Lungs and Pleurae (pp. 842–846; Figs. 22.9–22.11)
1. The lungs occupy all of the thoracic cavity except for the mediastinum; each lung is suspended within its own pleural cavity and connected to the mediastinum by vascular and bronchial attachments called the lung root.
 2. Each lobe contains a number of bronchopulmonary segments, each served by its own artery, vein, and tertiary bronchus.
 3. Lung tissue consists largely of air spaces, with the balance of lung tissue, its stroma, comprised mostly of elastic connective tissue.
 4. There are two circulations that serve the lungs: the pulmonary network carries systemic blood to the lungs for oxygenation, and the bronchial arteries provide systemic blood to the lung tissue.
 5. The lungs are innervated by parasympathetic and sympathetic motor fibers that constrict or dilate the airways, as well as visceral sensory fibers.
 6. The pleurae form a thin, double-layered serosa.
 - a. The parietal pleura covers the thoracic wall, superior face of the diaphragm, and continues around the heart between the lungs.
 - b. The visceral pleura covers the external lung surface, following its contours and fissures.

II. Mechanics of Breathing (pp. 846–854; Figs. 22.12–22.16; Tables 22.2–22.3)

- A. Pressure Relationships in the Thoracic Cavity (pp. 846–847; Fig. 22.12)
1. Intrapulmonary pressure is the pressure in the alveoli, which rises and falls during respiration, but always eventually equalizes with atmospheric pressure.
 2. Intrapleural pressure is the pressure in the pleural cavity. It also rises and falls during respiration, but is always about 4 mm Hg less than intrapulmonary pressure.
- B. Pulmonary Ventilation: Inspiration and Expiration (pp. 847–849; Figs. 22.13–22.14)
1. Pulmonary ventilation is a mechanical process causing gas flow into and out of the lungs according to volume changes in the thoracic cavity.
 - a. Boyle's law states that at a constant temperature, the pressure of a gas varies inversely with its volume.
 2. During quiet inspiration, the diaphragm and intercostals contract, resulting in an increase in thoracic volume, which causes intrapulmonary pressure to drop below atmospheric pressure, and air flows into the lungs.
 3. During forced inspiration, accessory muscles of the neck and thorax contract, increasing thoracic volume beyond the increase in volume during quiet inspiration.

4. Quiet expiration is a passive process that relies mostly on elastic recoil of the lungs as the thoracic muscles relax.
 5. Forced expiration is an active process relying on contraction of abdominal muscles to increase intra-abdominal pressure and depress the ribcage.
- C. Physical Factors Influencing Pulmonary Ventilation (pp. 849–851; Fig. 22.15)
1. Airway resistance is the friction encountered by air in the airways; gas flow is reduced as airway resistance increases.
 2. Alveolar surface tension due to water in the alveoli acts to draw the walls of the alveoli together, presenting a force that must be overcome in order to expand the lungs.
 3. Lung compliance is determined by distensibility of lung tissue and the surrounding thoracic cage, and alveolar surface tension.
- D. Respiratory Volumes and Pulmonary Function Tests (pp. 851–854; Fig. 22.16; Tables 22.2–22.3)
1. Respiratory volumes and specific combinations of volumes, called respiratory capacities, are used to gain information about a person's respiratory status.
 - a. Tidal volume is the amount of air that moves in and out of the lungs with each breath during quiet breathing.
 - b. The inspiratory reserve volume is the amount of air that can be forcibly inspired beyond the tidal volume.
 - c. The expiratory reserve volume is the amount of air that can be evacuated from the lungs after tidal expiration.
 - d. Residual volume is the amount of air that remains in the lungs after maximal forced expiration.
 - e. Inspiratory capacity is the sum of tidal volume and inspiratory reserve volume, and represents the total amount of air that can be inspired after a tidal expiration.
 - f. Functional residual capacity is the combined residual volume and expiratory reserve volume, and represents the amount of air that remains in the lungs after a tidal expiration.
 - g. Vital capacity is the sum of tidal volume, inspiratory reserve and expiratory reserve volumes, and is the total amount of exchangeable air.
 - h. Total lung capacity is the sum of all lung volumes.
 2. The anatomical dead space is the volume of the conducting zone conduits, which is a volume that never contributes to gas exchange in the lungs.
 3. Pulmonary function tests evaluate losses in respiratory function using a spirometer to distinguish between obstructive and restrictive pulmonary disorders.
 4. Nonrespiratory air movements cause movement of air into or out of the lungs, but are not related to breathing (coughing, sneezing, crying, laughing, hiccups, and yawning).

III. Gas Exchanges Between the Blood, Lungs, and Tissues (pp. 854–858; Figs. 22.17–22.20)

- A. Gases have basic properties, as defined by Dalton's law of partial pressures and Henry's law. (pp. 854–855)
1. Dalton's law of partial pressures states that the total pressure exerted by a mixture of gases is the sum of the pressures exerted by each gas in the mixture.
 2. Henry's law states that when a mixture of gases is in contact with a liquid, each gas will dissolve in the liquid in proportion to its partial pressure.

- B. The composition of alveolar gas differs significantly from atmospheric gas, due to gas exchange occurring in the lungs, humidification of air by conducting passages, and mixing of alveolar gas that occurs with each breath. (p. 855)
- C. External Respiration: Pulmonary Gas Exchange (pp. 855–858; Figs. 22.17–22.19)
 - 1. External respiration involves O₂ uptake and CO₂ unloading from hemoglobin in red blood cells.
 - a. A steep partial pressure gradient exists between blood in the pulmonary arteries and alveoli, and O₂ diffuses rapidly from the alveoli into the blood, but carbon dioxide moves in the opposite direction along a partial pressure gradient that is much less steep.
 - b. The difference in the degree of the partial pressure gradients of oxygen and carbon dioxide reflects the fact that carbon dioxide is much more soluble than oxygen in the blood.
 - c. Ventilation-perfusion coupling ensures a close match between the amount of gas reaching the alveoli and the blood flow in the pulmonary capillaries.
 - d. The respiratory membrane is normally very thin, and presents a huge surface area for efficient gas exchange.
- D. Internal Respiration: Capillary Gas Exchange in the Body Tissues (p. 858; Fig. 22.17)
 - 1. The diffusion gradients for oxygen and carbon dioxide are reversed from those for external respiration and pulmonary gas exchange.
 - 2. The partial pressure of oxygen in the tissues is always lower than the blood, so oxygen diffuses readily into the tissues, while a similar but less dramatic gradient exists in the reverse direction for carbon dioxide.

IV. Transport of Respiratory Gases by Blood (pp. 853–863; Figs. 22.20–22.23)

- A. Oxygen Transport (pp. 858–861; Figs. 22.20–22.22)
 - 1. Since molecular oxygen is poorly soluble in the blood, only 1.5% is dissolved in plasma, while the remaining 98.5% must be carried on hemoglobin.
 - a. Up to four oxygen molecules can be reversibly bound to a molecule of hemoglobin—one oxygen on each iron.
 - b. The affinity of hemoglobin for oxygen changes with each successive oxygen that is bound or released, making oxygen loading and unloading very efficient.
 - 2. At higher plasma partial pressures of oxygen, hemoglobin unloads little oxygen, but if plasma partial pressure falls dramatically, i.e. during vigorous exercise, much more oxygen can be unloaded to the tissues.
 - 3. Temperature, blood pH, P_{CO₂}, and the amount of BPG in the blood all influence hemoglobin saturation at a given partial pressure.
 - 4. Nitric oxide (NO), secreted by lung and vascular endothelial cells, is carried on hemoglobin to the tissues where it causes vasodilation and enhances oxygen transfer to the tissues.
- B. Carbon Dioxide Transport (pp. 861–863; Figs. 22.22–22.23)
 - 1. Carbon dioxide is transported in the blood in three ways: 7–10% is dissolved in plasma, 20% is carried on hemoglobin bound to globins, and 70% exists as bicarbonate, an important buffer of blood pH.
 - 2. The Haldane effect encourages CO₂ exchange in the lungs and tissues: when plasma partial pressure of oxygen and oxygen saturation of hemoglobin decrease, more CO₂ can be carried in the blood.

3. The carbonic acid–bicarbonate buffer system of the blood is formed when CO_2 combines with water and dissociates, producing carbonic acid and bicarbonate ions that can release or absorb hydrogen ions.

V. Control of Respiration (pp. 863–869; Figs. 22.24–22.27)

- A. Neural Mechanisms and Generation of Breathing Rhythm (pp. 863–865; Figs. 22.24–22.25)
 1. The medulla oblongata contains the dorsal respiratory group, or inspiratory center, with neurons that act as the pacesetter respiratory group, and the ventral respiratory group, which functions mostly during forced breathing.
 2. The pontine respiratory group within the pons modifies the breathing rhythm and prevents overinflation of the lungs through an inhibitory action on the medullary respiration centers.
 3. It is likely that reciprocal inhibition on the part of the different respiratory centers is responsible for the rhythm of breathing.
- B. Factors Influencing Breathing Rate and Depth (pp. 865–869; Figs. 22.25–22.27)
 1. The most important factors influencing breathing rate and depth are changing levels of CO_2 , O_2 , and H^+ in arterial blood.
 - a. The receptors monitoring fluctuations in these parameters are the central chemoreceptors in the medulla oblongata, and the peripheral chemoreceptors in the aortic arch and carotid arteries.
 - b. Increases in arterial P_{CO_2} cause CO_2 levels to rise in the cerebrospinal fluid, resulting in stimulation of the central chemoreceptors, and ultimately leading to an increase in rate and depth of breathing.
 - c. Substantial drops in arterial P_{O_2} are required to cause changes in respiration rate and depth, due to the large reserves of O_2 carried on the hemoglobin.
 - d. As H^+ accumulates in the plasma, rate and depth of breathing increase in an attempt to eliminate carbonic acid from the blood through the loss of CO_2 in the lungs.
 2. Higher brain centers alter rate and depth of respiration.
 - a. The limbic system, strong emotions, and pain activate the hypothalamus, which modifies respiratory rate and depth.
 - b. The cerebral cortex can exert voluntary control over respiration by bypassing medullary centers and directly stimulating the respiratory muscles.
 3. Pulmonary irritant reflexes respond to inhaled irritants in the nasal passages or trachea by causing reflexive bronchoconstriction in the respiratory airways.
 4. The inflation, or Hering-Breuer, reflex is activated by stretch receptors in the visceral pleurae and conducting airways, protecting the lungs from overexpansion by inhibiting inspiration.

VI. Respiratory Adjustments (pp. 869–870)

- A. Adjustments During Exercise (pp. 869–870)
 1. During vigorous exercise, deeper and more vigorous respirations, called hyperpnea, ensure that tissue demands for oxygen are met.
 2. Three neural factors contribute to the change in respiration: psychic stimuli, cortical stimulation of skeletal muscles and respiratory centers, and excitatory impulses to the respiratory areas from active muscles, tendons, and joints.
- B. Adjustments at High Altitude (p. 870)
 1. Acute mountain sickness (AMS) may result from a rapid transition from sea level to altitudes above 8000 feet.

2. A long-term change from sea level to high altitudes results in acclimatization of the body, including an increase in ventilation rate, lower than normal hemoglobin saturation, and increased production of erythropoietin.

VII. Homeostatic Imbalances of the Respiratory System (pp. 870–873; Fig. 22.28)

- A. Chronic obstructive pulmonary diseases (COPD) are seen in patients that have a history of smoking, and result in progressive dyspnea, coughing and frequent pulmonary infections, and respiratory failure. (pp. 871–872)
 1. Obstructive emphysema is characterized by permanently enlarged alveoli and deterioration of alveolar walls.
 2. Chronic bronchitis results in excessive mucus production, as well as inflammation and fibrosis of the lower respiratory mucosa.
- B. Asthma is characterized by coughing, dyspnea, wheezing, and chest tightness, brought on by active inflammation of the airways. (p. 872)
- C. Tuberculosis (TB) is an infectious disease caused by the bacterium *Mycobacterium tuberculosis* and spread by coughing and inhalation. (p. 872)
- D. Lung Cancer (pp. 872–873)
 1. In both sexes, lung cancer is the most common type of malignancy, and is strongly correlated with smoking.
 2. Squamous cell carcinoma arises in the epithelium of the bronchi, and tends to form masses that hollow out and bleed.
 3. Adenocarcinoma originates in peripheral lung areas as nodules that develop from bronchial glands and alveolar cells.
 4. Small cell carcinoma contains lymphocyte-like cells that form clusters within the mediastinum and rapidly metastasize.

VIII. Developmental Aspects of the Respiratory System (pp. 873–875; Fig. 22.29)

- A. By the fourth week of development, the olfactory placodes are present and give rise to olfactory pits that form the nasal cavities.
- B. The nasal cavity extends posteriorly to join the foregut, which gives rise to an outpocketing that becomes the pharyngeal mucosa.
- C. By the eighth week of development, mesoderm forms the walls of the respiratory passageways and stroma of the lungs.
- D. As a fetus, the lungs are filled with fluid, and vascular shunts are present that divert blood away from the lungs; at birth, the fluid drains away, and rising plasma P_{CO_2} stimulates respiratory centers.
- E. Respiratory rate is highest in newborns, and gradually declines to adulthood; in old age, respiratory rate increases again.
- F. As we age, the thoracic wall becomes more rigid, the lungs lose elasticity, and the amount of oxygen we can use during aerobic respiration decreases.
- G. The number of mucus glands and blood flow in the nasal mucosa decline with age, as does ciliary action of the mucosa, and macrophage activity.

Cross References

Additional information on topics covered in Chapter 22 can be found in the chapters listed below.

1. Chapter 1: Mediastinum
2. Chapter 2: Acids and bases
3. Chapter 3: Diffusion
4. Chapter 4: Hyaline and elastic cartilage; squamous, cuboidal, and pseudostratified epithelium; serous and mucous glands
5. Chapter 7: Bones of the skull
6. Chapter 10: Muscles of respiration
7. Chapter 12: Medulla and pons; cortex
8. Chapter 13: Chemoreceptors, proprioceptors
9. Chapter 14: Sympathetic effects
10. Chapter 15: Auditory tube; lysozyme
11. Chapter 18: Great vessels
12. Chapter 19: Autoregulation of blood flow; pulmonary circulation
13. Chapter 20: Tonsils
14. Chapter 21: Inflammation; macrophages
15. Chapter 26: Acid-base balance of the blood
16. Chapter 28: Role of acidosis in initiating fetal respirations

Laboratory Correlations

1. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Cat and Fetal Pig Versions*. Eighth Edition Updates. Benjamin Cummings, 2006.
Exercise 36: Anatomy of the Respiratory System
Exercise 37: Respiratory System Physiology
2. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Main Version*. Seventh Edition Update. Benjamin Cummings, 2006.
Exercise 36: Anatomy of the Respiratory System
Exercise 37: Respiratory System Physiology

Histology Slides for the Life Sciences

Available through Benjamin Cummings, an imprint of Pearson Education, Inc. To order, contact your local Benjamin Cummings sales representative.

- Slide 8 Pseudostratified Ciliated Columnar Epithelium, Nasal Mucosa.
- Slide 69 Respiratory Bronchiole Alveoli Blood Vessel—Lung Interior.
- Slide 70 Terminal Bronchiole, Respiratory Bronchiole, Alveolar Ducts—Lung.
- Slide 71 Part of the lung showing alveoli and alveolar ducts and sacs.
- Slide 72 Cross section through the trachea showing the pseudostratified ciliated epithelium, glands, and the supporting ring of hyaline cartilage.

Lecture Hints

1. Stress the difference between ventilation and respiration.

2. Show slides or acetates of the bones of the skull to illustrate the relationship between bony and soft tissue structures.
3. The conducting airways of the head are usually the most confusing of the respiratory structures. Spend some time with diagrams and photographs reinforcing the three-dimensional anatomy of the upper airway structures.
4. Point out the characteristics of the epithelia that line the conducting airways, and why those epithelia are the correct choice for that particular area. This will reinforce epithelial types and gradually establish an intuitive sense in the students so they can predict epithelia for any location in the body.
5. During a discussion of the trachea, ask students why the cartilage rings are C-shaped rather than continuous.
6. Be sure the class does not confuse the respiratory membrane with subcellular level membrane structures (plasma membrane, etc.).
7. Remind students that pulmonary vessels are exceptions to the rule that arteries = oxygenated blood and veins = deoxygenated blood. Students should not confuse the bronchial artery (oxygenated blood) with the pulmonary artery (deoxygenated blood).
8. Stress the development and importance of the slightly negative intrapleural pressure to normal inspiration.
9. Emphasize elastic recoil as the main mechanism of normal expiration.
10. A complete understanding of diffusion is necessary for comprehension of respiratory gas movement at lung and body tissue levels. Refer the class in advance to the section on diffusion in Chapter 3.
11. Mention that cellular respiration is not the same as internal or external respiration, but that cellular respiration involves the pathways of glucose catabolism.
12. Emphasize the increasing difficulty with which successive oxygens are removed from a hemoglobin molecule. This explains why hemoglobin is not unsaturated when returned to the lungs.
13. Point out that the carbon dioxide transport (bicarbonate buffering) system is the most important mechanism of maintaining pH of the blood.
14. Students often have the misconception that oxygen level is the principal stimulant of respiration. Emphasize that carbon dioxide level is the most important factor.

Activities/Demonstrations

1. Audio-visual materials listed under Multimedia in the Classroom and Lab.
2. Provide stethoscopes so that students can listen to respiratory (breathing) sounds over various regions of a partner's thorax. For example, bronchial sounds are produced by air rushing through the large passages (trachea and bronchi), whereas the more muffled vesicular breathing sounds are heard over the smallest airways and alveoli.
3. Using handheld spirometers, have students measure their respiratory volumes, particularly tidal volume and vital capacity.
4. Provide straws, beakers of water, and pH paper. Have students use the straws to blow into the water in the beakers. Since exhaled air contains a significant amount of CO₂, the water should become acidic. Have them measure the pH of the water at intervals to follow the pH change.
5. Provide tape measures so that students can measure the circumference of the rib cage before and after inspiration.
6. Use a torso model, respiratory system model, and/or dissected animal model to exhibit the respiratory system and related organs.

7. Use two glass slides with water between them to demonstrate the cohesive effect of the serous fluid between the chest cavity wall and the lungs via the pleura and its parts. (Note: Due to this force, chest cavity movement results in lung movement since the lungs cannot pull away from the chest wall under normal conditions.)
8. Use an open-ended bell jar with balloons inside to demonstrate the changing pressures as the diaphragm contracts and relaxes. (Note: Top of bell jar should have a one-hole stopper with a glass Y tube extending into the jar; to the Y tube will be attached two small balloons; the bottom of the jar will be covered with a flexible elastic sheeting.)
9. Use a stringed instrument to demonstrate the effect of vibration and thickness on sound production.
10. Add laundry detergent to a glass of water and immerse some cloth to demonstrate the role of surfactant in the lungs for reducing water surface tension and as attraction for other water molecules.
11. Use a freshly opened soft drink to demonstrate and explain Henry's law.
12. Demonstrate the location of the sinuses using a complete or Beauchene's skull.
13. Obtain a fresh lamb or calf pluck (lungs plus attached trachea and heart) from a slaughterhouse. Insert a rubber hose snugly into the trachea and attach the hose to a source of compressed air. Alternately inflate the lungs with air and allow them to deflate passively to illustrate the huge air capacity and elasticity of the lungs.
14. Obtain some animal blood and bubble air through the blood via a small section of tubing to demonstrate the color change that occurs when blood is well oxygenated.

Critical Thinking/Discussion Topics

1. Discuss why athletes would want to train at high altitudes if their competition was to be at a high altitude (relate to USA's Olympic training site, Denver, Colorado), or even if their competition was to be at a lower altitude.
2. Explore the changes in respiratory volumes with obstructive or congestive disorders.
3. Examine the relationship between oxygen debt and muscle fatigue and an elevated respiratory rate after exercise.
4. Discuss the logic behind the structure of the conducting airways. Why are cartilage rings necessary? Why is smooth muscle in the walls of the conducting tubes necessary?
5. Discuss the relationship between intrapulmonary pressure and intrapleural pressure. What happens to intrapulmonary pressure relative to intrapleural pressure when Valsalva's maneuver is performed?
6. Why are only slightly higher atmospheric levels of carbon monoxide gas dangerous?

Library Research Topics

1. Research and list the respiratory diseases caused by inhalation of toxic particles associated with occupations such as coal mining, etc.
2. Study the incidence of cancer in smokers versus nonsmokers, and in individuals working in respiratory hazard areas versus individuals working in relatively safe respiratory areas.
3. Examine the current status of heart-lung transplants, and why such a transplant would be considered.
4. Investigate the causes, known and supposed, of sudden infant death syndrome.
5. Research the respiratory problems a premature infant might face.
6. Research the emergence and incidence of respiratory ailments such as Severe Acute Respiratory Syndrome (SARS).

Multimedia in the Classroom and Lab

Online Resources for Students

www.anatomyandphysiology.com

www.myaandp.com

The following shows the organization of the Chapter Guide page in both the Anatomy & Physiology Place and MyA&P™. The Chapter Guide organizes all the chapter-specific online media resources for Chapter 22 in one convenient location, with e-book links to each section of the textbook. Please note that both sites also give you access to other general A&P resources, like InterActive Physiology®, PhysioEx 6.0™, Anatomy 360°, Flashcards, a Glossary, a Histology Tutorial, and much more.

Objectives

Section 22.1 Functional Anatomy of the Respiratory System (pp. 831–846)

InterActive Physiology® : Anatomy Review

Art Labeling Activity: Upper Respiratory Tract (Fig. 22.3, p. 834)

Art Labeling Activity: The Larynx (Fig. 22.4, p. 836)

Memory: The Respiratory System (Art)

Memory: The Respiratory System (Cadaver)

Section 22.2 Mechanics of Breathing (pp. 846–854)

InterActive Physiology® : Pulmonary Ventilation

PhysioEx: Respiratory System Mechanics

Section 22.3 Gas Exchanges Between the Blood, Lungs, and Tissues (pp. 854–858)

InterActive Physiology® : Gas Exchange

Section 22.4 Transport of Respiratory Gases by Blood (pp. 858–863)

InterActive Physiology® : Gas Transport

Case Study: Pulmonary Embolus

Section 22.5 Control of Respiration (pp. 863–869)

InterActive Physiology® : Control of Respiration

Section 22.6 Respiratory Adjustments (pp. 869–870)

Section 22.7 Homeostatic Imbalances of the Respiratory System (pp. 870–873)

Case Study: Lung Disease

Section 22.8 Developmental Aspects of the Respiratory System (pp. 873–875)

Video

1. *Breath of Life* (NIMCO; 30 min., 1994). This video traces the path of an oxygen molecule through the respiratory system and into the bloodstream.
2. *Breathing* (FHS; 20 min., 1995). From the award-winning *The New Living Body* series, this video looks at the typical day in the life of a cystic fibrosis sufferer, and problems encountered by individuals with that hereditary disease.
3. *The Human Respiratory System Videotape* (BC; 25 min., 1998). This video provides an excellent overview of the functions of the human respiratory system.
4. *Respiration* (FHS; 15 min., 1996). From *The World of Living Organisms* series, this video describes external and internal respiration and explains how energy for bodily functions is produced.

5. *Respiratory System: Intake and Exhaust* (FHS; 25 min., 2000). From *The Human Body: Systems at Work* series, this program uses the analogy of an automobile's system of fuel intake and exhaust to explore the makeup and functions of the respiratory system.

Software

1. A.D.A.M.[®] *InterActive Anatomy*[®] 4.0 (see p. 9 of this guide for full listing).
2. A.D.A.M.[®] *MediaPro* (see p. 9 of this guide for full listing).
3. A.D.A.M.[®] *Anatomy Practice* (see p. 86 of this guide for full listing).
4. *Bodyworks* (see p. 9 of this guide for full listing).
5. LOGAL[®] *Gateways*[™]: *The Human Respiratory System CD-ROM* (RIL; Win/Mac). Students can conduct complete, simulated physiology experiments on the human respiratory system without expensive equipment. Students set variables; generate, collect, and analyze data; form hypotheses; and develop models.
6. *InterActive Physiology*[®] 9-System Suite CD-ROM (BC; Win/Mac). Interactive software with a section on the respiratory system that explores the physiology of that system.
7. *Respiratory System* (NIMCO; Win/Mac). Simulates the mechanical and physiological workings of the human respiratory system.
8. *Spirocomp*[™] *Human Spirometry System* (WNS; Windows). Includes a computerized spirometry system. Consists of hardware and software designed to allow quick and easy measurement of standard lung volumes. Can be used in a lab setting with students.
9. *The Ultimate Human Body* (see p. 9 of this guide for full listing).

Answers to End-of-Chapter Questions

Multiple Choice and Matching Question answers appear in Appendix G of the main text.

Short Answer Essay Questions

17. The route of air from the external nares to an alveolus and the organs involved are as follows: conducting zone structures—external nares, nasal cavity, pharynx (nasopharynx, oropharynx, laryngopharynx), larynx, trachea, and right and left primary bronchi, secondary bronchi, tertiary bronchi and successive bronchi orders, bronchioles, and terminal bronchioles; respiratory zone structures—respiratory bronchioles, alveolar ducts, alveolar sacs, and alveoli. (pp. 831–842)
18. a. The trachea is reinforced with cartilage rings to prevent the trachea from collapsing and to keep the airway patent despite the pressure changes that occur during breathing. (p. 839)
b. The advantage of the rings not being complete posteriorly is that the esophagus is allowed to expand anteriorly during swallowing. (p. 839)
19. The adult male larynx as a whole is larger and the vocal cords are longer than those of women or boys. These changes occur at puberty under the influence of rising levels of testosterone. (p. 837)
20. a. The elastic tissue is essential both for normal inspiration and expiration; expiration is almost totally dependent on elastic recoil of the lungs when the inspiratory muscles relax. (p. 849)
b. The passageways are air conduits used to warm, moisten, and transport air. (p. 840)
21. The volume of gas flow to and from the alveoli is directly proportional to the difference in pressure between the external atmosphere and the alveoli. Very small differences in pressure are sufficient to produce large volumes of gas flow. When intrapulmonary pressure decreases as thoracic volume increases, air flows into the lungs to equalize the pressure. When the lungs recoil, intrapulmonary pressure increases, and gases flow out of the lungs. (p. 848)

22. The walls of the alveoli are composed of a single layer of squamous epithelium surrounded by a flimsy basal lamina fused to the endothelium of the pulmonary capillaries. The thinness of the respiratory membrane allows gas diffusion to occur very rapidly across the membrane. (p. 842)
23. Pulmonary ventilation is influenced by airway resistance in that gas flow is equal to the pressure gradient divided by the resistance. Gas flow changes inversely with resistance. Lung compliance is assessed by measuring the increase in lung volume resulting from an increase in intrapulmonary pressure. The greater the volume increase for a given rise in pressure, the greater the compliance. The ability of lung tissue to distend and recoil, called lung elasticity, is essential for normal lung compliance. Surfactant reduces the surface tension of alveolar fluid, so less energy is needed to overcome surface tension forces to expand the lungs. (pp. 849–859)
24. a. Minute respiratory volume is the total amount of gas that flows into and out of the respiratory tract in one minute. Alveolar ventilation rate takes into account the amount of air wasted in dead space areas and provides a measurement of the concentration of fresh gases in the alveoli at a particular time. (p. 853)
b. Alveolar ventilation rate provides a more accurate measure of ventilatory efficiency because it considers only the volume of air actually participating in gas exchange. (p. 853)
25. Dalton's law of partial pressure states that the total pressure exerted by a mixture of gases is the sum of the pressure exerted independently by each gas in the mixture. Henry's law states that when a mixture of gases is in contact with a liquid, each gas will dissolve in the liquid in proportion to its partial pressure and its solubility in the liquid. (p. 854)
26. a. Hyperventilation is deep breathing that flushes carbon dioxide rapidly out of the blood.
b. When you hyperventilate, you expel more carbon dioxide.
c. Hyperventilation increases blood pH. (p. 866)
27. Age-related changes include a loss of elasticity in the lungs and a more rigid chest wall. These factors result in a slowly decreasing ability to ventilate the lungs. Accompanying these changes is a decrease in blood oxygen levels and a reduced sensitivity to the stimulating effects of carbon dioxide. (pp. 874–875)

Critical Thinking and Clinical Application Questions

1. Hemoglobin is almost completely (98%) saturated with oxygen in arterial blood at normal conditions. Hence, hyperventilation will increase the oxygen saturation very little, if at all. However, hyperventilation will flush CO₂ out of the blood, ending the stimulus to breathe and possibly causing (1) cerebral ischemia due to hypocapnia, and (2) O₂ decrease to dangerously low levels, resulting in fainting. (p. 866)
2. a. The lung penetrated by the knife collapsed because the intrapleural pressure became equal to the atmospheric pressure, allowing the pleural membranes to separate.
b. Only the penetrated lung collapsed because it is isolated from the remaining mediastinal structures (and the other lung) by the pleural membranes. (p. 846)
3. Adjacent bronchopulmonary segments are separated from one another by partitions of dense connective tissue, which no major vessels cross. Therefore, it is possible for a surgeon to dissect adjacent segments away from one another. The only vessels that had to be cauterized were the few main vessels to each bronchopulmonary segment. (p. 842)
4. Mary Ann is suffering from decompression sickness, brought on by the rapid ascent in the plane. During the week of diving, she accumulated nitrogen gas in her tissues that at normal altitudes leaves her tissues slowly and unnoticed. However, on the flight, cabin pressure decreased quickly enough to allow residual nitrogen gas to leave more rapidly, causing her symptoms. The return to a lower altitude with a higher atmospheric pressure upon landing alleviates her symptoms. (pp. 868–869)

Suggested Readings

- Beall, Cynthia M., et al. "Pulmonary Nitric Oxide in Mountain Dwellers." *Nature* 414 (Nov. 2001): 411–412.
- Christensen, Damaris. "The Persistent Problem of Cystic Fibrosis." *Science News* 161 (4) (Jan. 2002): 59–60.
- Floyd, Katherine, et al. "Resources Required for Global Tuberculosis Control." *Science* 295 (5562) (March 2002): 2040–2046.
- Lipson, Stuart A. "Nitric Oxide and Respiration." *Nature* 413 (6852) (Sept. 2001): 118–121.
- Okada, Yasumasa, Chen, Zibin, and Kuwana, Shun-ichi. "Cyto-Architecture of Central Chemoreceptors in the Mammalian Ventral Medulla." *Respiration Physiology* 129 (Dec. 2001): 13–23.
- O'Toole, George A. "A Resistance Switch." *Nature* 416 (6882) (April 2002): 695–696.
- Russel, David G. "Mycobacterium Tuberculosis: Here Today, and Here Tomorrow." *Nature Reviews: Molecular Biology* 2 (8) (Aug. 2001): 569–577.
- Vogel, Gretchen. "Missing Gene Takes Mice's Breath Away." *Science* 295 (5553) (Jan. 2002): 253.
- Wiemann, Martin and Bingmann, Dieter. "Ventrolateral Neurons of Medullary Organotypic Cultures: Intracellular pH Regulation and Bioelectric Activity." *Respiration Physiology* 129 (Dec. 2001): 57–70.