Respiration Lab

Movement of Gases

- Air moves into and out of lungs due to pressure differences between intrapulmonary air (IP) and atmospheric air (ATM)
  - If IP Pr < ATM Pr, air rushes into lungs
  - If IP Pr > ATM Pr, air rushes out of lungs
- How is IP Pr changed?
  - Boyles Law
    - Pressure \( \propto \frac{1}{\text{Volume}} \)
- Air flow into and out of lungs driven by changing lung volume
  - ↑ Lung Volume, ↓ IP Pr, air flows in
  - ↓ Lung Volume, ↑ IP Pr, air flows out

Mechanics of Lung Ventilation

Inspiration (tidal) - active
- Due to contraction of inspiratory muscles
  - Diaphragm and External Intercostals
- Enlarges thoracic cavity
  - Expands lungs (↑ in V)
  - ↓ IP Pr below ATM Pr
  - Air moves into the lungs
- Forced Expiration
  - Contraction of accessory muscles (e.g., scalenes, sternocleidomastoid)

Expiration (tidal) - passive
- Due to relaxation of inspiratory muscles
- Compresses thoracic cavity
  - Compresses lungs (↓ in V)
  - ↑ IP Pr above ATM Pr
  - Air moves out of the lungs
- Forced Expiration
  - Contraction of expiratory muscles (internal intercostals and abdominal muscles)

Lung Volumes and Capacities

Primary Lung Volumes

- Tidal Volume (V\(_T\))
  - amount of air entering/leaving lungs in a single, “normal” breath
  - ca. 500 ml at rest,
  - ↑ w/ ↑ activity
- Inspiratory Reserve Volume (IRV)
  - additional volume of air that can be maximally inspired beyond V\(_T\) by forced inspiration
  - ca. 3100 ml at rest
Lung Volumes and Capacities

Primary Lung Volumes

• Expiratory Reserve Volume (ERV)
  – additional volume of air that can be
    maximally expired beyond \( V_T \) by
    forced expiration
  – ca. 1200 ml. at rest

Lung Capacities

• Total Lung Capacity (TLC)
  – total amount of air that the lungs can
    hold
  – amt of air in lungs at
    the end a maximal
    inspiration
  – \( V_T + IRV + ERV + RV \)

• Vital Capacity (VC)
  – max. amt. air that
can move out of
lungs after a person
inhales as deeply as
possible
  – \( VT + IRV + ERV \)

• Inspiratory Capacity (IC)
  – max amt. of air that can
    be inhaled from a
    normal end-expiration
  – breathe out normally,
    then inhale as much as
    possible
  – \( VT + IRV \)

• Residual Volume (RV)
  – volume of air still in
    lungs following
    forced max.
    expiration
  – ca. 1200 ml. at rest

• Functional Residual Capacity (FRC)
  – amt of air remaining in
    the lungs following a
    normal expiration
  – \( ERV + RV \)
Lung Ventilation Measures (air volume vs. time)

- Respiratory Frequency (RF) (breathing rate)
  - ca 12 breaths/minute at rest
- Minute Volume ($V_M$)
  - amount of air moved by the lungs in 1 min
  - $VT \times RF$

Alveolar Ventilation ($V_A$)

- amount of air that moved over the respiratory surfaces (alveoli) in 1 min.
- Must subtract dead-space vol. ($V_{ds} = 1/3$ resting $V_T$)
- $V_A = RF \times (V_T - V_{ds})$

 Forced Expiratory Volume (FEV$_t$)

- Amount of air forcibly expired in $t$ seconds
- $FEV_t = (V_t/VC) \times 100\%$
- Normally...
  - $FEV_1 = \sim 80\% VC$
  - $FEV_2 = \sim 94\% VC$
  - $FEV_3 = \sim 97\% VC$
- Index of air flow through the respiratory air passages

Air-Flow Disorders

- Obstructive disorders
  - obstruction of the pulmonary air passages
  - slight obstruction will have large ↓ in air flow
  - bronchiolar secretions, inflammation and edema (e.g. bronchitis), or bronchiolar constriction (e.g. asthma)
  - reduced FEV, normal VC
- Restrictive disorders
  - damage to the lungs results in abnormal VC test
  - e.g. pulmonary fibrosis
  - reduced VC, normal FEV

CO$_2$ and pH Regulation

- CO$_2$ can influence pH by reacting with water
  - $CO_2 + H_2O \Leftrightarrow H_2CO_3$ (carbonic acid) $\leftrightarrow HCO_3^-$ (bicarbonate) + $H^+$
- Two different pathways by which reaction occurs
  1. Inside red blood cells
  2. In blood plasma

Carbonic acid formation in RBCs

- Bicarbonate acts as a buffer (stabilizes plasma pH vs. addition of other acids)
Carbonic acid formation in blood plasma

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-
\]

- H⁺ produced in plasma
- With ↑[CO₂], ↑[H⁺] and ↓pH
- With ↓[CO₂], ↓[H⁺] and ↑pH

pH Regulation

- Lung ventilation used to regulate blood pH
- With ↑ activity, ↑CO₂ production
  - Compensated with ↑ alveolar ventilation
  - Maintain steady carbonic acid level in blood, prevents acidosis
- With ↓ activity, ↓ CO₂ production
  - Compensated with ↓ alveolar ventilation
  - Prevents alkalosis

Exercise: CO₂ Production Rates

- 150-200 ml distilled water w/ 5 ml of 0.1M NaOH and 2-3 drops of phenolphthalein indicator
  - pink in basic solutions, clear in neutral/acidic
- sit quietly, exhale through straw
- time how long it takes for solution to become clear
- exercise for a couple of minutes
- repeat experiment

Exercise: CO₂ Production and Ventilation

- record breathing rate (breaths/min) for 30 sec during relaxed, normal breathing
- hyperventilate for 10 seconds
- immediately after, record breathing rate again for 30 sec