The Respiratory System

- **Overview**
  - The major function of the respiratory system is to supply the body with oxygen and dispose of carbon dioxide.
  - To accomplish this function, at least four processes must happen (collectively called respiration):
    - **Pulmonary ventilation**
      - Movement of air into and out of the lungs so that the gases there are continuously changed and refreshed (i.e., breathing).
      - Consists of two phases: Inspiration and Expiration.
    - **External respiration**
      - Movement of oxygen from the lungs to the blood and of carbon dioxide from the blood to the lungs.
    - **Transport of respiratory gases**
      - Transport of oxygen from the lungs to the tissue cells of the body, and of carbon dioxide from the tissue cells to the lungs.
      - This is accomplished by the cardiovascular system using blood as the transporting fluid.
    - **Internal respiration**
      - Movement of oxygen from blood to the tissue cells and of carbon dioxide from tissue cells to blood.

- **Functional Anatomy of the Respiratory System**
  - **Principal Organs of the Respiratory System**
    - **Nose**
      - **Overview**
        - Jutting external portion is supported by bone and cartilage.
        - Internal nasal cavity is divided by midline nasal septum and lined with mucosa.
      - **Function**
        - Produces mucus; filters, warms and moistens incoming air.
        - Resonance chamber for speech
    - **Nasal cavity**
      - **Overview**
        - Roof of nasal cavity contains olfactory epithelium.
      - **Function**
        - Has receptors for sense of smell on the roof of nasal cavity
    - **Paranasal sinuses**
      - **Overview**
        - Mucosa-lined, air-filled cavities in cranial bones surrounding nasal cavity.
      - **Function**
        - Receptors for sense of smell
        - Lighten the skull
    - **Pharynx**
      - **Overview**
- Passageway connecting nasal cavity to larynx and oral cavity to esophagus.
- Houses tonsils which are lymphoid tissue masses involved in protection against pathogens.

- **Function**
  - Passageway for air and food
  - Facilitates exposure of immune system to inhaled antigens

- **Larynx**
  - **Overview**
    - Connects pharynx to trachea.
    - Has framework of cartilage and dense connective tissue
    - Opening (glottis) can be closed by epiglottis or vocal folds
    - Houses vocal folds (i.e., true vocal cords)
  - **Function**
    - Air passageway
    - Prevents food from entering lower respiratory tract
    - Vocal folds produce voice

- **Trachea**
  - **Overview**
    - Flexible tube running from larynx and dividing interiorly into two main bronchi.
    - Walls contain C-shaped cartilages that are incomplete posteriorly where connected by trachealis muscle.
  - **Function**
    - Air passageway
    - Cleans, warms and moistens incoming air

- **Bronchi Tree**
  - **Overview**
    - Consists of right and left main bronchi, which subdivide within the lungs to form lobar and segmental bronchi and bronchioles.
    - Bronchiolar walls lack cartilage but contain complete layers of smooth muscle
    - Constriction of this muscle impedes expiration
  - **Function**
    - Air passageways connecting trachea with alveoli
    - Cleans, warms, and moistens incoming air

- **Alveoli**
  - **Overview**
    - Microscopic chambers at termini of bronchial tree.
    - External surfaces are intimately associated with pulmonary capillaries
    - Special alveolar cells produce surfactant
  - **Function**
    - Main sites of gas exchange
    - Surfactant reduces surface tension; helps prevent lung collapse

- **Lungs**
  - **Overview**
Paired composite organs that flank mediastinum in thorax. Composed primarily of alveoli and respiratory passageways. Stroma is fibrous elastic connective tissue, allowing lungs to recoil passively during expiration.

- **Function**
  - House respiratory passages smaller than the main bronchi

- **Pleurae**
  - **Overview**
    - Serous membranes
    - Parietal pleura lines thoracic cavity
    - Visceral pleura covers external lung surfaces
  - **Function**
    - Produce lubricating fluid and compartmentalize lungs

- **Mechanics of Breathing**
  - **Pressure Relationships in the Thoracic Cavity**
    - Respiratory pressures are always described relative to atmospheric pressure ($P_{\text{atm}}$)—which is the pressure exerted by the air (gases) surrounding the body.
    - At sea level, atmospheric pressure is 760 mm Hg which is also expressed in atmosphere units (atm) (760 mm Hg = 1 atm).
  - **Pulmonary Ventilation**
    - **Inspiration**
      - **Sequence of Events**
        - Inspiratory muscles contract
          - Diaphragm descends
          - Rib cage rises
        - Thoracic cavity volume increases
        - Lungs are stretched; intrapulmonary volume increases
        - Intrapulmonary pressure drops (to -1 mm Hg).
          - Anytime the intrapulmonary pressure is less than atmospheric pressure, air rushes into the lungs along the pressure gradient.
        - Air (gases) flow into lungs down its pressure gradient until intrapulmonary pressure is 0 (equal to atmospheric pressure).
    - **Expiration**
      - **Sequence of Events**
        - Inspiratory muscles relax
          - Diaphragm rises
          - Rib cage descends due to recoil of costal cartilages
        - Thoracic cavity volume decreases
        - Elastic lungs recoil passively; intrapulmonary volume decreases
        - Intrapulmonary pressure rises (to +1 mm Hg)
        - Air (gases) flows out of lungs down its pressure gradient until intrapulmonary pressure is 0.

- **Gas Exchanges Between Blood, Lungs and Tissues**
  - **External Respiration**
    - Aka, Pulmonary Gas Exchange
- Dark red blood flowing through the pulmonary circuit is transformed into scarlet river that is returned to the heart for distribution by systemic arteries to all body tissues.
- Color change is due to oxygen uptake and binding to hemoglobin in red blood cells.
  - Internal Respiration
    - Involves capillary gas exchange in body tissues
    - Gas exchange that occurs between the blood and alveoli and between blood and tissue cells takes place by simple diffusion driven by the partial pressure gradients of oxygen and carbon dioxide that exist on the opposite side of the exchange membranes.
- Controls of Respiration
  - The control of respiration primarily involves neurons in the reticular formation of the medulla and pons.
    - **Reticular formation** = functional system that spans the brain stem; involved in regulating sensory input to the cerebral cortex, cortical arousal, and control of motor behavior
    - **Medulla** = inferior most part of the brain stem.
    - **Pons** = part of the brain stem connecting the medulla with the midbrain, providing linkage between upper and lower levels of the central nervous system.
- Homeostatic Imbalances of the Respiratory System
  - **Chronic Obstructive Pulmonary Disease (COPD)**
    - Exemplified best by emphysema and chronic bronchitis
      - **Emphysema**
        - Distinguished by permanent enlargement of the alveoli accompanied by destruction of the alveolar walls
        - Lungs lose their elasticity
          - Accessory muscles are enlisted to breathe
          - Individuals are exhausted due to using 3-4 times more energy to breath
          - Air gets trapped in alveoli leading to “barrel chest” and flattening the diaphragm—thus reducing ventilation efficiency
          - Causes the right ventricle to overwork and enlarge due to damage to pulmonary capillaries (creating resistance in the pulmonary circuit).
      - **Chronic bronchitis**
        - Inhaled irritants lead to chronic excessive mucus production by the mucosa of the lower respiratory passageways and to inflammation and fibrosis of that mucosa.
        - Obstructions lead to impaired lung ventilation and gas exchange
        - Pulmonary infections are frequent because bacteria thrive in the stagnant pools of mucus.
    - Major cause of death and disability in North America
    - Key physiological feature is an irreversible decrease in the ability to force air out of the lungs
    - More than 80% of patients have a history of smoking
- Coughing and frequent pulmonary infections are common
- **Dyspnea** = difficult or labored breathing often referred to as “air hunger” occurs and gets progressively more severe.
- Most COPD victims develop respiratory failure manifested as hypoventilation (insufficient ventilation in relation to metabolic needs, causing carbon dioxide retention), respiratory acidosis, and hypoexemia.
  - **Respiratory acidosis**
    - Respiratory acidosis is a condition that occurs when the lungs cannot remove all of the carbon dioxide the body produces. This causes body fluids, especially the blood, to become too acidic.
    - Symptoms may include:
      - Confusion
      - Easy fatigue
      - Lethargy
      - Shortness of breath
      - Sleepiness
    - Complications include poor organ function, respiratory failure, and shock.
  - **Hypoexemia**
    - Low blood oxygen
    - In order to function properly, your body needs a constant level of oxygen circulating in the blood to cells and tissues. When this level of oxygen falls below a certain amount, hypoxemia occurs and you may experience shortness of breath.
    - An approximate blood oxygen level can be determined using a pulse oximeter — a small device that clips on your finger.
      - Though the pulse oximeter actually measures the saturation of oxygen in your blood, the results are often used as an estimate of blood oxygen levels.
      - Normal pulse oximeter readings range from 95 to 100 percent, under most circumstances.
      - Values under 90 percent are considered low.
- **Asthma**
  - Characterized by episodes of coughing, dyspnea, wheezing and chest tightness (alone or in combination).
  - According to research, in asthma, active inflammation of the airways comes before other factors in causing an asthma attack.
  - The airway inflammation is an immune response.
  - About one in ten people in North America suffer from asthma.