THE UNIVERSITY of VERMONT

Lung Mechanics: Theory and Practice I

The Basics of Measuring Lung Mechanics

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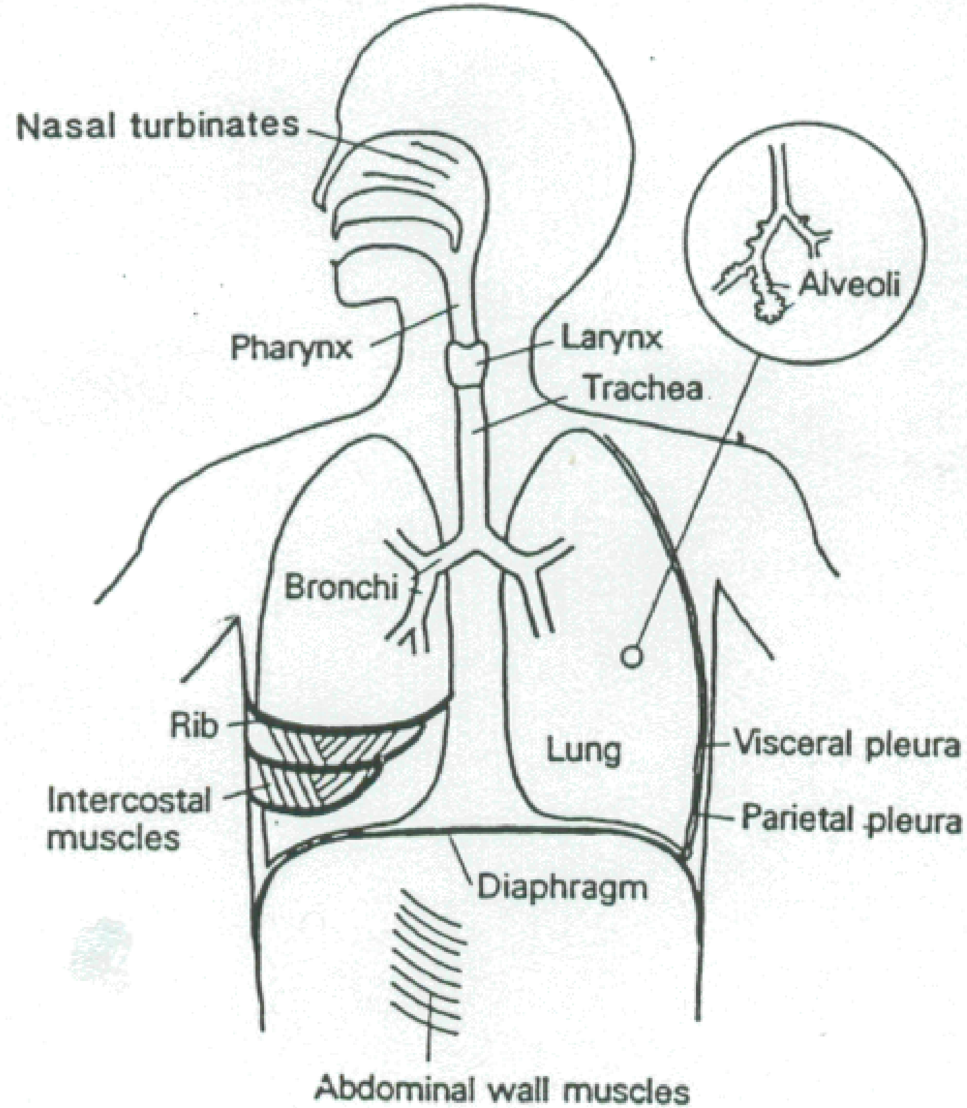
What are lung mechanics?

- The lungs have to breathe, but this takes *pressure*.
- Pressure is required to drive gas along the *pulmonary airways*.
- Pressure is required to stretch the *tissues* of the respiratory system (i.e. the lungs and thorax).

In a *spontaneously breathing* subject at rest these pressures are provided by the *respiratory muscles* during inspiration, and by the tendency of stretched respiratory tissues to *recoil* to their resting configurations during expiration.

In a *mechanically ventilated* patient the pressures required to produce inspiration are provided by a machine.



Lung mechanics…

- reflect the *physical properties* of the components of the lung.

- is a general term to describe all those things that determine the *relationships* between *pressures*, *flows* and *volumes* in the lung.

Lung mechanics are important because…

- they are determinants of the breathing process (e.g. how much *effort* it takes, how *comfortable* it feels).

- they reflect specific *disease states. For example…*

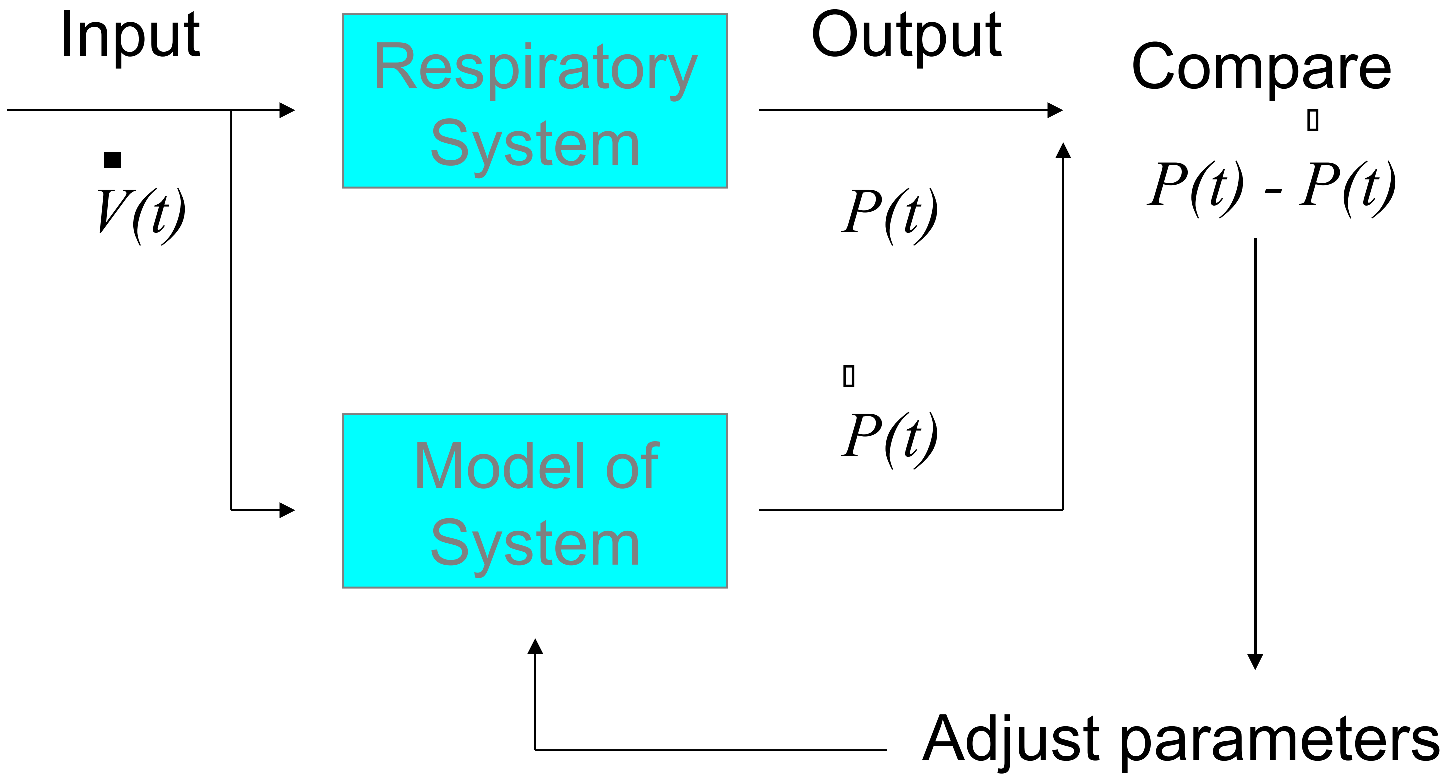
- During an *asthma* attack: The pulmonary airways become narrowed, so more pressure than normal is required to force air through them.

- In a patient with *emphysema*: Parenchymal destruction makes the lungs more easily inflated than normal, so less pressure than normal is required to inflate them.

Question: How can we relate structure to function in the lung?

Answer: By using a *mathematical model*.

How are mathematical models used?



The mathematical model should have…

- easily *identifiable* and important *physiological counterparts*.
- an *equation of motion* which states how pressure is related to flow and volume.

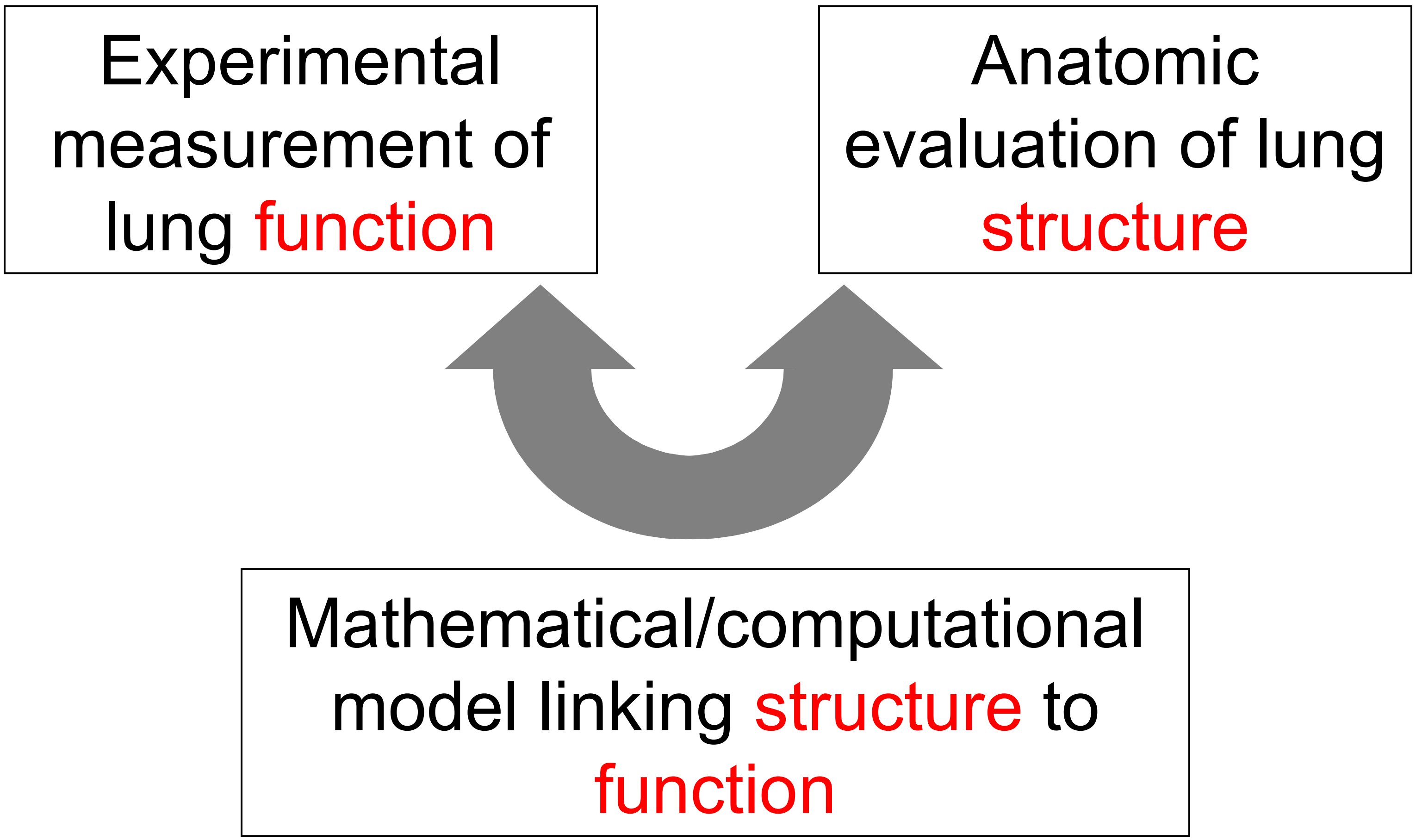
The equation of motion…

- tells us exactly how the model will behave under every conceivable circumstance.

- contains *variables*, which are measurable things that vary in time (typically pressures, flows and volumes).

- contains *parameters* which have fixed values, and which characterize *physical attributes* of the model (such as airway resistance).

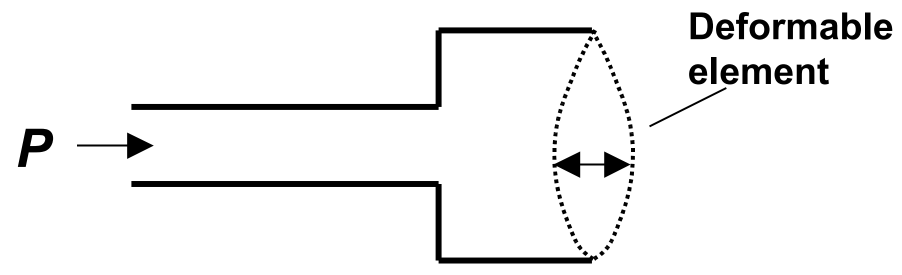
The investigative paradigm…



What do we need to measure?

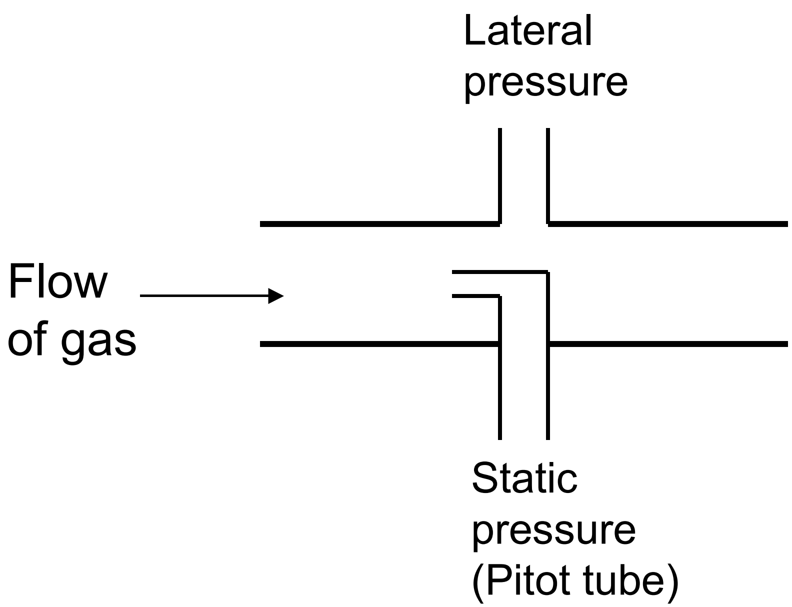
- Pressure
- Flow
- Volume

Measuring pressure



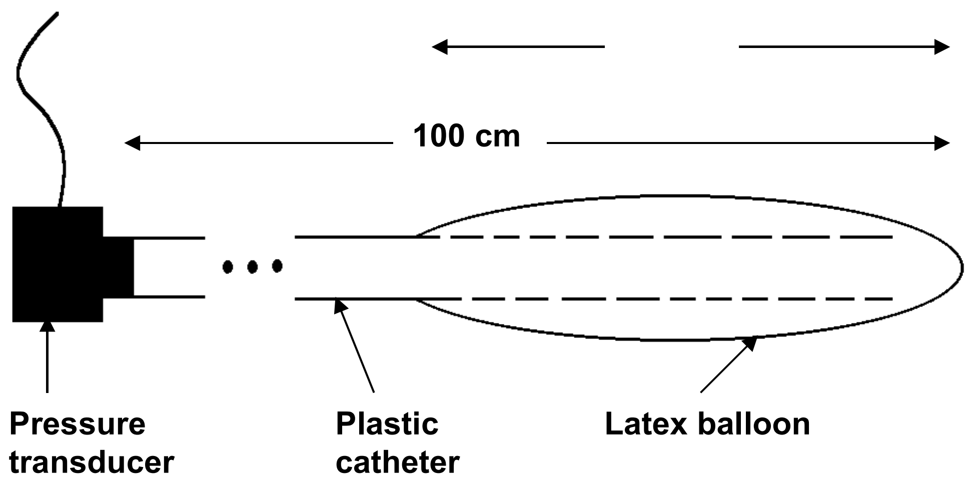
Pressure (*P*) transduction relies on converting the deformation of an elastic element into a proportional electrical signal.

Airway opening pressure

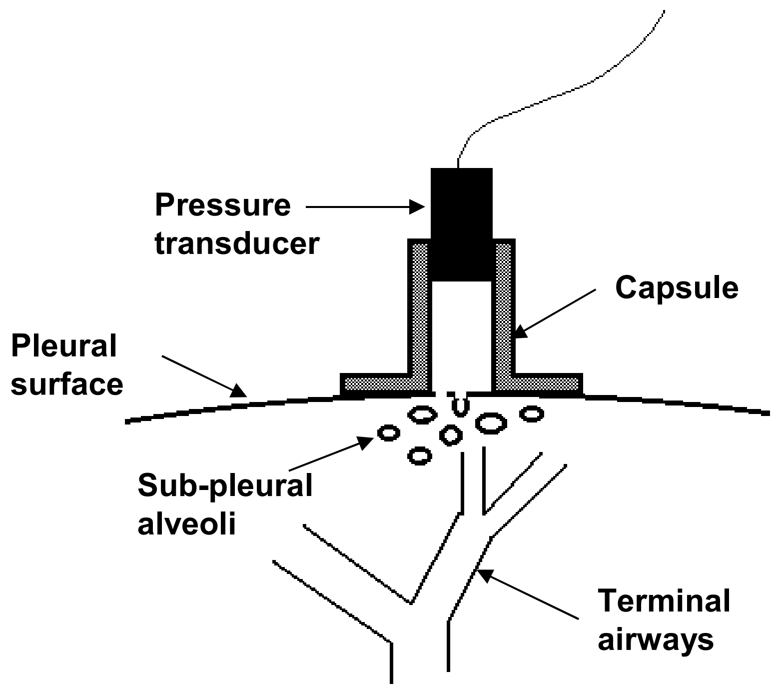


Lateral pressure is easiest to measure in a flowing stream of gas. However, this pressure is less than *static pressure* due to the *Bernoulli effect* (which may be substantial if the tube radius is small).

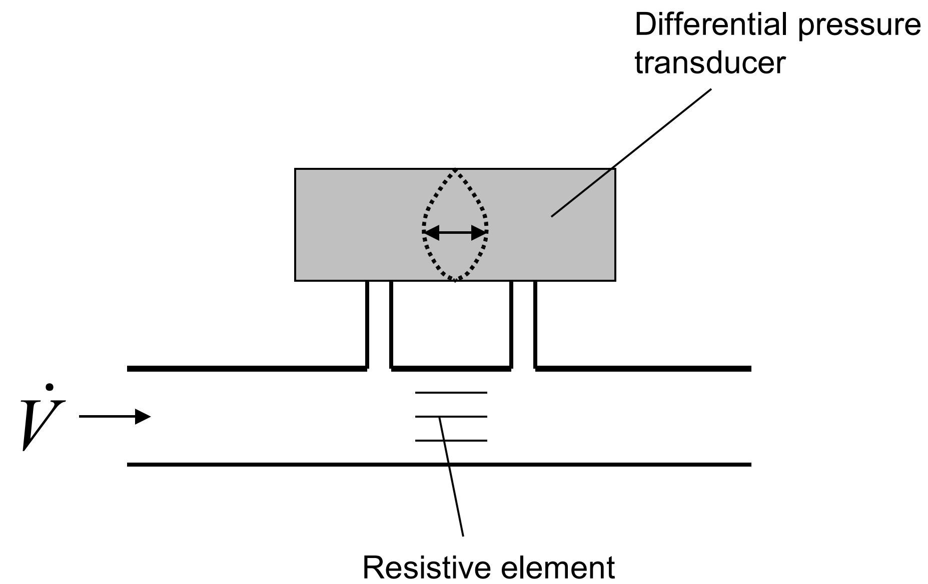
Esophageal pressure
(a surrogate for pleural pressure)



Alveolar pressure



Measuring Flow



Flow $(\dot{V})$ transduction typically involves measuring the pressure drop (ΔP) across a calibrated resistance (R).

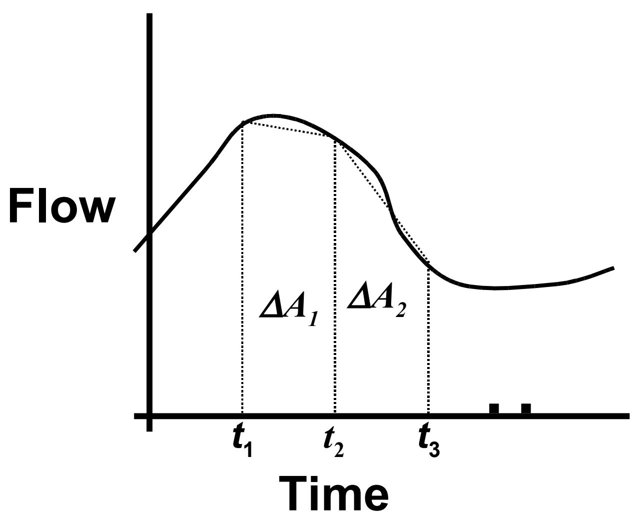
$$\dot{V} = \frac{\Delta P}{R}$$

Measuring Volume

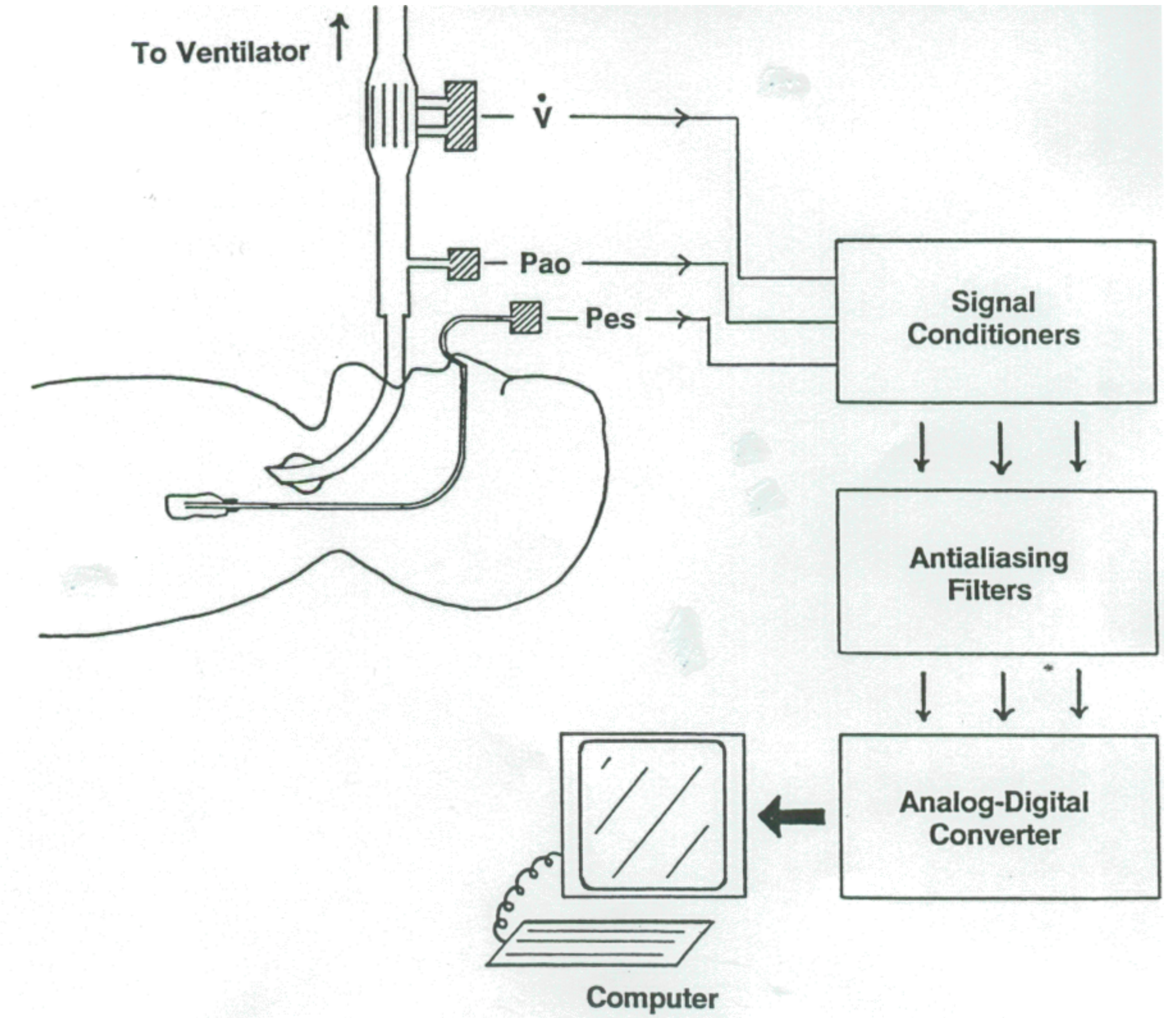
A. Direct measurement with a *spirometer*

B. Integration of flow

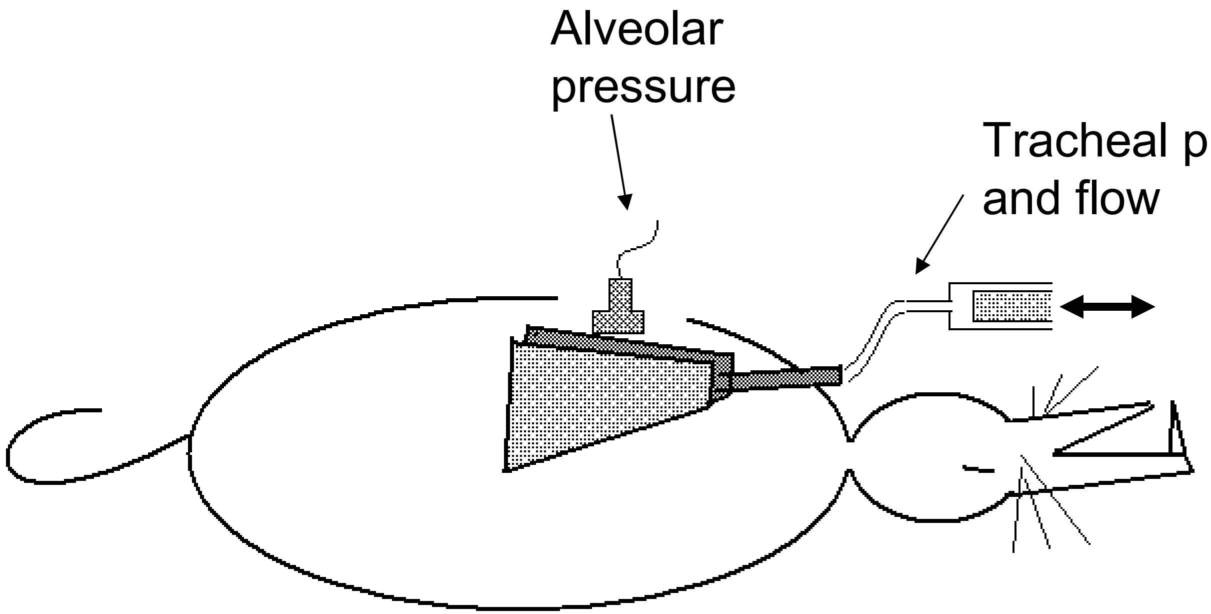
$$V = \int_0^t \dot{V} dt$$



A measurement scenario in humans…

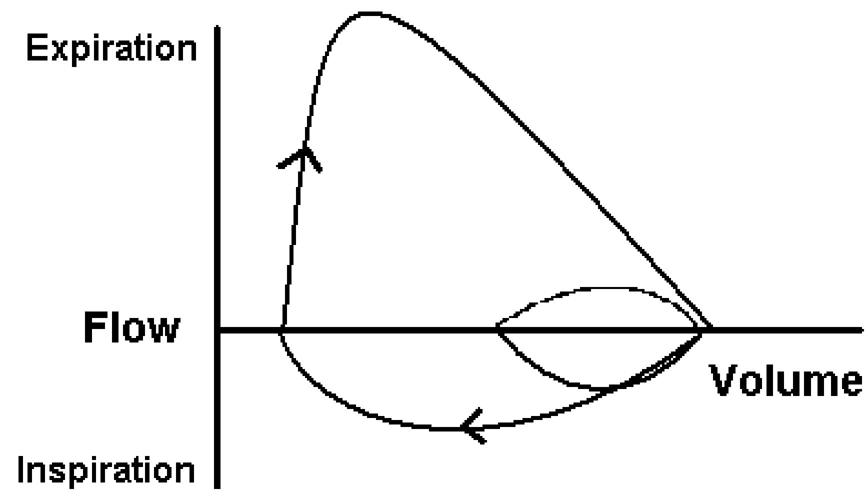


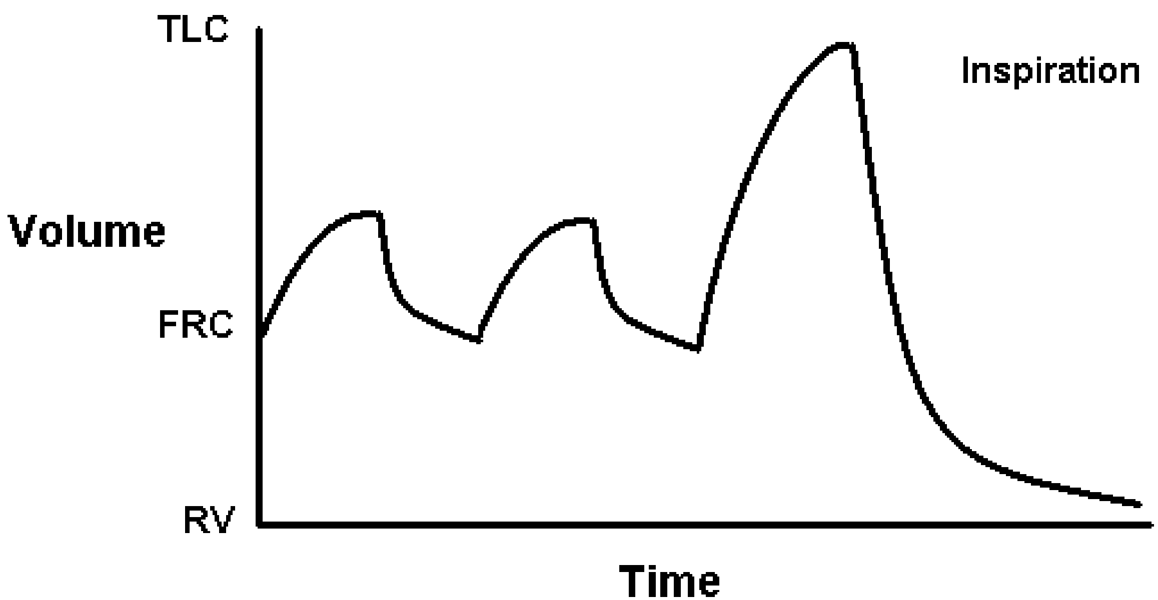
A measurement scenario in animals…



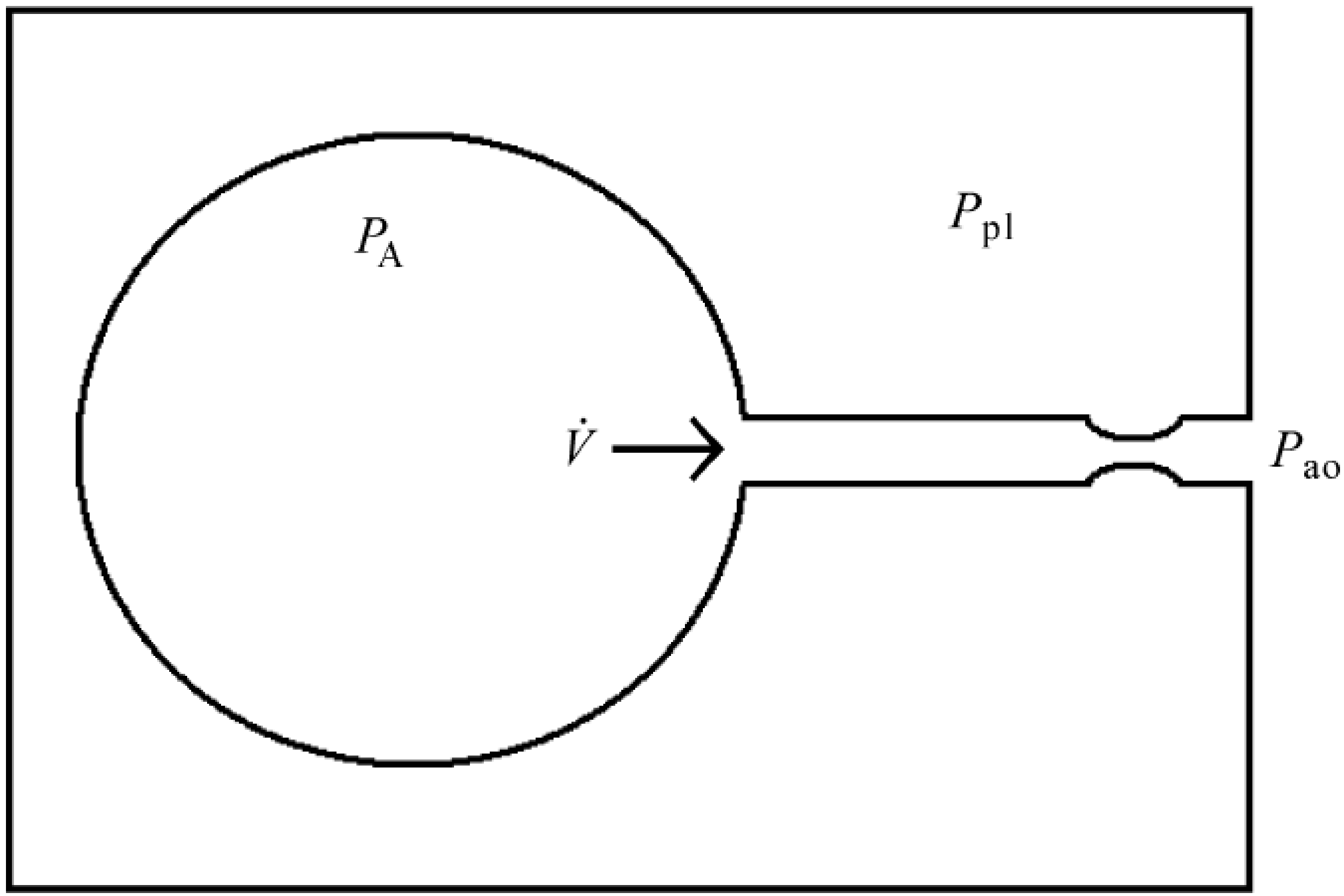
Measurement of lung mechanics provides tools for *diagnosing pulmonary diseases*.

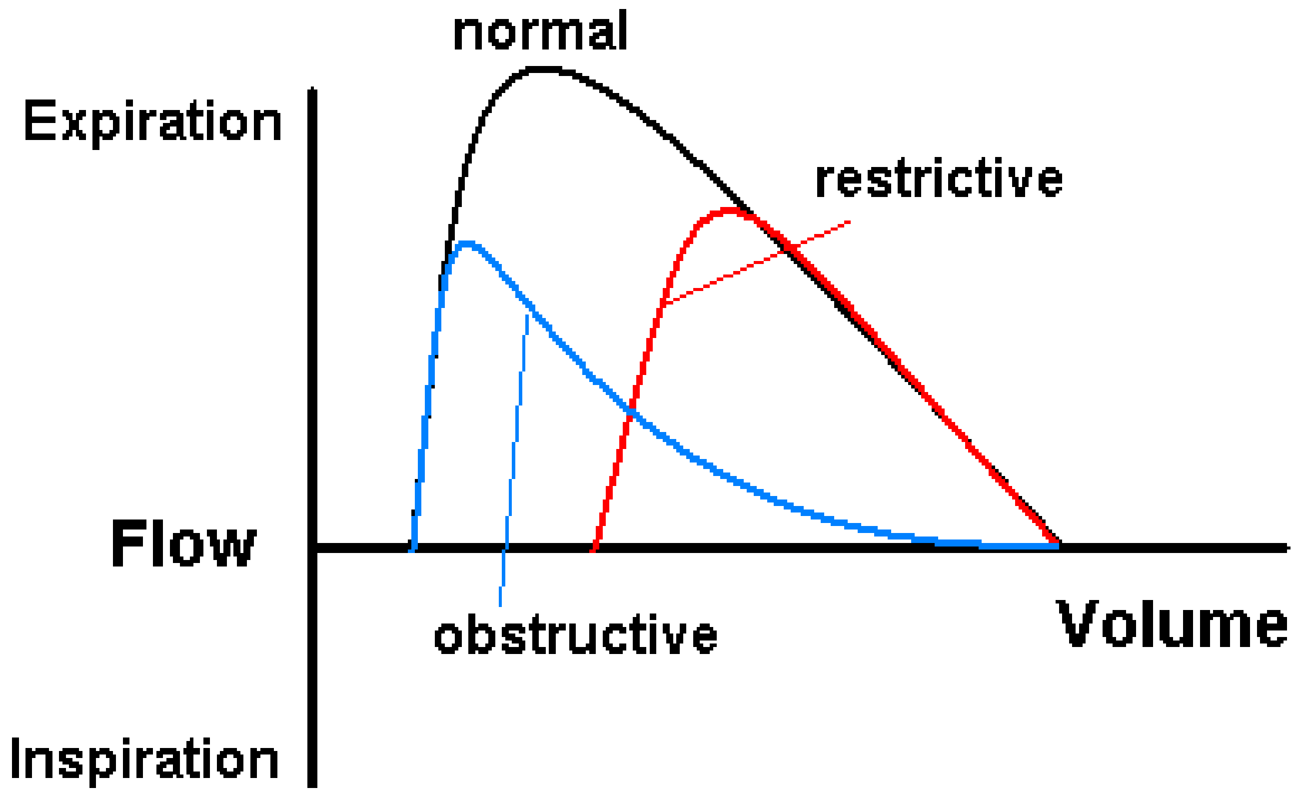
Clinical tests of lung function: Forced expiration





Expiratory flow limitation



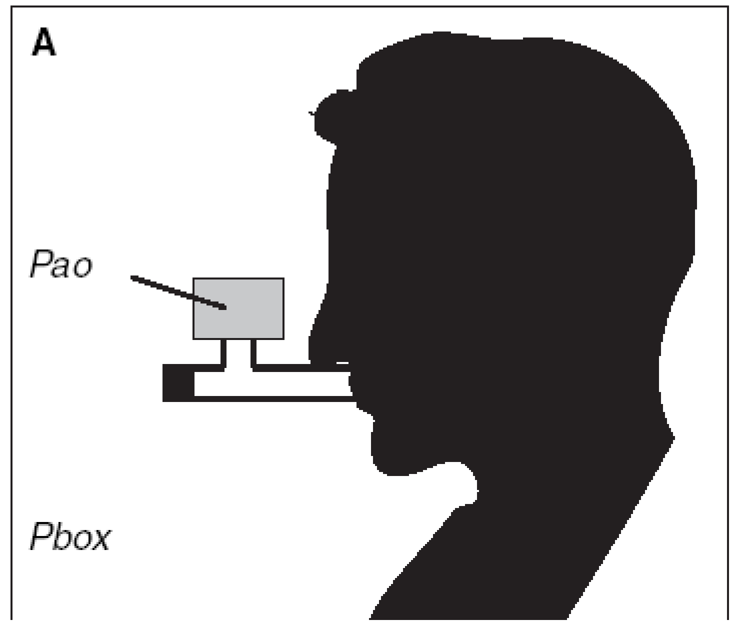

normal
Expiration
restrictive
Flow
obstructive
Volume
Inspiration

Clinical tests of lung function: Plethysmography

Thoracic gas volume (Vtg)

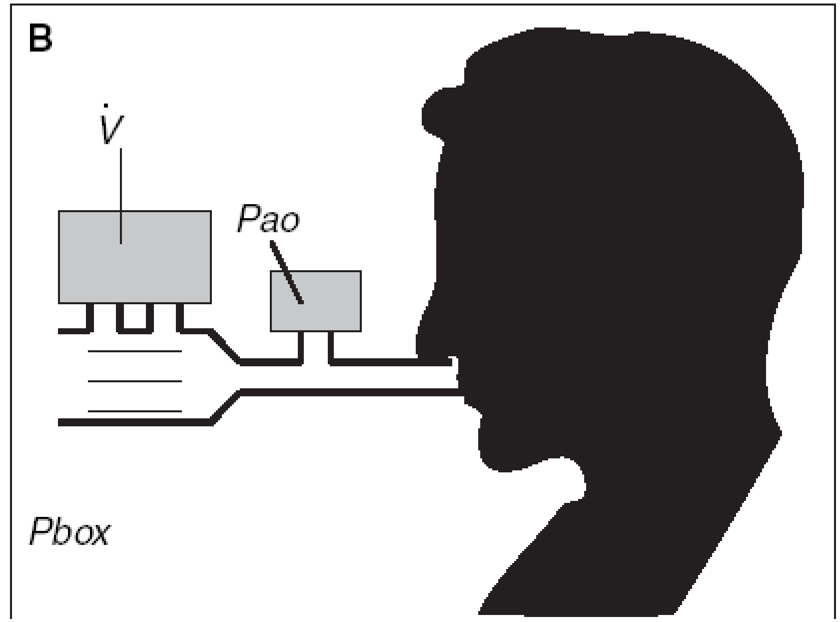
$$\frac{\Delta Pao}{\Delta Pbox} = \frac{Vbox}{Vtg}$$

(Boyle's law)



Airway resistance (R_{aw})

$$R_{aw} = \frac{\Delta Pbox\left(\frac{Vbox}{Vtg}\right)}{\dot{V}}$$



Summary 1

- Lung mechanics embody the dynamic relationships between pressure, flow and volume in the lung
- Our ultimate goal is to link lung mechanical function to lung structure
- This requires a mathematical model of lung mechanics

Summary 2

- To assess lung mechanics, we need to measure pressure, flow and volume of gas
- Clinical tests of lung function are mostly based on forced expired flow and body plethysmography

http://mbi.osu.edu/2006/tut1materials/Mechanics%20Course%201.ppt