

Pulmonary Physiology

James Tucker

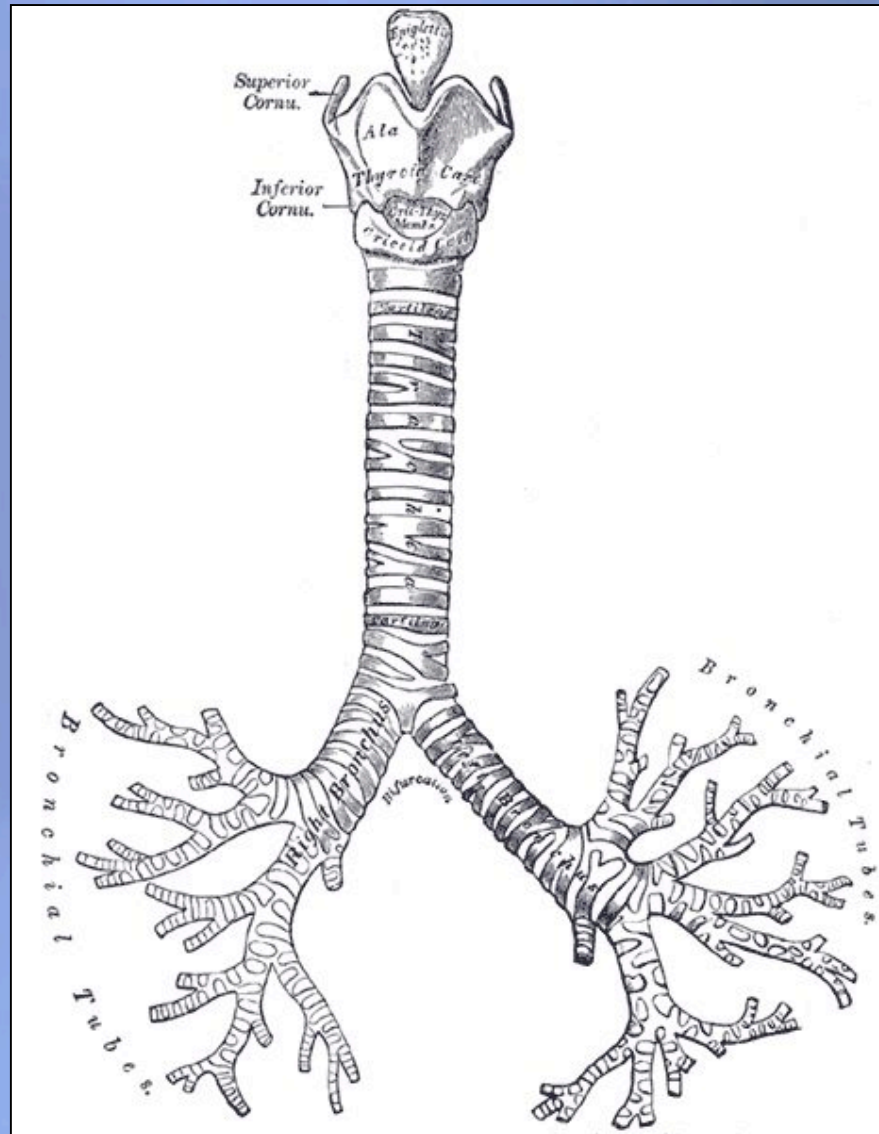
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Objectives

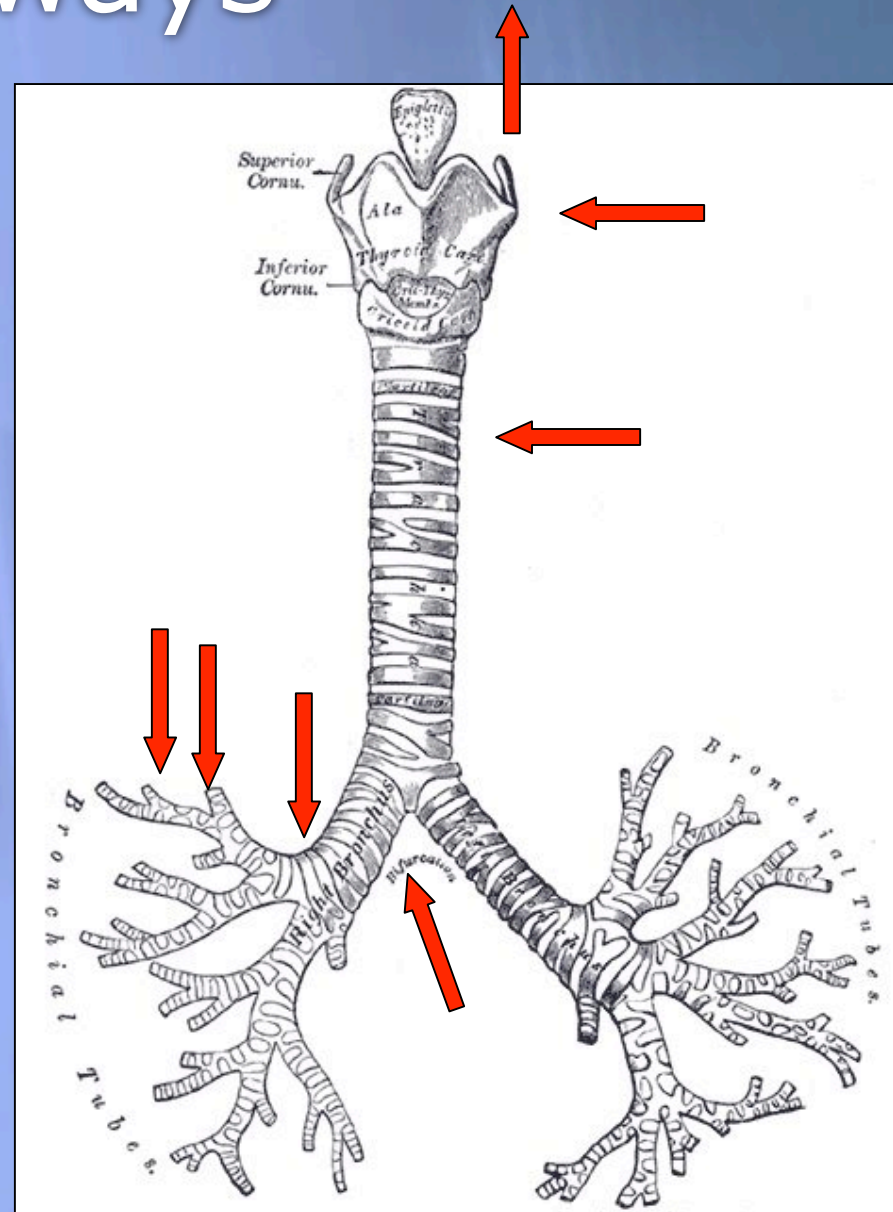
- ✦ Airways and Poiseuille's Law
- ✦ Surface tension and surfactant
- ✦ Lung / Chest wall system
- ✦ Lung Volumes and Spirometry
- ✦ Obstructive vs. Restrictive Disease

Airways



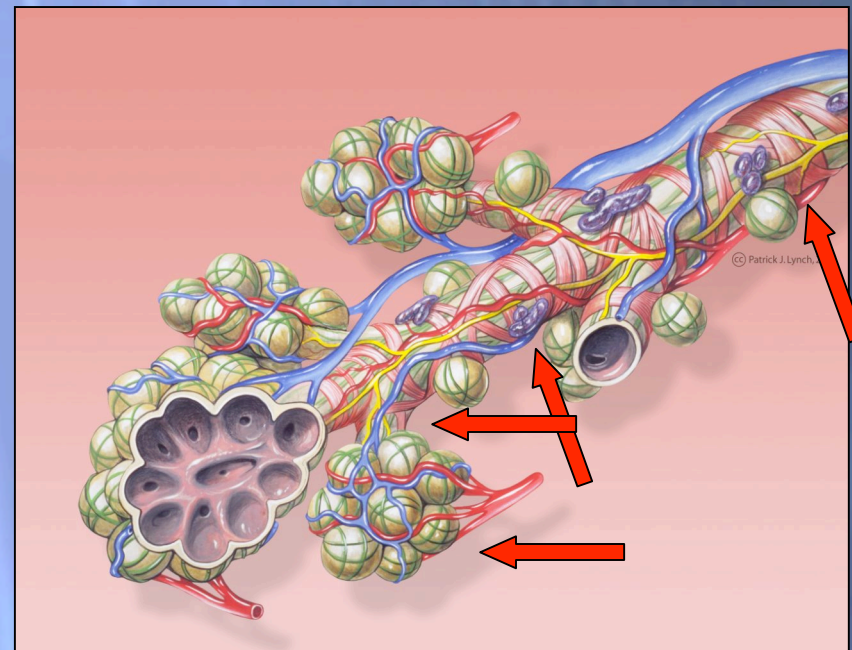
Airways

- ✦ Oropharynx / Nasopharynx
- ✦ Larynx (Voice Box)
- ✦ Trachea
- ✦ Mainstem Bronchi
- ✦ 2° (Lobar) Bronchi
 - ✦ Left Lung: 2 lobes
 - ✦ Right lung: 3 lobes
- ✦ 3° (Segmental) Bronchi
 - ✦ One for each bronchopulmonary segment
 - ✦ 1° Bronchioles



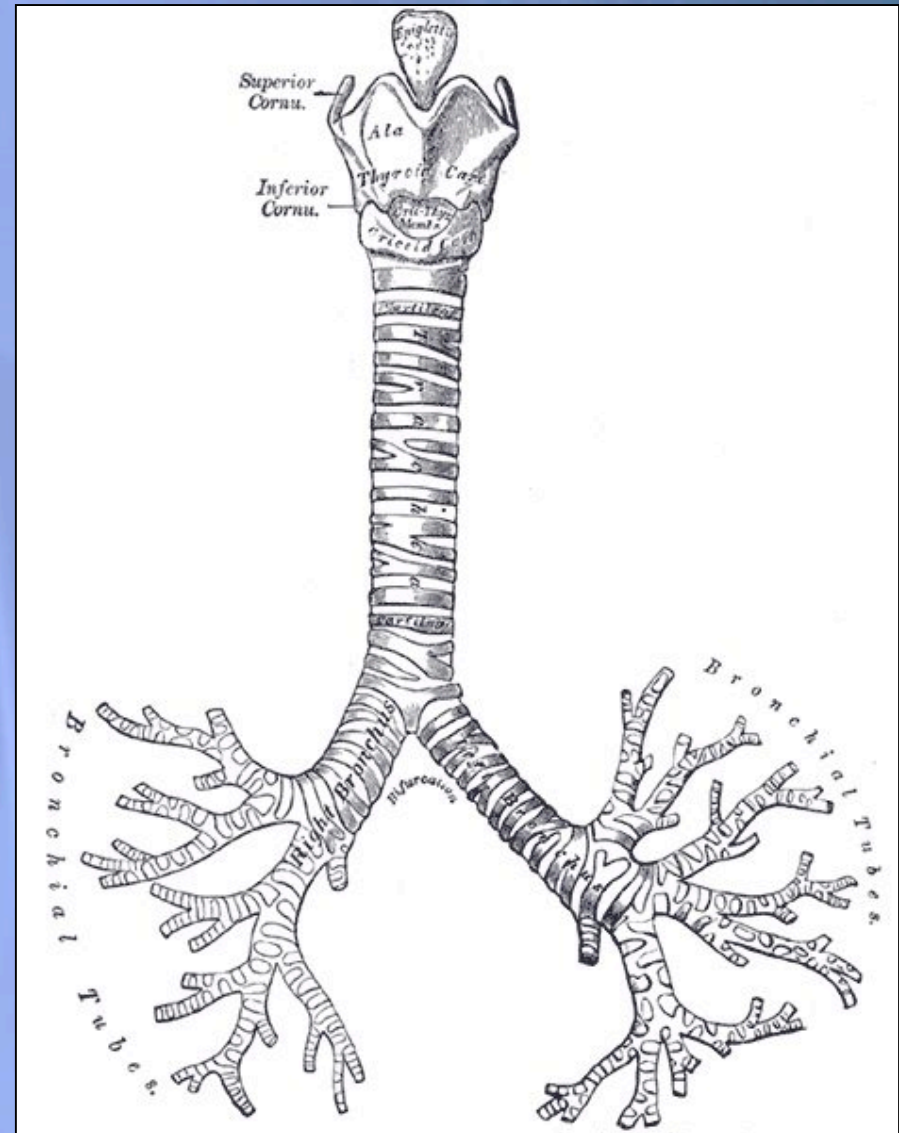
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- ✦ 1° Bronchioles
- ✦ Terminal Bronchioles
- ✦ Respiratory Bronchioles
- ✦ Alveolar Ducts
- ✦ Alveoli



Airways

- ✦ Transport air from mouth to respiratory areas
- ✦ Warm and moisturize air
- ✦ Resistance increases quickly as size decreases
- ✦ **Poiseuille's Law**



Poiseuille's Law

$$\Phi = \frac{dV}{dt} = v\pi R^2 = \frac{\pi R^4}{8\eta} \left(\frac{-\Delta P}{\Delta x} \right) = \frac{\pi R^4}{8\eta} \frac{|\Delta P|}{L}$$

- ✦ Φ : laminar flow through tube
- ✦ V : volume of liquid
- ✦ R : internal radius of tube
- ✦ η : dynamic fluid viscosity
- ✦ ΔP : pressure difference along tube
- ✦ L : length of tube

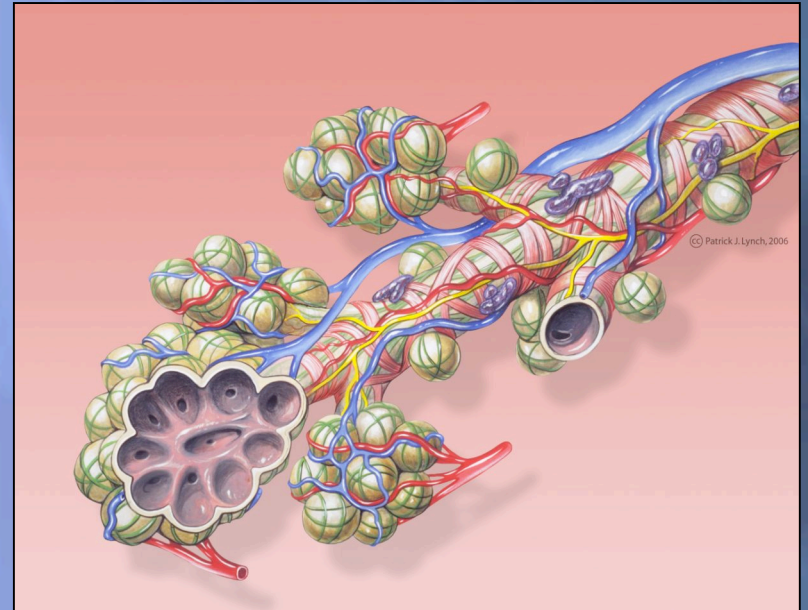
Poiseuille's Law

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- ✦ 2x Radius → 16x Flow
- ✦ $\frac{1}{2}$ x Radius → $\frac{1}{16}$ x Flow
- ✦ Airflow is quickly compromised with decreasing tube size

Alveoli

- ✦ Small air-filled sacs covered with a capillary bed
- ✦ Site of gas transfer between inhaled air and blood
- ✦ Total surface area of $\sim 80\text{m}^2$
- ✦ Lined with mucus that causes surface tension



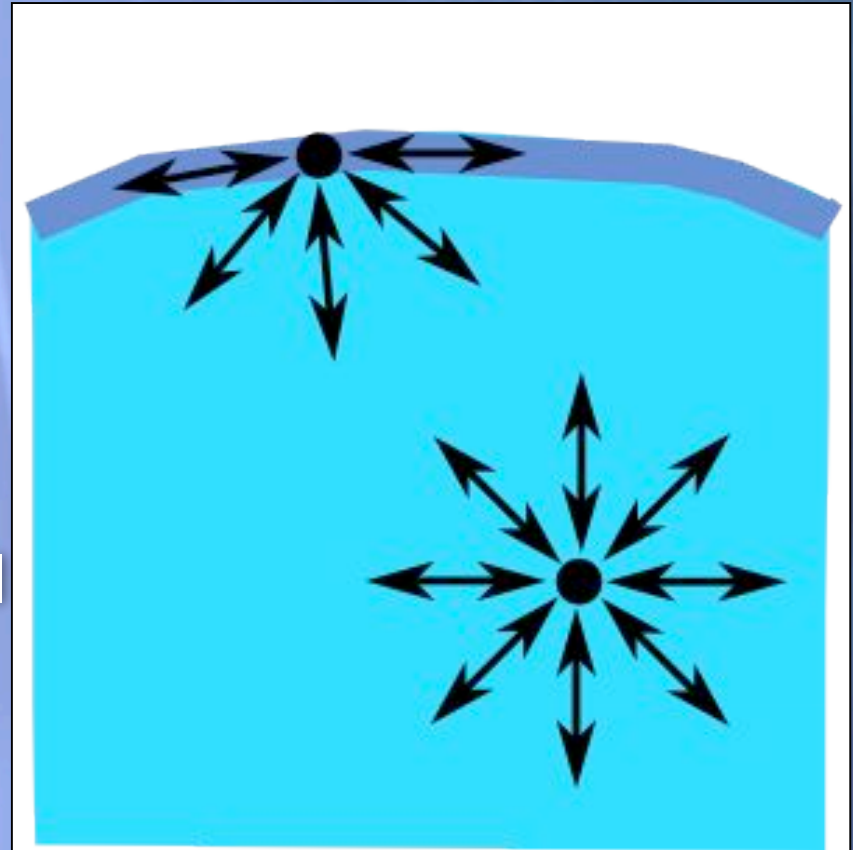
Surface Tension



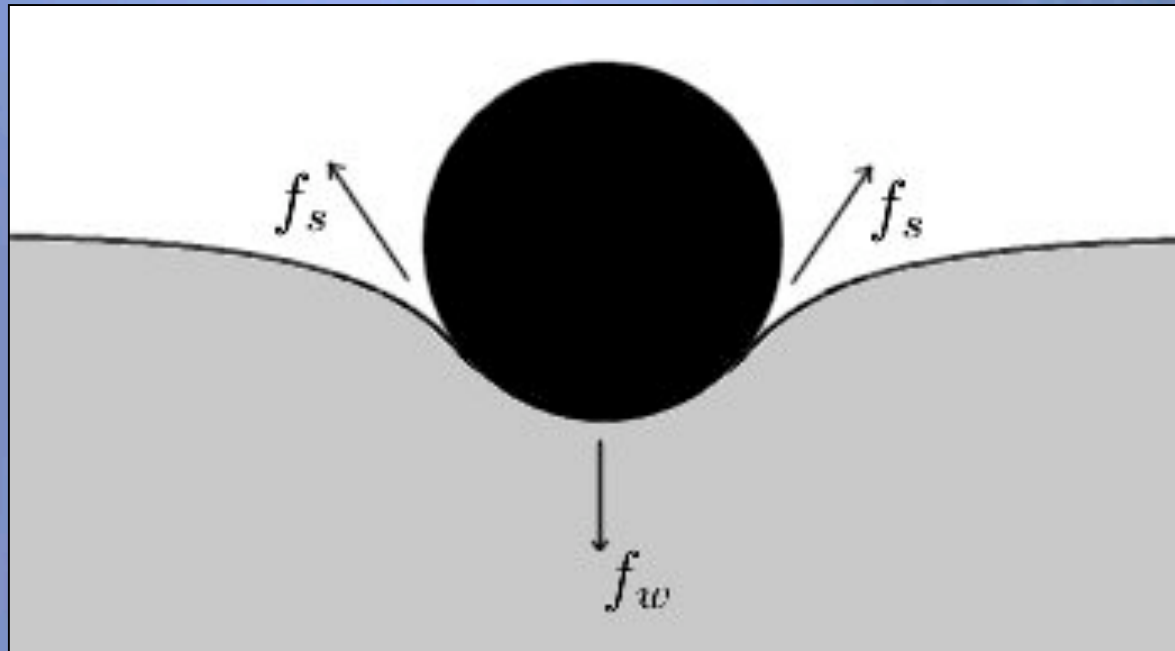
Intermolecular forces cause the surface of a liquid to behave like an elastic sheet

Surface Tension

- ✦ Middle of liquid
 - ✦ Intermolecular forces pull equally in all directions
- ✦ Edge of liquid
 - ✦ Intermolecular forces cause a net inward pull
 - ✦ Balanced by a resistance to compression
 - ✦ Causes surface to behave like an elastic sheet



Surface Tension



- ✦ The forces associated with resistance to compression can counter the weight of a light object

Surface Tension

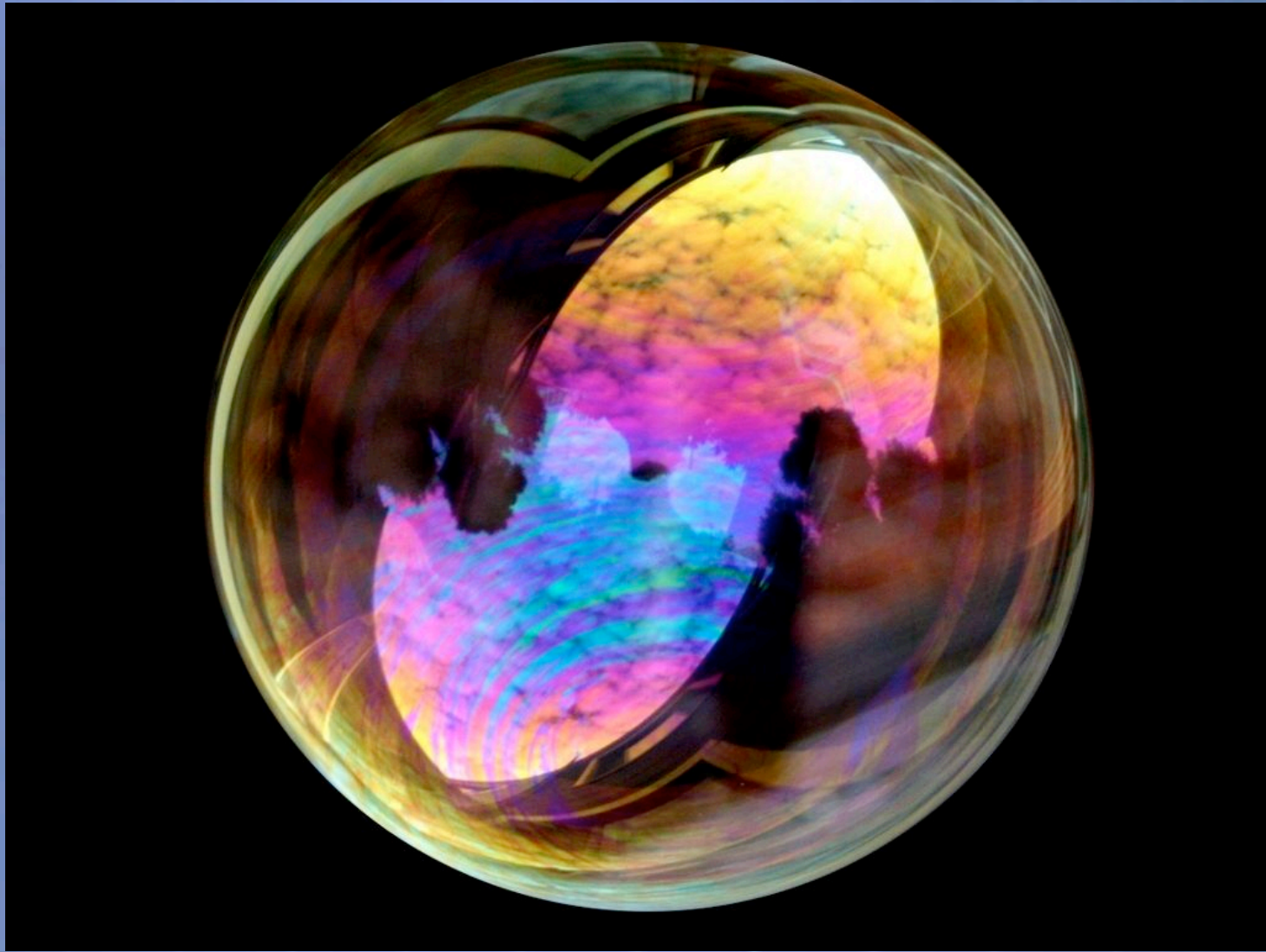


Surface Tension

- ✦ Inward compressive forces cause water droplets to assume a spherical shape
- ✦ A sphere represents the minimum surface area attainable for a given volume

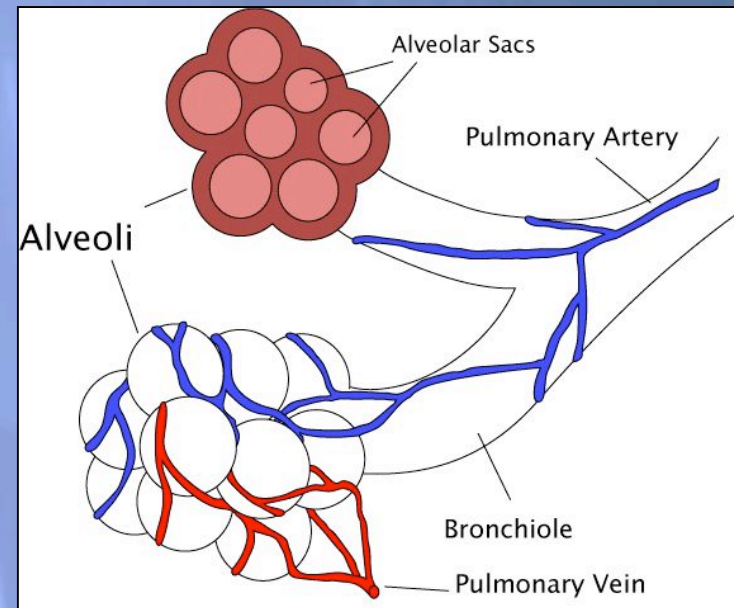


Surface Tension



Surface Tension

- ✦ Inside of alveoli coated with liquid mucus
 - ✦ Behave like little soap bubbles
- ✦ Surface tension wants to minimize volume
 - ✦ Acts to collapse alveoli
 - ✦ Resists expansion (↓ compliance)
- ✦ Surfactant
 - ✦ Acts to counter surface tension



Surfactant

- ✦ Decreases surface tension by interrupting intermolecular forces along the surface
- ✦ Increases “compliance” of the lungs
 - ✦ Less collapsing force
- ✦ Secreted by Type II Pneumocytes
 - ✦ Deficient in premature babies

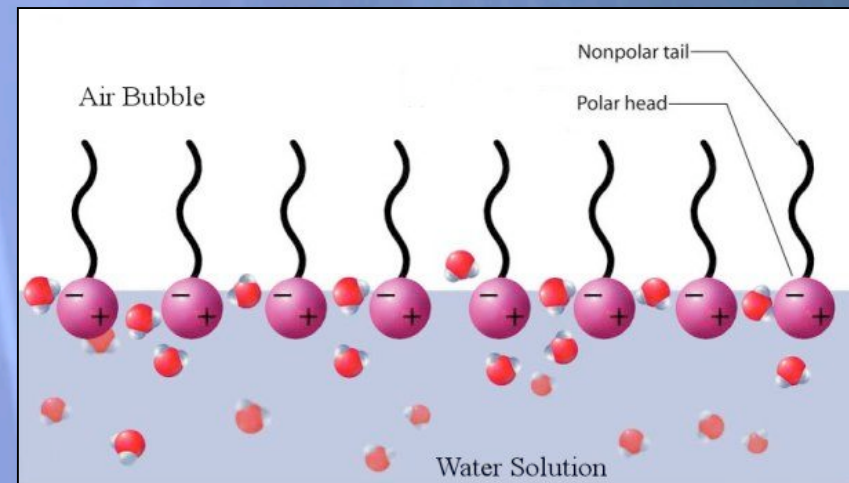
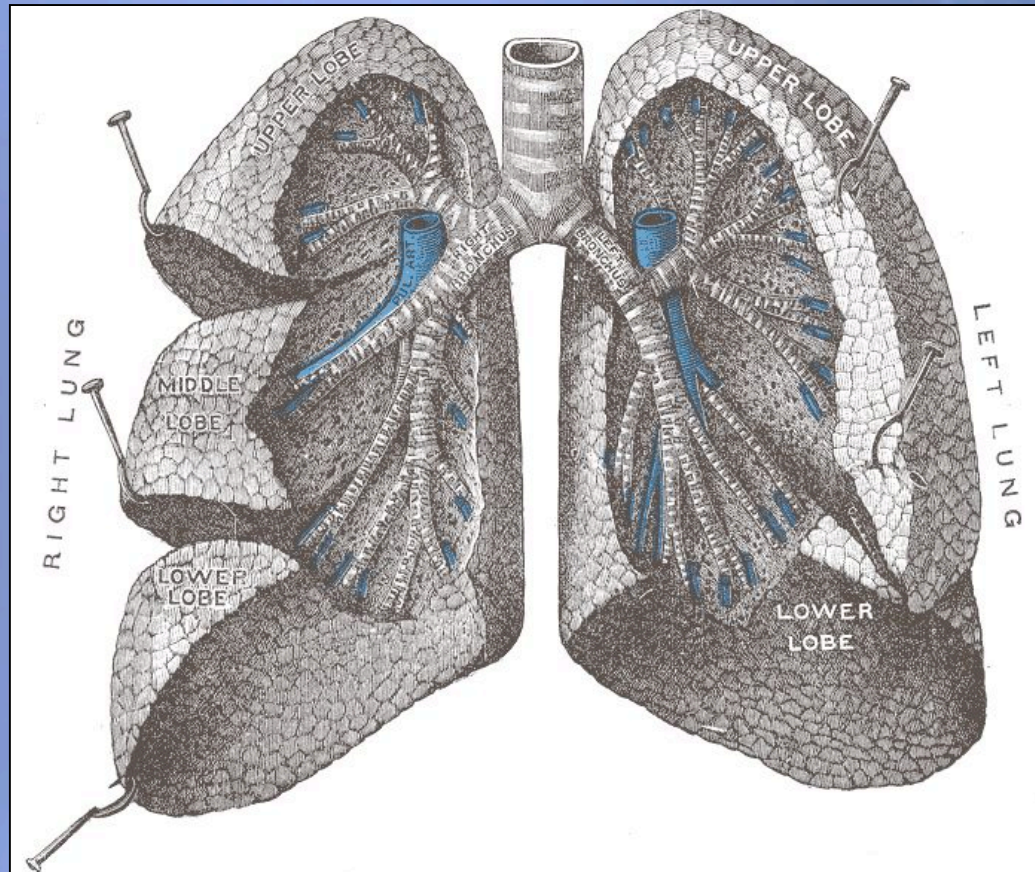


Image taken from: www.jimseven.com/?p=191

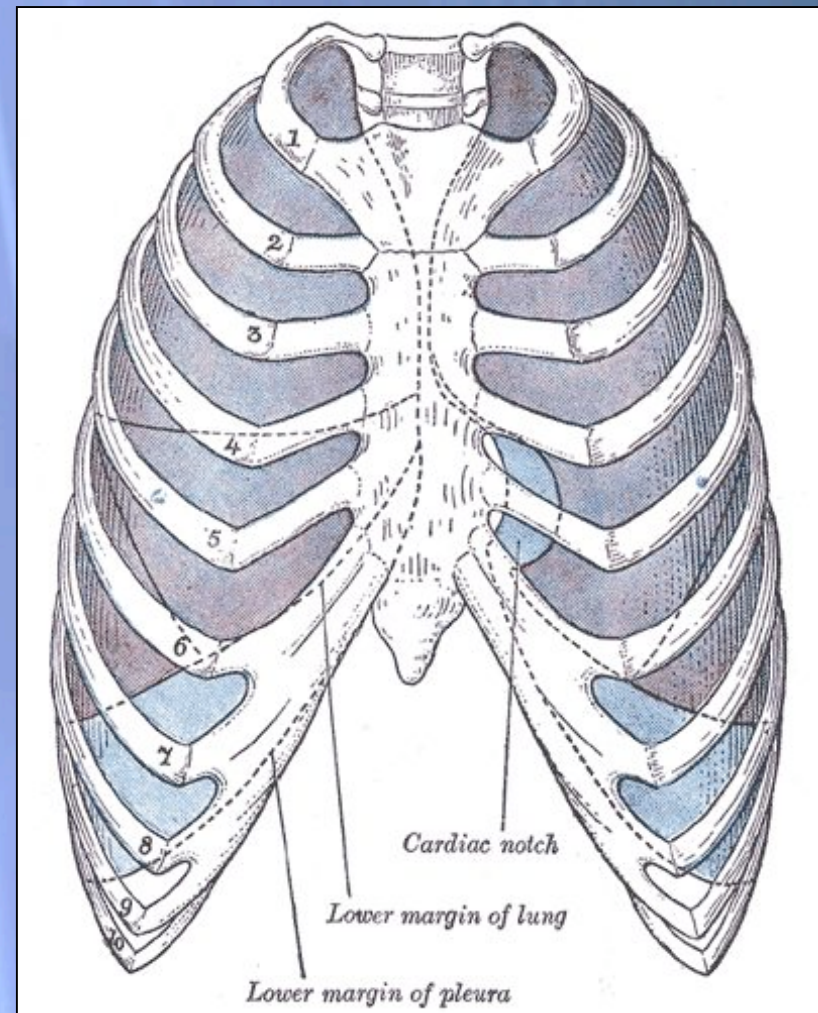
Lungs



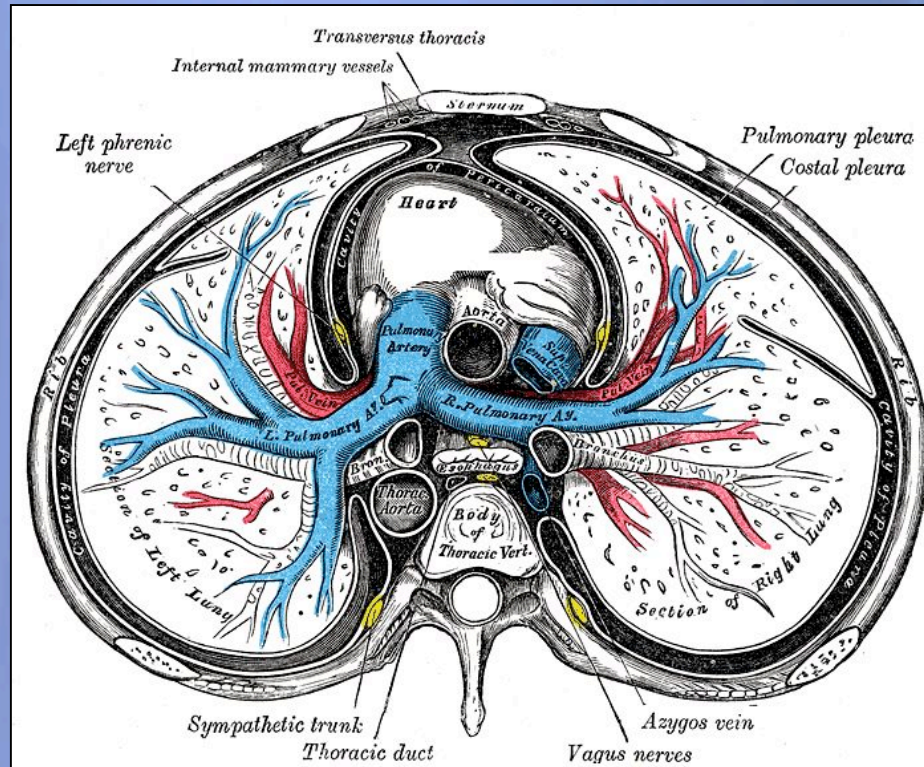
✦ Surface tension makes the lungs tend to collapse

Chest Wall

- ✦ Structure of the skeleton and cartilage makes the chest wall tend to expand

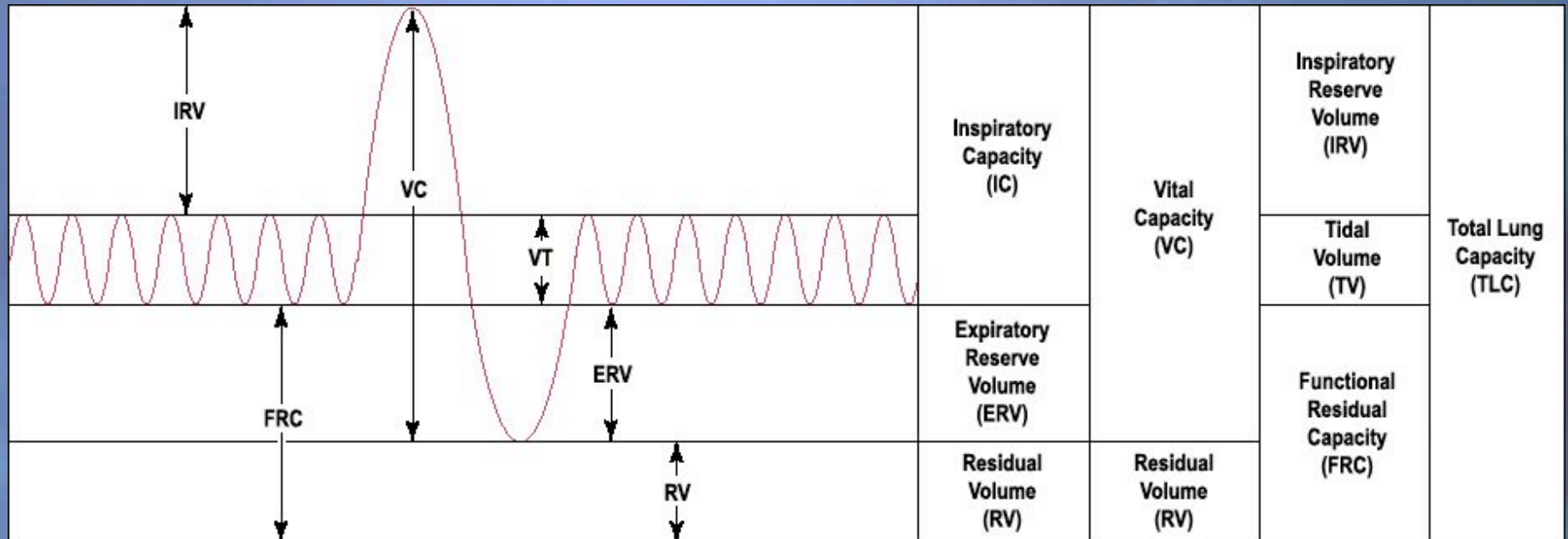


Chest Wall + Lungs



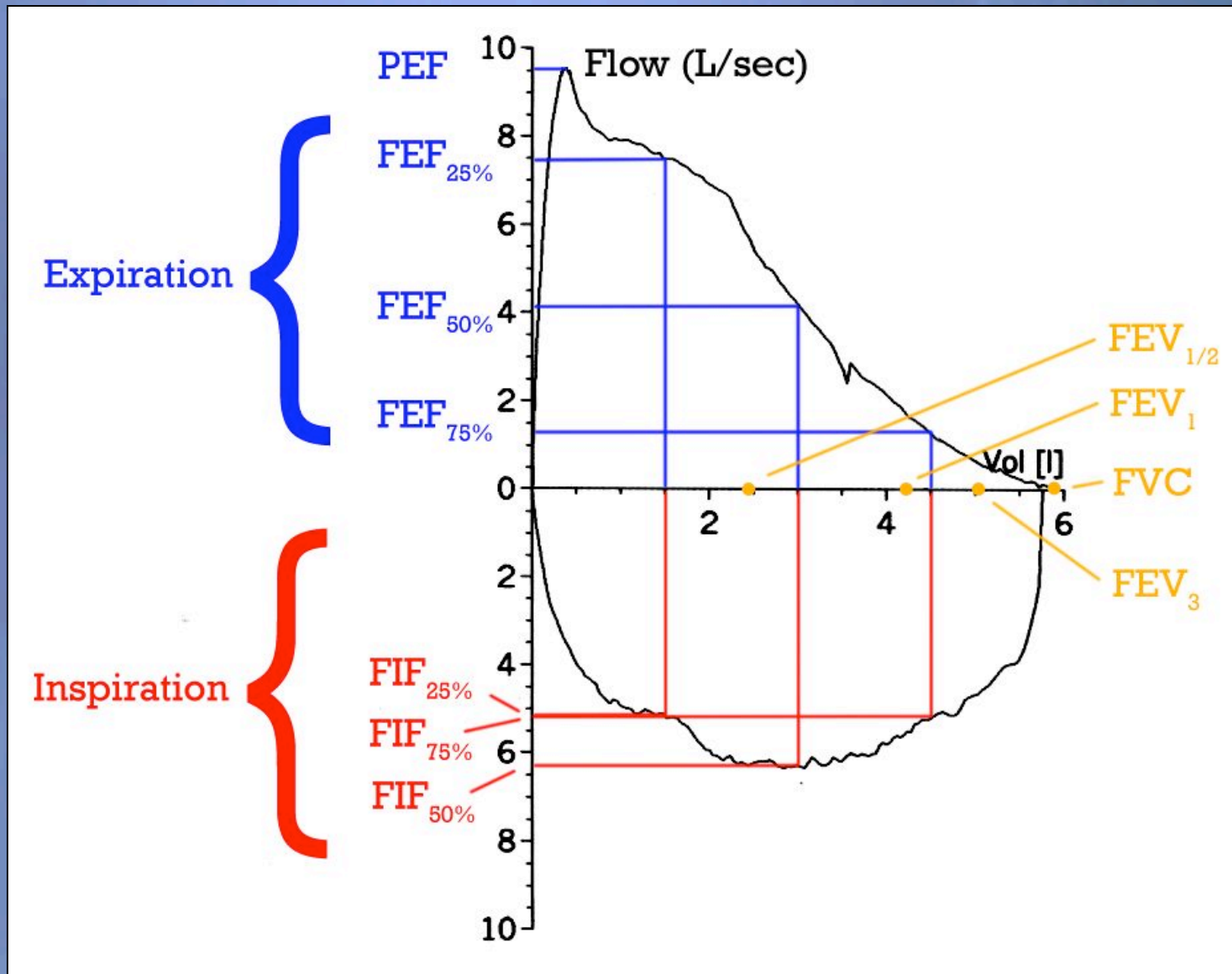
- ✦ Negative "intrapleural" pressure links lung and thorax volumes
- ✦ System comes to an equilibrium

Lung Volumes



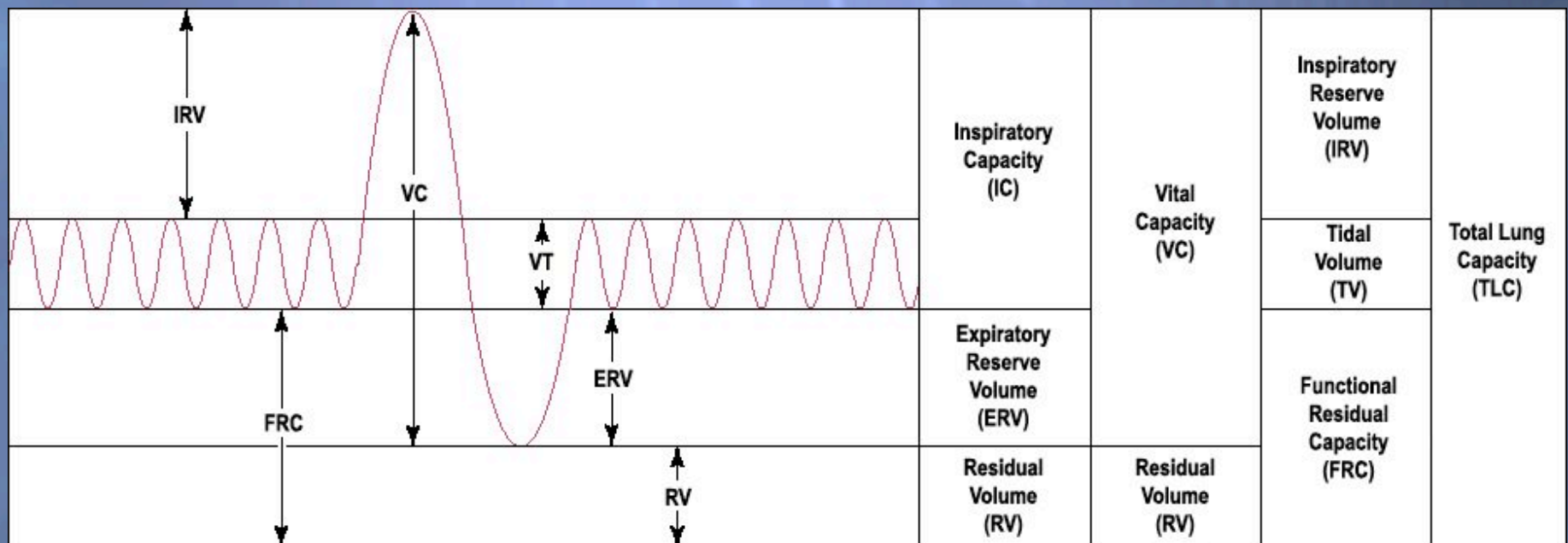
- ✦ FRC: Balance between lungs collapsing and chest wall expanding
- ✦ Normal breathing: Tidal Volume

Flow Volume Loop



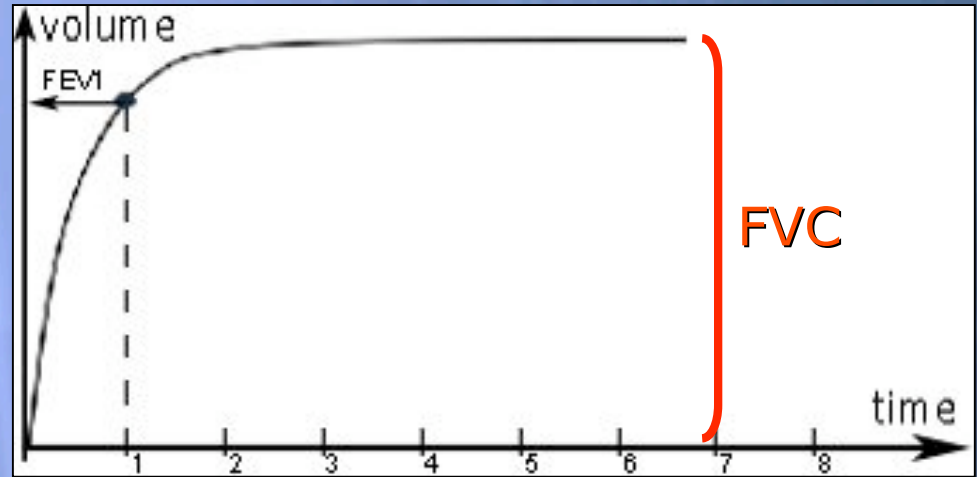
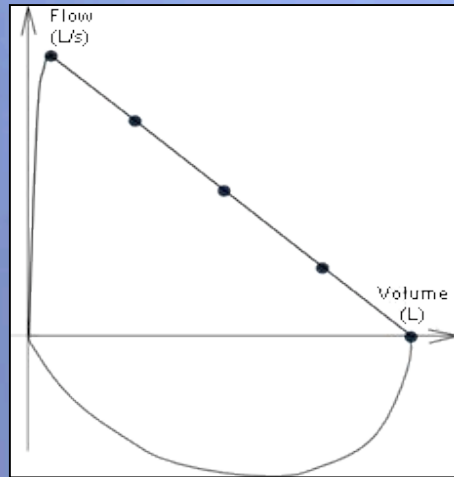
Restrictive Lung Disease

- ✦ Intrinsic disease of the lung tissue
- ✦ "Restricts" the lung's ability to inflate
- ✦ **Decrease in Lung Volumes**
- ✦ Decreased compliance (stiffer lungs)

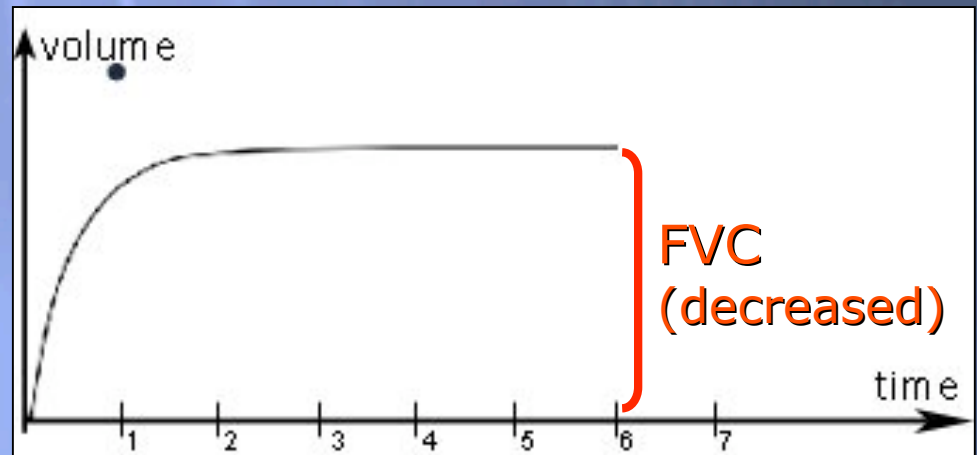
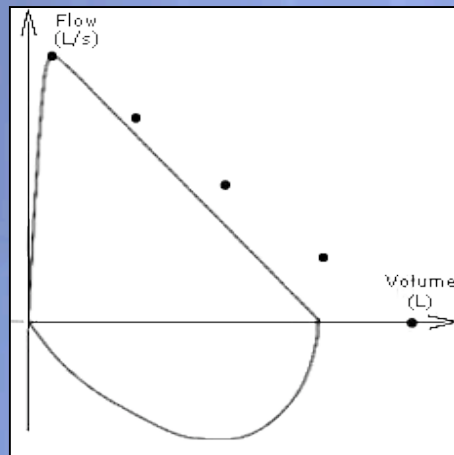


Restrictive Lung Disease

Normal



Restrictive

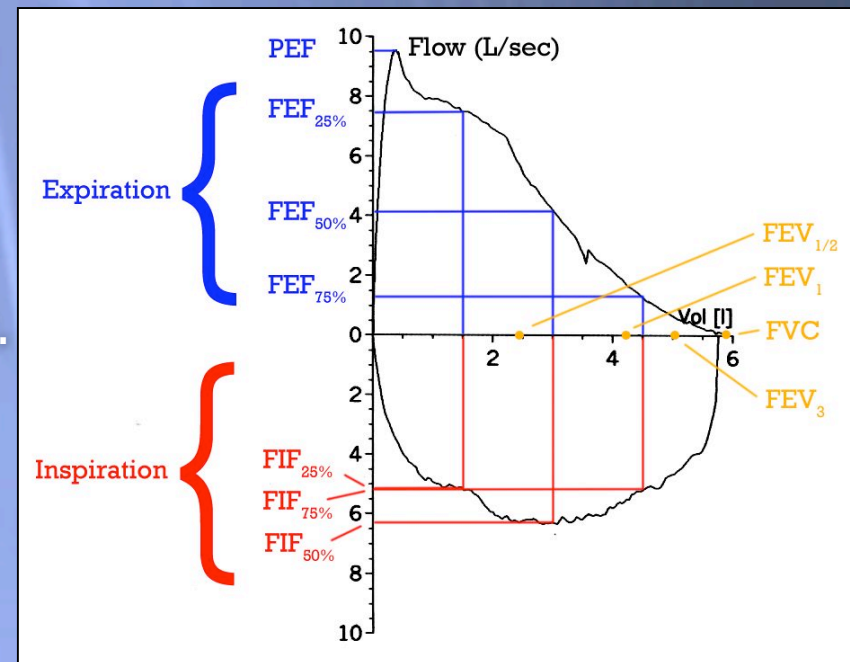


Note: Decreased FVC (Forced Vital Capacity)

Obstructive Lung Disease

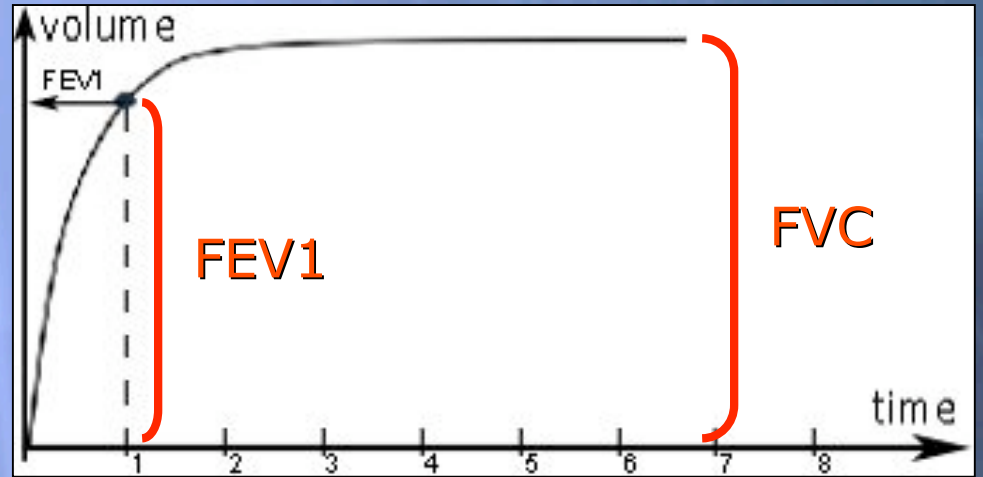
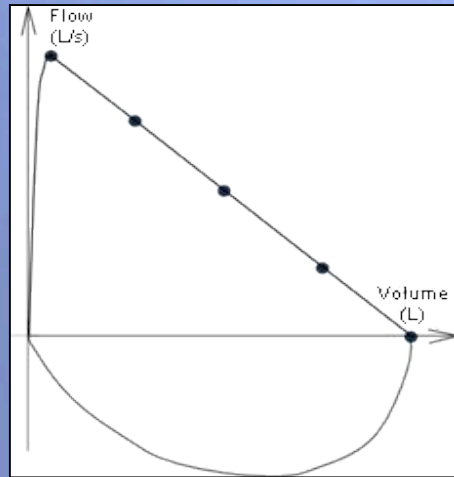
- ✦ Airflow is impeded for 1 of 2 reasons:
 - ✦ Airway obstruction (Asthma)
 - ✦ Air can't get out even when forced
 - ✦ Increased lung compliance (Emphysema)
 - ✦ Lung isn't forcing air out

- ✦ **Decreased FEV1/FVC ratio**
- ✦ FEV1: Forced Expiratory Volume
 - ✦ Amount you can exhale in 1 sec.
- ✦ FVC: Forced Vital Capacity
 - ✦ Total amount you can exhale

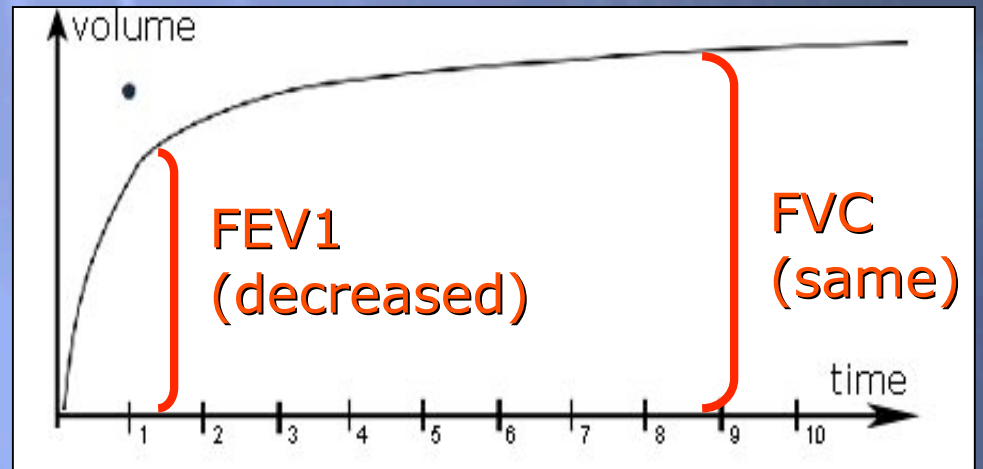
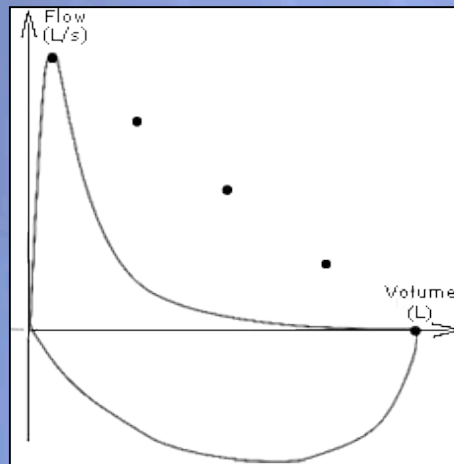


Obstructive Lung Disease

Normal



Obstructive



Note: Decreased FEV1/FVC Ratio

1) If you decrease the radius of an airway by half, by what fraction do you change the airflow?

- ✦ A) Increase by 2x
- ✦ B) Decrease by 2x
- ✦ C) Increase by 4x
- ✦ D) Decrease by 4x
- ✦ E) Increase by 16x
- ✦ F) Decrease by 16x

2) A patient having an asthma attack suffers from a 10% decrease in the radius of his airways. What is his airflow? (you can use a calculator)

- ★ A) 25% of normal
- ★ B) 45% of normal
- ★ C) 65% of normal
- ★ D) 85% of normal

3) A patient suffers a penetrating trauma to the chest, puncturing the pleural sac. What will happen to his chest and lungs?

- ✦ A) Both will collapse
- ✦ B) Chest will collapse, lung will expand
- ✦ C) Chest will expand, lung will collapse
- ✦ D) Both will expand

4) If a person were to die or become completely paralyzed, at what volume would their lungs come to rest?

- ✦ A) Tidal Volume (TV)
- ✦ B) Functional Residual Capacity (FRC)
- ✦ C) Vital Capacity
- ✦ D) Completely Empty

5) The volume of the biggest breath you can possibly blow out all at once is the:

- ✦ A) Tidal Volume (TV)
- ✦ B) Functional Residual Capacity (FRC)
- ✦ C) Vital Capacity
- ✦ D) Completely Empty

6) Surface Tension acts to do what to the surface area / volume ratio of a volume of liquid:

- ✦ A) Increase it, encouraging formation of a sphere
- ✦ B) Decrease it, encouraging formation of a sphere
- ✦ C) Increase it, discouraging formation of a sphere
- ✦ D) Decrease it, discouraging formation of a sphere

7) Surfactant has what effect on surface tension?

- ✦ A) Encourages intermolecular bonds, increasing surface tension
- ✦ B) Encourages intermolecular bonds, decreasing surface tension
- ✦ C) Disrupts intermolecular bonds, increasing surface tension
- ✦ D) Disrupts intermolecular bonds, decreasing surface tension

8) A person having respiratory distress undergoes spirometry testing and is told by his physician that he has an obstructive pulmonary disease. Which finding from the spirometry could lead to this diagnosis?

- ✦ A) Increase in FVC
- ✦ B) Decrease in FVC
- ✦ C) Increased FEV₁/FVC ratio
- ✦ **D) Decreased FEV₁/FVC ratio**