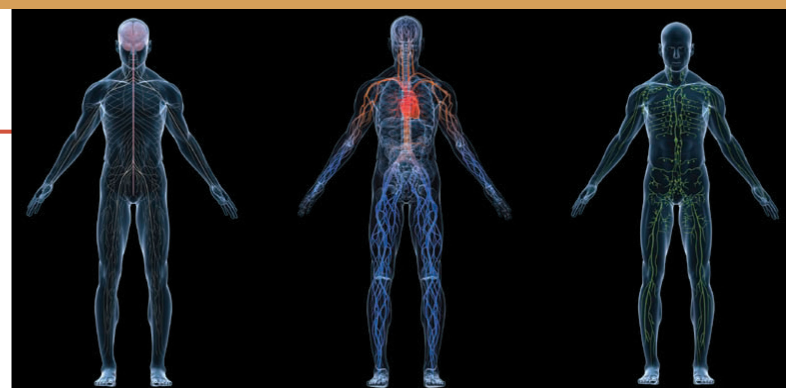
UNIT VII

GUYTON AND HALL *Textbook of* Medical Physiology

TWELFTH EDITION



CHAPTER 37:

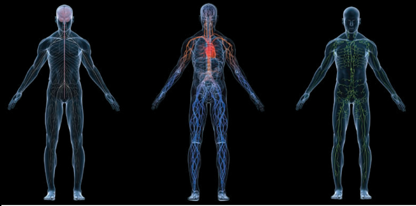
Lung Compliance

Slides by Robert L. Hester, PhD

Work of breathing

Work in the respiratory system is of 2 major types (discussed in the previous lecture):

1. *Work to overcome elastic forces (70%):* that required to expand the lungs against the lung and chest elastic forces. Two third is duo to surface tension and one third is duo to elastic fibers.
2. *Work to overcome non-elastic forces (30%):* that required to overcome:
   1. The viscosity of the lung and chest wall structures (20%).
   2. *Airway resistance work (80%):* that required to overcome airway resistance to movement of air into the lungs.



Minimal Volume

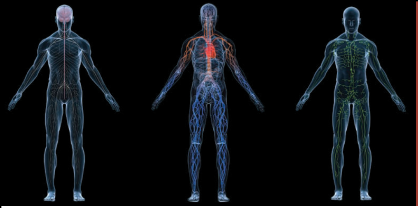
- The lungs, if alone, (outside the body) or during open-chest surgery, will collapse up to 150 ml air **= minimal volume MV (this is not anatomic dead space volume even though it is 150 ml)**. MV is used for medico legal purposes (WHY?). MV is also known as unstressed volume or resting volume of the lung.

Compliance

- Distensibility (stretchability):
  - How easy the lungs can expand. How much force we need to expand the lung? If the force is small, then the lung is stretchable.
- It is the change in lung volume per unit change in transpulmonary pressure.

$$\Delta V / \Delta P$$

- Lung is 100 times more distensible than a child balloon. **This means, 100 times more distending pressure is required to inflate a child toy balloon than to inflate the lung.**
  - Compliance is reduced when distension is difficult.



Compliance…cont.

COMPLIANCE is the ability of the lung to stretch

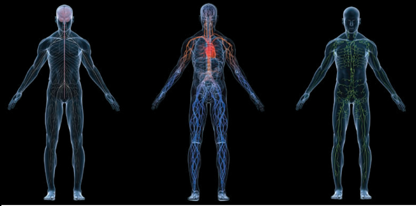
Specific compliance = C/FRC to correct for differences in lung volume between a child and an adult.

C_L = 200ml/cm H_2O. For the lung alone

C_W = 200ml/cm H_2O. For the thoracic wall alone

C_S = 100ml/cm H_2O. S stands for lung-thorax system (For both)

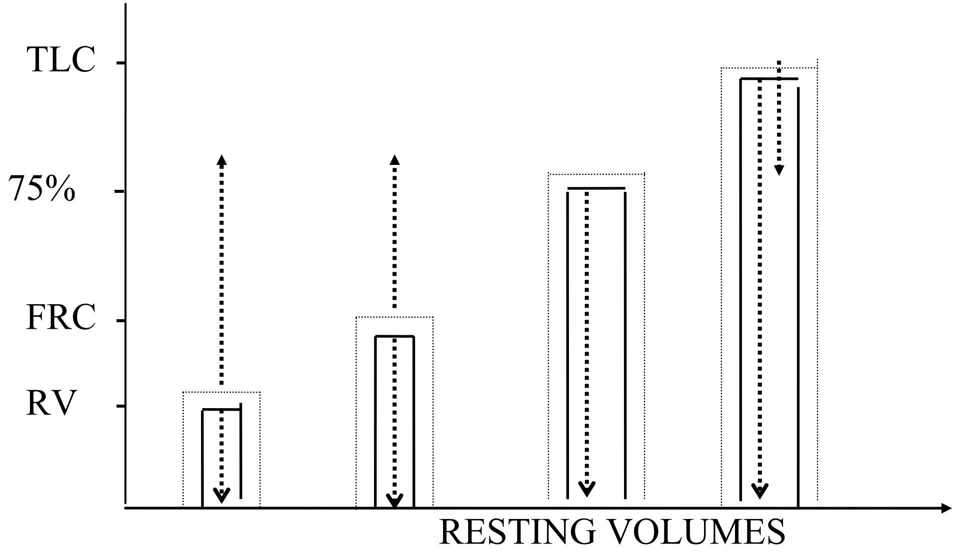
Inflating one balloon is easier than inflating two balloons, one inside the other. The two balloons are the lung and the thorax.



Elasticity

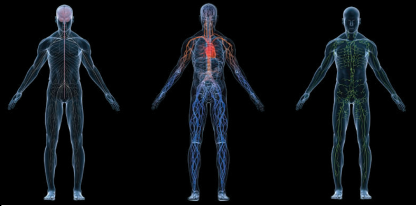
- Tendency to return to initial size after distension.
- High content of elastin proteins.
  - If the lung is very elastic and resist distension…this means high recoil tendency or high collapsing forces Too much recoil tendency is bad (high collapsing forces) and too little recoil tendency is also bad (high compliance).
- Elastic tension increases during inspiration.

RESTING VOLUMES



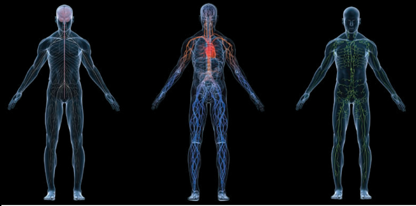
BINDING BETWEEN LUNGS & THORAX.

- Lungs are covered by a visceral pleura & the mediastinum & chest wall are lined by parietal pleura. Both pleural surfaces are covered with a thin film of fluid & the intermolecular forces of this film between the two surfaces holds the lungs against the thorax. It is like two glasses slide over each others but not easily separated.



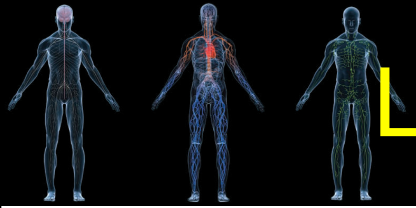
Intrapleural Pressure

- The magnitude of the intrapleural pressure equals the separate elastic forces of the lungs or chest wall rather than the sum of their combined forces. It reflects either the strength of the collapsing elastic lung tissue or the strength of the expanding chest wall force
- Since chest wall elasticity usually remains unchanged in respiratory pathology, “P_{pl}” reflects the elastic strength of the lungs. At all volume P_{pl} reflects how strongly the lungs are tending to collapse. P_{pl} can be measured using a tube inside the esophagus.



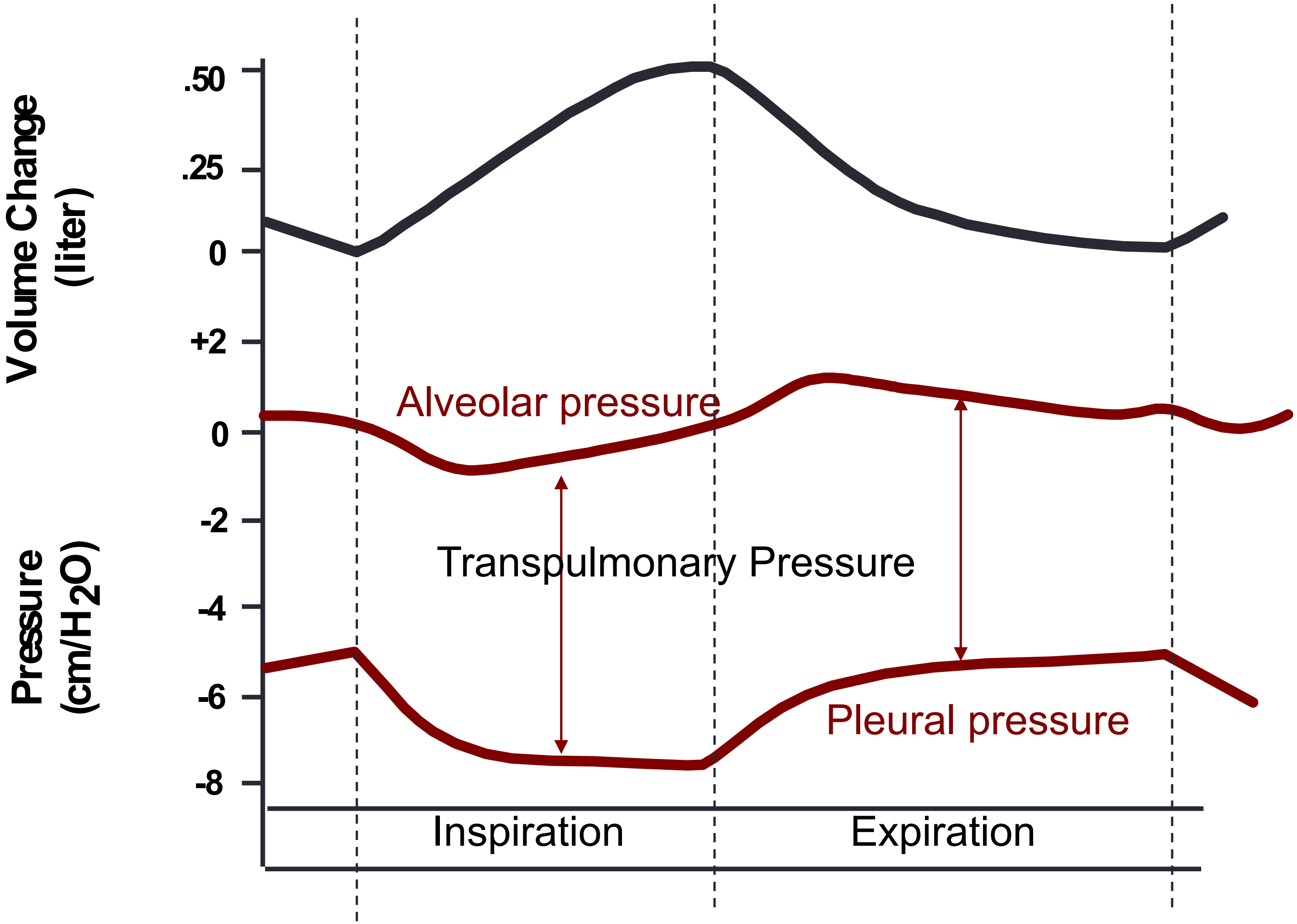
Relaxation Curve

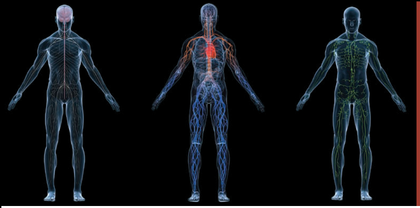
- When generating the **Relaxation Curve**, all respiratory muscles (inspiratory & expiratory) are relaxed and we plot volume versus intra-alveolar pressure.
- At each lung volume we can study whether the lung-chest wall system is tending to expand or to relax.
- Relaxation curve is generated under static conditions when no air flow occurs.
- Under these conditions, Ppl reflects the strength of the elastic forces of the chest wall



Lung-Thorax Resting Volume

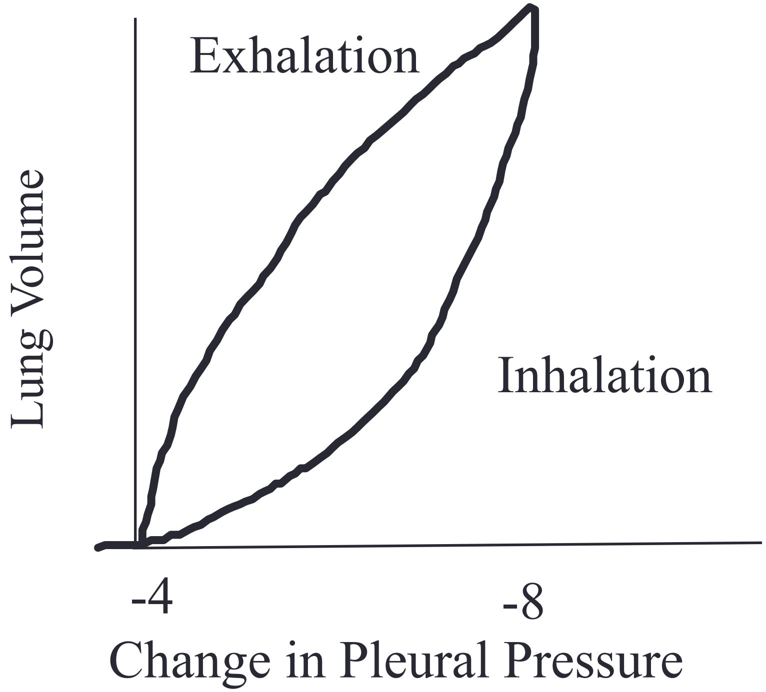
- In vivo, we can't measure P_{alv} below residual volume.
- To move the system from FRC you need to apply force such as muscle contraction…but to bring it back to its resting volume (FRC) is passive. This is another way to look at inspiration is active and expiration being passive process.

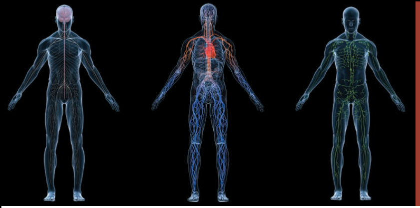

Volume Change (liter)
.50
.25
0
+2
0
-2
-4
-6
-8
Pressure (cm/H2O)
Alveolar pressure
Transpulmonary Pressure
Pleural pressure
Inspiration
Expiration



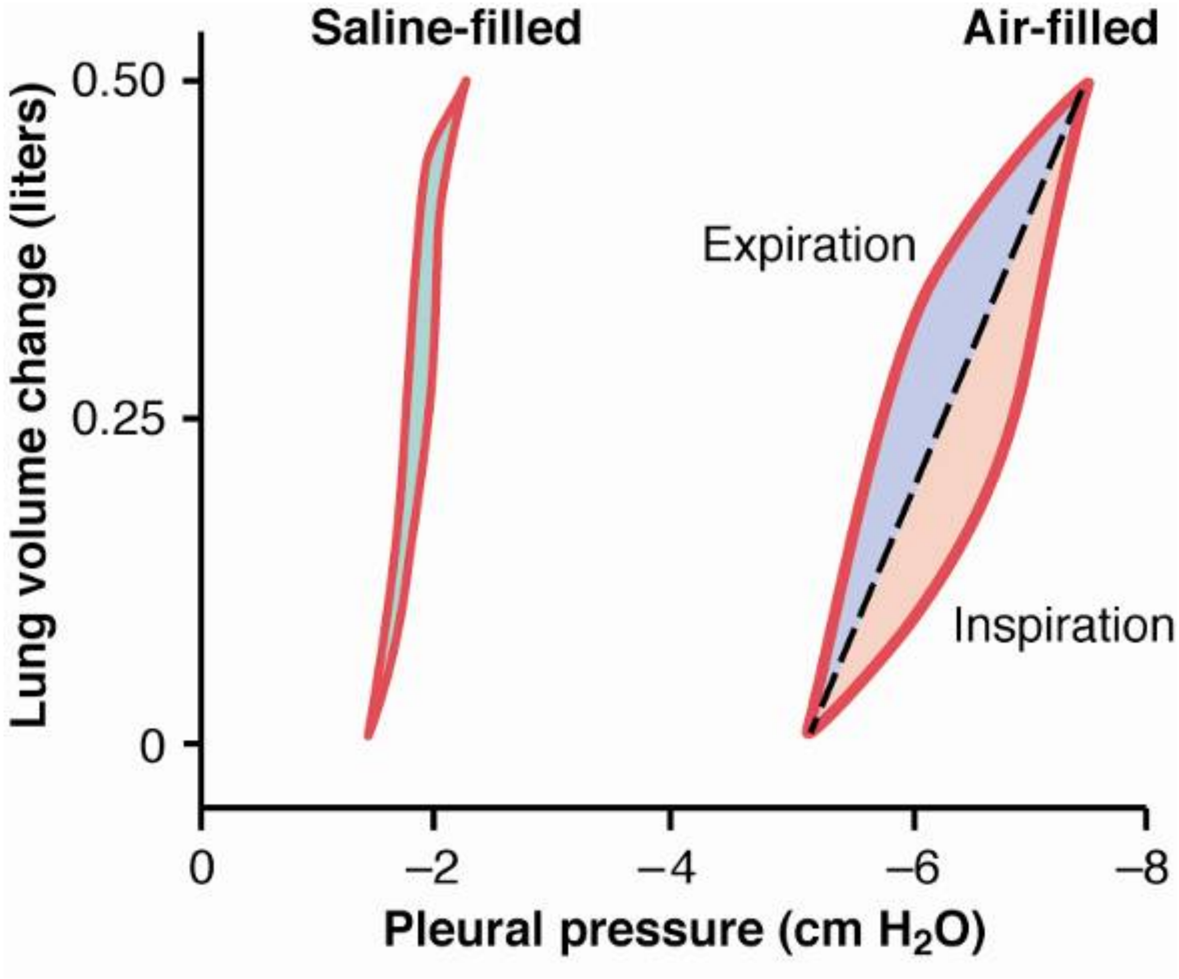
COMPLIANCE OF LUNGS

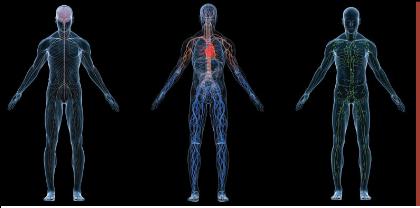
- Determined by elastic forces
- Elastic forces
  - lung tissue… one third
  - surface tension…two thirds

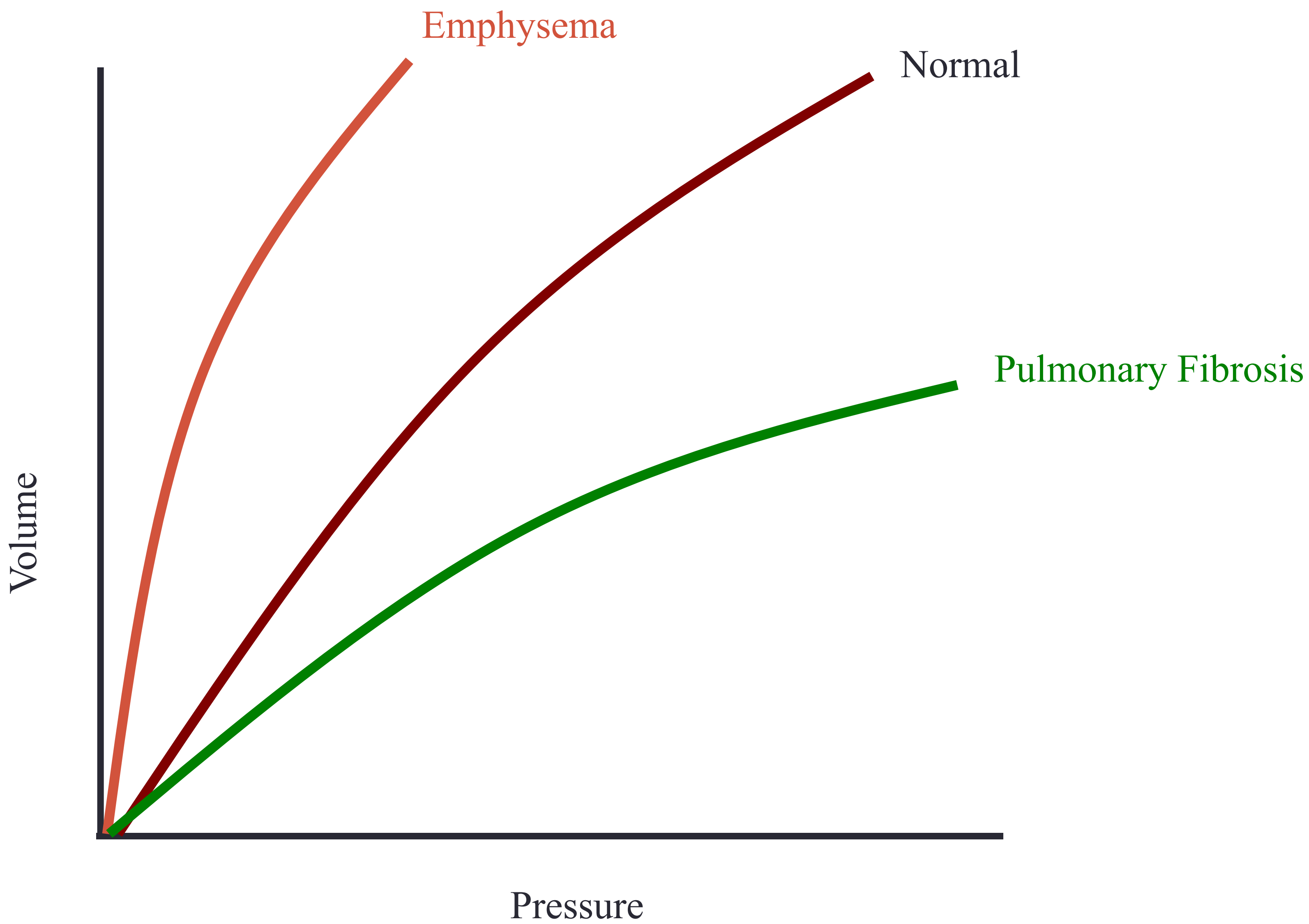


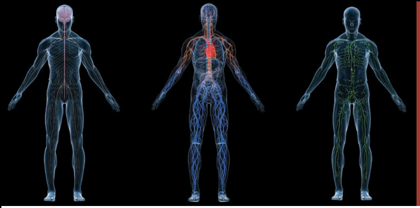


Compliance of Lungs






Emphysema
Normal
Pulmonary Fibrosis
Volume
Pressure



Compliance of Lungs

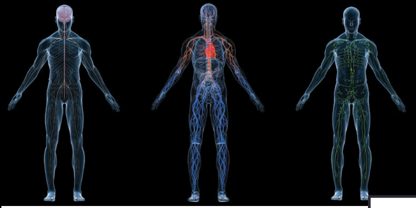
Surface tension T can be looked as a

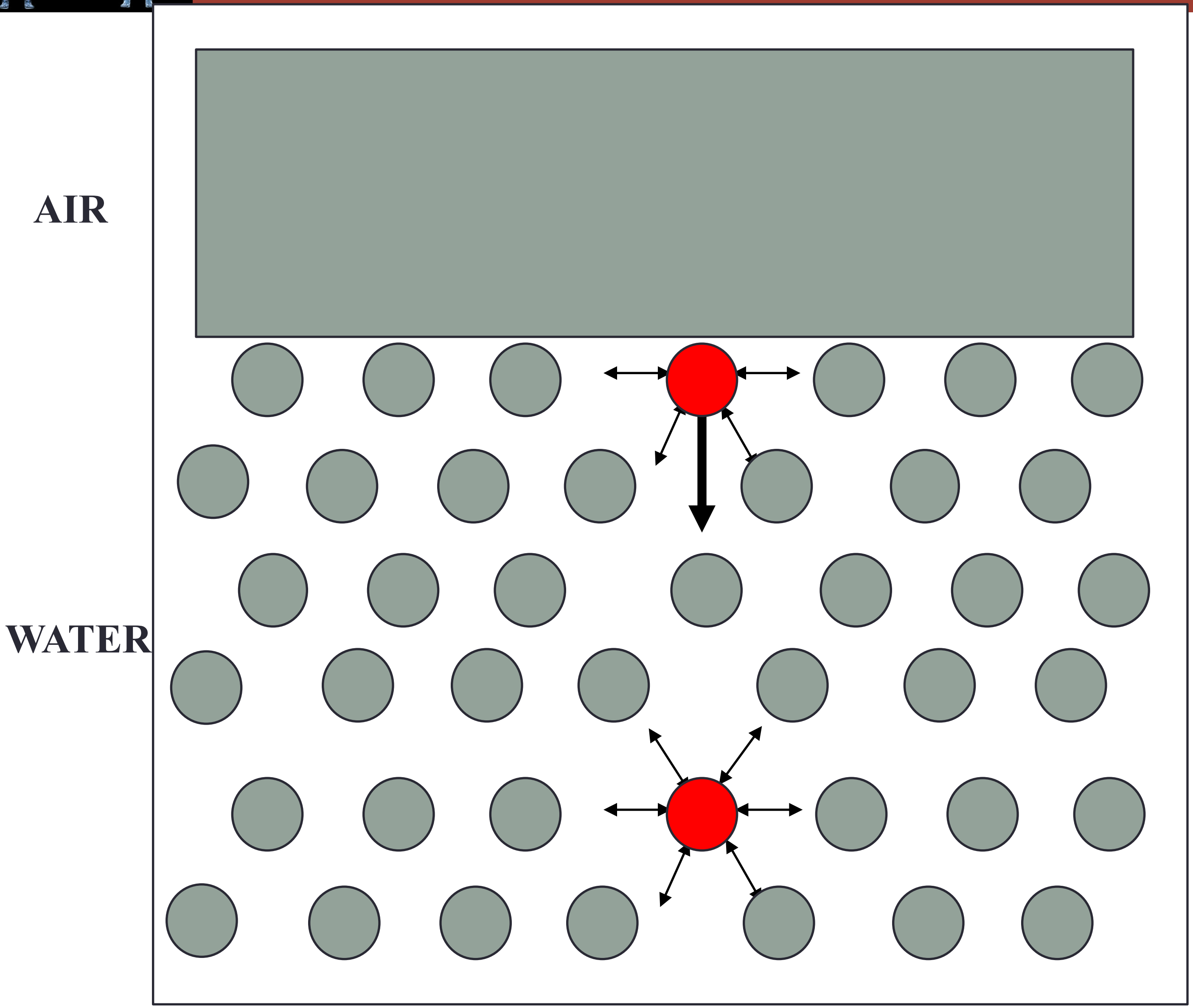
collapsing force which is going to

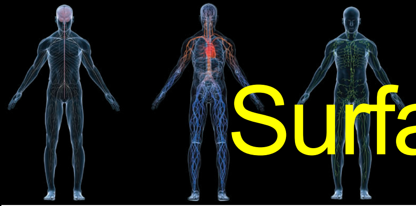
collapse the alveoli…

- T is duo to attraction of water molecules at air-water interface
- T is reduced by the presence of surfactant

SURFACE TENSION- asymetrical forces acting at an air/water interface produce a net force acting to decrease surface area

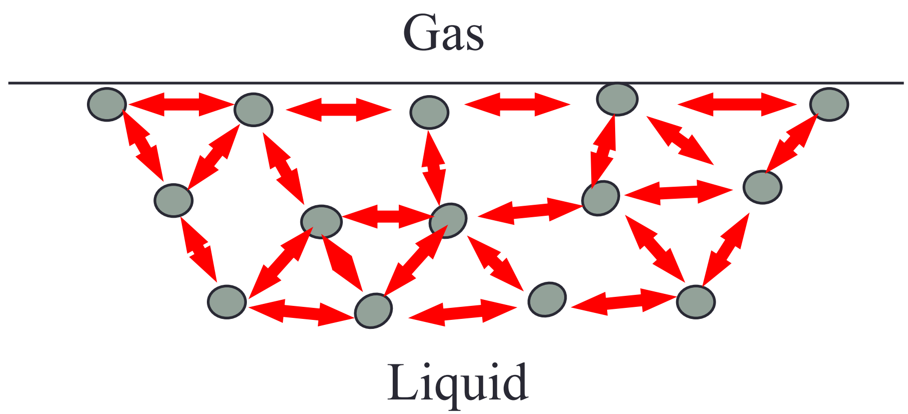






Surface Tension and recoil of the lung

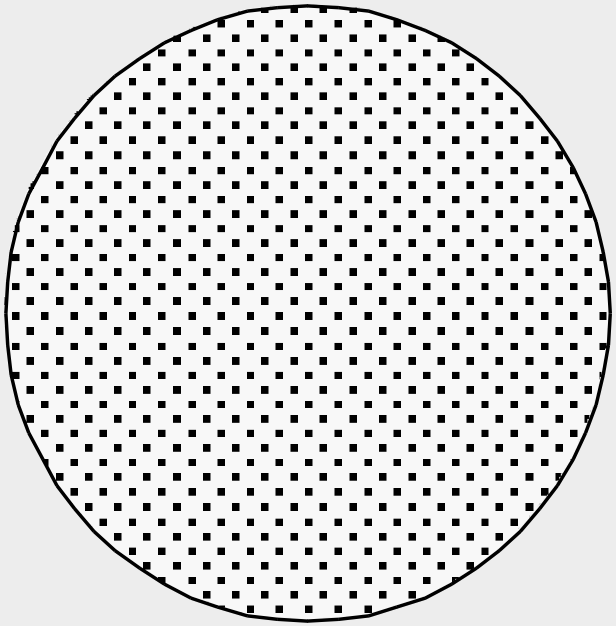
Molecular interactions resulting from hydrogen bonds between water molecules in liquid but not between water and air.

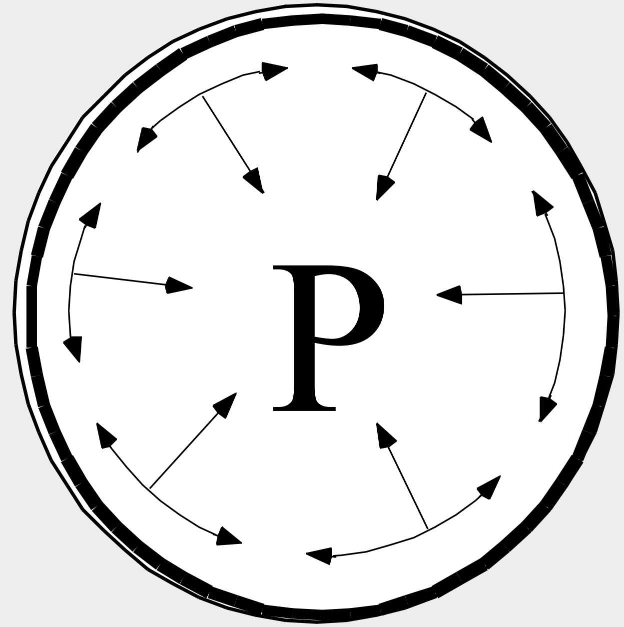


When water forms a surface with air, the water molecules on the surface of the water have an especially strong attraction for one another. Therefore, the water surface is always attempting to contract.

Liquid filled alveolus

Gas filled alveolus with thin liquid layer





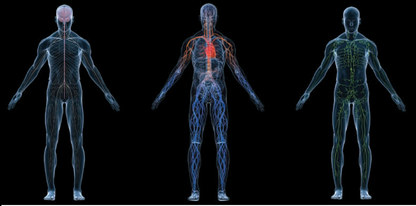
No Surface Tension

Because there is no air/water interface

+ Surface Tension

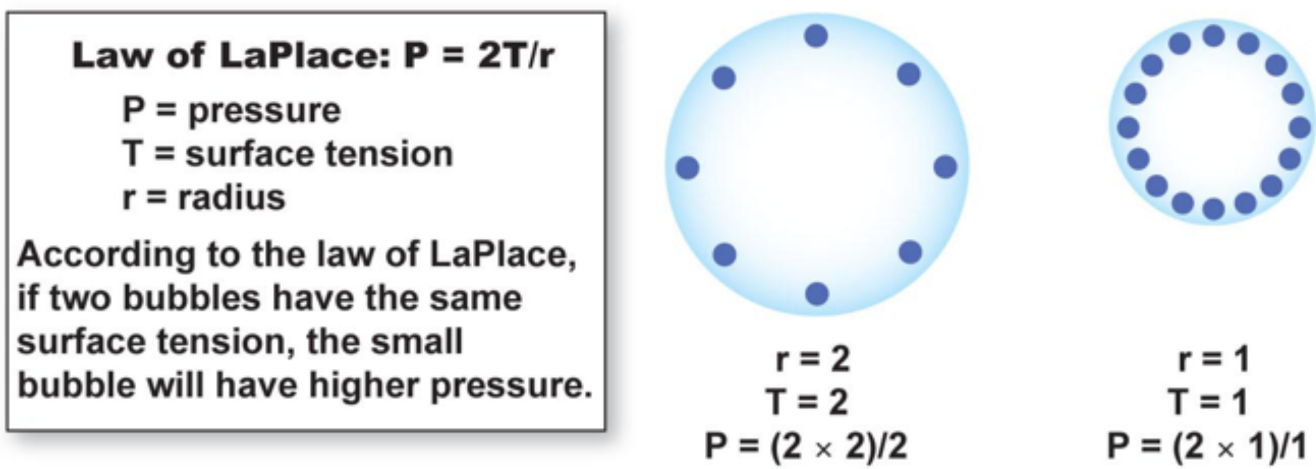
Recoil Pressure

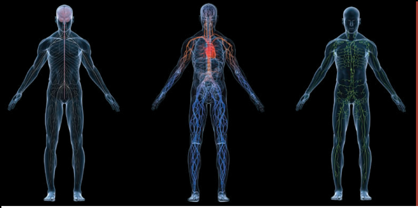
Compliance



Surfactant

- ***Surfactant***: Means surface-active agent
- Surfactant is produced by Alveolar type II cells
  - It is Glyco(2%)-lipo(90%)-protein(8%) plus calcium ions.
  - Disrupts the surface tension & cohesion of water molecules
  - Maturation of surfactant needs T_4, prolactin, estrogen, and other steroids
    - prevents alveoli from sticking together during expiration





Laplace's Law

$T = P \times r / 2$ or $P = 2T/r$

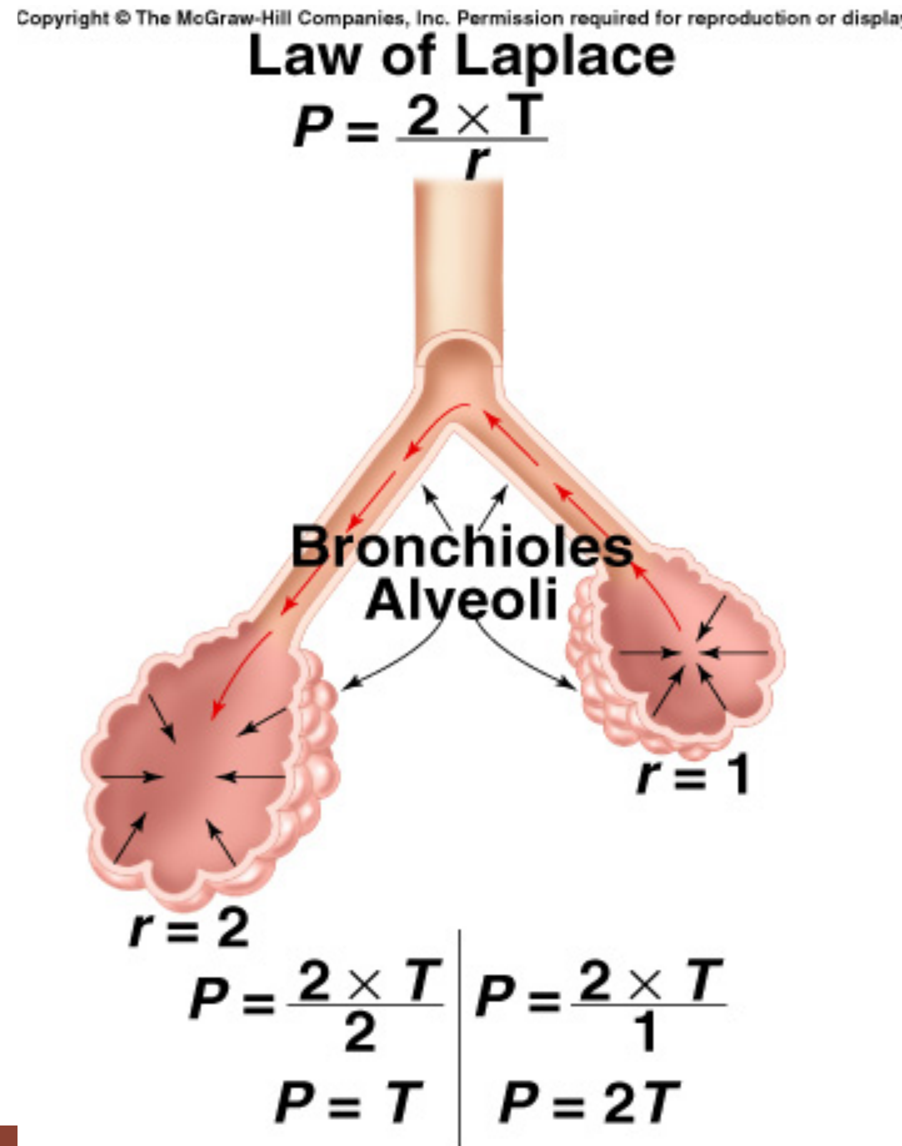
P = pressure required to prevent alveolar collapse <u>at rest</u>
T = surface tension
r = radius…

- **The smaller the radius , the larger the pressure required to prevent collapse…this point is important in IRDS where alveolar diameter is extremely small.**

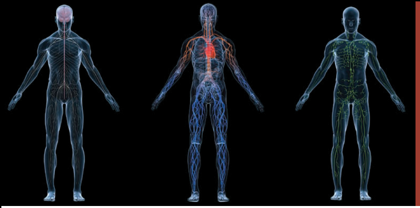
  - **If T = 2; r = 2; P = 2**
  - **If T = 2; r = 4; P = 1**

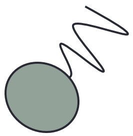
Surface Tension… Law of Laplace (continued)

- Law of Laplace:
  - Pressure in pleural cavity is directly proportional to surface tension; and inversely proportional to radius of alveoli.
  - Pressure in smaller alveolus would be greater than in larger alveolus, if surface tension were the same in both.



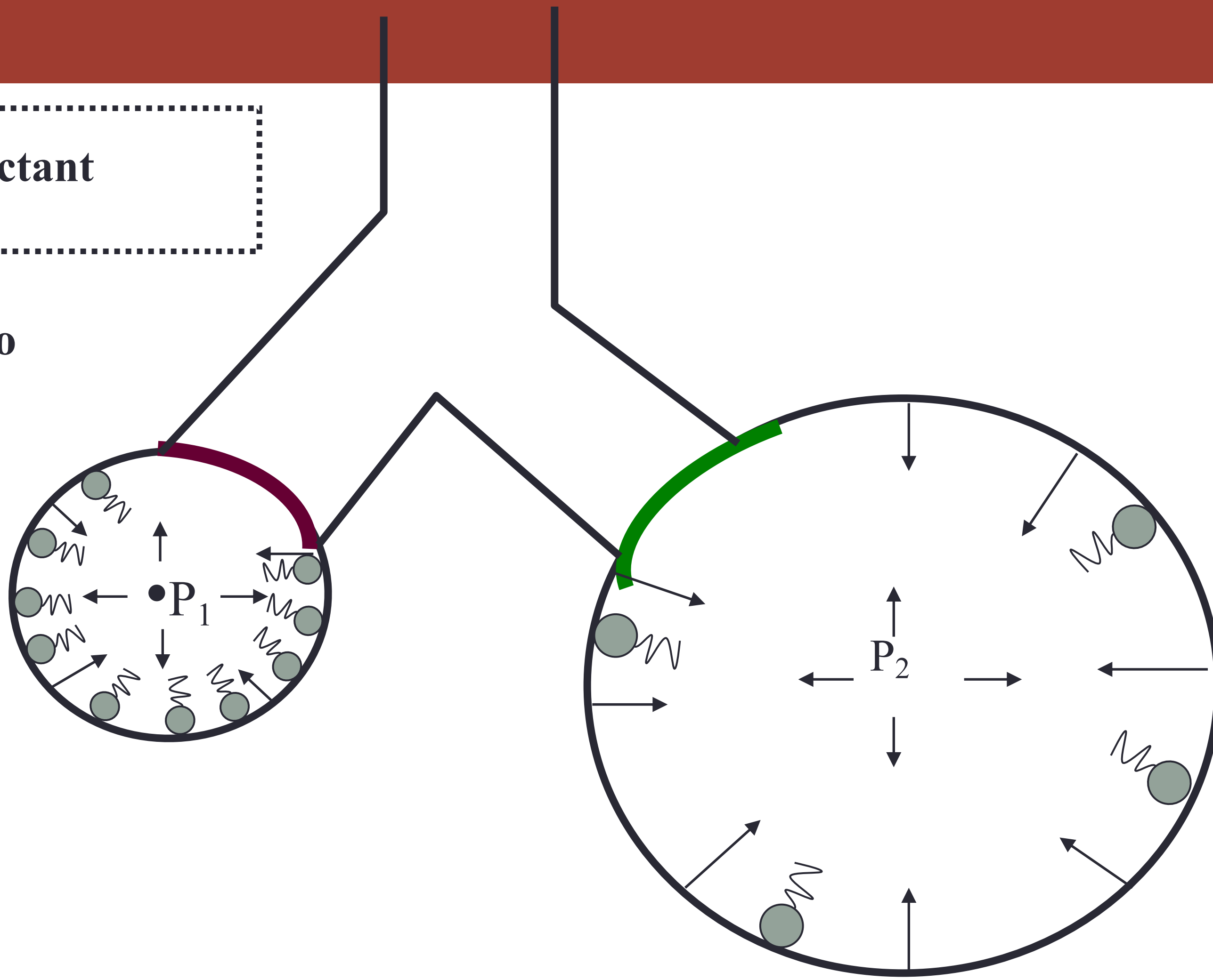
nc.





Pulmonary surfactant

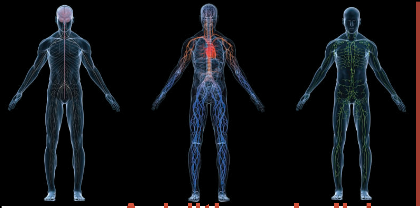
P_1 = Pressure required to prevent alveoli #1 from collapsing.



P_2 = Pressure required to prevent alveoli #2 from collapsing.

Deficiency of Surfactant causes collapse of the lungs

- IRDS: Respiratory distress syndrome (in premature babies)
- ARDS: Acute Respiratory distress syndrome in adults and children
- Since lung inflation requires large pleural pressure drops, deep breaths are difficult for patients with Restrictive Ventilatory Defects RVD; These patients exhibit shallow and rapid breathing patterns.



Additional slide…just take a look…you don't have to memorize any of the following numbers

Berlin criteria for ARDS severity

PaO_2/FiO_2 ratio	Inference
200 - 300 mm Hg	Mild ARDS
100 - 200 mm Hg	Moderate ARDS
< 100 mm Hg	Severe ARDS

ARDS is characterized by an acute onset within 1 week, bilateral radiographic pulmonary infiltrates, respiratory failure not fully explained by heart failure or volume overload, and a PaO_2/FiO_2 ratio < 300 mm Hg

ARDS

	Mild	Moderate	Severe
Timing	Acute onset within 1 week of a known clinical insult or new/worsening respiratory symptoms		
Hypoxemia	PaO_2/FiO_2 201-300 with PEEP/CPAP ≥ 5	PaO_2/FiO_2 ≤ 200 with PEEP ≥ 5	PaO_2/FiO_2 ≤ 100 with PEEP ≥ 10
Origin of Edema	Respiratory failure associated to known risk factors and not fully explained by cardiac failure or fluid overload. Need objective assessment of cardiac failure or fluid overload if no risk factor are present		
Radiological Abnormalities	Bilateral opacities*	Bilateral opacities*	Opacities involving at least 3 quadrants*
Additional Physiological Derangement	N/A	N/A	$V_{E\,Corr}$ > 10 L/min or C_{RS}<40 ml/cmH_2O

*Not fully explained by effusions, nodules, masses, or lobar/lung collapse; use training set of CXRs; $V_{E\,Corr} = V_E \times PaCO_2/40$ (corrected for Body Surface Area)