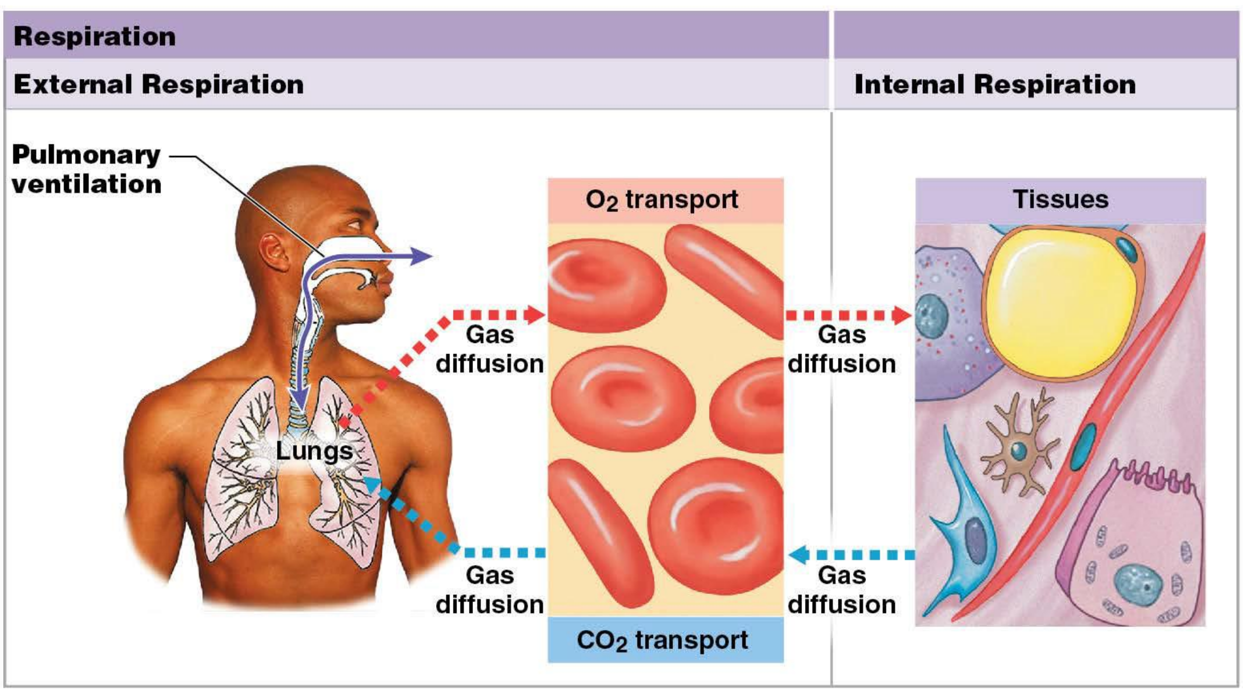
Respiratory Physiology

Respiration: Two integrated processes: external respiration and internal respiration.

- **External respiration**: exchange of gases between blood, lungs, and external environment; **gas diffusion** occurs across blood air barrier between alveolar air and alveolar capillaries.
- **Pulmonary ventilation**(breathing): air movement in/out of lungs Maintains **alveolar ventilation**—air movement in/out of alveoli .
- **Internal respiration**: occurs between blood and tissues (Absorption of oxygen from blood and Release of carbon dioxide by tissue cells).



Abnormalities affecting external respiration affect gas concentrations in interstitial fluids and cellular activities

- **Hypoxia**= low tissue oxygen levels(Severely limits metabolic activities).
- **Anoxia**= no oxygen supply(Much of damage caused by heart attacks and strokes is the result of localized anoxia).

Pulmonary ventilation is driven by pressure changes within the pleural cavities

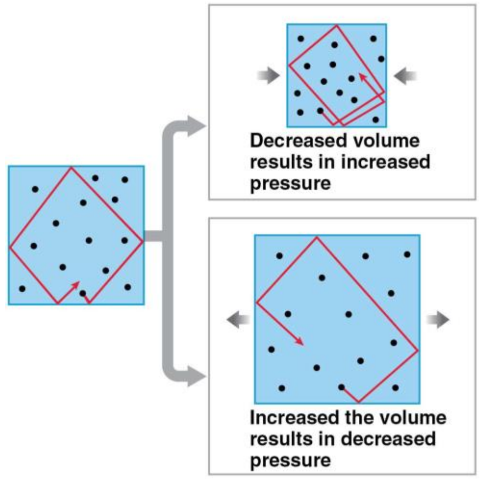
Gas volume and pressure: Molecules in a gas bounce around independently When contained, collisions with container wall cause pressure. More collisions = more pressure

More collisions occur when molecules are in smaller container ,Pressure is inversely related to volume (P = 1/V) ,Relationship called **Boyle's law**

↑Volume causes ↓Pressure ↓ Volume causes ↑Pressure

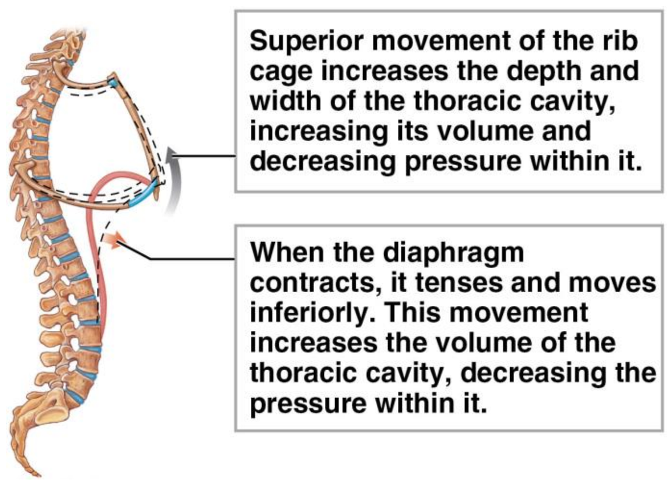
Decreasing the container's volume increases the number of molecular collisions, which increases the pressure

Summary of Boyle's Law



Pulmonary ventilation:

- Changing volume of the thoracic cavity
- -Movements of the diaphragm and rib cage change the volume of the thoracic cavity, which expands or compresses the lungs (changes lung volume)
- -Change in volume = change in pressure.



Start of breathing :

Pressures inside and outside thorax are identical; no air movement

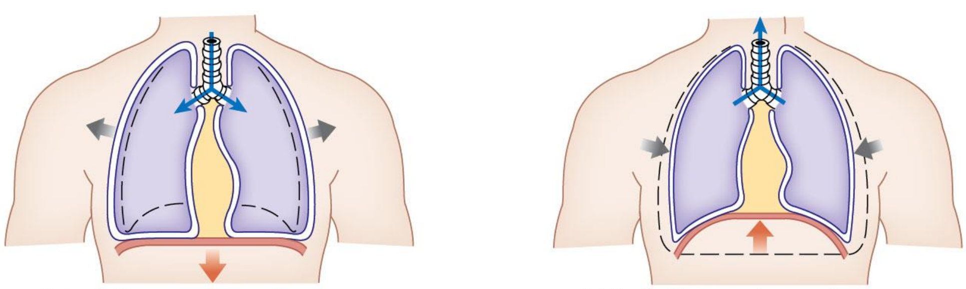
Expanding thoracic cavity expands lungs:

- -Parietal pleura attached to thoracic wall; visceral pleura to lungs
- -Pleural fluid forms bond between layers
- -If injury allows air into pleural cavity, bond is broken
- Lung collapses(**atelectasis**)

Air flows from an area of higher pressure to an area of lower pressure

During inhalation :Thoracic cavity enlarges, Increased volume causes decreased pressure (Poutside> Pinside) and Air moves *in* from an area of high pressure to low pressure.

During exhalation: Thoracic cavity decreases in volume, Decreased volume causes increased pressure (Poutside< Pinside)and Air is forced *out* from an area of high pressure to low pressure



Inhalation: volume increases
$P_{outside} > P_{inside}$
Pressure inside decreases, so air flows in

Exhalation: volume decreases
$P_{outside} < P_{inside}$
Pressure inside increases, so air flows out

Direction of air flow determined by difference between:

- **Atmospheric pressure**—pressure of air around us; and
- **Intra pulmonary pressure**—pressure inside respiratory tract, usually measured at the alveoli .

Tidal volume

Tidal volume = volume of air moved into and out of lungs in normal breath

- -Inhalation: Intrapulmonary pressure < atmospheric pressure

  Negative intrapulmonary pressure pulls air into lungs

- -Exhalation: Intrapulmonary pressure > atmospheric pressure

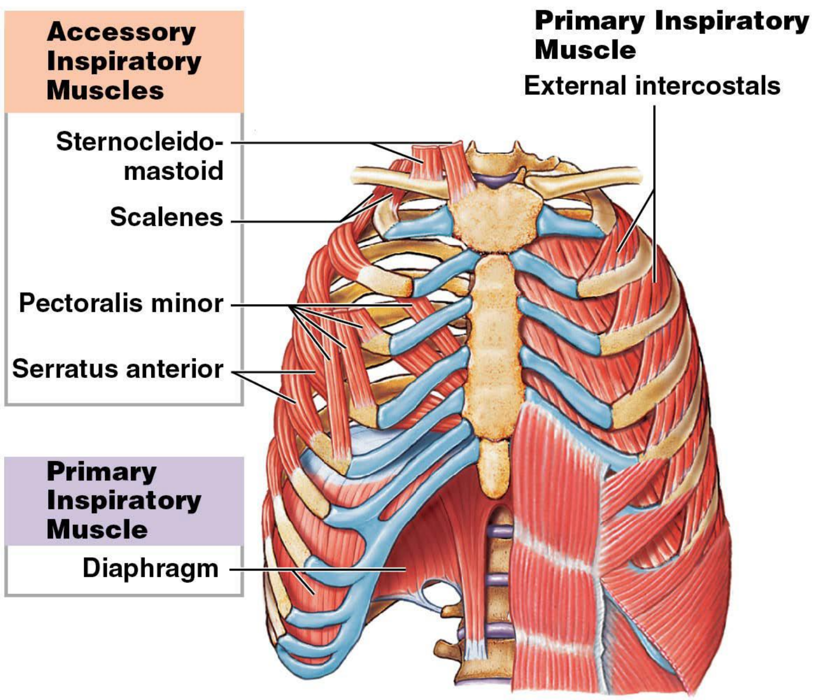
  Positive intrapulmonary pressure pushes air out of lungs

Four Common Units for Reporting Gas Pressures

- **Millimeters of mercury (mm Hg)**: This is the most common unit for reporting blood pressure and gas pressures. Normal atmospheric pressure is approximately 760 mm Hg.
- **Torr**: This unit of measurement is preferred by many respiratory therapists; it is also commonly used in Europe and in some technical journals. One torr is equivalent to 1 mm Hg; in other words, normal atmospheric pressure is equal to 760 torr.
- **Centimeters of water (cm H_2O)**: In a hospital setting, anesthetic gas pressures and oxygen pressures are commonly measured in centimeters of water. One cm H_2O is equivalent to 0.735 mm Hg; normal atmospheric pressure is 1033.6 cm H_2O.
- **Pounds per square inch (psi)**: Pressures in compressed gas cylinders and other industrial applications are generally reported in psi. Normal atmospheric pressure at sea level is approximately 15 psi.

Respiratory muscles

- **inspiratory muscles** (inhalation).
- **Primary inspiratory muscles**—diaphragm, external intercostals.
- **Accessory inspiratory muscles:** Sternocleidomastoid, Scalenes, Pectoralisminor, Serratusanterior and Increase speed/amount of rib
- **expiratory muscles**(exhalation).



Respiratory volumes

- **Tidal volume (VT)**:Amount of air moved in or out of lungs during single respiratory cycle at rest (normal quiet breathing)and Averages 500 mL.

- **Inspiratory reserve volume**(**IRV**):Amount of air you can breathe in beyond tidal volume.
- **Expiratory reserve volume** (**ERV**):Amount of air you can exhale beyond tidal volume (after normal exhalation).
- **Residual volume :**Amount of air left in lungs after maximal exhalation
- **Minimal volume:** Amount of air in the lungs if they were allowed to collapse, Included in residual volume and Cannot be measured in a healthy person.

Respiratory capacities

Respiratory capacities: calculated by taking sum of various respiratory volumes:

VT = tidal volume, IRV = inspiratory reserve volume, ERV = expiratory reserve volume

- **Inspiratory capacity**: VT+ IRV Amount of air you can inhale after normal exhalation.
- **-Vital capacity**: ERV + VT+ IRV Maximum amount of air you can move in or out of lungs per cycle.
- **-Functional residual capacity**(**FRC**):ERV + residual volume Amount of air remaining in lungs after complete quiet cycle.

- **-Total lung capacity:** Vital capacity + residual volumeTotal volume of lungs, Averages 6000 mL in adult males, 4200 mL in adult females .

Sex differences in respiratory volumes and capacities

Sex Differences

	Males	Females
VT	500 mL	500 mL
IRV	3300 mL	1900 mL
ERV	1000 mL	700 mL
Residual volume	1200 mL	1100 mL
Total lung capacity	6000 mL	4200 mL
Vital capacity	4800 mL	3100 mL
Inspiratory capacity	3800 mL	2400 mL
Functional residual capacity	2200 mL	1800 mL

Respiratory Minute Volume

$$V_E = f \times V_T$$

$$\left(\text{Volume of air moved each minute}\right) = \left(\text{Respiratory rate}\right) \times \left(\text{Tidal volume}\right)$$

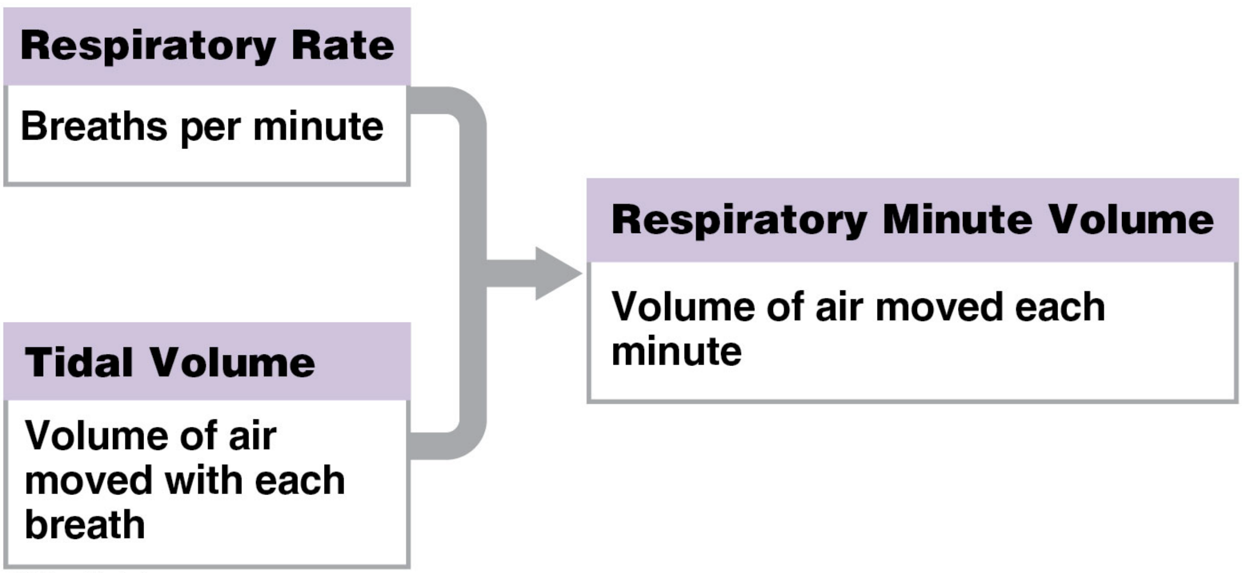
$= 12 \times 500$ mL per minute

$= 6000$ mL per minute

$= 6.0$ liters per minute

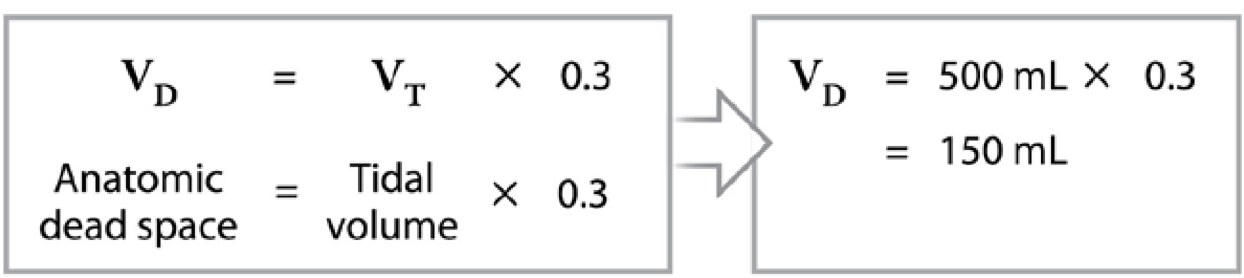
In other words, the respiratory minute volume at rest is approximately 6 liters per minute.

Because the respiratory minute volume is determined by multiplying respiratory rate and tidal volume, altering either factor will change the respiratory minute volume



Alveolar ventilation(**VA**) = amount of air reaching alveoli/minute

Some air never reaches alveoli; remains in conducting portion of lungs (= **anatomic dead space**—VD) At rest, averages ~150 mL



Alveolar ventilation :Calculated as breaths per minute multiplied by volume of air in the alveoli ,Volume of air in the alveoli is tidal volume (VT) minus anatomic dead space (VD)

$$VA= f\times(VT-VD)$$

$$V_A = f \times V_T - V_D$$

$$\text{Alveolar ventilation} = \text{Breaths per minute} \times \left(\text{Tidal volume} - \text{Anatomic dead space}\right)$$

$$V_A = 12 \times (500\text{ mL} - 150\text{ mL})$$
$$= 12 \times 350\text{ mL}$$
$$= 4200\text{ mL/min}$$

When demand for oxygen increases, both tidal volume and respiratory rate must be increased.