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Respiratory Anatomy

Advanced Care Paramedicine

Module: 06

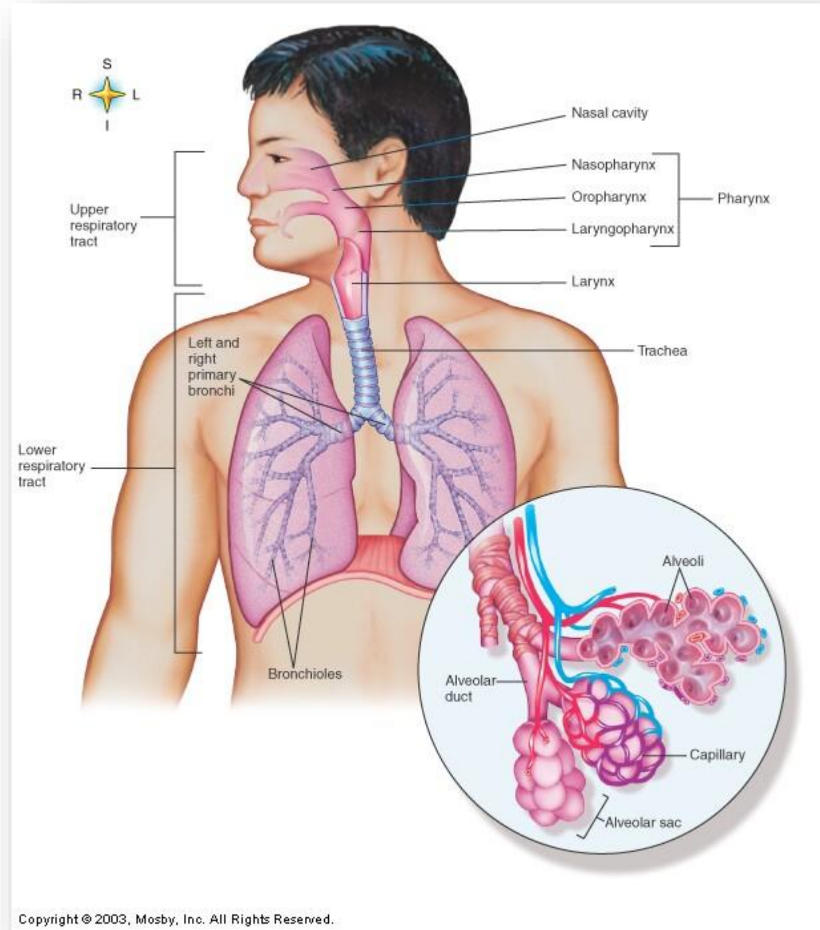
Section: 01

The Respiratory System

- "A complex series of interacting and coordinated processes that have a critical role in maintaining the stability, or constancy of our internal environment."

The Respiratory System

- Divided into two sections:
  - Upper Airway
  - Lower Airway

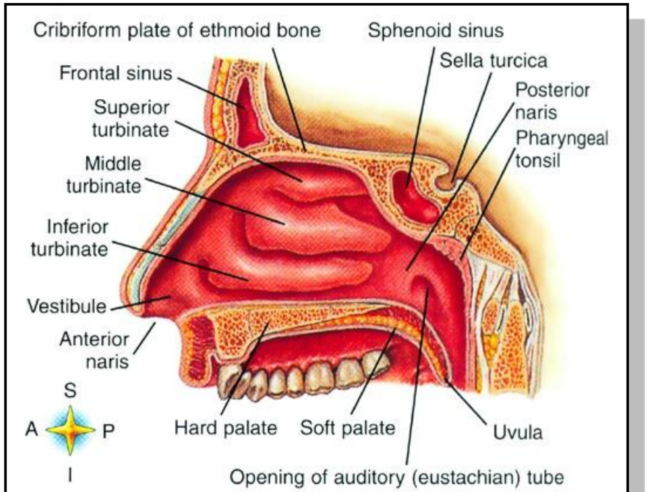


Upper Airway

- Nasal cavity
- Oral Cavity
- Pharynx
  - Nasopharynx
  - Oropharynx
  - Laryngopharynx
- Larynx (Above the vocal cords)

Nasal Cavity

- Anatomy
  - Anterior (External) Nares
  - Nasal Septum
  - Vestibule
  - Turbinates (Conchae)
    - Inferior, Middle and Superior
  - Internal (Posterior) Nares



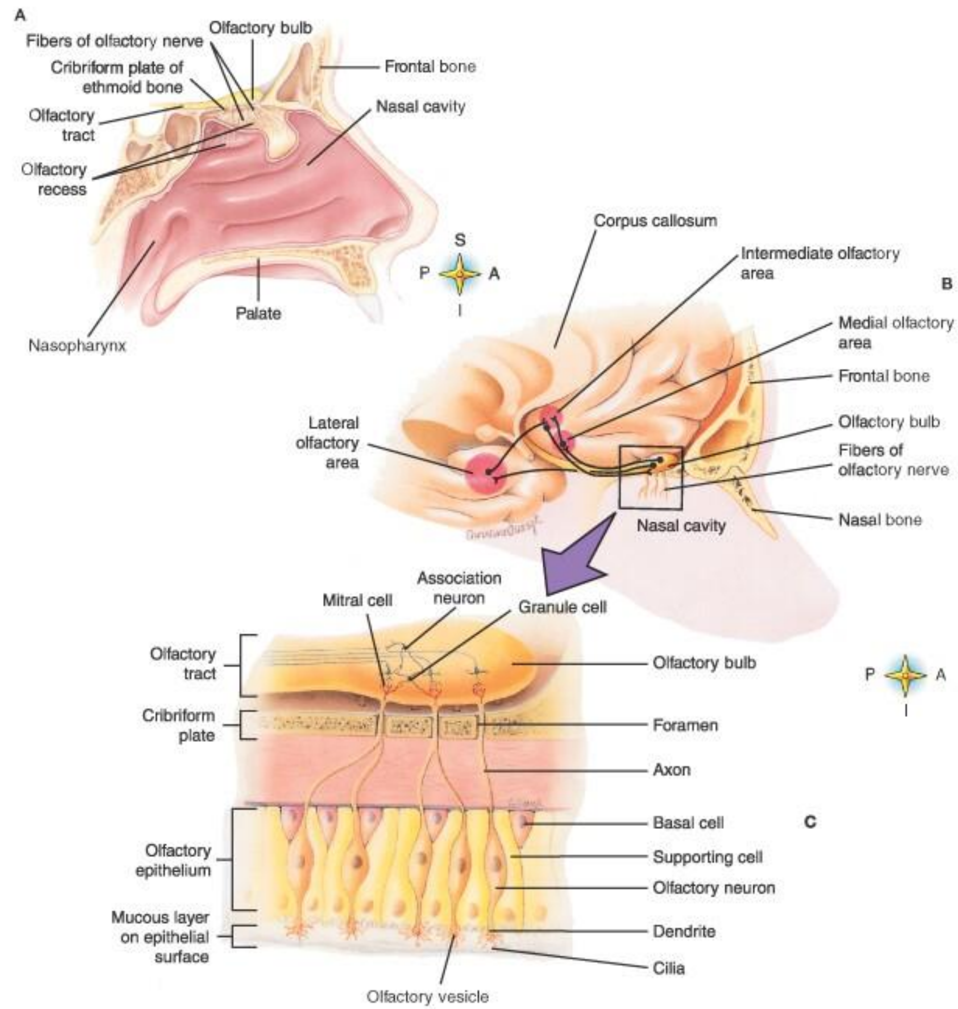
- Function
  - Nasal Mucosa
    - Ciliated columnar epithelium
    - Rich in goblet cells
  - Rich in vasculature
    - Heat air as it enters the system
    - Cilia trap foreign materials
    - Goblet cells "package" for excretion
  - Roof of nose (above superior turbinate)
    - Olfactory epithelium

Paranasal Sinuses

- Air containing spaces in the bones of the face that open and drain into the nasal cavity
  - Four pairs named for the bone they occupy
    - Frontal
    - Maxillary
    - Ethmoid
    - Sphenoid
  - Lined with respiratory mucosa
- Help trap particulates and moisten air as it enters the system
- Provide resonating chambers for speech
- Lighten the weight of the bones

Olfactory

- Air redirected by middle and superior turbinates are examined by the olfactory sense
- Looks for chemically irritating substances as a defense
- Gives us our sense of smell



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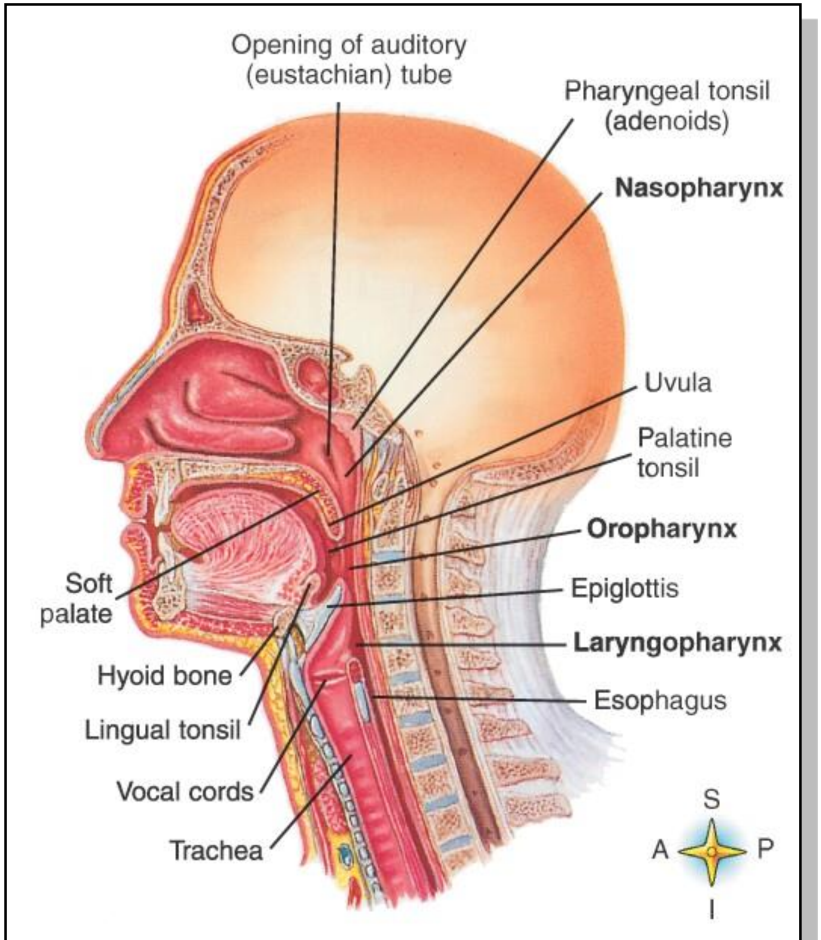
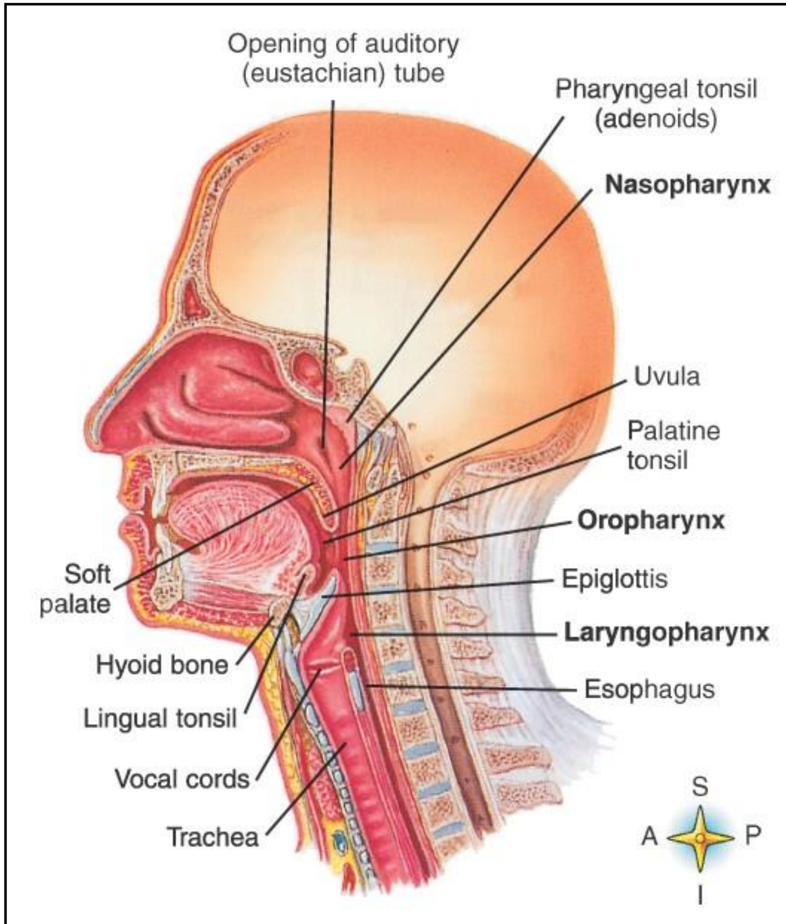
Oral Cavity



- Anatomy
  - Entrance of nutrients and liquid
    - Lips
    - Teeth
    - Tongue
    - Hard Palate
    - Soft Palate
    - Uvula
- Function
  - Acts as a secondary respiratory tract if nasal cavity blocked
  - Direct food and liquid down towards the esophagus

Pharynx



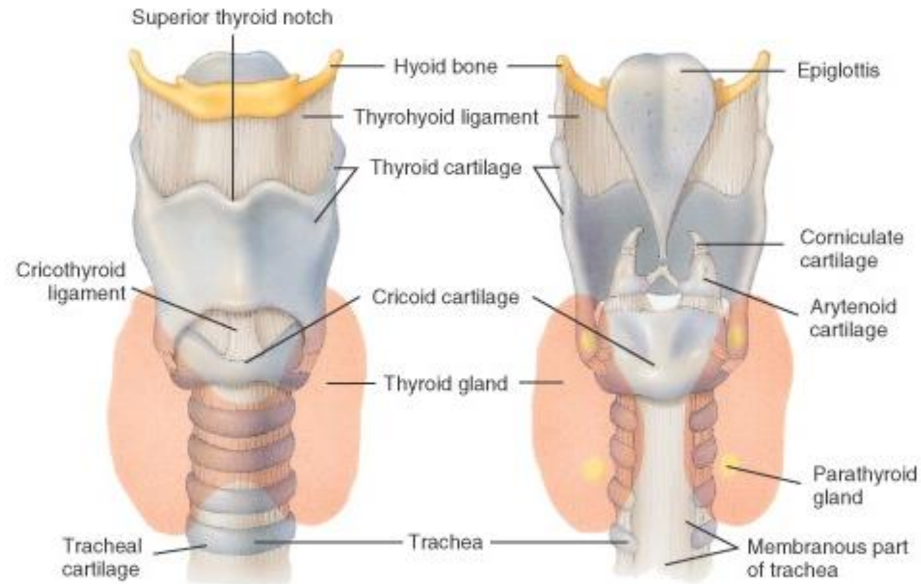
- Extends from the base of the skull to the esophagus
- Divided into 3 sections:
  - Nasopharynx
    - Pharyngeal tonsils (Adenoids if enlarged)
    - Does not collapse
  - Oropharynx
    - Palatine tonsils (at the fauces)
    - Lingual tonsils (base of the tongue)
  - Laryngopharynx
- Muscular with a mucous membrane
- Ciliated

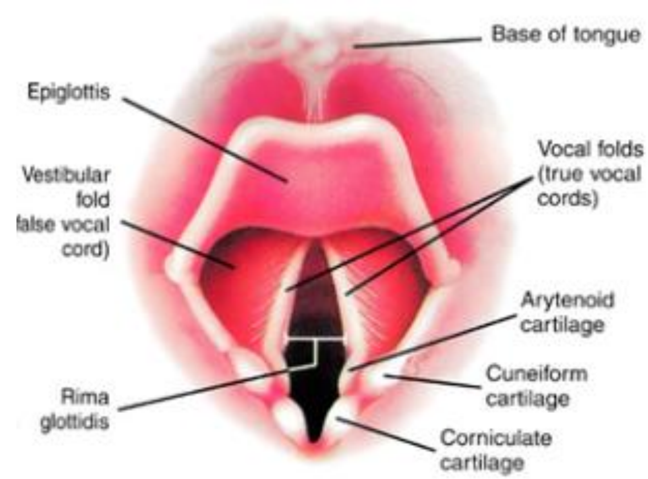
Lower Airway

- Larynx (Below the vocal cords)
- Trachea
- Bronchi
- Alveoli

Larynx

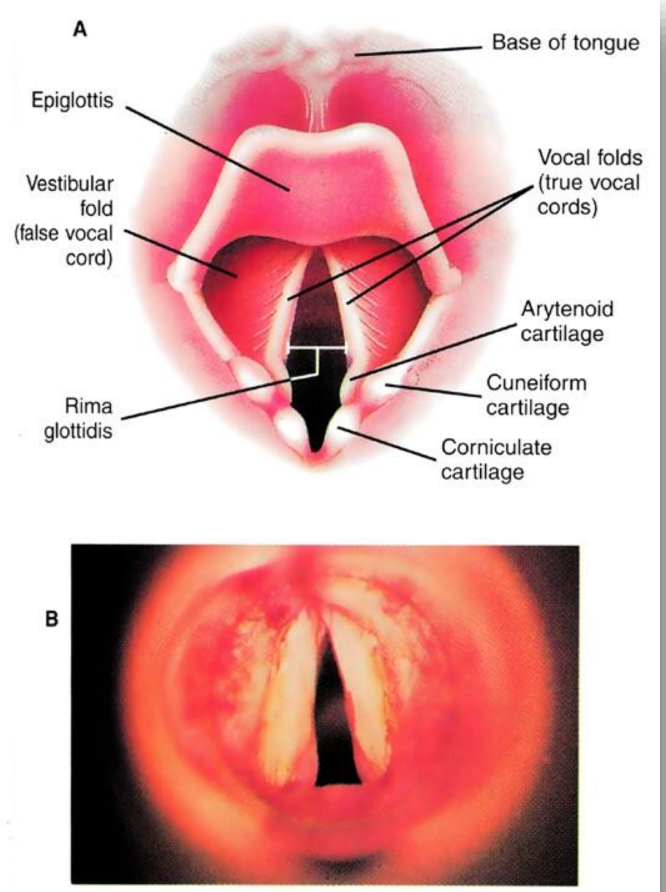
- Comprised of 9 Cartilages
  - Thyroid Cartilage
  - Cricoid Cartilage
  - Epiglottis
  - Corniculate (X 2)
  - Cuneiform (X 2)
  - Arytenoid (X 2)
- Extends from the root of the tongue to the trachea
- Lined with ciliated mucous membrane
- This membrane forms two pairs of folds





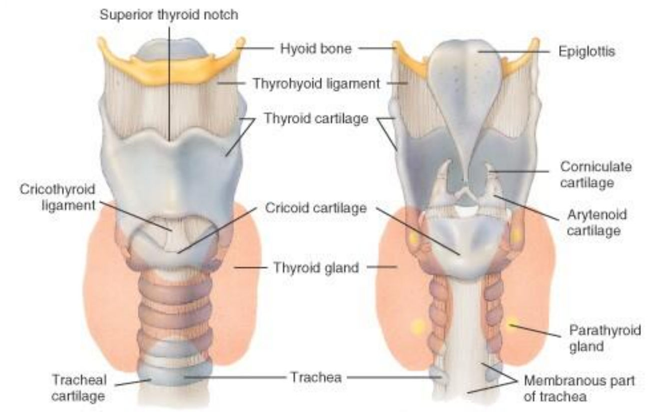
Larynx

- Upper pair
  - Vestibular fold (False Vocal Cords)
  - Play no part in pronunciation
- Lower pair
  - Vocal Folds (True Vocal Cords)



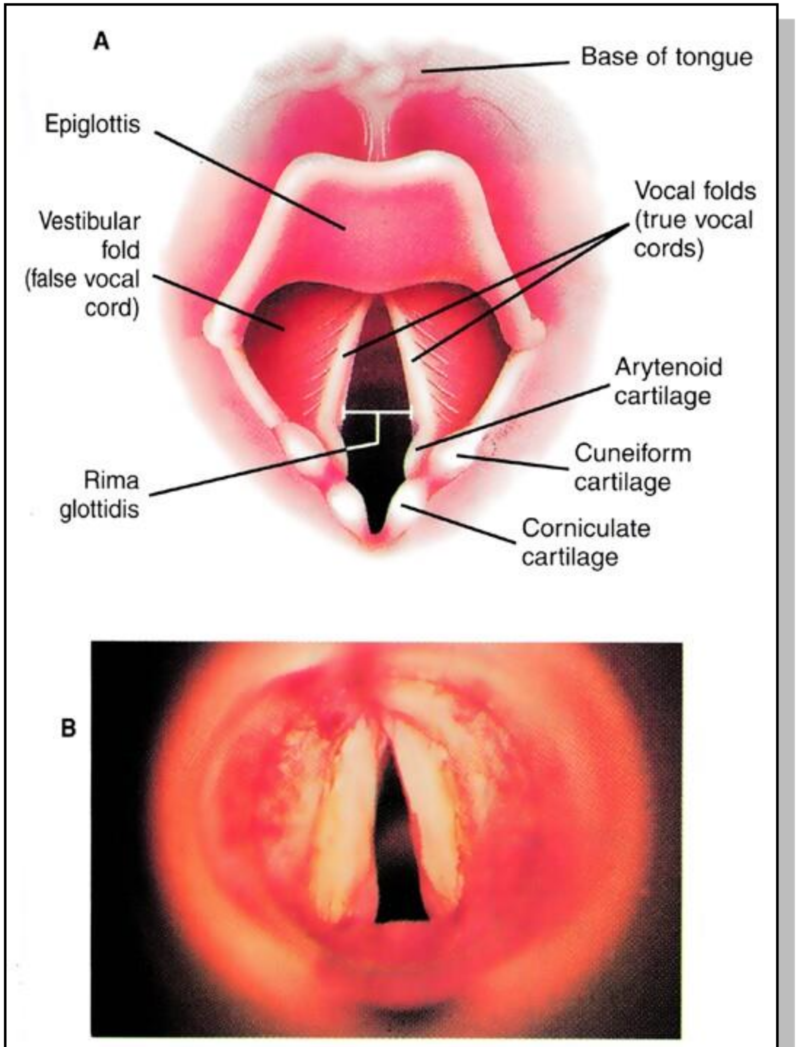
Larynx

- Muscular tissue
  - Intrinsic
    - Origin and insertion are within the larynx
    - Muscles between arytenoid cartilage and epiglottis cause closure of the glottic opening during swallowing
    - Movement of the FVC and TVC for speech
  - Extrinsic
    - Attached to the larynx and an external point (hyoid)
    - Will move the larynx as a unit



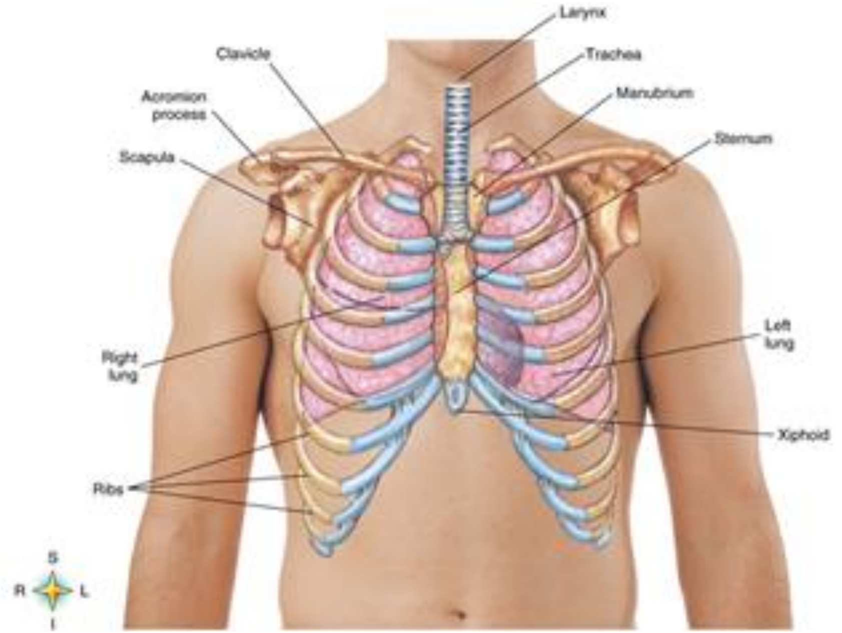
Larynx

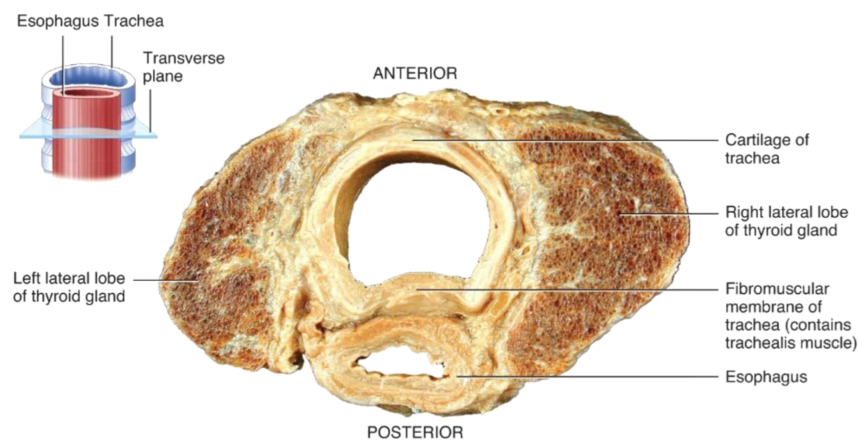
- Function
  - Continues with removal of particulate
  - Continues with warming of air
  - "Voice Box"



Trachea

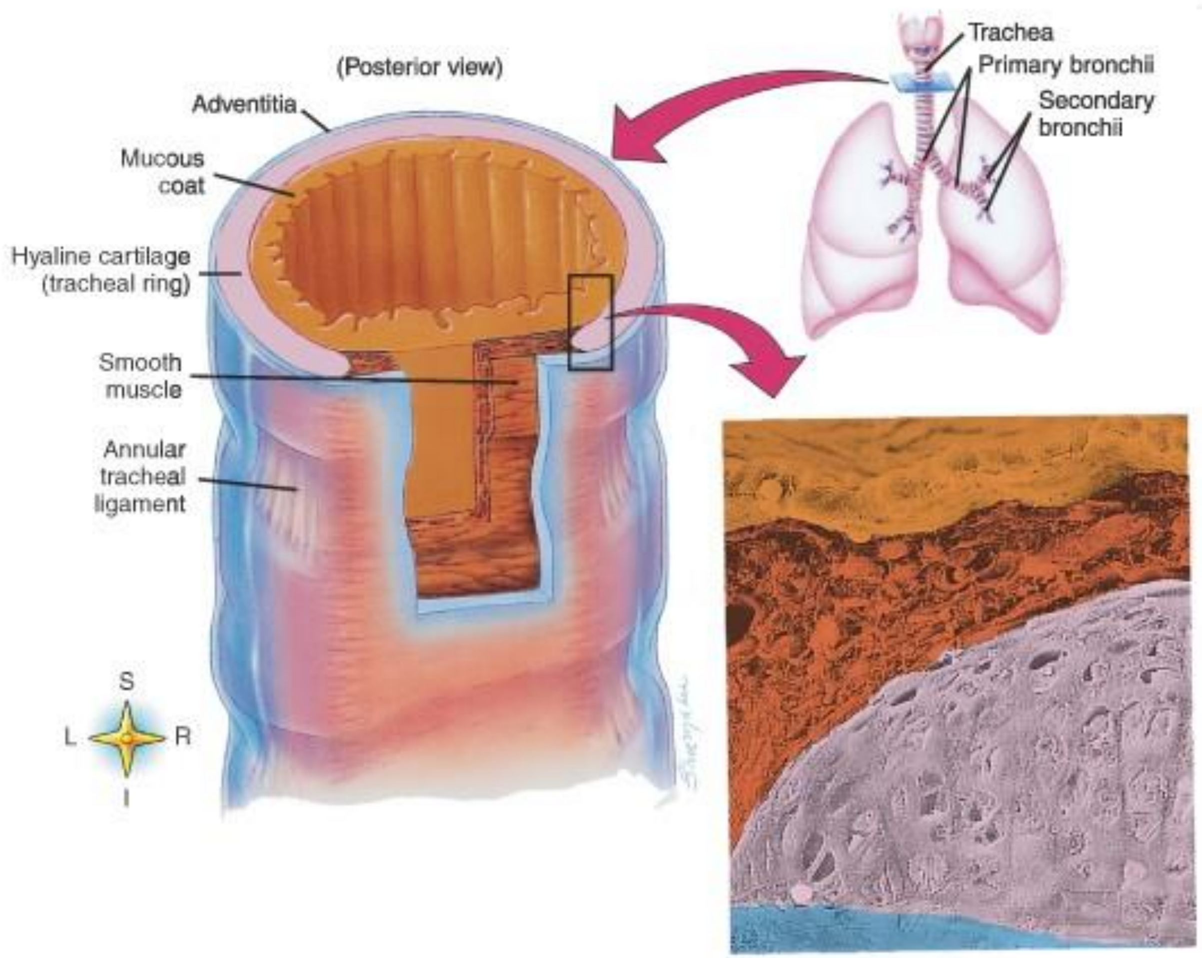
- Approx. 12 cm long
  - Extends from the larynx to the primary bronchi
  - Is approx. 2.5 cm in diameter
- C-Shaped cartilage
- Has ciliated epithelium cells





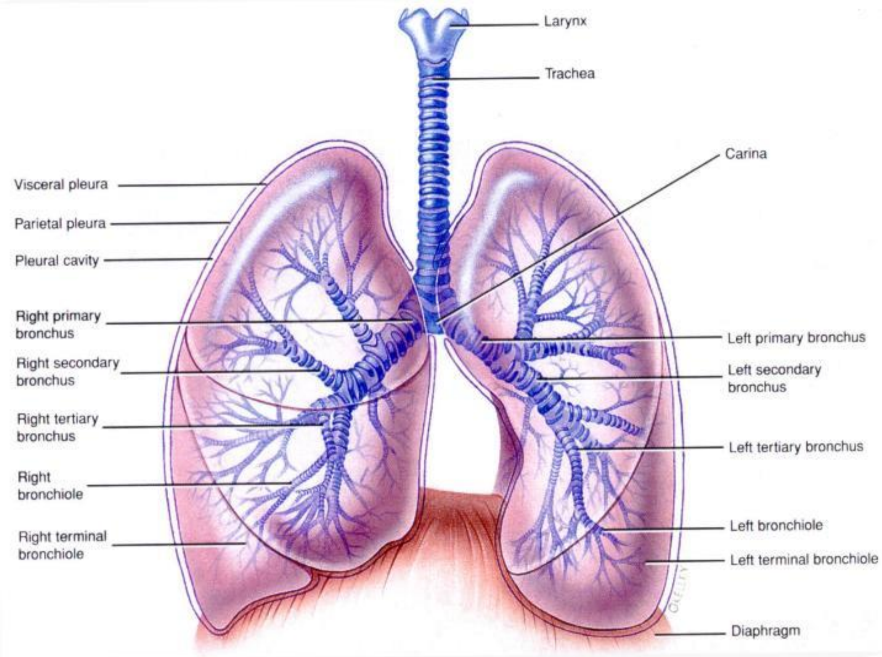
Superior view of transverse section of thyroid gland, trachea, and esophagus

Trachea

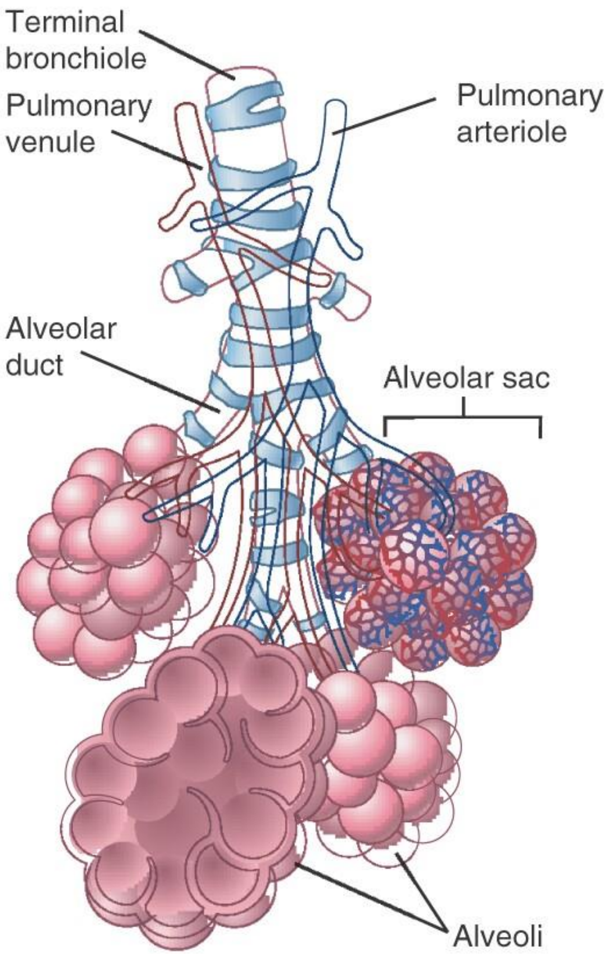

(Posterior view)
Adventitia
Mucous coat
Hyaline cartilage (tracheal ring)
Smooth muscle
Annular tracheal ligament
S
L
R
I
Trachea
Primary bronchii
Secondary bronchii

Bronchi

- Anatomy
  - Carina
  - Ciliated membranes
  - Primary bronchi (Right and left mainstem)
    - Still C-shaped
  - Secondary bronchi (complete rings)
  - Tertiary bronchi (complete rings)
  - Bronchioles (no cartilage, muscular)
- Function
  - Distribution of air to the alveoli



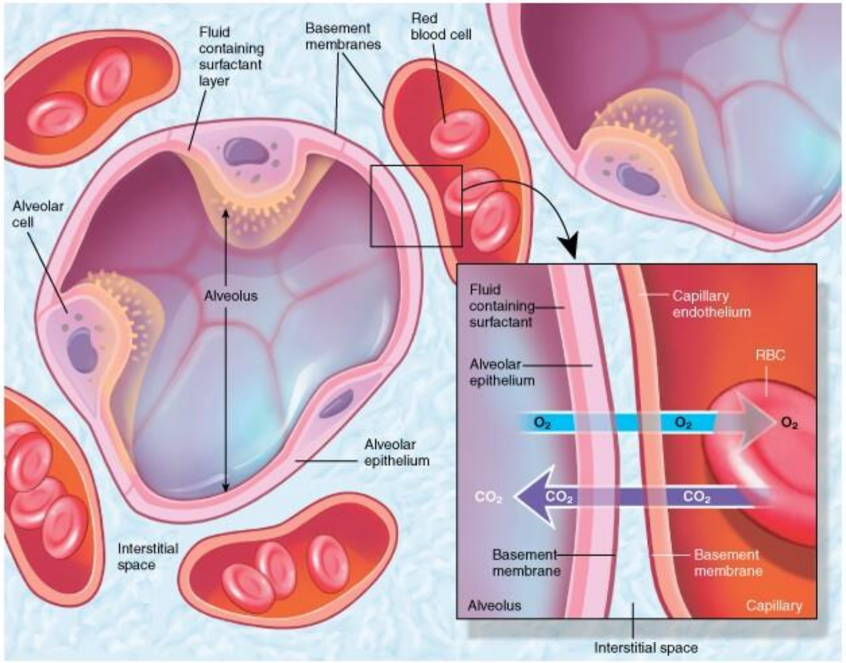
Alveoli



- Anatomy
  - Alveolar ducts
  - Alveoli
    - Capillary abundant on outer surface
  - Surfactant
    - Lipid derivative that helps reduce surface tension
    - Produced by Type II Alveolar cells
    - Prevents collapse of the lung
  - Single layer of epithelial tissue (respiratory membrane)
- Function
  - Location of gas exchange

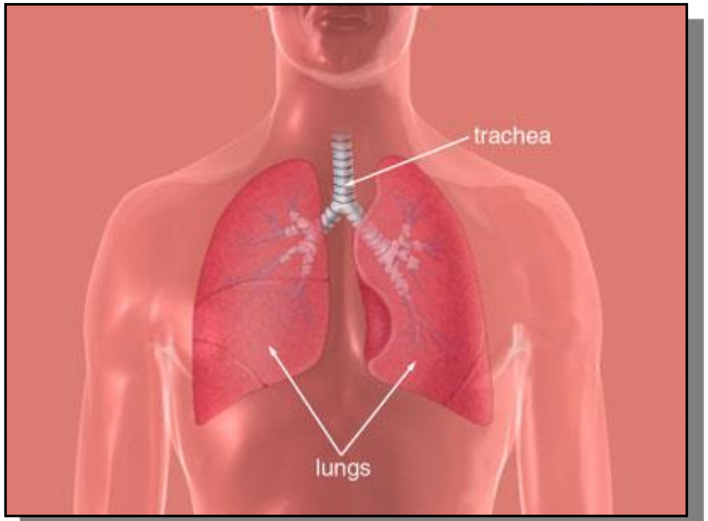
Alveoli

- Respiratory Membrane
- Surfactant
  - Reduce surface tension



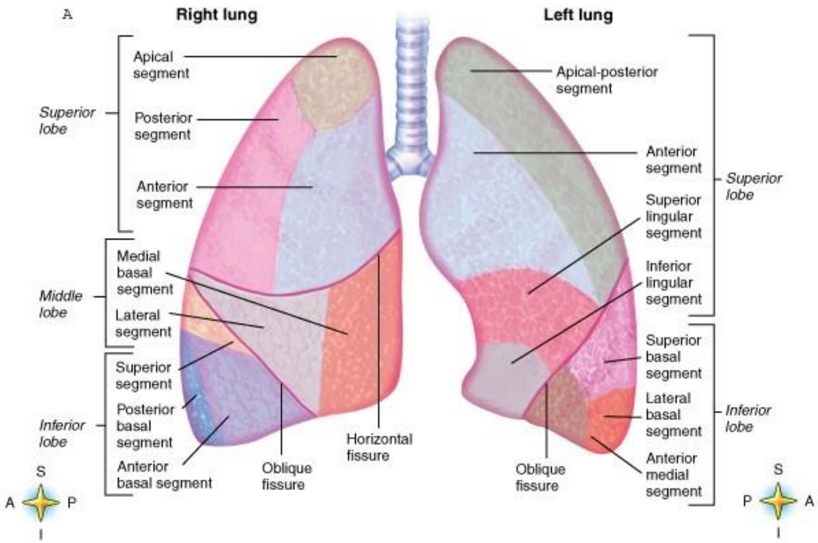
Lungs

- Cone shaped
- Base
  - rests on the diaphragm
- Apex
- Costal surface
  - Lies against the rib cage
- Only point of attachment is the hilum
- Right and Left lungs are separated by the mediastinum



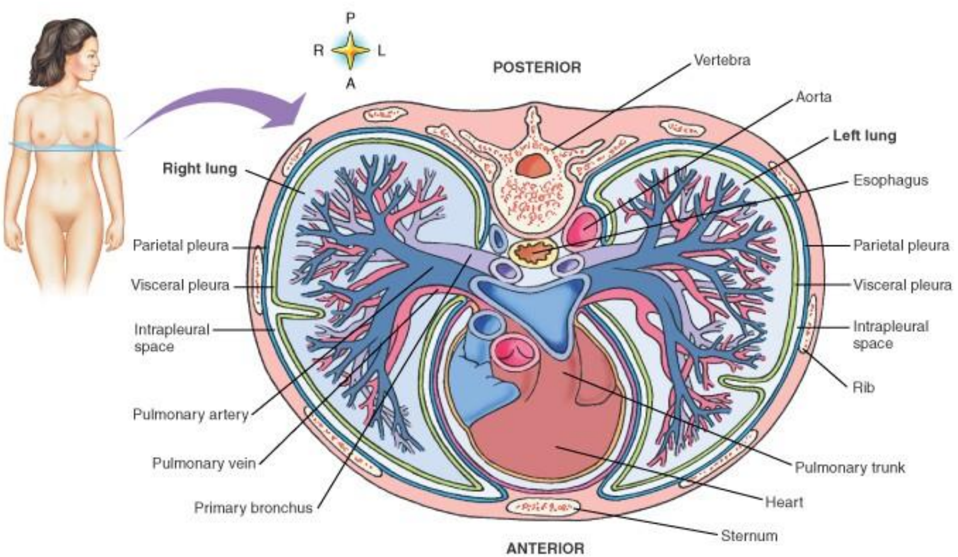
Lungs

- Right
  - 3 lobes
    - URL, MRL, LRL (superior, middle and inferior)
  - Divided by oblique and horizontal fissures
- Left
  - 2 lobes (cardiac notch)
    - ULL, LLL (superior and inferior)
  - Divided by oblique fissure



Lungs

- Each lung covered with pleura
  - Visceral
    - firmly attached to the surface of the lung
  - Parietal
    - lines the wall of the thorax
- Potential space in between is called the pleural cavity
- This contains a serous fluid that acts as a lubricant to reduce friction



Respiratory Anatomy

PHYSIOLOGY

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Function

- Gas exchange:
  - The body needs a continuous supply of O_2 for the metabolic processes that sustain life
  - Works with the circulatory system to provide O_2 and to remove the waste products of metabolism (CO_2)
- Regulation:
  - Helps in regulating the pH of the blood
  - Body temperature

Respiration

- Respiration results in the exchange of O_2 and CO_2 between the atmosphere and the tissue
- Ventilation is stimulated by nerve impulses

Respiration

- External respiration
  - Exchange of gases between the lungs and the blood
- Internal respiration
  - Exchange of gases between the blood and the tissues
- Cellular respiration
  - Cells utilize the O_2 for metabolism

Ventilation

- Defined as the movement of air through the conducting passages between the atmosphere and the lungs

- Conducting Passages
  - Upper Respiratory Tract
    - Nose, pharynx
  - Lower Respiratory Tract
    - Larynx, Trachea, bronchial tree and lungs

Ventilation

- Terms used to describe the process of breathing
  - Inspiration: moves air into the system
  - Expiration: moves air out of the system

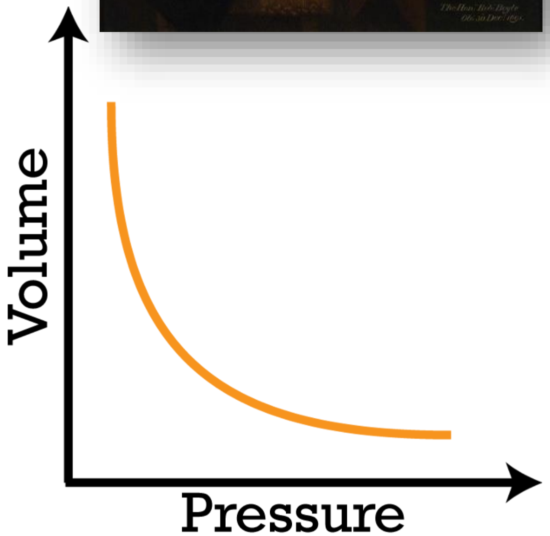
- Air moves based on the same principles as fluid
  - Movement down a pressure gradient

Gas Laws

- In order to appreciate the function of the respiratory system you should be familiar with the basic gas laws:
  - Boyle's Law
  - Charles' Law
  - Dalton's Law
  - Henry's Law

Boyle's Law

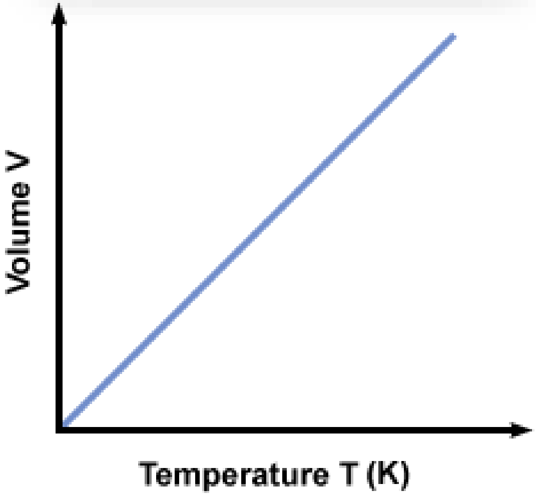
- The volume of a gas is inversely proportional to its pressure.
  - If the pressure is increased the volume will decrease
  - May be written in the form of an expression: $P_1V_1=P_2V_2$



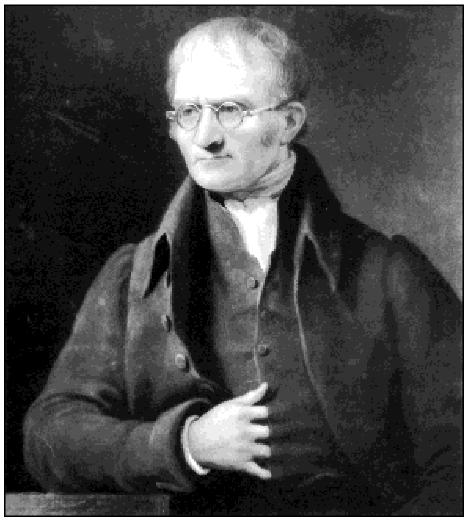
- Pressures in ventilation
  - Atmospheric pressure
  - Intra-alveolar (intrapulmonary) pressure
  - Intra-pleural pressure

Charles' Law

- Volume is directly proportional to the temperature as long as the pressure is constant
  - So as air is heat within the respiratory system it will expand



Dalton's Law of Partial Pressures



John Dalton

- Dalton surmises that the total partial pressure of a gas (if its mixture) is the sum of all the partial pressures of its components

$$p_{\text{Total}}=p_{\text{gas1}}+p_{\text{gas2}}+p_{\text{gas3}}+p_{\text{gas4}}$$

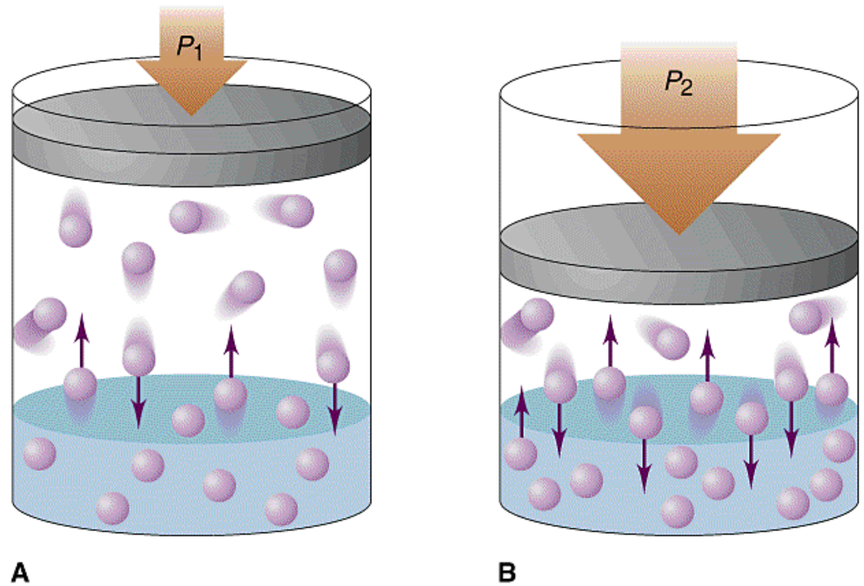
$$p(\text{air}) = p(N_2) + p(O_2) + p(CO_2) + ...$$

$$\mathit{760\ mmHg} = 592.8\ \text{mmHg} + \mathit{159.6\ mmHg} + \mathit{0.2\ mmHg} + ...$$

$$100\ \% = 76\ \% + 21\ \% + 0.03\ \% + ...$$

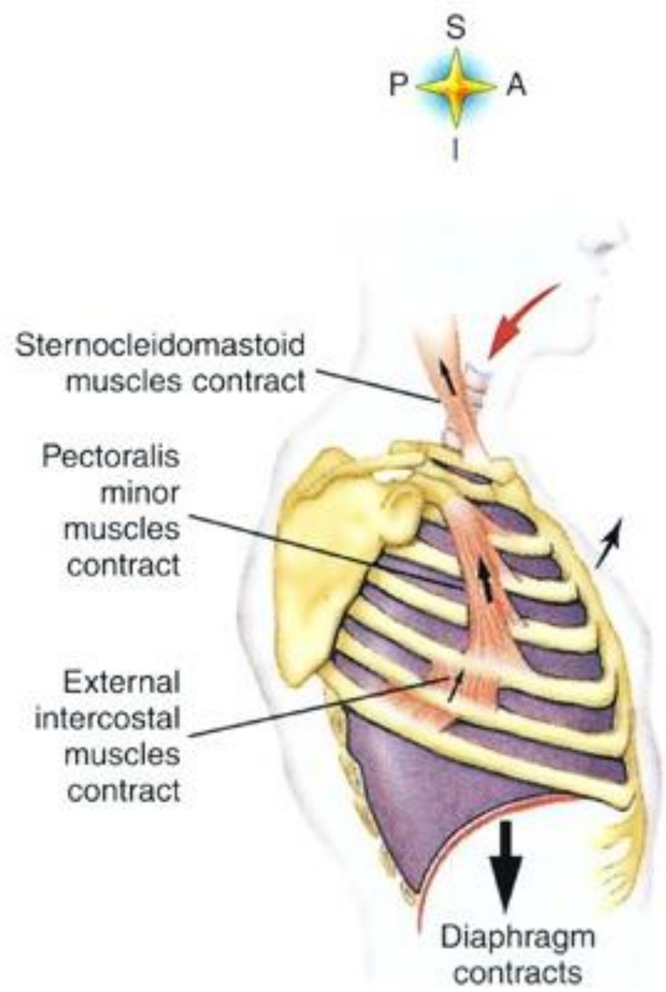
Henry's Law

- The concentration of a gas in a solution depends on the partial pressure of the gas and its' solubility (as long as the temperature stays constant)
  - The higher the solubility, the more gas will dissolve
  - The higher the pressure the more gas will dissolve



Mechanics of Ventilation

- Quiet Inspiration
  - Diaphragm
  - External intercostals
- Forceful Inspiration
  - Sternocleidomastoid
  - Pectoralis minor
  - Serratus anterior (scapula)



At Rest

- At rest:
  - Atmospheric pressure = 760 mmHg
  - Intrapleural pressure = 756 mmHg
  - Intrapulmonary pressure = 760 mmHg
    - This pressure difference helps create surface tension with surfactant to overcome "the collapse tendency of the lungs"

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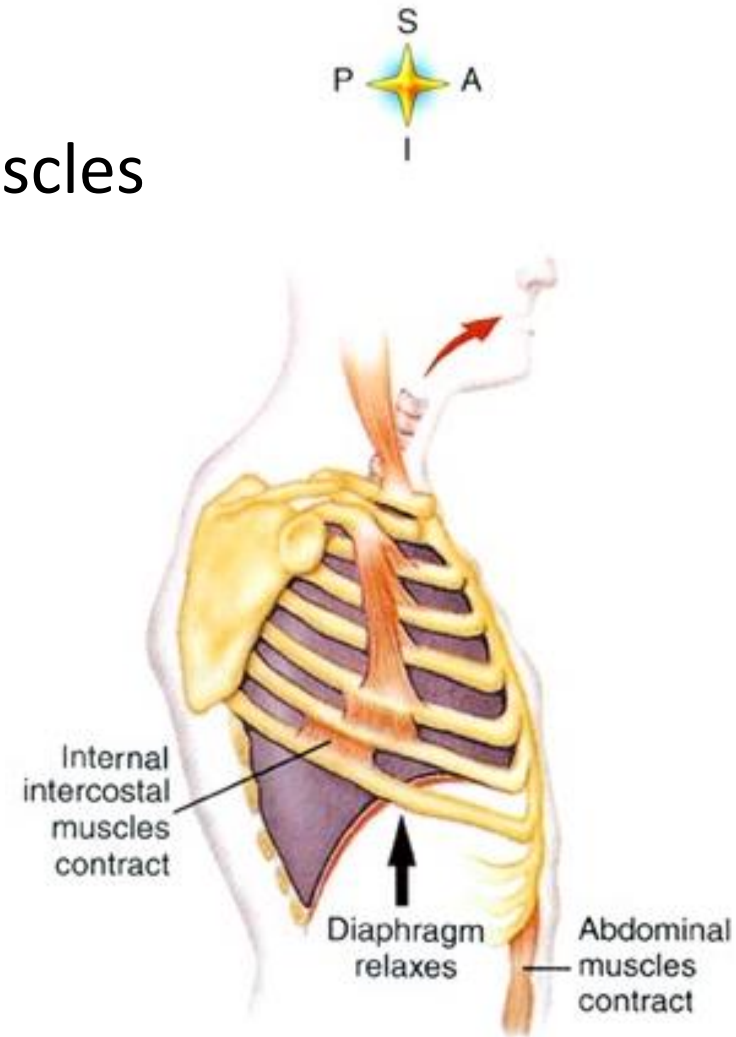
Inspiration

- As thoracic cavity increases in size
  - Cohesion between parietal and visceral layers allows the lungs to be “pulled”
  - This change in cavity size changes the pressures of the cavity
    - Atmospheric pressure = 760 mmHg
    - Intrapleural pressure = 754 mmHg (-6)
    - Intrapulmonary pressure = 758 mmHg (-2)

Mechanics of Ventilation

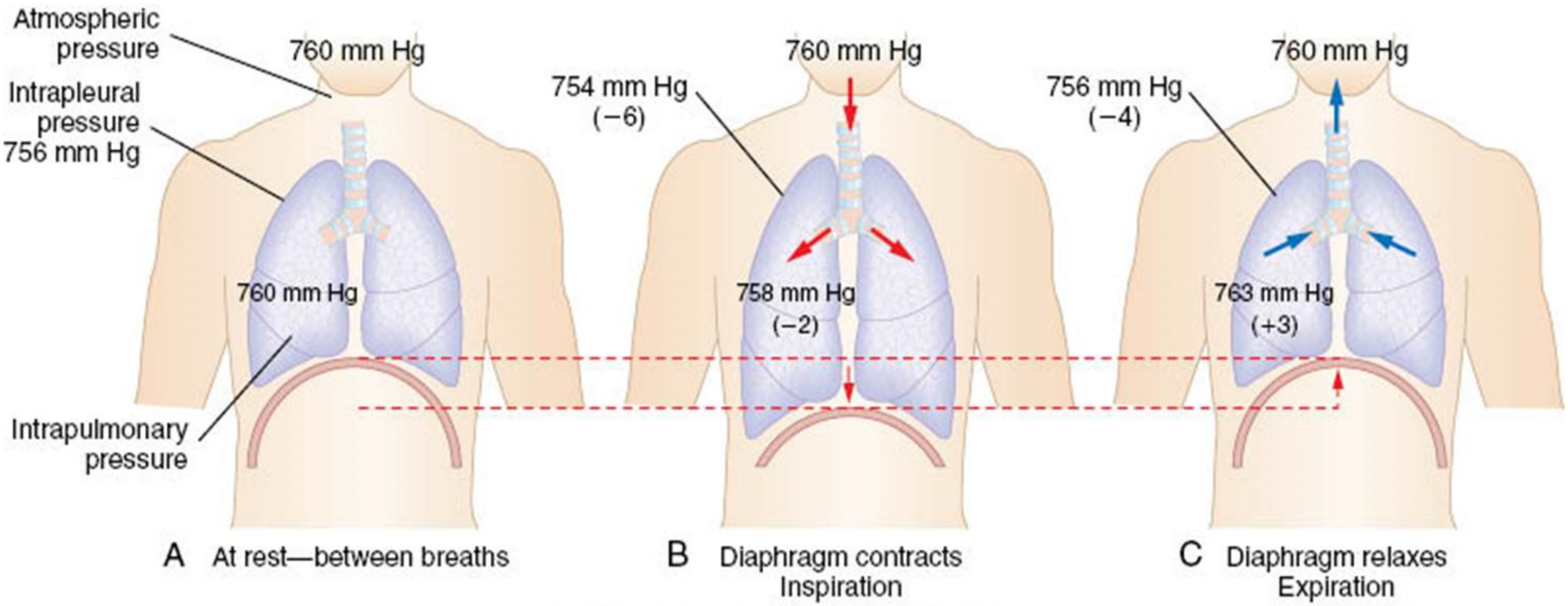
- Quiet Expiration (Passive)
  - Relaxation of inspiration muscles
  - Diaphragm
  - Internal intercostals
- Forceful Expiration
  - Abdominal Muscles



Expiration

- As thoracic cavity decreases in size
  - This change in cavity size changes the pressures of the cavity
    - Atmospheric pressure = 760 mmHg
    - Intrapleural pressure = 756 mmHg (-4)
    - Intrapulmonary pressure = 763 mmHg (+3)

Pressures in Pulmonary Ventilation



- (A) Illustrates the lungs at rest
- In inspiration (B), the intrapulmonary pressure is less than atmospheric pressure and air flows into the lungs.
- In expiration (C), intrapulmonary pressure is greater than atmospheric pressure and air flows out of the lungs. Intrapleural pressure is always less than either intrapulmonary or atmospheric pressure.

Mechanics of Ventilation

- Elastic Recoil:
  - The tendency for the lungs and thorax to return to their pre-inspiration state
  - Disease states may require forceful expirations even at rest
- Compliance:
  - The ability for the lungs and thorax to stretch is essential for respiration
  - Disease states may make inspiration more difficult
- Resistance:
  - Opposition to air flow from narrow air passages, or airway blockages

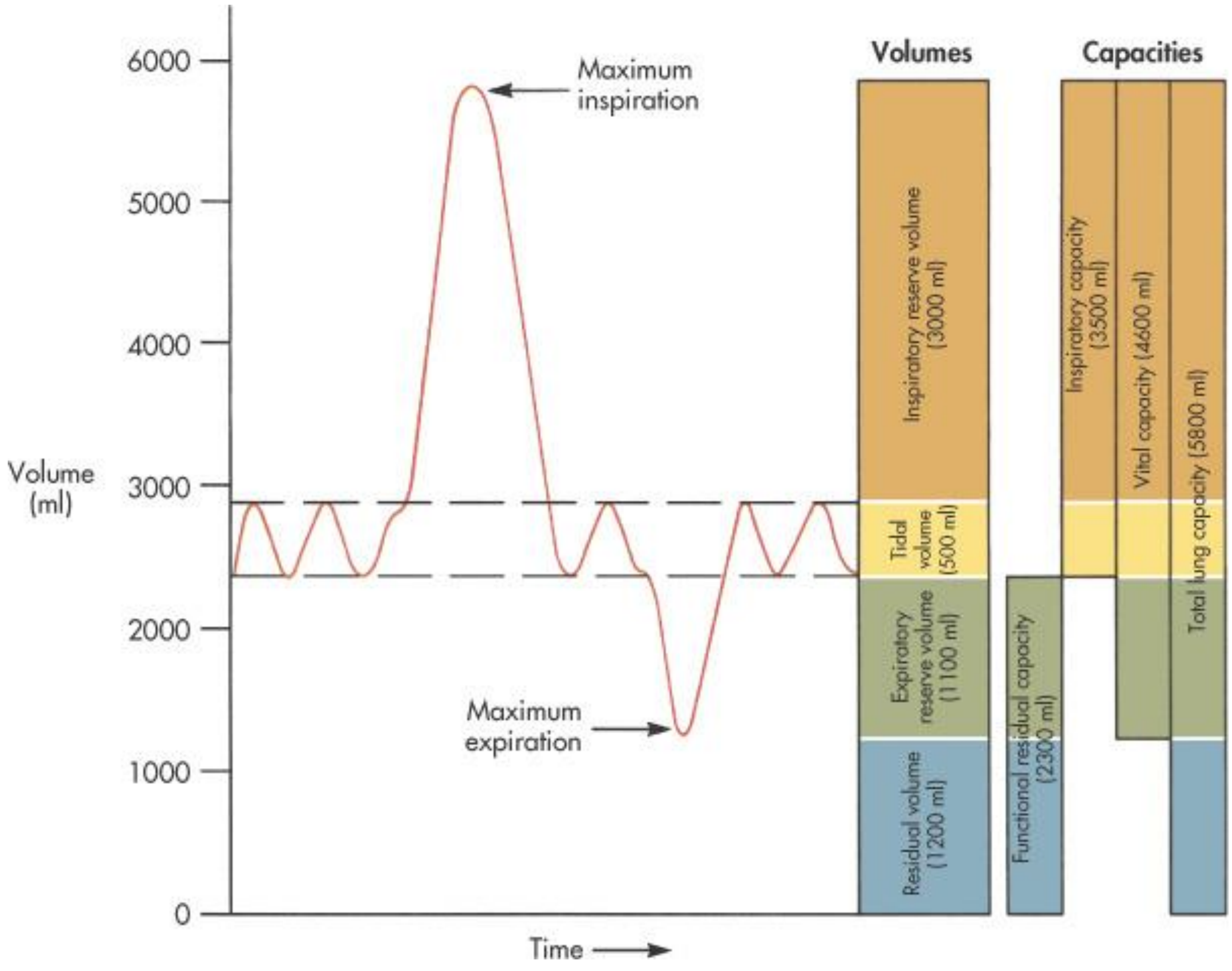
Volumes and Capacities

- Four respiratory volumes
  - Tidal volume (TV)
    - Amount of air exhaled after an inspiration
  - Inspiratory reserve volume (IRV)
    - Max amount that can be forcefully inhaled after TV
  - Expiratory reserve volume (ERV)
    - Max amount that can be forcefully exhaled after TV
  - Residual volume (RV)
    - Amount remaining after max expiration

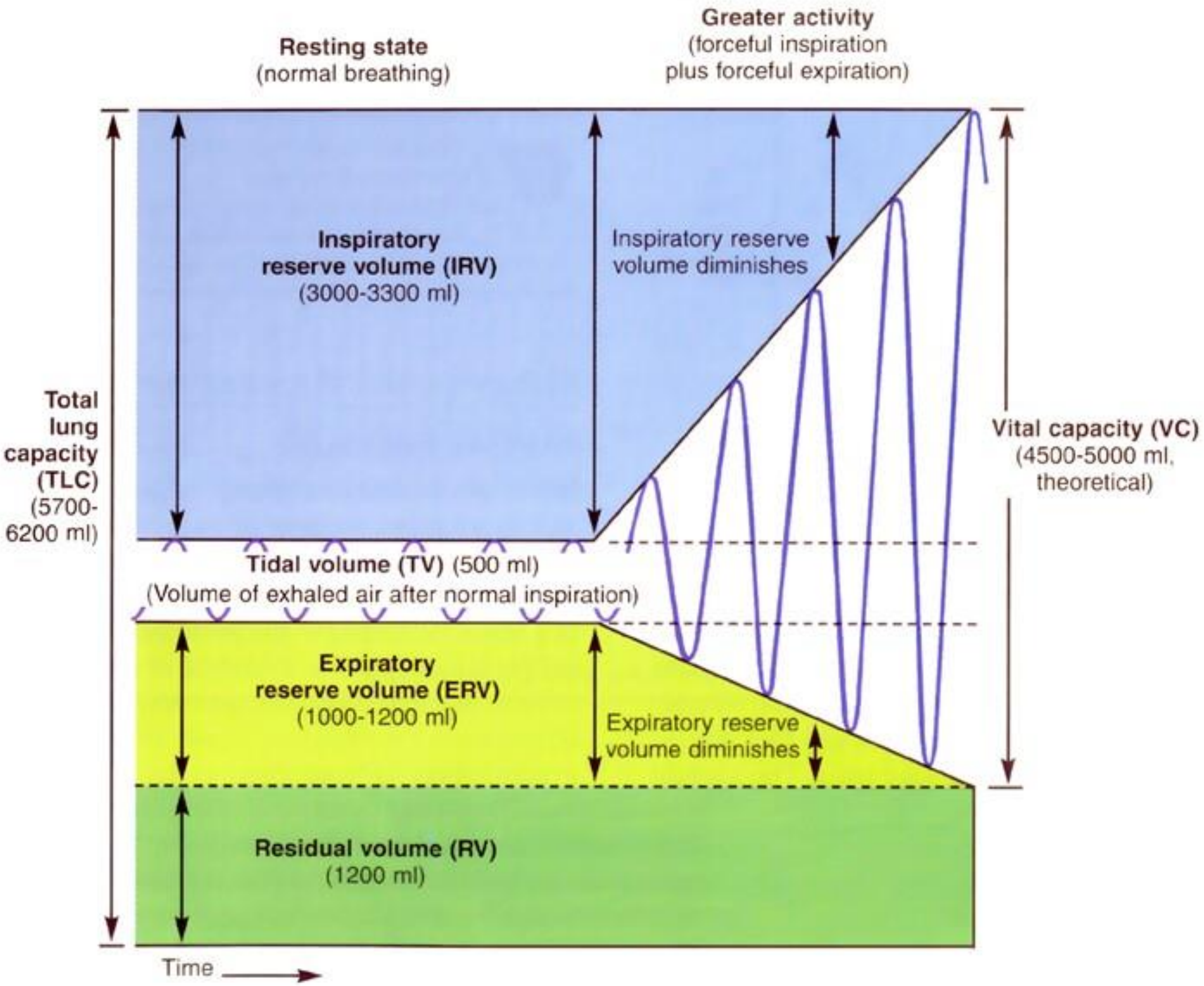
Volumes and Capacities

- Respiratory capacities
  - Vital Capacity (VC)
    - Max amount of air that can be exhaled after max inspiration (TV+IRV+ERV)
  - Inspiratory Capacity (IC)
    - Max amount of air inhaled (TV+IRV)
  - Functional residual capacity (FRC)
    - Amount remaining after tidal expiration (RV+ERV)
  - Total Lung capacity (TLC)
    - Total amount of air the lung can hold (RV+TV+IRV+ERV)
  - Minute Volume
    - Total volume of inspired air per respiration times the respiratory rate

Volumes and Capacities



Volumes and Capacities



Alveolar Ventilation

- The volume of inspired air that reaches the alveoli
- Only air that takes part in exchange of gases

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Dead Space

- Volume of air which is inhaled, but does not take part in gas exchange either because it remains in the conducting airways or in alveoli that are poorly perfused
  - Anatomic Dead Space
    - Portion of the airways which conduct gas to the alveoli
  - Alveolar Dead Space
    - Sum of the volumes of those alveoli that are ventilated but not perfused
  - Physiological Dead Space
    - Anatomical Dead Space + Alveolar Dead Space

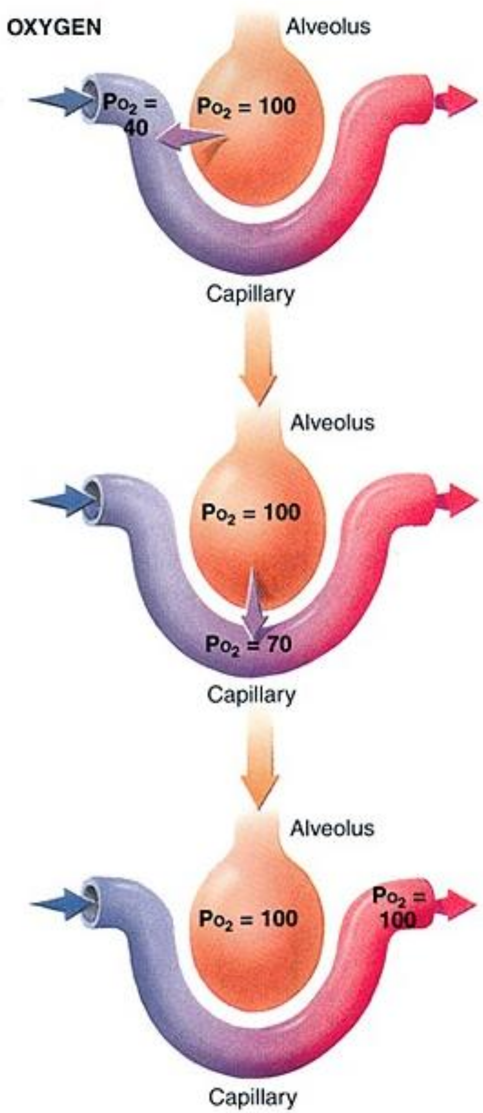
Exchange of Gases in the Lungs

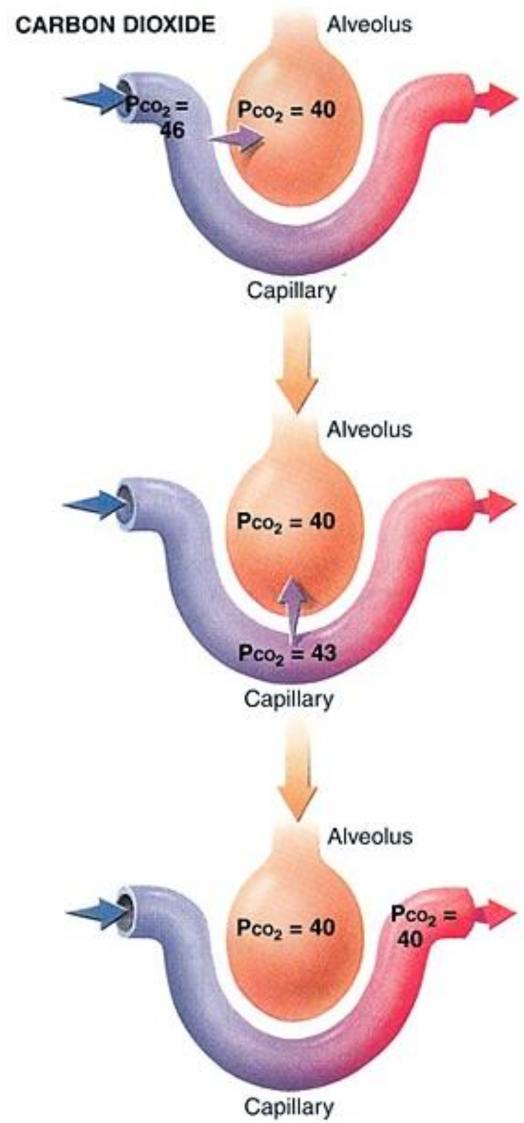
- Gas exchange occurs between the lungs and the blood at the capillary level
- Gases move in both directions through the respiratory membrane
- Occurs due to pressure differentials in the system

Exchange of Gases in the Lungs

- Amount of oxygen diffusion depends on many factors:
  - O_2 pressure gradient between alveoli and blood (Altitudes)
  - Total functional surface area of the membrane (Pneumothorax)
  - Minute volume (Morphine)
  - Alveolar ventilation (COPD)

Exchange of Gases in the Lungs



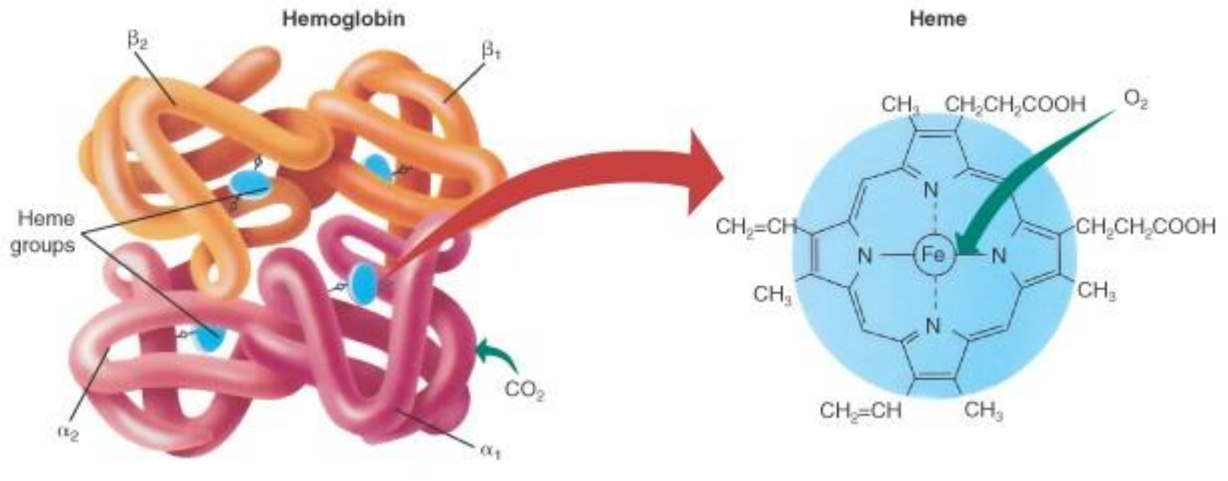


Transport of Gases

- Blood transports O_2 and CO_2 as either solutes or combined with other chemicals
- As they enter the blood stream they are dissolved in plasma
- Since plasma can only hold small amounts of gas they combine chemically with another molecule
  - Hemoglobin, plasma proteins or water
- As they combine with the molecules, plasma concentrations decrease providing more space for in the plasma

Transport of Gases

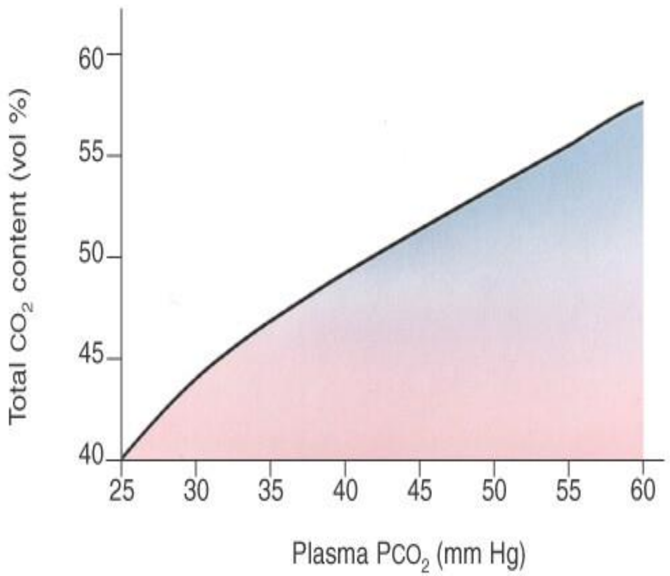
- Remember that hemoglobin:
  - Contain four polypeptide chains
  - Each chain has a heme group (contains iron)
  - O_2 can combine with the Fe
  - CO_2 can be absorbed in the chains



Transport of gases

- Oxygen transport
  - 3% stays in plasma
  - Remainder combines with hemoglobin in the RBC
    - Loading (In the lungs)
    - $Hb + O_2 \rightarrow HbO_2$
    - Unloading (In the tissues)
  - $HbO_2 \rightarrow Hb + O_2$
  - Temperature, O_2 & CO_2 levels and pH affect loading and unloading

Transport of gases

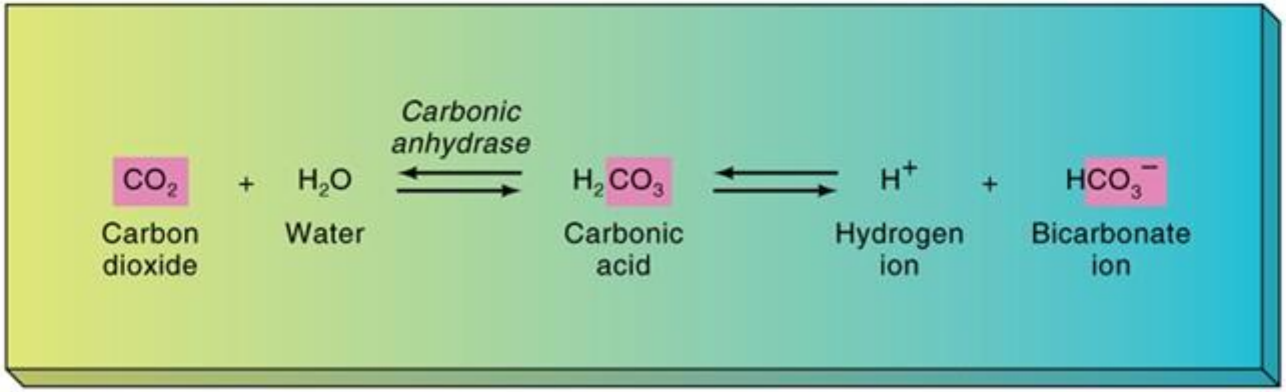


- Carbon Dioxide transport
  - Dissolved in plasma (7 – 10 %)
  - Combine with amine (NH2) groups which combine with hemoglobin in the RBC (20 - 23%)

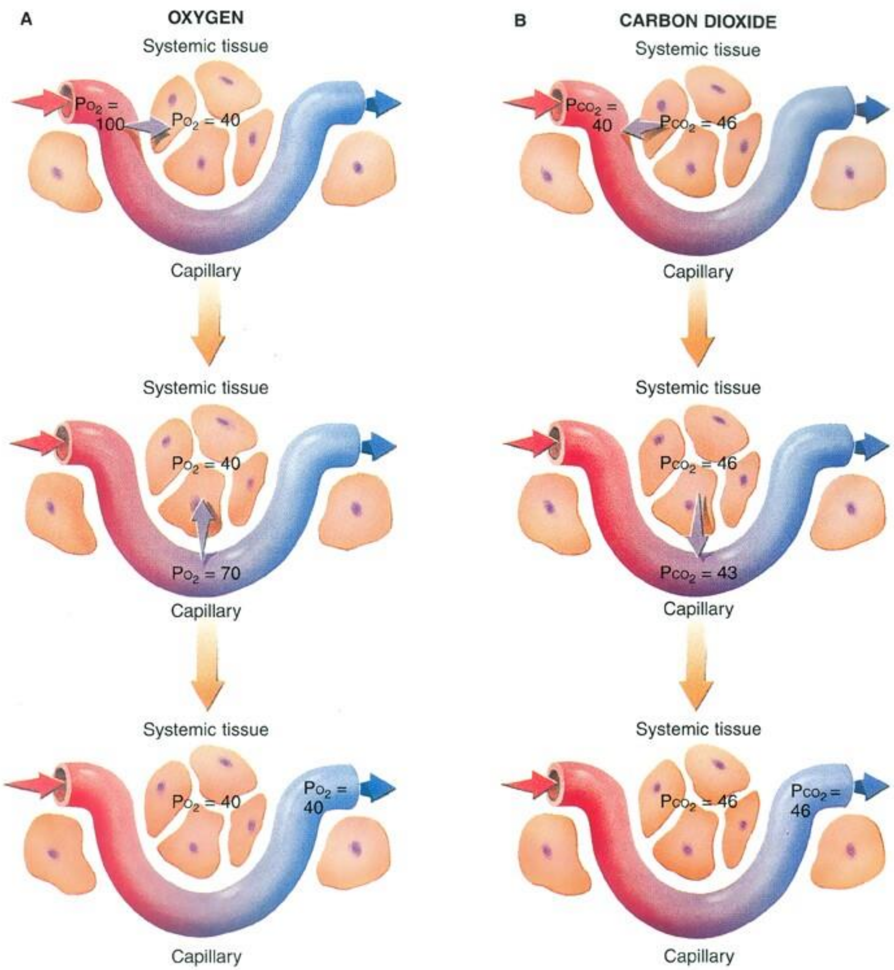
$$Hb + NH_2 + CO_2 \rightarrow HbNCOOH^- + H^+$$

(Carbaminohemoglobin)

- Carbon Dioxide transport
  - As part of bicarbonate ions (70%)
    - Dissolved in H_20 (Blood plasma) to make carbonic acid, sped up by carbonic anhydrase enzyme and dissociates into bicarb and hydrogen



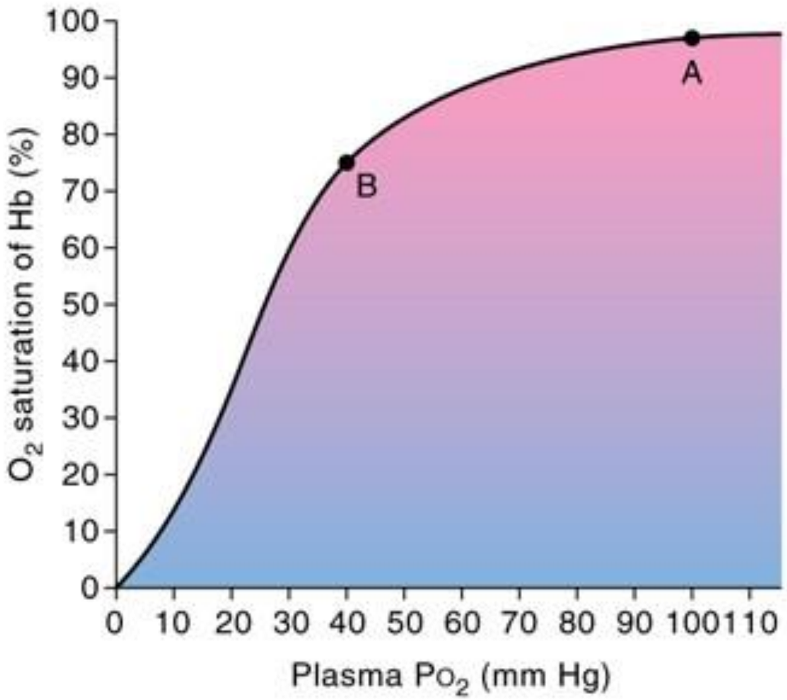
Systemic Gas Exchange

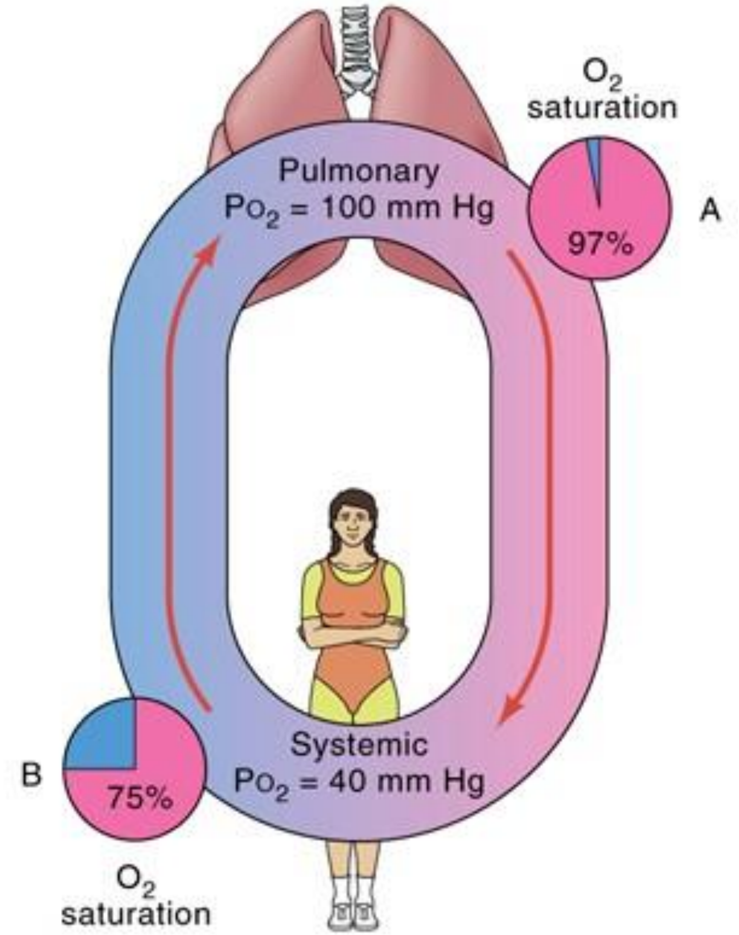


Oxyhemoglobin Dissociation Curve

- A non-linear graph showing the relationship between pO_2 of plasma with the Hb Saturation (%)
- Is the difference between hypoxia and hypoxemia
  - Many factors can influence how rapidly hemoglobin can associate or dissociate with oxygen in the system
  - An increasing blood pO_2 accelerates association of Hb with O_2
  - A decreasing blood pO_2 accelerates dissociation of Hb with O_2

Oxyhemoglobin dissociation curve





Oxyhemoglobin Dissociation Curve

- Influencing factors:
  - Acidity
    - Hb affinity for oxygen is lower and oxygen dissociates easily from the Hb
    - To acidic will result in no affinity of Hb to oxygen
  - Partial Pressure of CO_2
    - As pCO_2 increases hemoglobin releases O_2 more readily
    - The increase in pCO_2 may result in a large amount of bicarbonate and hydrogen ions in the blood, thus decreasing the pH

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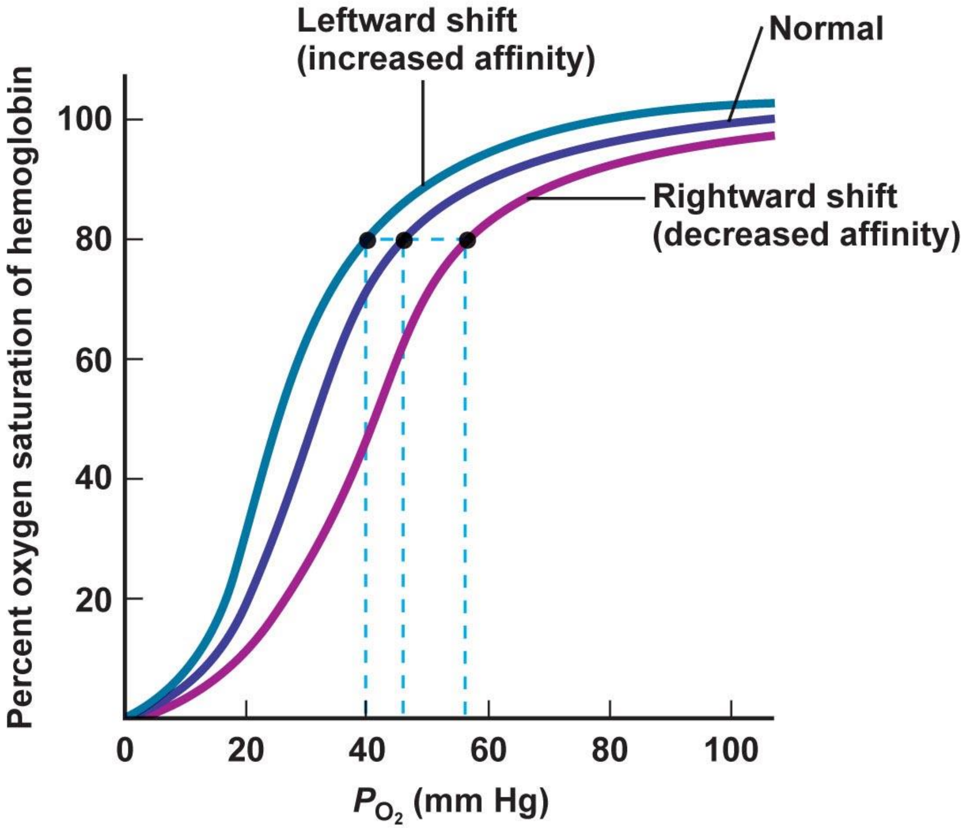
Oxyhemoglobin Dissociation Curve

- Influencing factors:
  - Temperature
  - 2, 3 biphosphoglycerate (2, 3 BPG)
    - Formed in the RBC's when glucose is broken down during glycolysis
    - BPG decreases the Hb affinity
    - When BPG combines with Hb, oxygen is easily dissociated and more oxygen can be delivered to the tissues
      - Certain hormones can increase BPG content such as epi, nor-epi and testosterone
      - High altitudes can affect BPG as well

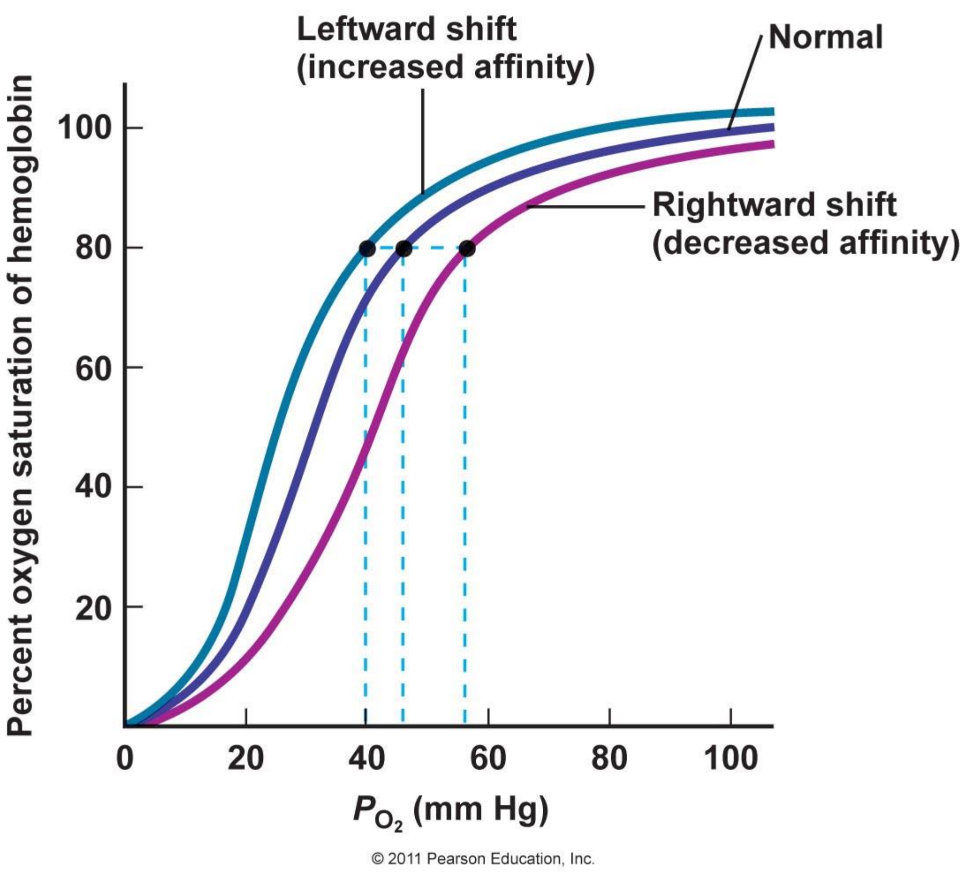
Oxyhemoglobin Dissociation Curve

- Right Shift (Bohr Effect)
  - An decrease in oxygen's affinity to Hb
    - Weaker bonds (more dissociation)
    - Results in a right shift in the curve
  - Causes:
    - Decreased pH (acidosis)
    - Increased CO_2
    - Increased temperature
    - Increased BPG
      - COPD, CHF…



Oxyhemoglobin Dissociation Curve

- Left Shift (Haldane Effect)
  - An increase in oxygen's affinity to Hb
    - Stronger bonds (less dissociation)
    - Results in a left shift in the curve
  - Causes:
    - Increased pH (alkalosis)
    - Decreased CO_2
    - Decreased temperature
    - Decreased BPG
      - Septic shock



Clinical Use

- The oxyhemoglobin dissociation curve is important clinically in understanding the relationship of SaO_2 to the pO_2 particularly as it relates to disease.
- In healthy patients the slope of the curve increases significantly from the mid-sixties (PaO_2) downward
  - indicates that decreases in PaO_2 in this region will have dramatic effects on SaO_2
- A good grasp on the influence of factors that can affect the curve or the affinity of hemoglobin to oxygen.
  - Remember the powerful effects of carbon monoxide in trying to explain hypoxemia in the presence of a normal PaO_2 and SaO_2.
- Understanding the elements of the dissociation curve, such as the basis of oxygen saturation, can also help explain clinical problems.
  - a patient that presents with SOB in the presence of adequate ventilation and SaO_2 with a hemoglobin deficiency

Clinical Use

30	4	7
60	5	8
90	6	9

Factors that influence breathing

- Medulla and pons form the Respiratory center in brainstem
  - Inspiratory phase send signals down phrenic nerve to the diaphragm
  - Also to intercostal nerves for deep breath
  - Expiration occurs when the impulse stop

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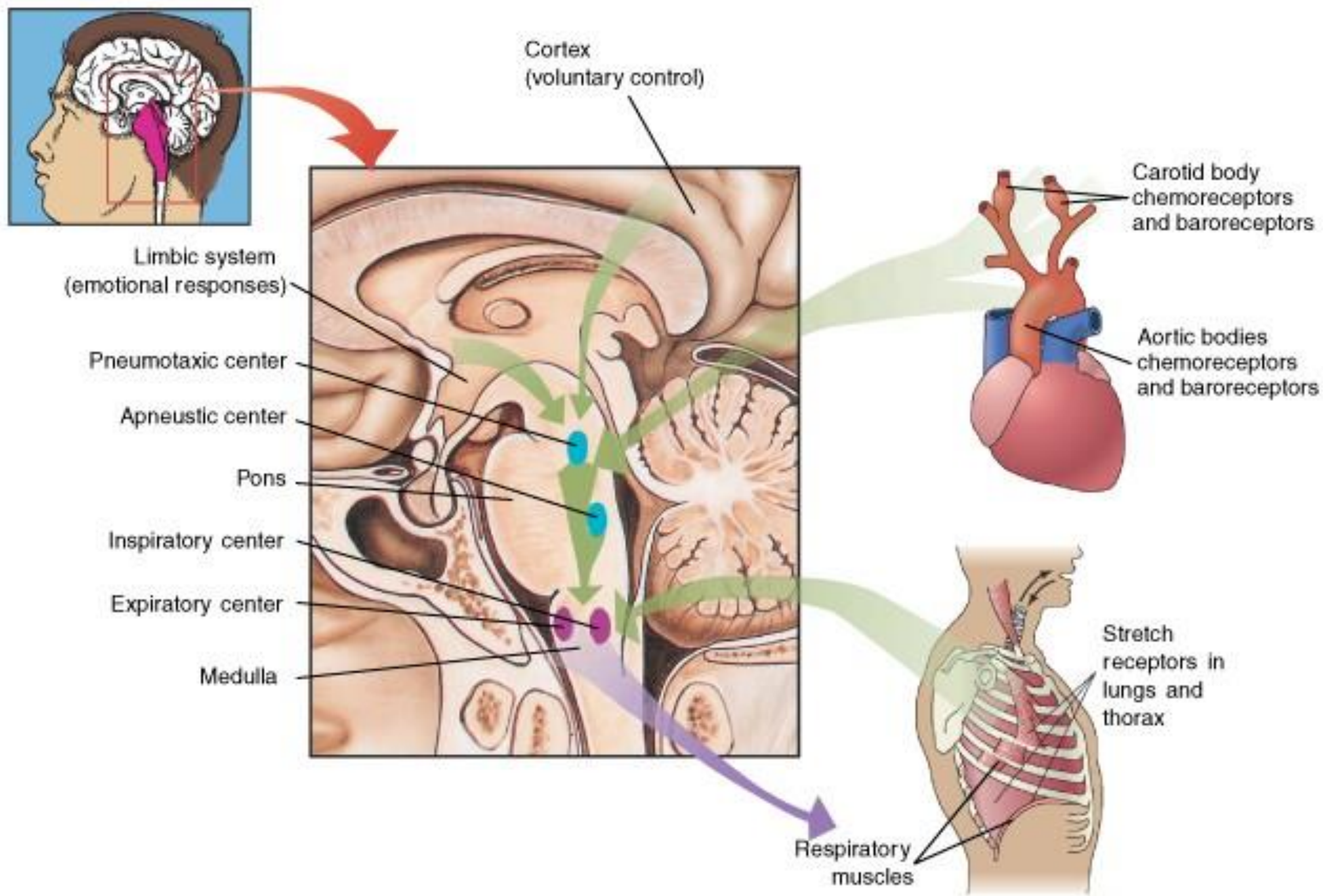
Respiratory Control Centers

- Medulla
  - The main integrators that control the nerves that affect respiration are located in the brainstem (respiratory centers)
  - Medullary Rhythmicity Area
    - Consists of:
      - Inspiratory center (primary respiratory pacemaker)
      - Expiratory center
        - » Typically is only active for forceful expiration

Respiratory Control Centers

- Pons
  - Apneustic center
    - Stimulates the inspiratory center to increase length and depth of inspiration
  - Pneumotaxic center
    - Inhibits both the apneustic center and the inspiratory center
    - Helps prevent overinflation of the lungs

Factors that influence breathing



Control Systems

- A complex control system exists to control
  - pH
  - pCO_2
  - pO_2

- pO_2 must be controlled to ensure all tissues receive O_2
- pCO_2 must be controlled to keep pH near 7.4
- pH must be controlled to keep
  - enzymes functioning normally
  - membrane and other proteins functioning normally
  - biological processes functioning that depend on pH

- Minute Volume
  - Is altered to keep pO_2 high and pCO_2 near 40 mmHg
  - Caused by changes in respiratory rate and tidal volume

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Control Systems

- Control Systems in regulating pH and pO_2
  - Mechanical Control System
  - Chemically Mediated Control System
  - Nonspecific Respiratory Drives

- Each of these alter the Respiratory centers to alter breathing as required

Control Systems

- Mechanical Control
  - Hering-Breuer Reflex
  - Large lung inflations cause
    - Deflation
    - Decrease in rate of breathing
  - Large deflations of the lung cause
    - Inspiration
    - Increased rate of breathing

- Receptors for mechanical control
  - Stretch receptors
    - Airway smooth muscle in Trachea, Bronchi and Bronchioles
  - Sensory information is carried to medulla via Vagus nerve
  - Efferent information is carried by Motor neurons to respiratory muscles
    - Phrenic (innervates the diaphragm)
    - External & Internal intercostal motor neurons

Factors that influence breathing

- Chemical
  - Chemoreceptors
    - Are sensitive to changes in CO_2 and pH
      - Central: medulla oblongata
        - » Recognizes slight changes in pCO_2
      - Peripheral: carotid bodies and aorta
        - » Recognize large changes in pCO_2

    - Increase in pCO_2 results in faster breathing with greater volume
    - Decrease in pCO_2 results in inhibition of chemoreceptors and slows breathing rates
    - May note a change in pO_2 if the levels drop below 70 mmHg as a emergency respiratory control mechanism
    - ↓ pH will result in ↑ minute volume

Factors that influence breathing

- Stretch Receptors of the lungs
  - Initiates the Hering-Breuer Reflex to prevent overinflation
- Cerebral cortex
  - Stimulus from higher brain centers
  - Involuntary or voluntary
  - Catecholamine releases
- Temperature
  - Increase in temp increases respiratory rate
  - Sudden cold stimuli may cause reflex apnea

Factors that influence breathing

- Pain
  - Sudden painful stimulation will cause reflex apnea
  - Continued pain will increase rate and depth of respirations
- Stimulation of pharynx or larynx
  - by chemicals or touch may cause a temporary apnea
  - A protective measure against aspiration

Nonrespiratory Air Movements

- Reflexes, voluntary and emotions
  - Coughing
    - Stimulated by foreign material in trachea or bronchi
    - Epiglottis and glottis close and the expiratory muscles contract to force them open and a gush of air up
  - Sneezing
    - Contaminants in the nasal cavity
  - Sighing
  - Hiccup
    - Spasmodic contraction of the diaphragm followed by a sudden closure of the glottis
  - Crying
  - Laughing
  - Yawning