Breathing Mechanics

L.D. Lord

Outline

- Ventilation vs Respiration
- “Dead space”, “Alveolar”, and “Minute”-ventilation
- Primary & Accessory muscles of respiration
- Respiratory system pressures (alveolar, intrapleural)
- Clinical application: Pneumothorax
- Role of surfactant
- Spirometry
- Practice Questions (WooClap!)

Ventilation vs Respiration

- **“Breathing” = Ventilation + Respiration**
- **Ventilation =** the process by which we move air into and out of the lungs to enable gas exchange
- **Respiration =** gas exchange (CO_2 for O_2), deep in lungs, between alveoli and pulmonary capillaries **[external respiration]** as well as gas exchange between tissues and the bloodstream **[internal respiration]**

Ventilation vs Respiration: Anatomical Considerations

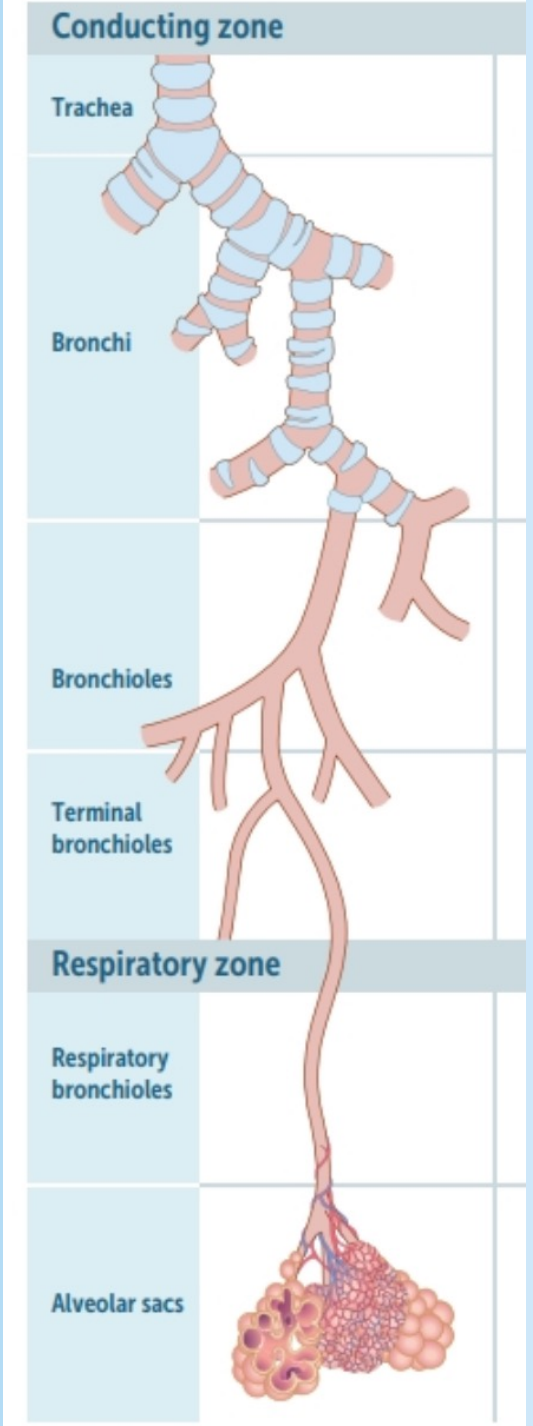
- **<u>Conducting zone:</u>**

trachea → 1° bronchus → 2° bronchi → 3° bronchi → bronchioles → terminal bronchioles → …

- **<u>Respiratory zone* (gas exchange):</u>**

respiratory bronchioles → **alveoli**

Gas exchange is exclusive to the respiratory zone



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Dead space ventilation

- NOT all the air we breathe participates in gas exchange

- **Anatomic dead space:**

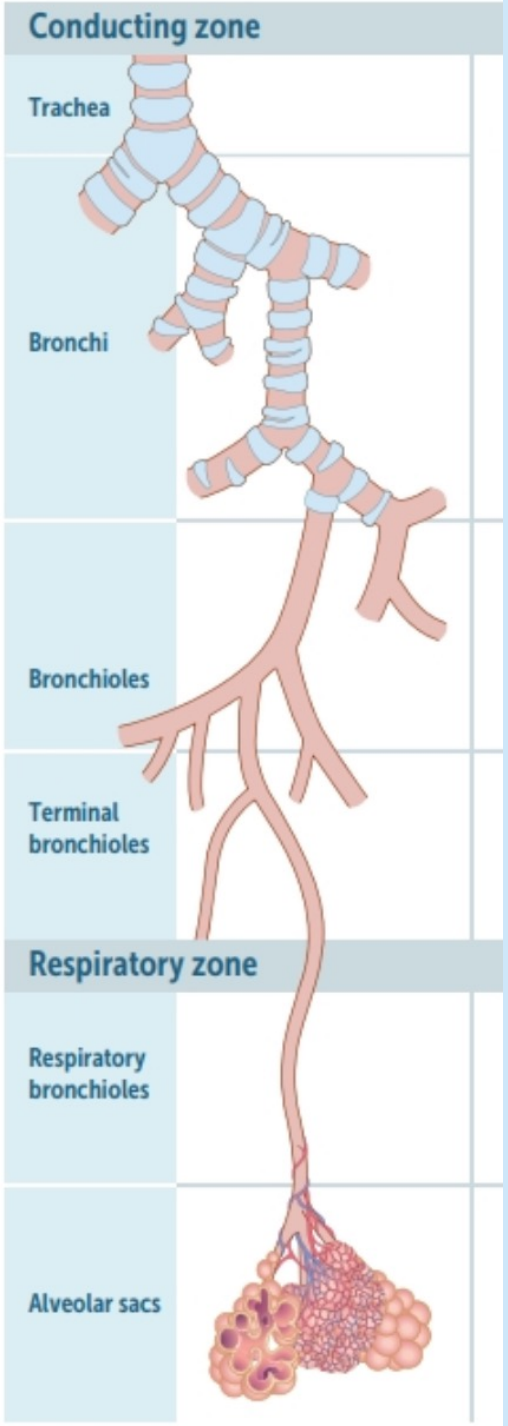
Areas of the lung that are **structurally incapable of gas exchange**: trachea, bronchi, and terminal bronchioles

- **Alveolar dead space :**

Alveoli that do not participate in gas exchange due to **insufficient perfusion** (usually pathological)

- **Physiologic (total) dead space :**

Anatomic dead space + Alveolar dead space



Minute ventilation (VE)

- **Minute ventilation (VE)** = rate of air entering the lungs per minute (ml / min)

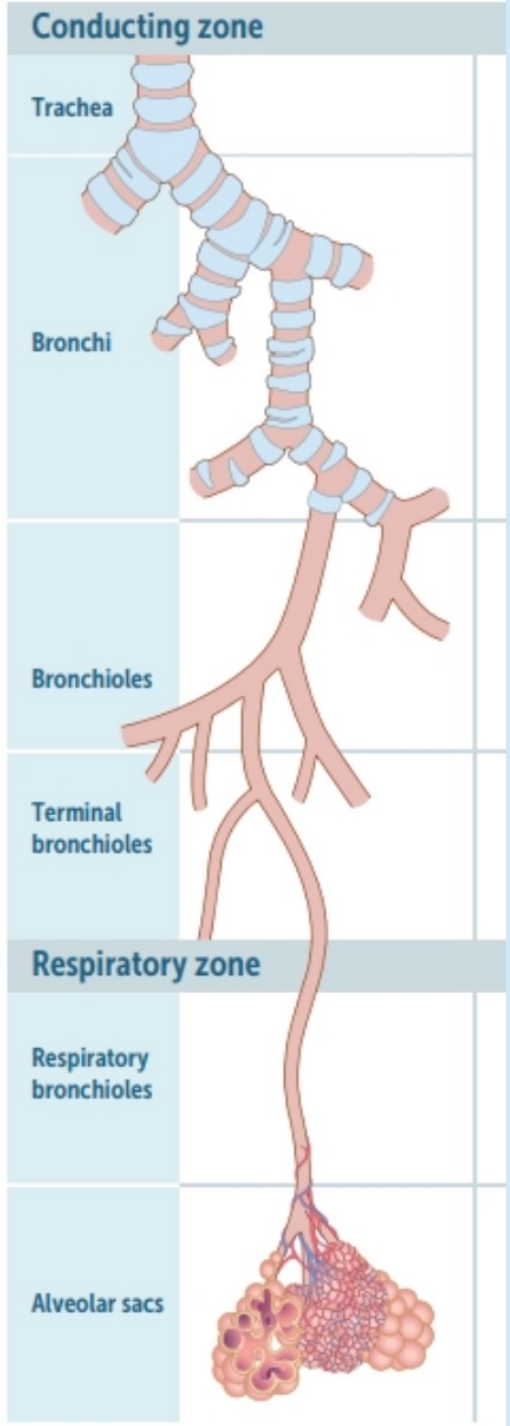
[does not matter whether or not air reaches alveoli and participates in gas exchange]

$VE = V_t * RR$

V_t = tidal volume* (ml) (~500ml)

RR = respiratory rate

**Tidal volume is the amount of air that moves in or out of the lungs with each respiratory cycle*



Alveolar ventilation

- **Alveolar ventilation (V_a)** = rate of air (ml / min) that reaches the alveoli and participates in gas exchange

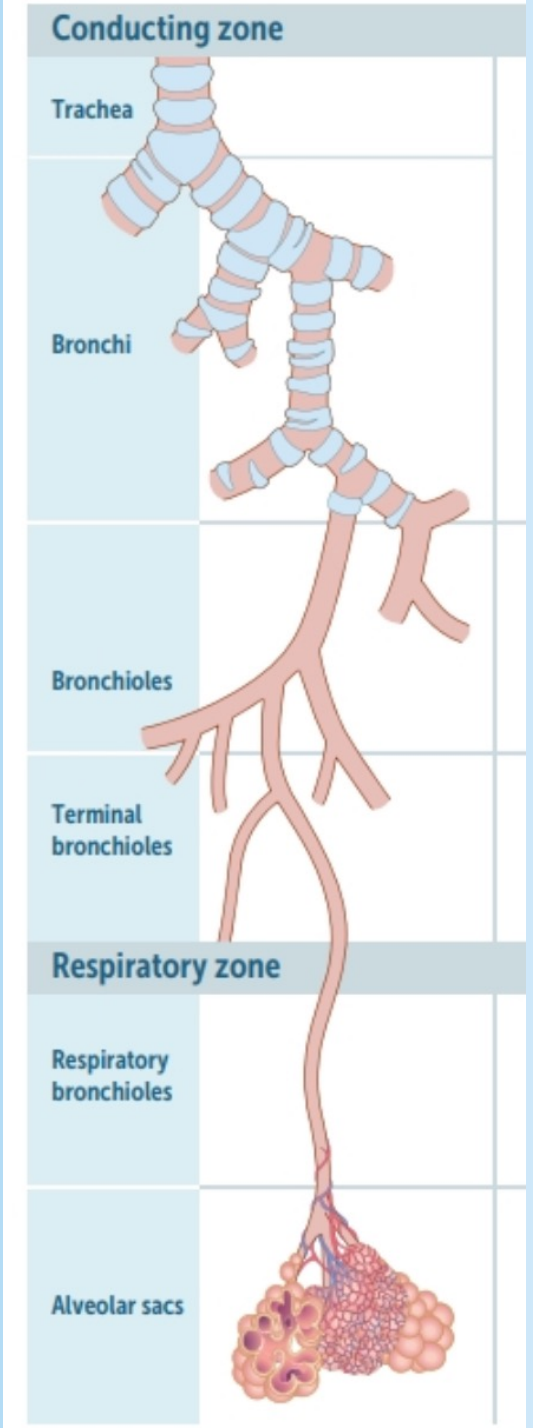
$V_a = (V_t - V_d) * RR$

V_t = tidal volume (ml) [~500ml]

V_d = total dead space (ml)

RR = respiratory rate

**Tidal volume is the amount of air that moves in or out of the lungs with each respiratory cycle*



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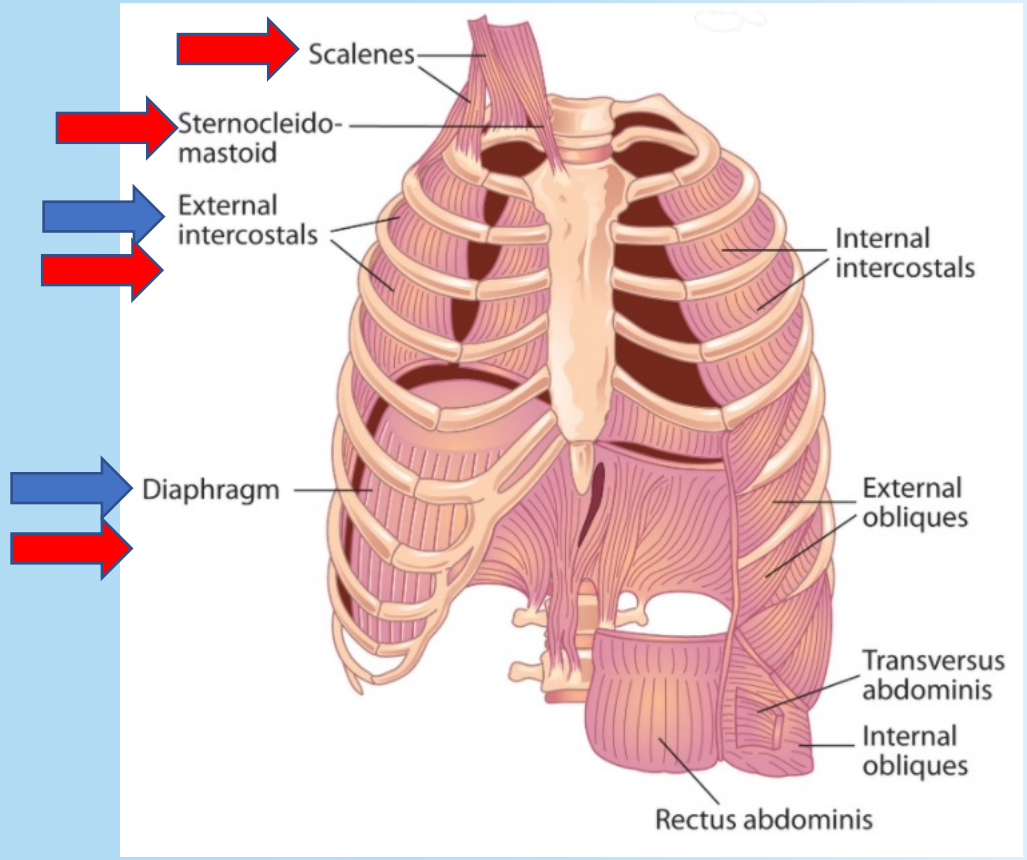
Muscles of Respiration: Inspiration

- **Normal / quiet inspiration** is driven by the **diaphragm*** with some assistance from the **external intercostal muscles**

- **Deep / forced inspiration** requires the diaphragm + external intercostals, but **in addition to these: SCM**, **scalenes**, serratus anterior



diaphragm contracts during inspiration*

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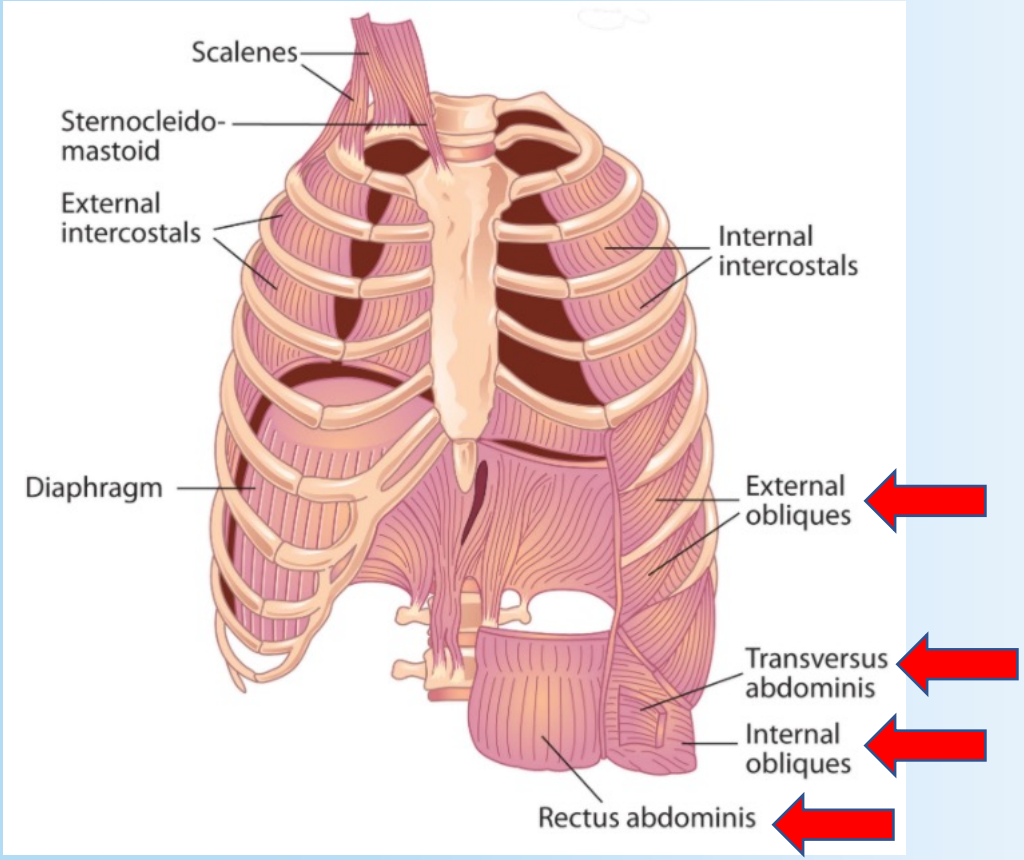
Muscles of Respiration: Expiration

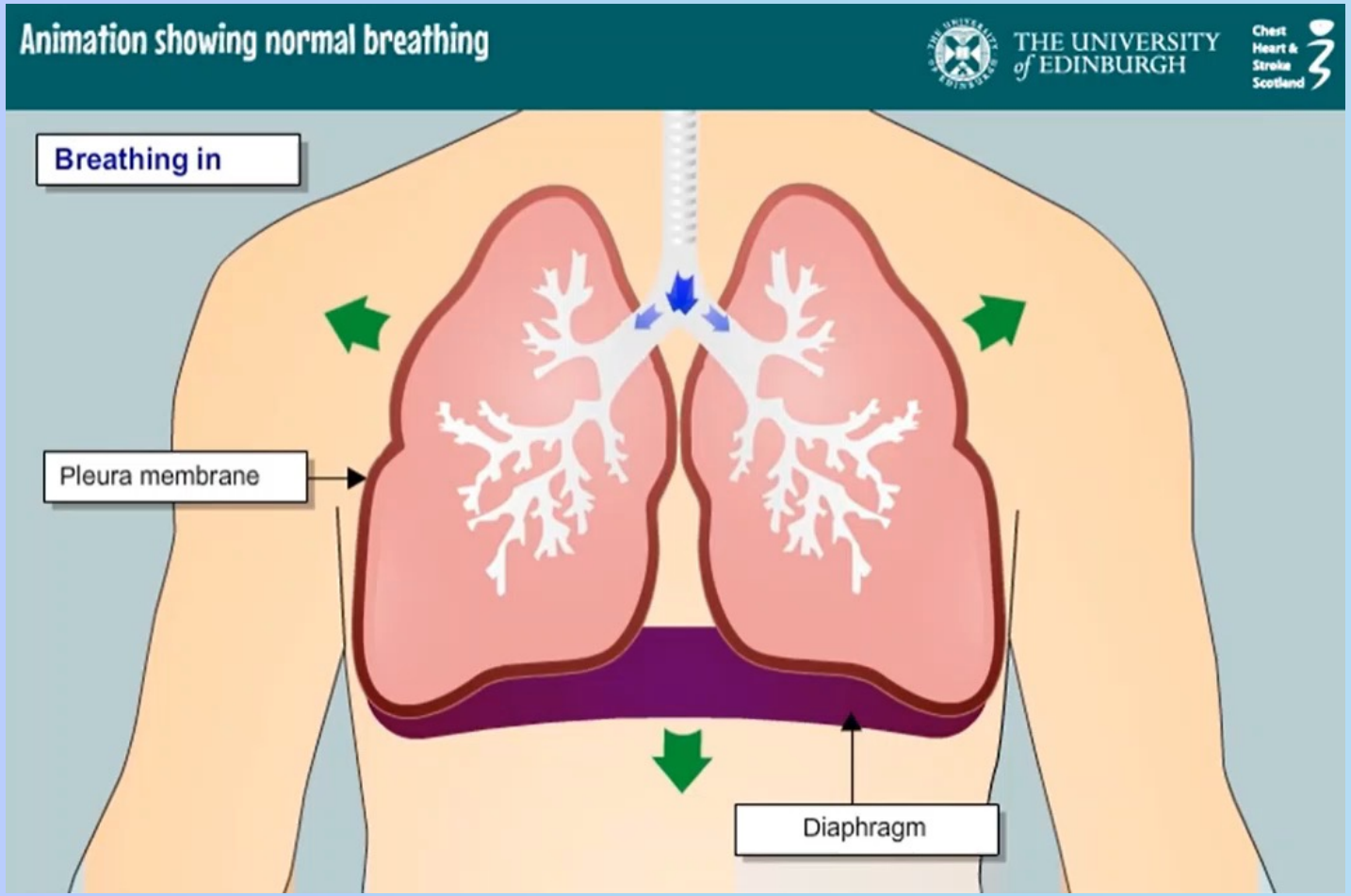
- **Normal / quiet expiration** is a **passive activity** that occurs once the diaphragm relaxes

- **Deep / forced expiration**

principally involves **abdominal muscles: rectus+transeversus abdominis, internal+external obliques**



Q: What`s the goal of all this muscle activity?
A: To create pressure gradients (so you can breathe)



Boyles Law: $P_1V_1 = P_2V_2$

$$P \propto \frac{1}{V}$$

Inspiration

Diaphragm contracts (flattens)

lung/alveolar vol ↑

alveolar pressure ↓

$P_{atm} > P_{alveolar}$

Air flows into the lungs

☆ As with any fluid, air wants to flow **DOWN its pressure gradient**

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Boyle`s Law. Inspiration & Expiration

Boyles Law: $P_1V_1 = P_2V_2$

$$P \propto \frac{1}{V}$$

Inspiration

Diaphragm contracts (flattens)

lung/alveolar vol ↑

alveolar pressure ↓

$P_{atm} > P_{alveolar}$

Air flows INTO the lungs

Expiration

Diaphragm relaxes

lung/alveolar vol ↓

alveolar pressure ↑

$P_{atm} < P_{alveolar}$

Air flows OUT OF the lungs

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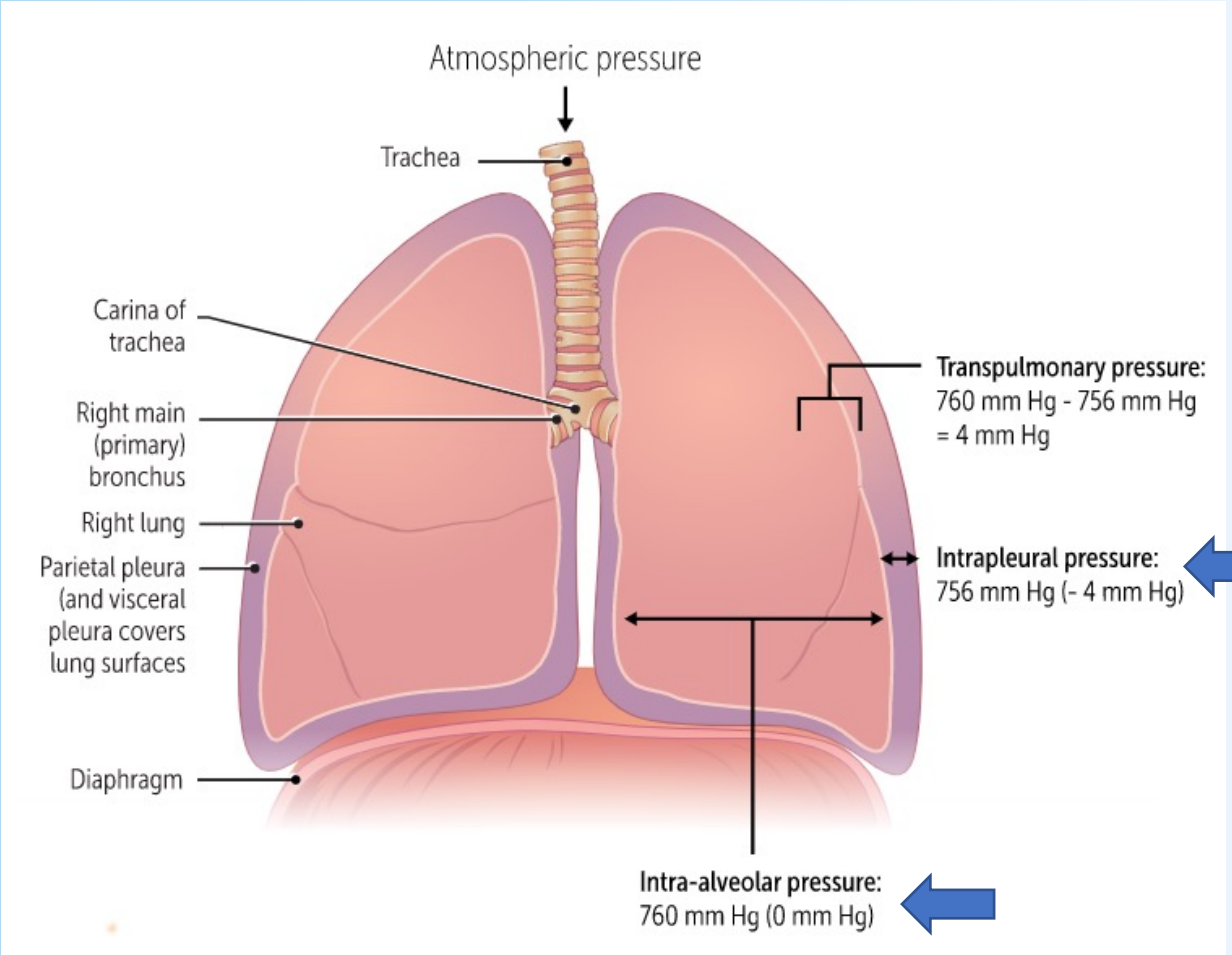
Respiratory system pressures: Overview

- **Intra-alveolar pressure** (aka intrapulmonary pressure)
- **Intrapleural pressure**



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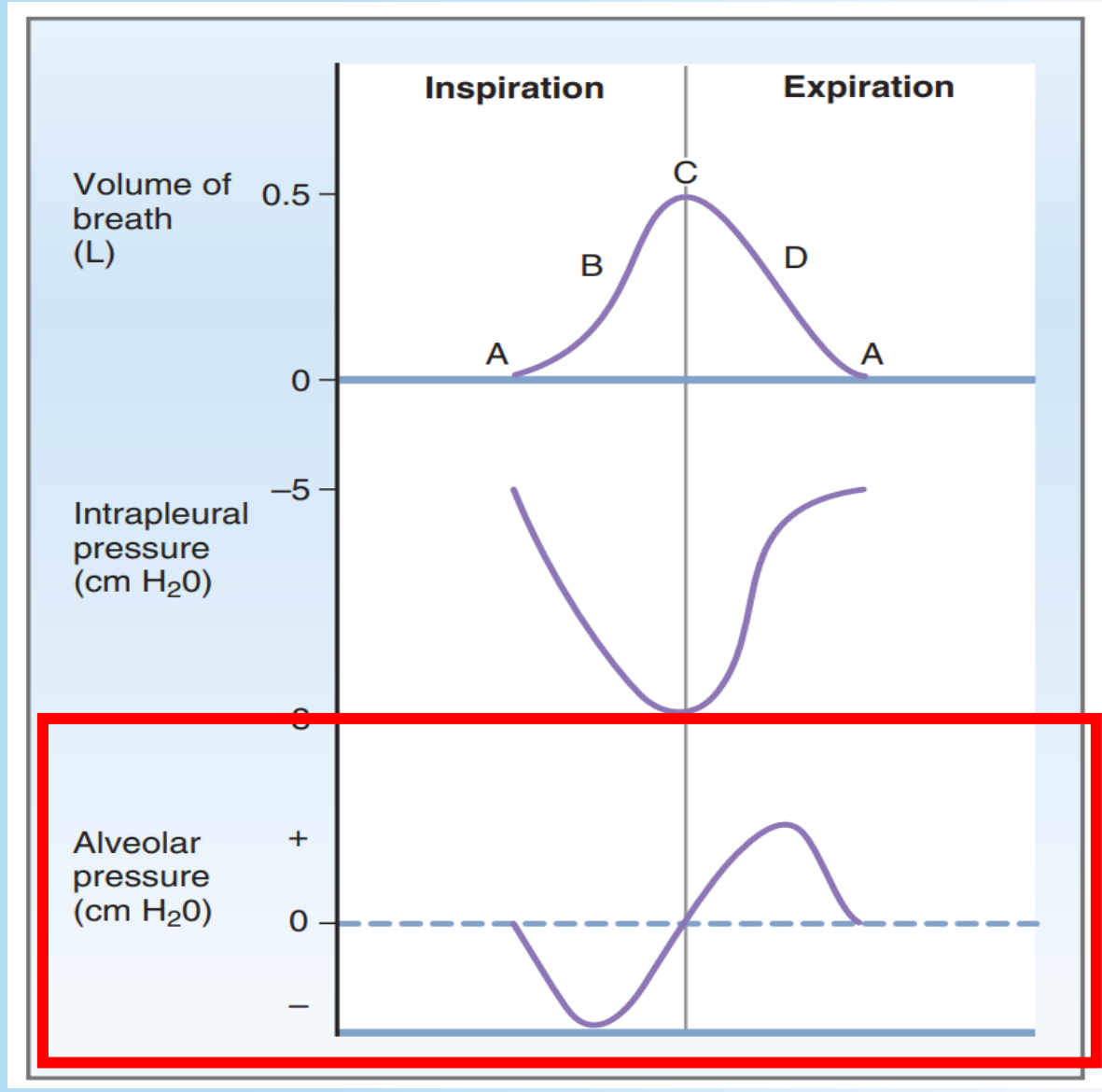
Respiratory system pressures: Alveolar Pressure (aka intrapulmonary pressure)

- **Alveolar pressure** is the pressure within the alveoli.
- **Alveolar pressure** changes during the respiratory cycle.

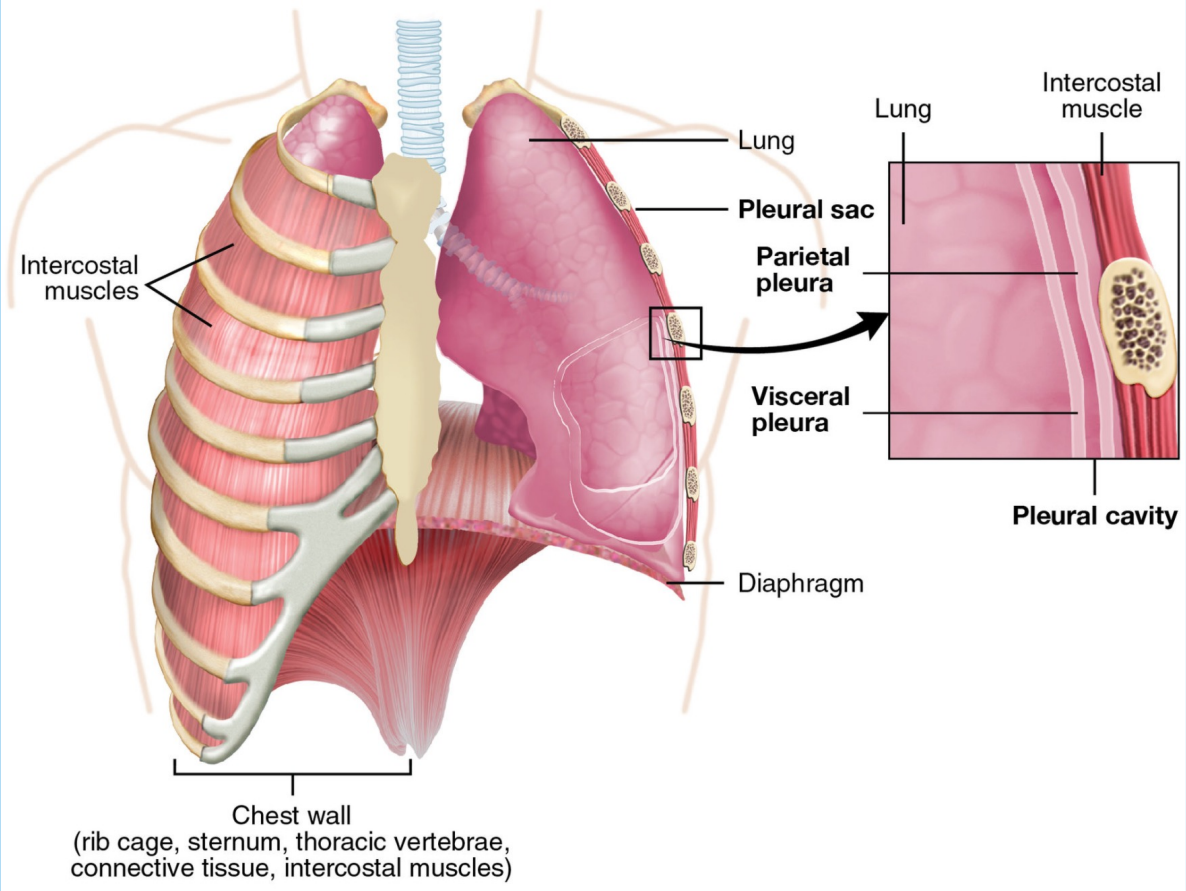
- Inspiration: $P_{alveolar} < P_{atm}$
- Expiration: $P_{alveolar} > P_{atm}$
- No air movement: $P_{alveolar} = P_{atm}$

"negative pressure" = negative with respect to P_{atm}
i.e. below 760 mmHg. ***NOT*** *< 0 mmHg*



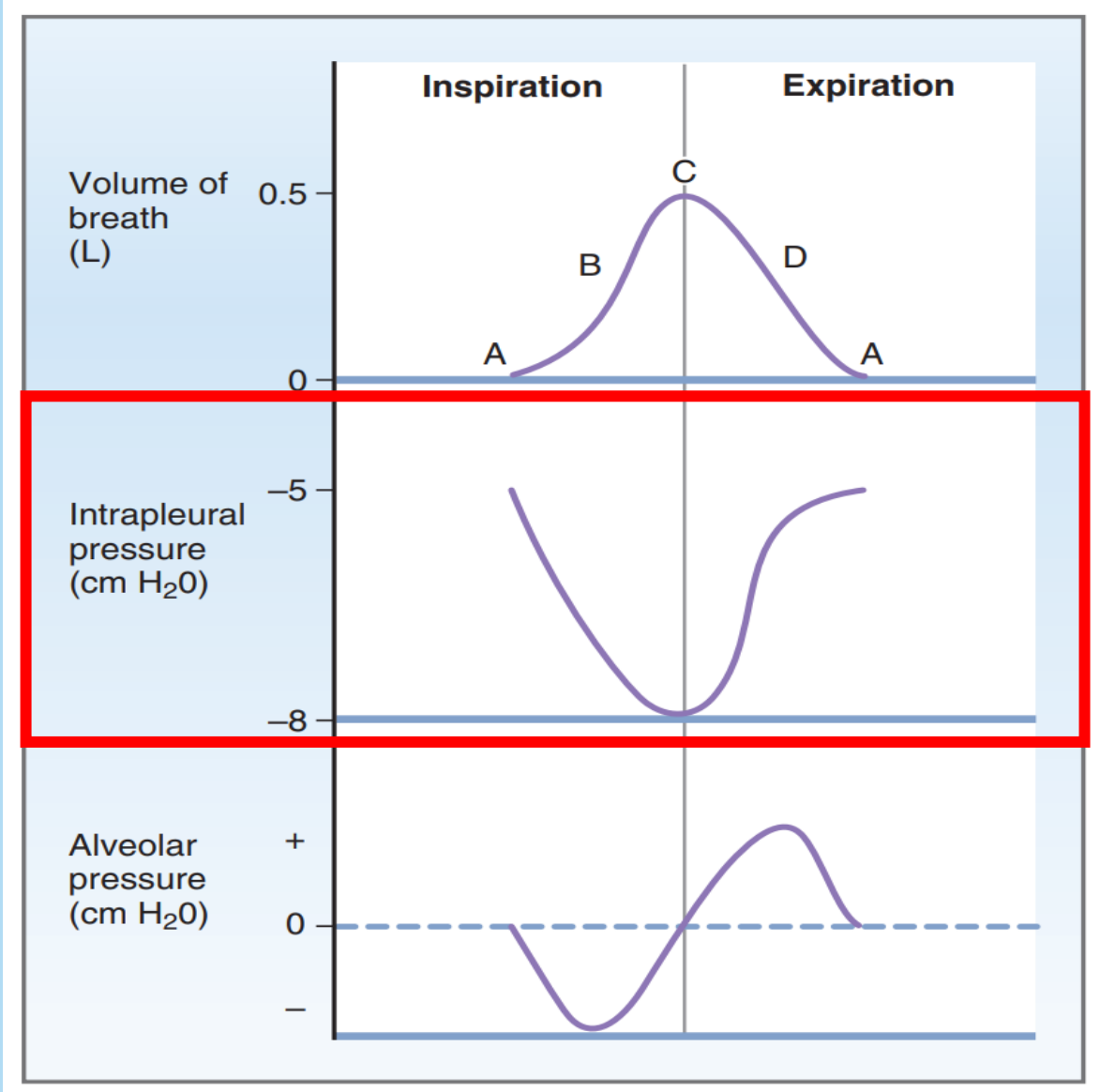
Respiratory system pressures: Intrapleural pressure (i)

- **Intrapleural pressure** is the pressure within the pleural space (between visceral & parietal pleura)
- **Always negative pressure** under physiological conditions
- **Negative pressure prevents** the **lungs from collapsing** *AND* prevents the chest wall from springing out



Respiratory system pressures: Intrapleural pressure (ii)

- **Always negative** under physiological conditions
- **during inspiration**, the pleural space volume expands (as diaphragm pulls downwards) and **intrapleural pressure becomes "even more negative"**
- **during expiration**, **intrapleural pressure becomes "less negative", but still negative!**



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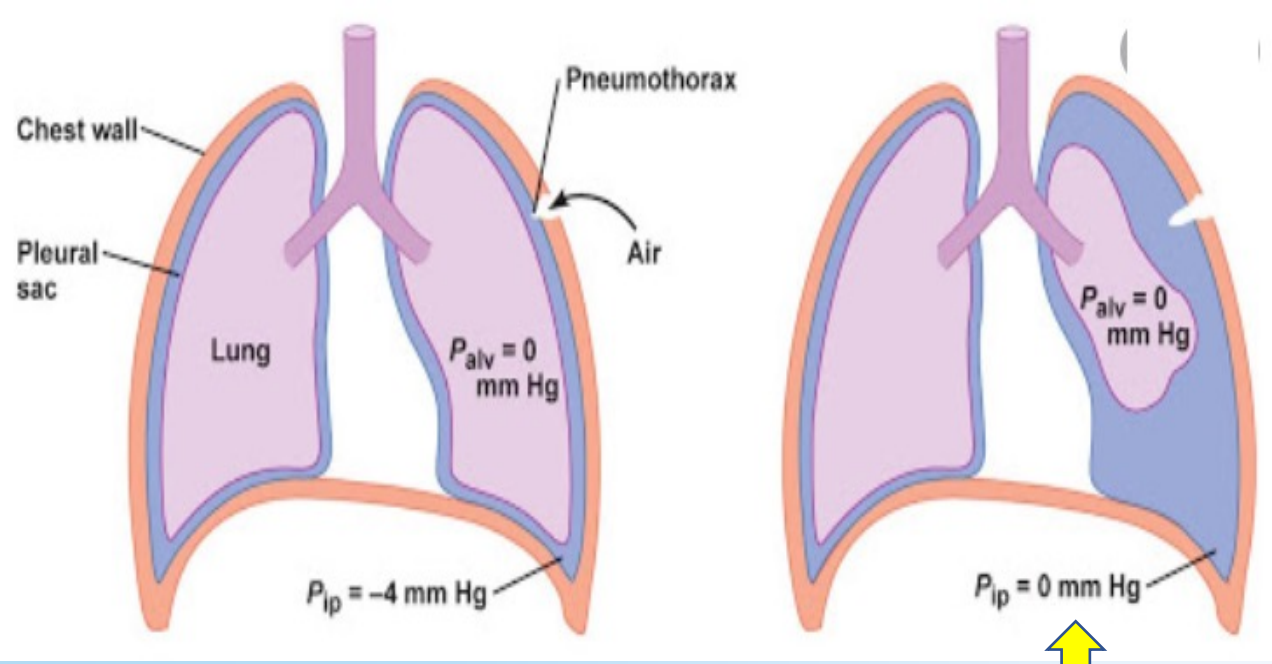
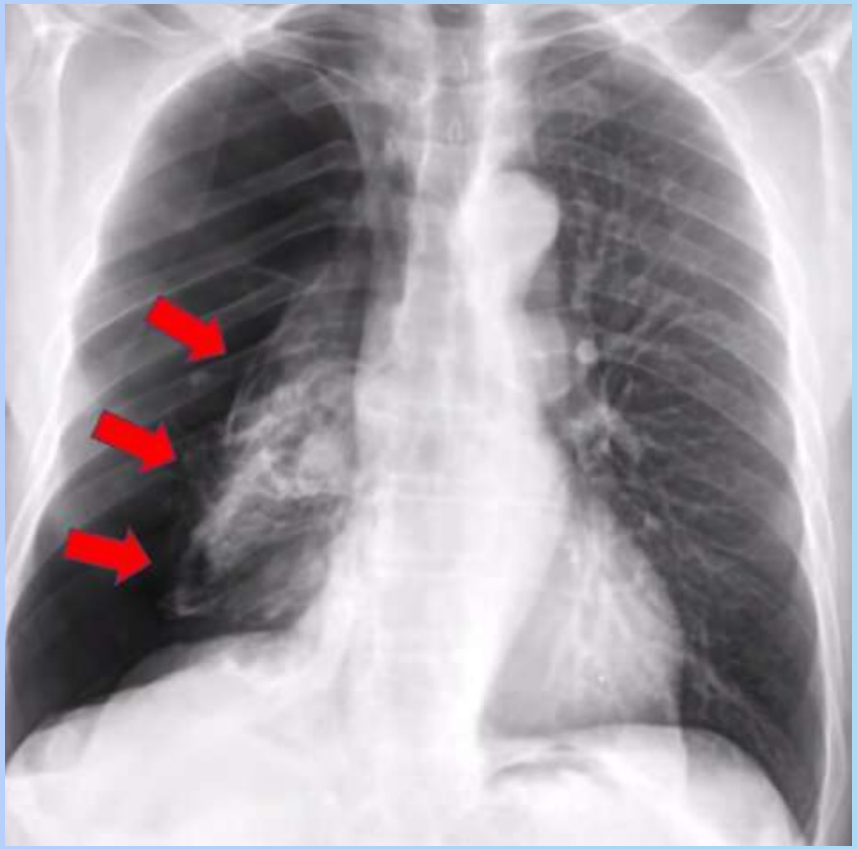
Pneumothorax (i)

- Usually due to penetrating injury (i.e. stab & gun shot wounds) to chest wall
- **Negative intrapleural pressure is lost** as **air inappropriately enters the intrapleural space**
- Alveoli's **natural tendency to recoil** (due to elasticity) is now **unopposed**
- **Affected lung collapses** & **chest wall expands**

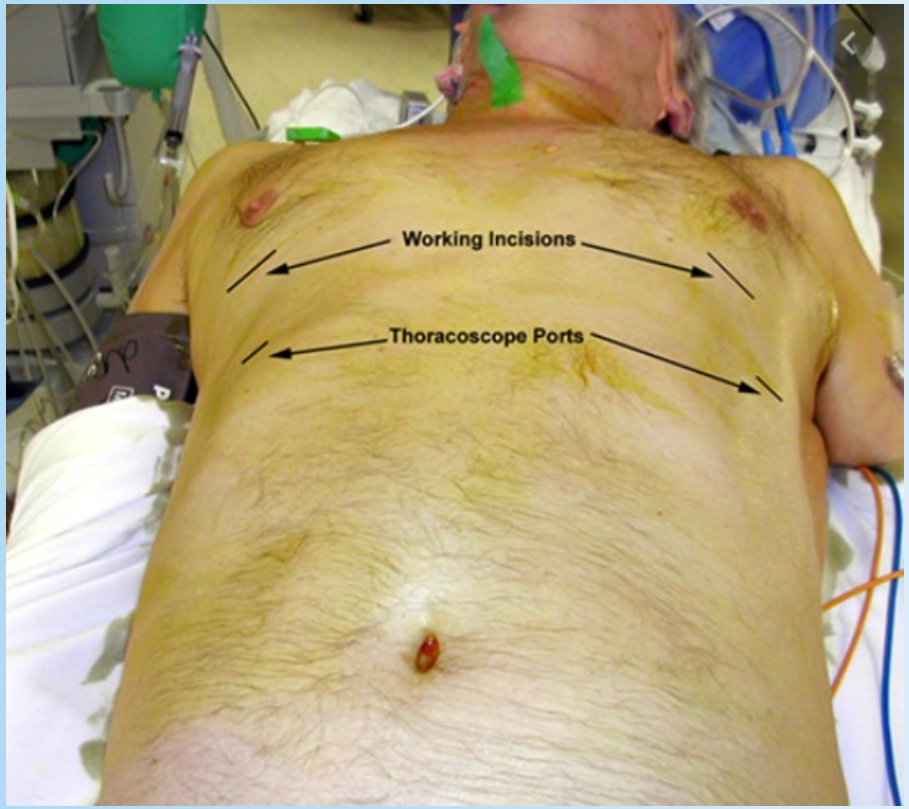


Pneumothorax (ii)

Collapsed lung



Chest wall expansion



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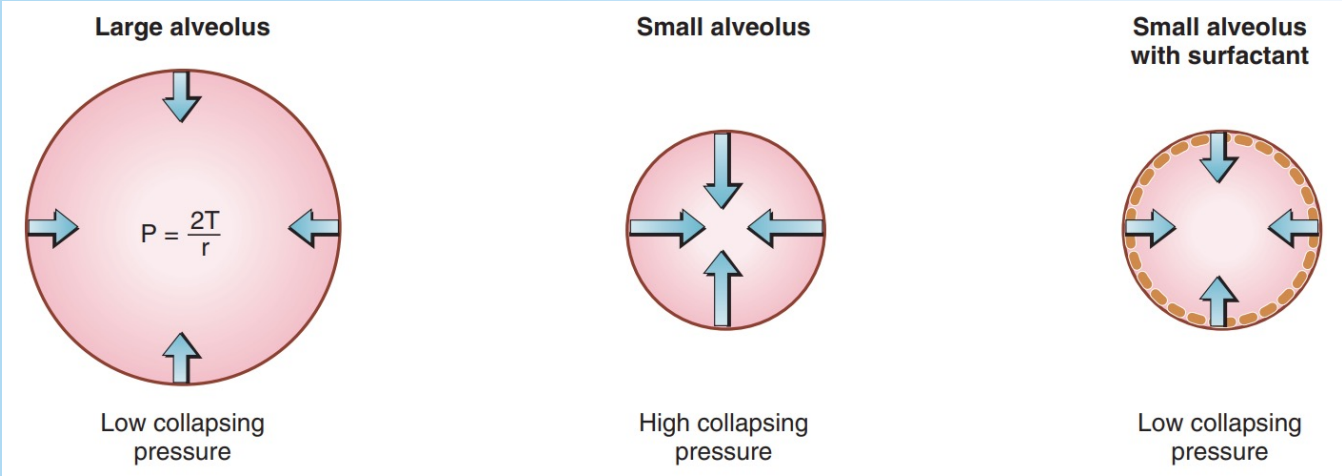
Role of surfactant (i)

- Surfactant is essential to survival.
- Without surfactant, your **alveoli would collapse**
- **Surfactant ↓ alveolar surface tension**
- Smaller alveoli are at greater risk of collapse then large alveoli



- Law of Laplace:

$$P_{collapsing} = \frac{2*T}{r}$$

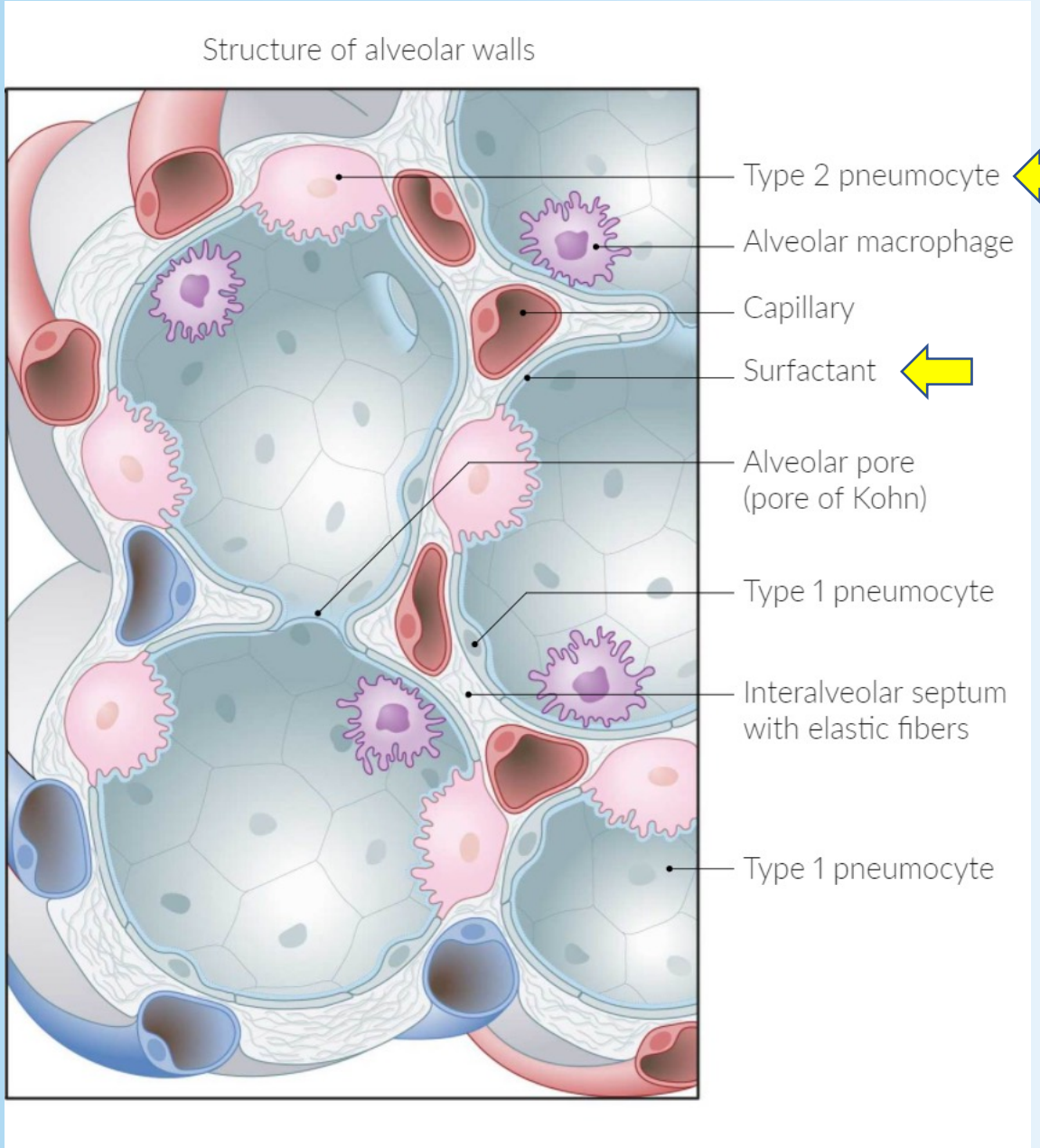
T = surface tension

r = alveolar radius

Role of surfactant (ii)

- Surfactant is made by **Type 2 pneumocytes**

- Surfactant is composed of **90% lipids,** and reduces surface tension at the air/liquid interface



Role of surfactant (iii): Neonatal respiratory distress syndrome

- Premature birth earlier than week 24 → **NO surfactant** present
- Premature birth between week 24 – week 35 → **"uncertain surfactant status"**

- **Lack of surfactant → alveolar collapse → collapsed alveoli cannot be ventilated**

Treatment: Endotracheal admin of artificial surfactant + nasal CPAP

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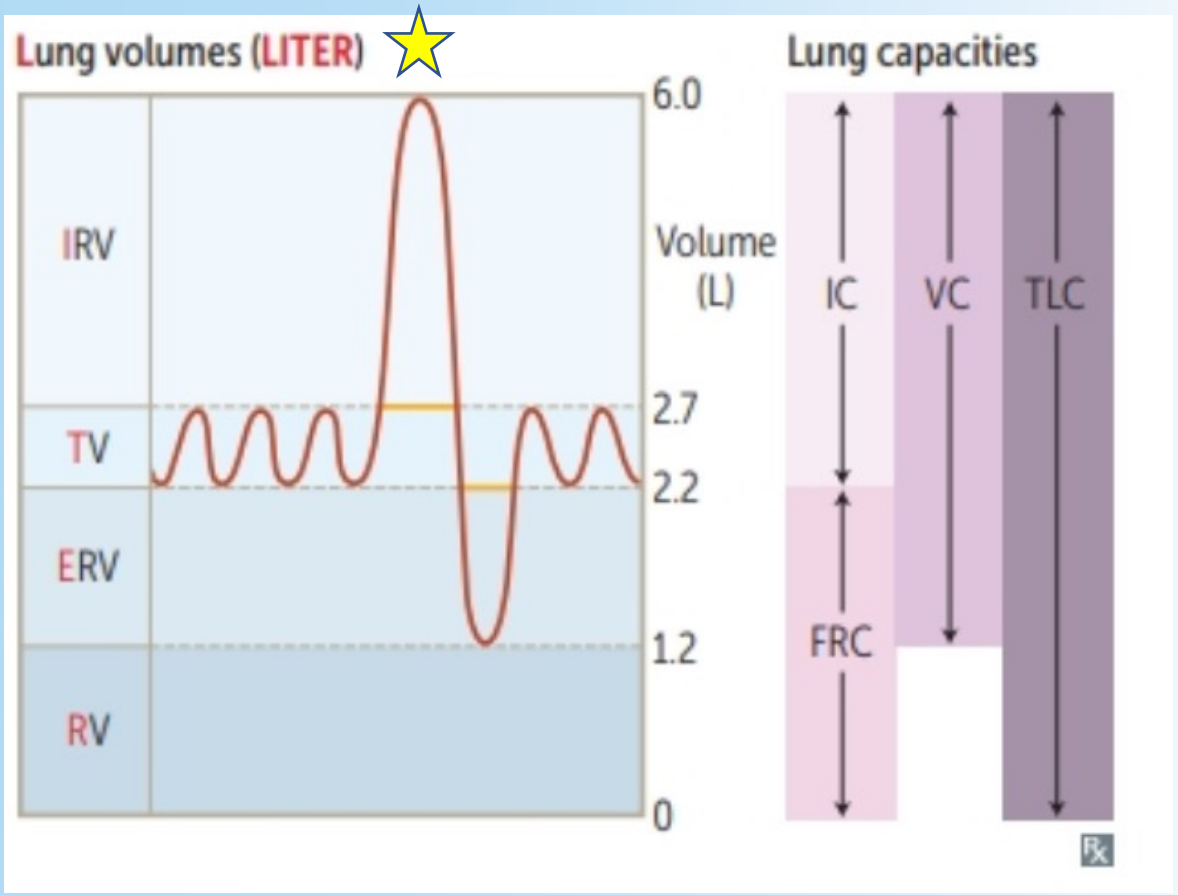
Spirometry: Volumes (i)

- **TV =** tidal volume
- **IRV =** inspiratory reserve volume
- **ERV =** expiratory reserve volume
- **RV** = residual volume*

*RV = *Air that is left in the lungs after maximal expiration.* ***Cannot*** *be measured with spirometry.*



* It is important to know all these definitions (volumes and capacities) for your midterm.

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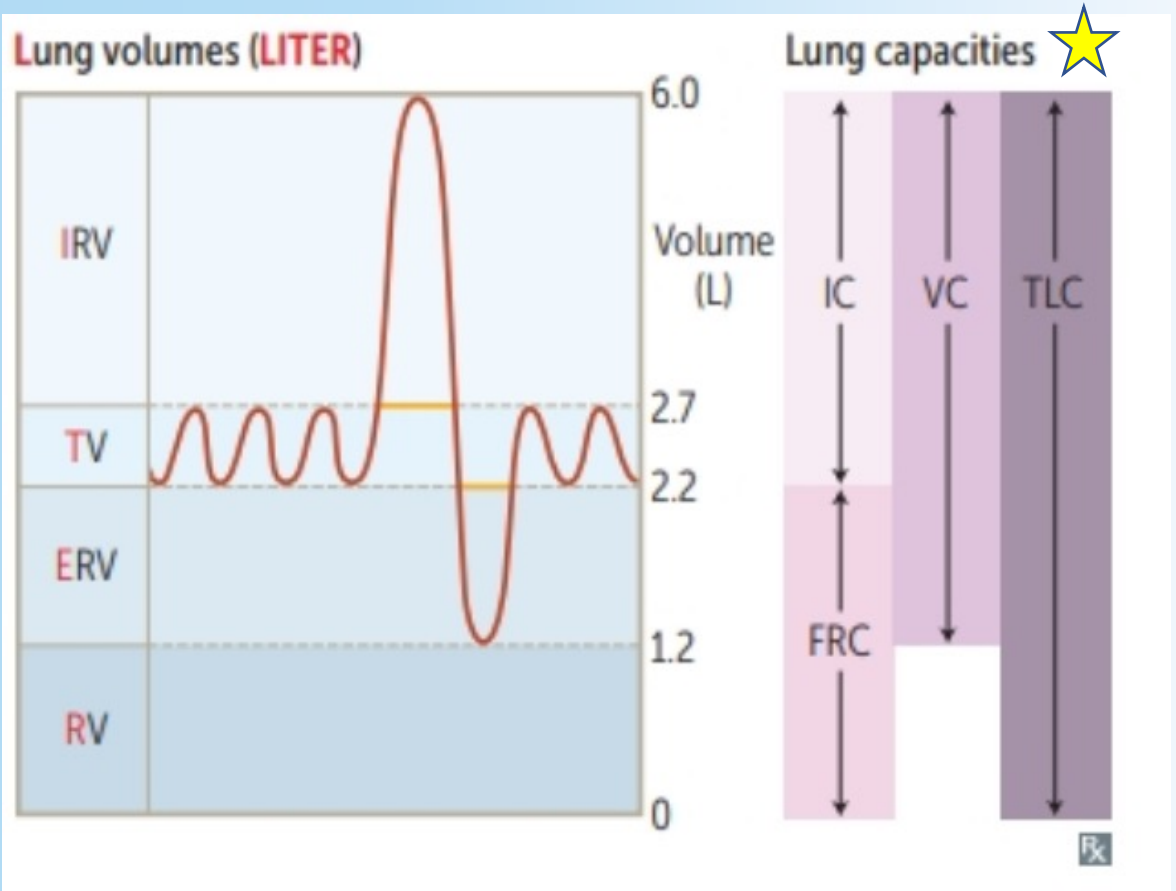
Spirometry: Capacities (ii)

- **Volume vs Capacities:** A <u>capacity</u> is the sum of ≥ 2 lung volumes

- **<u>Vital capacity (VC):</u>** volume of air that can be forcefully expired after max inspiration

- **<u>Total lung capacity (TLC):</u>** vital capacity + residual volume



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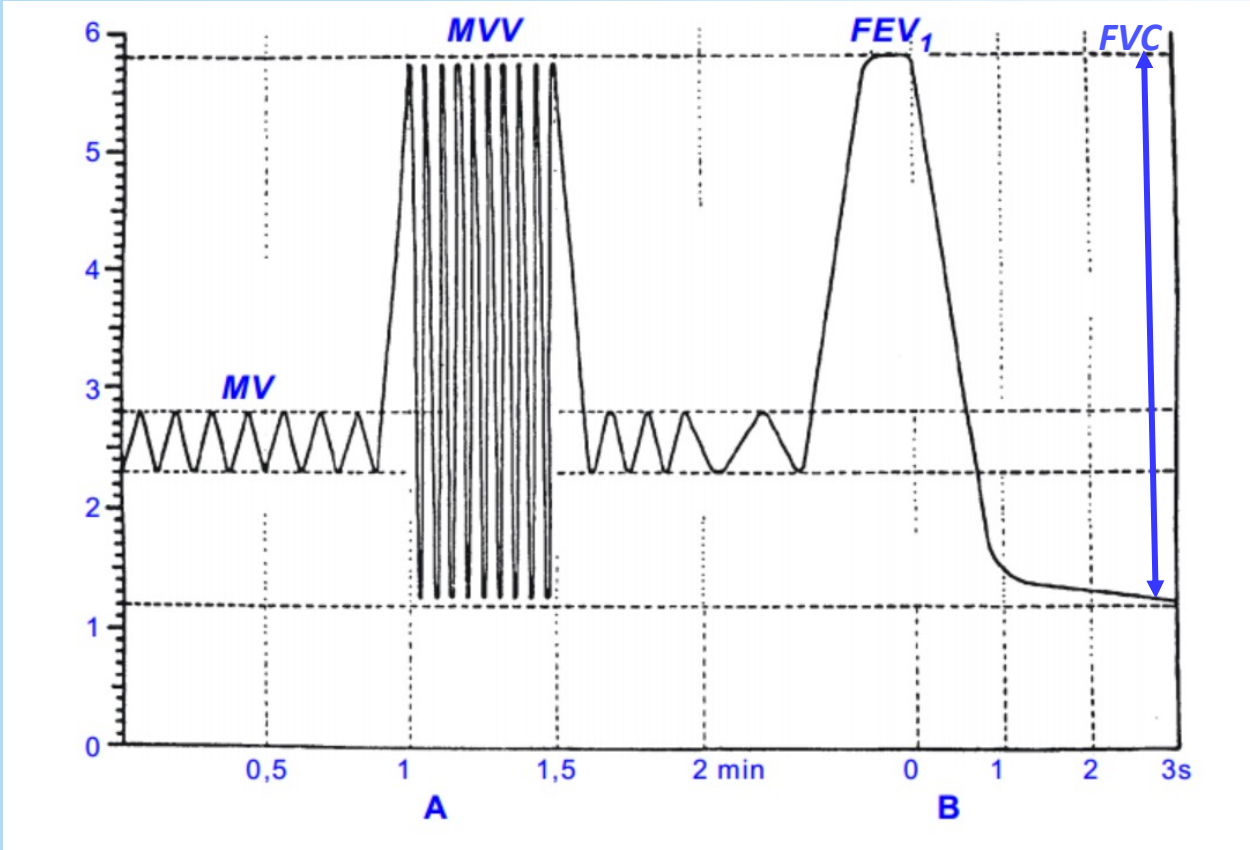
Spirometry: Other Measures (ii)

- **MVV (maximal voluntary ventilation):** total volume of air that can be exhaled during 12 seconds of deep breathing

- **FEV_1 (forced expiratory volume, during first second):** Volume that has been exhaled by the end of the first second of forced expiration

- The **FEV_1 / FVC ratio** is also used for diagnostic purposes (normal ~80%)



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How to participate?

WEB

1. Connect to **www.wooclap.com/BREATHMEC**
2. You can participate