The Respiratory System

Functions of the Respiratory System
- Gas exchanges between the blood and external environment
  - Occurs in the alveoli of the lungs
  - Passageways to the lungs purify, humidify, and warm the incoming air

Organs of the Respiratory System
- Nose
- Pharynx
- Larynx
- Trachea
- Bronchi
- Lungs—alveoli

The Nose
- Only externally visible part of the respiratory system
- Air enters the nose through the external nostrils (nares)
- Interior of the nose consists of a nasal cavity divided by a nasal septum

Upper Respiratory Tract

Anatomy of the Nasal Cavity
- Olfactory receptors are located in the mucosa on the superior surface
- The rest of the cavity is lined with respiratory mucosa that
  - Moisten air
  - Trap incoming foreign particles

Anatomy of the Nasal Cavity
- Lateral walls have projections called conchae
  - Increase surface area
  - Increase air turbulence within the nasal cavity
- The nasal cavity is separated from the oral cavity by the palate
  - Anterior hard palate (bone)
  - Posterior soft palate (muscle)

Paranasal Sinuses
- Cavities within bones surrounding the nasal cavity are called sinuses
- Sinuses are located in the following bones
  - Frontal bone
  - Sphenoid bone
  - Ethmoid bone
  - Maxillary bone

Paranasal Sinuses
- Function of the sinuses
  - Lighten the skull
  - Act as resonance chambers for speech
  - Produce mucus that drains into the nasal cavity

Upper Respiratory Tract—Paranasal Sinuses
Pharynx (Throat)
- Muscular passage from nasal cavity to larynx
- Three regions of the pharynx
  - Nasopharynx—superior region behind nasal cavity
  - Oropharynx—middle region behind mouth
  - Laryngopharynx—inferior region attached to larynx
- The oropharynx and laryngopharynx are common passageways for air and food

Structures of the Pharynx
- Pharyngotympanic tubes open into the nasopharynx
- Tonsils of the pharynx
  - Pharyngeal tonsil (adenoids) are located in the nasopharynx
  - Palatine tonsils are located in the oropharynx
  - Lingual tonsils are found at the base of the tongue

Upper Respiratory Tract: Pharynx

Larynx (Voice Box)
- Routes air and food into proper channels
- Plays a role in speech
- Made of eight rigid hyaline cartilages and a spoon-shaped flap of elastic cartilage (epiglottis)

Structures of the Larynx
- Thyroid cartilage
  - Largest of the hyaline cartilages
  - Protrudes anteriorly (Adam’s apple)
- Epiglottis
  - Protects the superior opening of the larynx
  - Routes food to the esophagus and air toward the trachea
  - When swallowing, the epiglottis rises and forms a lid over the opening of the larynx

Structures of the Larynx
- Vocal folds (true vocal cords)
  - Vibrate with expelled air to create sound (speech)
- Glottis—opening between vocal cords

Upper Respiratory Tract: Larynx

Trachea (Windpipe)
- Four-inch-long tube that connects larynx with bronchi
- Walls are reinforced with C-shaped hyaline cartilage
- Lined with ciliated mucosa
  - Beat continuously in the opposite direction of incoming air
  - Expel mucus loaded with dust and other debris away from lungs

Trachea (Windpipe)

Main (Primary) Bronchi
- Formed by division of the trachea
- Enters the lung at the hilum (medial depression)
- Right bronchus is wider, shorter, and straighter than left
- Bronchi subdivide into smaller and smaller branches
  - Bronchi
  - Bronchioles
  - Tertiary bronchioles

22. **Main Bronchi**

23. **Main Bronchi**

24. **Lungs**
   - Occupy most of the thoracic cavity
     - Heart occupies central portion called mediastinum
   - Apex is near the clavicle (superior portion)
   - Base rests on the diaphragm (inferior portion)
   - Each lung is divided into lobes by fissures
     - Left lung—two lobes
     - Right lung—three lobes

25. **Lungs**

26. **Coverings of the Lungs**
   - Serosa covers the outer surface of the lungs
     - Pulmonary (visceral) pleura covers the lung surface
     - Parietal pleura lines the walls of the thoracic cavity
   - Pleural fluid fills the area between layers of pleura to allow gliding
   - These two pleural layers resist being pulled apart

27. **Lungs**

28. **Bronchial (Respiratory) Tree Divisions**
   - All but the smallest of these passageways have reinforcing cartilage in their walls
     - Primary bronchi
     - Secondary bronchi
     - Tertiary bronchi
     - Bronchioles
     - Terminal bronchioles

29. **Bronchial (Respiratory) Tree Divisions**

30. **Respiratory Zone**
   - Structures
     - Respiratory bronchioles
     - Alveolar ducts
     - Alveolar sacs
     - Alveoli (air sacs)
   - Site of gas exchange = alveoli only

31. **Bronchial (Respiratory) Tree Divisions**

32. **Respiratory Membrane (Air-Blood Barrier)**
   - Thin squamous epithelial layer lines alveolar walls
- Alveolar pores connect neighboring air sacs
- Pulmonary capillaries cover external surfaces of alveoli
- On one side of the membrane is air and on the other side is blood flowing past

**Respiratory Membrane (Air-Blood Barrier)**

**Gas Exchange**
- Gas crosses the respiratory membrane by diffusion
  - Oxygen enters the blood
  - Carbon dioxide enters the alveoli
- Alveolar macrophages ("dust cells") add protection by picking up bacteria, carbon particles, and other debris
- Surfactant (a lipid molecule) coats gas-exposed alveolar surfaces

**Four Events of Respiration**
- Pulmonary ventilation—moving air in and out of the lungs (commonly called *breathing*)
- External respiration—gas exchange between pulmonary blood and alveoli
  - Oxygen is loaded into the blood
  - Carbon dioxide is unloaded from the blood

**External Respiration**

**Four Events of Respiration**
- Respiratory gas transport—transport of oxygen and carbon dioxide via the bloodstream
- Internal respiration—gas exchange between blood and tissue cells in systemic capillaries
- Two phases
  - Inspiration = inhalation
    - flow of air into lungs
  - Expiration = exhalation
    - air leaving lungs

**Mechanics of Breathing (Pulmonary Ventilation)**
- Completely mechanical process that depends on volume changes in the thoracic cavity
- Volume changes lead to pressure changes, which lead to the flow of gases to equalize pressure

**Inspiration**
- Diaphragm and external intercostal muscles contract
- The size of the thoracic cavity increases
- External air is pulled into the lungs due to
  - Increase in intrapulmonary volume
  - Decrease in gas pressure

**Expiration**
- Largely a passive process which depends on natural lung elasticity
- As muscles relax, air is pushed out of the lungs due to
- Decrease in intrapulmonary volume
- Increase in gas pressure
- Forced expiration can occur mostly by contracting internal intercostal muscles to depress the rib cage

Expiration

Nonrespiratory Air (Gas) Movements
- Can be caused by reflexes or voluntary actions
- Examples:
  - Cough and sneeze—clears lungs of debris
  - Crying—emotionally induced mechanism
  - Laughing—similar to crying
  - Hiccup—sudden inspirations
  - Yawn—very deep inspiration

Respiratory Volumes and Capacities
- Normal breathing moves about 500 mL of air with each breath
  - This respiratory volume is tidal volume (TV)
- Many factors that affect respiratory capacity
  - A person’s size
  - Sex
  - Age
  - Physical condition

Respiratory Volumes and Capacities
- Inspiratory reserve volume (IRV)
  - Amount of air that can be taken in forcibly over the tidal volume
  - Usually between 2100 and 3200 mL
- Expiratory reserve volume (ERV)
  - Amount of air that can be forcibly exhaled
  - Approximately 1200 mL

Respiratory Volumes and Capacities
- Residual volume
  - Air remaining in lung after expiration
  - About 1200 mL

Respiratory Volumes and Capacities
- Vital capacity
  - The total amount of exchangeable air
  - Vital capacity = TV + IRV + ERV
  - Dead space volume
    - Air that remains in conducting zone and never reaches alveoli
    - About 150 mL

Respiratory Volumes and Capacities
- Functional volume
  - Air that actually reaches the respiratory zone
  - Usually about 350 mL
Respiratory capacities are measured with a spirometer

**Respiratory Volumes**

**External Respiration**

- Oxygen loaded into the blood
  - The alveoli always have more oxygen than the blood
  - Oxygen moves by diffusion towards the area of lower concentration
- Pulmonary capillary blood gains oxygen

**External Respiration**

- Carbon dioxide unloaded out of the blood
  - Blood returning from tissues has higher concentrations of carbon dioxide than air in the alveoli
  - Pulmonary capillary blood gives up carbon dioxide to be exhaled
- Blood leaving the lungs is oxygen-rich and carbon dioxide-poor

**Internal Respiration**

- Exchange of gases between blood and body cells
- An opposite reaction to what occurs in the lungs
- Carbon dioxide diffuses out of tissue to blood (called *loading*)
- Oxygen diffuses from blood into tissue (called *unloading*)

**Neural Regulation of Respiration**

- Neural centers that control rate and depth are located in the medulla and pons
  - Medulla—sets basic rhythm of breathing and contains a pacemaker called the self-exciting inspiratory center
  - Pons—appears to smooth out respiratory rate

**Hyperventilation and Hypoventilation**

- Hyperventilation
  - Results from increased CO₂ in the blood (acidosis)
  - Breathing becomes deeper and more rapid
  - Blows off more CO₂ to restore normal blood pH

- Hypoventilation
Results when blood becomes alkaline (alkalosis)
- Extremely slow or shallow breathing
- Allows CO₂ to accumulate in the blood

Non-Neural Factors Influencing Respiratory Rate and Depth
- Physical factors
  - Increased body temperature
  - Exercise
  - Talking
  - Coughing
- Volition (conscious control)
- Emotional factors

Non-Neural Factors Influencing Respiratory Rate and Depth
- Chemical factors: CO₂ levels
  - The body’s need to rid itself of CO₂ is the most important stimulus
  - Increased levels of carbon dioxide (and thus, a decreased or acidic pH) in the blood increase the rate and depth of breathing
- Chemical factors: oxygen levels
  - Changes in oxygen concentration in the blood are detected by chemoreceptors in the aorta and common carotid artery

Respiratory Disorders: Chronic Obstructive Pulmonary Disease (COPD)
- Exemplified by chronic bronchitis and emphysema
- Major causes of death and disability in the United States

Respiratory Disorders: Chronic Obstructive Pulmonary Disease (COPD)
- Features of these diseases
  - Patients almost always have a history of smoking
  - Labored breathing (dyspnea) becomes progressively more severe
  - Coughing and frequent pulmonary infections are common
  - Most victims are hypoxic, retain carbon dioxide, and have respiratory acidosis
  - Those infected will ultimately develop respiratory failure

Respiratory Disorders: Chronic Bronchitis
- Mucosa of the lower respiratory passages becomes severely inflamed
- Mucus production increases
- Pooled mucus impairs ventilation and gas exchange
- Risk of lung infection increases
- Pneumonia is common
- Called “blue bloaters” due to hypoxia and cyanosis

Respiratory Disorders: Emphysema
- Alveoli enlarge as adjacent chambers break through
- Chronic inflammation promotes lung fibrosis
- Airways collapse during expiration
- Patients use a large amount of energy to exhale
- Overinflation of the lungs leads to a permanently expanded barrel chest
- Cyanosis appears late in the disease; sufferers are often called “pink puffers”
Other disorders
- Infant respiratory distress syndrome (IRDS)—surfactant production is inadequate
- Cystic fibrosis—oversecretion of thick mucus clogs the respiratory system
- Asthma
  - Chronic inflamed hypersensitive bronchiole passages
  - Response to irritants with dyspnea, coughing, and wheezing
- Sudden Infant Death Syndrome (SIDS)
  - Apparently healthy infant stops breathing and dies during sleep
  - Some cases are thought to be a problem of the neural respiratory control center
  - One third of cases appear to be due to heart rhythm abnormalities
  - Recent research shows a genetic component

A Closer Look: Lung Cancer
- Accounts for one-third of all cancer deaths in the United States
- Increased incidence is associated with smoking
- Three common types
  - Squamous cell carcinoma
  - Adenocarcinoma
  - Small cell carcinoma

Developmental Aspects of the Respiratory System
- Surfactant is a fatty molecule made by alveolar cells
  - Lowers alveolar surface tension so that lungs do not collapse between breaths
  - Not present until late in fetal development and may not be present in premature babies
  - Appears around 28–30 weeks of pregnancy

Developmental Aspects of the Respiratory System
- Aging effects
  - Elasticity of lungs decreases
  - Vital capacity decreases
  - Blood oxygen levels decrease
  - Stimulating effects of carbon dioxide decrease
  - Elderly are often hypoxic and exhibit sleep apnea
  - More risks of respiratory tract infection