RESPIRATORY PHYSIOLOGY

- Important muscles in inspiration that raise the ribcage are:
  1. External intercostals
  2. Sternocleidomastoid
  3. Serratus anterior
  4. Scaleni
- Important muscles in expiration that pull the ribcage downward:
  1. Abdominal recti
  2. Internal intercostals
- In inspiration, pleural pressure rise from -5 cmH_2O to -7.5 cmH_2O
- Alveolar pressure
  During inspiration = -1 cmH_2O
  During expiration = +1 cmH_2O
- **Transpulmonary pressure** is the difference between alveolar pressure and pleural pressure
- **Lung Compliance:** The extent to which the lungs will expand for each unit increase in transpulmonary pressure is called lung compliance.
  The total compliance of both lungs together in the normal adult averages about 200ml of air/cmH_2O transpulmonary pressure i.e. every time transpulmonary pressure increases by 1 cmH_2O, the lung volume, after 10 to 20 sec, will expand 200 ml.
- Alveolar surfactant is a complex mixture of several phospholipids, proteins, and ions.
  The most important components are:
  1. Dipalmitoyl phosphatidylcholine (phospholipid)
  2. Surfactant apoprotein
  3. Calcium ions
- Surface tension of
  - Pure water = 72 dynes/cm
  - Normal fluids lining alveoli but without surfactant = 50 dynes/cm
  - Normal fluids lining the alveoli but with normal amounts of surfactant = 5 – 30 dynes/cm
- Inspiration → active
  Expiration during quiet breathing → Passive
  Expiration during forced breathing → Active
- Three types of work done by inspiration:
  1. Compliance work or elastic work – required to expand the lungs against the lung and chest elastic forces
  2. Tissue resistance work – required to overcome viscosity of the lung and chest wall structures
  3. Airway resistance work – required to overcome airway resistance to movement of air into the lungs
- VALUES
  - Tidal volume = 500 ml
  - Normal respiratory rate = 12 breaths/min
  - Minute respiratory volume = 6 L/min

    - Dead space air volume = 150 ml
    - Alveolar ventilation = 4200 ml/min
    - Systolic pulmonary arterial pressure = 25 mmHg
    - Diastolic pulmonary arterial pressure = 8 mmHg
    - Mean pulmonary arterial pressure = 15 mmHg
    - Mean pulmonary capillary pressure = 7 mmHg
    - Blood volume of the lungs = 450 ml
    - Inspiratory Reserve Volume = 3000 ml
    - Expiratory Volume = 1100 ml
    - Residual Volume = 1200 ml
    - Inspiratory Capacity = 3500 ml
    - Functional Residual Capacity = 2300 ml
    - Total Lung Capacity = 5800 ml
- Structures prevented from collapsing by:
    1. Trachea and bronchi → cartilage rings
    2. Bronchioles → Transpulmonary pressures that expand the alveoli
- Sympathetic Dilation of bronchioles by:
    1. Epinephrine
    2. Norepinephrine
- Parasympathetic constriction of bronchioles
    1. Acetylcholine
- Local Bronchial Constriction by:
    1. Histamine
    2. Slow reactive substance of anaphylaxis
       (both released by mast cells during allergic reactions)
- Dead space is the volume of air that is inhaled but does not take part in the gas exchange, because it either remains in the conducting airways or reaches alveoli that are not perfused or poorly perfused. In other words, not all the air in each breath is available for the exchange of oxygen CO_2
- Alveolar ventilation is the exchange of gas between alveoli and external environment
- For cough reflex, the afferent nerve impulse pass from respiratory passages mainly through the vagus nerves to the medulla of the brain.
  The afferent impulse for sneeze reflex pass in the 5^{th} cranial nerve to the medulla
- Shift of blood from pulmonary circulation to systemic circulation seen:
    1. When a person blows out air with force
    2. Due to hemorrhage
- Shift of blood from systemic to pulmonary circulation seen in:
    1. Failure of left side of heart
    2. Mitral valve stenosis
    3. Mitral Regurgitation
- Pulmonary vasoconstriction observed due to hypoxia (Although hypoxic cause systemic vasodilation)
- Three zones of lungs
  ZONE 1

- No blood flow
- Alveolar air pressure greater than arterial pressure

ZONE 2

- Intermittent flow
- Systolic arterial pressure rises higher than alveolar air pressure
- Diastolic arterial pressure falls below alveolar air pressure

ZONE 3

- Continuous flow
- Arterial pressure and pulmonary capillary pressure remain greater than alveolar air pressure at all times

- Factors increasing thickness of respiratory membrane and thereby decreasing rate of gas diffusion across the membrane:
  1. Edema fluid in the interstitial fluid of the membrane and in the alveoli
  2. Lung fibrosis
- Ventilation Perfusion Ratio = $\frac{V_A}{Q}$

  V_A : Alveolar ventilation

  Q: Blood flow
- When V_A/Q equals zero
  - Alveolar ventilation is zero
  - Perfusion i.e. blood flow is not zero
  - Seen in alveolar dead space
- When V_A/Q equals infinity
  - No capillary blood flow
  - Alveolar ventilation is not zero
  - Increased V_A/Q ratio seen in emphysema and heart disease
- Normal Ventilation perfusion ratio

  $\frac{V_A}{Q} = \frac{4L\ air/min}{5L\ air/min} = 0.8$
- Respiratory center divided into:
  1. Dorsal Respiratory Group
     - Located in dorsal portion of medulla
     - Mainly cause inspiration
  2. Ventral Respiratory Group
     - Located in ventrolateral part of medulla
     - Mainly cause expiration
  3. Pneumotaxic Center
     - Located dorsally in superior portion of pons
     - Mainly controls rate and depth of breathing
- The **Hering-Breur inflation reflex** is a reflex triggered to prevent over-inflation of the lungs. Pulmonary stretch receptors present on the wall of bronchi and bronchioles of the airways respond to excessive stretching of the lung during large inspirations.

It is activated by tidal volume greater than 1.5L

- **Glomus cells** are mainly located in the carotid bodies and aortic bodies.
  Glomus Type I cells are peripheral chemoreceptors which sense oxygen, CO_2 and pH levels of blood.
- When blood PO_2 decreases markedly, the following steps takes place:
  1. O_2-sensitive potassium channels of glomus cells are inactivated
  2. Opening of voltage-gated calcium channels to increase intracellular calcium ion concentration
  3. Stimulation of a neurotransmitter that activates afferent neurons that send signals to CNS and stimulate respiration
     Neurotransmiiter may be dopamine, acetylcholine or ATP
- Spirometry can measure
  1. Inspiratory Reserve Volume
  2. Tidal Volume
  3. Expiratory Reserve Volume

  Spirometry cannot measure residual volume

- **Hypoxic hypoxia** (arterial hypoxia) refers to hypoxia resulting from an inadequate saturation of blood oxygen due to a reduced supply of oxygen in the air, decreased lung ventilation or respiratory disease
  Some of the causes are
    - High altitude
    - Pulmonary edema
    - Obstruction in the respiratory passages
    - Emphysema
- Total lung capacity (TLC) = Vital Capacity + Residual Volume
- TLC = Inspiratory Capacity + Functional Residual Capacity
  TLC = IC + FLC
- Cyanosis appears when arterial blood contain 5gm of deoxygenated Hb/100 ml
- Normal alveolar, arterial and venous pressures of O_2 and CO_2
    - Alveolar PO_2 = 100 mmHg
    - Arterial PO_2 = 100 mm Hg
    - Venous PO_2 = 40 mmHg

    - Alveolar PCO_2 = 40 mmHg
    - Arterial PCO_2 = 40 mmHg
    - Venous PCO_2 = 45 – 45 mmHg
- **Restrictive Lung Disease** – A decrease in the total volume of air that the lungs are able to hold. It is often due to a decrease in the elasticity of the lungs themselves or caused by a problem related to the expansion of chest wall during inhalation
- Functional Residual Capacity increase in obstructive, but not in restrictive lung disease
- The bulk of CO_2 in arterial and venous blood is transported as bicarbonate
- Transport of oxygen

    - As oxyhemoglobin – 97%
    - Dissolved in plasma – 3%
- Transport of CO2
    - As bicarbonate ions – 70%
    - Carboxyhemoglobin – 23%
    - Dissolved in plasma – 7%
- **Histotoxic hypoxia** refers to a reduction in ATP production by the mitochondria due to a defect in the cellular usage of oxygen. An example of histotoxic hypoxia is cyanide poisoning.
- Bucket-handle movement increase transverse diameter of the thorax
- Pleurisy is inflammation of pleural membrane
- Destruction of pneumotaxis center located in pons causes apneustic respiration.
  Apneustic breathing is an abnormal breathing pattern. It is characterized by regular deep inspirations with an inspiratory pause followed by inadequate expiration.
- With increased CO_2 excretion, increased H^+ ion concentration and increased partial temperature, the oxygen dissociation curve is shifted to the right, promoting oxygen dissociation. At this time, the affinity of Hb for oxygen increase.
- The negative pressure in pleural cavity is thought to be generated by the lymphatic drainage of fluid from the pleural space
- The diffusing capacity of the lung increase during exercise due to increased pulmonary capillary blood flow and capillary distention in ventilated areas of lung.
- Conducting zone of airways extends from nose to terminal bronchioles
- Vital Capacity is the total amount of air exhaled after maximum inhalation
- Alkalosis causes a leftward shift of the oxyhemoglobin dissociation curve, thus impairing release of oxygen from Hb to tissues at a time when oxygen delivery already may be less
- Lung 'J' receptors present in alveolar walls in juxtaposition to the pulmonary capillaries. They are stimulated especially when pulmonary capillaries become engorged with blood or when pulmonary edema occurs in conditions as congestive heart failure.
  Their excitation may give the person a feeling of dyspnea
- Increased activity of pneumotaxic center is likely to cause tachypnea
  Decreased activity of pneumotaxic center is likely to cause bradypnea
- Pulmonary edema safety factor is 21 mmHg
- **Significance of Oxygen Hb Dissociation Curve**:
  The strength by which oxygen binds to Hb is affected by several factors and can be represented as a shift to the left or right in oxygen dissociation curve.
  A rightward shift indicates that Hb has a decreased affinity for oxygen, thus oxygen actively unloads (to the tissues)
  A shift to the left indicates increased Hb affinity for oxygen and an increased reluctance to release oxygen
- Factors shifting the curve to the right (Oxygen Unloading)
  1. Decreased pH
  2. Increase in acidity/ CO_2
  3. High temperature e.g. during exercise
- Factors shifting the curve to the left

1. Increase in pH
2. Decreased CO_2
3. Carbon monoxide
4. Fetal hemoglobin (due to which fetus can pull oxygen from maternal circulation)

- Vital Capacity represent total volume of exchangeable air
- The work of breathing is inversely related to lung compliance