

## **Chapter 16 - Respiratory System**

### **16.1 Introduction**

- A. The respiratory system consists of tubes that filter incoming air and transport it into the microscopic alveoli where gases are exchanged.
- B. The entire process of exchanging gases between the atmosphere and body cells is called respiration and consists of the following: ventilation, gas exchange between blood and lungs, gas transport in the bloodstream, gas exchange between the blood and body cells, and cellular respiration.

### **16.2 Organs of the Respiratory System (Fig. 16.1; Table 16.1)**

- A. The organs of the respiratory tract can be divided into two groups: the upper respiratory tract (nose, nasal cavity, sinuses, and pharynx), and the lower respiratory tract (larynx, trachea, bronchial tree, and lungs).
- B. Nose
  - 1. The nose, supported by bone and cartilage, provides an entrance for air in which air is filtered by coarse hairs inside the nostrils.
- C. Nasal Cavity (Figs. 16.2-16.3)
  - 1. The nasal cavity is a space posterior to the nose that is divided medially by the nasal septum.
  - 2. Nasal conchae divide the cavity into passageways that are lined with mucous membrane, and help increase the surface area available to warm and filter incoming air.
  - 3. Particles trapped in the mucus are carried to the pharynx by ciliary action, swallowed, and carried to the stomach where gastric juice destroys any microorganisms in the mucus.
- D. Paranasal Sinuses
  - 1. Sinuses are air-filled spaces within the maxillary, frontal, ethmoid, and sphenoid bones of the skull.
  - 2. These spaces open to the nasal cavity and are lined with mucus membrane that is continuous with that lining the nasal cavity.
  - 3. The sinuses reduce the weight of the skull and serve as a resonant chamber to affect the quality of the voice.
- E. Pharynx (Figs. 16.1, 16.2)
  - 1. The pharynx is a common passageway for air and food.
  - 2. The pharynx aids in producing sounds for speech.
- F. Larynx (Figs. 16.4-16.5)
  - 1. The larynx is an enlargement in the airway superior to the trachea and inferior to the pharynx.
  - 2. It helps keep particles from entering the trachea and also houses the vocal cords.
  - 3. The larynx is composed of a framework of muscles and cartilage bound by elastic tissue.
  - 4. Inside the larynx, two pairs of folds of muscle and connective tissue covered with mucous membrane make up the vocal cords.
    - a. The upper pair is the false vocal cords.
    - b. The lower pair is the true vocal cords.
    - c. Changing tension on the vocal cords controls pitch, while increasing the loudness depends upon increasing the force of air vibrating the vocal cords.
  - 5. During normal breathing, the vocal cords are relaxed and the glottis is a triangular slit.
  - 6. During swallowing, the false vocal cords and epiglottis close off the glottis.
- G. Trachea (Fig. 16.6)



1. The trachea extends downward anterior to the esophagus and into the thoracic cavity, where it splits into right and left bronchi.
  2. The inner wall of the trachea is lined with ciliated mucous membrane with many goblet cells that serve to trap incoming particles.
  3. The tracheal wall is supported by 20 incomplete cartilaginous rings.
- H. Bronchial Tree (Fig. 16.7)
1. The bronchial tree consists of branched tubes leading from the trachea to the alveoli.
  2. The bronchial tree begins with the two primary bronchi, each leading to a lung.
  3. The branches (Figs. 16.8-16.9) of the bronchial tree from the trachea are right and left primary bronchi; these further subdivide until bronchioles give rise to alveolar ducts which terminate in alveoli.
  4. It is through the thin epithelial cells of the alveoli (Fig. 16.10) that gas exchange between the blood and air occurs.
- I. Lungs (Figs. 16.1, 16.6, 16.7, 16.11; Table 16.1)
1. The right and left soft, spongy, cone-shaped lungs are separated medially by the mediastinum and are enclosed by the diaphragm and thoracic cage.
  2. The bronchus and large blood vessels enter each lung.
  3. A layer of serous membrane, the visceral pleura, folds back to form the parietal pleura.
  4. The visceral pleura is attached to the lung, and the parietal pleura lines the thoracic cavity; serous fluid lubricates the “pleura cavity” between these two membranes.
  5. The right lung has three lobes, the left has two.
  6. Each lobe is composed of lobules that contain air passages, alveoli, nerves, blood vessels, lymphatic vessels, and connective tissues.

### 16.3 Breathing Mechanism

- A. Ventilation (breathing), the movement of air in and out of the lungs, is composed of inspiration and expiration.
- B. Inspiration (Figs. 16.12-16.13)
1. Atmospheric pressure is the force that moves air into the lungs.
  2. When pressure on the inside of the lungs decreases, higher pressure air flows in from the outside.
  3. Air pressure inside the lungs is decreased by increasing the size of the thoracic cavity; due to surface tension between the two layers of pleura, the lungs follow with the chest wall and expand.
  4. Muscles involved in expanding the thoracic cavity include the diaphragm and the external intercostal muscles.
  5. A mixture of lipoproteins, called surfactant, is secreted into the alveolar air spaces to help keep the alveoli from collapsing when internal air pressure is low.
- C. Expiration (Fig. 16.14)
1. The forces of expiration are due to the elastic recoil of lung and muscle tissues and from the surface tension within the alveoli.
  2. Forced expiration is aided by thoracic and abdominal wall muscles that compress the abdomen against the diaphragm.
- D. Respiratory Air Volumes and Capacities (Fig. 16.15; Table 16.2)
1. The measurement of different air volumes is called spirometry, and it describes four distinct respiratory volumes.
  2. One inspiration followed by expiration is called a respiratory cycle; the amount of air that enters or leaves the lungs during one respiratory cycle is the tidal volume.
  3. During forced inspiration, an additional volume, the inspiratory reserve volume, can be inhaled into the lungs.  $IRV + TV$  gives us the inspiratory capacity.
  4. During a maximal forced expiration, an expiratory reserve volume can be exhaled,



but there remains a residual volume in the lungs. Adding the two together gives us the functional reserve capacity.

5. Vital capacity is the tidal volume plus inspiratory reserve and expiratory reserve volumes combined.
6. Vital capacity plus residual volume is the total lung capacity.
7. Anatomic dead space is air remaining in the bronchial tree.

#### **16.4 Control of Breathing**

- A. Normal breathing is a rhythmic, involuntary act even though the muscles are under voluntary control.
- B. Respiratory Areas (Figs. 16.16-16.17)
  1. Groups of neurons in the brain stem comprise the respiratory center, which controls breathing by causing inspiration and expiration and by adjusting the rate and depth of breathing.
  2. The components of the respiratory center include the rhythmicity center of the medulla and the pneumotaxic area of the pons.
  3. The medullary rhythmicity center includes two groups of neurons: the dorsal respiratory group and the ventral respiratory group.
    - a. The dorsal respiratory group is responsible for the basic rhythm of breathing.
    - b. The ventral respiratory group is active when more forceful breathing is required.
  4. Neurons in the pneumotaxic area control the rate of breathing.
- C. Factors Affecting Breathing (Fig. 16.18)
  1. Chemicals, lung tissue stretching, and emotional state affect breathing.
  2. Chemosensitive areas (central chemoreceptors) are associated with the respiratory center and are sensitive to changes in the blood concentration of carbon dioxide and hydrogen ions.
    - a. If either carbon dioxide or hydrogen ion concentrations rise, the central chemoreceptors signal the respiratory center, and breathing rate increases.
  3. Peripheral chemoreceptors in the carotid sinuses and aortic arch sense changes in blood oxygen concentration, transmit impulses to the respiratory center, and breathing rate and tidal volume increase.
  4. An inflation reflex, triggered by stretch receptors in the visceral pleura, bronchioles, and alveoli, helps to prevent overinflation of the lungs during forceful breathing.
  5. Hyperventilation lowers the amount of carbon dioxide in the blood.

#### **16.5 Alveolar Gas Exchanges**

- A. The alveoli are the only sites of gas exchange between the atmosphere and the blood.
- B. Alveoli (Fig. 16.8)
  1. The alveoli are tiny sacs clustered at the distal ends of the alveolar ducts.
- C. Respiratory Membrane (Fig. 16.19)
  1. The respiratory membrane consists of the epithelial cells of the alveolus, the endothelial cells of the capillary, and the two fused basement membranes of these layers.
  2. Gas exchange occurs across this respiratory membrane.
- D. Diffusion Across the Respiratory Membrane
  1. Gases diffuse from areas of higher pressure to areas of lower pressure.
  2. In a mixture of gases, each gas accounts for a portion of the total pressure; the amount of pressure each gas exerts is equal to its partial pressure.
  3. When the partial pressure of oxygen is higher in the alveolar air than it is in the capillary blood, oxygen will diffuse into the blood.
  4. When the partial pressure of carbon dioxide is greater in the blood than in the



- alveolar air, carbon dioxide will diffuse out of the blood and into the alveolus.
5. A number of factors favor increased diffusion; more surface area, shorter distance, greater solubility of gases, and a steeper partial pressure gradient.

## 16.6 Gas Transport (Table 16.3)

- A. Gases are transported in association with molecules in the blood or dissolved in the plasma.
- B. Oxygen Transport (Fig. 16.21)
  1. Over 98% of oxygen is carried in the blood bound to hemoglobin of red blood cells, producing oxyhemoglobin.
  2. Oxyhemoglobin is unstable in areas where the concentration of oxygen is low, and gives up its oxygen molecules in those areas.
  3. More oxygen is released as the blood concentration of carbon dioxide increases, as the blood becomes more acidic, and as blood temperature increases.
  4. A deficiency of oxygen reaching the tissues is called hypoxia and has a variety of causes.
- C. Carbon Dioxide Transport (Figs. 16.22-16.23)
  1. Carbon dioxide may be transported dissolved in blood plasma, as carbaminohemoglobin, or as bicarbonate ions.
  2. Most carbon dioxide is transported in the form of bicarbonate.
  3. When carbon dioxide reacts with water in the plasma, carbonic acid is formed slowly, but instead much of the carbon dioxide enters red blood cells, where the enzyme carbonic anhydrase speeds this reaction.
  4. The resulting carbonic acid dissociates immediately, releasing bicarbonate and hydrogen ions.
  5. Carbaminohemoglobin also releases its carbon dioxide, which diffuses out of the blood into the alveolar air.