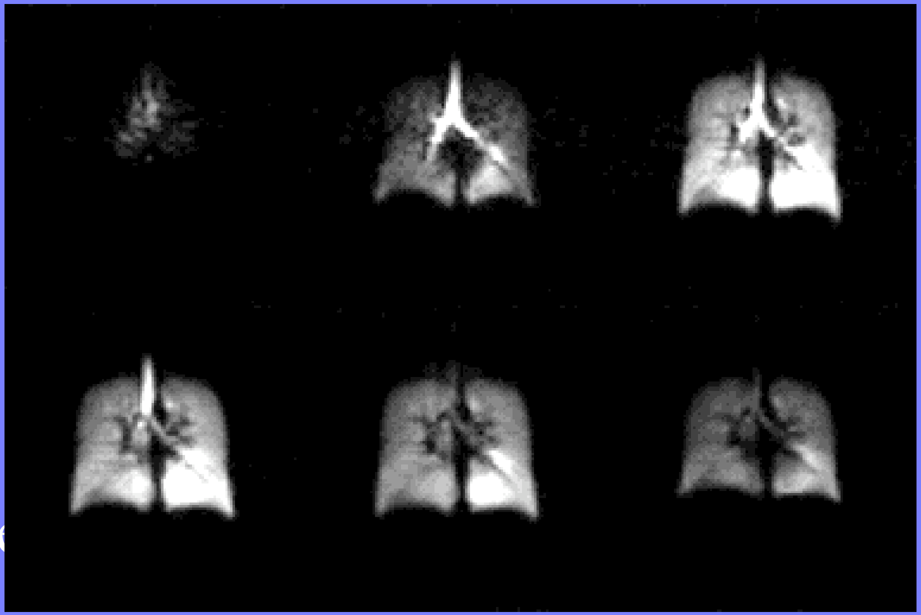
Lecture 10: The Physics of Breathing

ref: J.B. West: Respiratory Physiology 6th ed., Wiliams & Wilkins (2000)

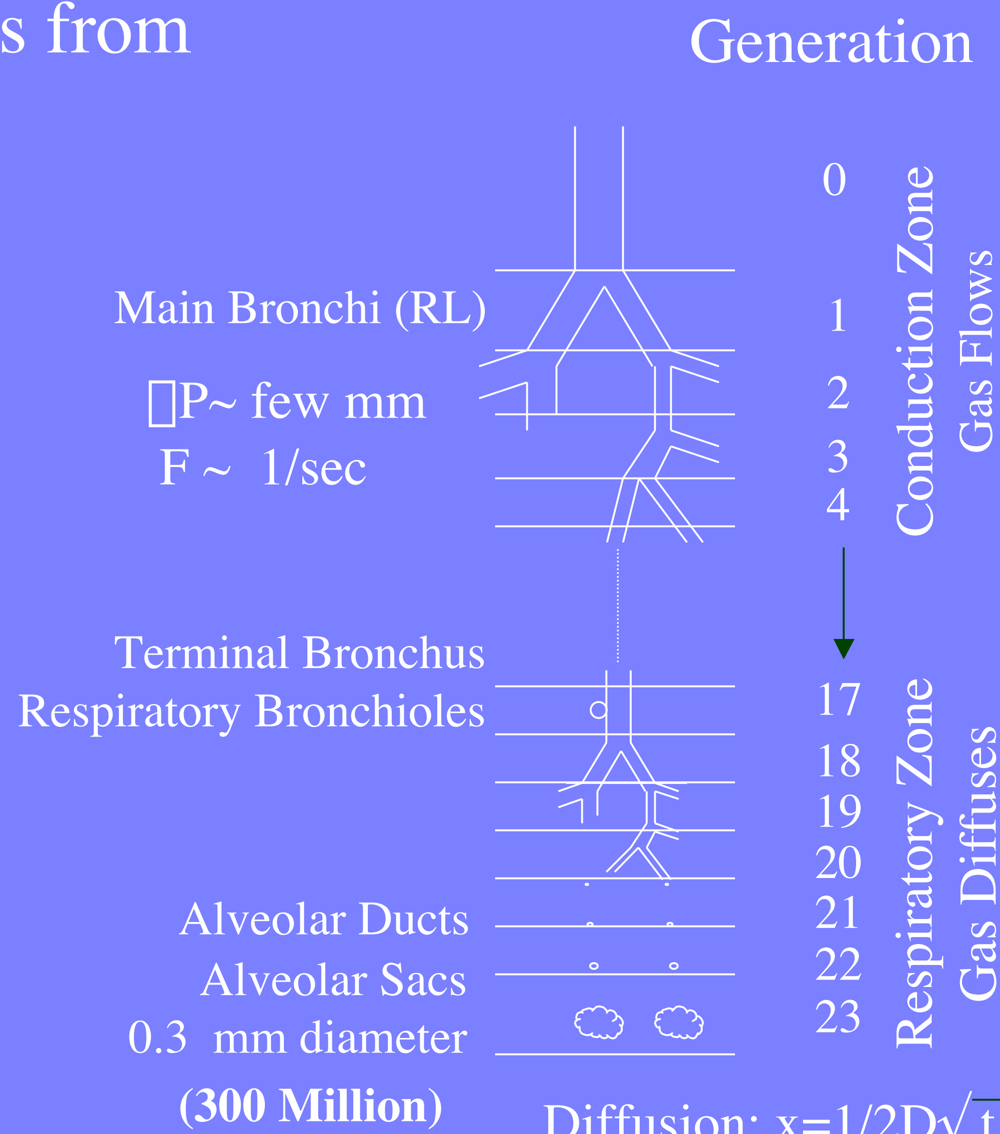
- The Lungs Exchange Gas
- Ventilation
  - The exchange of gas with the atmosphere



- Perfusion
  - The exchang

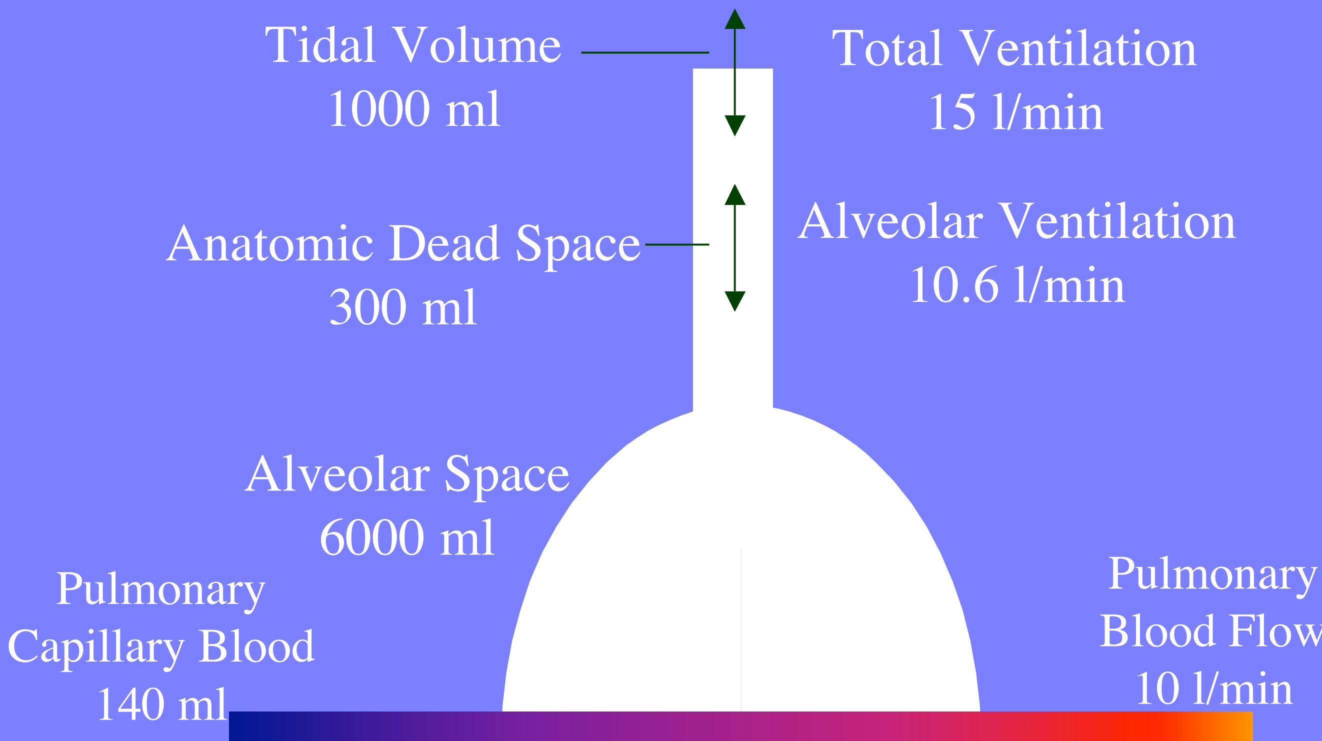
The Airways

- A series of branching tubes from
  - The **TRACHEA**
  - To the **ALVEOLI**



Lung Volumes and Flows

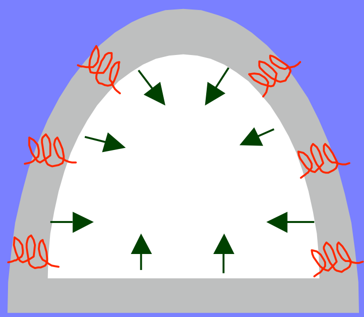
(Typical)

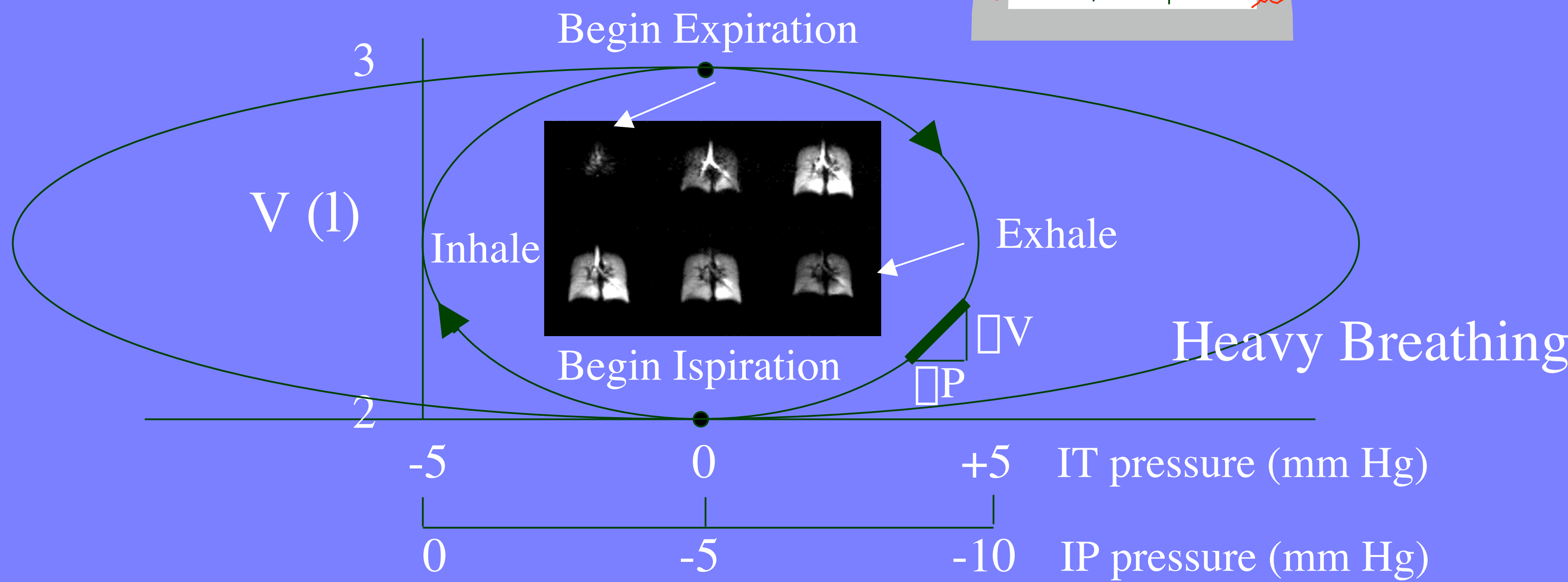


Total Lung Capacity	7 liters
Vital Capacity (max in - max out)	6 liters
Residual Volume	1 liter
Normal Lung Volume (inhaled)	4 liters
Tidal Volume (normal breath)	1 liter
Functional Residual Capacity	3 liters

Pressure vs Volume

- Intrapulmonary pressure: - 1.5 mm (inhaling)
- Itrathoracic Pressure:
  - Chest expands/Lungs recoil





- Compliance: □V/□P (liters/cm H_2O) 1 mm Hg = 1.36 cm H_2O

(Infant Lungs: Low Compliance/Fibrotic Lung: High Compliance/Flabby Lung)

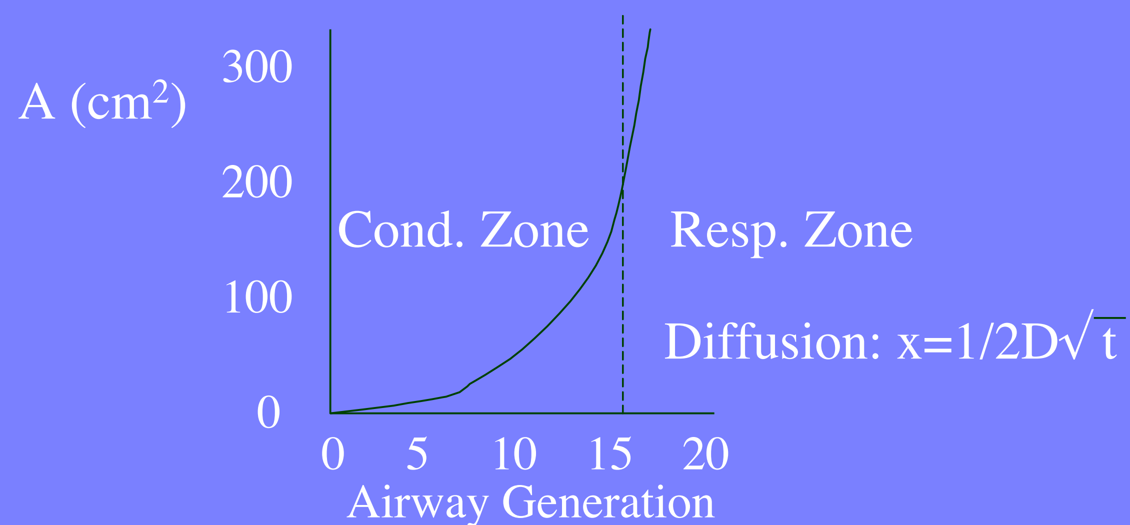
Airway Resistance

- $\Delta P = R * (\Delta V/\Delta t)$ R has units of Pa/l/s

  Pressure Volume Flow

- R = 330 Pa/l/s = 3. 3 cm H_2O/l/s = 2.5 mm Hg/l/s

- $R \sim \eta L/A^2$ for airway



Other Lung Features

- Surface Tension in alveoli -> collapses alveolus
- Inhaling pressure (200 Pa) -> expands alveolus
- Stability requires $2\gamma/R < 200$ Pa (1.5 mm)
  - Surfactant stabilizes alveoli

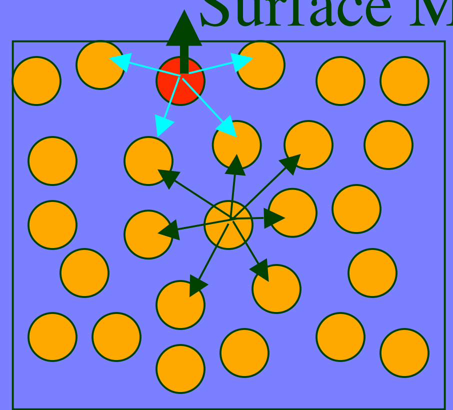
- Foreign Objects: dust etc.
  - Cilia move bronchial mucous upward

Liquid Surface Tension

- Fluids are 3 dimensional

- T=□L
- P=F/A=2□/R

(per surface of sphere)



□

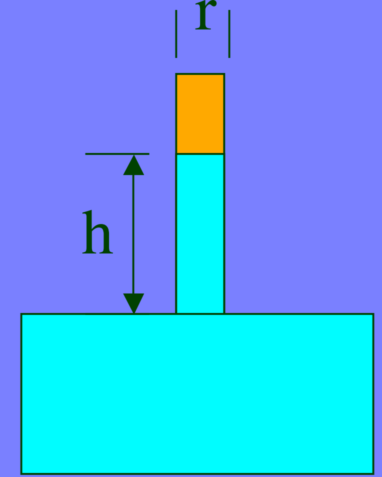
Water	+0.072 N/m	
Hg	0.44 N/m	
Lung Surfactant	0	(deflated)
	0.02 N/m (inflated)	

cos□$_c$ > 0 for H_2O-glass

cos□$_c$ < 0 for Hg-glass

Stability requires □/2R < 200 Pa (1.5 mm)

–Surfactant stabilizes alveoli

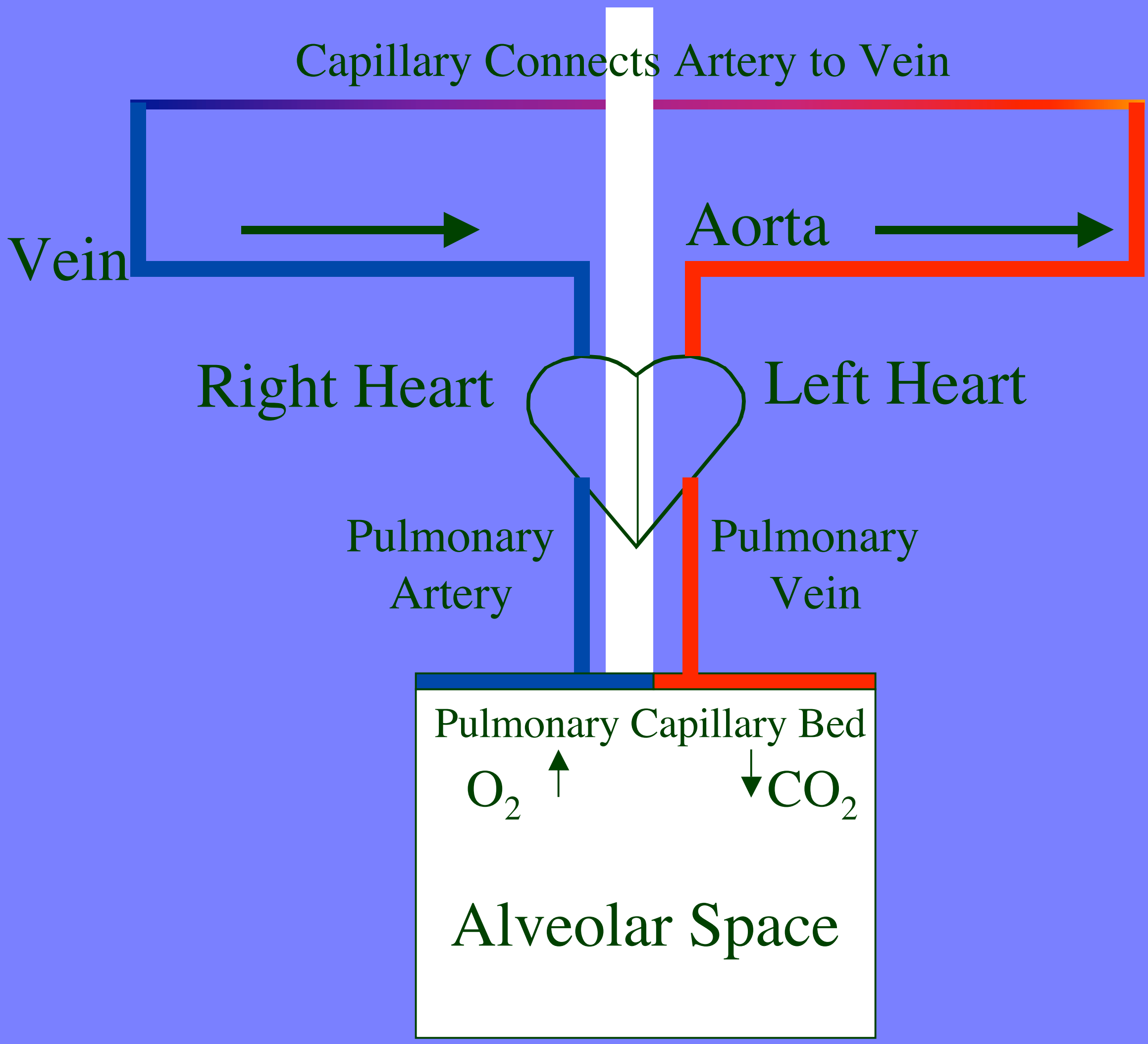


□2□rcos□$_c$ = □□□r^2h

h = 2□cos□$_c$/□□r

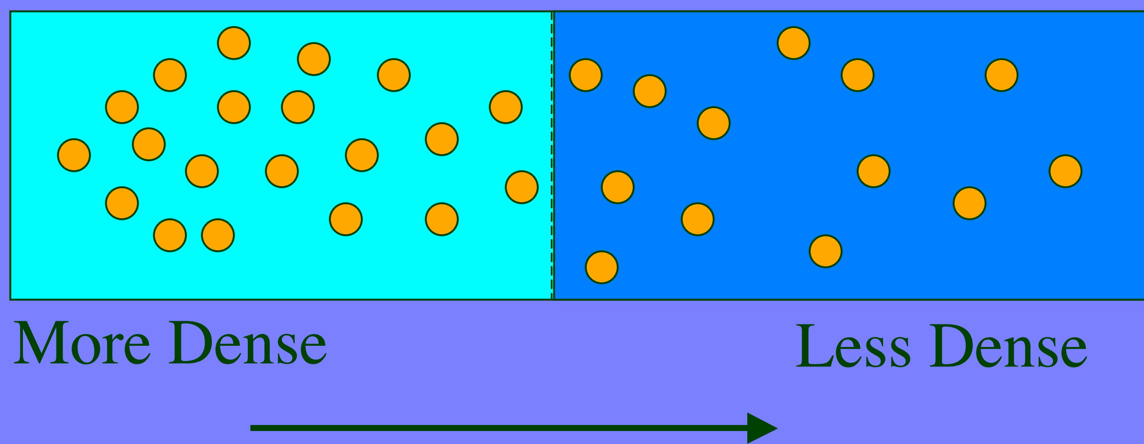
□$_c$ is the contact angle

The Blood-Gas Interface



The Blood-Gas Interface

- O_2 CO_2 and other gases FREELY DIFUSE
- Concentration Gradient Drives DIFFUSION



Diffusion: $x=1/2D\sqrt{t}$

- DIFFUSION grows with SURFACE AREA

Alveolar Sacs Fill Lung Volume with Surface

Gas Partial Pressure

- Partial Pressure: $P_a V = n_a RT$ Total $P = \Sigma P_a$

	Inhaled	Exhaled
N_2	78%	78%
O_2	21%	17%
CO_2	<1%	4%

- $P_{gas} \Rightarrow P_{blood}$ as blood moves through capillary ~1/2 s)
- $C_{blood} = \lambda_{BG} C_{gas}$ (λ_{BG} is the solubility or partition coef.)

Blood Plasma $\lambda_{O2} = 2\%$ (42 ml O_2/l_{blood})

$\lambda_{CO2} = 48\%$