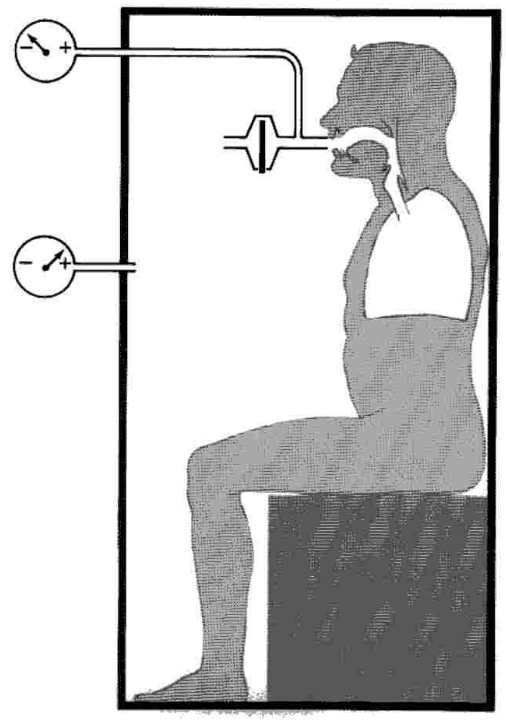
Lecture 38
Lung Compliance and Resistance



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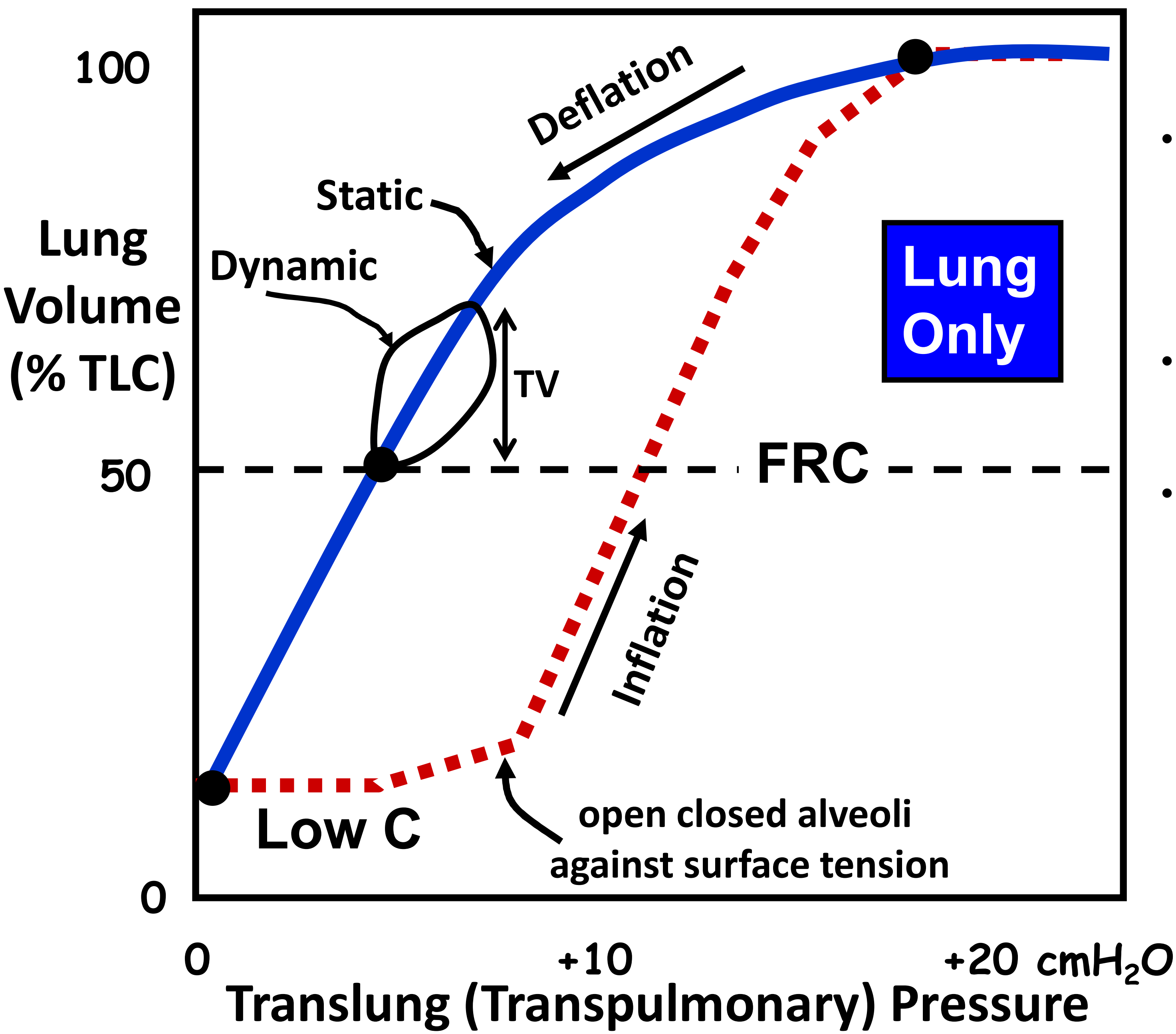
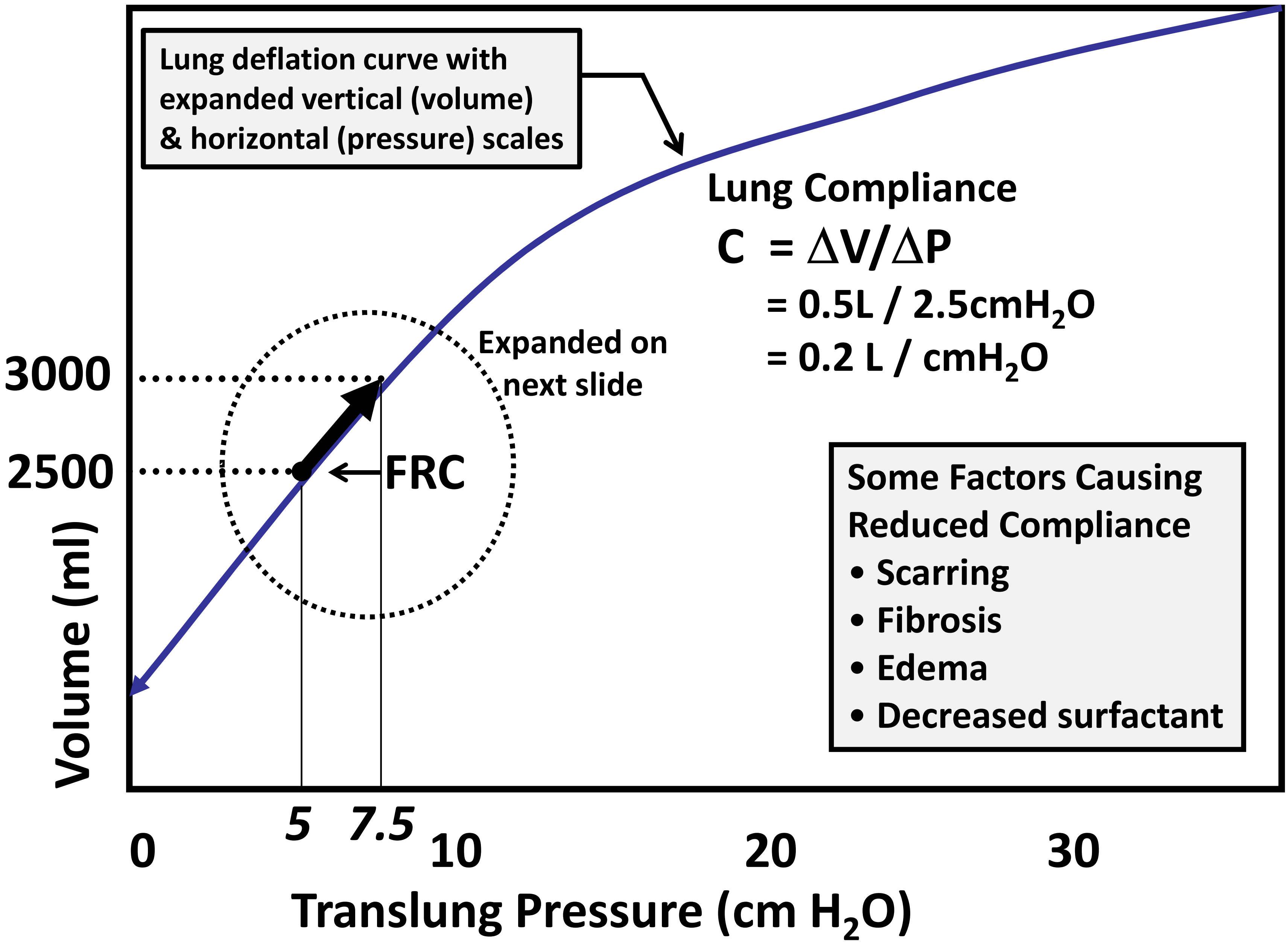
Compliance Issues

JUST Lung Pressure-Volume Relations

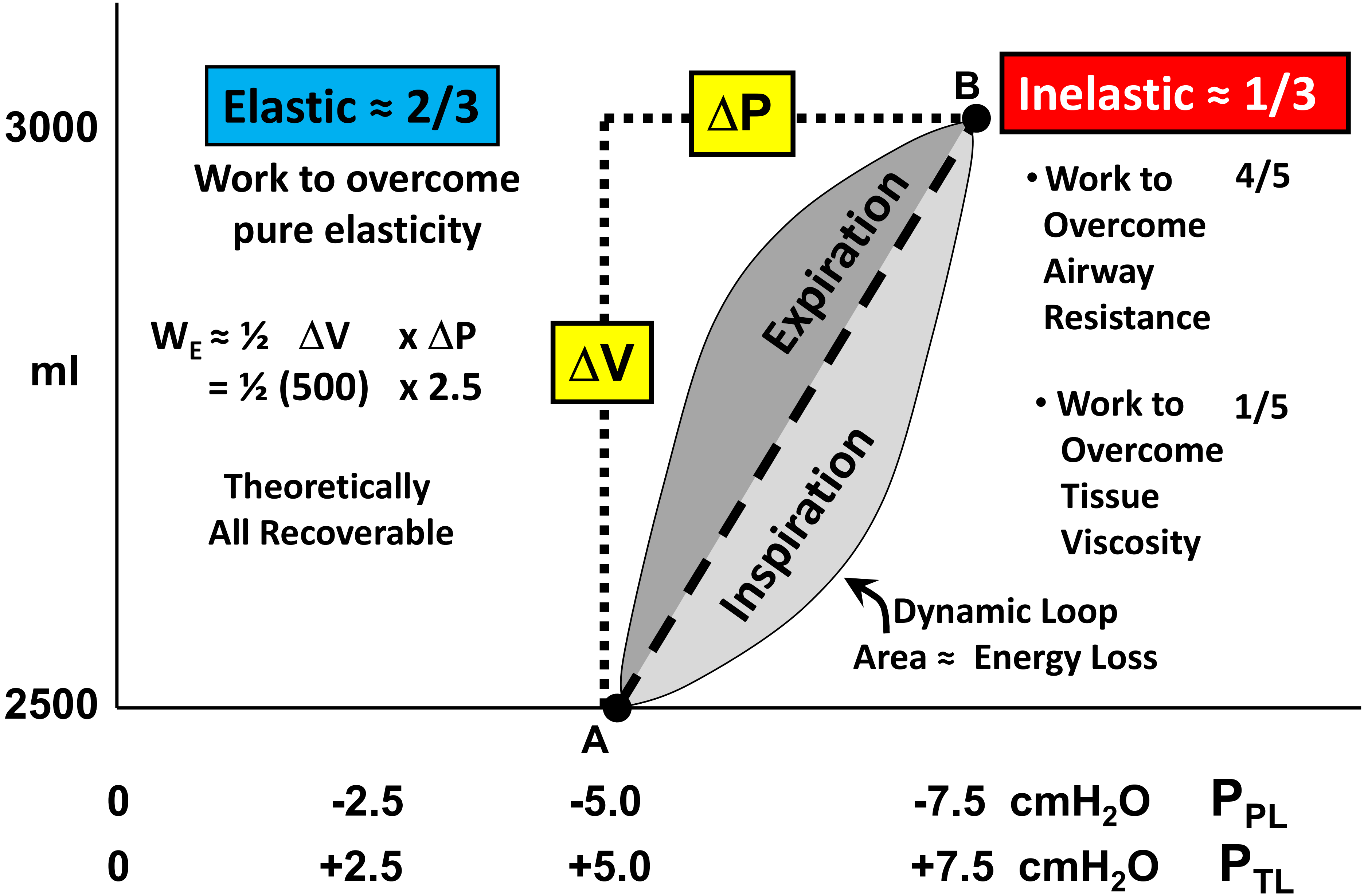


- Inflation and deflation curves differ mainly due to the energy needed to open previously closed alveoli
- For standardization, the deflation curve is used
- The figure shows the superimposed dynamic loop that represents the path taken during quiet breathing

Lung Compliance



Elastic vs. Inelastic Work



Lung and Chest Wall Forces

Lung + Thorax Interactions Determine Respiratory System P-V and Compliance

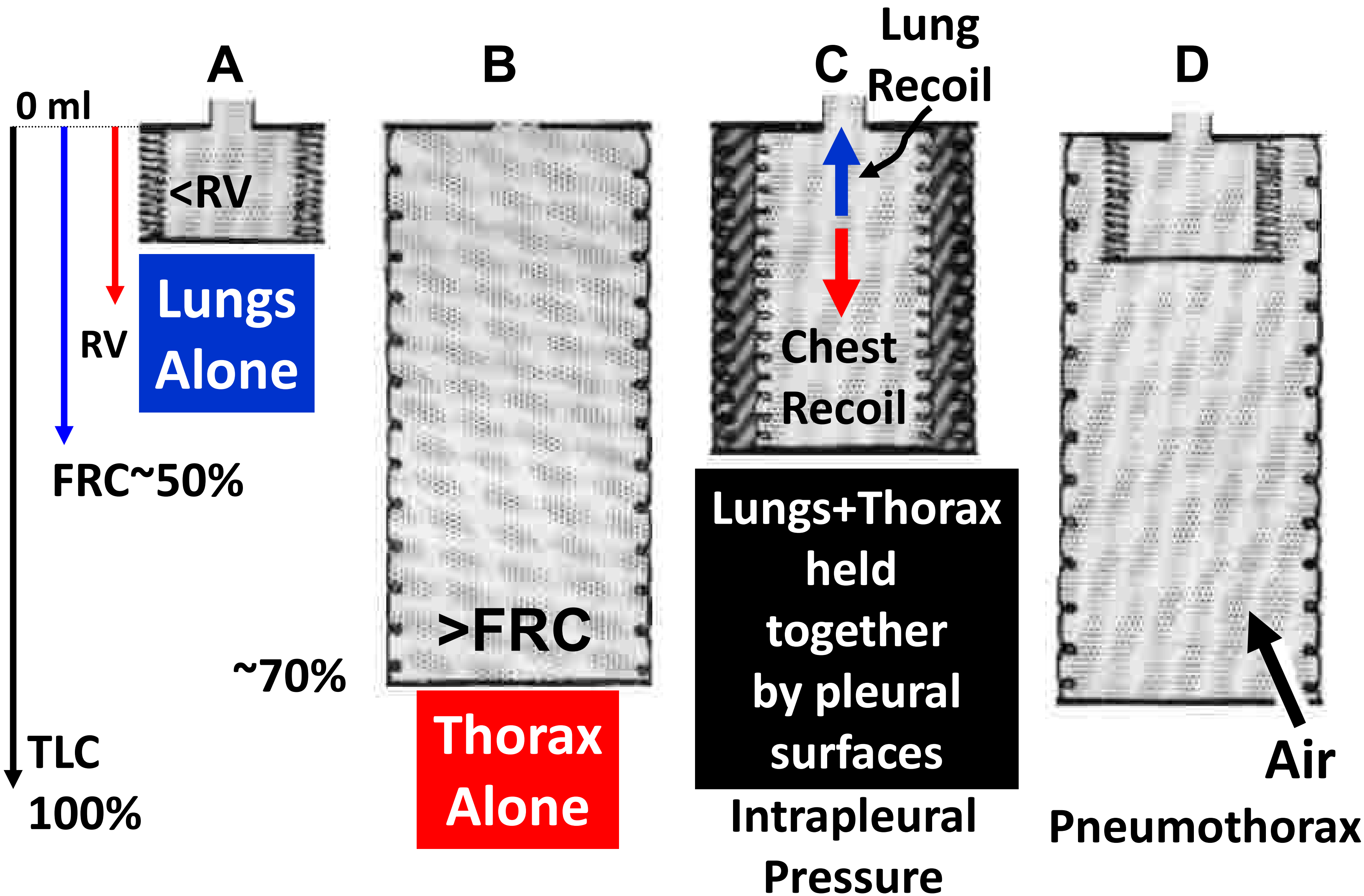
- **Lung Elastic Forces**: *tend to close the lung at any lung volume*
- **Chest Wall Elastic Forces**: *tend to expand lung for most lung volumes*

- **At FRC**: Forces are equal but oppositely directed

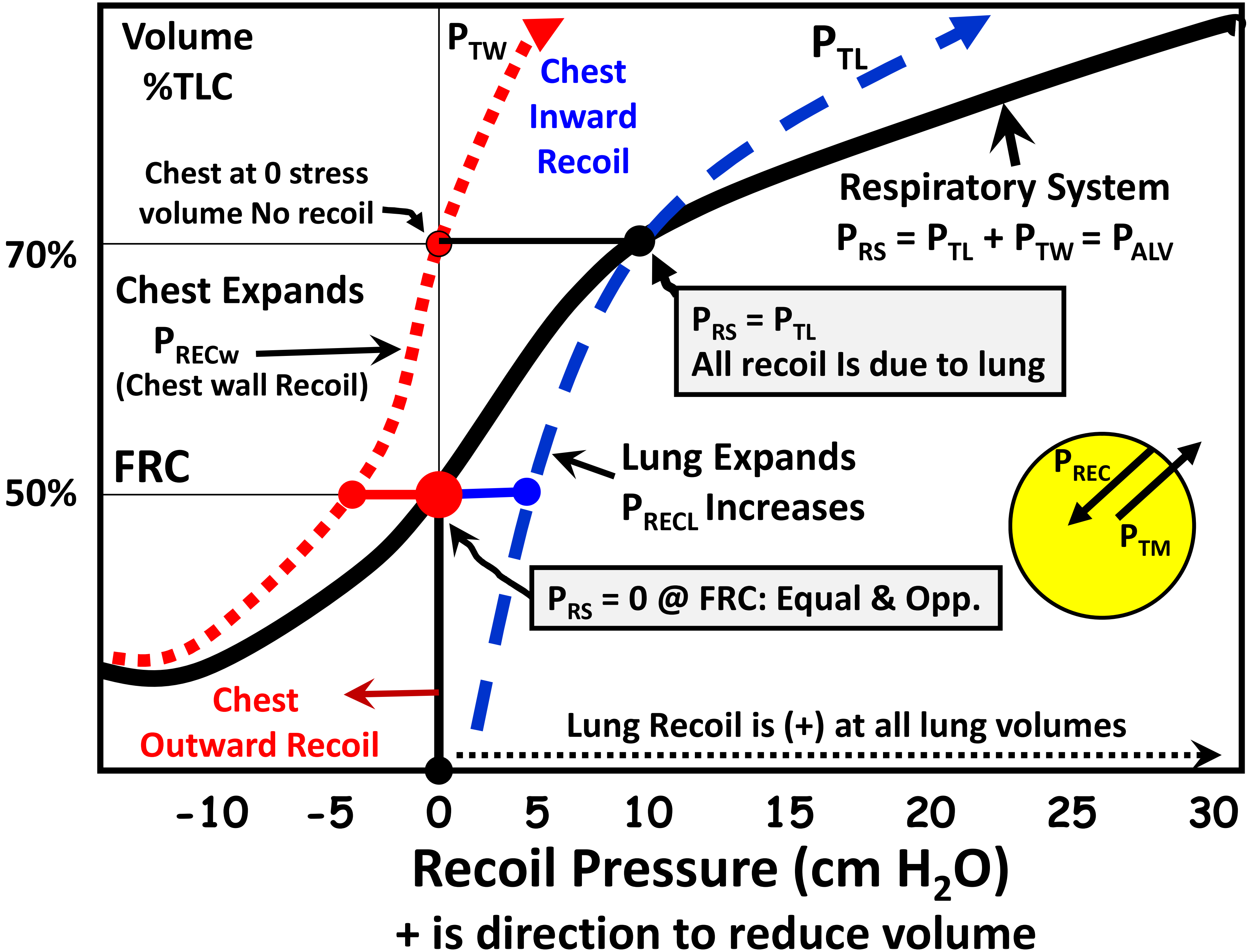
Inspiration: Lung force ↑ Chest force ↓

- **At ~60-70% TLC**: Chest force = 0 (at 0 stress position)
- **> ~60-70% TLC**: Lung & Chest forces tend to close lung

Lung and Thorax as Springs



Respiratory System P-V relations

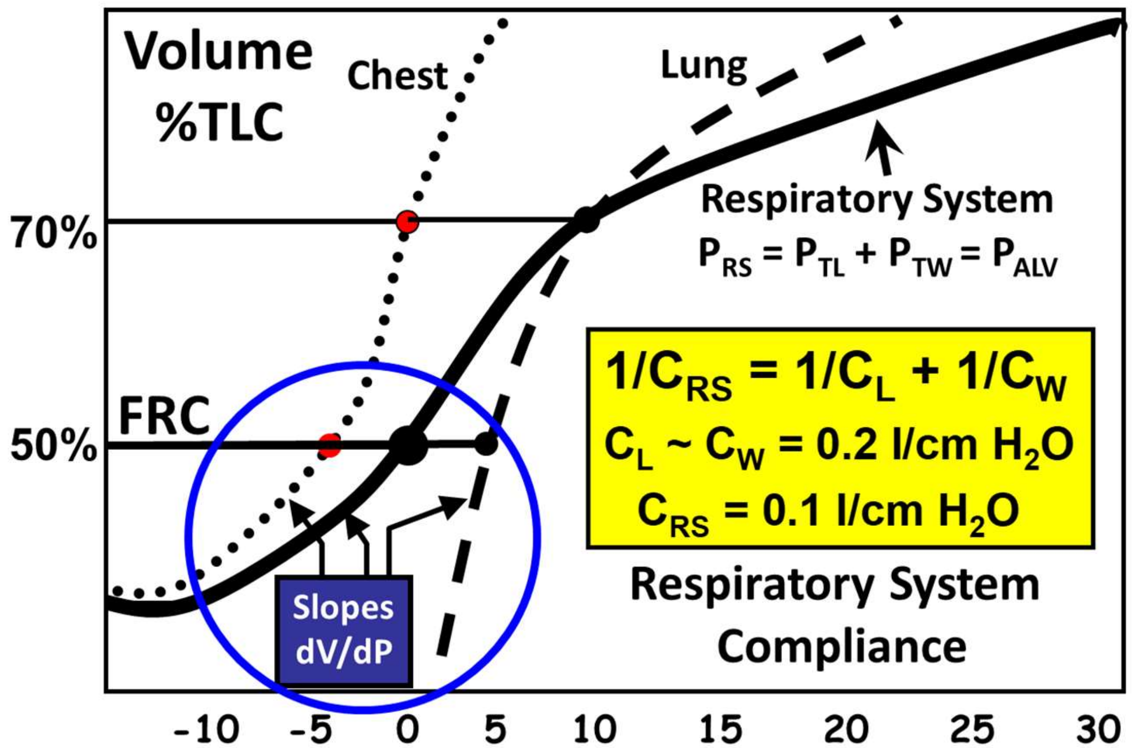


Respiratory System Compliance

- Total respiratory system compliance C_{RS} depends on compliance of <u>lung</u> C_L and compliance of <u>chest wall</u> C_W

$$1/C_{RS} = 1/C_L + 1/C_W$$

- The overall compliance (C_{RS}) is less than either individual compliance

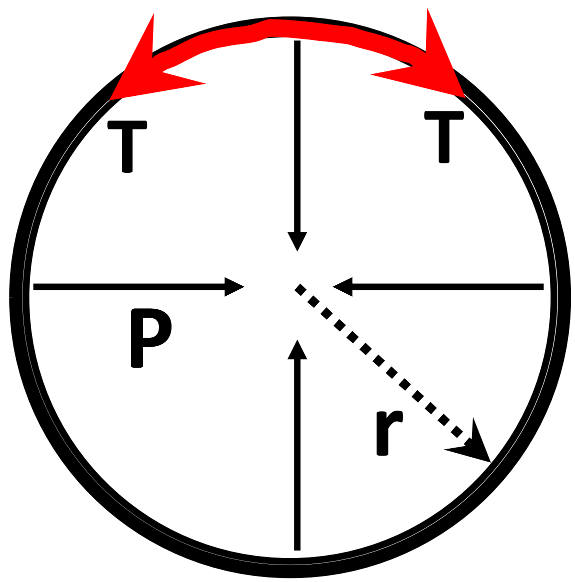


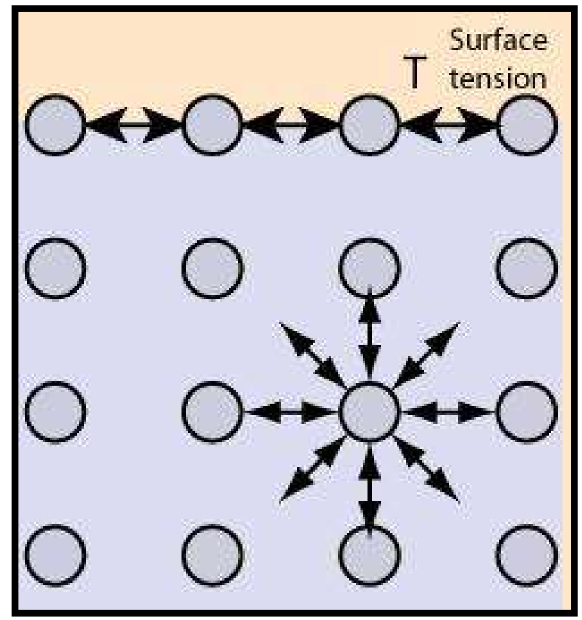
Slopes show lung & chest wall compliances near equal at FRC

Surface Tension-Surfactant Effects

- Surface Tension = T causes inward pressure P = 2T/r
- T is reduced by presence of lung surfactant (LS)

Alveolus pictured as a Soap Bubble

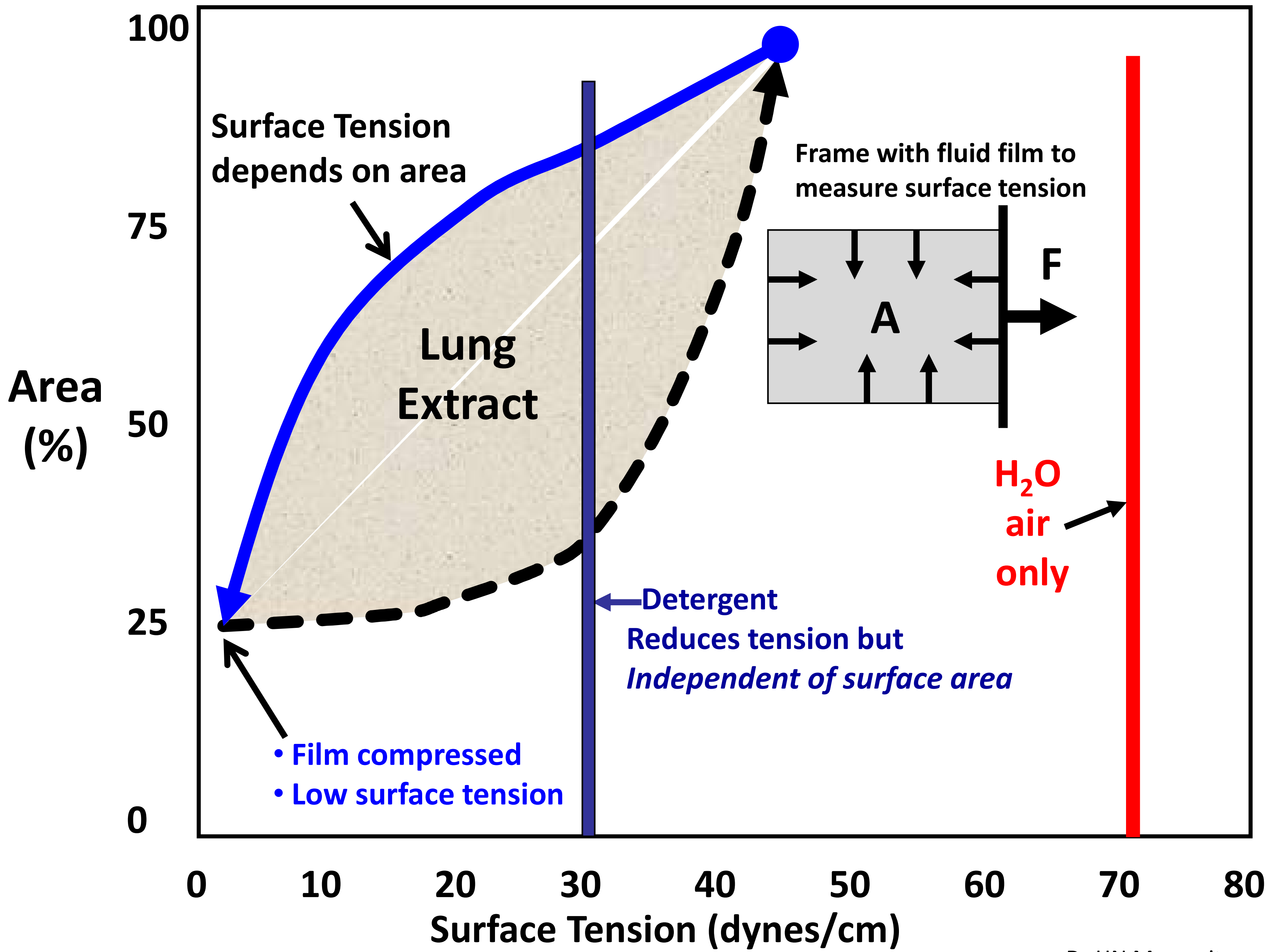




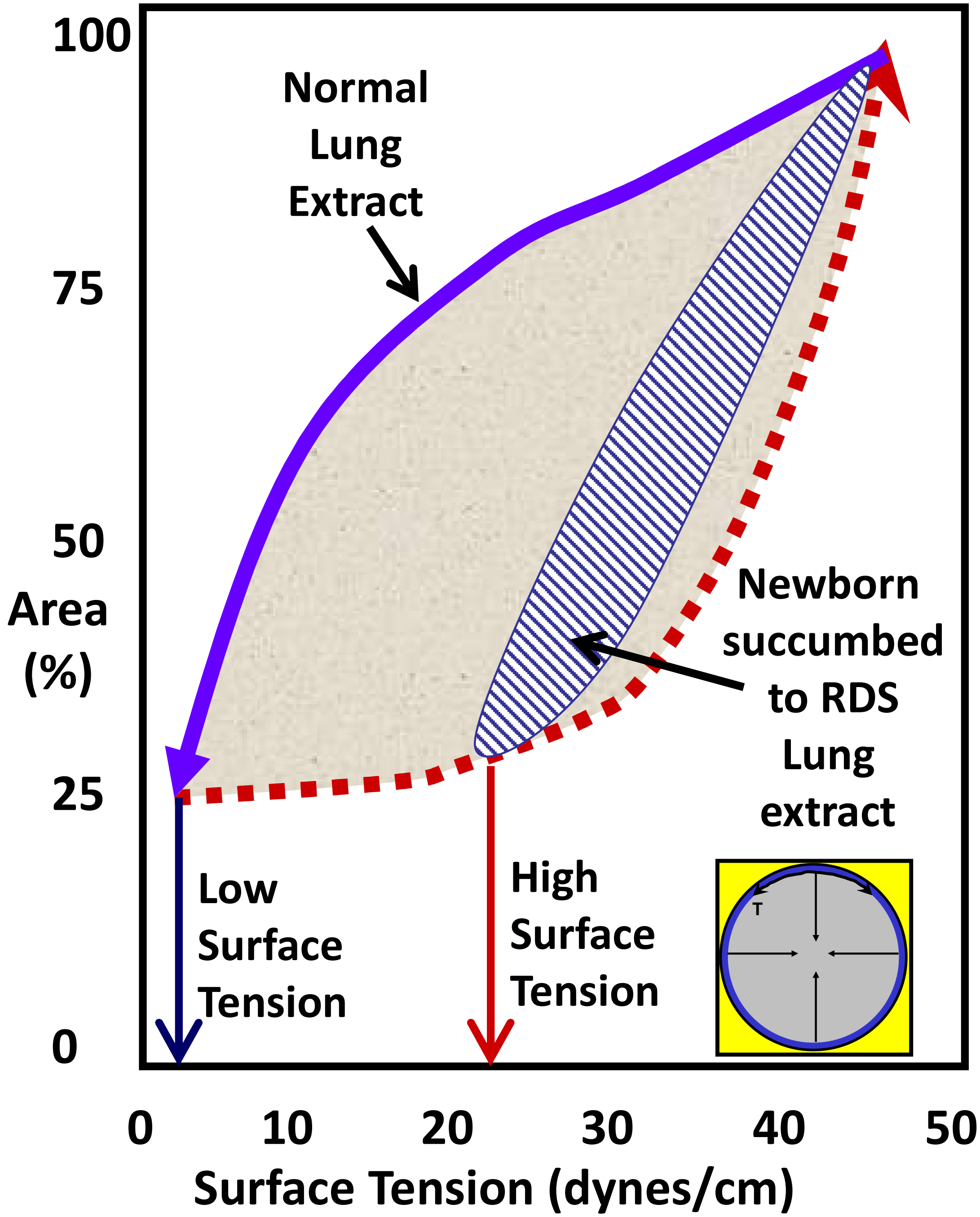
Effects of Lung Surfactant

- Increases Compliance
- Reduces tendency for closure (atelectasis)
- Reduces tendency for alveolar capture
- Reduces tendency for fluid transudation

Lung Surfactant: Special Features



Respiratory Distress Syndrome (RDS)



Deflation: Low surfactant

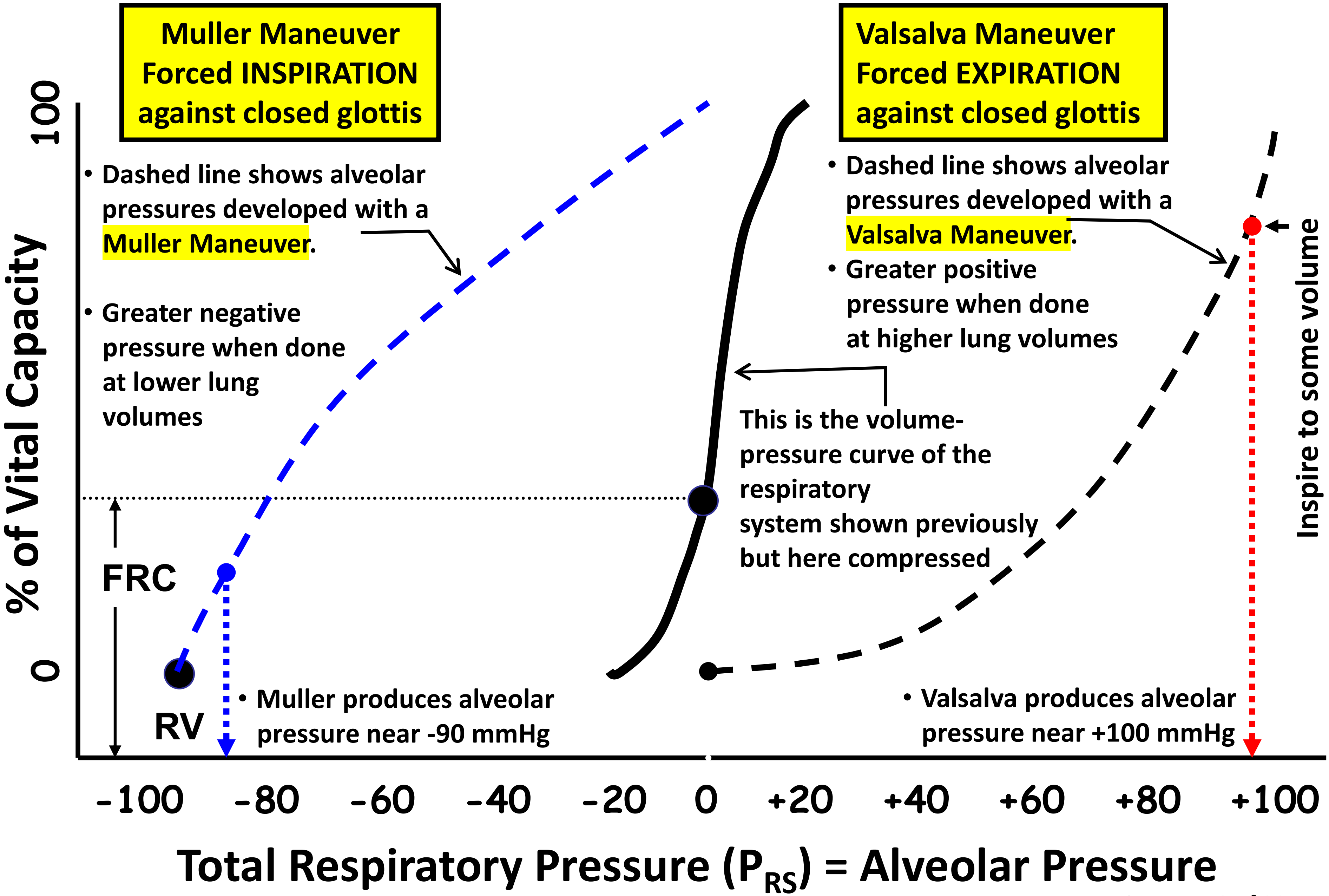
- Normal decrease in surface tension not present
- Greater force at any alveolar volume acts to close alveoli

Inflation: Once closed:

- Big work/breath needed to re-inflate lungs
- Increased muscular work fatigues diaphragm

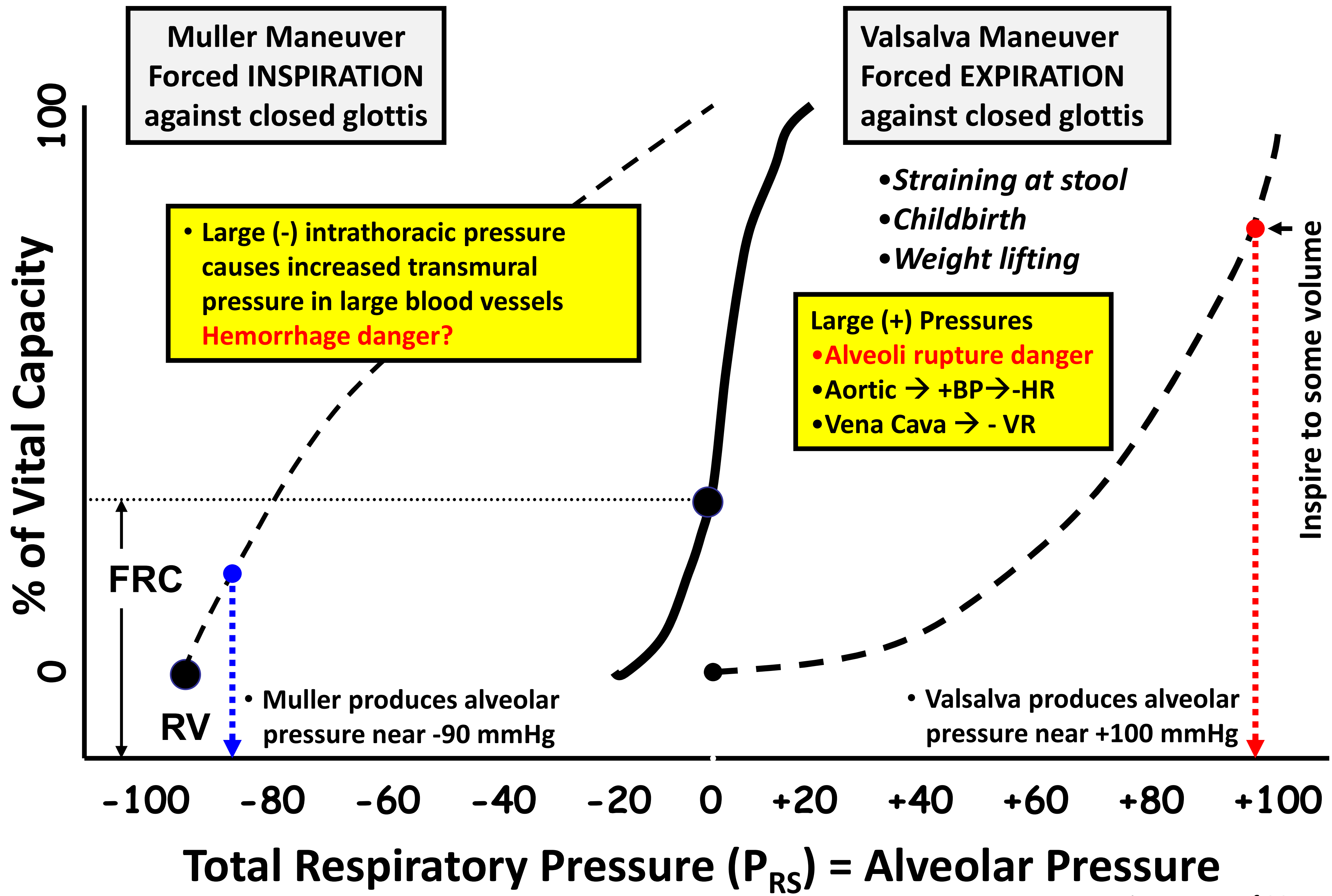
Muller and Valsalva Maneuvers

Large ± Pressures due to Active/Forced Inspiration/Expiration



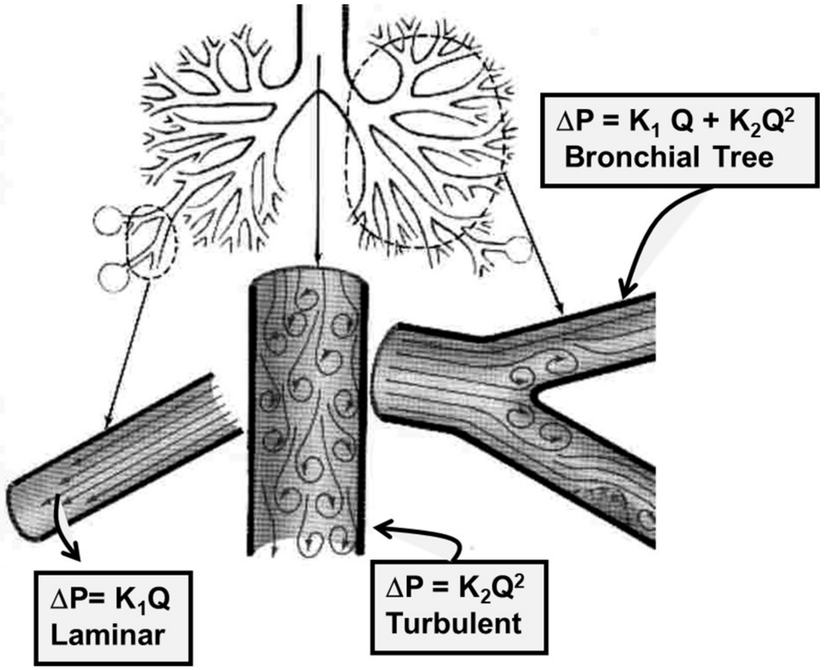
Muller and Valsalva Maneuvers

Large ± Pressures due to Active/Forced Inspiration/Expiration



Airway Resistance Issues

Turbulence in Airways?



Theoretical Critical Reynold's Number
(Long – Straight – Smooth – tubes)
$N_{RC} = [(U \times D) / \nu] = 2000$
ν = kinematic viscosity = $\eta/\rho = 1.7 \times 10^{-5}\ m^2/s$
D = 2.5 cm → Now calculate U_{CR}

Calculated: U_{CR} = 1.3 m/s → Q_{CR} = 667 ml/s

Experimental: *BOUHUYS, A. Acta Med. Scand. 159: 91, 1957.*

Tracheal peak flow during quiet breathing (n=28)

Inspiration: 220 - 970 ml/s (mean 570 ml/s)

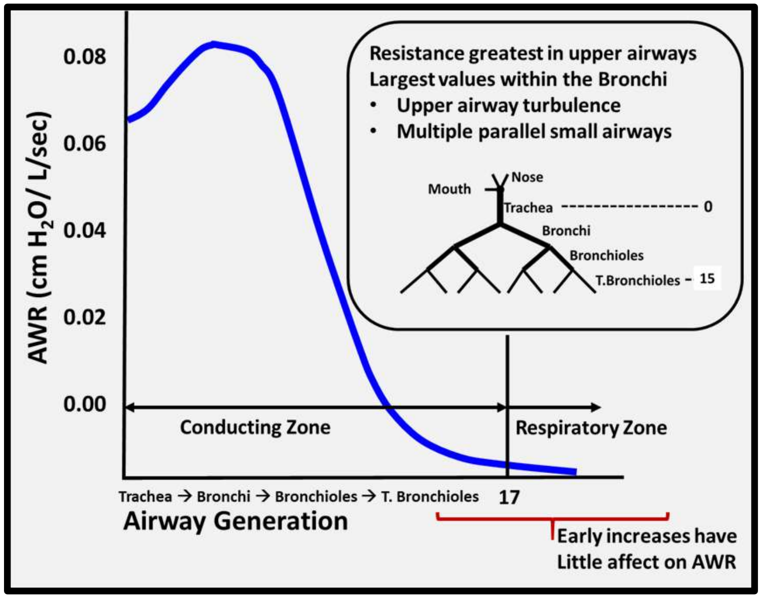
Expiration: 180 - 780 ml/s (mean 450 ml/s)

Some turbulence during quiet breathing

Q_{CR} ~ 220 ml/s based on model experiments

Accounting for branching etc. so threshold

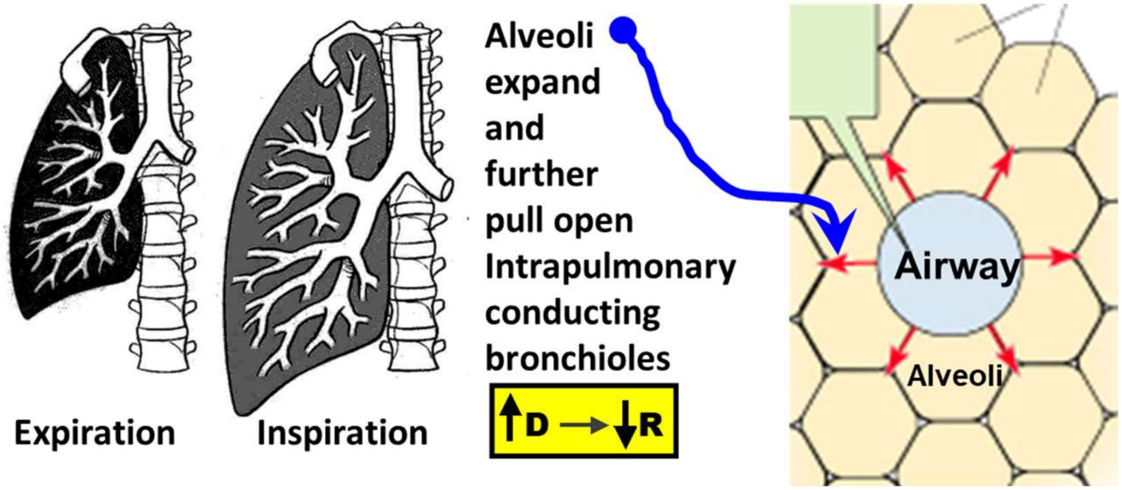
Is much less than theoretically calculated



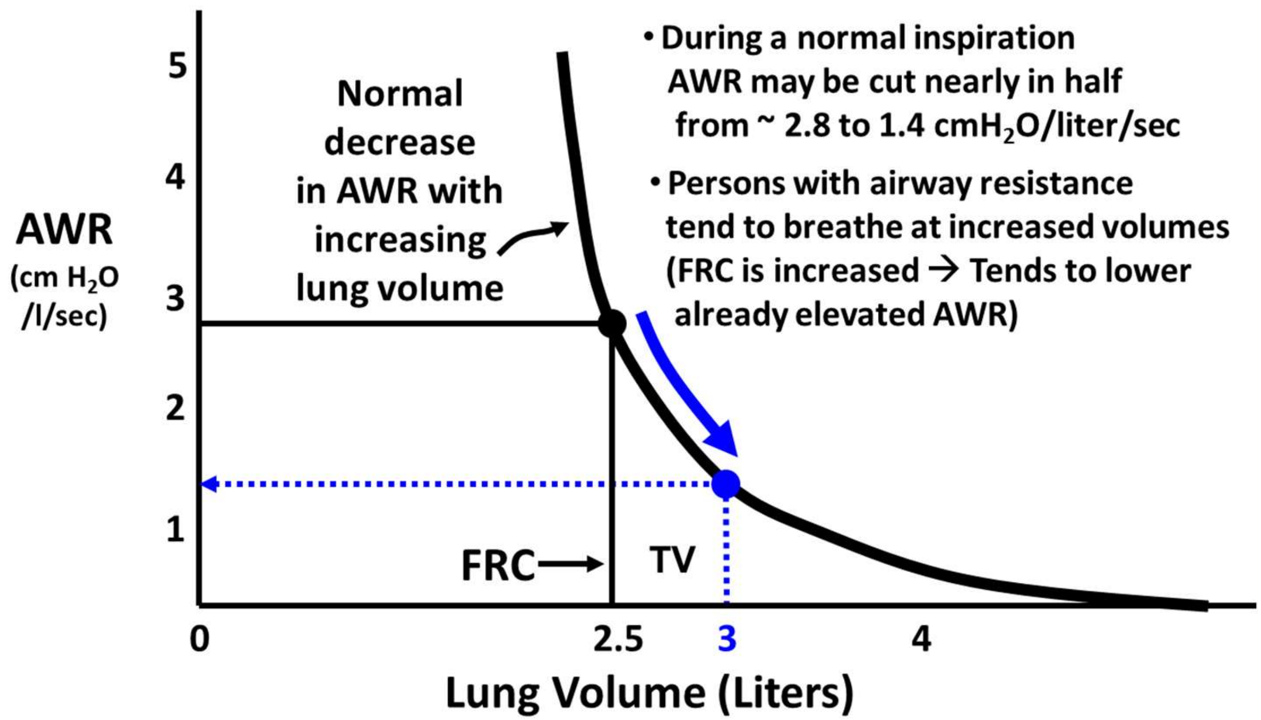
- **Airway resistance (AWR) greatest in upper airways**
- **Slight increase in Bronchi due to a combination of airway size, air flow velocity and branching effects**
- **Because of the relatively low value of peripheral small AWR, pathological increases may not show up with symptoms in the earliest phases**

Airway resistance decreases with increasing volume

Process

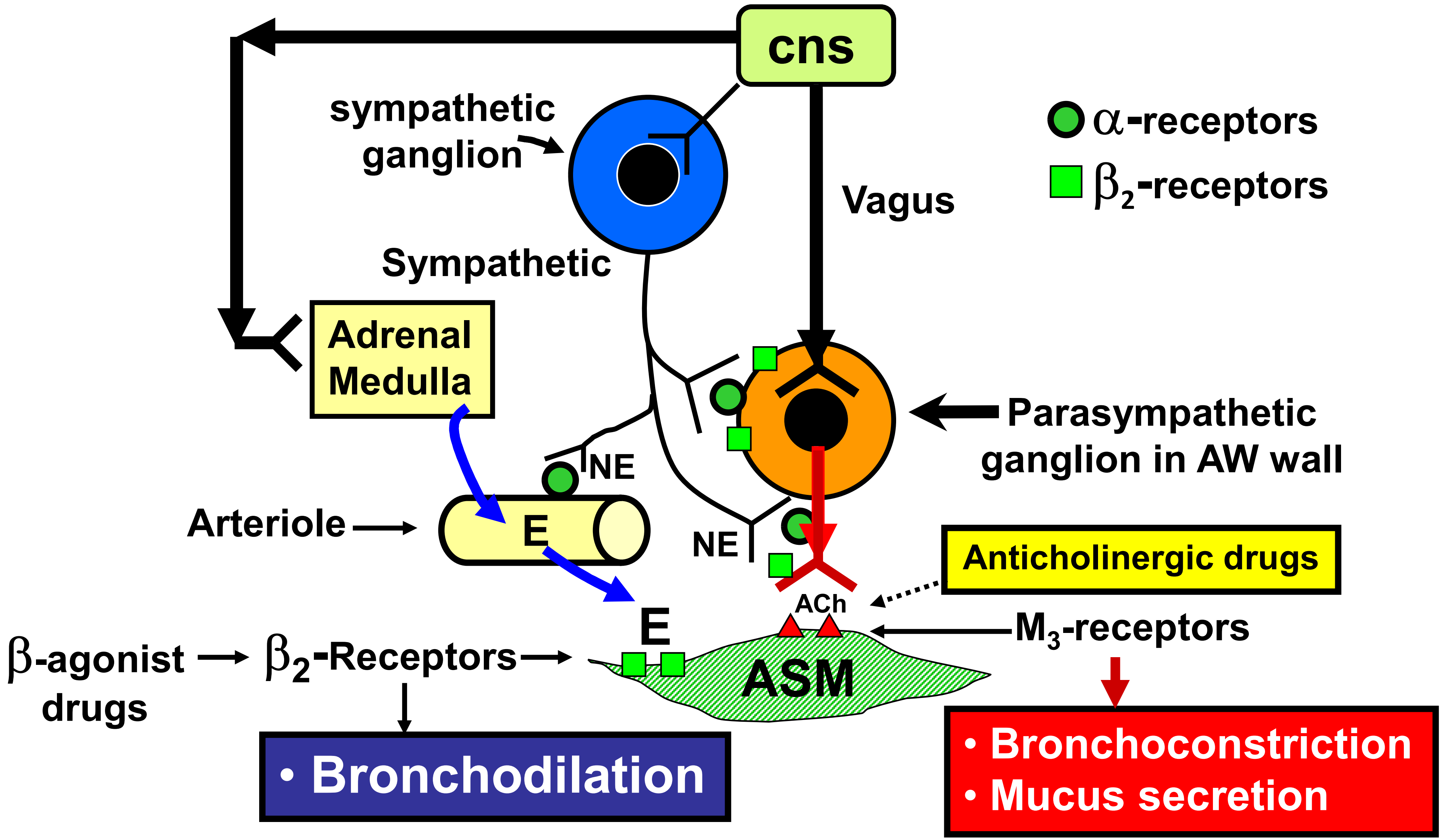


Result

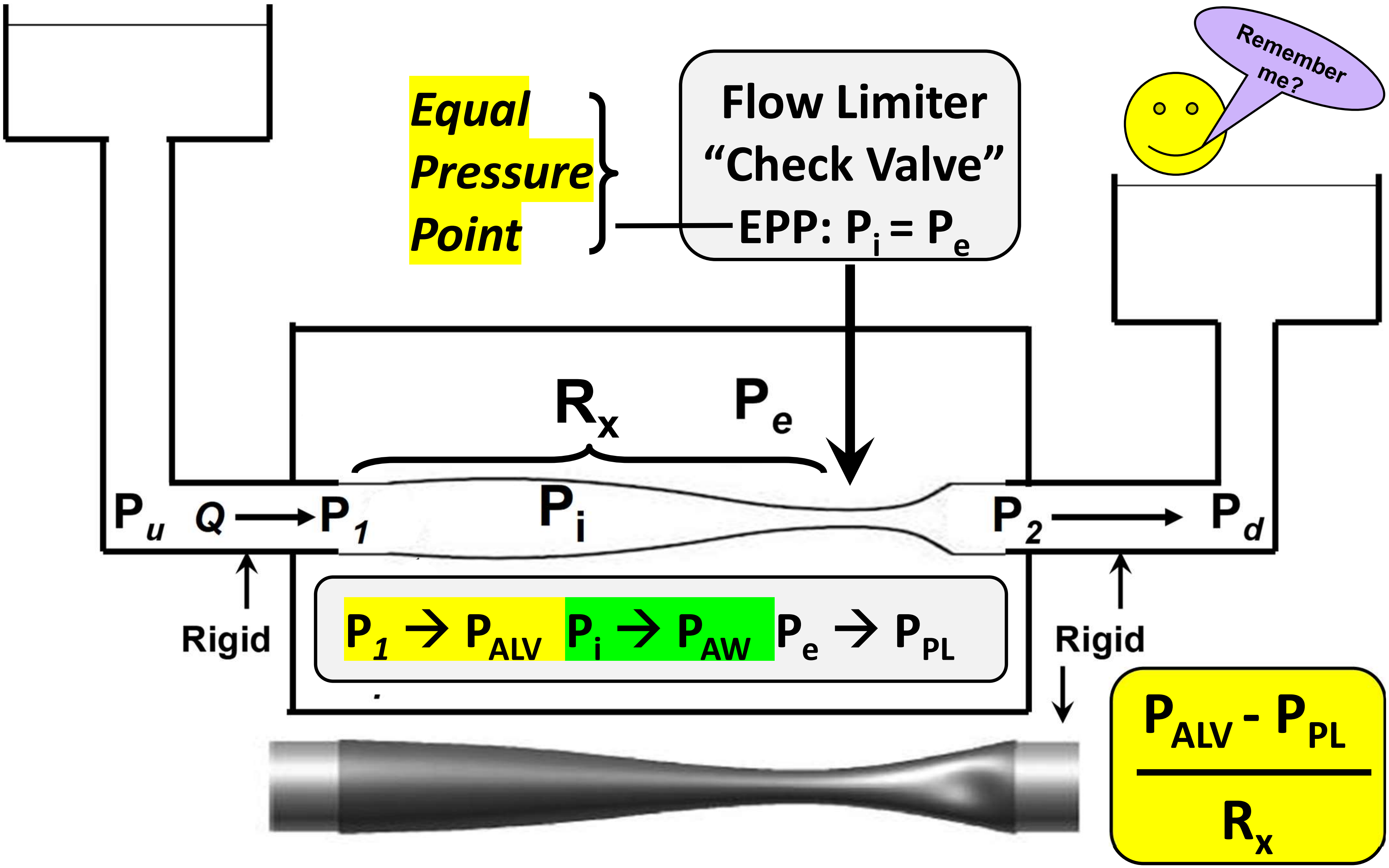


- During a normal inspiration AWR may be cut nearly in half from ~ 2.8 to 1.4 cmH_2O/liter/sec
- Persons with airway resistance tend to breathe at increased volumes (FRC is increased → Tends to lower already elevated AWR)

Airways - Neural Mechanism (In Brief)



Air Flow in Collapsible Airways



If $P_i < P_e$ at any point, then $Q \sim (P_1 - P_e)/R_x$

Dynamic Compression Issues

Dynamic Compression-Airway Closure: Basic Concept

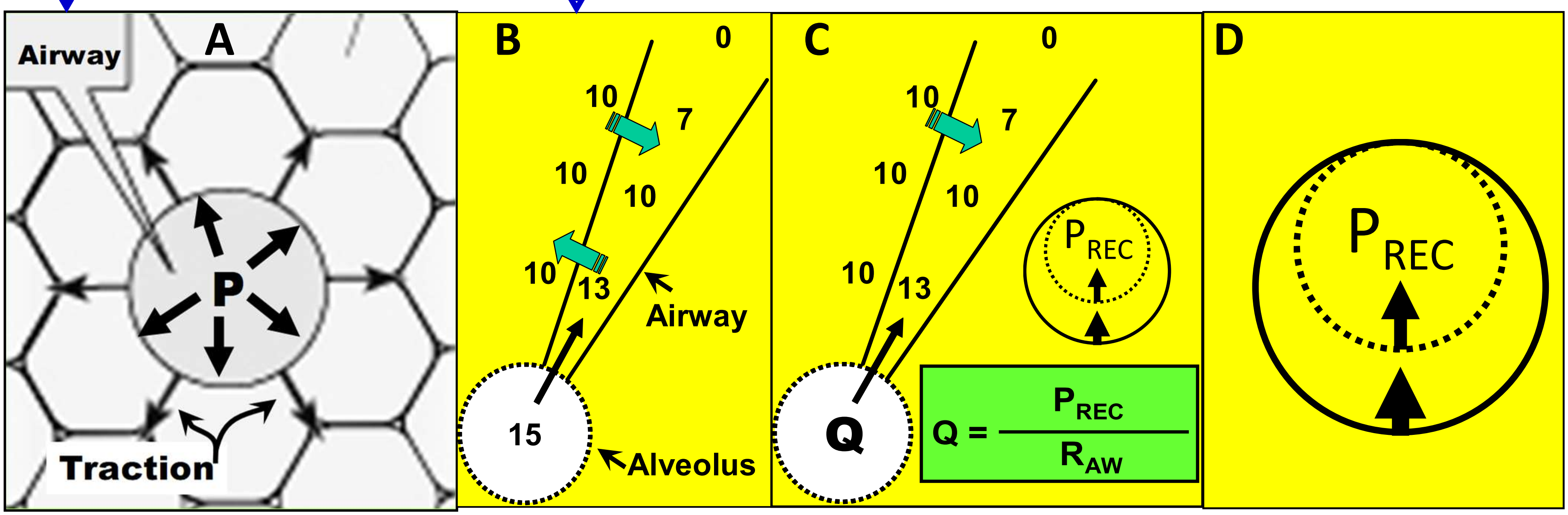
A. Small intrapulmonary airways are distensible and compressible. Held open by combination of: (1) Airway transmural pressure (P) and (2) TRACTION by attachments to surrounding tissue.

B. During a **forced expiration**, P_{PL} becomes + causing pressure surrounding some airways to become greater than pressure inside.

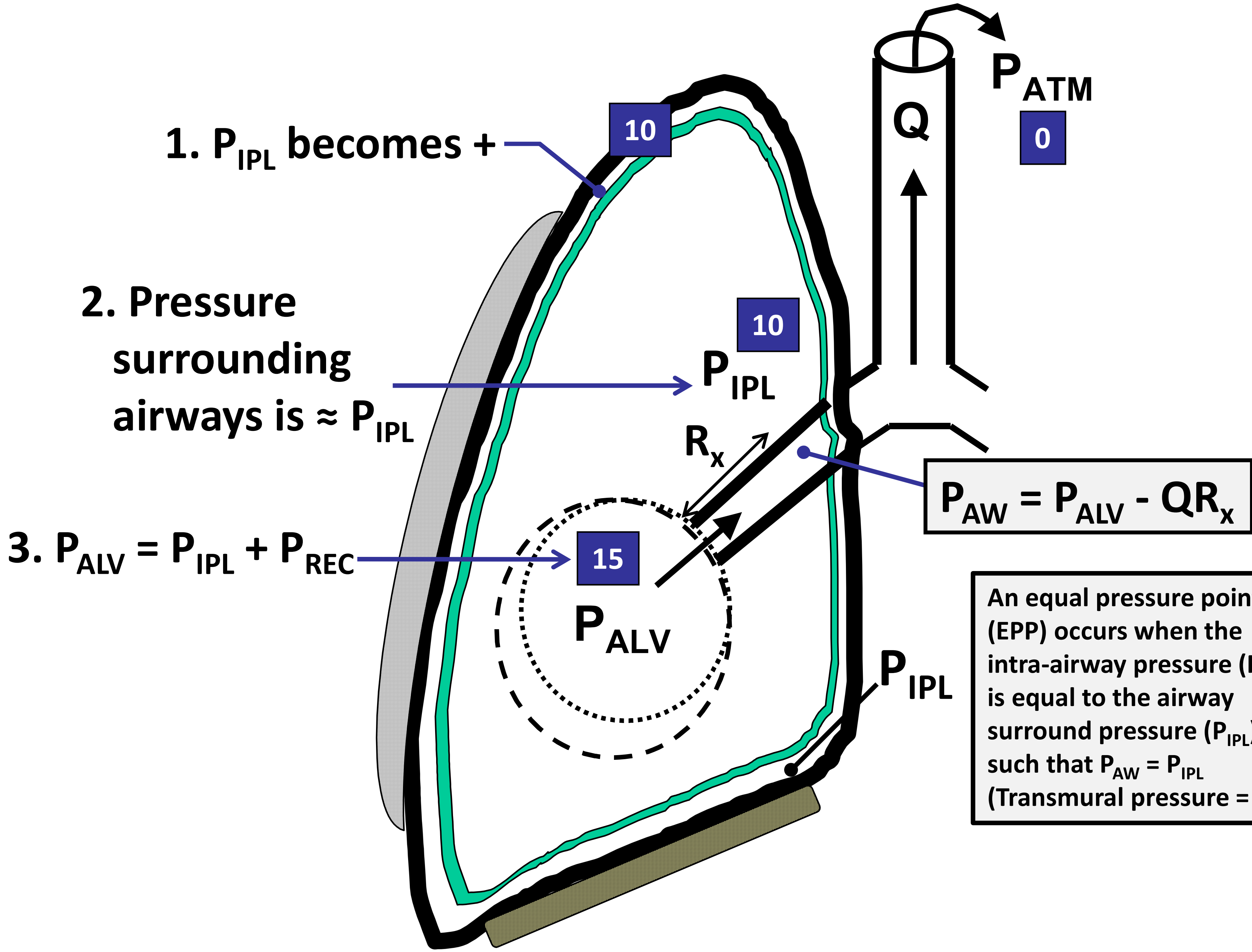
C. This collapsible condition causes airflow to be determined mainly by P_{REC} alone which itself decreases with lung volume.

D. As volume falls so does P_{REC} ultimately causing airway closure. Net result: No further volume can be expelled. This occurs in normal lungs at low volumes.

In obstructive lung conditions the volume at which closure occurs is larger.



Forced Expiration Events: Reviewed



An equal pressure point (EPP) occurs when the intra-airway pressure (P_{AW}) is equal to the airway surround pressure (P_{IPL}) such that $P_{AW} = P_{IPL}$ (Transmural pressure = 0)

Dynamic Compression: Example

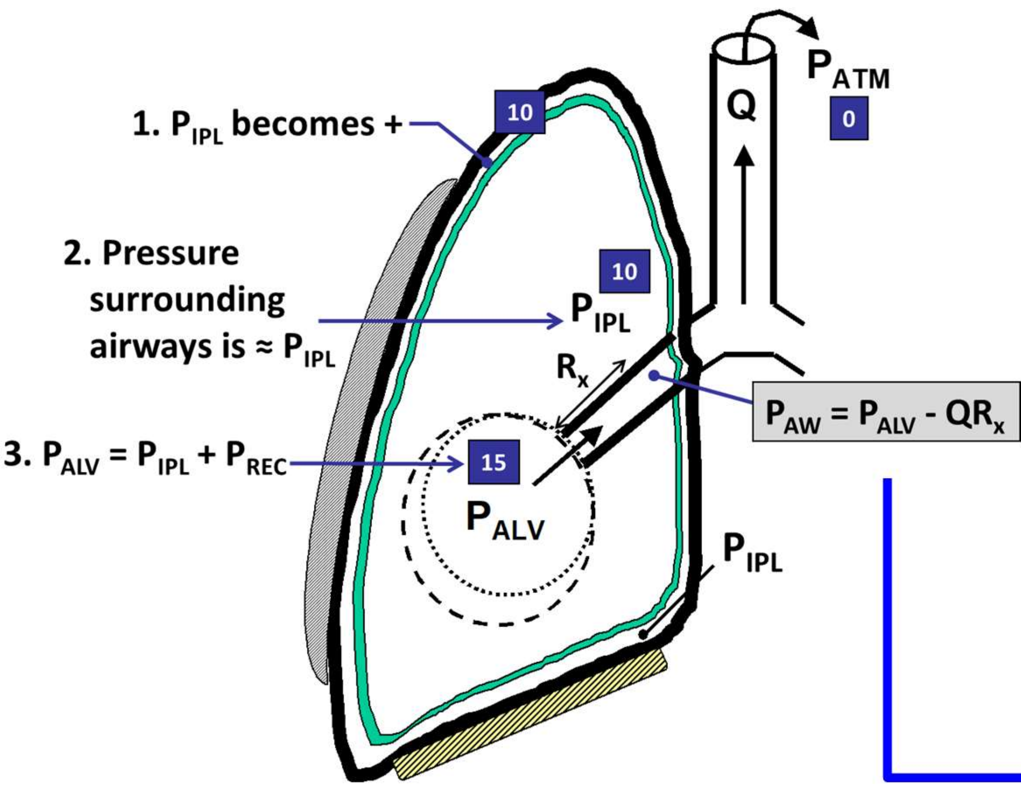
Outward Flow Normally

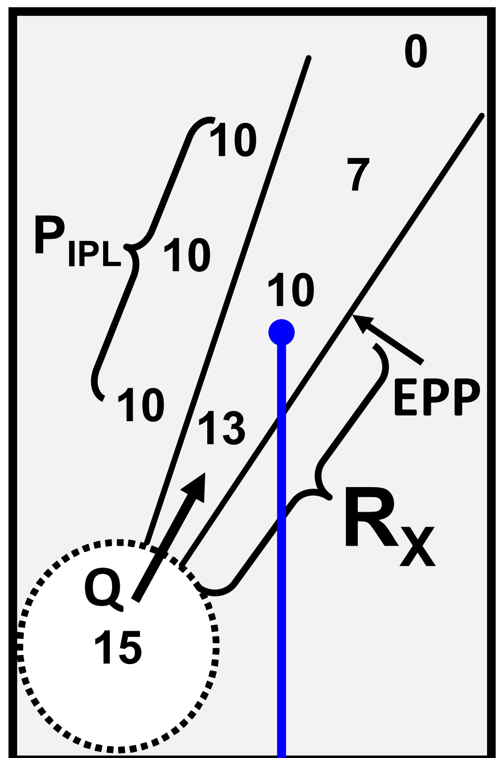
$$Q = \frac{P_{ALV} - P_{ATM}}{R_{AW}}$$

Collapsible Airway Flow

$$Q = \frac{P_{ALV} - P_{PL}}{R_X}$$

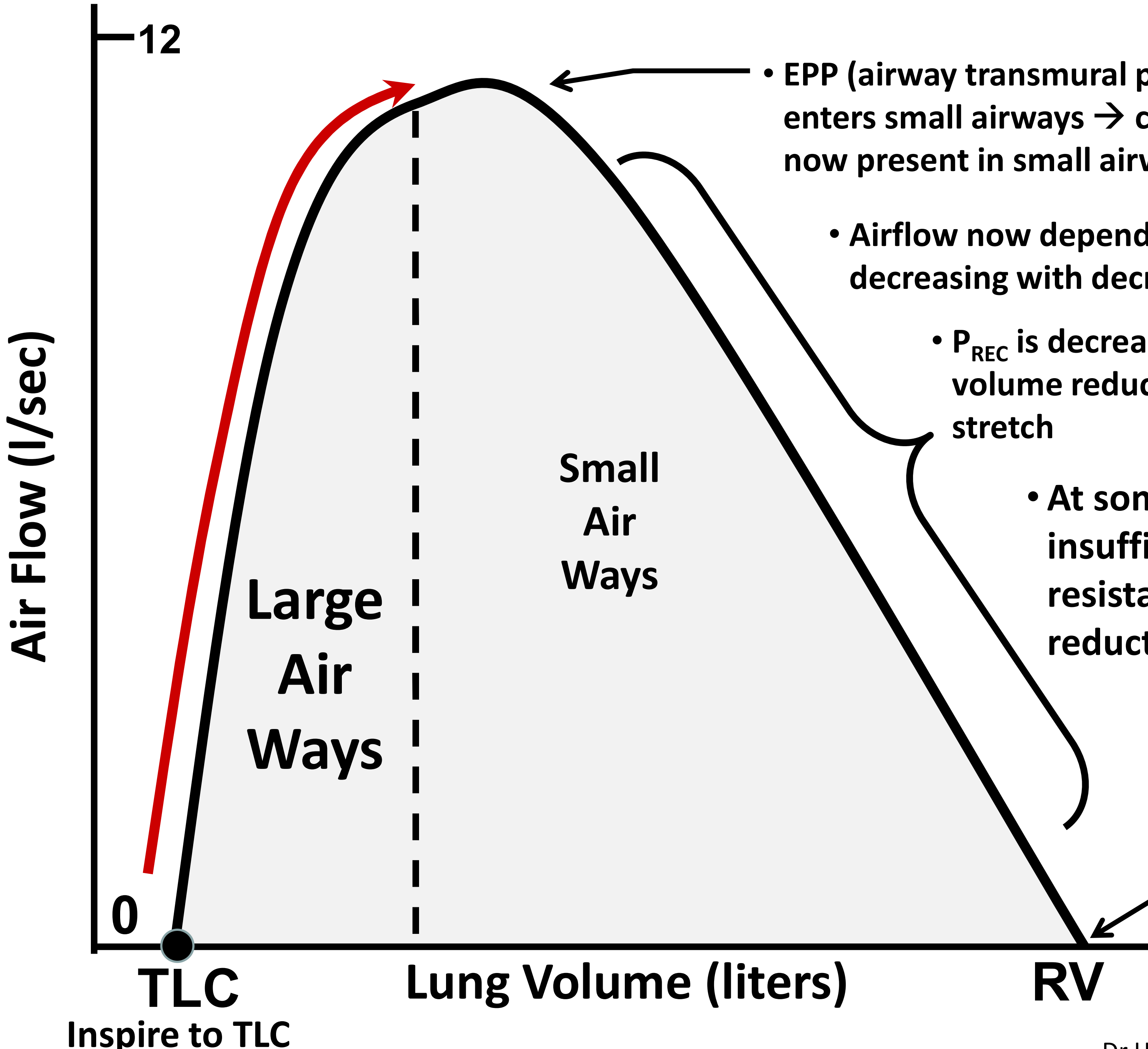
$$P_{ALV} = P_{REC} + P_{PL}$$





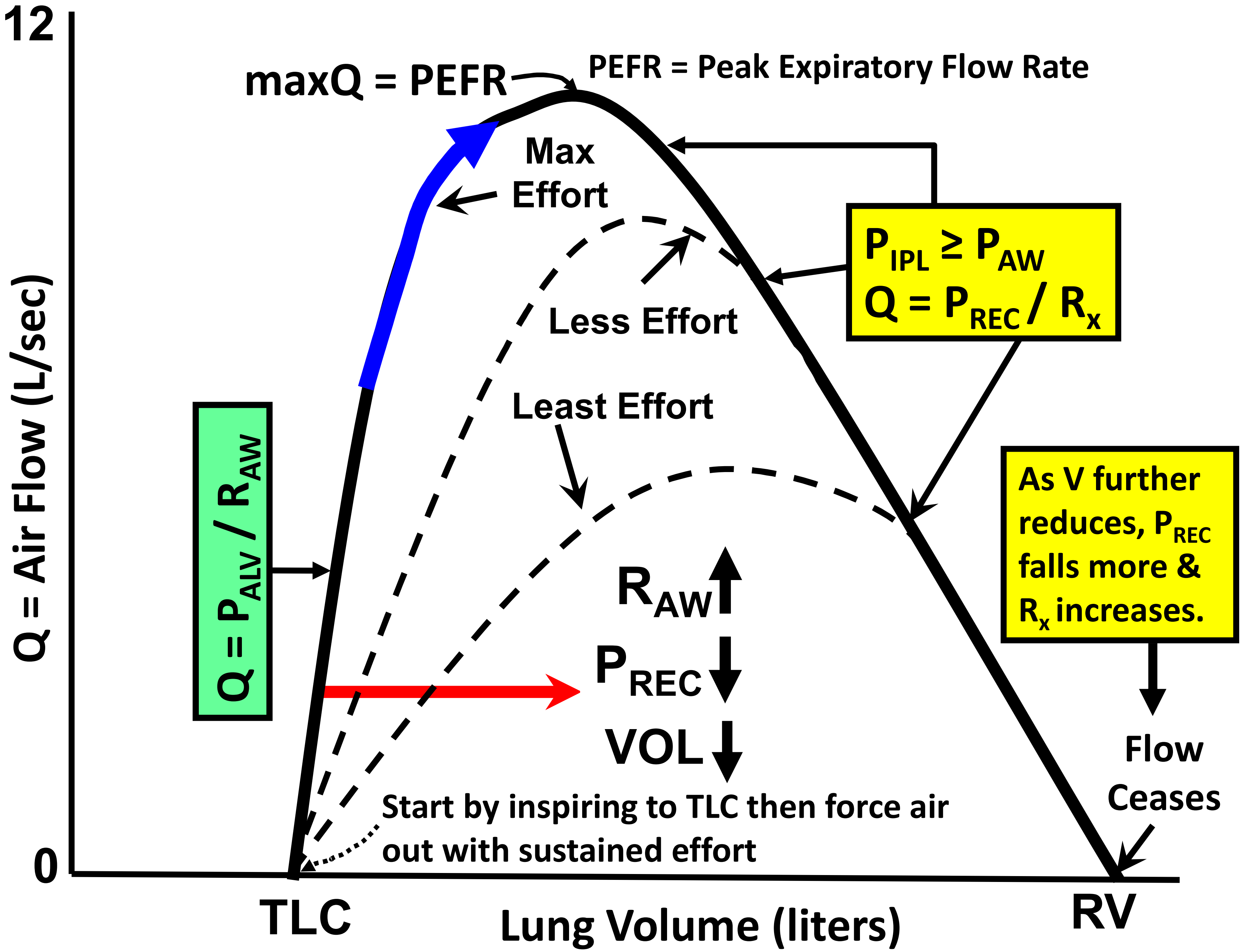
$$Q = \frac{P_{REC}}{R_X}$$

Forced Expiration: Role of EPP



- EPP (airway transmural pressure = 0) enters small airways → collapsible state is now present in small airways
- Airflow now depends on P_{REC} that is decreasing with decreasing volume
- P_{REC} is decreasing since as volume reduces so does alveolar stretch
- At some volume P_{REC} is insufficient to overcome resistance so volume reduction ends at RV

Forced Expiration: Flow-Volume



Interactive Questions

Interactive MCQs

A deficiency of pulmonary surfactant would:
A) decrease surface tension in the alveoli
B) decrease the change in intrapleural pressure required to achieve a given tidal volume
C) increase lung compliance
D) decrease the work of breathing
E) decrease FRC

Dan has a pulmonary compliance of 0.25 L/cm H_2O. His intrapleural pressure changes from -4 cm H_2O to -12 cm H_2O when he inhales. How much air did he inhale?
A) 0.5 liter
B) 0.75 liter
C) 1.0 liter
D) 1.5 liter
E) 2.0 liter

A pneumothorax that occurs at a lung volume of about 85% of TLC will result in:
A. outward movement of thorax
B. outward movement of the lung
C. inward movement of both the lung and thorax
D. outward movement of the lung and thorax
E. inward movement of the lung but outward movement of the thorax

Which of the following would most likely result in an increase in lung compliance?
A. Pulmonary vascular engorgement
B. Lung edema
C. Alveolar atelectasis
D. Emphysema
E. Lung fibrosis

Interactive MCQs

Which pulmonary feature largely accounts for the normally high value of lung interstitial oncotic pressure?
A. Low pulmonary capillary hydrostatic pressure
B. High pulmonary capillary oncotic pressure
C. High value of pulmonary lymphatic flow
D. Low value of pulmonary capillary reflection coefficient
E. High value of total pulmonary blood flow

At FRC, which of the following is true?
A. Lung compliance is at, or near, its minimum value
B. Pulmonary vascular resistance is near its maximum value
C. Chest wall recoil is at its minimum value
D. Chest wall recoil is at its maximum value
E. Chest wall and lung recoil are equal and oppositely directed

Which one of the following statements is true regarding airway resistance?
A. It decreases as the lung expands because airways lengthen
B. It is largest in smaller airways because of their smaller diameter
C. Its value decreases with increasing lung volume
D. If increased, it will tend to cause airway collapse during inspiration
E. Its increase is the main finding in restrictive lung disease

End Respiratory Physiology
Lecture 38