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Respiratory Mechanics II

M1 – Cardiovascular/Respiratory Sequence

Louis D'Alecy, Ph.D.

Fall 2008

Friday 11/14/08, 9:00
Mechanics of Ventilation II

30 slides, 50 minutes

1. Tidal Volume
2. Intraplural Pressure
3. Alveolar Distending Pressure
4. Lung Compliance
5. Airway Resistance
6. Lung volumes (Spirometer)
7. Functional Residual Capacity
8. Forced vital capacity
9. Measurement of airway resistance

Tidal Volume (TV)

-- air volume entering or leaving

the respiratory system

in a **single breath**.

It adds to, and mixes with,

alveolar gases.

Contrast with :

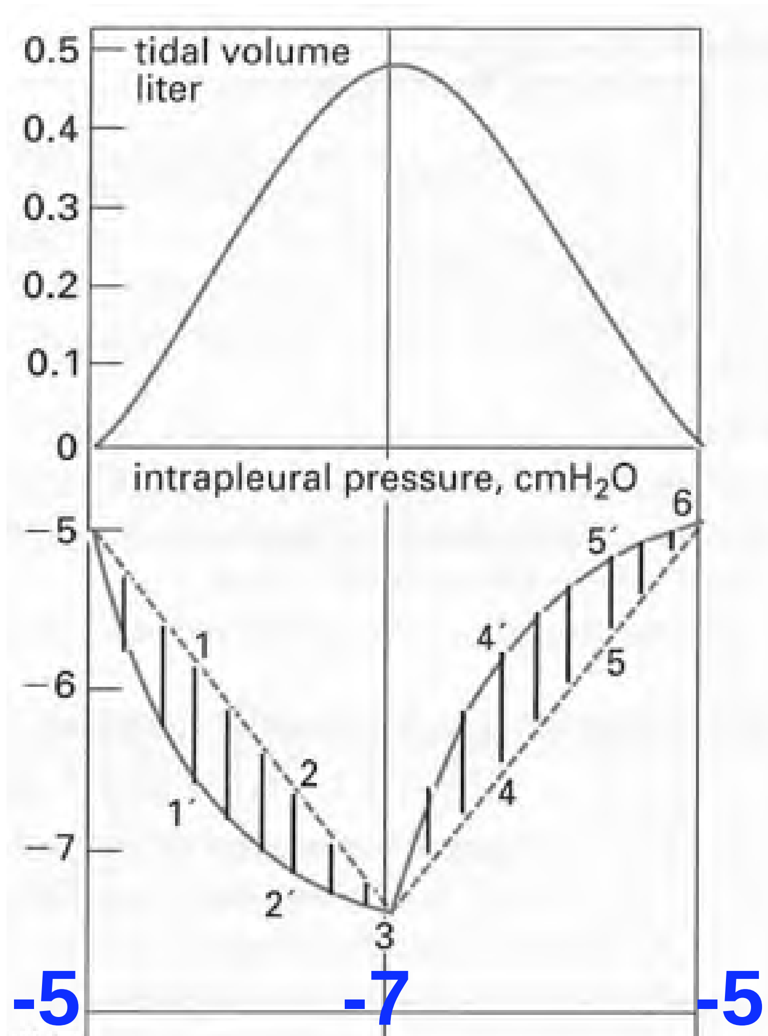
Minute ventilation that is total

Ventilation per minute = TV X Rate

Tidal Volume & Intraplural (P_{ip})

Inspiration **Expiration**

Air Entering Lung



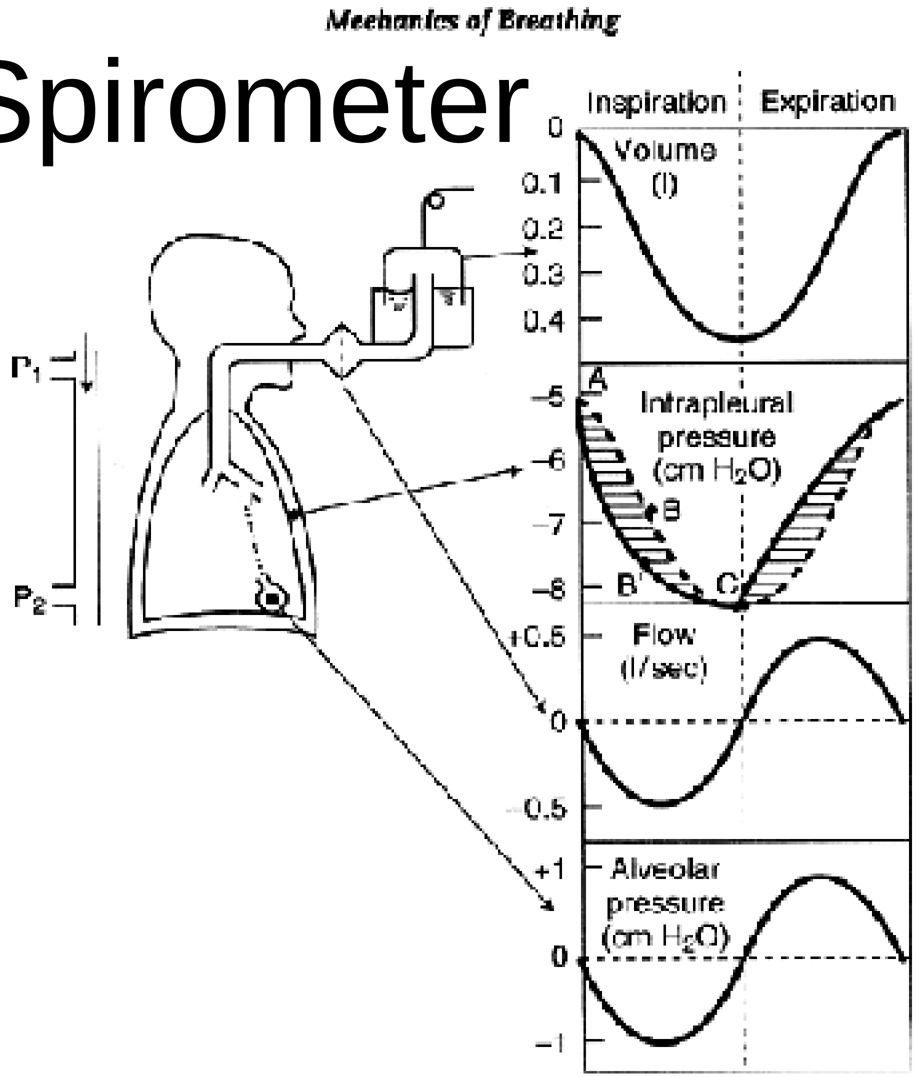
Air Leaving Lung

P_{ip} is **-5** **-7** **-5**

Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

Mechanics of Breathing

Spirometer



Tidal Volume
Figure shows
opposite direction,
“down”,
but volume is same

Esophagus balloon

Flow meter

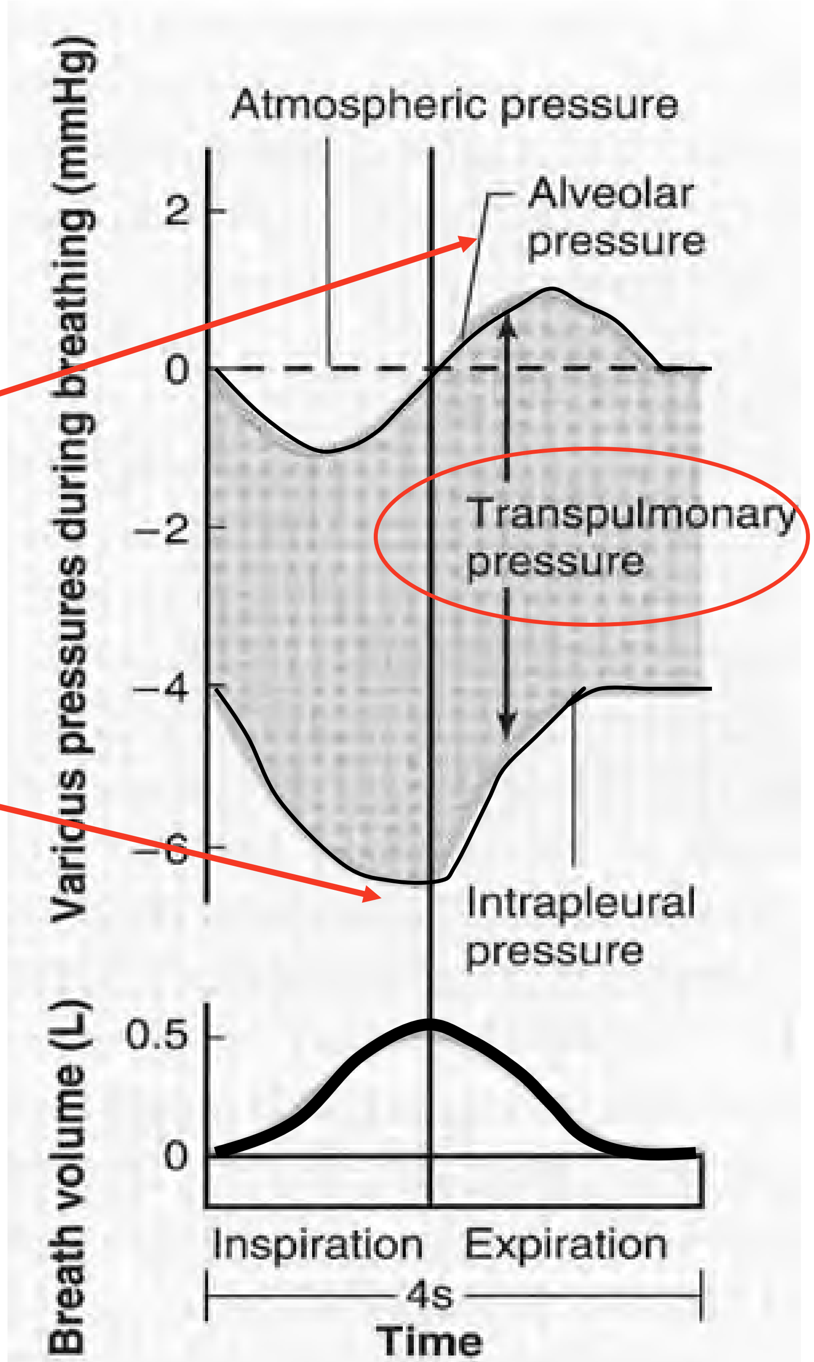
Calculated P_A

Trans-pulmonary or alveolar-distending pressure .

$= P_A - P_{ip}$

-“across” lung wall

- **P_{ip}** always negative
- not symmetrical
- max @ end of Insp.



PD-INCL Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

Transpulmonary Pressure by "pumping" into isolated lung (positive)

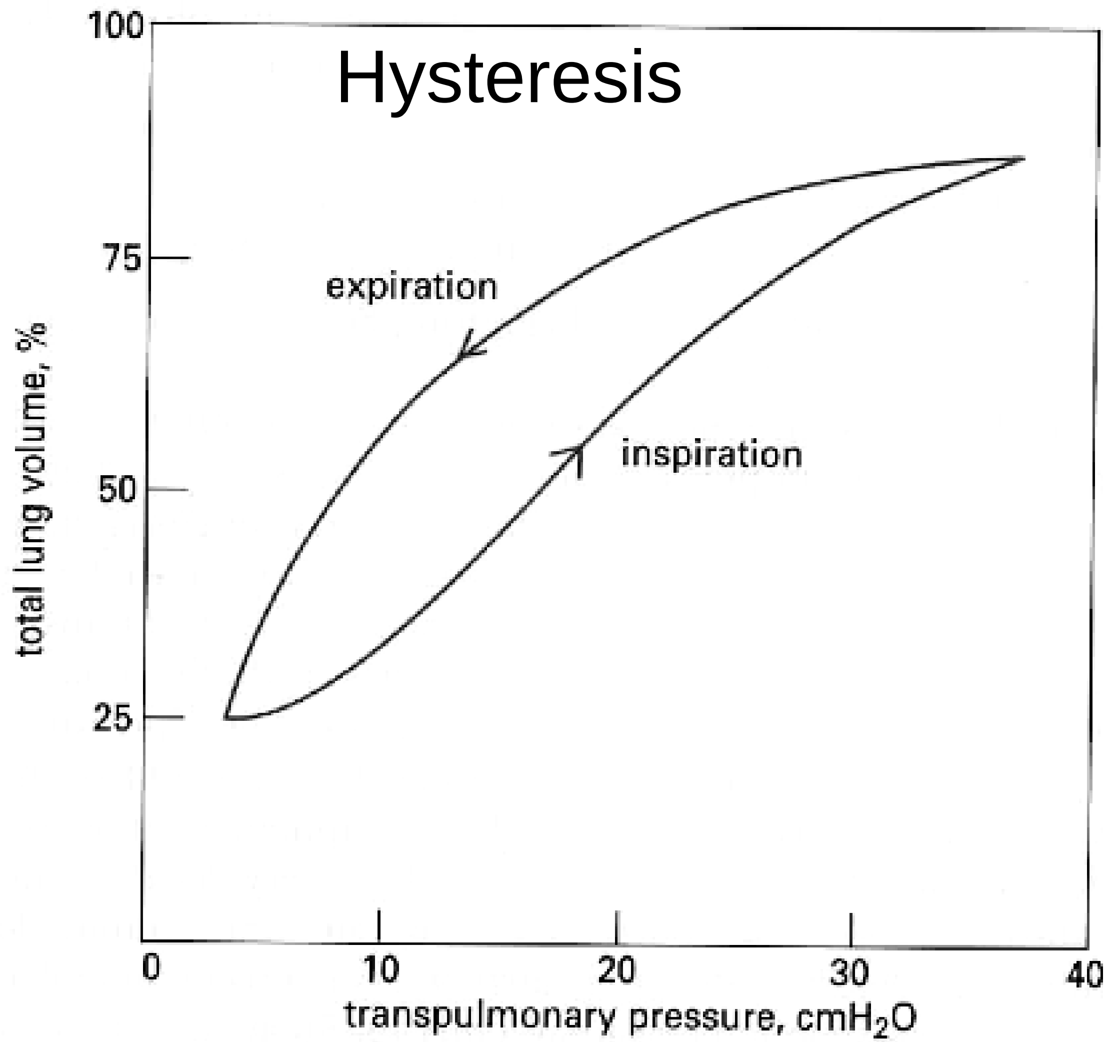


Figure 2-6 Pressure-volume curve for isolated lungs.

PD-INEL Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

Isolated Lung

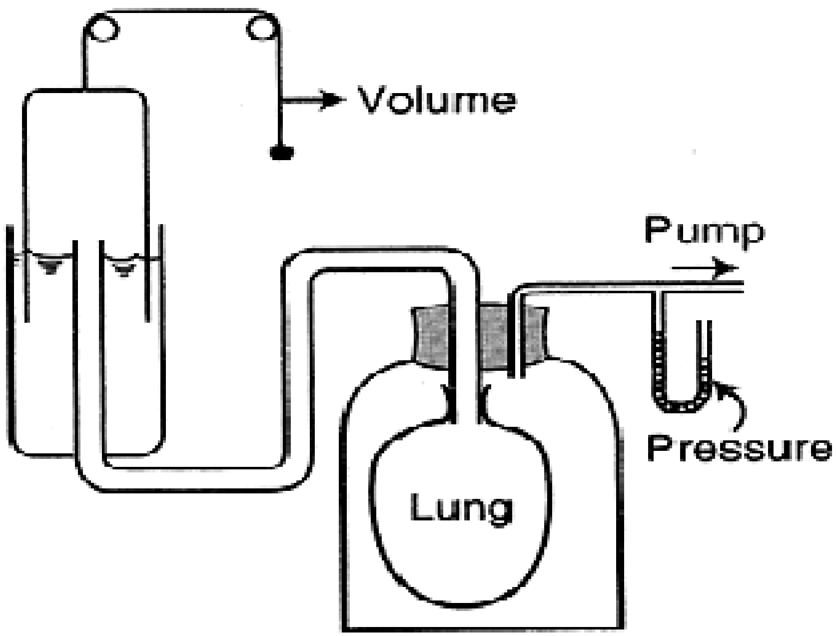
Compliance = (slope)

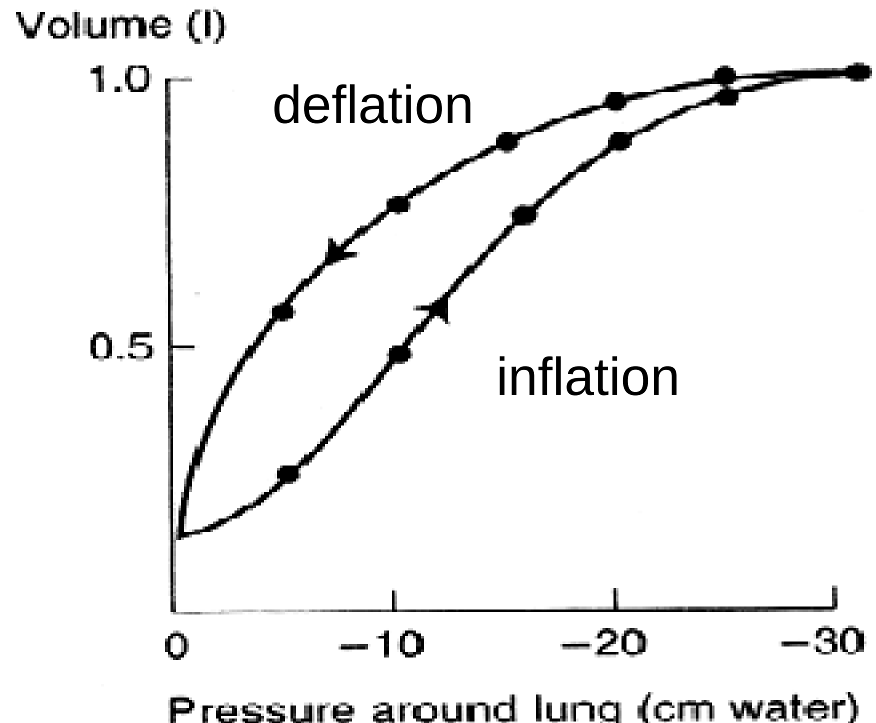
$$\frac{\Delta V}{\Delta P}$$

"ease of stretching" or "inverse of elasticity"

Transpulmonary Pressure by "sucking" on outside of isolated lung (negative)

Hysteresis = difference on inflation and deflation





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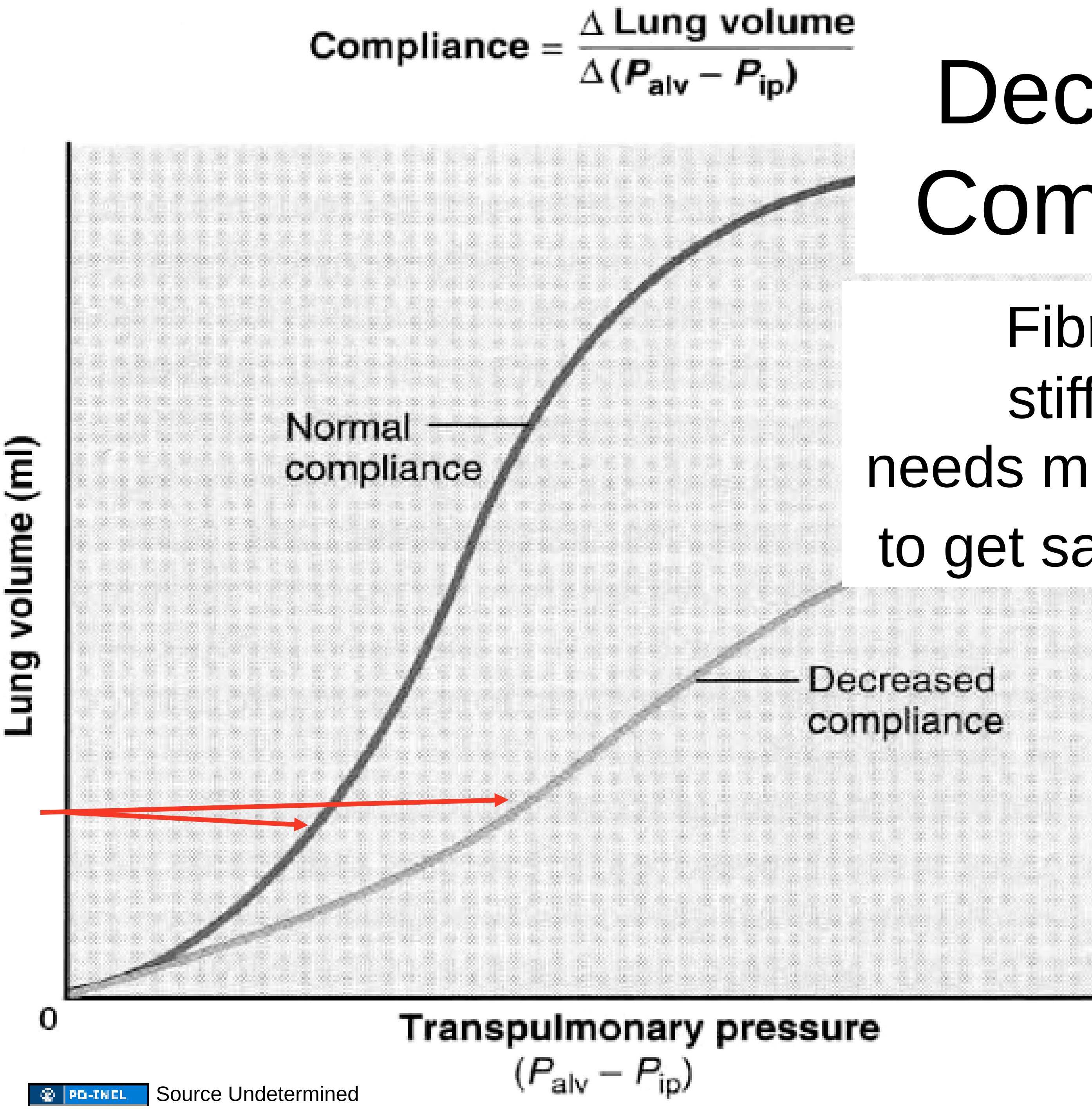
- -Surfactant
- -Recruiting alveoli

Same with positive or negative pressure.

Decreased Compliance

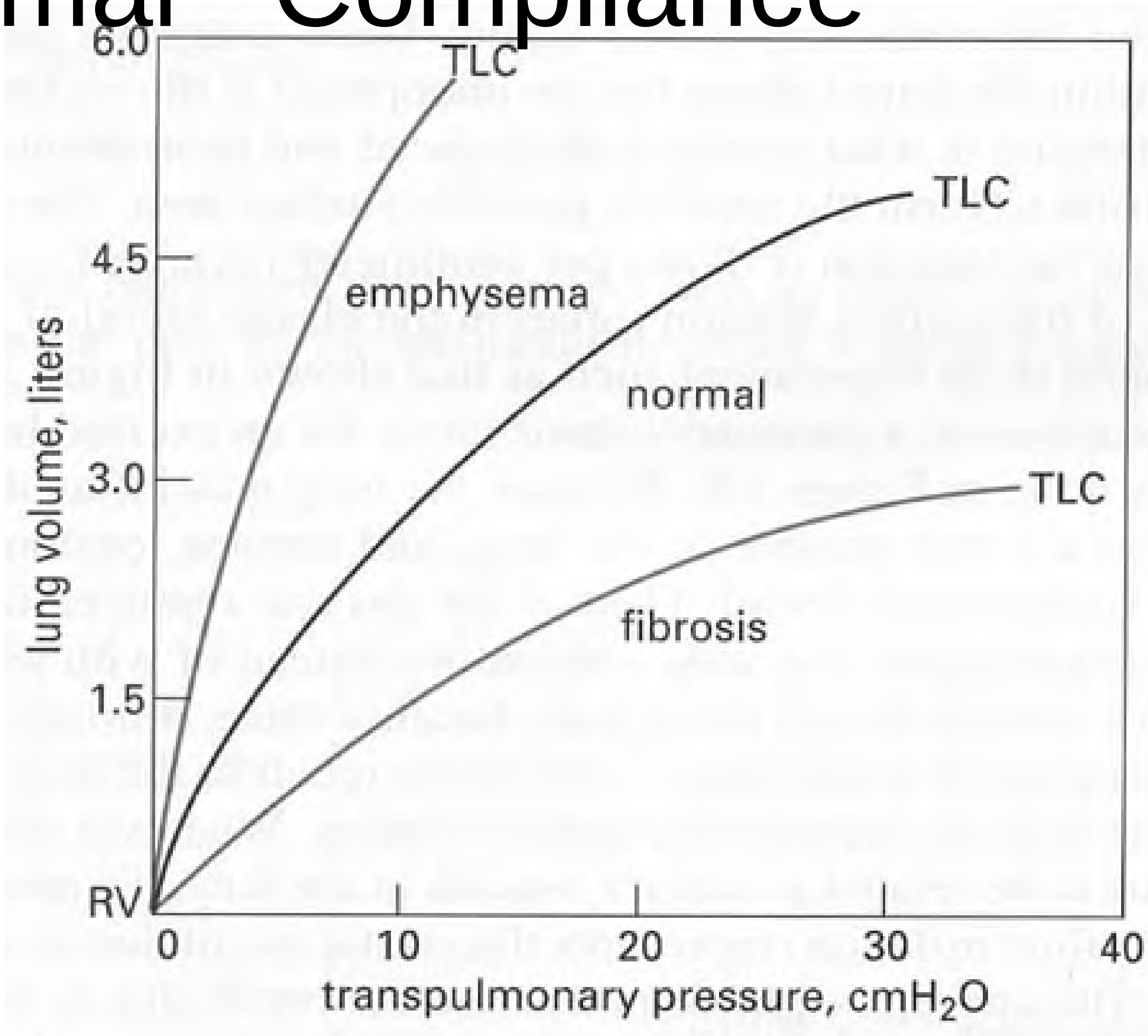


Fibrosis or
stiffer lung
needs more pressure
to get same volume.

Abnormal Compliance

$\frac{\Delta V}{\Delta P}$

Emphysema
Greater
volume change
with
smaller
pressure change



 Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

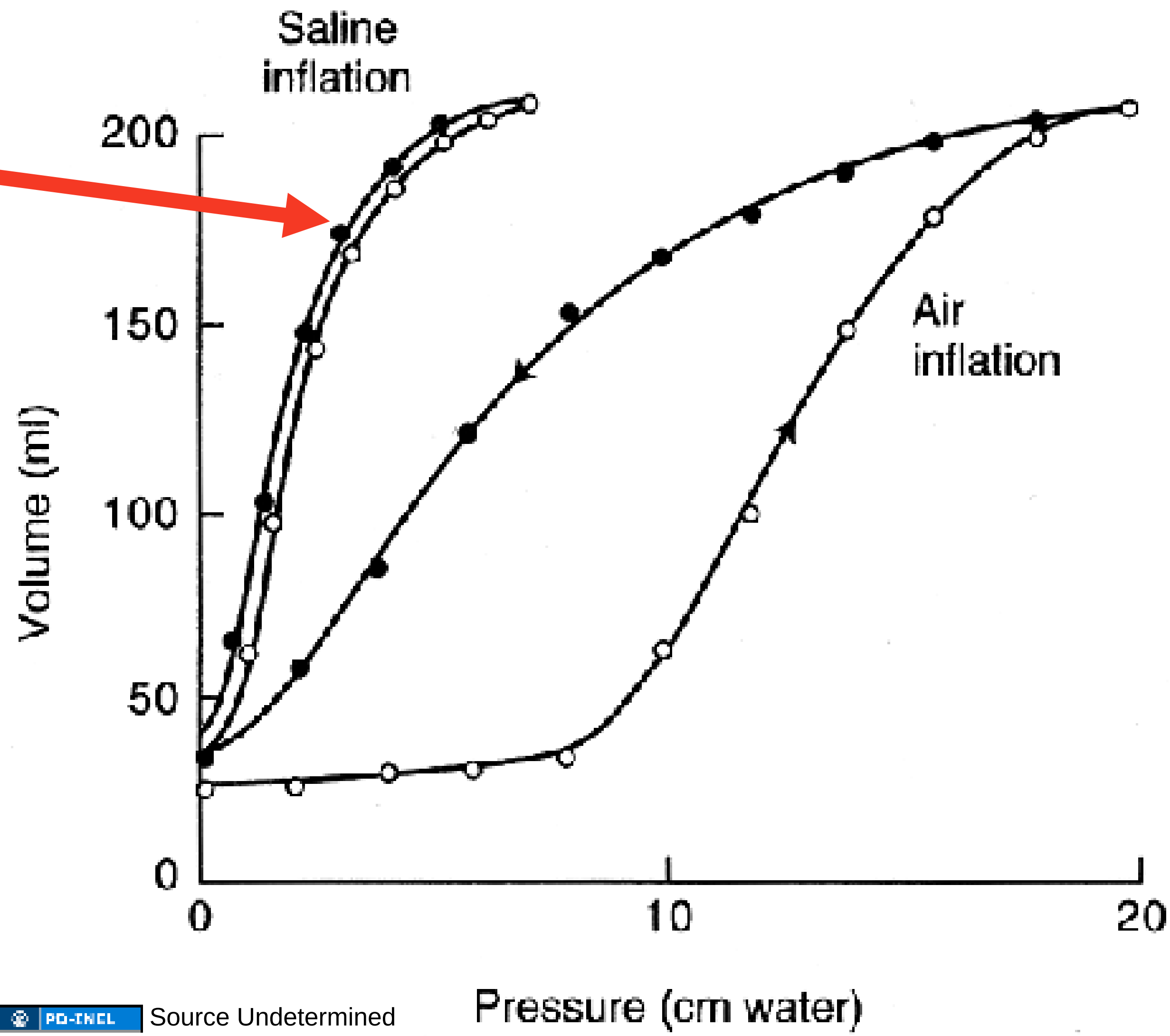
Static P / V Excised Isolated Lung

Air filled harder to inflate than saline filled BUT…

No air = no surface tension.

Thus

most inflation pressure is to overcome surface tension.



Surfactant

TABLE 15–3 Some Important Facts about Pulmonary Surfactant

1. Pulmonary surfactant is a mixture of phospholipids and protein.
2. It is secreted by type II alveolar cells.
3. It lowers surface tension of the water layer at the alveolar surface, which increases lung compliance (that is, makes the lungs easier to expand).
4. A deep breath increases its secretion (by stretching the type II cells). Its concentration decreases when breaths are small.

Infant Respiratory Distress Syndrome

- No functional pulmonary surfactant
- Great difficulty inflating lungs
- If inflated for them -- tend to collapse
- Very low compliance (very stiff)
- Strenuous effort needed to breathe
- Die from complete exhaustion

Work of breathing

Work ~ Pressure change X Volume change

Elastic work overcomes:

- **recoil of chest wall**
- **recoil of lung parenchyma**
- **surface tension of alveoli**

Resistive Work overcomes:

- **Tissue resistance**
- **Airway resistance**

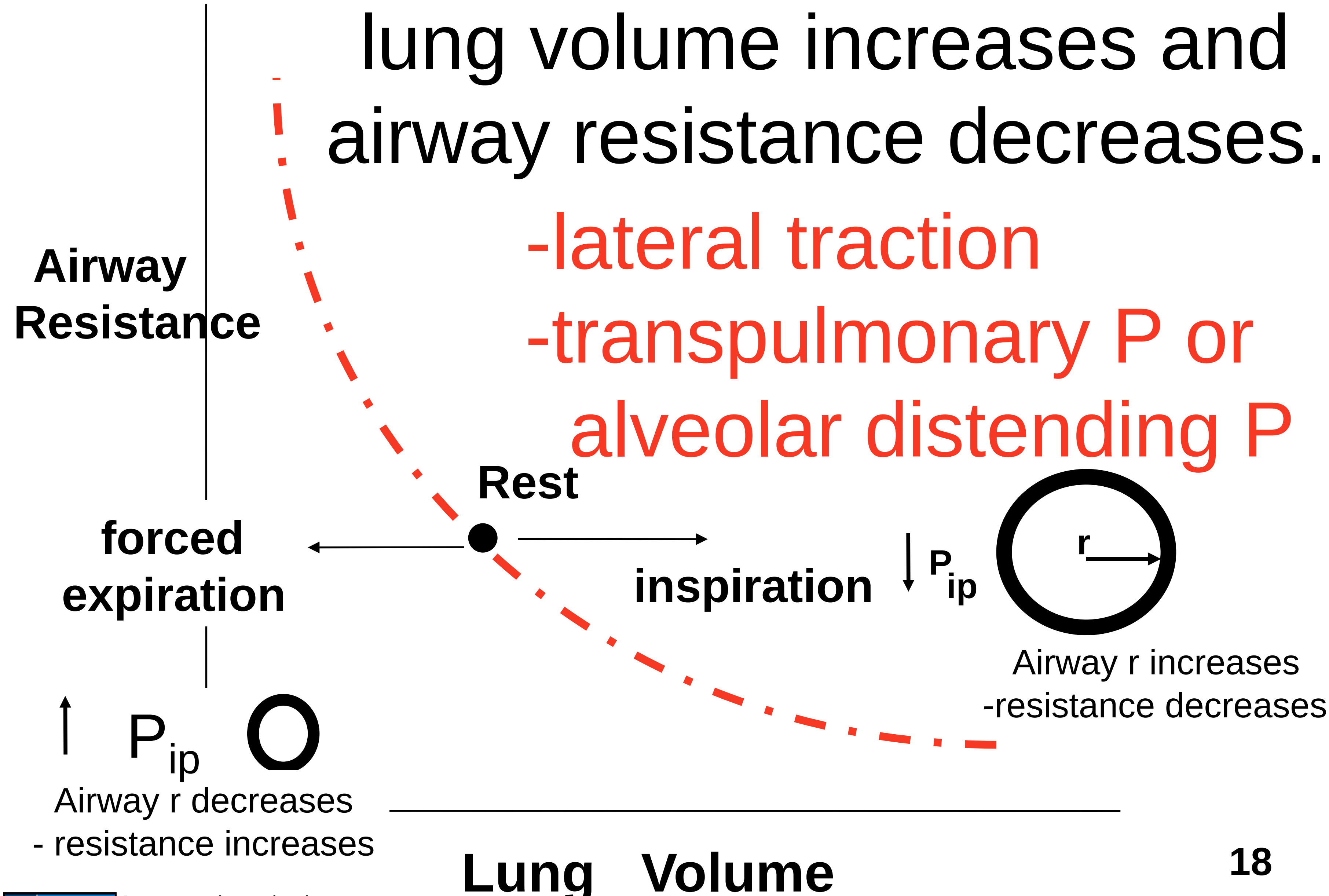
Airway Resistance

The major determinant of airway resistance is the radius (r) of the airway, just as in blood vessels.

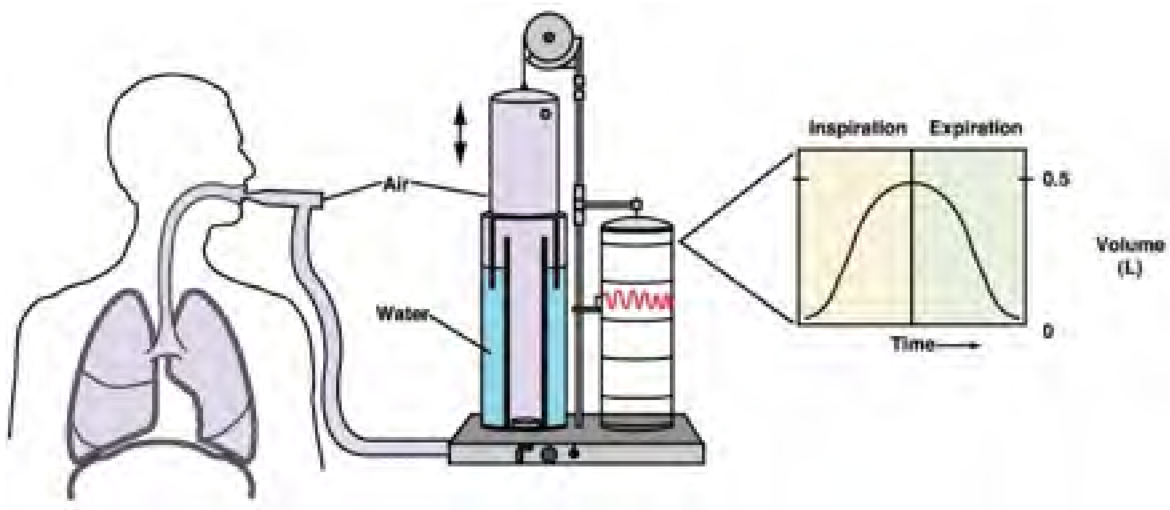
The walls of the airways are subjected to the same changes in transmural pressures as alveolar walls.

During inspiration as the intrapleural pressure decreases (becomes more negative), the transmural pressure across the airway walls will increase and the radius of the airway will increase resulting in a **decrease in airway resistance during inspiration.**

During inspiration lung volume increases and airway resistance decreases.



Measurement of Lung Volumes by Spirometer



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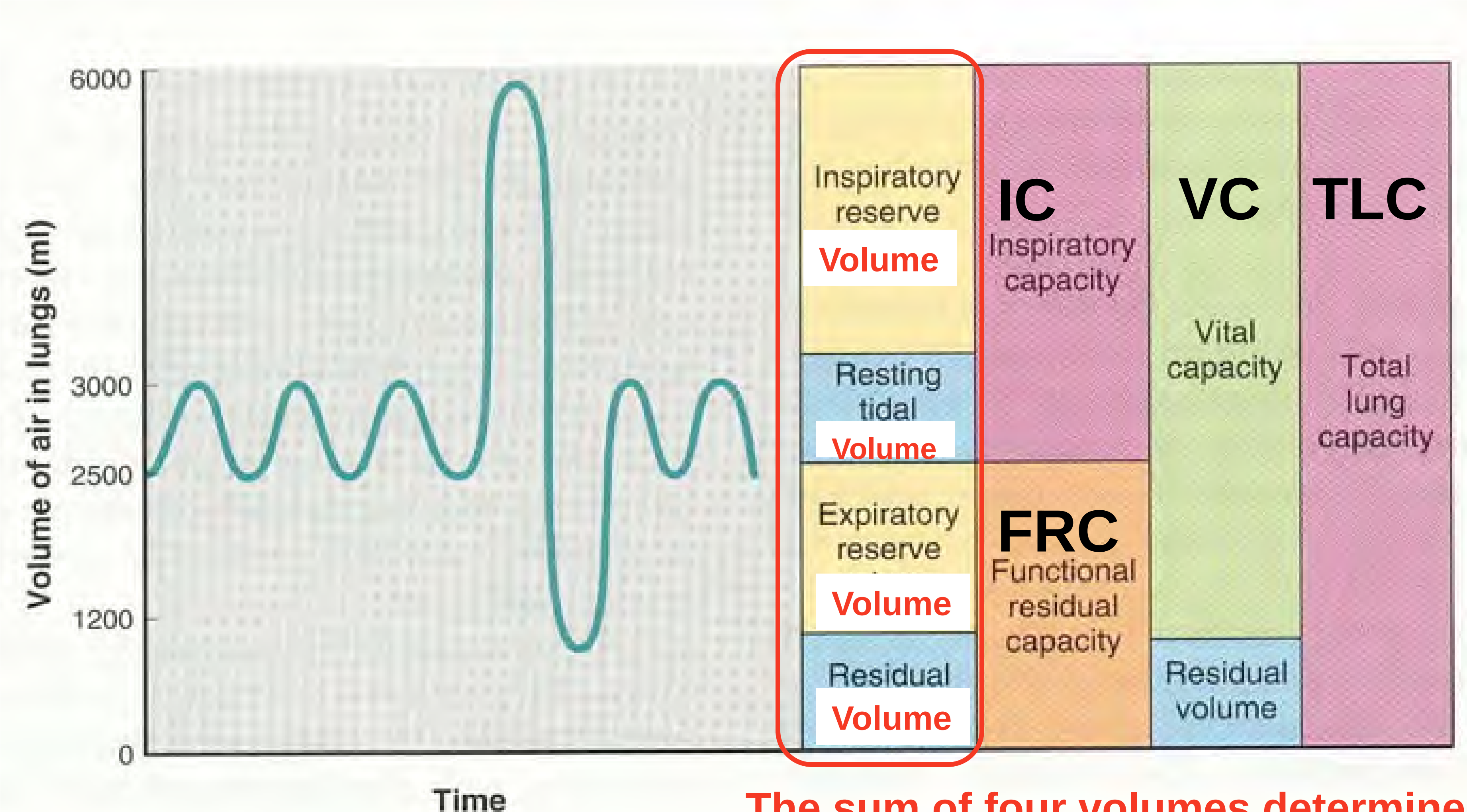
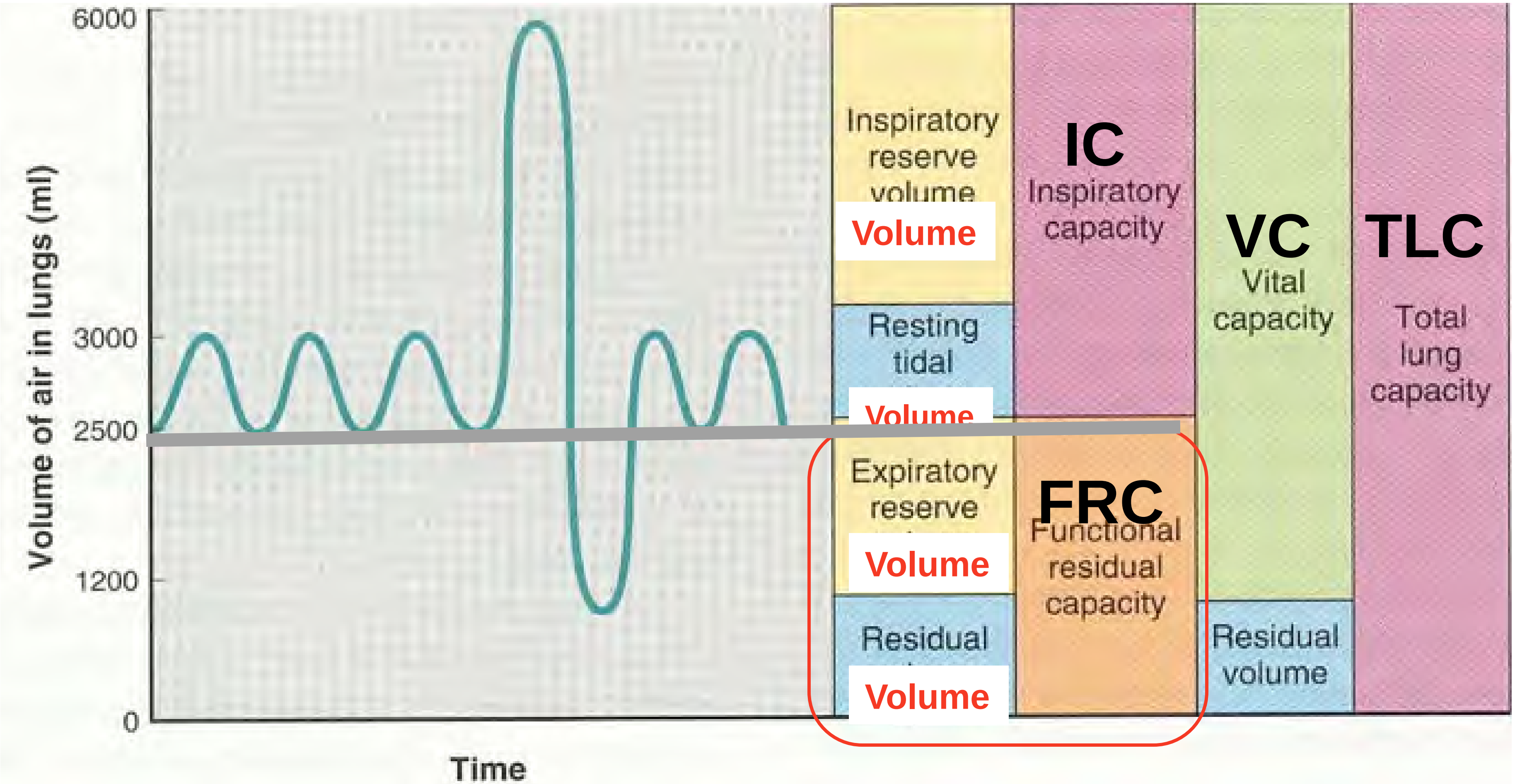
Please see: http://www.cvrti.utah.edu/~macleod/bioen/be6000/labnotes/resp/figures/spirometer.jpg

Measurement of lung volumes and capacities and their relationships under different conditions is used clinically to distinguish obstructive and restrictive disease.

All Volumes & Capacities



The sum of four volumes determine the total lung capacity (TLC).



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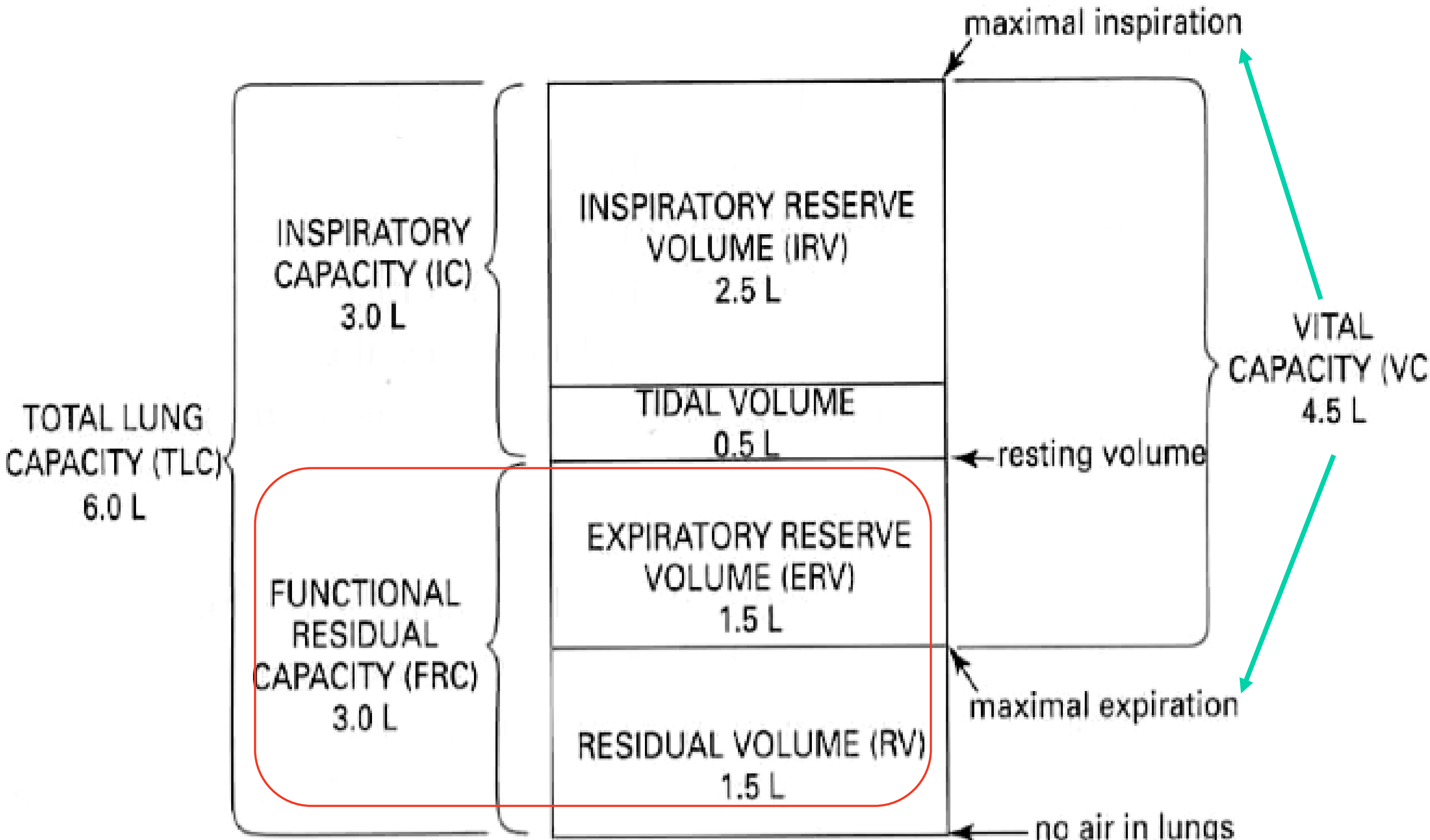
Each "capacity" is the sum of two or more volumes.

FRC is rest position and made of ERV + RV.

VC is maximum tidal volume.

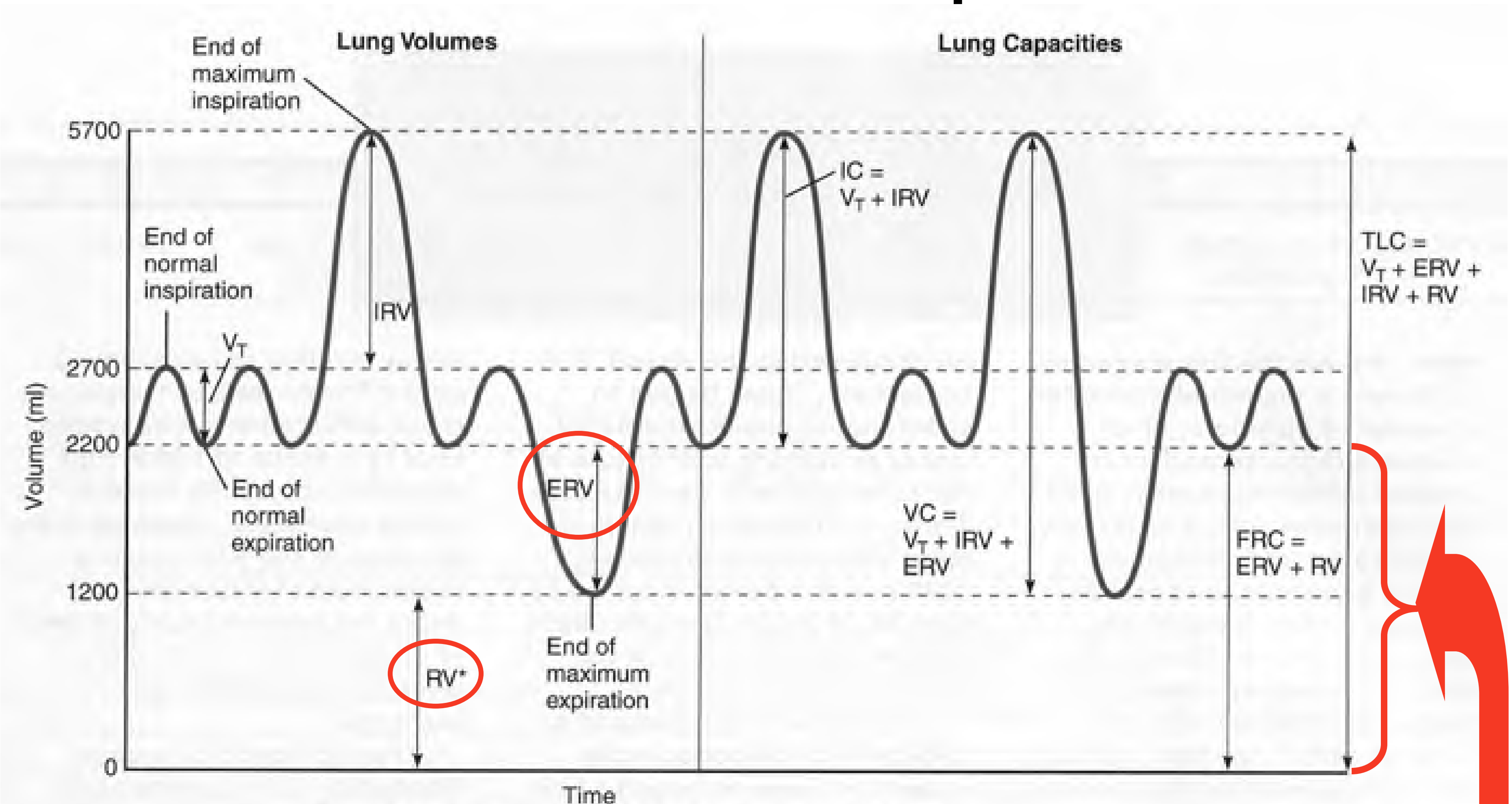
Levitzky Volumes & Capacities



 Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

FRC = ERV + RV

Volumes & Capacities



Normal lung volumes and capacities for a healthy 70 kg male

Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

FRC = ERV + RV

FRC & RV

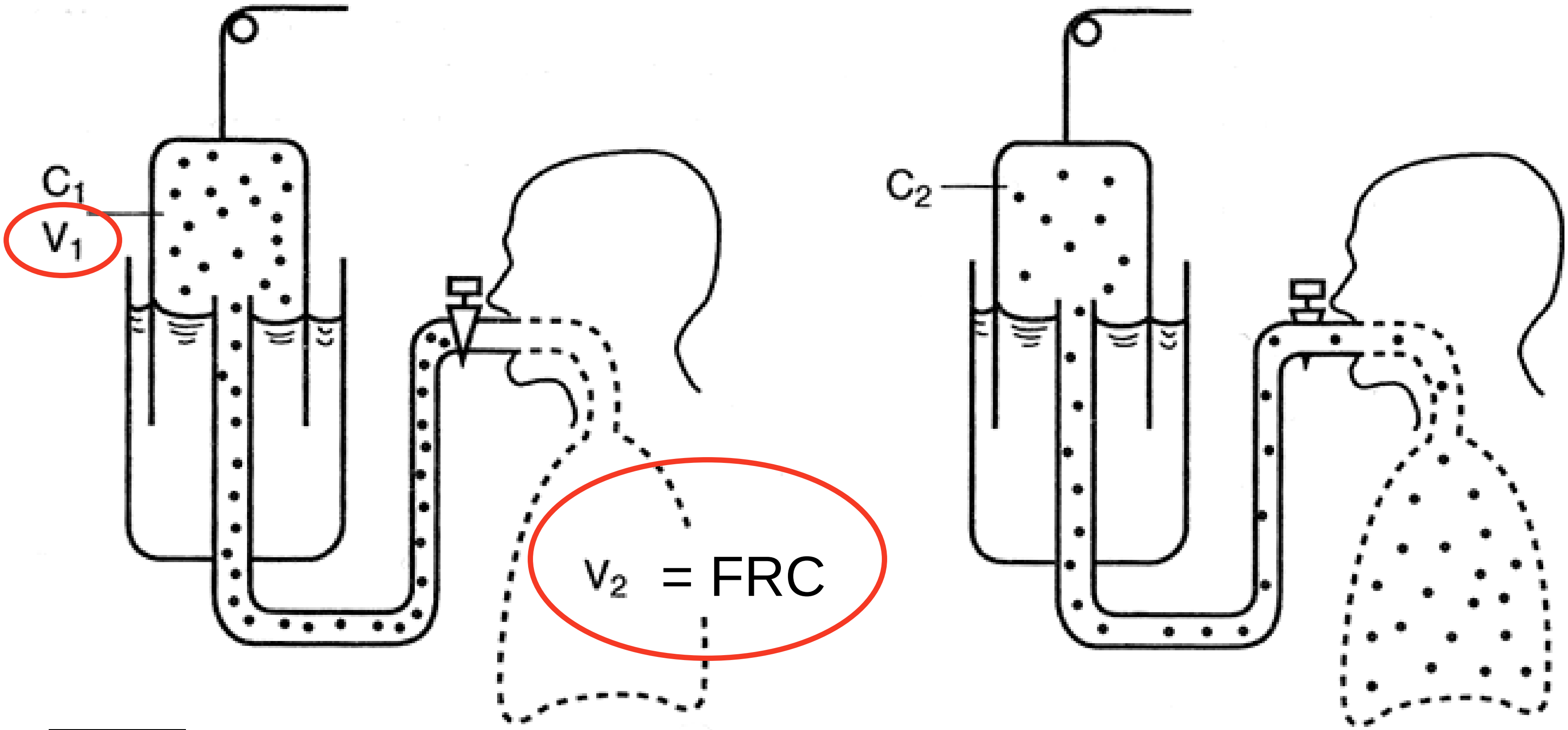
Neither functional residual capacity (FRC) nor residual volume (RV) can be measured with simple spirometer.
THREE CLINICAL OPTIONS

1) Gas (helium) dilution***** (poor solubility)**
(no metabolism)
(no diffusion)

2) Nitrogen-Washout Technique

3)Body plethysmography

Measurement of Functional Residual Capacity



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Before Equilibration **After Equilibration**

“Dilution”

$$C_1 \times V_1 = C_2 \times (V_1 + V_2)$$

Amount of He “Before” = Amount of He “After”

Solve for V_2.

Measure by

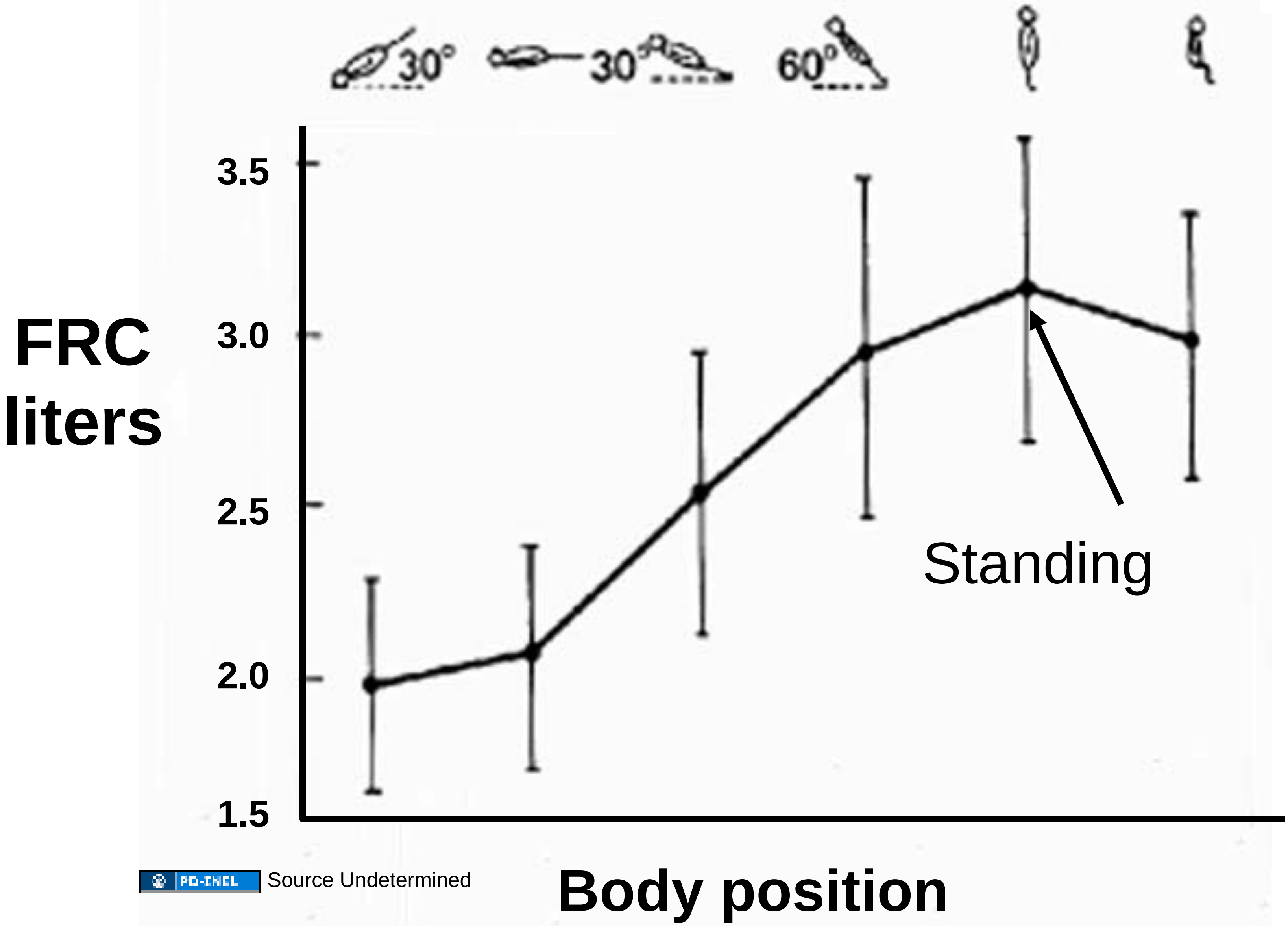
Helium dilution

Spirometry

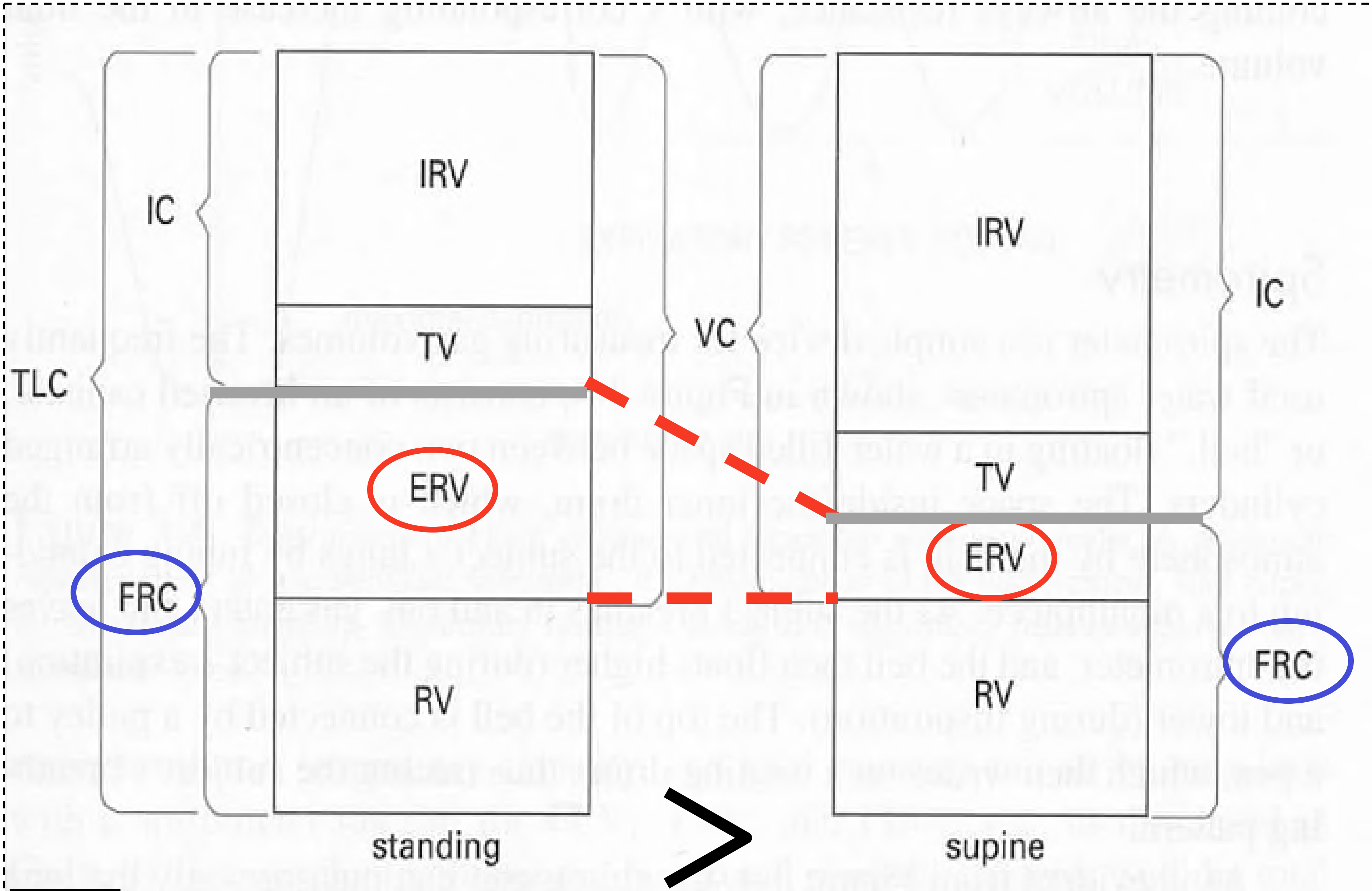
FRC = ERV + RV

Calculate

Standing increase FRC by increasing ERV



FRC Standing is Larger Than FRC Supine

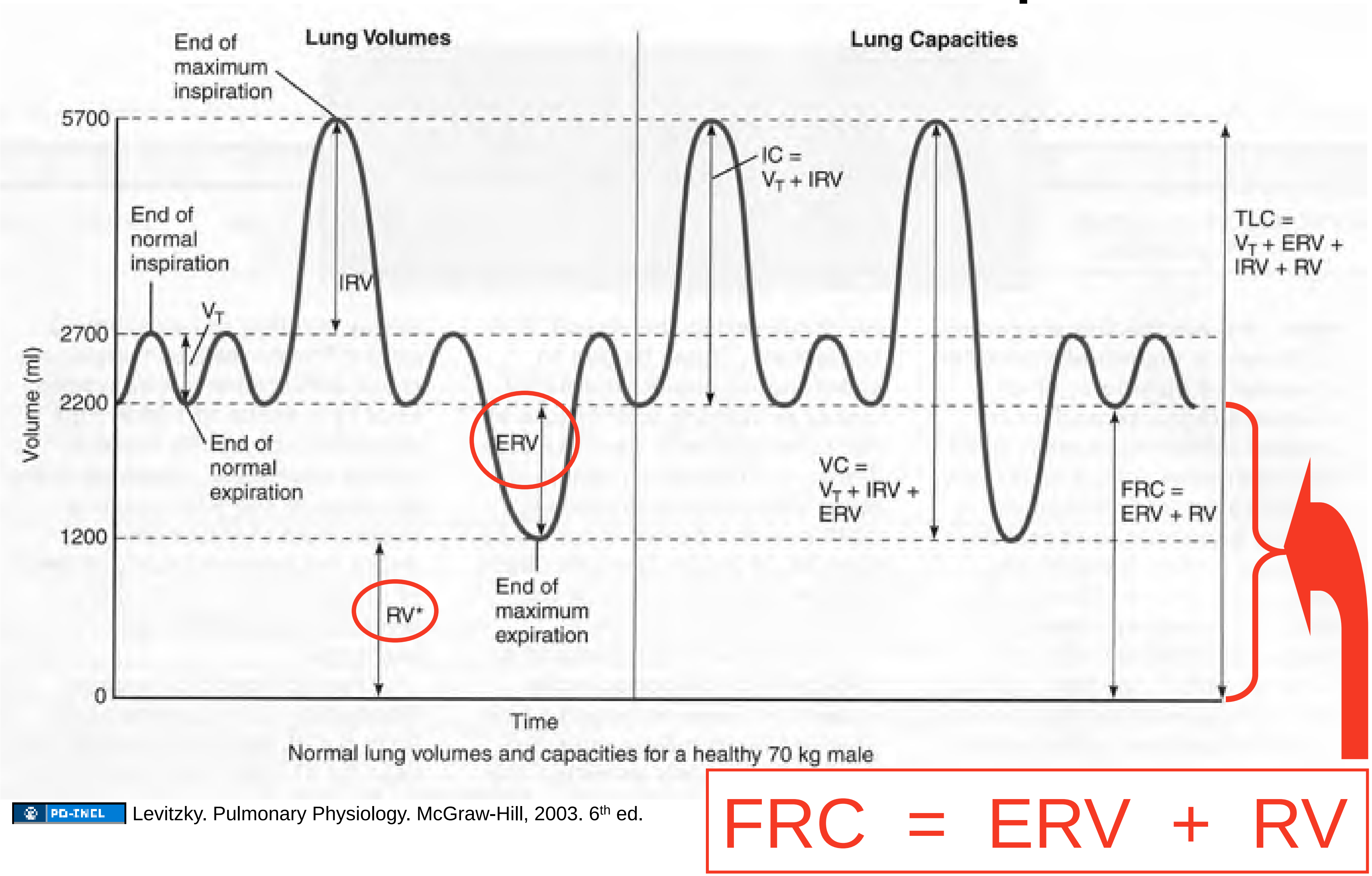


FRC Standing & Supine

When standing the abdominal contents pull down on diaphragm increasing FRC so chest has more air in it at <u>rest</u> (FRC).

When supine abdominal contents push diaphragm up into chest reducing FRC so chest has less air in it at <u>rest</u> (FRC).

“Static” Volumes & Capacities



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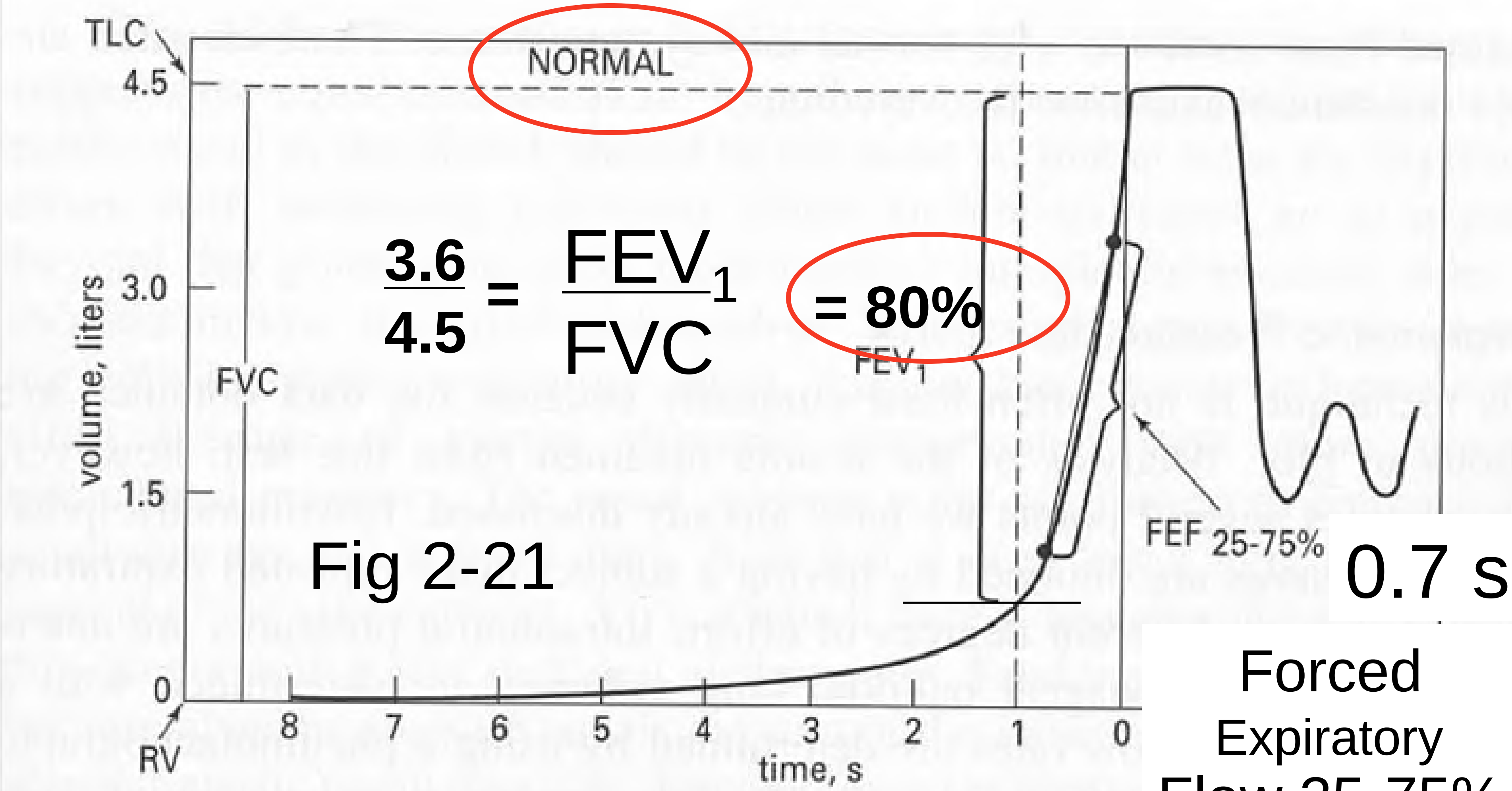
Airway Resistance 1 (Normal)

Forced expired volume in 1 sec (FEV_1) as a faction of Forced Vital Capacity (FVC)



$$\frac{3.6}{4.5} = \frac{FEV_1}{FVC} = 80\%$$

Fig 2-21

0.7 s

Forced Expiratory Flow 25-75%

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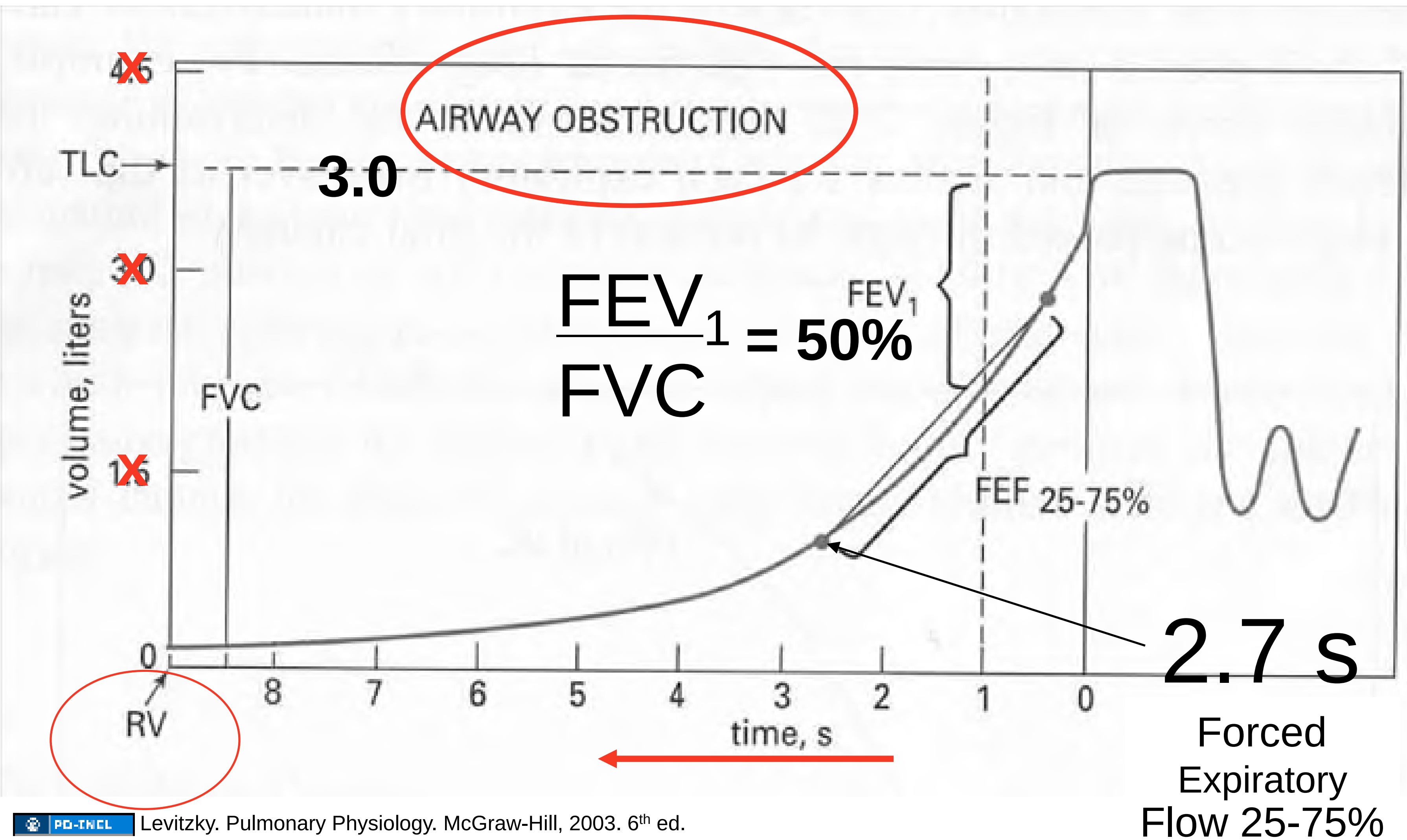
Airway Resistance 2 (Obstruction)

More resistance so less and slower flow



$$\frac{FEV_1}{FVC} = 50\%$$

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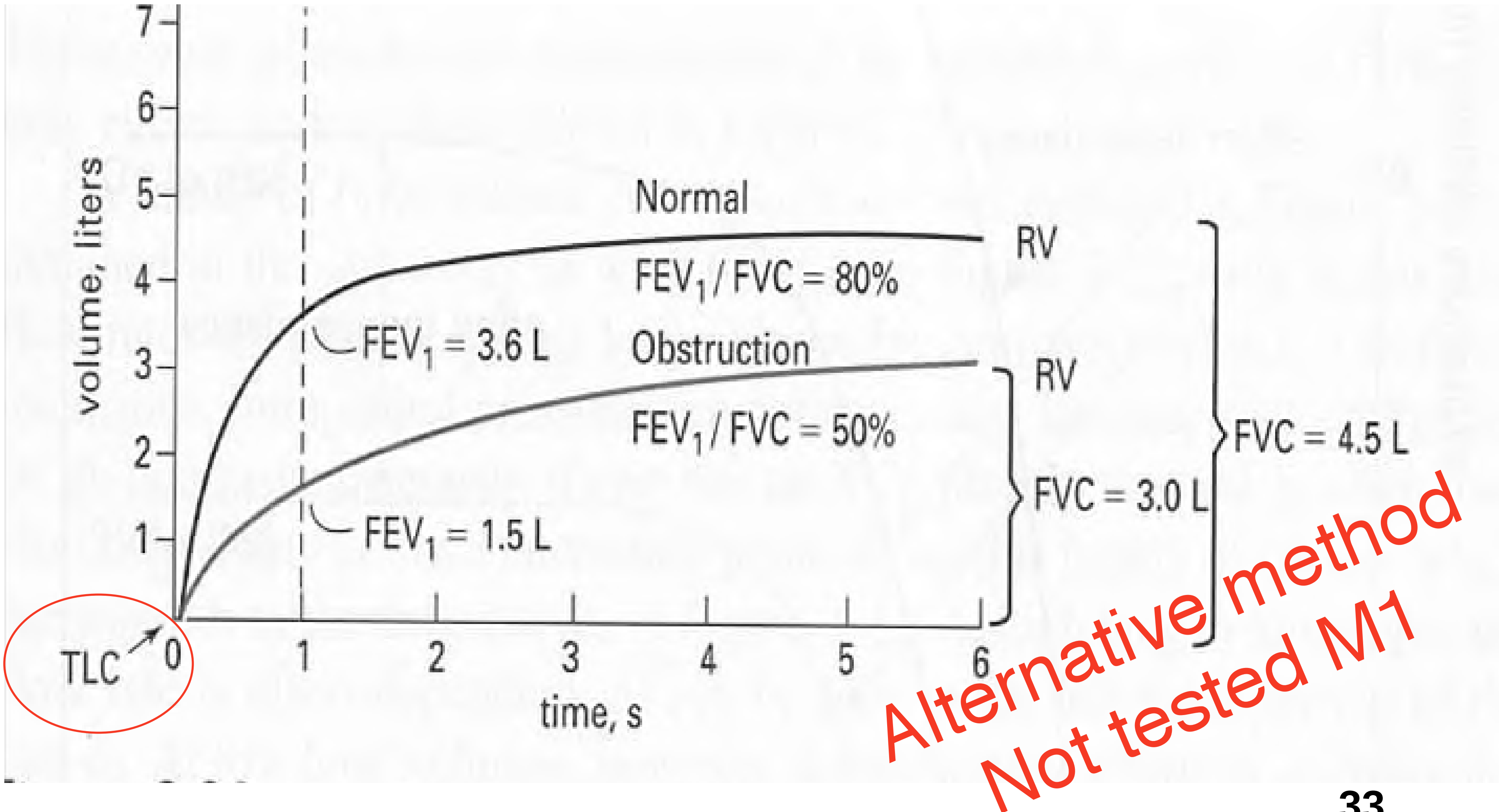
Airway Resistance 3

"Rolling Seal Spirometer"



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