Respiratory System -Training Handout

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FUNCTIONS:

- Provides oxygen to the blood stream and removes carbon dioxide
- Enables sound production or vocalization as expired air passes over the vocal chords.
- Enables protective and reflexive non-breathing air movements such as coughing and sneezing, to keep the air passages clear
- Control of Acid-Base balance and Control of blood pH

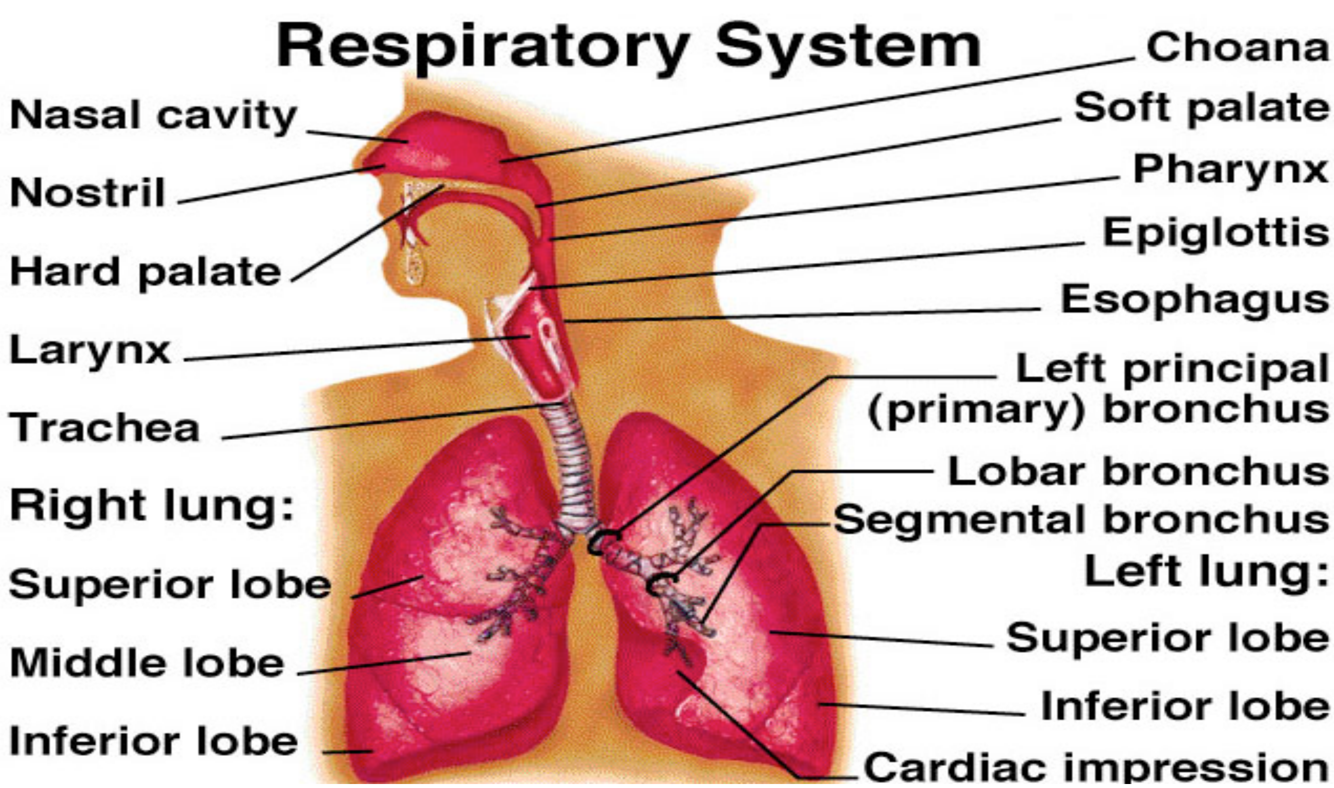
PROCESSES: a collective term for the following processes:

Pulmonary ventilation - movement of air into the lungs (inspiration) and movement of air out of the lungs (expiration)

External respiration - movement of oxygen from the lungs to the blood and movement of carbon dioxide from the blood to the lungs

Transport of respiratory gases -Transport of oxygen from the lungs to the tissues and transport of carbon dioxide from the tissues to the lungs

Internal respiration - Movement of oxygen from blood to the tissue cells and movement of carbon dioxide from tissue cells to blood



PRINCIPAL ORGANS OF THE RESPIRATORY SYSTEM

Nose

Functions

Provides an airway for respiration
Moistens and warms entering air
Filters and cleans inspired air
Resonating chamber for speech
Detects odors in the airstream

Anatomical features

Vibrissae (guard hairs) – stiff hairs that filter large particles from the air
Nasal cilia – hair-like projections that propel trapped particles towards the throat for digestion by digestive enzymes
Capillaries - rich supply of capillaries warm the inspired air
Nasal conchae – folds in the mucous membrane that increase air turbulence and ensures that most air contacts the mucous membranes
Olfactory mucosa – mucous membranes that contain smell receptors
Respiratory mucosa – pseudostratified ciliated columnar epithelium containing goblet cells that secrete mucus
Mucus - Stickiness traps inhaled particles and Lysozyme kills bacteria
Lymphocytes and IgA antibodies - protect against bacteria

Pharynx (throat)

Three regions of the pharynx

Nasopharynx – air passage (pseudostratified columnar epithelium)
Oropharynx – passageway for air, food, and drink (stratified squamous epithelium)
Laryngopharynx – passageway for air, food, and drink (stratified squamous epithelium)

Larynx (voice box)

Functions

Keeps food and drink out of the airway
Sound production
Acts as a sphincter during abdominal straining (ex. During defecation and heavy lifting)

***Anatomical features*:**

Nine c-rings of hyaline cartilage form the framework of the larynx
Muscular walls aid in voice production and the swallowing reflex
Glottis – the superior opening of the larynx
Epiglottis – prevents food and drink from entering airway when swallowing
False vocal cords – aid in closing the glottis when swallowing
True vocal cords – produce sound when air passes between them
Note: The shorter and thinner these membranes are, the faster air moves over them – produces high pitched sounds while the longer and thicker these membranes are, the slower air moves over them – produces low pitched sounds

Trachea (windpipe)

Functions

Air passageway

Cleans, warms, and moistens incoming air

Anatomical features

Rings of hyaline cartilage – reinforce the trachea and keep it from collapsing when you inhale

Ciliated pseudostratified epithelium – traps inhaled debris and propels mucus up to the pharynx where it is swallowed

Bronchi

Function

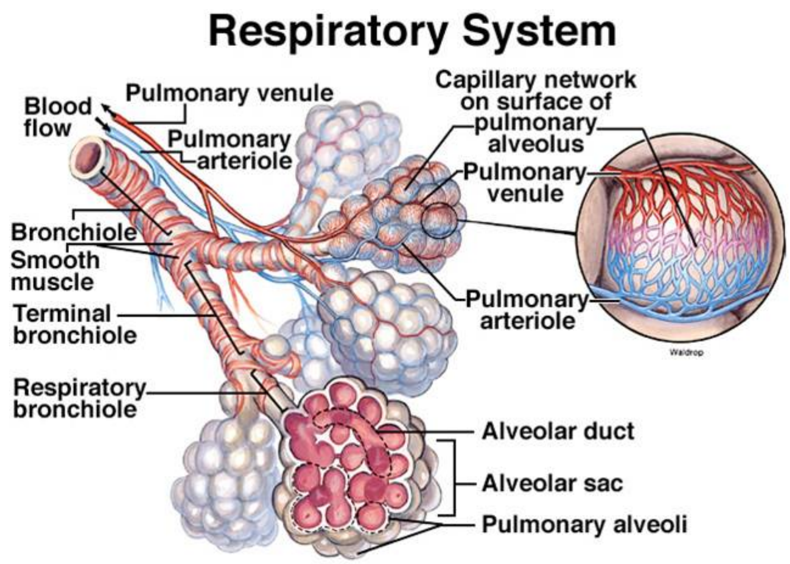
Solely an air passageway

Anatomical features

Left and right primary bronchi branch off from trachea Once the left and right primary bronchi enter the lungs they are subdivided into smaller tubes:

Secondary bronchi (one for each lobe) → tertiary bronchi → bronchioles → terminal bronchioles → respiratory bronchioles → alveolar ducts → alveolar sacs

Alveolar sacs are clusters of alveoli - the site of gas exchange



Cell populations present in alveoli

Type I alveolar cells – allow for diffusion of gases (simple squamous epithelia)

Type II alveolar cells – secrete surfactant (simple cuboidal epithelia)

Dust cells – alveolar macrophages (leukocytes)

Other tissue types present in the alveoli

Smooth muscle rings aid in resistance to air flow

Elastic connective tissue fibers aid in expelling air from the lungs

Lungs

Left Lung: Divided into 2 lobes; Smaller than the right lung because the cardiac notch accommodates the heart

Right Lung: Divided into 3 lobes

Note: Each lobe is separated by connective tissue and has its own arteries and veins which allows for compartmentalization, esp. when portions of the lungs are diseased. Serous membranes cover the entire surface of the lungs and produce pleural fluid which enables the lungs to expand and contract with minimal friction

MECHANISM OF PULMINARY VENTILATION

Two phases of Pulmonary Ventilation – involves diaphragm, Intercostal muscles, Pectoralis minor mucscle and the gas laws.

Physiology of Pulmonary Ventilation & the Gas Laws

Airflow is governed by basic pressure, flow, and resistance principles Atmospheric pressure is the weight of the air is the force that moves air into the lungs. **Boyle's law** - at constant temperature, the pressure of a given quantity of gas is inversely proportional to its volume. **Charles' Law** - the volume of a given quantity of gas is directly proportional to its absolute temperature As the inhaled air is warmed, it expands and inflates the lungs.

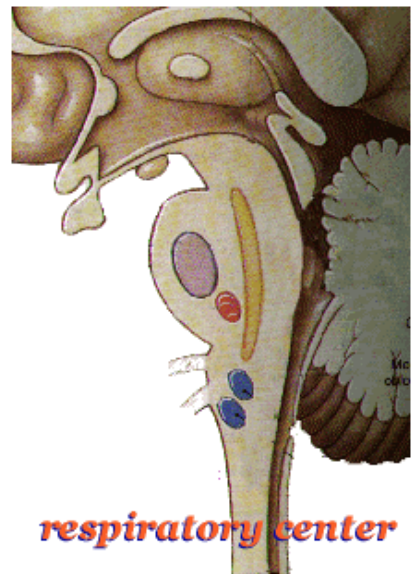
Inspiration, or inhalation – a very **active** process that requires input of energy
Air flows into the lungs when the thoracic pressure falls below atmospheric pressure.
The diaphragm moves downward and flattens, when stimulated by phrenic nerves. ***External (inspiratory)*** intercostals muscles and thoracic muscles can be stimulated to contract and expand the thoracic cavity.

Expiration, or exhalation – a **passive** process that takes advantage of the recoil properties of elastic fibers
Air is forced out of the lungs when the thoracic pressure rises above atmospheric pressure. The diaphragm and expiratory muscles relax. The elasticity of the lungs and the thoracic cage allows them to return to their normal size and shape. To exhale more than usual, internal (expiratory) intercostals muscles and other muscles can be stimulated.

Physical factors influencing pulmonary ventilation

- Resistance to airflow
- Pulmonary compliance – the ease at which lungs expand. Compliance can be reduced by degenerative lung disease, such as tuberculosis.
- Diameter of bronchioles – controlled by smooth muscle
- Bronchoconstriction – reduce airflow
- Bronchodialation - increase airflow
- Alveolar surface tension – surfactant reduces the surface tension in the alveoli and keep them from collapsing during expiration.
- Neural control of pulmonary ventilation

Control centers in the brainstem



- Respiratory control centers – found in the pons and the medulla oblongata
- Control breathing
- Adjusts the rate and depth of breathing according to oxygen and carbon dioxide levels
- Afferent connections to the brainstem
- Hypothalmus and limbic system send signals to respiratory control centers
- Chemoreceptors in the brainstem and arteries monitor pH, oxygen, and carbon dioxide levels
- Vagus nerve (X) transmits sensory signals to the respiratory centers when irritated by smoke, dust, noxious fumes, etc.
- Inflation reflex – prevents the lungs from over-inflating
- Voluntary control – controlled by the motor cortex of the cerebrum
- Very limited voluntary control exists

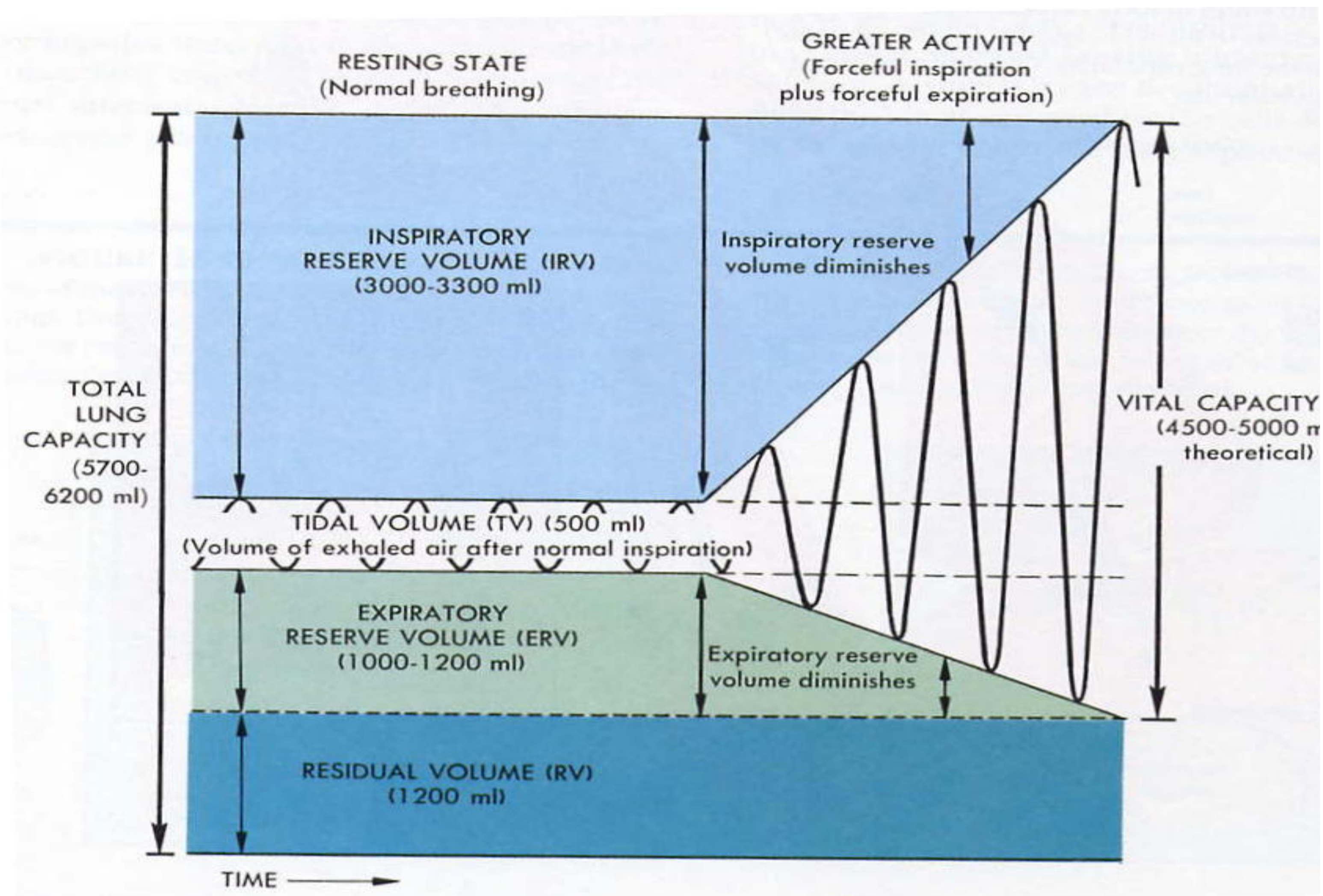
Patterns of Breathing

- **Apnea** – temporary cessation of breathing (one or more skipped breaths)
- **Dyspnea** – labored, gasping breathing; shortness of breath
- **Eupnea** – Normal, relaxed, quiet breathing
- **Hyperpnea** – increased rate and depth of breathing in response to exercise, pain, or other conditions
- **Hyperventilation** – increased pulmonary ventilation in excess of metabolic demand
- **Hypoventilation** – reduced pulmonary ventilation
- **Orthopnea** – Dyspnea that occurs when a person is lying down
- **Respiratory arrest** – permanent cessation of breathing
- **Tachypnea** – accelerated respiration

Measures of Pulmonary Ventilation

Respiratory Volumes– values determined by using a spirometer

- ***Tidal Volume*** **(TV)** – amount of air inhaled or exhaled with each breath under resting conditions **(500 mL)**
- ***Inspiratory Reserve Volume*** **(IRV) –** amount of air that can be inhaled during forced breathing in addition to resting tidal volume **(3000 to 3300 mL)**
- ***Expiratory Reserve Volume*** **(ERV)** – amount of air that can be exhaled during forced breathing in addition to tidal volume **(1000 to 1200 mL)**
- ***Residual Volume*** – **(RV)** - amount of air remaining in the lungs after a forced exhalation. **(1200 mL)**



Note: learn the names and their abbreviations

Respiratory Capacities – values determined by adding two or more of the respiratory volumes

- ***Vital Capacity*** **(VC)** – maximum amount of air that can be expired after taking the deepest breath possible **(4500 to 5000 mL)** **VC = TV + IRV + ERV**

- ***Inspiratory Capacity*** **(IC)** – maximum volume of air that can be inhaled following exhalation of resting tidal volume **IC = TV + IRV**

- ***Functional Residual Capacity*** **(FRC)** – volume of air remaining in the lungs following exhalation of resting volume **FRC = ERV + RV**

- ***Total Lung Capacity*** **(TLC) -** total volume of air that the lungs can hold (**5700 to 6200 mL (cm^3) for adults and 2690 to 3600 mL for Junior High Youth)**
  - **TLC = VC + RV**

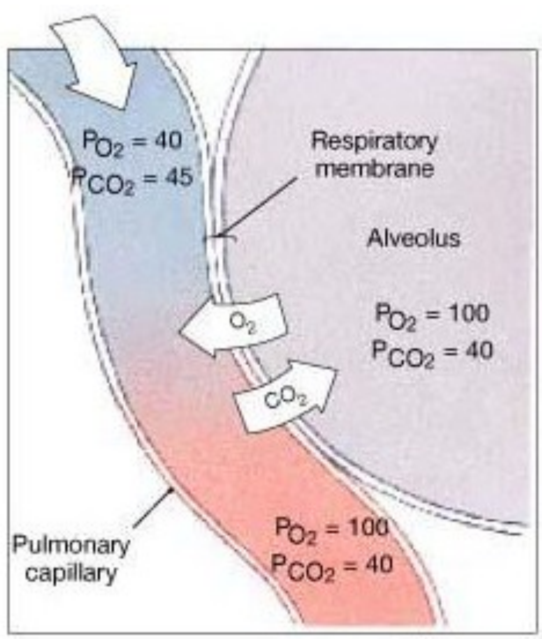
Boyles Law: $P_1V_1 = P_2 V_2$

P_1 is initial pressure, V_1 is initial volume,
P_2 is final pressure, V_2 is final volume,

Partial pressure of gases – the amount of pressure exerted by each gas in a mixture.

- It is equal to the total pressure x fractional composition of a gas in the mixture.
- It affects the diffusion of oxygen and carbon dioxide.
- Based on the original Torricelli barometer design, one atmosphere of pressure will force the column of mercury (Hg) in a mercury barometer to a height of 760 millimeters. A pressure that causes the Hg column to rise 1 millimeter is called a **torr** (you may still see the term 1 mm Hg used; this has been replaced by the torr).

Partial Pressure of oxygen = Sea level atmospheric Pressure of 760 torr or (mm Hg) x 21% oxygen = 760 torr (mm Hg) x .21 = 160 mm Hg



GAS EXCHANGE AND TRANSPORT

Composition of Air

Air is a mixture of gases, each of which contributes a share, called its partial pressure, to the total atmospheric pressure. **Dalton's Law** says that the total pressure of a gas mixture is the sum of the partial pressures of the individual gases

The Air-Water Interface

When air and water are in contact with each other, gases diffuse down their concentration gradients until the partial pressure of each gas in the air is equal to its partial pressure in the water. If a gas is more abundant in the water than the air, it diffuses into the air. At the air-water interface, **(Henry's Law)** for a given temperature, the amount of gas that dissolves in the water is determined by its solubility in water and its partial pressure in the air. In alveoli, the greater the partial pressure of oxygen in the alveolar air, the more oxygen the blood picks up. Since the blood arriving at an alveolus has a higher partial pressure of carbon dioxide than air, the blood releases carbon dioxide into the air.

Alveolar Gas Exchange – the loading of oxygen and the unloading of carbon dioxide in the lungs

Factors affecting the efficiency of alveolar gas exchange

- Concentration gradients of the gases
- Solubility of the gases – carbon is 20 times more soluble as oxygen and diffuses more rapidly
- Membrane thickness – very thin, to facilitate diffusion
- Membrane area – refers to the alveolar surface area
- Ventilation-perfusion coupling – the ability to match ventilation and perfusion to each other
- Poor ventilation of part of a lung, reduces the blood flow to that area
- Good ventilation increases the blood flow to that area

Role of Surfactant:

The surface of the alveolar membrane is covered with a substance called **surfactant** which reduces the surface tension in the fluid on the surface of the alveoli, allowing them to expand at the first breath, and remain open. If the sacs either fail to expand, or expand then collapse on expiration, the result is labored breathing.

Gas Transport

Oxygen – most is bound to hemoglobin of red blood cells; small amount dissolved in blood plasma

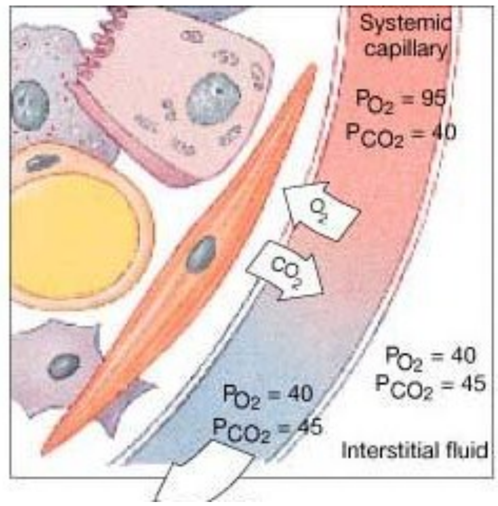
Carbon dioxide is transported in three forms

- **Carbonic acid** – 90% of carbon dioxide reacts with water to form carbonic acid
- **Carboamino compounds** – 5% binds to plasma proteins and hemoglobin
- **Dissolved gas** – 5% carried in the blood as dissolved gas

Systemic Gas Exchange

Carbon dioxide loading -**The Haldane effect** – the lower the partial pressure of oxygen and saturation of it in hemoglobin, the more carbon dioxide can be carried in the blood
Oxygen unloading from hemoglobin molecules
Factors that adjust the rate of oxygen unloading to metabolic rates of different tissues

- **Ambient PO2** – low partial pressures in the air promote oxygen unloading
- **Temperature** – high temperatures promote oxygen unloading
- **The Bohr effect** – oxygen unloading in response to low pH
- **Binding of hydrogen ions** reduces the affinity of hemoglobin for oxygen
- **BPG** – bi-product of aerobic respiration in red blood cells; increases in BPG levels promote oxygen unloading



Blood Chemistry and the Respiratory Rhythm

- Hydrogen ion concentrations strongly influence respiration
- Carbon dioxide concentrations strongly influence respiration
- Oxygen concentrations have little effect on respiration

Dead Space

- **Anatomical dead space** –areas of the conducting zone that contains air that never contributes to the gas exchange in the alveoli
- **Alveolar dead space** – alveoli that or collapsed or obstructed and are not able to participate in gas exchange

Pulmonary Function Tests - enable obstructive pulmonary disorders to be distinguished from restrictive disorders.

- **Obstructive disorders** – do not reduce respiratory volumes, but the narrow the airway and interfere with airflow
- **Restrictive disorders** – disorders that stiffen the lungs and thus reduce compliance and vital capacity

DISORDERS AND DISEASES OF THE RESPIRATORY SYSTEM

- **Chronic obstructive pulmonary diseases** (COPD) – long-term obstruction of airflow and a substantial reduction in pulmonary ventilation
- **Asthma** – allergens trigger the release of histamine and other inflammatory chemicals that cause intense bronchoconstriction
- **Emphysema** – alveolar walls break down and the surface area of the lungs is reduced
- **Pneumonia** – lower respiratory infection that causes fluid build up in the lungs
- **Sleep apnea** – Cessation of breathing for 10 seconds or longer during sleep
- **Cystic Fibrosis** – an inherited disorder that causes causes thick, sticky mucus to build up in the lungs
- **Tuberculosis** – pulmonary infection with Mycobacterium tuberculosis; reduces lung compliance
- **Pulmonary edema** – excess fluid in the lungs
- **Pleurisy** – inflammation of the pleura lining surrounding the lungs – very painful
- **Lung cancer** – malignancy of pulmonary tissue
- **Hypoxia** – deficiency of oxygen in a tissue or the inability to use oxygen
- **Oxygen toxicity** – excess oxygen, causing the build up of peroxides and free radicals
- **Chronic bronchitis** – cilia are immobilized and reduced in number; goblet cells increase their production of mucus → mucus clogs the airways and breeds infection
- **Acute rhinitis** – the common cold
- **Laryngitis** – inflammation of the vocal folds

INTERACTION OF RESPIRATORY AND MUSCULAR SYSTEMS:

- The Intercostal Muscles and the Diaphram work together to allow breathing to occur.

Effects of Exercise on Respiratory

- During exercise the muscle cells use up more oxygen and produce increased amounts of carbon dioxide.
- The lungs and heart have to work harder to supply the extra oxygen and remove the carbon dioxide.
- Your breathing rate increases and you breathe more deeply. Heart rate also increases in order to transport the oxygenated blood to the muscles.
- Muscle cell respiration increases - more oxygen is used up and levels of carbon dioxide rise.
- The brain detects increasing levels of carbon dioxide - a signal is sent to the lungs to increase breathing.
- Breathing rate and the volume of air in each breath increase - This means that more gaseous exchange takes place.
- The brain also tells the heart to beat faster so that more blood is pumped to the lungs for gaseous exchange.

More oxygenated blood is gets to the muscles and more carbon dioxide is removed.