Lecture 12: Respiration (Spirometers)

0. Review

1. Basics of Lung Anatomy

2. Spirometers

3. Pneumotachometers

- PreLab 5 due at lab session
- Thu: HW 5 due
- Lab 4 report due Fri (Feb 21)

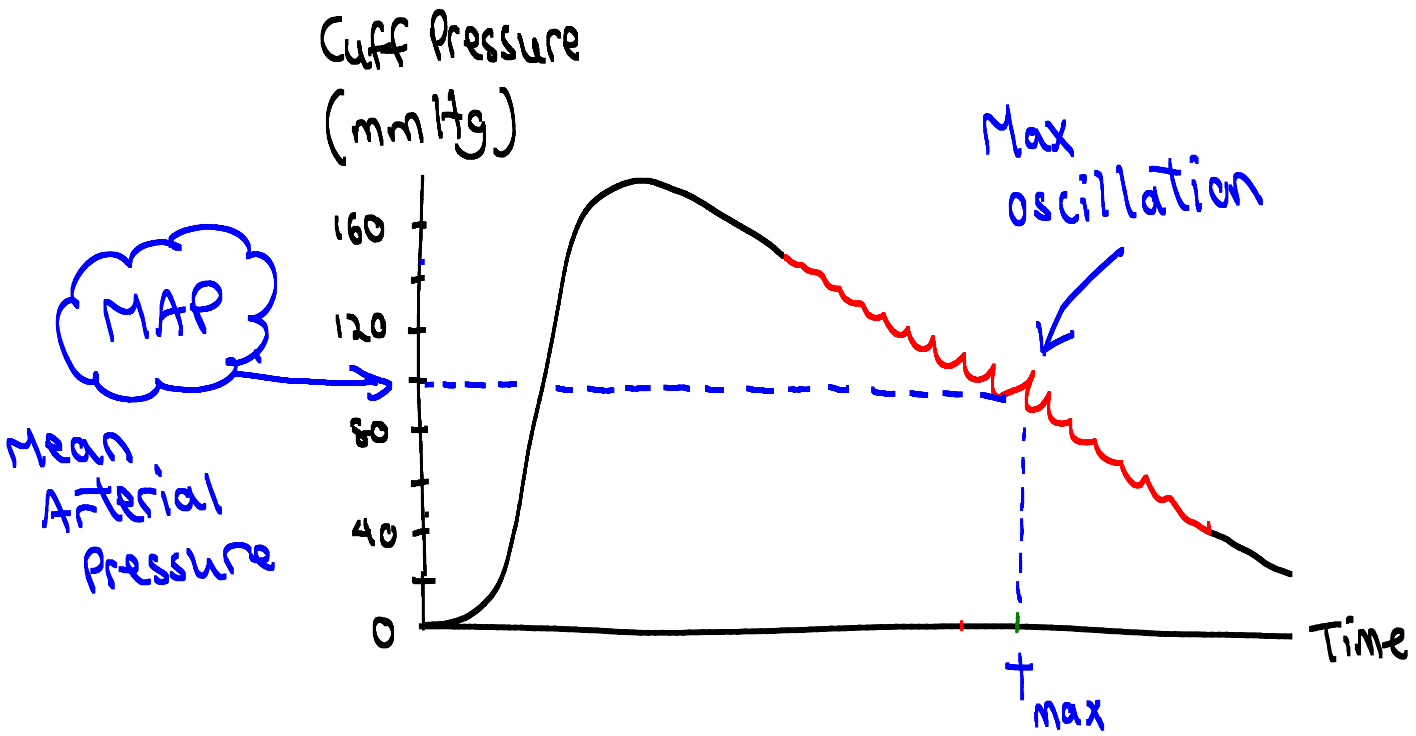
★ Ellis Hospital Tour
Mar 10 (Tue)
GROUP 1: 12:45-2:30PM
2: 2:45-4:30PM

★ Student presentations (Mar 10+12)
→ Teams of 2-3 students (3 is preferable)
→ 15 min powerpoint
- Disease or medical condition
- Electronic instrumentation

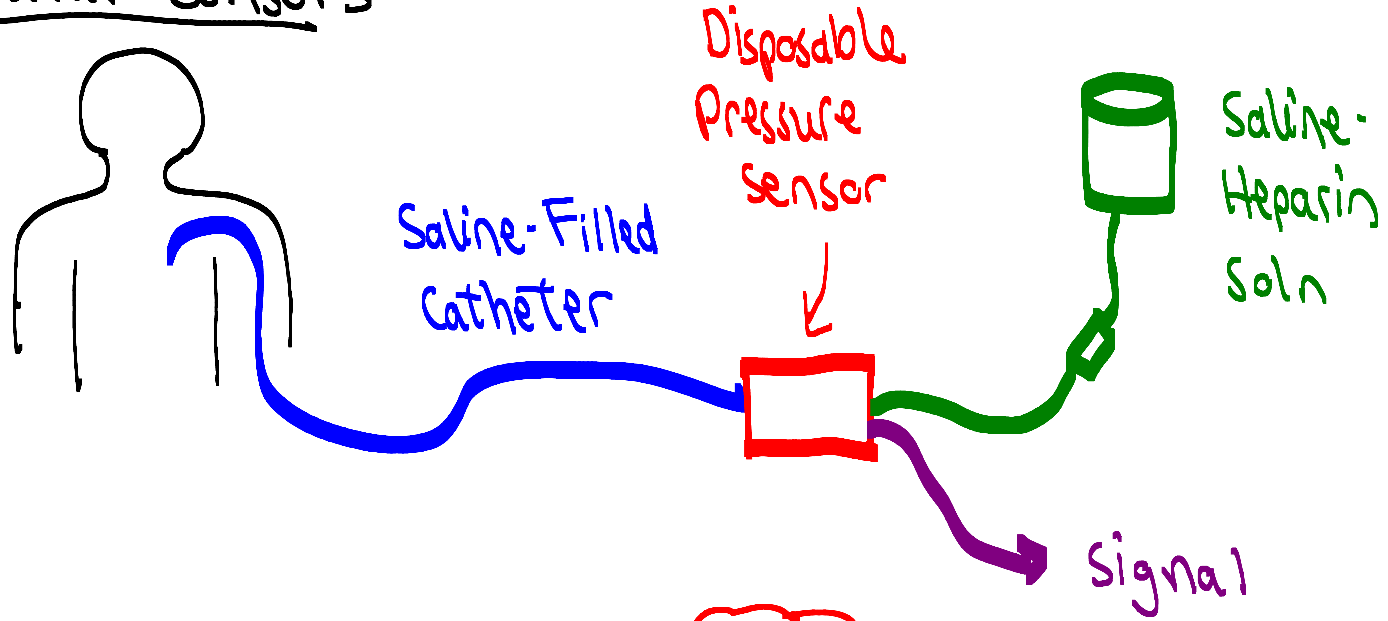
← See course website for guidelines

0. Review

① Oscillometric Method

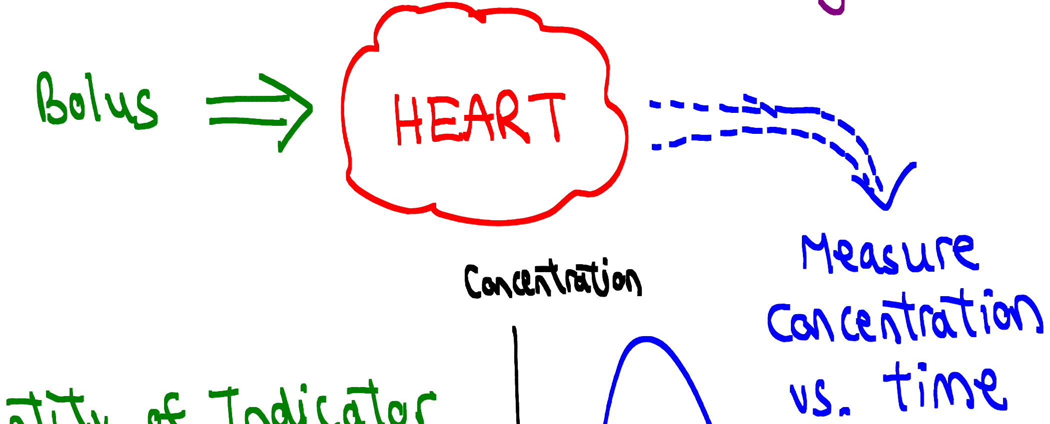


② Extravascular Sensors

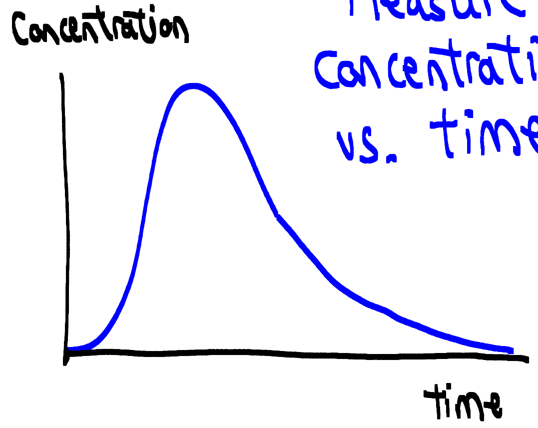


③ Cardiac Output

Liters/min



Indicator Dilution Method: $F = \dfrac{\text{Quantity of Indicator}}{\int [\text{Concentration}]\, dt}$



Thermodilution is common technique

1. Basics of Lung Anatomy

- Purpose of respiratory system:

① Deliver O_2 to blood

② Remove CO_2 from blood ← and other gas waste

Ventilation ≡ movement of air into and out of lungs

Breathing Rate

~ 6 Liters/min rest

~ 75 Liters/min exercise

Bronchial Tree

Trachea

↓

Bronchial Tubes

↓

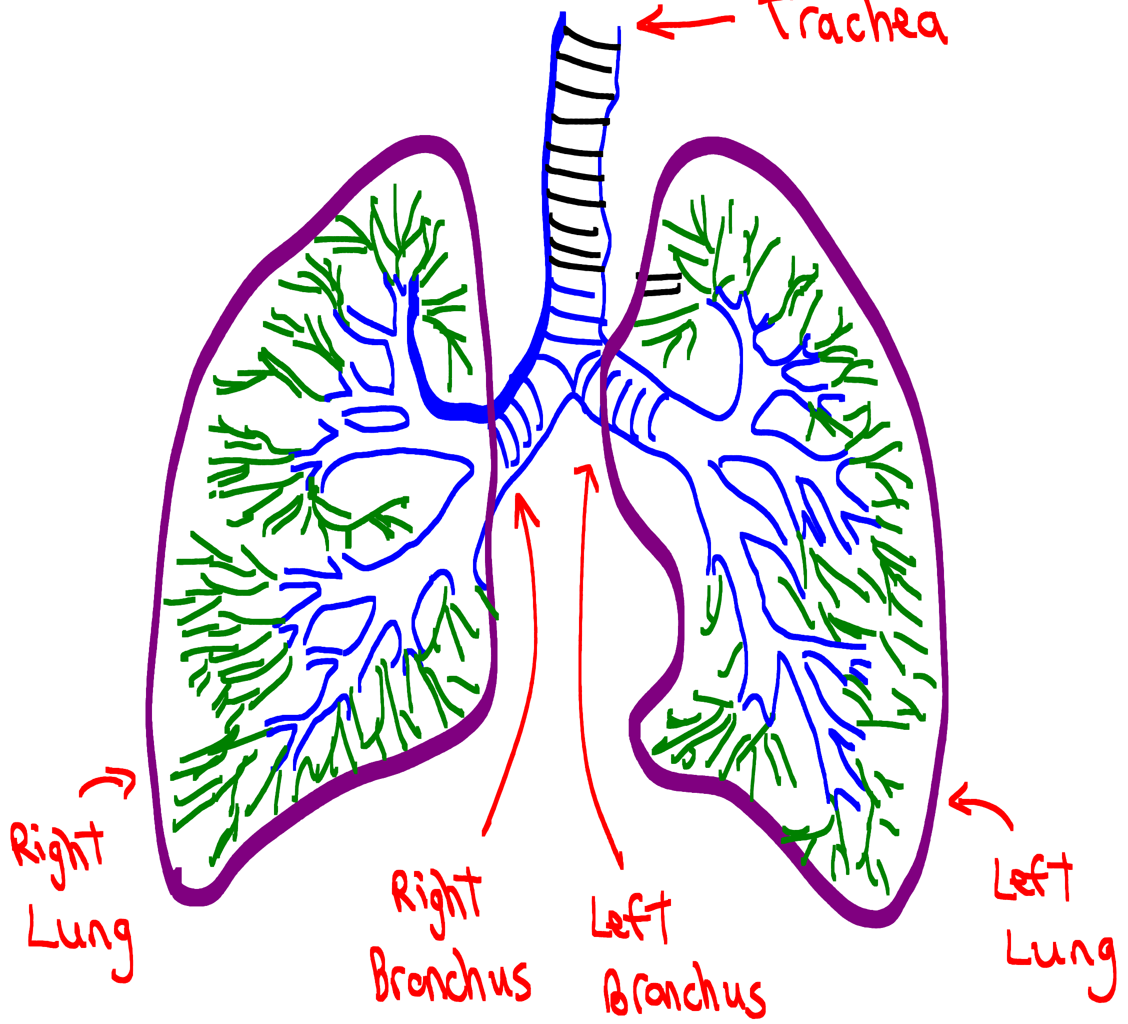
Bronchioles

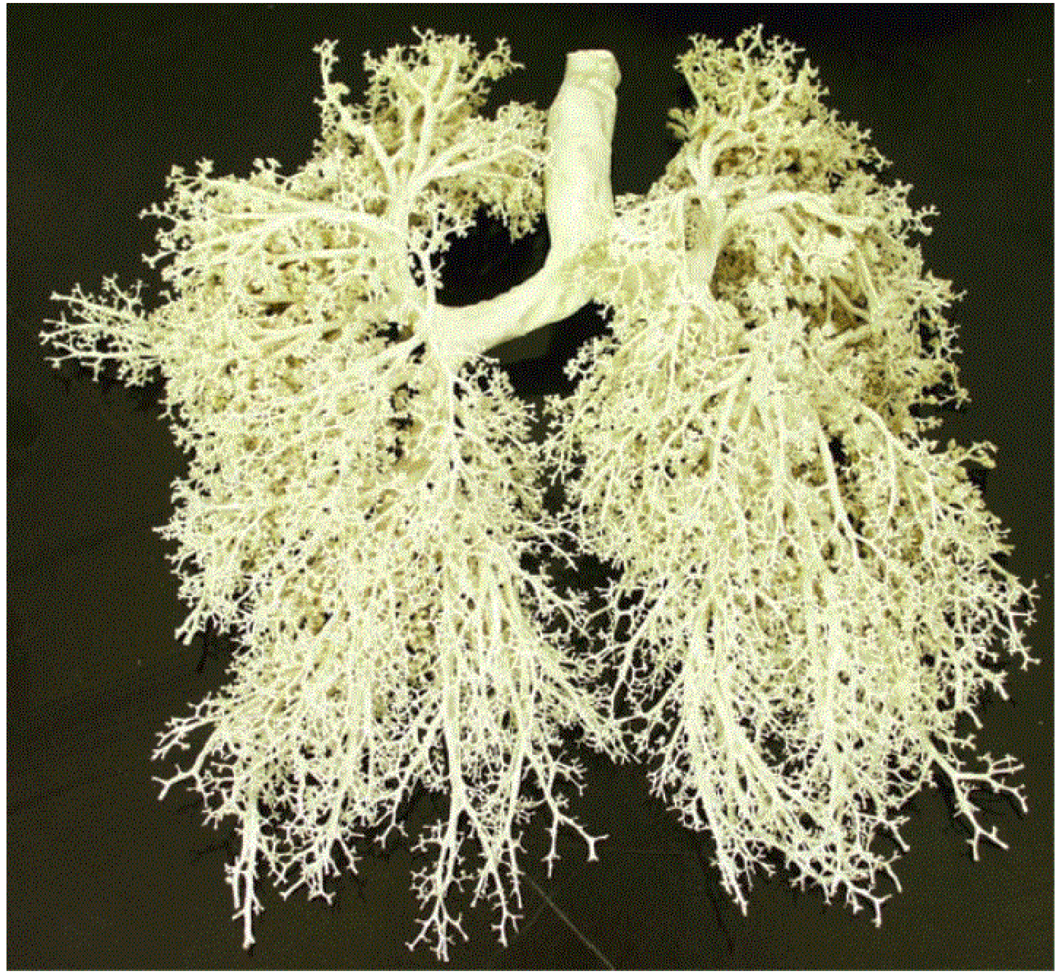
↓

Alveoli

Gas is exchanged between alveoli and capillaries

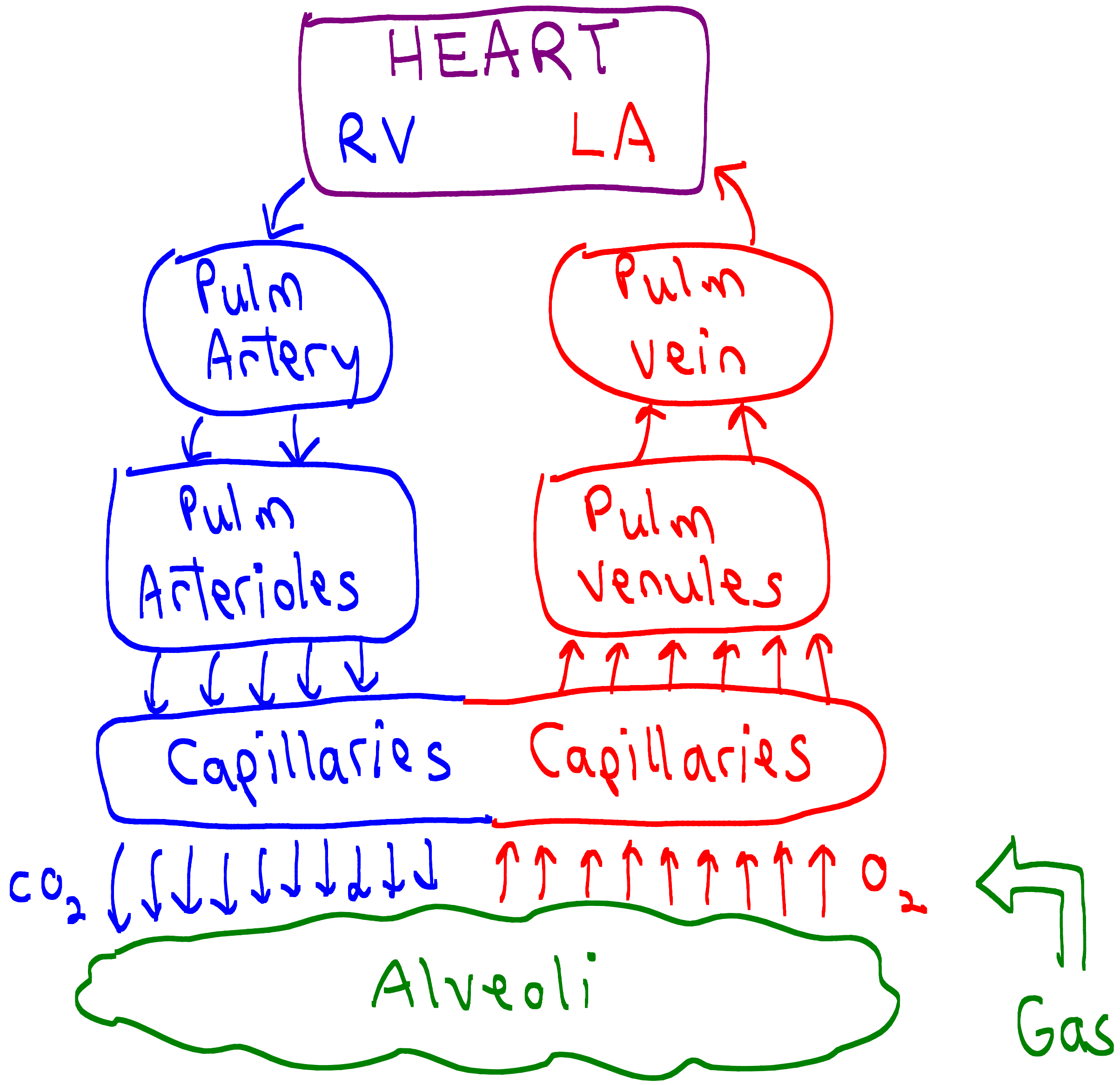
~300 million alveoli have same surface area as a tennis court!



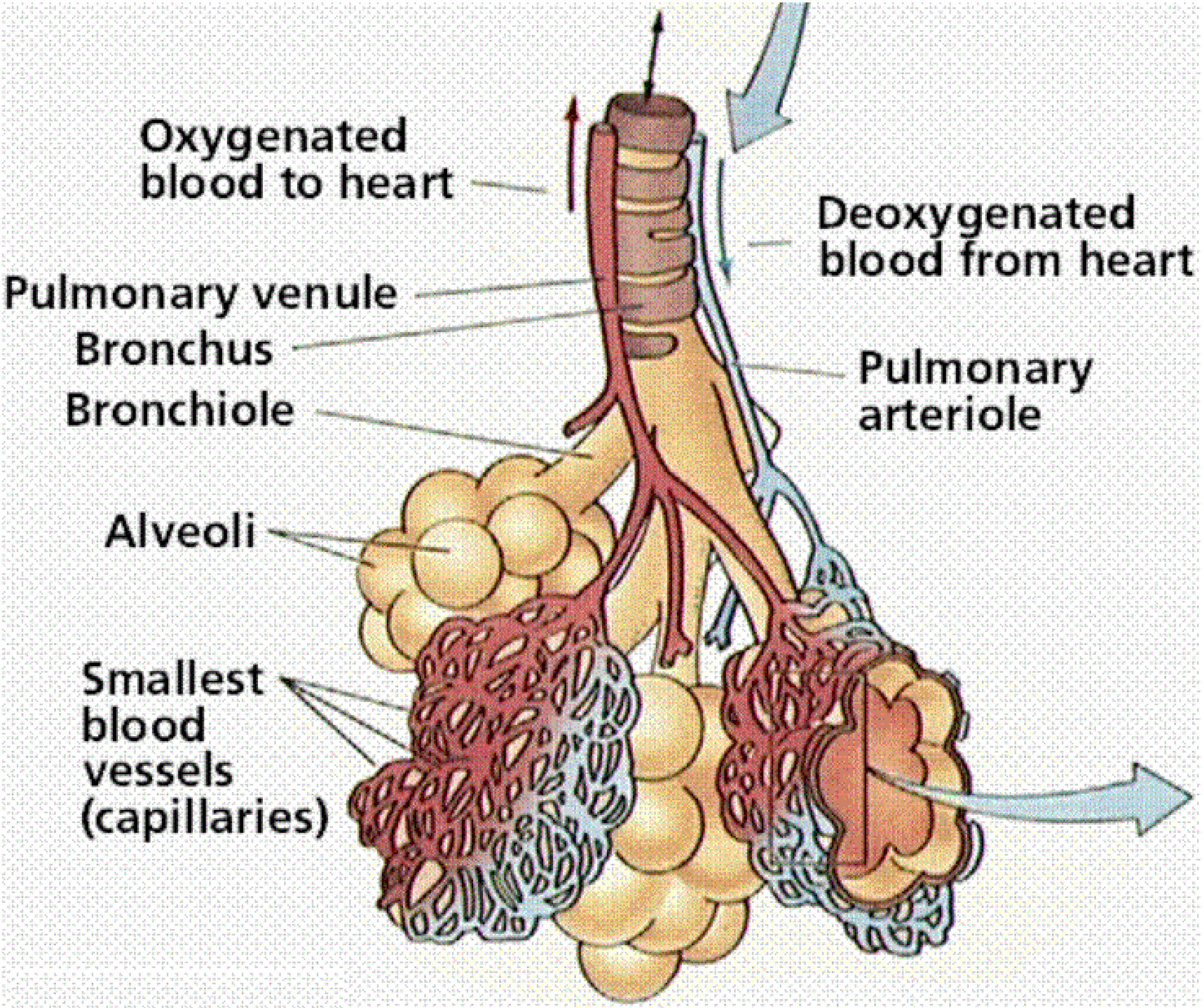


F. deJongh, Breathe, pp. 251-254 (2008)

- Bronchial Tree + Pulmonary Vasculature



Gas exchange between alveoli and capillaries!



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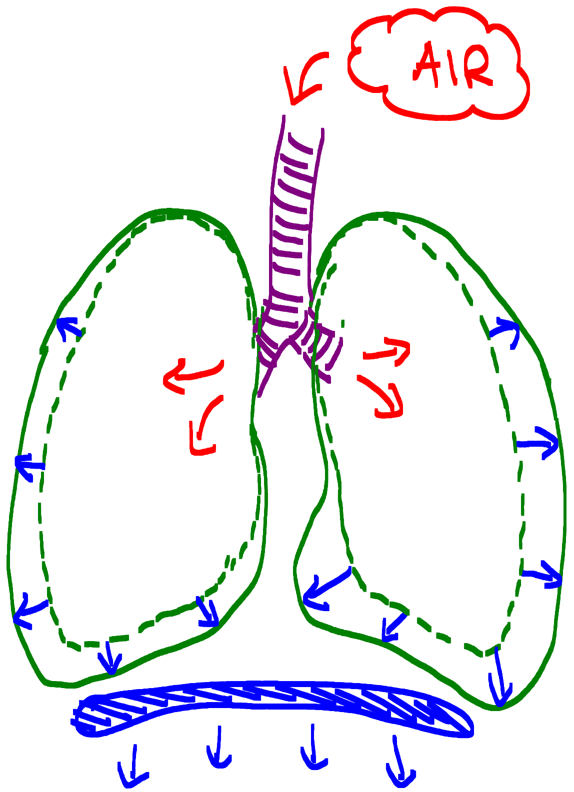
- Ventilation

INSPIRATION

- Diaphragm contracts
  → Pushes abdomenal organs down
- External intercostal muscles contract
  → Raises rib cage

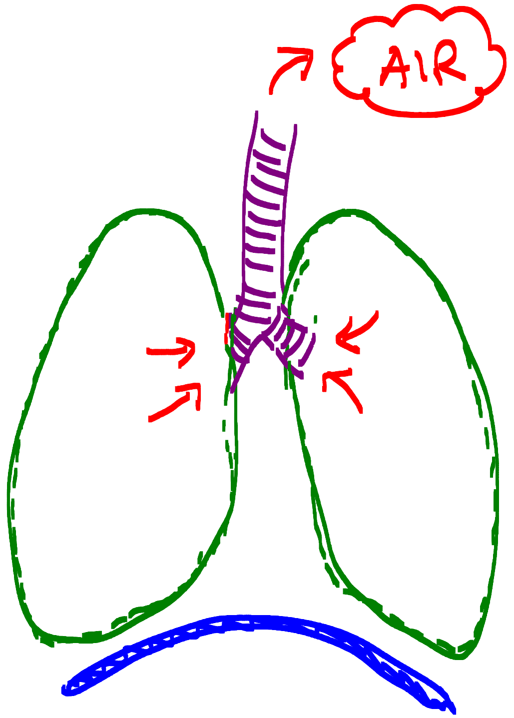
⇒ Increases chest cavity size

⇒ Negative relative pressure draws air into the lungs



EXPIRATION

- Elastic recoil
  returns the lungs to original size



⇒ Pushes air out of lungs

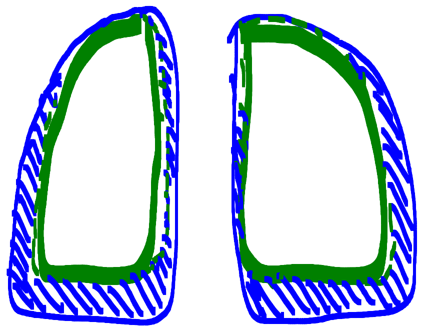
NOTE: Forced expiration involves contraction of internal intercostals

- Lung Volume Parameters

① Tidal Volume (TV)

Volume change of lungs during normal breathing

NORMAL INHALE



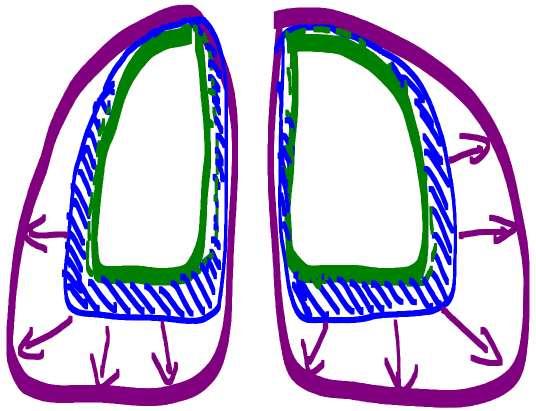
(Typically 0.5L)

(IRV)

② Inspiratory Reserve Volume

Additional volume increase during forced inhalation

FORCED INHALE



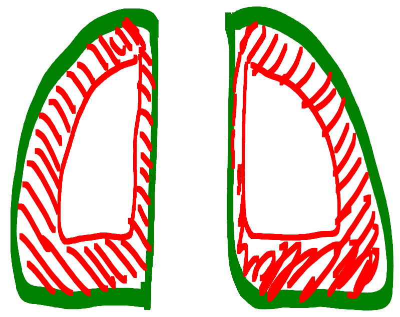
(Typically 2-3L)

(ERV)

③ Expiratory Reserve Volume

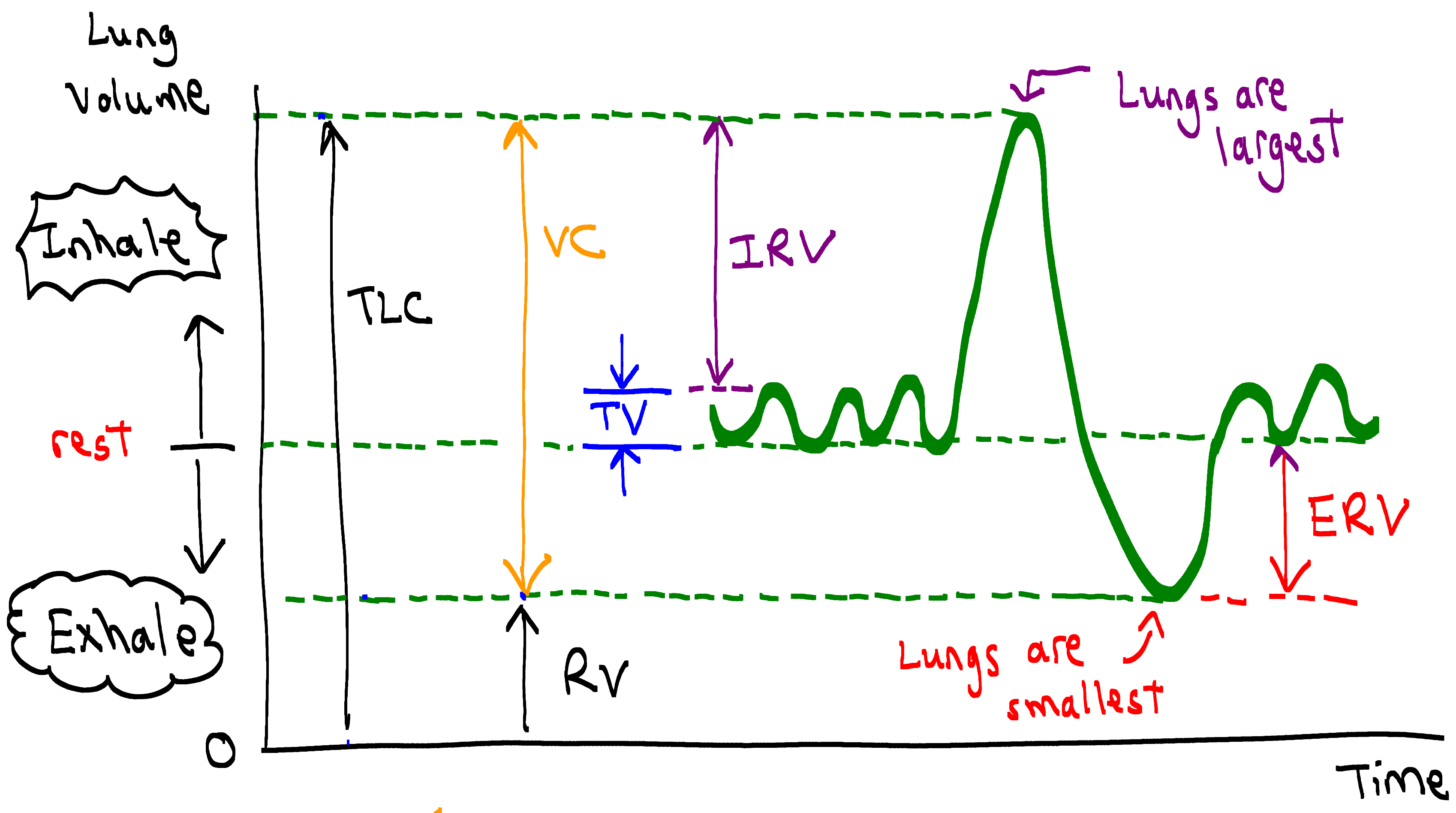
Additional volume decrease during forced exhalation

FORCED EXHALE



(Typically 1L)

Summary of lung volume parameters



Absolute Volume

$\boxed{\text{TLC}}$ (Total Lung Capacity)

$\boxed{\text{RV}}$ (Reserve Volume)

~1L

Change in volume

$\boxed{\text{VC}}$ (Vital capacity) = $\boxed{\text{IRV}}$ (Inspiratory Reserve Volume) + $\boxed{\text{TV}}$ (Tidal Volume) + $\boxed{\text{ERV}}$ (Expiratory Reserve Volume)

3.5-4.5L

2. Spirometers

- Spirometry: Medical screening test that measures breathing and lung function.

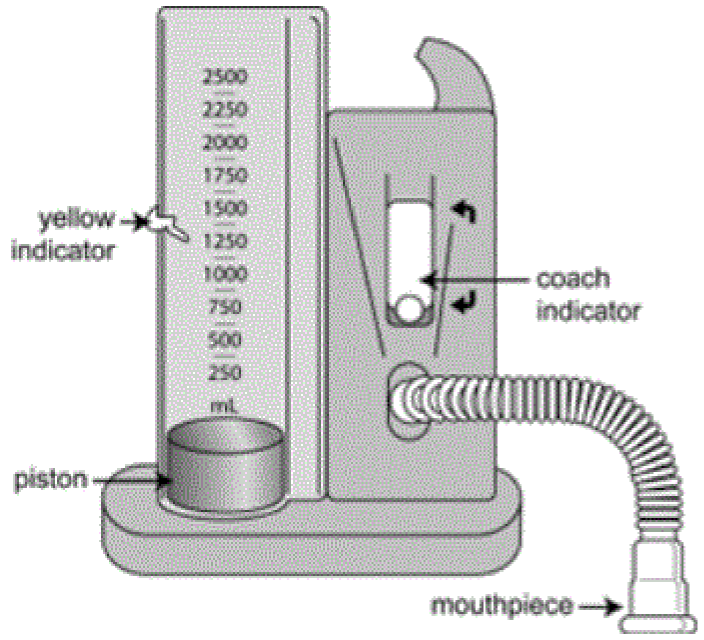
(1) Subject is asked to perform a forced expiratory maneuver (FEM)

- Take a full deep breath
- Exhale as forcefully as possible

(2) Inhaled + exhaled air are measured by a spirometer (2 types)

Traditional kind

(1) VOLUME



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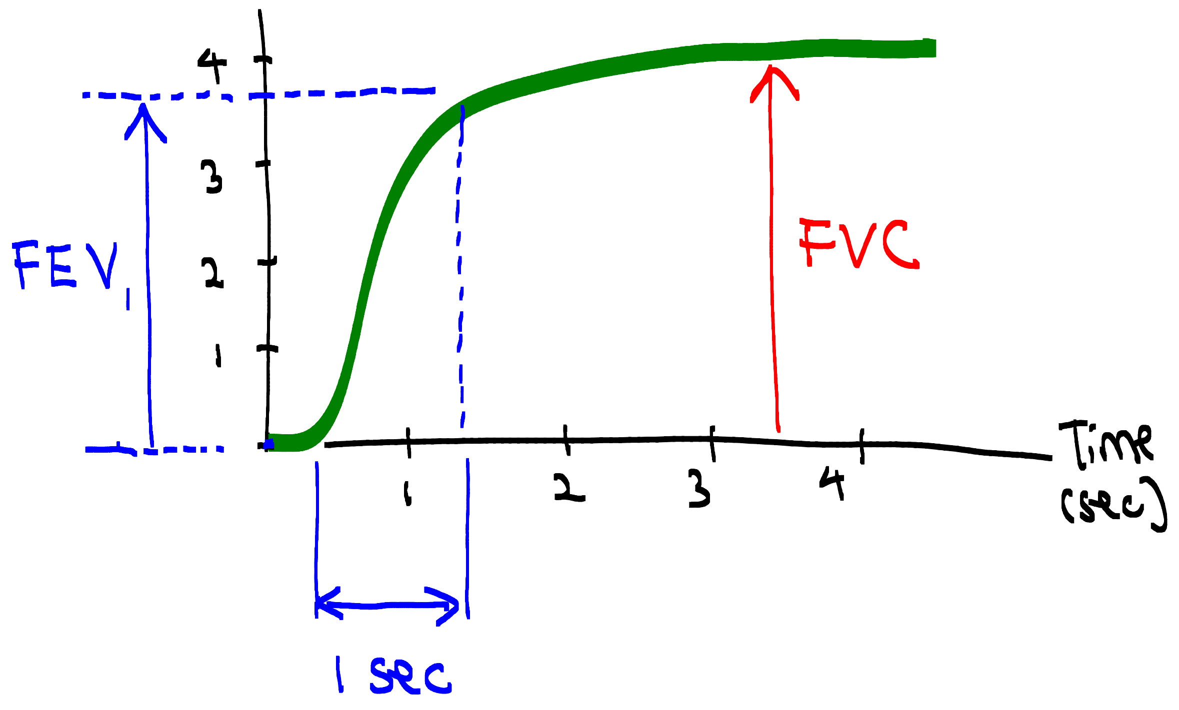
Most portable electronic systems

(2) FLOW

wikipedia

- Volume Measurement



Expandable compartment

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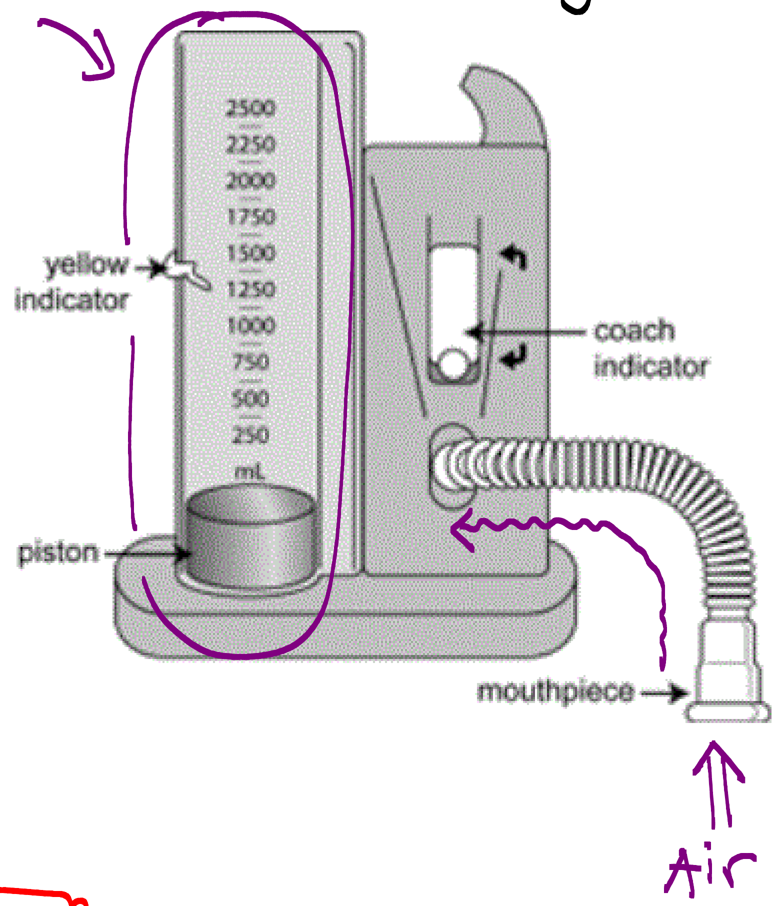


$\boxed{FEV_1}$ Forced Expiratory Volume in one second

- Volume spirometers are bulky :(
  but maintain accurate calibration :)
  Cross-contamination is also an issue

$\boxed{FVC}$ Forced Vital Capacity

similar to VC, but exhaling is done with maximum force

- Flow Measurement

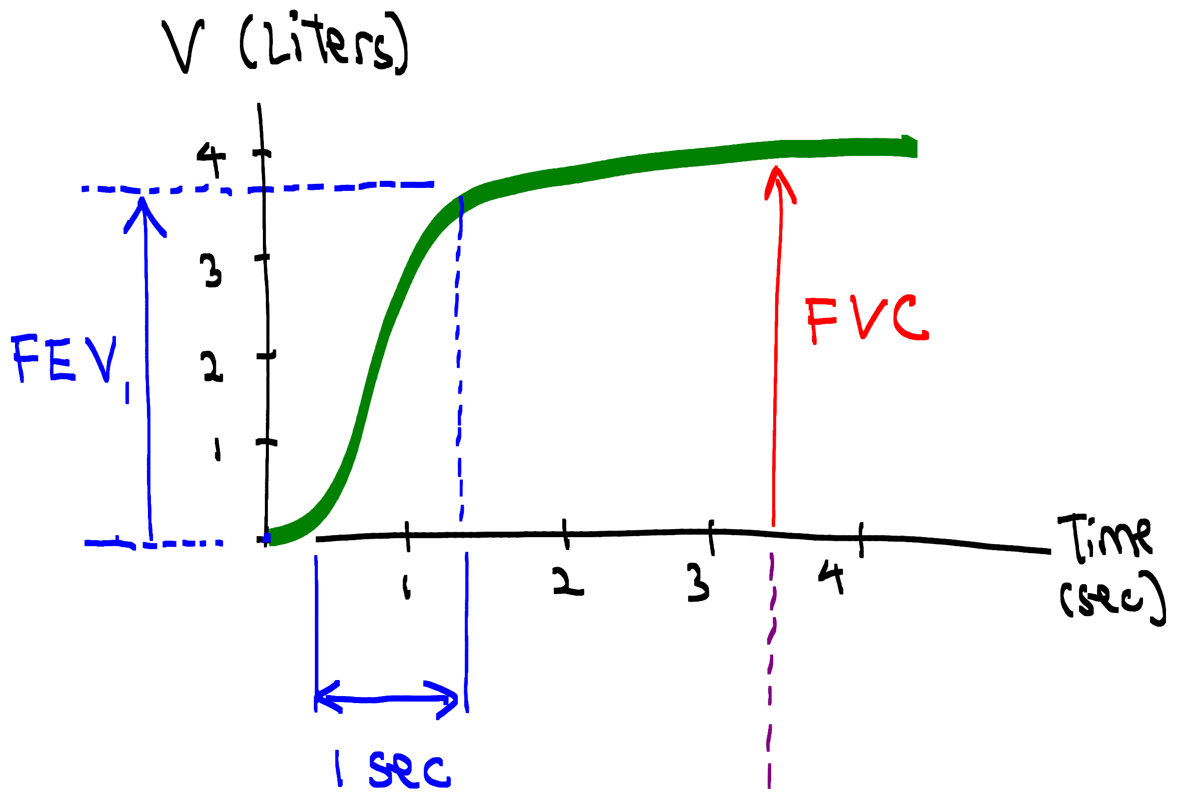
Q: How to measure flow (L/sec) with a volume spirometer?

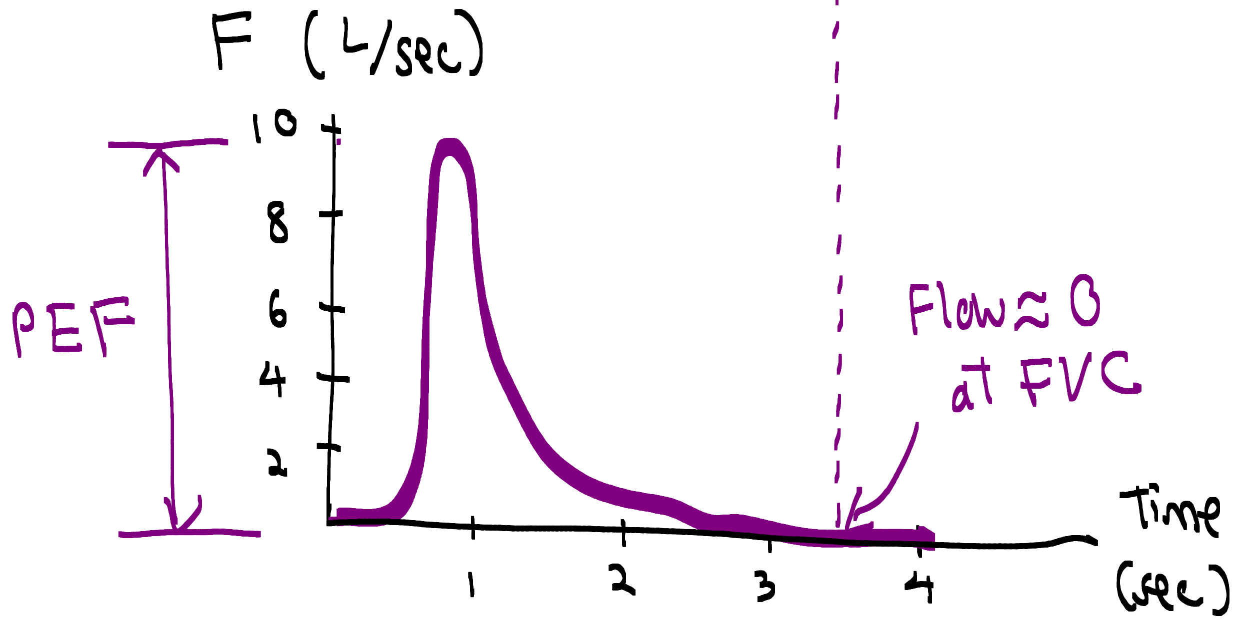
A: Compute the derivative!

$$\text{Flow} = \frac{dV}{dt} \quad (\text{Liters/sec})$$

$$\text{Max Flow} = \left(\frac{dV}{dt}\right)_{max} = \boxed{PEF} \leftarrow \text{Peak Expiratory Flow}$$

* Most portable electronic spirometers directly measure flow, and then compute volume by $V(t) = \int_0^t F\,dt$





(12.9)

3. Pneumotachometers

← Most common type of spirometer

Pneumotachometers measure flow by a pressure difference between 2 points

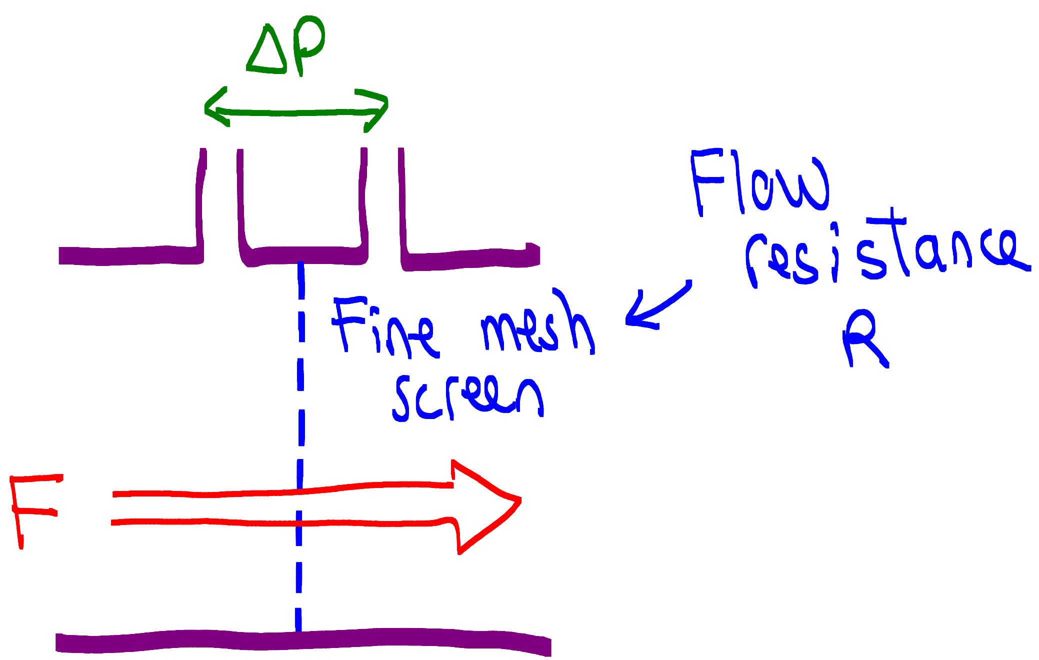
① Lilly: ★ Linear relationship between pressure change and flow.

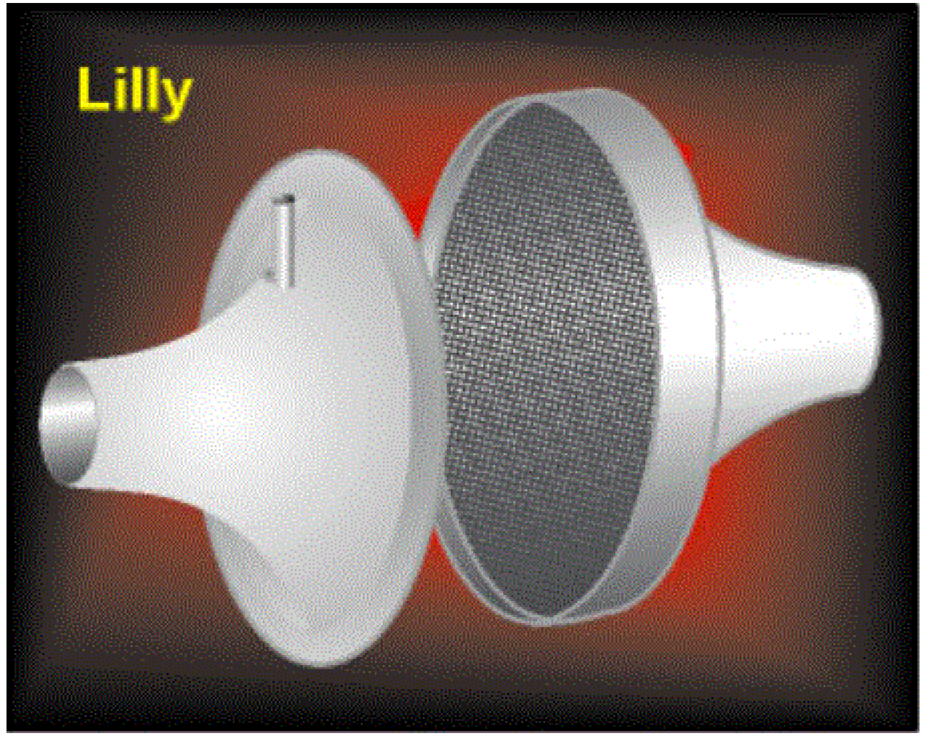
- use fine mesh screen as flow resistance element

$$\Delta P = F \times R$$

F ↑ Flow

R ↑ Flow resistance





www.spirexpert.com

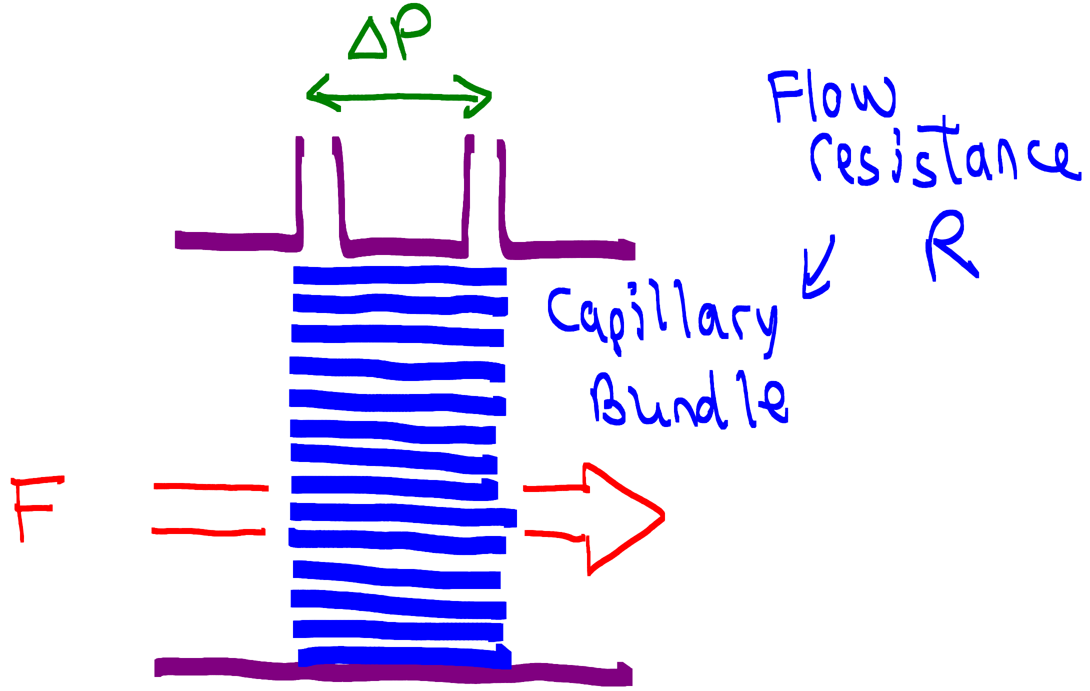
② Fleisch: ★ Linear relationship between pressure change and flow.

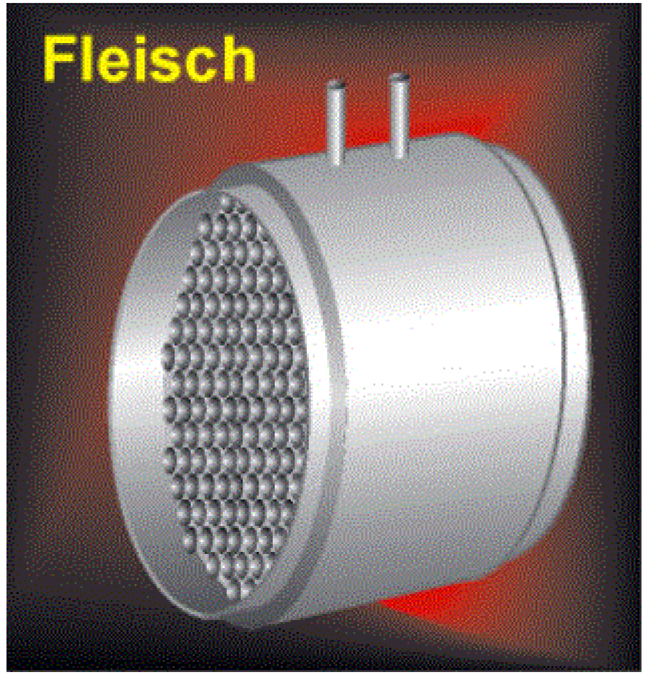
- use bundle of capillaries as flow resistance element

$$\Delta P = F \cdot R$$

Flow (F)

Flow resistance (R)





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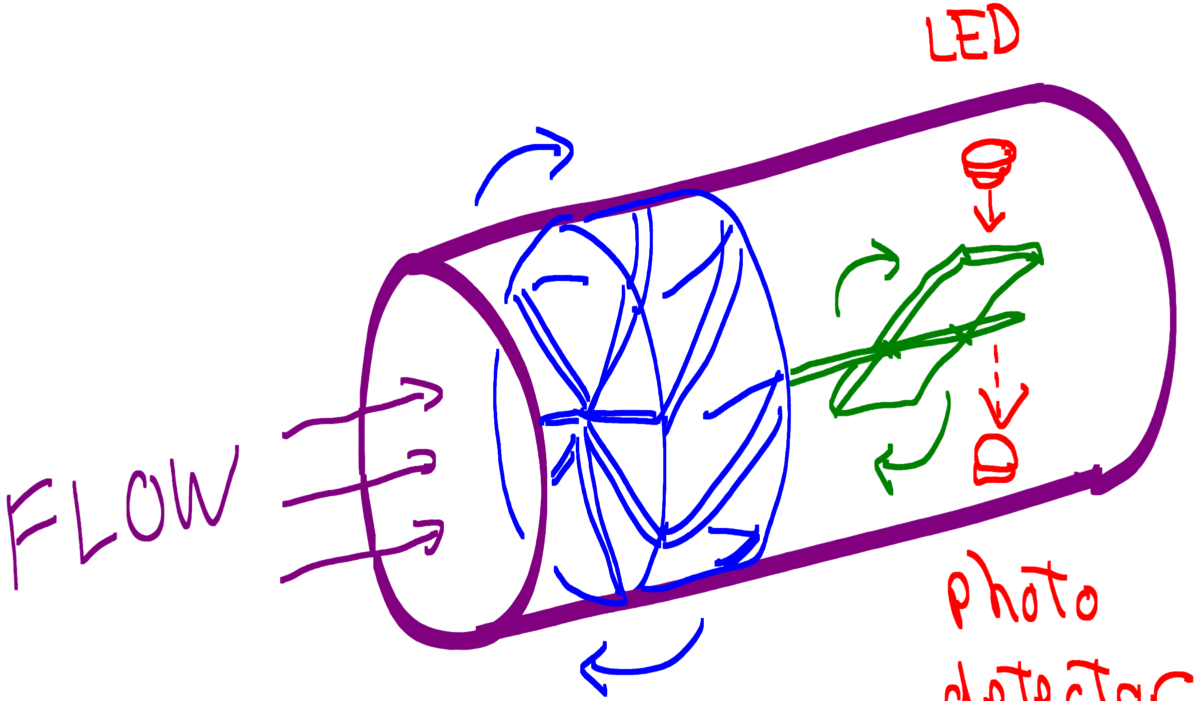
NOTE: Both Lilly and Fleisch need the flow-resistance element to be heated to 37°C to minimize condensation

③ Turbine (Rotary vane) ← Does not rely on ΔP

- Air flow pushes turbine-like blades
- Blades turn a rotating vane
- Rotating vane interrupts an LED beam

☆ Rotations per second $\propto$ Air flow



Pro: No heating required :)

Con: Rotational inertia

Affects accuracy [
- Low flow (start blade motion)
- High flow (blades continue to spin)

NOTE: Any type of spirometer must be periodically calibrated!