Pulmonary Anatomy and Physiology
Basic Principles

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Functions of the Respiratory System

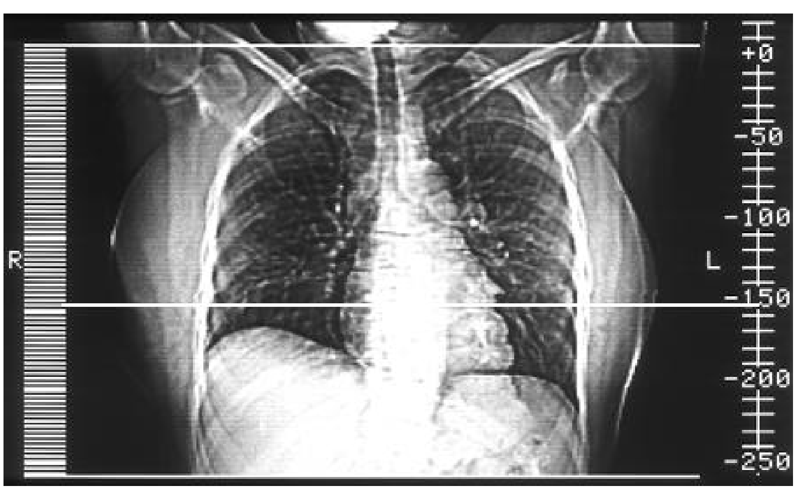
- Gas Exchange
  - O_2 and CO_2
- Acid-base balance
  - $CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$
- Phonation
- Pulmonary defense (air conditioning & filtering)
- Pulmonary metabolism and handing of bioactive materials

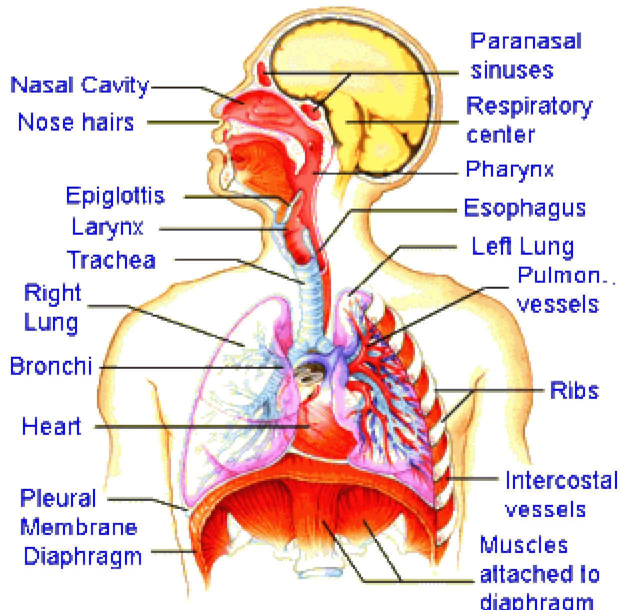
Additional Reasons to Study the Lungs

Alveolar blood-air interface: “window” into the body.

- Non-invasive drug delivery
- Non-invasive measurement of health
- Variety of physics, chemistry, math

Chest X-ray





http://www.medem.com/MedLB/a

Surface Markings of the Lung & Pleura – Anterior View

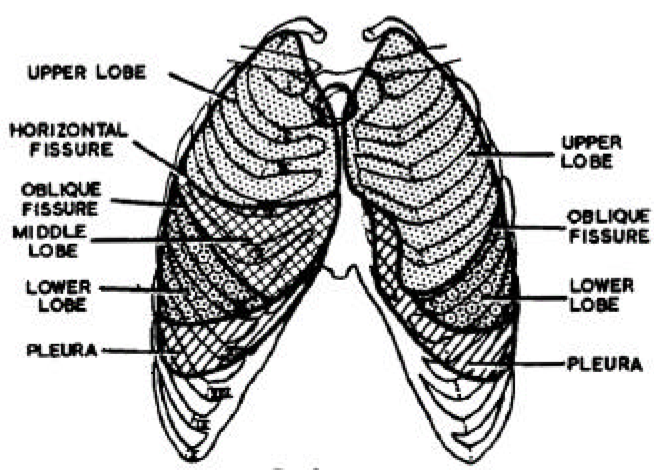
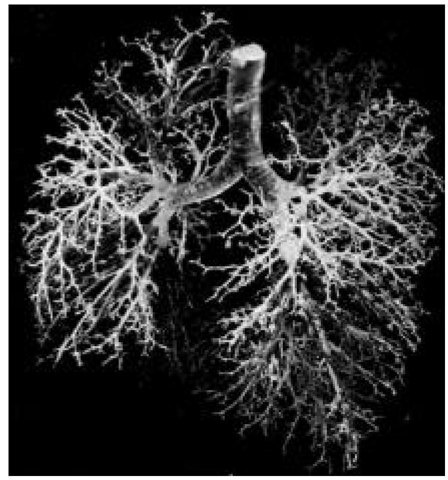


FIG. 2
The surface markings of the lungs and pleura—anterior view.

Clinical Anatomy, Ellis, 5th Ed., 1971

Branching Structure of Airways

- Dichotomous branching
- ~23 generations
- Can we describe this?
- Can we model this?



Trachea and Main Bronchi – Anterior View

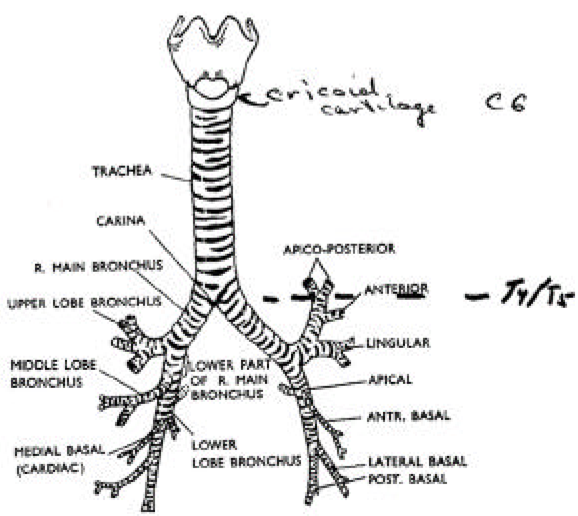
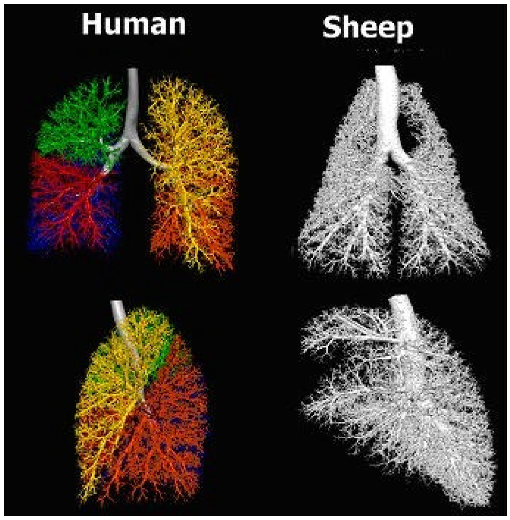


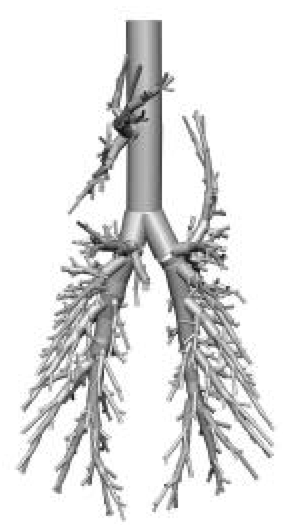
FIG. 13B
The trachea and main bronchi viewed from the front.

Clinical Anatomy, Ellis, 5th Ed., 1971

Monopodial vs. Bifurcating Airways



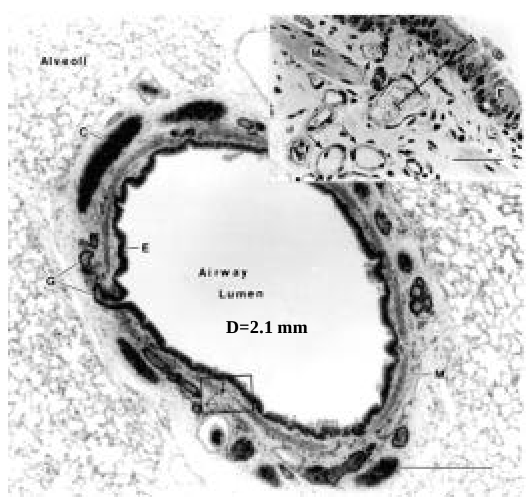
From the U. of Iowa



Monopodial structure of sheep airways

Conducting Airways

- Trachea, bronchi, small bronchi
- Cartilage
  - C-shaped in trachea
  - Irregular plates
- Cilia
- Goblet cells



Anderson 1998 (Courtesy of Dan Luchtel)

Airway Diameter vs Generation

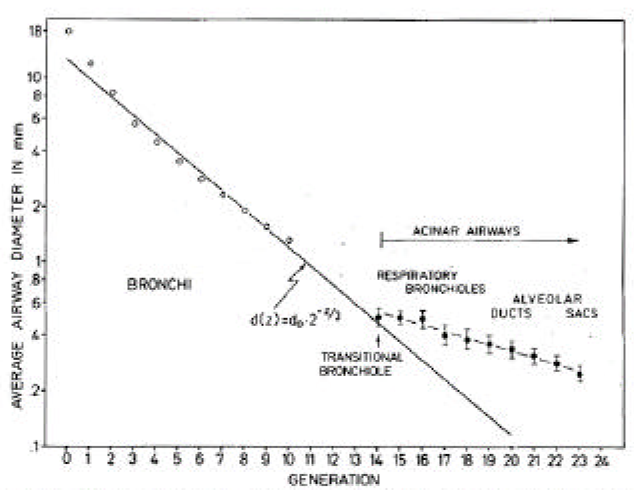


FIG. 6. Semilogarithmic plot of mean airway diameter versus generation. (From ref. 9.)

The Lung: Scientific Foundations,
Weibel, 1991

Airway Path: Weibel Model

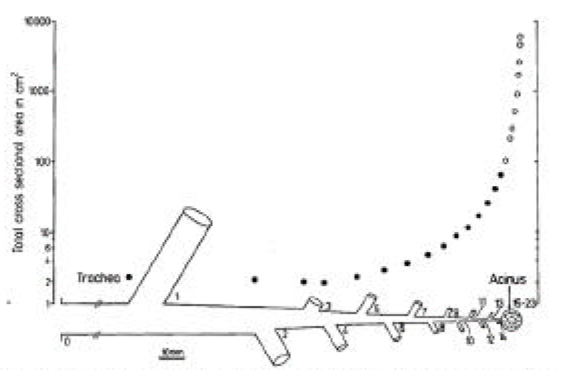
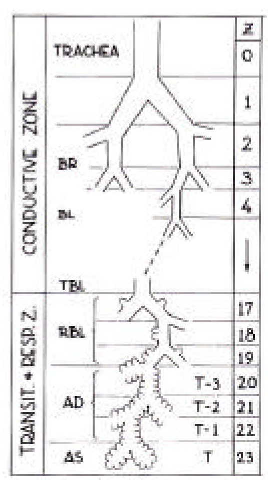
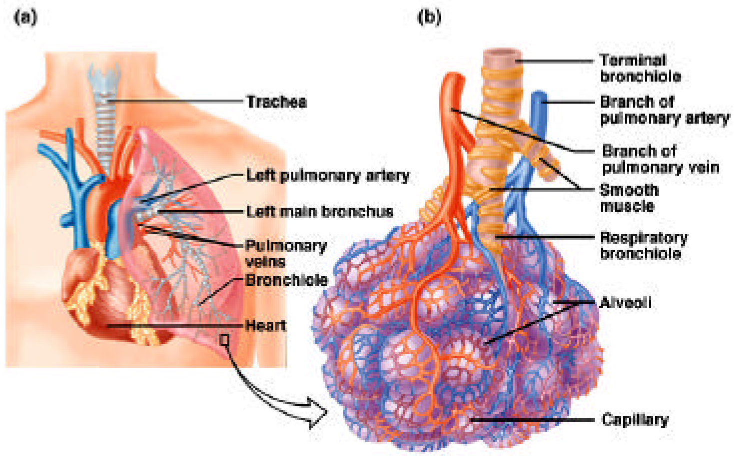


FIG. 7. Symmetric typical path model drawn to scale along abscissa, with increase of total airway cross-sectional area shown on logarithmic ordinate. Filled circles represent conducting airways, and unfilled circles represent acinar airways.



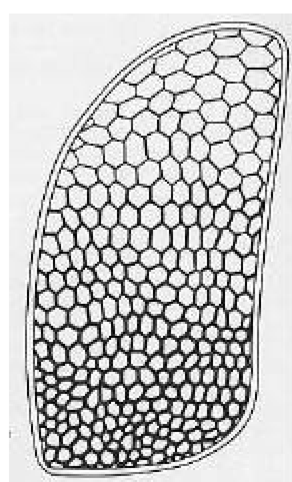
The Lung: Scientific Foundations,
Weibel, 1991

Respiratory Unit



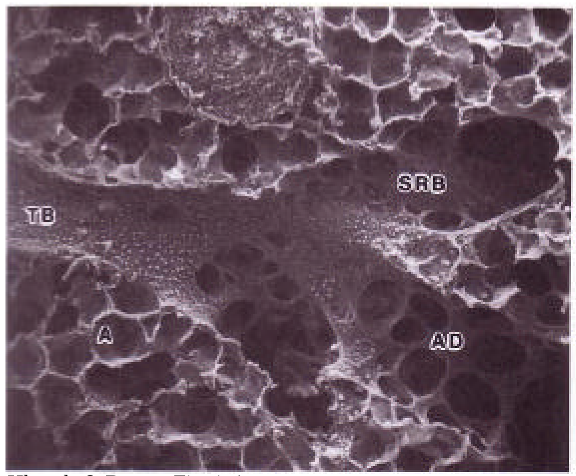
Static Lung Volumes

- Lung is easily extensible
- Alveoli in non-dependent regions tend to be larger than in dependent regions
- Lung is tethered



From Levitzky, Fig 5-5

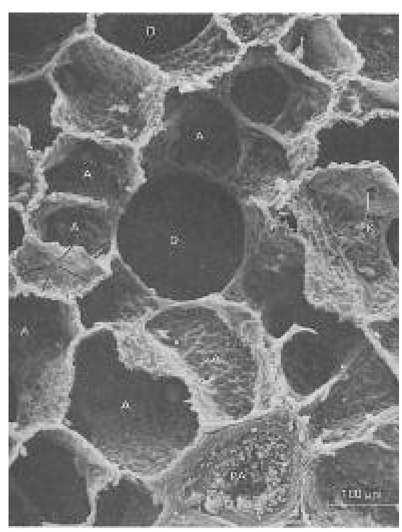
Respiratory Zone



Hlastala & Berger, Fig. 1-4

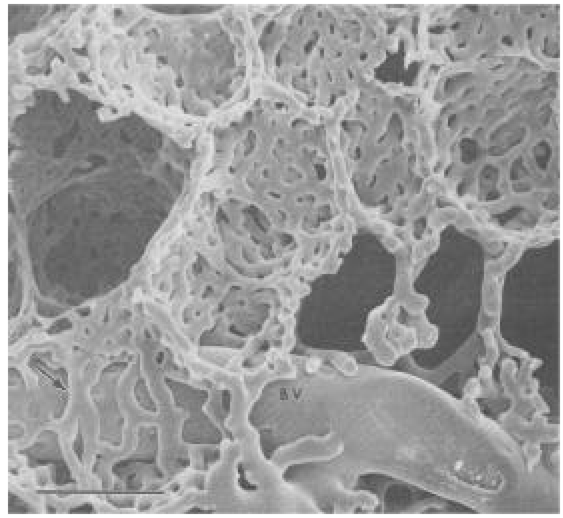
Airspace Microstructure

- Alveoli
- Alveolar ducts
- Pores of Kohn
- Liquid lining layer


Levitzky, Fig 1-2

Pulmonary Microcirculation Network

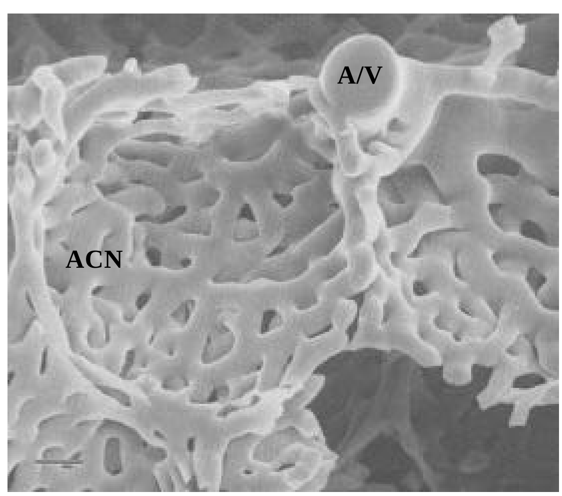
- Pulmonary capillaries encapsulate alveoli



Guntheroth et al. J. Appl. Physiol, 1982

Alveolar Capillary Network

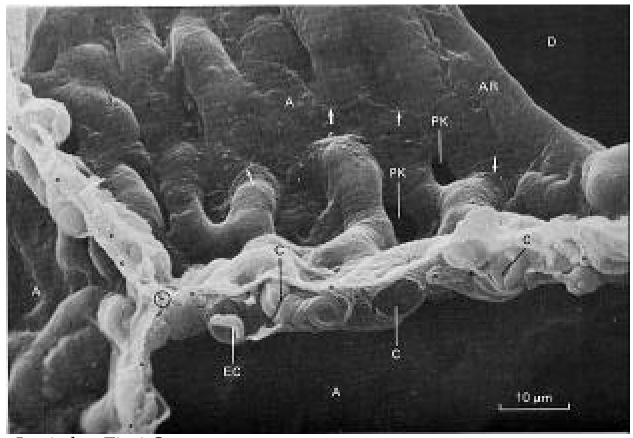
- Forms continuous sheet of blood



Guntheroth et al. J. Appl. Physiol, 1982

Cross-section of Microcirculation

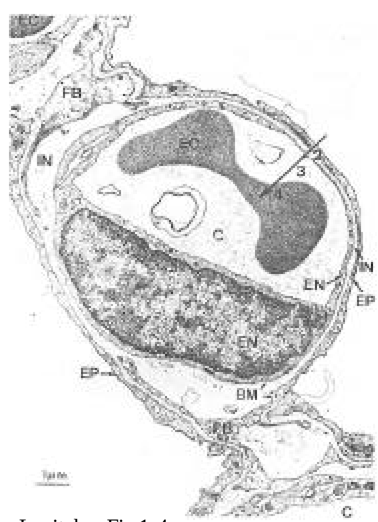
- Capillaries surround alveoli
- Sheet flow of blood



Levitzky, Fig 1-3

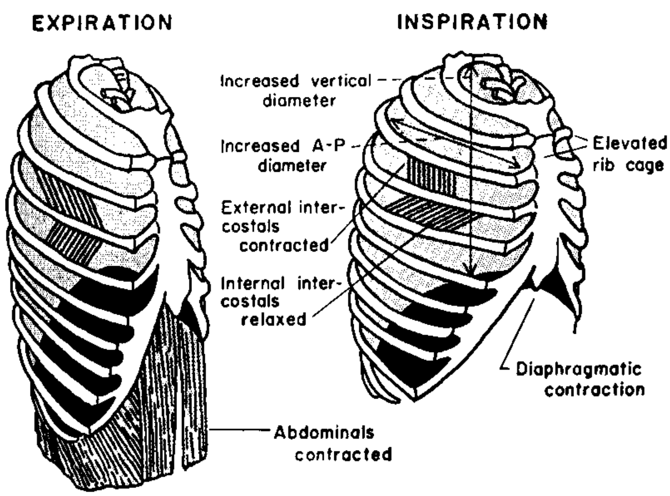
Diffusion Barrier

- Capillary cross-section
- Diffusion barrier
  - ~0.2-0.5 µm



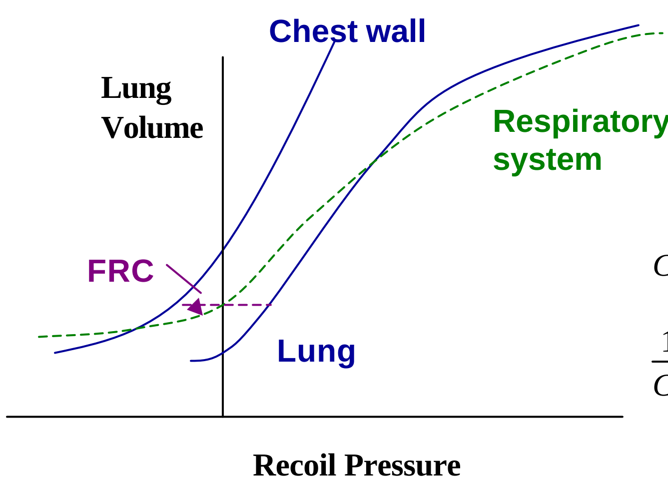
Levitzky, Fig 1-4

Rib Cage, Diaphragm and Lung



Textbook of Medical Physiology, Guyton, 4th Ed., 1971

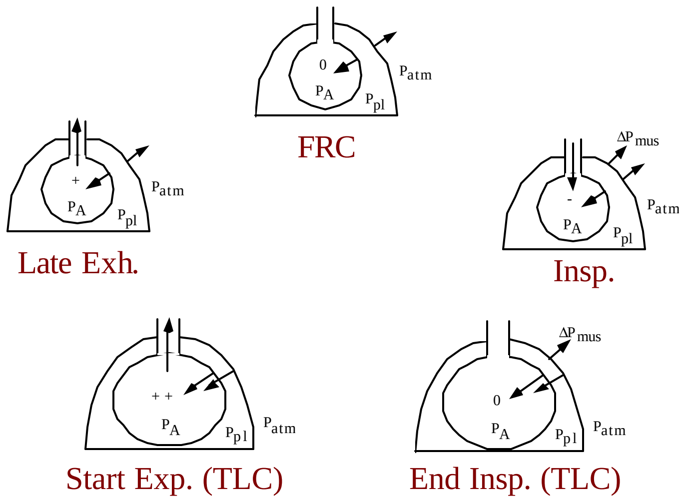
Lung and Chest Wall



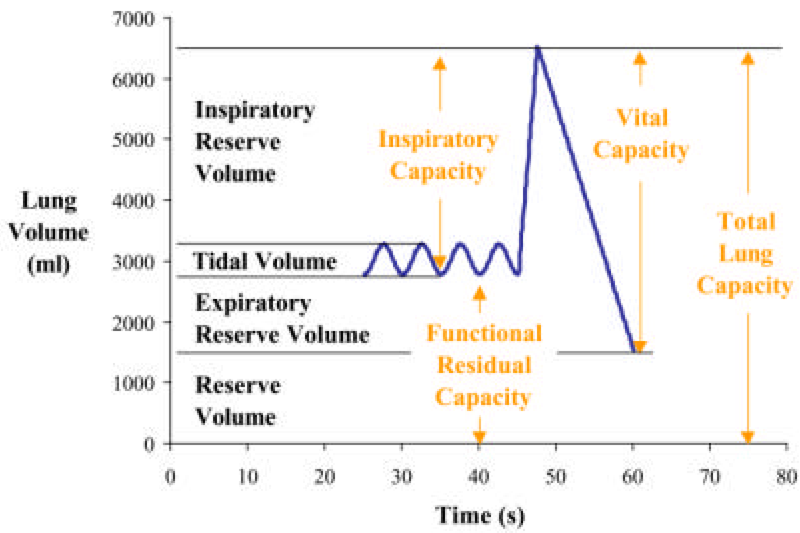
$$C = \frac{DV}{DP}$$

$$\frac{1}{C_T} = \frac{1}{C_L} + \frac{1}{C_{CW}}$$

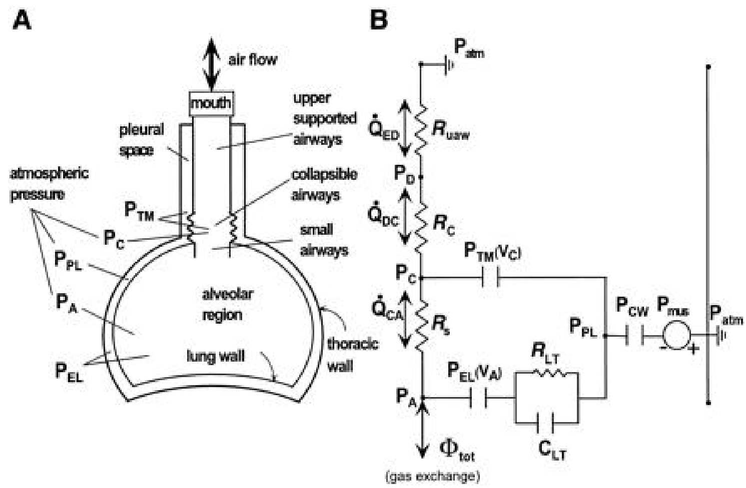
Relative Pressures of the Breathing Cycle



Lung Volumes

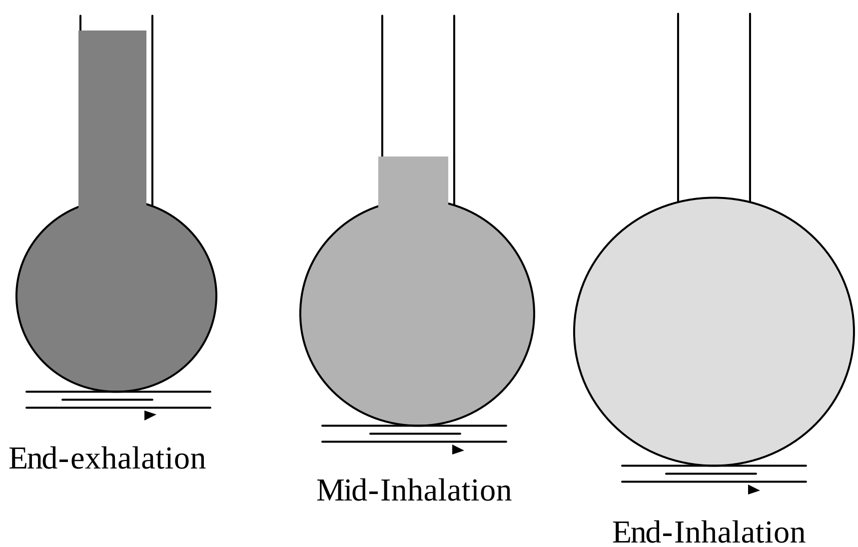


A Lumped Parameter Analogue



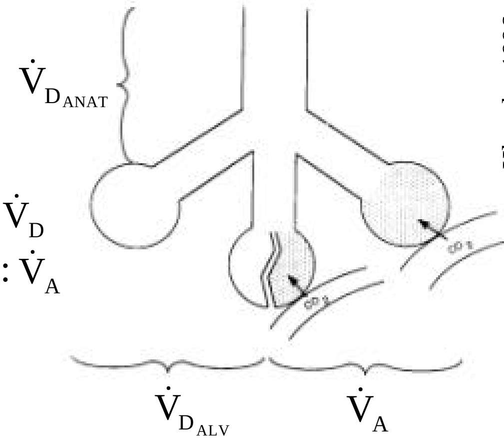
Lu, APJ Heart, 2001

Airways and Ventilation



Dead Space

- Dead space: V_D
- Wasted Ventilation: $\dot{V}_D$
- Alveolar Ventilation: $\dot{V}_A$

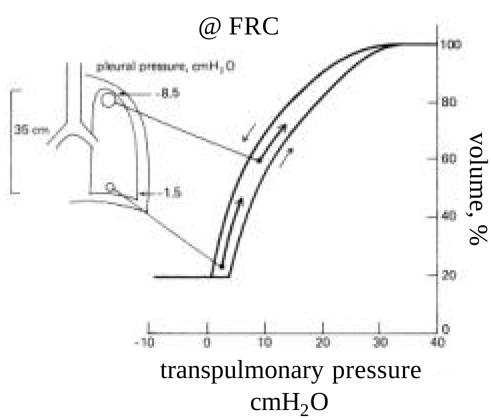


Hlastala, 1996

$$V_{D_{physiol}} = V_{D_{anat}} + V_{D_{alv}}$$

Ventilation Heterogeneity

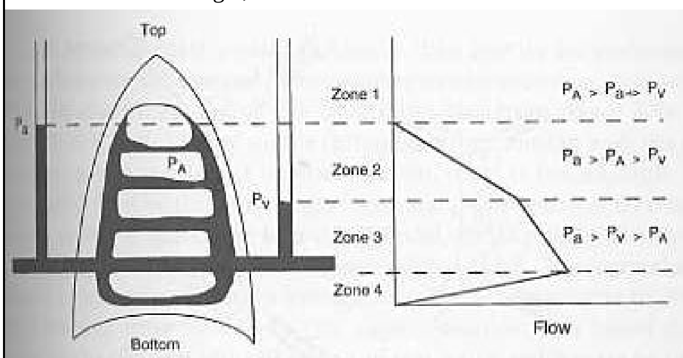
- Gradient in intrapleural pressure (~0.2 cmH_2O/cm)
- Larger transpulmonary pressures in non-dependent regions

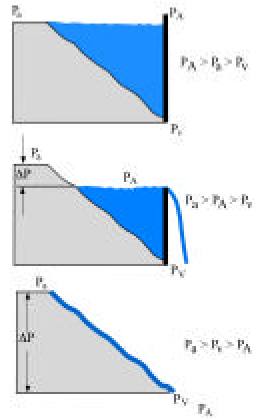


Levitzky, 1991

Pulmonary Perfusion: Zone Model

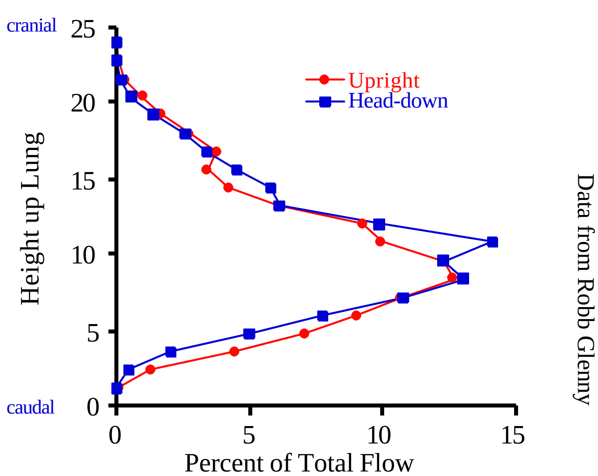
Hlastala & Berger, 1996



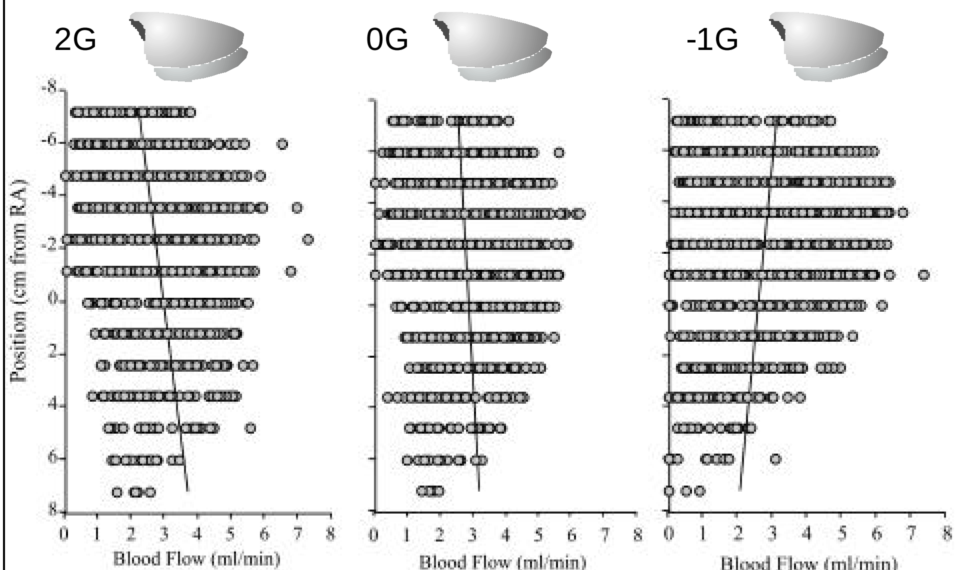


Then, there is the other point of view...

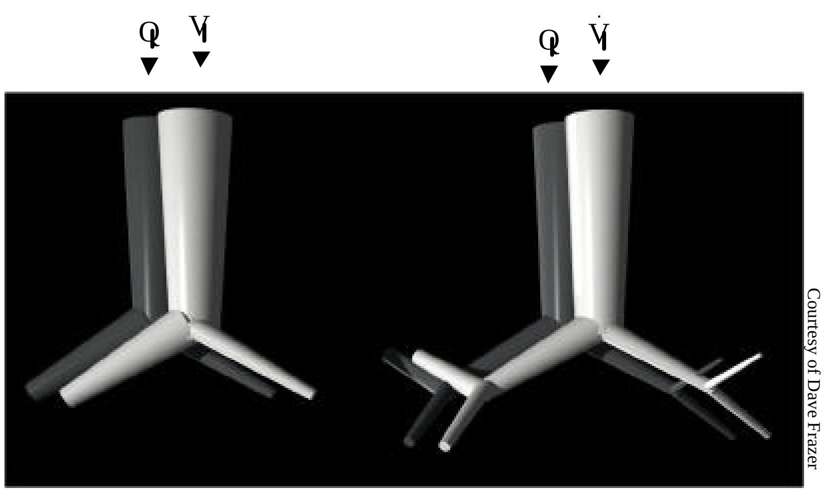
Upright vs Head-down



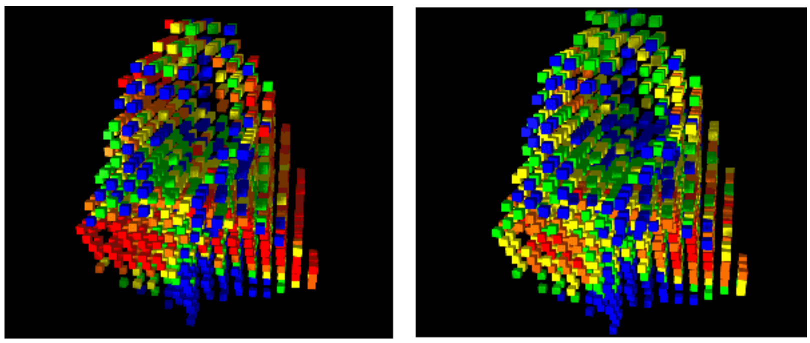
Gravity Effects



Ventilation and perfusion



Ventilation/perfusion matching



V Q

Courtesy of Bill Altemeier

Why Model the Lung?

Summarize findings

Simplify complex system

Predictions – inaccessible for measurement

Develop new research strategies

Pulmonary Parameters

Respiratory Rate	12-15 per min
Tidal Volume	500 ml
Dead space volume	150-200
Compliance	200 ml/cmH_2O
Cardiac Output	100 ml/s
O_2-blood sol. (P>150)	1.18E-6 M/mmHg
O_2-blood sol. (P~40)	2.35E-5 M/mmHg
CO_2-blood solubility	3.1E-4 M/mmHg
Alveolar PO_2	100 mmHg
Alveolar PCO_2	40 mmHg