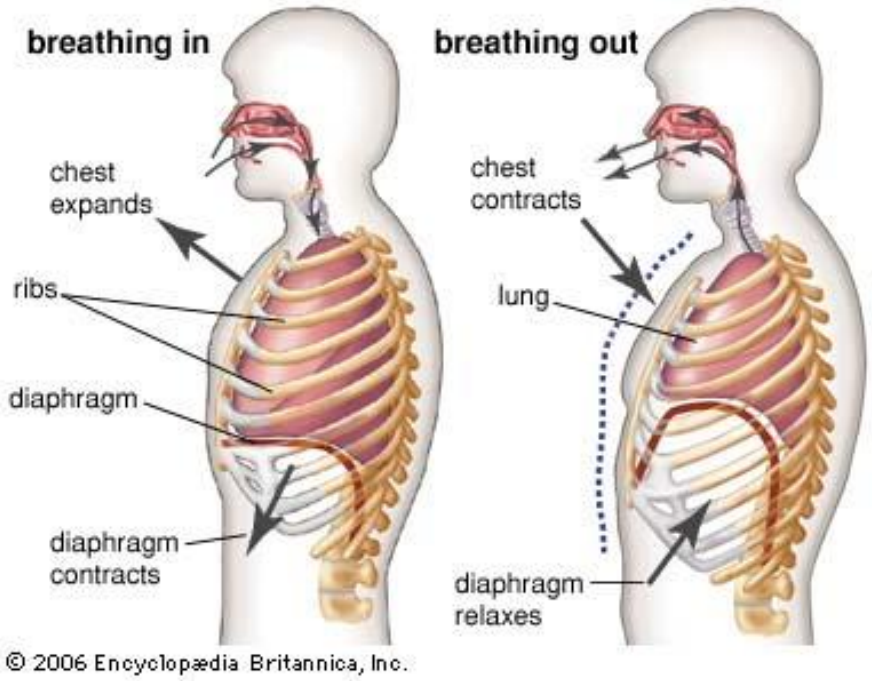
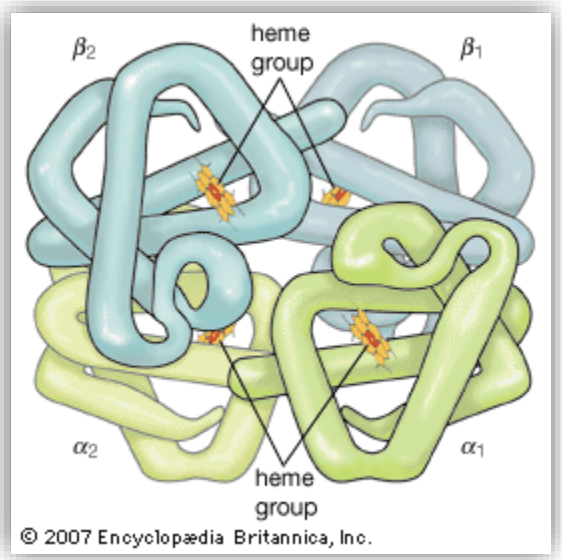
Mechanics of Breathing



Hemoglobin And Gas Transport

Hemoglobin (carrier protein) binds O2. This creates a diffusion gradient since the concentration of O2 is lower in plasma than in the alveolus.

- Hb is composed of four polypeptide subunits containing iron that binds O2
- Hemoglobin is red but much redder when oxygen is attached



Hemoglobin

Hemoglobin

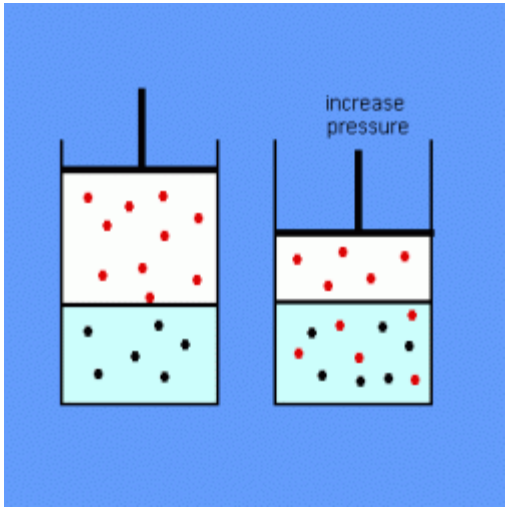
- When red blood cells carrying oxygen reach the tissues of the body, the presence of CO_2 makes the hemoglobin molecule change shape and give up oxygen
- Hemoglobin will then pick up some of the CO_2. The rest of the CO_2 is carried in the cytoplasm of red blood cells that go to the lungs
  - CO_2 combines with water in the cytoplasm to make carbonic acid.
- The rbc's release the CO_2 and the CO_2 moves across the walls of capillaries and into the alveoli where it will eventually be exhaled

Breathing

- **Inspiration**: the act of taking air INTO the lungs, occurs when **pressure** inside the lungs is LOWER than pressure outside the lungs (i.e. atmospheric pressure)
- **Expiration**: the act of breathing OUT, occurs when **pressure** inside the lungs is GREATER than pressure outside the lungs (atmospheric)

Breathing Movements

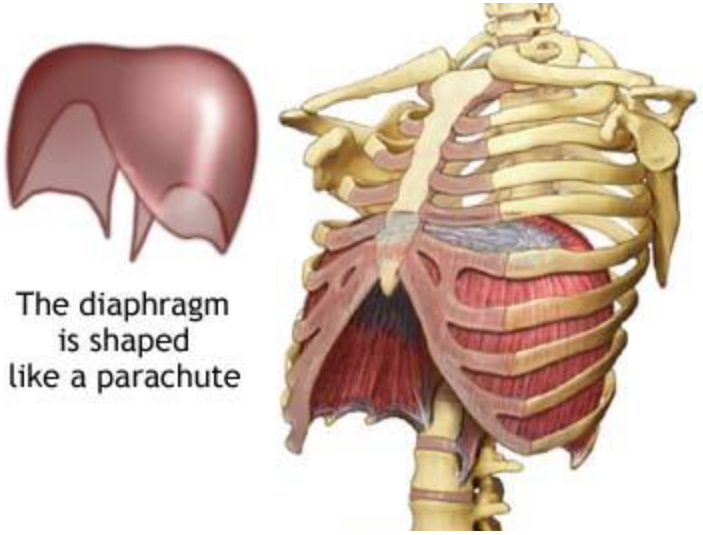
- The body uses **muscles** to change the VOLUME of the thoracic cavity.
- This alters the PRESSURE inside the lungs
- An increase in volume = decrease in pressure (and vice versa)

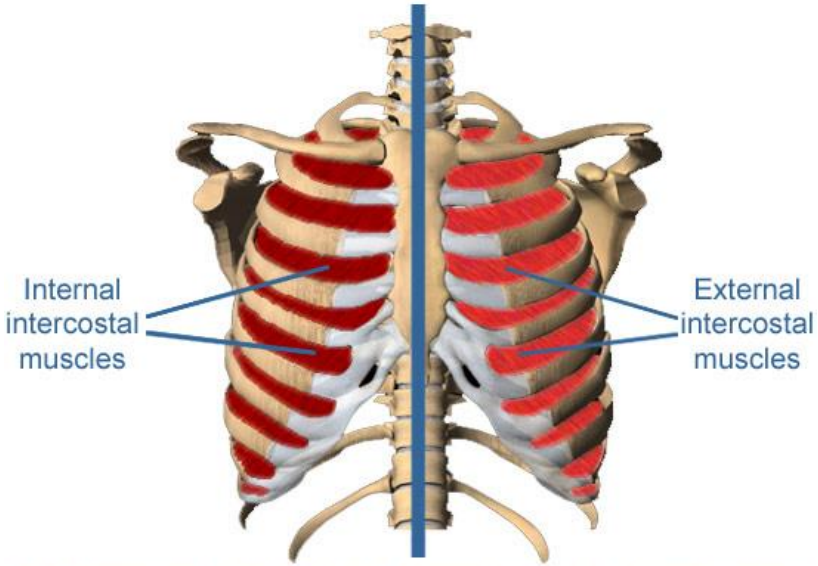


Respiratory Muscles

- **Diaphragm**: dome shaped sheet of muscle separating thoracic and abdominal cavities.

- **Intercostal muscles**: muscles of the ribcage
  - External intercostals: outer surface, pull ribs up
  - Internal intercostals: inner surface, pull ribs down

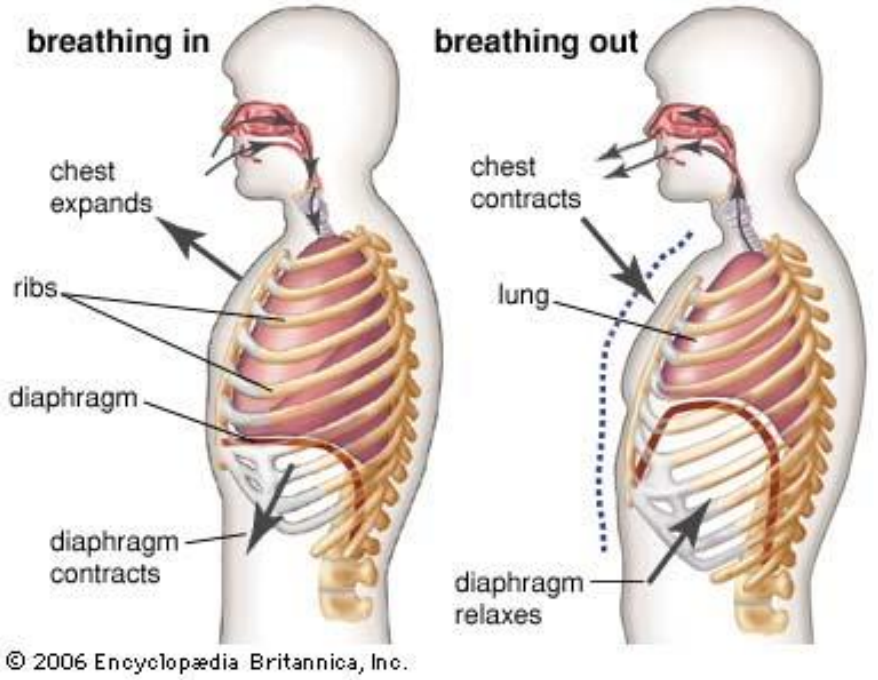




Note: the external muscles are a layer on top of the internal muscles,but for the purposes of illustration the diagram has been split to show the inner layer on the left and the outer layer on the right.

Mechanics of INSPIRATION

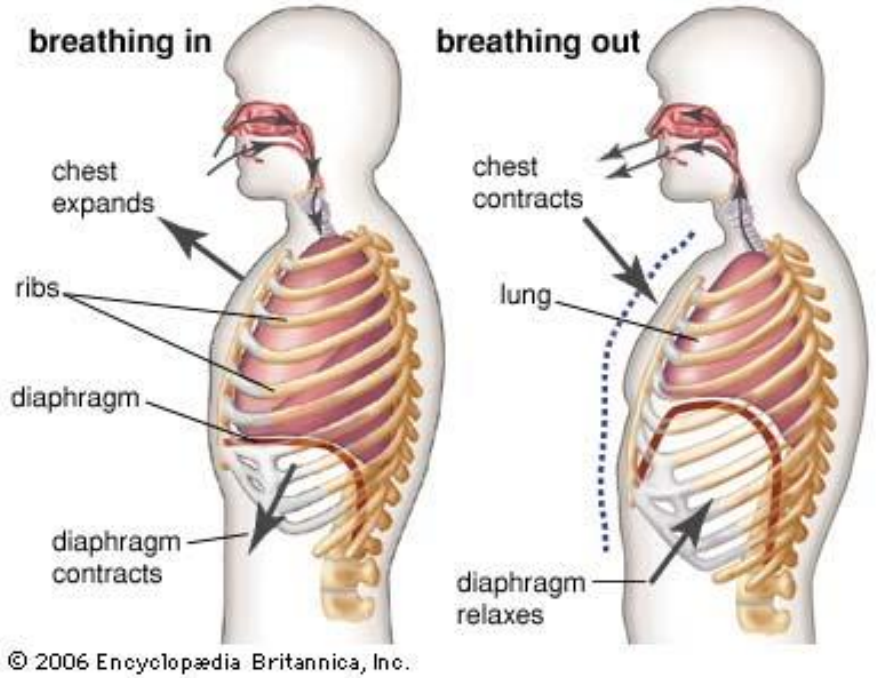
- Diaphragm CONTRACTS and FLATTENS (moves downwards)
- Intercostals CONTRACT and move ribcage UPWARDS
- Pleural membrane pulls on lungs
- Result:
  - Lung volume: INCREASED
  - Pressure inside the lungs: DECREASED
  - AIR MOVES IN



Mechanics of EXPIRATION

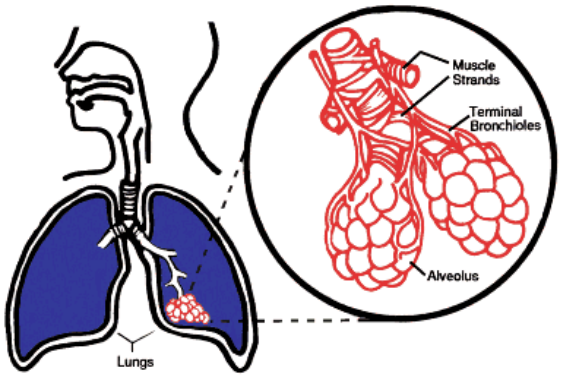
- Diaphragm RELAXES and RETURNS to DOME shape
- Intercostals RELAX and move ribcage DOWNWARDS
- Pleural Membrane no longer pulling on lungs
- Result:
  - Lung volume: DECREASED
  - Pressure inside the lungs: INCREASES
  - AIR MOVES OUT

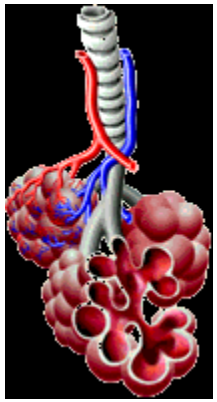
- *Internal intercostals can pull ribs in further to force exhalation

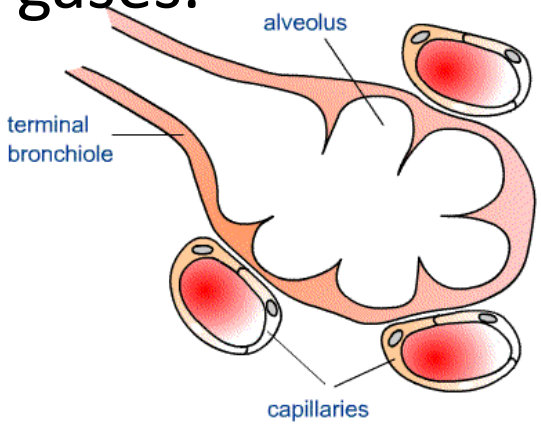


Respiration and Gas Exchange

- Once inside the lungs, air is exchanged with the gases in the bloodstream.
- **External Respiration**: The exchange of O_2 and CO_2 between air and blood (occurs in the lungs).
- The alveoli are surrounded by tiny blood vessels (capillaries); both have walls that are only a single cell layer thick to allow for diffusion of gases.



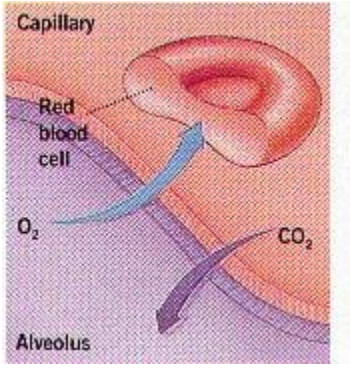




Respiration and Gas Exchange

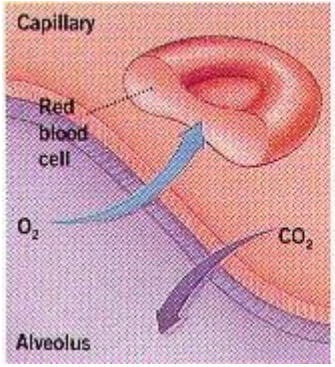
- the gases are exchanged due to differences in CONCENTRATION.
  - O_2 in inhaled air **>** O_2 in blood of capillaries in lungs.
  - CO_2 in inhaled air **<** CO_2 in blood of capillaries in lungs.

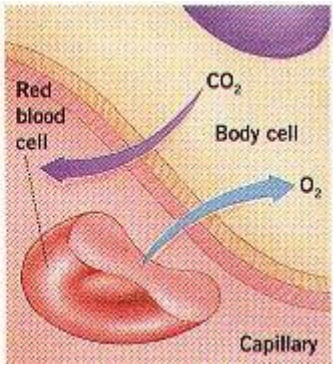
- So in external respiration,
  - O_2 **diffuses** from the alveoli to the capillaries and
  - CO_2 **diffuses** from the capillaries to the alveoli.



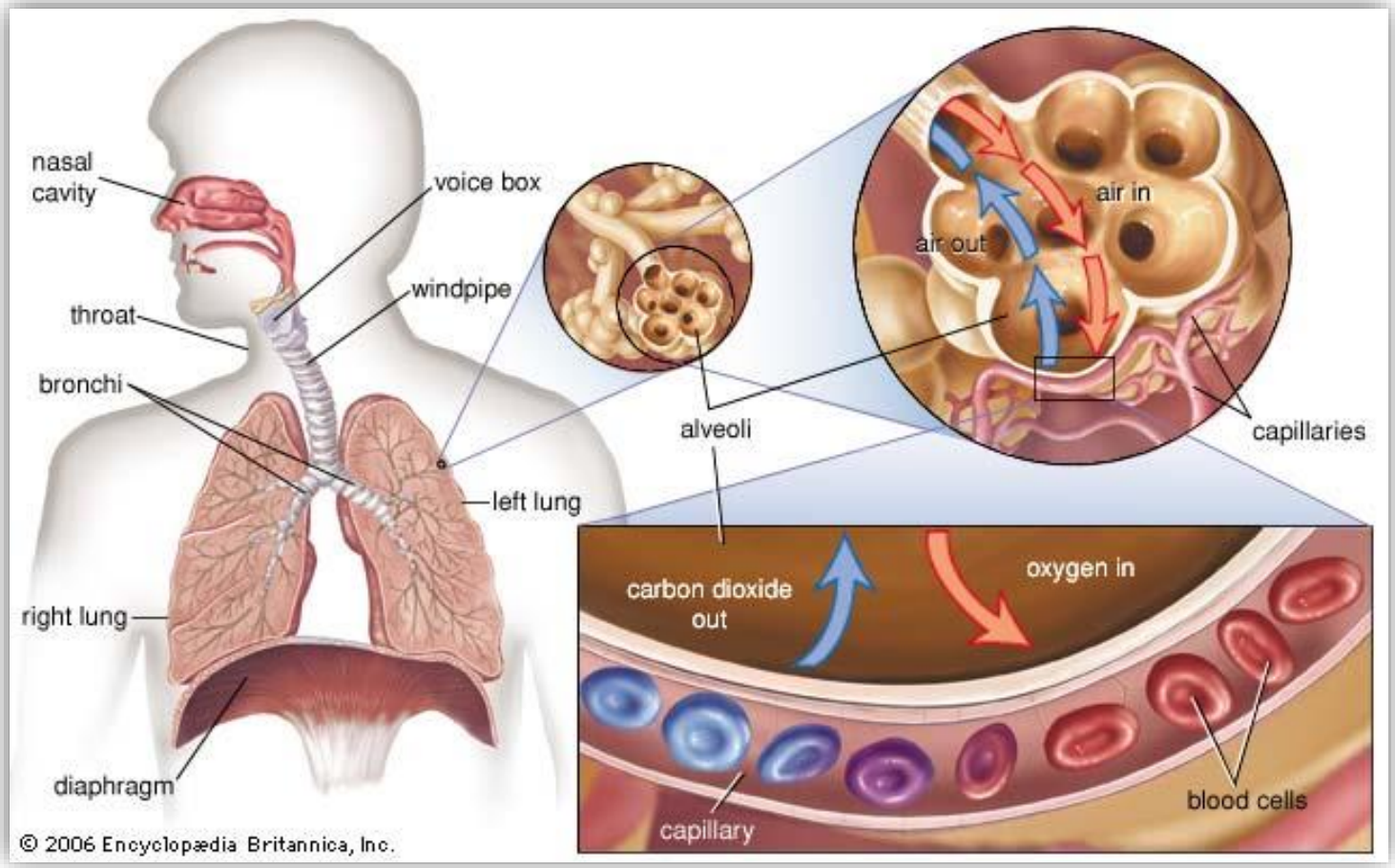
Respiration and Gas Exchange

- Once in the bloodstream, oxygen travels throughout the body.
- **Internal Respiration**: The exchange of O_2 and CO_2 between blood and the cells of the surrounding tissue (occurs in the body tissues).
- As is passes body cells O_2 **diffuses** from the capillaries to the tissue and CO_2 **diffuses** from the tissue to the capillaries.





Gas Exchange Across Alveoli and Capillaries



- When red blood cells carrying oxygen reach the tissues of the body, the presence of CO_2 makes the hemoglobin molecule change shape and give up oxygen

Cellular Respiration

- Organisms use oxygen for cellular respiration to obtain energy from glucose
- glucose + oxygen ---> carbon dioxide + water + useable energy

  $C_6H_{12}O_6 + O_2 \text{ ------> } CO_2 + H_2O + \text{useable energy}$
- Partial pressure of oxygen (P_{o2}) in the alveoli is higher (~13.3 kPa) than the blood in the capillaries surrounding the alveoli (~5.33 kPa). This is a high enough pressure difference to cause O2 to diffuse from the air in the alveoli into the PLASMA of the blood.
- Oxygen is transported two ways: attached to Hb (98.5 %) and dissolved in the blood plasma (1.5%).

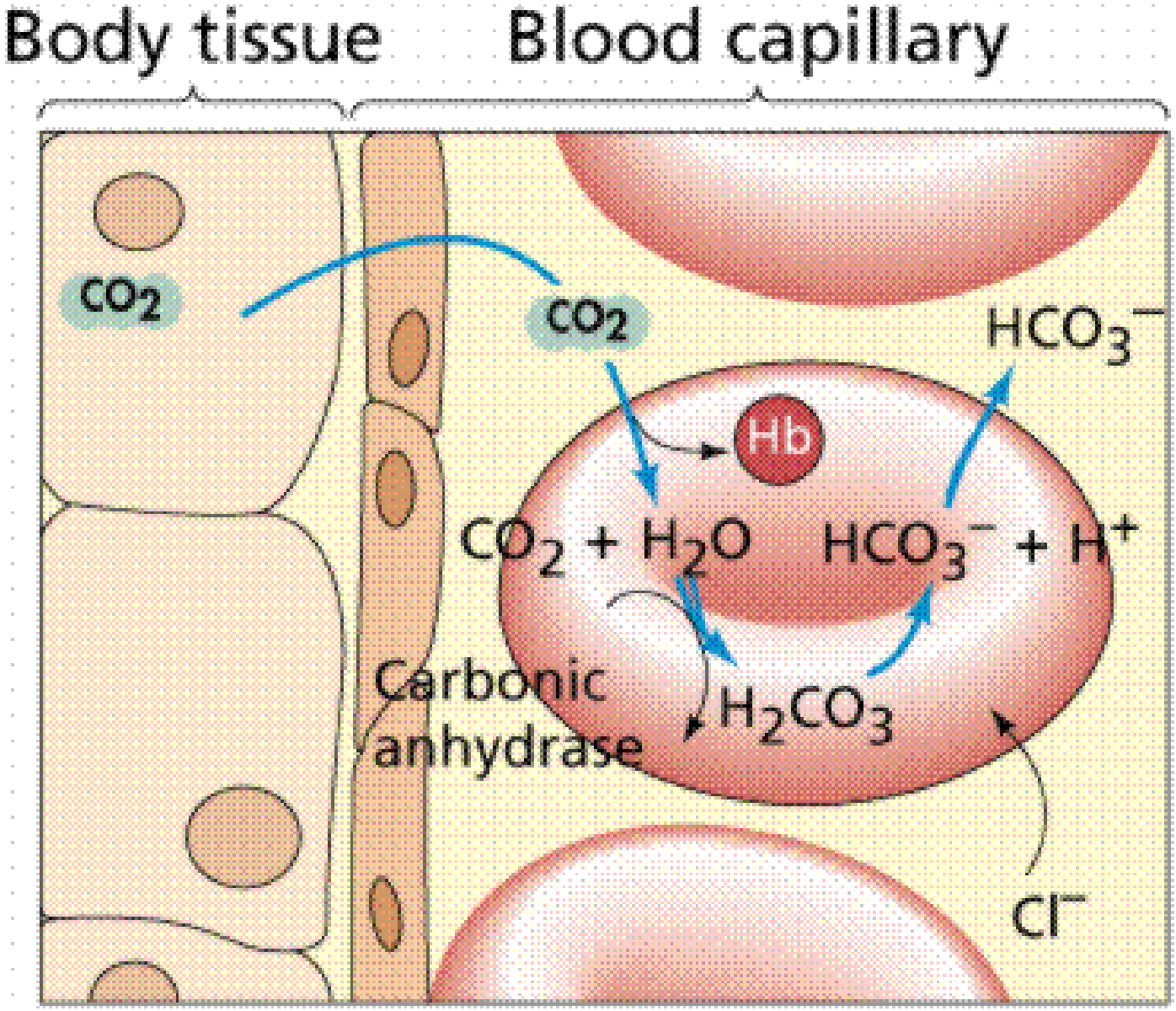
Oxygen vs. Carbon Dioxide

- Hb inc the blood's O2 carrying capacity by ~70 times.
- When O2 containing rbc's reach tissues, O2 in plasma diffuses 1st causing O2 molecules attached to Hb to separate and diffuse 1st into the plasma and then 2nd into the tissue cells.
- Normally the P_{CO2} of tissue fluid is 5.60 kPa which is higher than in capillaries (~5.33 kPa).
- **CO2 is transported 3 ways:**

1. **~7% remains dissolved in the plasma**
2. **~20% attaches to hemoglobin to form carbaminohemoglobin.**
3. **~73% reacts with water in plasma to form carbonic acid that quickly dissociates into HCO3- ions and H+ ions.**

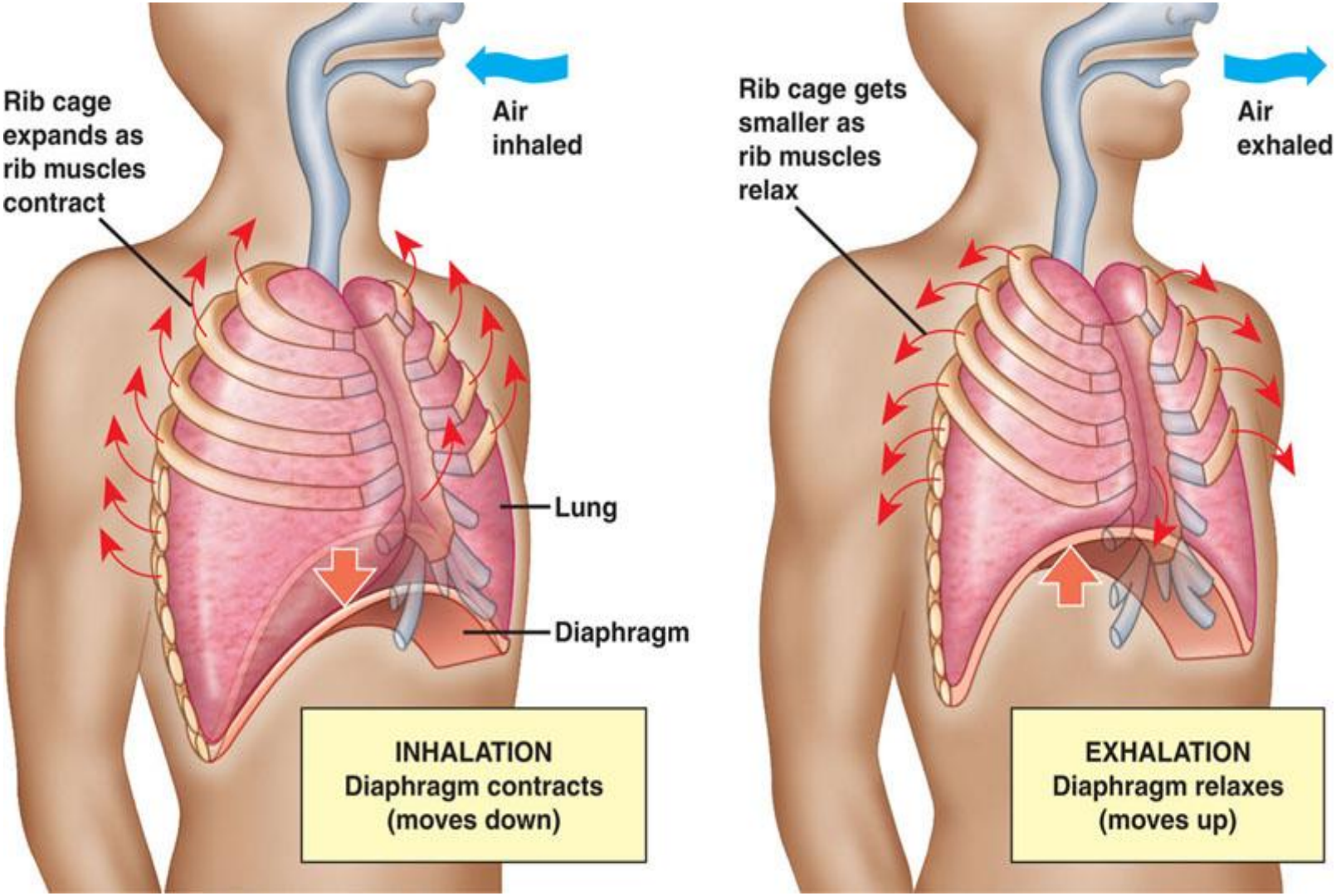
The H+ ion dilemma

- Too many H+ ions = too much acidity in the blood
- Hb to the rescue!! As Hb releases O_2 into tissue cells, it attaches H^+ ions and thus dec. acidity.
- HCO_3- remain dissolved in plasma until the lungs where they react with H^+ ions to re-form CO_2 and H_2O. Then this CO2 mixes with the CO2 carried in dissolved form in the blood plasma.
- Thus, the P_{CO2} of the capillary blood is ~5.60 kPa and the P_{CO2} of the air is ~5.33 kPa causing the diffusion of CO2 out of the lungs.

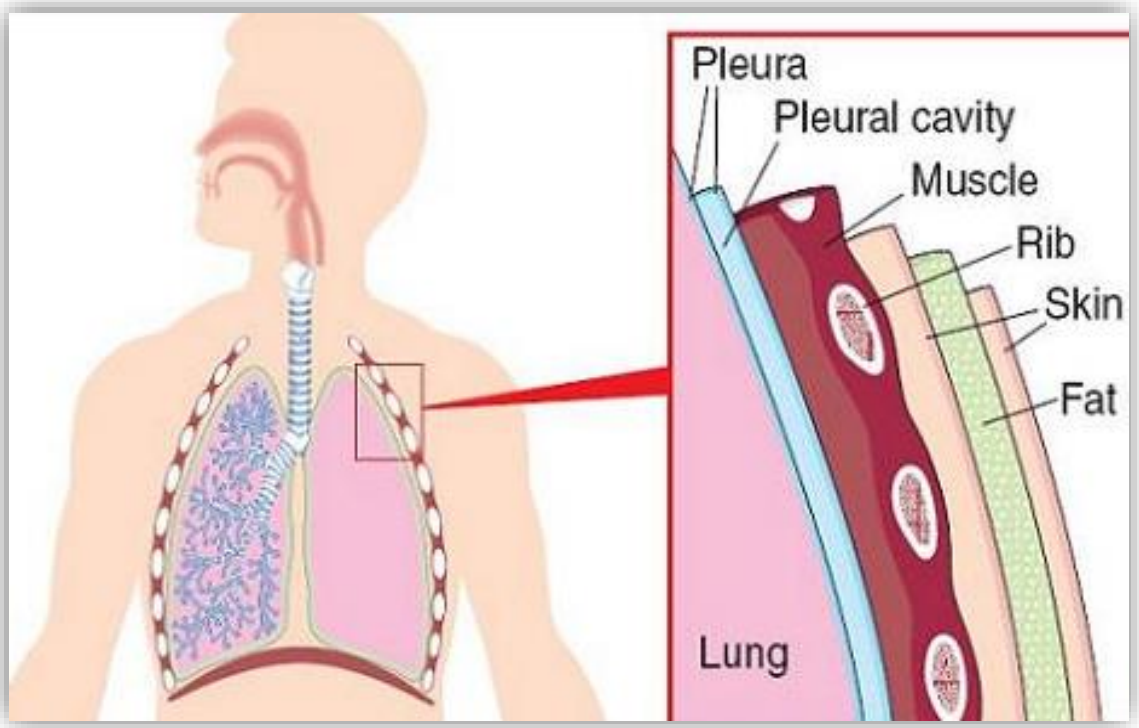

Body tissue
Blood capillary
CO_2
CO_2
HCO_3^-
Hb
$CO_2 + H_2O$
$HCO_3^- + H^+$
Carbonic anhydrase
H_2CO_3
Cl^-

uic.edu

Mechanics Of Breathing



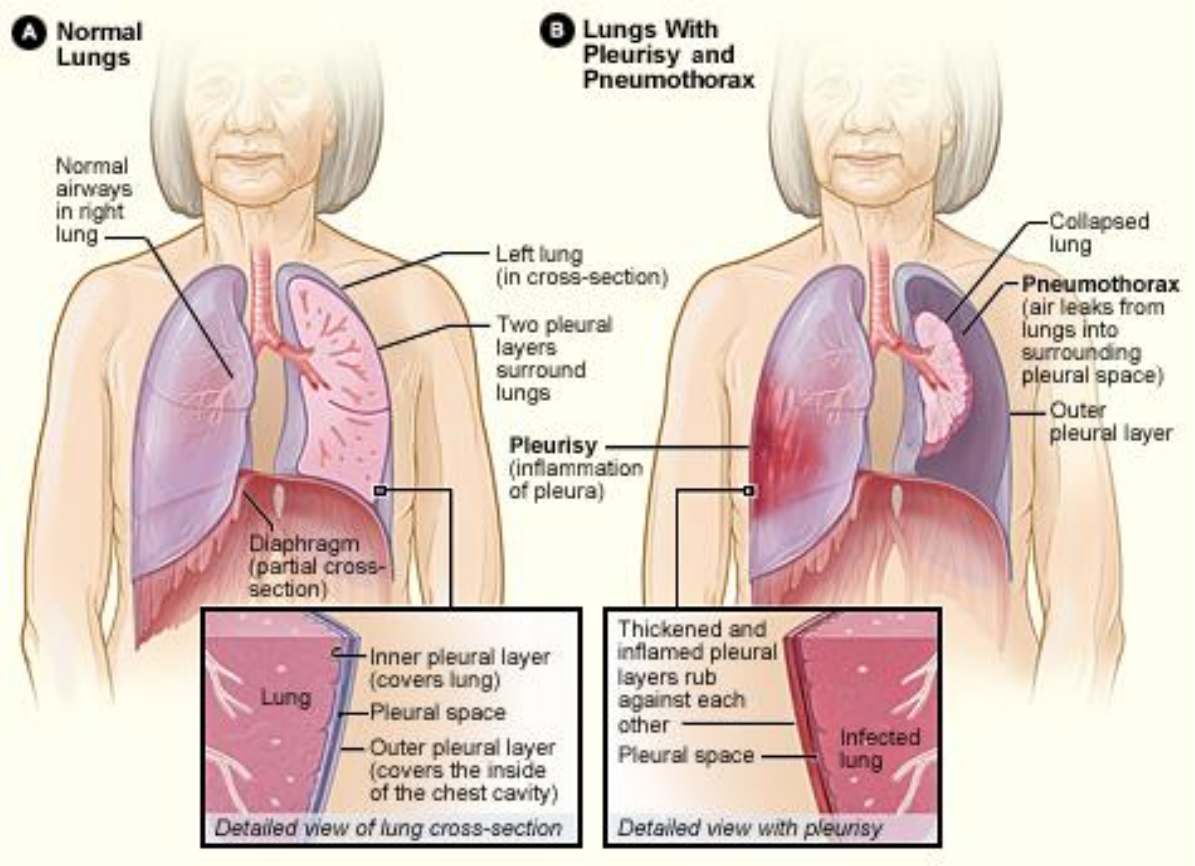
Breathing



- **PLEURA** is a slippery membrane with two layers.
  - the outer pleura is attached to the chest wall
  - the inner pleura covers the lungs
  - between those layers is fluid that lubricates and reduces friction when lungs move against ribs. As the ribs (chest) expands so do the lungs.

Pleurisy: Inflammation of the pleural membranes and the build up of fluids in the chest cavity (caused by the two membranes rubbing together).

- This inc pressure makes exhalation easier but inhalation more difficult.
- Pneumothorax: collasped lung from pleurisy



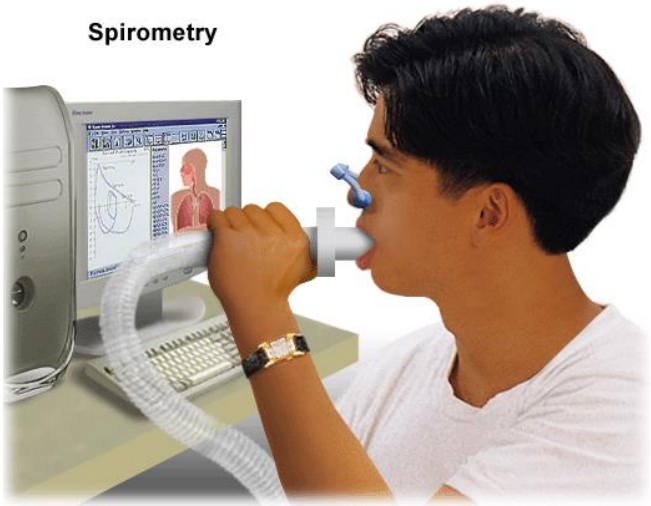
nhlbi.nih.gov

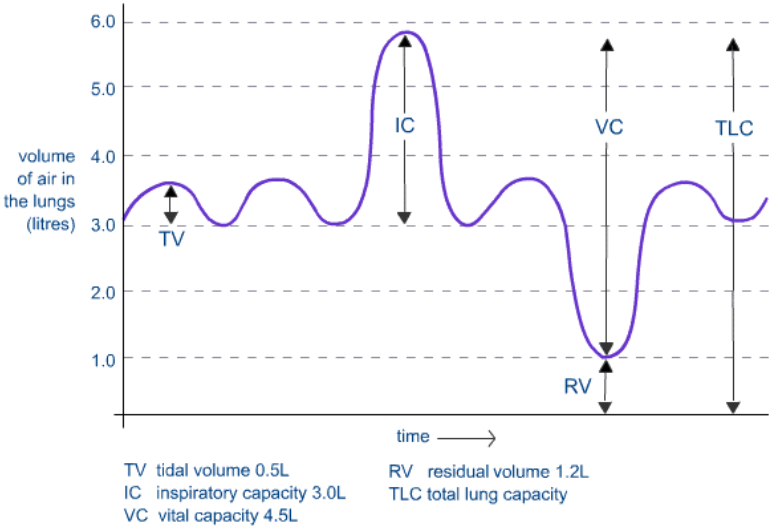
Ventilation

- **DIAPHRAGM**
  - a muscular sheet that consists of 3 overlapping groups of muscle fibers
  - forms the floor of the chest and separates it from the abdomen
  - relaxed, it is dome shaped and it bulges up into the chest
  - contracted, it is flat and the chest is larger

Lung Capacities

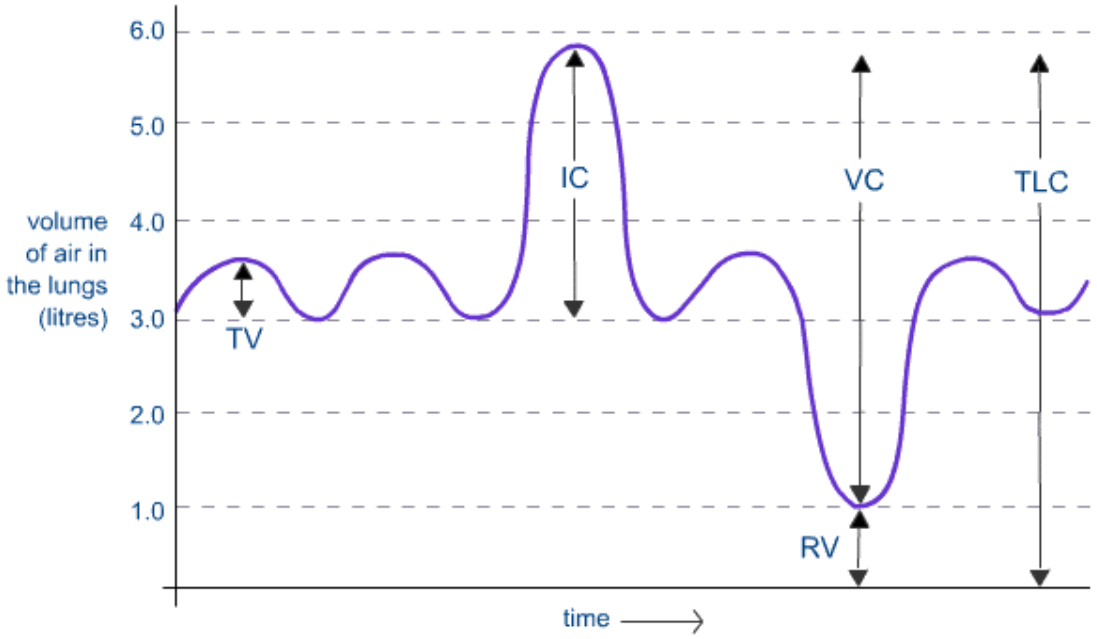
- The full capacity of your lungs is not used up under normal conditions - consider yawning, or blowing out a candle, or exercising.
- A spirometer is used to measure lung capacities and produces a spirograph





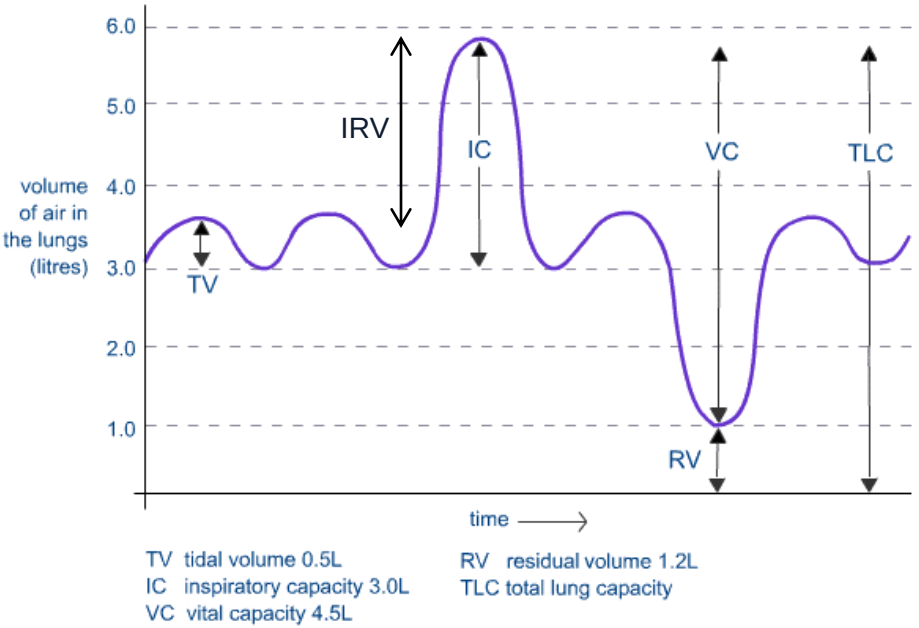
Lung Capacities

- **Tidal Volume**: volume of air inhaled and exhaled in a normal breathing movement



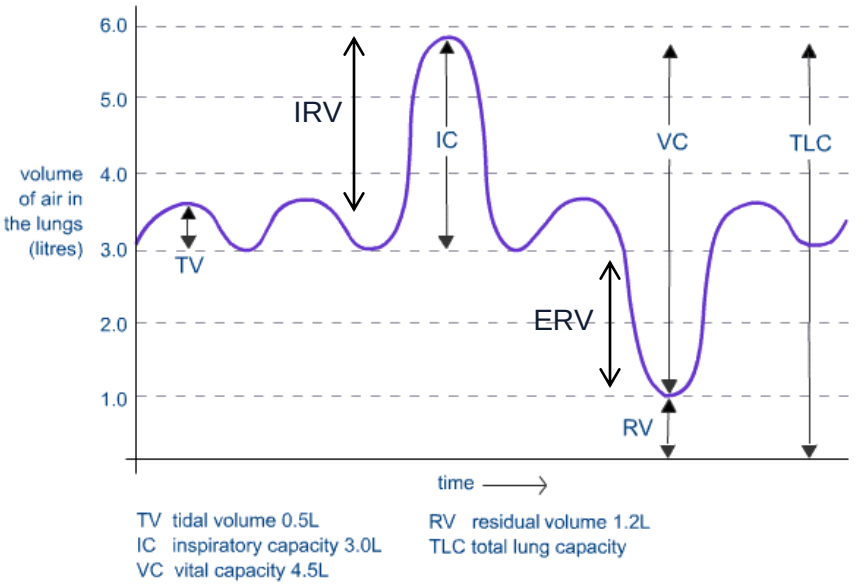
Lung Capacities

- **Inspiratory Reserve Volume**: the additional volume of air that can be taken in, beyond a regular or tidal inhalation.
- **Inspiratory Capacity**: total volume of air that can be taken in
  - (TV + IRV)



Lung Capacities

- **Expiratory Reserve Volume**: the additional volume that can be forced out of lungs
- **Vital Capacity**: the total volume of gas that can be moved in or out of the lungs
  - TV + IRV + ERV = VC



Lung Capacities

- **Residual Volume**: the amount of gas that remains in the lungs and passageways of the respiratory system even after full exhalation (prevents collapse, no value for gas exchange)