# Pulmonary volume and capacities

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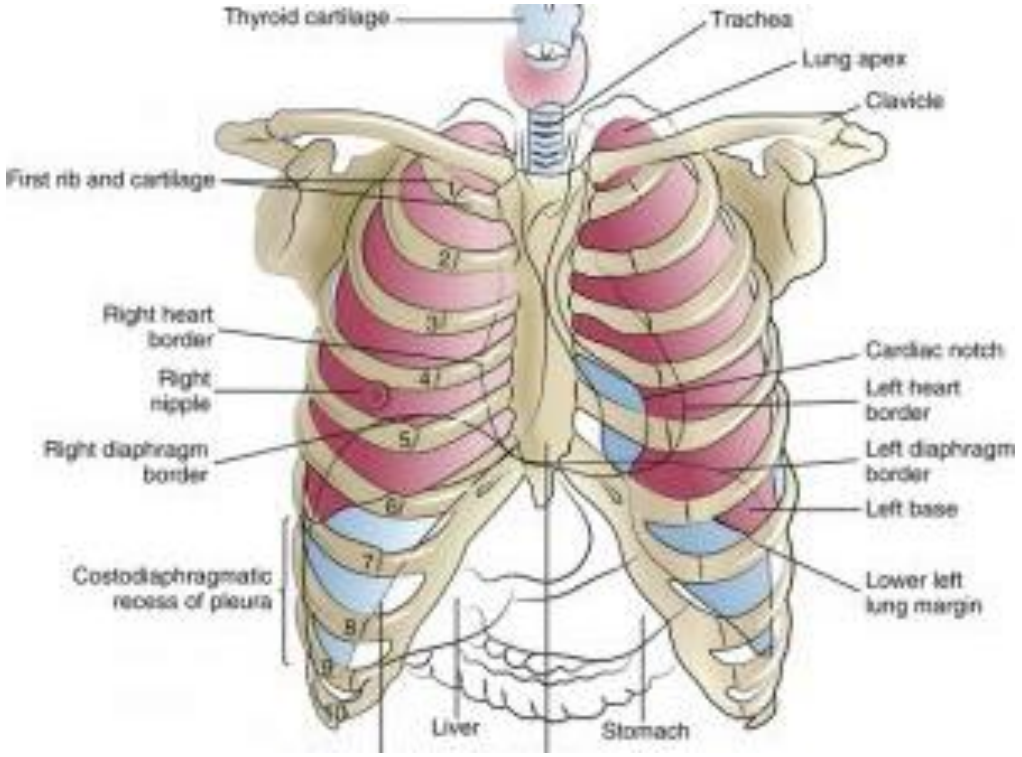
# Quit normal breathing

Inspiration ( negative pressure)

Expiration ( positive pressure)

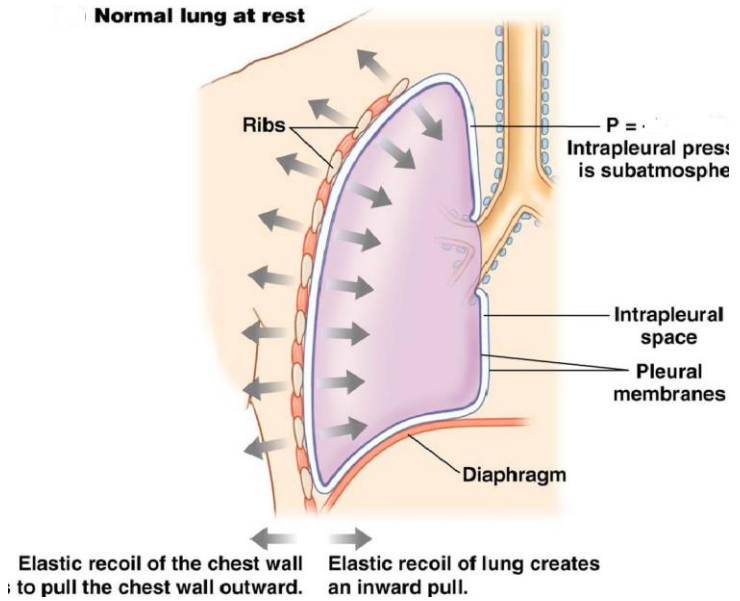
Intrapleural or intrathoracic pressure: is always negative due to dynamic harmonious antagonism between the chest wall and the lung



# Mechanics of breathing

Intra plural pressure

- -5 to -7 normal
- Less negative emphysema
- Zero at birth and stab wound without valve
- Positive stab wound tension pneumothorax with valve and Valsalva maneuver




There are **three types** of pressure:

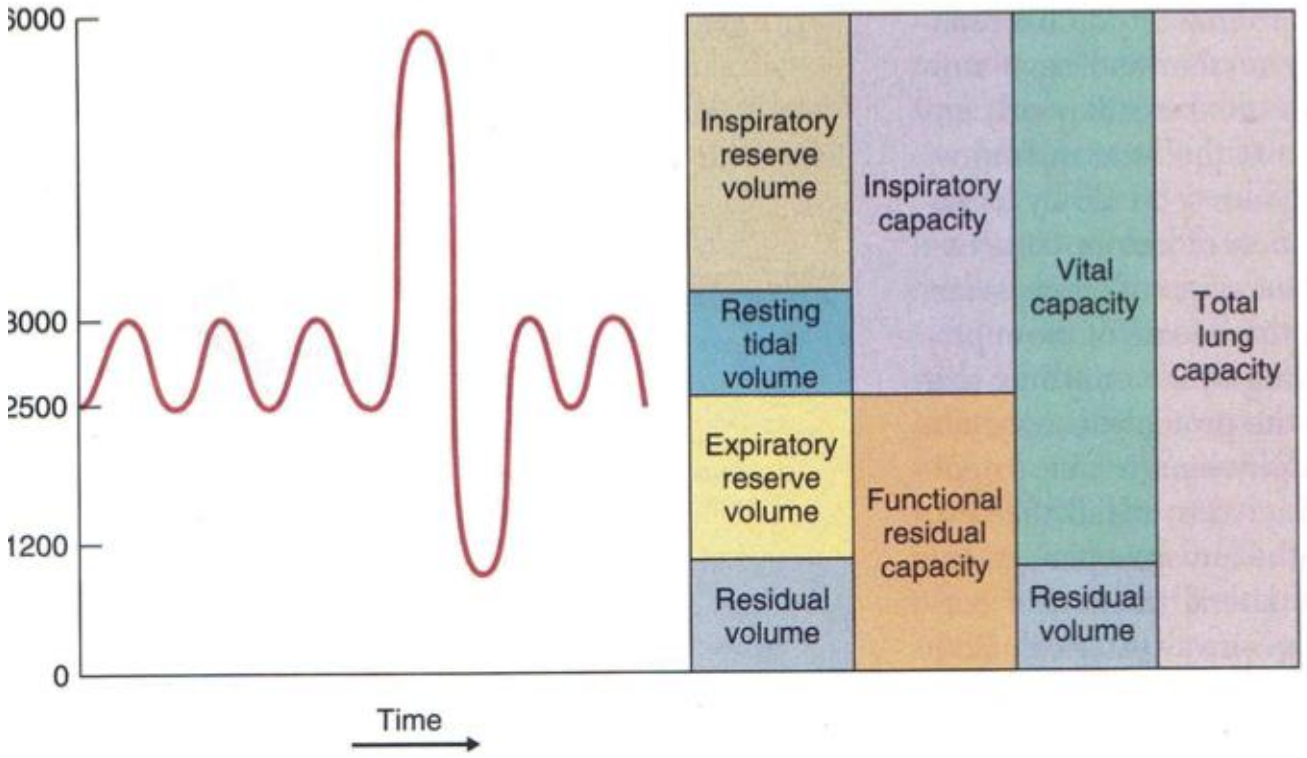
1. Intrapulmonary a.k.a. intra-alveolar. [can be positive or negative]
2. Intrapleural a.k.a. intrathoracic. [always negative]
3. Transthpulmonary a.k.a. transmural: the difference between 1 and 2 [always positive]

- The greater resistance is found in the **bronchi**.
    - That's why **asthma** can be dangerous —> bronchial hyperreactivity —> constriction of bronchi (which already have more resistance than bronchioles) —> decreased radius —> increased resistance —> air cannot exit —> obstructive lung disease.

- Quesiton: is the problem worse during inspiration or expiration?
    - Answer: -expiration, because the airways are narrower —> less radius —> more resistance.
        - so, during expiration, I cannot get the air out (Obstructive lung disease)

| | ***inspiration*** | ***expiration*** |
|---|---|---|
| Nature | active | passive |
| Duration | longer | shorter |
| Dimensions | expansion in 3 dimensions | decrease in 3 dimensions (lung recoils) |
| | increased volume —> decreased pressure (Boyle's law)<br>• *I mean the intrapulmonary (intra-alvelolar pressure)*<br>pressure decreasd to **-1 cmH2O**<br>*assuming that the atmospheric pressure is zero.* | decreased volume —> increased pressure (Boyle's law)<br>• *I mean the intrapulmonary (intra-alvelolar pressure)*<br>pressure increasd to **+1 cmH2O**<br>*assuming that the atmospheric pressure is zero.* |
| Muscles | • Diaphragm: decends.<br>• external intercostals:<br>◦ —> elevate ribs —> increase transverse diameter.<br>◦ —> evert ribs —> increases AP diameter | — passive—<br><br>-diaphragm ascends, lungs shrink by their elastic recoil. |
| Accessory muscles for forced... | Forced inspiration:<br>• Sternocleidomastoid.<br>• serratous anterior<br>• scalene muscles | Forced expiration (voluntary "musical instuments", obstruvtive [COPD], restrictive [fibrosis]):<br>• internal intercostals<br>• abdominal muscles "abdominal recti" [abdominal breathing] |
| Effect on murmurs | Inspiration accentuates the right-sided murmurs ❤️ | Expiration accentuates the murmurs of left side of the heart |

# Lung volume and capacities




- Volume: one thing
- Capacity: more than one volume

Spirometer cannot measure

- RV
- FRV
- TLC

# Residual volume

RV: the air that remains in the lung after maximal forced expiration

**Physiological significance**

Maintain aeration of blood

Prevent sudden flotation of blood gases

**Clinical significance**

Obstructive lung disease ( emphysema)

RV/TLC>30% emphysema  normal =21%

**Forensic significance**

Autopsy

Stillborn  lung will sink in water

Child homicide  lung float on water

VC= IRV+TV+ERV=4600mL

Male=2.5L/m2

Female = 2L/m2

Note

FVC (Timed ) 3600mL and VC ( not timed)  4600mL

Low vital capacity

**Physiological**

Pregnancy

Recumbent position

**Pathological**

Chest wall

Deformities in the bone ( kyphosis, lordosis…..)

Neuromuscular ( muscular dystrophy, myasthenia gravis…….)

Lung Obstructive ( emphysema)and restrictive ( pulmonary fibrosis)

Heart ( congestive heart failure) pulmonary edema

Abdomen Hepatomegaly splenomegaly and ascities

# FEV1/FVC ratio

FEV1/FVC ratio: 4L/5L=80%

FEV1: the amount of air quickly and forcibly exhale in 1 second

FVC: the amount of air quickly and forcibly exhale after maximum inhalation ( timed)

- low FEV1/FVC ratio —> obstructive lung disease
- low TLC —> restrictive lung disease.
- high FEV1/FVC ratio —> restrictive lung disease
- low FEV1/FVC ratio and low TLC —> mixed lung disease (obstructive + restrictive)

# Alveolar ventilation

External respiration

Pulmonary Ventilation

Alveolar ventilation

Perfusion

Diffusion

Internal respiration

Mitochondria

$FIO_2$ $PAO_2$ $PaO_2$ $SaO_2$ Carbmino-Hgb $PVO_2$ $CO_2$ breathout

# Alveolar capillary membrane diffusion ( blood gas barrier)

- Very thin  Fibrosis = 1 micron
- Huge surface area  Pneumonectomy “ Restrictive”
- 6 layers

Fluid lining the alveoli  Pneumonia ( consolidation)

Alveolar epithelium Emphysema

Epithelial basement membrane fibrosis

Fluid in interstitial space capillary endothelium pulmonary edema

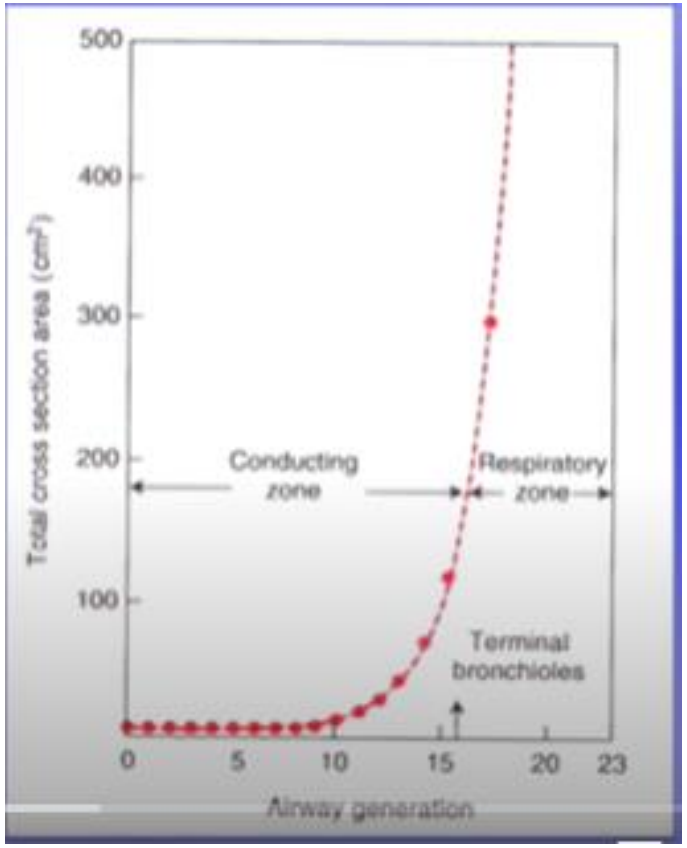
Endothelium basement membrane

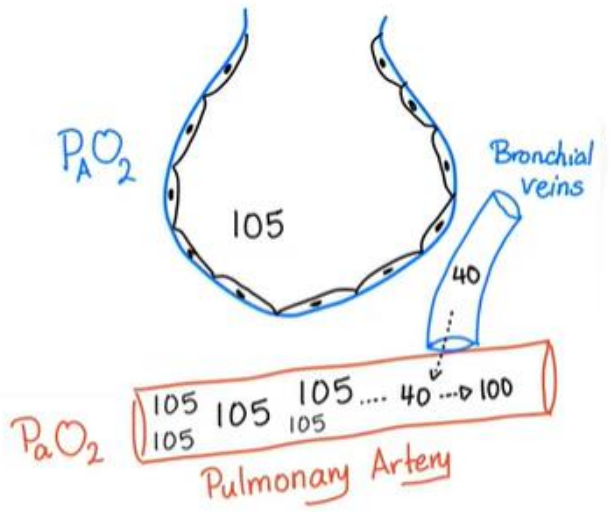
Simple diffusion  no ATP

- $CO_2$ out

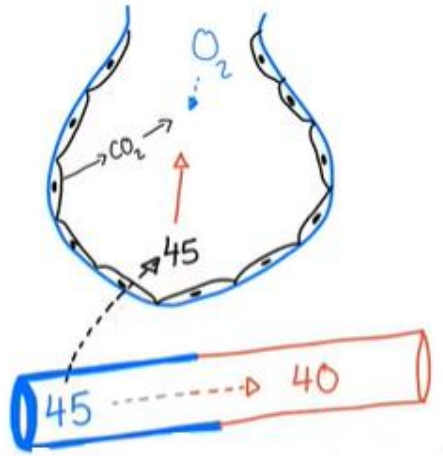
Narrow range of PH 7- 7.7

# Cross sectional area of the airways




$$P_AO_2 = \underbrace{[(P_b - P_{H_2O}) \times F_iO_2]}_{P_iO_2} - \underbrace{\left[\frac{P_aCO_2}{0.8}\right]}_{P_ACO_2}$$




A-a gradient  normal extrinsic restrictive lung disease
A-a  gradient abnormal intrinsic restrictive lung disease

Patient A "normal"

- RR = 12/min, TV = 500 mL
  - Pulmonary ventilation = respiratory rate x tidal volume = 12 x 500 = 6 liters.
  - Alveolar ventilation = respiratory rate x (tidal volume - dead space) = 12 x (500-150) = 12x350 = 4.2 liters.

Patient B "increased respiratory rate"

- RR = 30/min, TV = 200 mL
  - Pulmonary ventilation = respiratory rate x tidal volume = 30 x 200 = 6 liters.
  - Alveolar ventilation = respiratory rate x (tidal volume - dead space) = 30 x (200 - 150) = 1.5 liters.

Patient C "increased tidal volume"

- RR = 6/min. TV=1,000 mL
  - Pulmonary ventilation = respiratory rate x tidal volume = 6 x 1000 = 6 liters.
  - Alveolar ventilation = respiratory rate x (tidal volume - dead space) = 6 x (1000-150)= 5.1 liters.

Therefore, increasing the tidal volume is a better way to achieve more alveolar ventilation than increasing the respiratory rate.

- But, everything is good within limits.
  - if you increase the tidal volume too much —> the alveoli will expand tremendously (inspiration) and then collapse (expiration)…This big difference, repeated over and over again, can lead to INFLAMMATION!