The Respiratory System

Chapter 21

→ *21.1 Overview of the Respiratory System*

- Classified anatomically into upper and lower tracts:
  - _____ – passageways from nasal cavity to larynx
  - _____ – passageways from trachea alveoli
    - _____ – tiny air sacs, site of gas exchange
    - _____ – a collection of millions of alveoli and their blood vessels embedded in elastic connective tissue

Basic Functions of the Respiratory System

- Classified functionally into **conducting** and **respiratory zones**:
  - _____ **zone** - pathway air travels
    - Air is filtered, warmed, and moistened
    - Includes structures from nose and nasal cavity to bronchioles
  - _____ **zone** – where gas exchange occurs; alveoli

- **Respiration** – process that provides body cells with oxygen and removes waste product carbon dioxide:
  1. **Pulmonary ventilation** –
  2. **Pulmonary gas exchange** – movement of gases between _____ and _____
  3. **Gas transport** – movement of gases through blood

4. **Tissue gas exchange** – movement of gases between _____ and _____

- Other functions – serve to maintain homeostasis:
    1.
    2.
    3. Assist with defecation, urination, and childbirth by increasing pressure in thoracic cavity
    4. Assist with flow of venous blood and lymph
    5. Maintaining acid-base balance
    6. Produces angiotensin-II

→ *21.2 Anatomy of the Respiratory System*

The Nose and Nasal Cavity

- Nose and nasal cavity are entryway into respiratory system; serve following functions:
    1.
    2. Filter debris from inhaled air and secrete antibacterial substances
    3.
    4. Resonates of voice
- Anatomy of nasal cavity:
    1. _____ – divided into left and right portions by nasal septum from nostrils (anterior nares) to posterior nares
    2. _____ – contain bristle-like hairs
    3. **Superior**, **inferior**, and **middle conchae** create turbulence

4. _____ – hollow cavities found within frontal, ethmoid, sphenoid, and maxillary bones
    - Warm and humidify air; also enhance voice resonance and reduce weight of skull

- Histology of nasal cavity:
    1. **Vestibule** is lined with _____; resists mechanical stress
    2. Most of nasal cavity is lined with mucosa composed of _____ and goblet cells
        - Traps foreign particles in mucus → ciliated cells move it toward posterior nasal cavity and pharynx

The Pharynx

- **Pharynx** (throat) – three divisions:
    1. _____ – posterior to nasal cavity; lined with PSCCE

        - Extends from posterior nares to soft palate

    - _____ – posterior to oral cavity

        - Extends from uvula to hyoid bone

        - stratified squamous epithelium

    - _____ – **hyoid bone** to **esophagus**

        - stratified squamous epithelium

The Larynx

- **Larynx** or **voice box** – houses _____
    -

-

- Composed of nine pieces of **cartilage**
  - _____ **cartilage** – largest of three unpaired sections ("**Adam's apple**")
  - _____ **cartilage** –inferior to thyroid cartilage
  - _____ –posterior to thyroid cartilage

Remaining six found in _____:

- **Cuneiform cartilages** –help support epiglottis
- **Arytenoid cartilages** –involved in sound production
- **Corniculate cartilages** – involved in sound production

- **Vestibular folds** (false vocal cords) close off glottis during swallowing; play no role in sound production
- **True vocal cords** and **Vocal ligaments** – elastic bands; vibrate to produce sound when air passes over them

The Trachea

- **Trachea** (**windpipe**) - C shape cartilage rings
  -

Smoker's Cough

- Deep, rattling cough of a smoker is linked directly to numerous adverse effects of smoke on the respiratory system
- Chemicals in smoke
  - Act as irritants, increasing mucus secretion
  - Partially paralyze and eventually destroy cilia lining tract

- As result, more mucus is present, but cilia are less able to sweep it out of airways
- Cough develops as only way to prevent mucus buildup
- Cilia will reappear within a few months after smoking stops

The Bronchial Tree

- **Primary bronchi** (enters the left or right lung at hilum)
  - **_____ primary bronchus** – wider, shorter, and straighter than left
  - **Secondary bronchi** once inside each lung; three on right and two on left
  - **Tertiary bronchi** continue to branch smaller and smaller
  - **_____** – smallest airways
  - **Terminal bronchioles → Respiratory bronchioles**
  - As airways divide and get smaller:
  - Epithelium gradually changes from _____ to _____ cells with cilia
  - Amount of smooth muscle increases
  -

Alveoli and the Respiratory Membrane

- **Alveolar ducts → Alveolar sacs** - grapelike clusters of alveoli (site of gas exchange)

  1. Type I alveolar cells (_____)

  2. Type II alveolar cells (simple cuboidal cells) produce surfactant (_____)

  3. Alveolar _____ are mobile phagocytes

The Lungs and Pleurae

- Right and left lungs are separated by heart and mediastinum
    -
    -
    - _____ – where primary bronchi, blood and lymphatic vessels, and nerves enter and exit lung
    - Cardiac notch
    - Right lung - _____ lobes; left lung - _____ lobes
- Each lung is found within a **pleural cavity**
    - _____ – outer layer of serous membrane
    - _____ continuous with surface of lungs
    - Pleural membranes secrete a thin layer of **serous fluid** to lubricate surfaces of lungs as they expand and contract

Pleuritis and Pleural Friction Rub

- Many conditions (heart failure to pneumonia) can cause inflammation of the visceral and parietal pleura (**pleuritis**)
- **Pleuritic pain** – one of most common symptoms; chest pain with inhalation; results from inflamed pleura rubbing together as lungs expand and contract
- Rubbing can sometimes be *heard with stethoscope*; termed **pleural friction rub**; resembles sandpaper rubbing against itself

→ *21.3 Pulmonary Ventilation*

The Pressure-Volume Relationship

- First process of respiration is **pulmonary ventilation**

- The **pressure-volume relationship** provides driving force for pulmonary ventilation
    - Gas molecules move from areas of high pressure to areas of low pressure
- **_____ –** pressure and volume of a gas are _____ related

    As volume

    Pressure

        (and vise versa)

The Process of Pulmonary Ventilation

- Process of pulmonary ventilation consists of **inspiration** and **expiration**
- Volume changes in thoracic cavity and lungs leads to pressure changes and air to move into or out of the lungs
    - Inspiration:
        - _____ – main inspiratory muscle
        - _____ – muscles found between ribs
            - These muscles increase thoracic cavity volume along with lung volume
    - Maximal inspiration aided by contraction of _____ , _____, and _____ muscles
    - Expiration is a *mostly passive* process that does not *utilize muscle contraction*
        - Diaphragm returns to its original dome shape that pushes up on lungs
        - _____ decrease lung volume and *raise intrapulmonary pressure* above *atmospheric pressure* so air flows out of lungs

- Maximum expiration muscles include _____ and _____ **muscles**
    - Forcefully decrease size of thoracic cavity; why your abdominal and back muscles are often sore after having a cough
    - **Heimlich maneuver** – delivering abdominal thrusts that push up on diaphragm

- **Nonrespiratory movements**, not intended for ventilation, include yawns, coughs, sighs, sneeze, laughing, hiccups, crying, etc.
- Pressures at work during ventilation :
    - **Atmospheric pressure** – at sea level atmospheric pressure is about _____
    - **Intrapulmonary pressure** – rises and falls with inspiration and expiration
    - **Intrapleural pressure** – rises and falls with inspiration and expiration; always _____ intrapulmonary pressure

Infant Respiratory Distress Syndrome

- Inadequate _____ makes alveolar inflation between breaths very difficult
- Surfactant is not produced significantly until last 10–12 weeks of gestation; premature newborns may therefore suffer from infant respiratory distress syndrome (RDS)
- Treatment – delivery of surfactant by inhalation; also positive airway pressure (CPAP); slightly pressurized air prevents alveoli from collapsing during expiration

Pulmonary Volumes and Capacities

- _____ – amount of air inspired or expired during normal quiet ventilation
- _____ – volume of air that can be forcibly inspired after a normal TV inspiration

- _____ – amount of air that can be forcibly expired after a normal tidal expiration (700–1200 ml)
- _____ **–** air remaining in lungs after forceful expiration

→ *21.4 Gas Exchange*

Gas Exchange

- Pulmonary ventilation only brings new air into and removes oxygen-poor air from alveoli
- Two processes are involved in **gas exchange**:
  - _____ **gas exchange** involves exchange of gases between alveoli and blood
  - _____ **gas exchange** involves exchange of gases between blood in systemic capillaries and body's cells

The Behavior of Gases

- **Gas behavior** – important factor that affects gas exchange

  1.

  2. Surface area of respiratory membrane

  3. Thickness of respiratory membrane

  4.

  - _____ **of partial pressures** – each gas in a mixture exerts its own pressure, called its **partial pressure** ($\mathbf{P_{gas}}$); total pressure of a gas mixture is sum of partial pressures of all its component gases

    $P_{N_2} + P_{O_2} + P_{CO_2} + P_{others}$ = Atmospheric pressure (760 mm Hg)

    $P_{N_2} = 0.78 \times 760 = 593$ mm Hg

    $P_{O_2} = 0.21 \times 760 = 160$ mm Hg

    Partial pressure of a gas in a mixture determines where gas diffuses

Pulmonary Gas Exchange

- Pulmonary gas exchange (_____ **respiration**) is diffusion of gases between alveoli and blood;
  -
  - Carbon dioxide simultaneously diffuses in opposite direction
    - Blood has a low PO_2 (40 mm Hg) while PO_2 in air is 104 mm Hg
    - Blood has a high CO_2 (45 mm Hg) compared to alveoli air (40 mm Hg)

Hyperbaric Oxygen Therapy

- Person placed in chamber and exposed to *higher than normal partial pressures of oxygen*; increases oxygen levels dissolved in plasma; in turn increases *delivery to tissues*
- Used to treat conditions benefiting from increased oxygen delivery: severe blood loss, crush injuries, anemia (decreased O_2 carrying capacity of blood), chronic wounds, certain infections, burns
- Also used for **decompression sickness** ("**bends**"); seen in divers who *ascended too rapidly*; caused by dissolved gases in blood coming out of solution and *forming bubbles* in bloodstream; therapy forces gases back into solution, eliminating bubbles

Factors Affecting Efficiency of Pulmonary Gas Exchange

- **Surface area of respiratory membrane** of both lungs is extremely large (approximately 1000 square feet)
  - Any factor that reduces surface area decreases efficiency of pulmonary gas exchange
  - _____ – low blood oxygen level; sign of severely impaired pulmonary gas exchange

- _____ – high blood carbon dioxide level; sign of severely impaired pulmonary gas exchange

- **Thickness of respiratory membrane** – distance that a gas must diffuse
  -
  - Thickening of the membrane reduces exhange efficiency (**inflammation)**
- **Ventilation-perfusion matching** – degree of match between amount of air reaching alveoli (**ventilation**) and amount of blood flow (**perfusion**) in pulmonary capillaries
  - **Ventilation/perfusion ratio** (**V/Q**) – measurement that describes this match; when affected by disease, called a _____

Tissue Gas Exchange

- Tissue gas exchange (_____ **respiration**) is oxygen and carbon dioxide between blood and tissues
  - Cells use oxygen constantly for cellular respiration so PO_2 in tissue is low
  - Tissues produce large quantities of PCO_2 so partial pressure is high

Factors affecting efficiency of tissue gas exchange include:

- _____**available for gas exchange** (of branched systemic capillaries); large enough to allow for gas exchange efficiency
- **Distance over which diffusion must occur**; less distance to diffuse results in more efficient gas exchange
- _____ **of tissue** – greater blood supply results in more efficient gas exchange

→ *21.5 Gas Transport through the Blood*

Gas Transport

- Only _____ of inspired oxygen is _____ in blood plasma due to its *poor solubility*; majority of oxygen is transported in blood plasma by **hemoglobin**
- There are three ways that carbon dioxide is transported

Oxygen Transport

- Oxygen transport is facilitated by **hemoglobin** (**Hb**)
  -
  - Hemoglobin is a protein found in erythrocytes
  - Consists of four subunits, each including a **heme group**; each heme contains one iron atom that can bind to one molecule of oxygen
- Hemoglobin binds and releases oxygen
  - Oxygen from alveoli binds to hemoglobin in pulmonary capillaries; **oxyhemoglobin** (**HbO_2**)
  -
- Effect of affinity on hemoglobin saturation is determined by four factors:
  1.
     - Lower blood PO_2; unloading reaction is favored as fewer O_2 molecules are available to bind to Hb
  2.
     - PCO_2 increase, Hb binds oxygen less strongly so more oxygen is unloaded
  3.
     - When pH decreases, Hb binds oxygen less strongly so more oxygen is unloaded

4.

- Increasing **temperature** decreases Hb's affinity for oxygen; facilitates unloading reaction of oxygen into tissues; reverse also true

Carbon Dioxide Transport

- Carbon dioxide is transported from tissues to lungs in blood three ways:

1.

2. _____ - CO_2 binds to Hb's protein component (not heme group that oxygen binds) - **carbaminohemoglobin**

3.

- CO_2 quickly diffuses into erythrocytes
- **Carbonic anhydrase** (**CA**) catalyzes:

- Most HCO_3^- diffuses into blood plasma and H^+ binds to Hb
- HCO_3^- carries a negative charge; counteracted by **chloride shift**; chloride ions move into erythrocytes as bicarbonate ions move out to balance charges

- The PCO_2 level in blood is determined by the following two factors:

1. _____ – rate and/or depth of breathing increase; increases amount of CO_2 expired from lungs

- pH of blood rises; more oxygen may be dissolved in blood as well

2. _____ – rate and/or depth of breathing decrease; causes retention of CO_2 (increases PCO_2)

- Blood becomes more acidic; oxygen levels (PO_2) in blood may drop (**hypoxemia**)

Carbon Monoxide Poisoning

- **Carbon monoxide** (**CO**) is produced from *burning organic compounds*; colorless, odorless, tasteless found in smoke from fires, cigarettes, exhaust fumes (from engines, heaters, stoves)
- Binds reversibly with Hb, producing **carboxyhemoglobin**; occupies oxygen binding sites with *affinity 200–230 times that of oxygen*; small concentrations of CO can therefore cause serious problems
- CO binding changes *Hb's shape*, increasing *affinity for oxygen*; decreases amount of oxygen *released to tissues*
- **Symptoms** – confusion, dizziness, nausea; severe cases include seizures, coma, and death
- **Treatment** – 100% oxygen at atmospheric or hyperbaric pressure

→ *21.7 Neural Control of Ventilation*

Neural Control of Ventilation

- **Breathing** usually occurs without conscious thought or control
  - _____ – normal breathing; one of most vital functions body carries out as absence of breathing leads to death
- Control of breathing is by neurons found in brainstem; specialized cells detect and monitor CO_2 levels, H^+ levels, and O_2 levels in body
- Negative feedback loops and stretch receptors in lungs also ensure oxygen intake and carbon dioxide elimination match metabolic requirements

Control of the Basic Pattern of Ventilation

- _____ controls ventilation; neurons in _____ influence respiratory rhythm

- **Respiratory rhythm generator** (**RRG**) – group of neurons that creates basic rhythm for breathing; found within a structure called the **ventral respiratory column**
- Neurons found in **medullary reticular formation** assist RRG; known as **ventral** and **dorsal respiratory groups**
- **Ventral respiratory group** (**VRG**) found in anterior and lateral portion of medulla, contains both inspiratory and expiratory neurons

Both nerves also supply certain accessory muscles of inspiration and expiration

- **Dorsal respiratory group** (**DRG**) found in posterior medulla; primarily involved in inspiration

Control of the Rate and Depth of Ventilation

- _____ are specialized cells that respond to changes in the concentration of a specific chemical
  - High PCO_2 or H^+ concentration triggers hyperventilation
  - Low PCO_2 or H^+ concentration triggers hypoventilation
  - Most sensitive to PO_2 in arterial blood
- _____ – neurons in medullary reticular formation
  - Detects changes in both CO_2 and H^+ concentrations CSF

High-Altitude Acclimatization

- **High-altitude acclimatization** allows peripheral chemoreceptors to stimulate an increase *in ventilation*, permitting body to maintain *acceptable blood PO_2 levels*, if elevation is gradually increased over period of days (rather than hours)
- Requires days because sensitivity of chemoreceptors for low PO_2 increases with prolonged exposure; the longer they are exposed to a low PO_2, the more they stimulate an increase in ventilation

- Allows experienced climbers to reach *great elevations* without *supplemental oxygen*