Mechanics of Breathing

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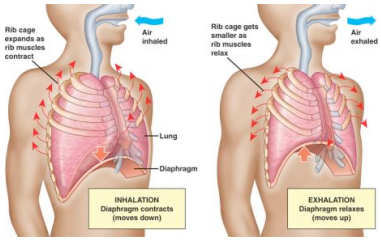
Pulmonary Ventilation

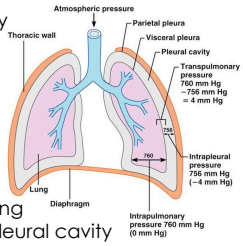


Respiration Review

- respiration - process of **gas exchange** between the atmosphere and cells
  - a. pulmonary ventilation (breathing) - movement of air into and out of the lungs
    - 2 phases
      - inspiration - air flows into lungs (inhale)
      - expiration - gases exit lungs (exhale)
    - nonrespiratory movements - voluntary or reflexive movement of air into and out of the lungs
      - coughing, sneezing, laughing, crying, hiccups, and yawning

Pressure Relationships in the Thoracic Cavity

- atmospheric pressure (P_{atm}) - pressure exerted by the air surrounding the body
  - P_{atm} = 760 mm Hg at sea level
  - negative respiratory pressure is lower than 760 mm Hg
  - positive respiratory pressure is higher than 760 mm Hg
- intrapulmonary pressure (P_{pul}) - pressure in alveoli
  - rises and falls with phases of breathing
- intrapleural pressure (P_{ip}) - pressure in pleural cavity
  - rises and falls with phases of breathing
  - ALWAYS negative (about 4 mm Hg) relative to P_{pul}
- transpulmonary pressure - difference between intrapulmonary and intrapleural pressures (P_{pul} - P_{ip})
  - keeps lungs from collapsing



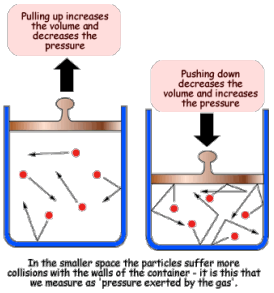
Boyle's Law

at constant temperature...

$$P_1V_1 = P_2V_2$$

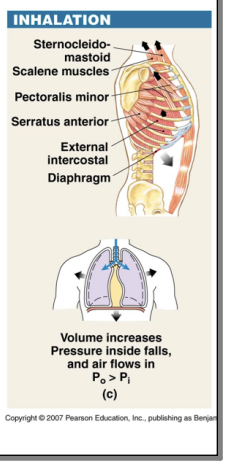
where,
P = pressure of a gas
V = volume
1 = initial conditions
2 = resulting conditions

- pressure of a gas varies inversely with its volume



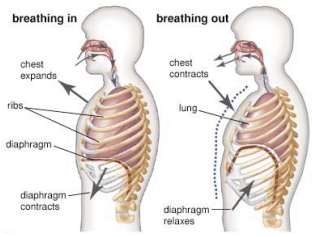
Inspiration

- normal inhale = quiet inspiration
  - moves about 500 mL of air into lungs
- inspiratory muscles increase intrapulmonary volume
  - diaphragm - contracts and flattens
  - external intercostal muscles - elevate ribs and sternum
- as volume increases, P_{pul} decreases about 1 mm Hg relative to P_{atm}
- anytime P_{pul} is less than P_{atm} air rushes into the lungs until the two are equal
- P_{ip} decreases to -6 mm Hg relative to P_{atm}
- deep or forced inspiration = accessory muscles increase volume further



Sequence of Events - Inspiration

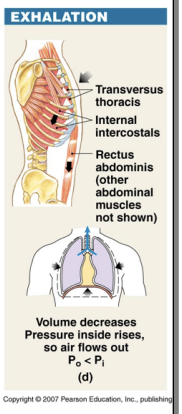
1. inspiratory muscles (diaphragm and external intercostals) contract
2. thoracic cavity volume increases
3. intrapulmonary pressure drops (-1 mm Hg)
4. air flows into lungs



Mechanics of Breathing

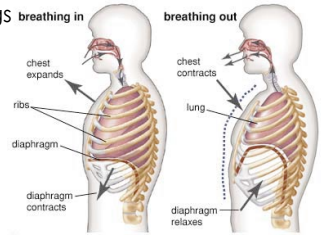
Expiration

- normal exhale = quiet expiration
- ***passive*** process dependent on elastic recoil of lung and thoracic wall tissue
- when inspiratory muscles relax, lungs return to original/resting state
- volume decreases, P_{pul} increases about 1 mm Hg above P_{atm}
- anytime P_{pul} is greater than P_{atm} air is forced out of the lungs until the two are equal
- forced expiration (deep exhale) is an *active* process that relies on contraction of the abdominal wall (pushes diaphragm higher into lungs) and internal intercostals (pull rib and sternum down and in) to further decrease lung volume



Sequence of Events - Expiration

1. inspiratory muscles relax
2. thoracic cavity volume decreases
3. intrapulmonary pressure rises (1 mm Hg)
4. air rushes out of lungs



Factors Influencing Ventilation

- airway resistance
  - F = gas flow
  - P = pressure
  - R = resistance

$$F = \frac{\Delta P}{R}$$

- alveolar surface tension
  - surfactant - mixture of lipids and proteins that reduces the surface tension of water and prevents alveoli from collapsing
- lung compliance - lung stretchy-ness
  - determined by distensibility of lung tissue and alveolar surface tension
  - diminished by decreases in lung elasticity (inflammation or infection) and decreases in surfactant

Respiratory Volumes

- different intensities of breathing move different volumes of air into and our of the lungs (respiratory volumes)
- normal inspiration = about 500 mL
- normal expiration = about 500 mL
- tidal volume (TV) = 500 mL
  - amount of air that moves into and out of the lungs during quiet breathing
- inspiratory reserve volume (IRV) = 1900-3100 mL
  - amount of air that can be forcibly inhaled after normal tidal volume
- expiratory reserve volume (ERV) = 700- 1200 mL
  - amount of air that can be forcefully exhaled after a normal tidal volume exhalation
- residual volume (RV) = 1100-1200 mL
  - amount of air remaining in the lungs after a forced exhalation

Respiratory Capacities

- specific combinations of respiratory volumes
- inspiratory capacity (IC) = 2400-3600 mL
  - maximum amount of air that can be inspired after a normal expiration
  - IC = TV + IRV
- functional residual capacity (FRC) = 1800-2400 mL
  - volume of air remaining in the lungs after a normal tidal volume expiration
  - FRC = ERV + RV
- vital capacity (VC) = 3100-4800 mL
  - maximum amount of air that can be expired after a maximum inspiratory effort
  - VC = TV + IRV + ERV
- total lung capacity (TLC) = 4200-6000 mL
  - maximum amount of air contained in the lungs
  - TLC = TV + IRV + ERV + RV