Lecture 39
Mechanical Aspects of Obstructive and Restrictive Diseases

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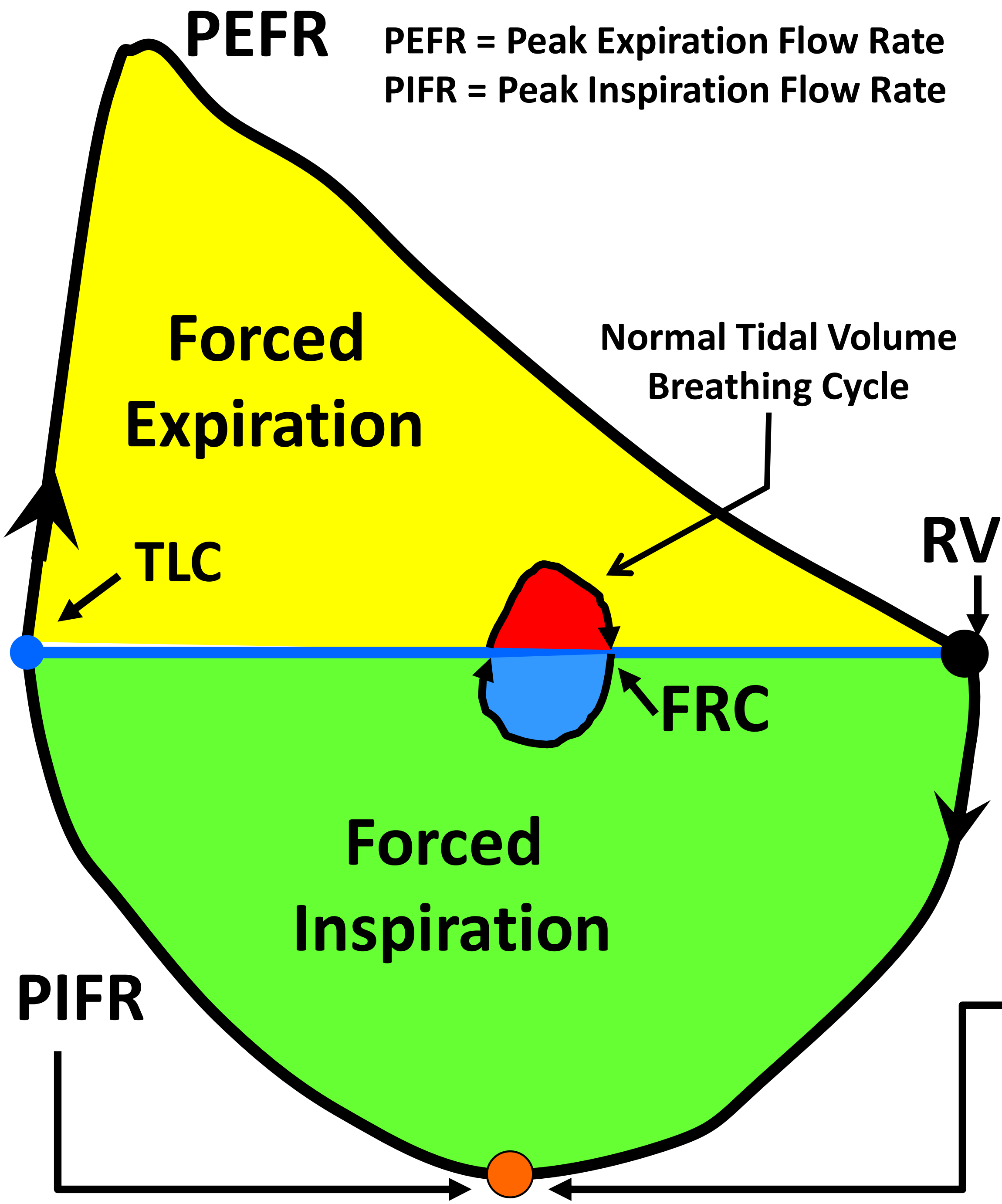
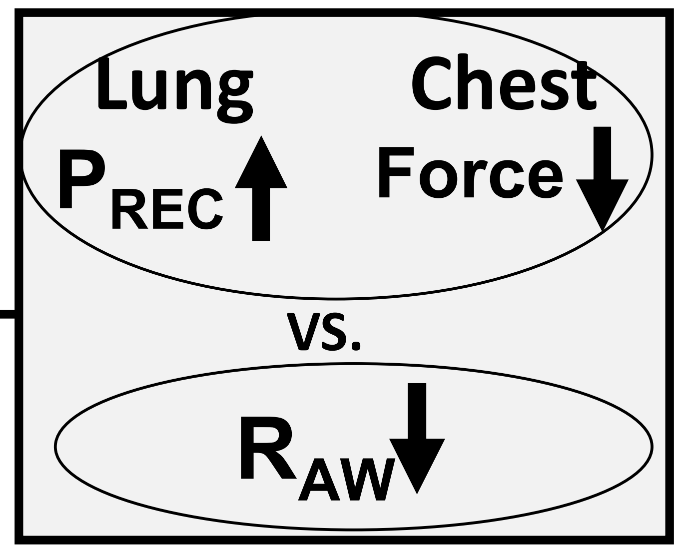
Normal Complete Flow-Volume Loop



- As lung expands from RV the inward lung recoil increases so P_{REC} increases
- Chest wall outward recoil force decreases as thoracic volume gets closer to 0 stress
- These two forces work against increasing IFR
- But, as lung expands, AWR falls and favors air inflow
- PIFR is achieved due to these oppositely directed factors

PIFR Determinants



Obstructive vs. Restrictive Lung Disease

Basic Features

Obstructive = Abnormal Increase in ???
Airway Resistance (R)

Restrictive = Abnormal Decrease in ???
Respiratory Compliance (C)
→ More difficult to expand
→ Greater recoil force

Could (and do) have combinations – Mixed Disease

Obstructive Lung Disease

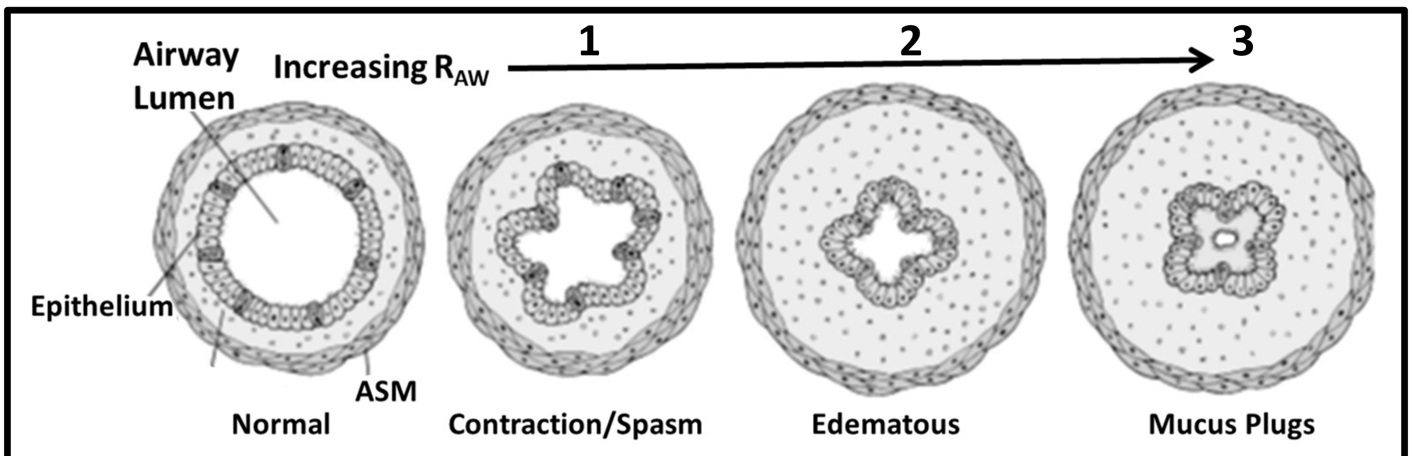
Key Features of Main Obstructive Lung Diseases

Chronic Obstructive Pulmonary Disease (COPD) → **Emphysema**

Chronic Bronchitis
- Bronchial Inflammation
- Mucus
- Cough

Emphysema
- Alveolar-capillary wall destruction
- Loss of alveoli
- Increased air spaces
- More compliant but less alveolar recoil
- Airway collapse due to traction loss
- More difficult to expel air
- Mucus secretion
- ASM enhanced contraction

Asthma
- 1. Airway smooth muscle (ASM) contraction in response to neuro and inflammatory mediators
- 2. Airway wall thickening by hyperplasia or hypertrophy, edema and cellular infiltration
- 3. Airway obstruction by mucus, secretions and cellular debris

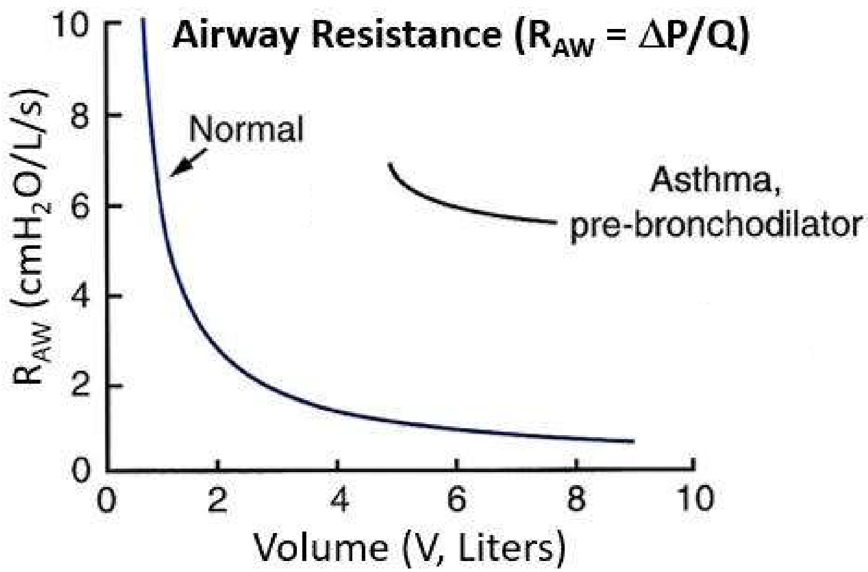


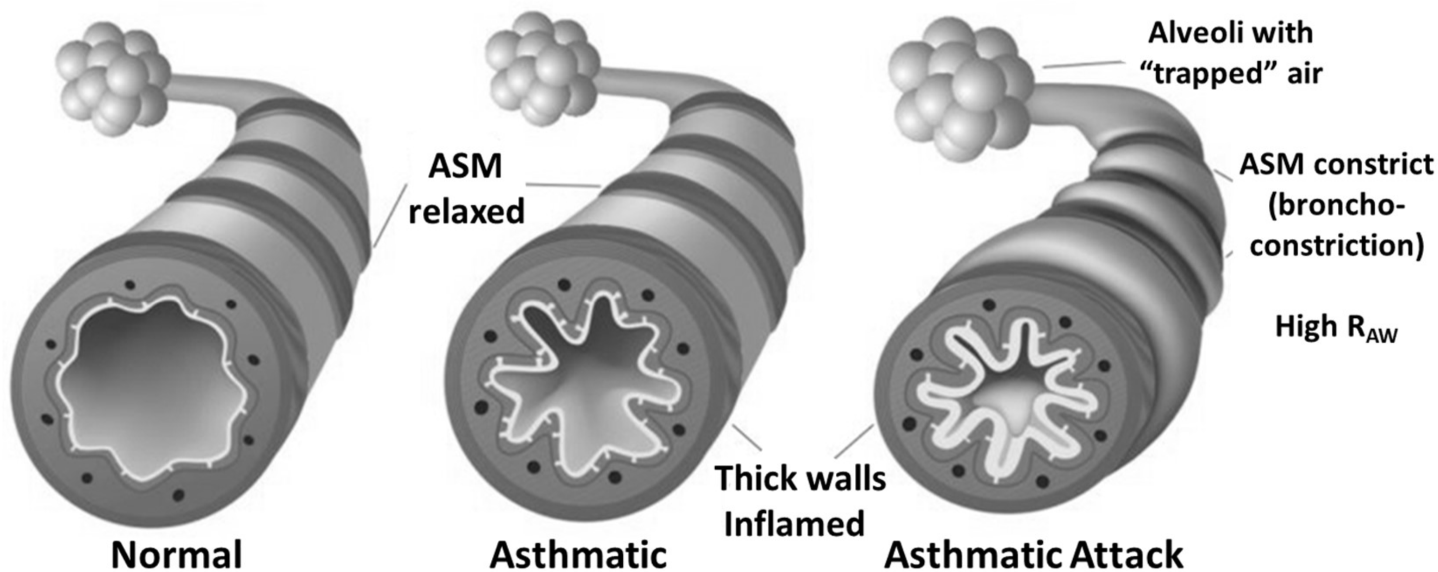
Obstructive Overview: COPD vs. Asthma

- Both considered due to **chronic respiratory tract inflammation**
- Both associated with **increased airway resistance**
- Asthma → Variable airflow limitation that is **usually reversible**
- COPD → Persistent airflow limitation **usually irreversible**

Parameter	Asthma	COPD
Symptoms	• Wheeze • Cough • Short of breath Variable – not usually progressive	• Short of breath • Cough • Mucus Persistent-Progressive
Onset	Usually Young	Usually > 40 years
Course	Variable – not usually progressive	Progressive
Bronchodilator response	Usually Good	Usually Good
Steroids Response	Usually Good	Usually Poor
Main Features	• Bronchoconstriction • Mast cell activation • Hyperresponsive ASM • Edema • Mucus Plugging	• Emphysema • Mucus exudate • Small airway fibrosis • Edema • Distal airway destruction
Main Airways Generations	• Larger ≥ 2 mm • (0-7) conducting zone	• Smaller < 2 mm • Mostly respiratory zone

Asthma: *Increased Airway Resistance*





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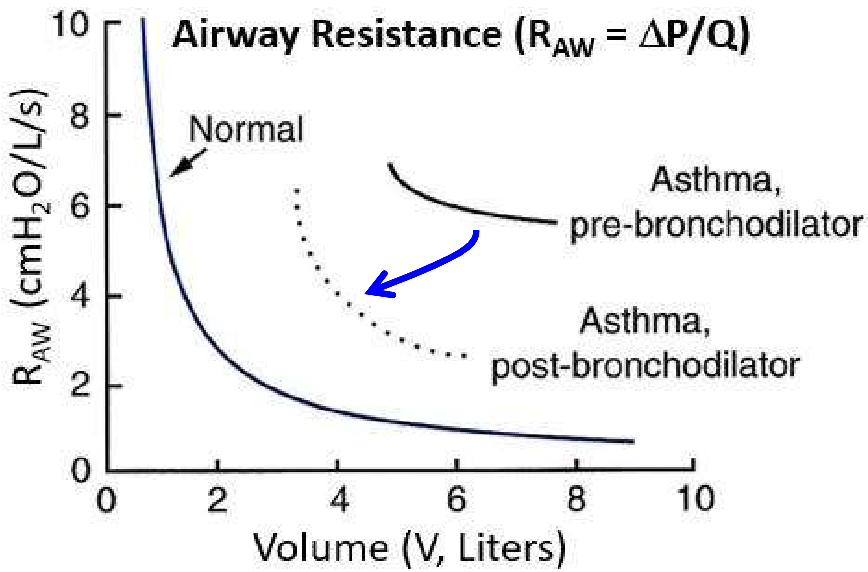

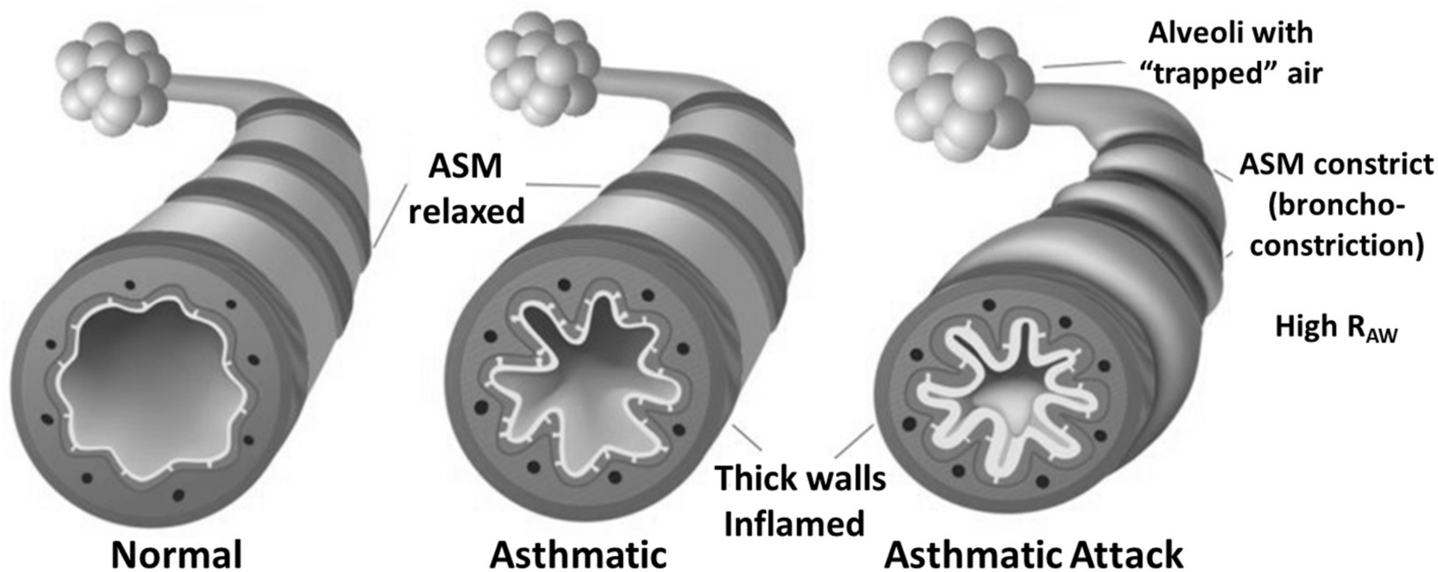

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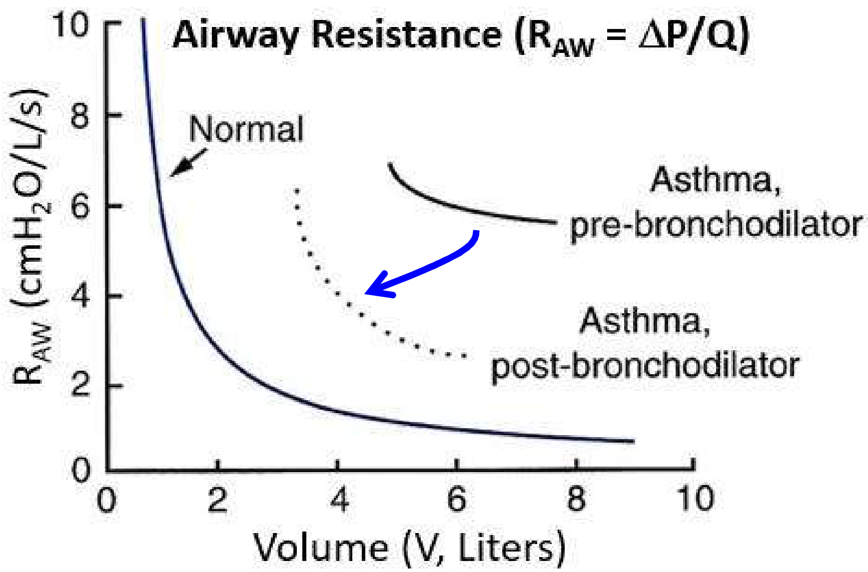
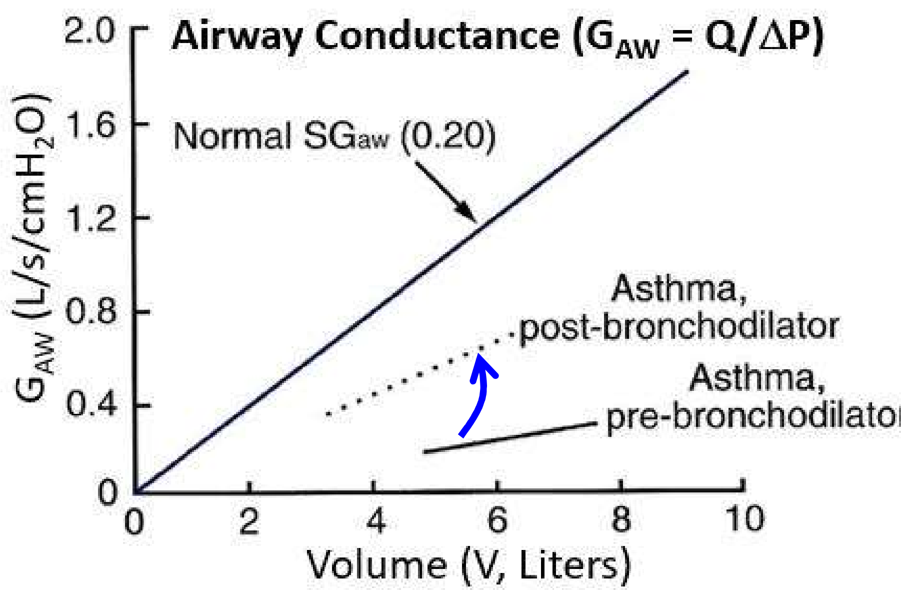
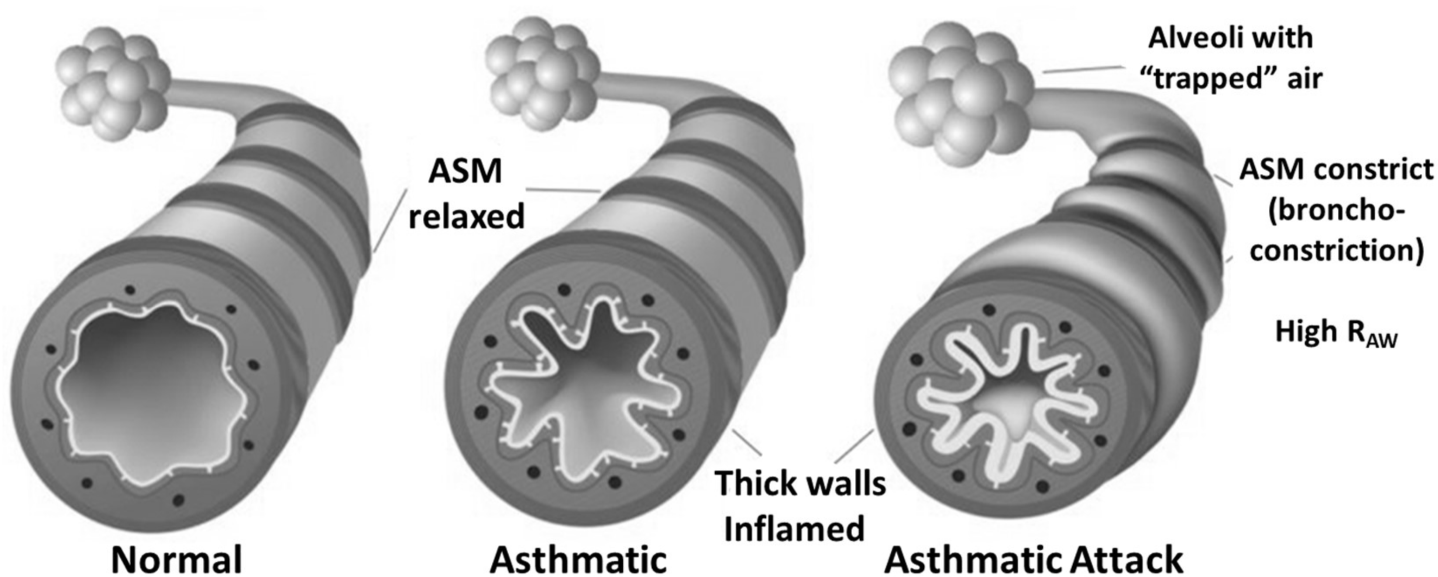
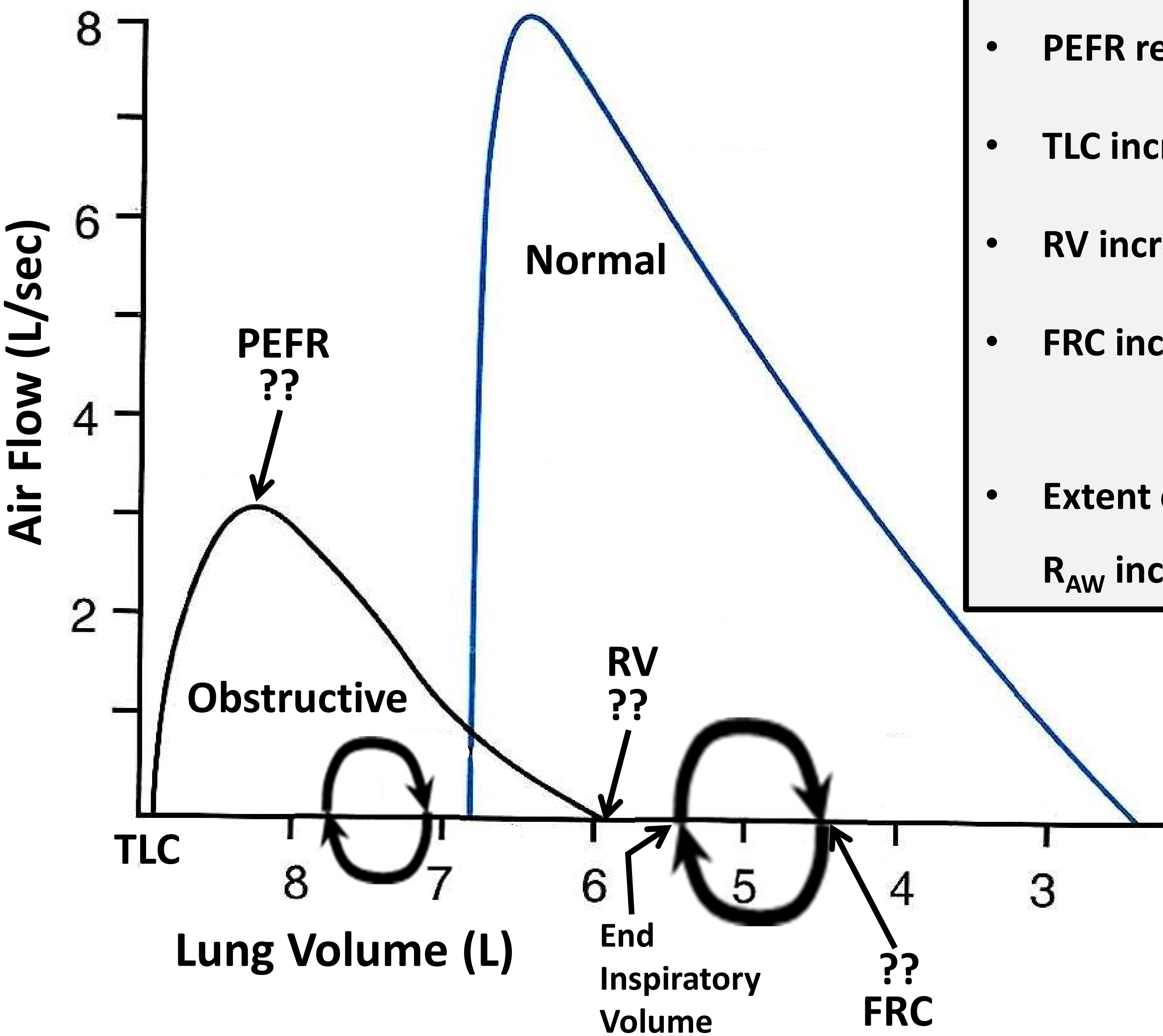




SG_{AW} = Specific Conductance = $\Delta G_{AW}/\Delta V$ = SLOPE

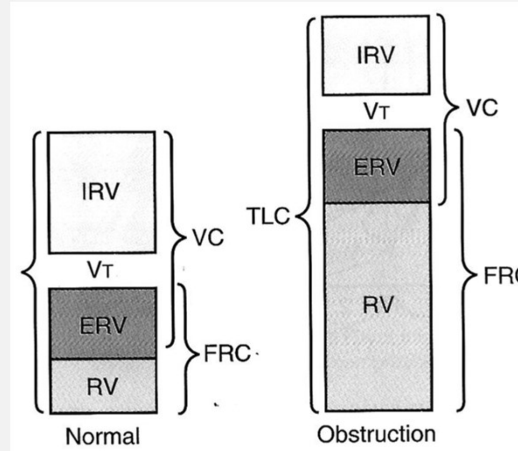


Obstructive Lung Disease: Flow-Volume Changes



As compared to Normal

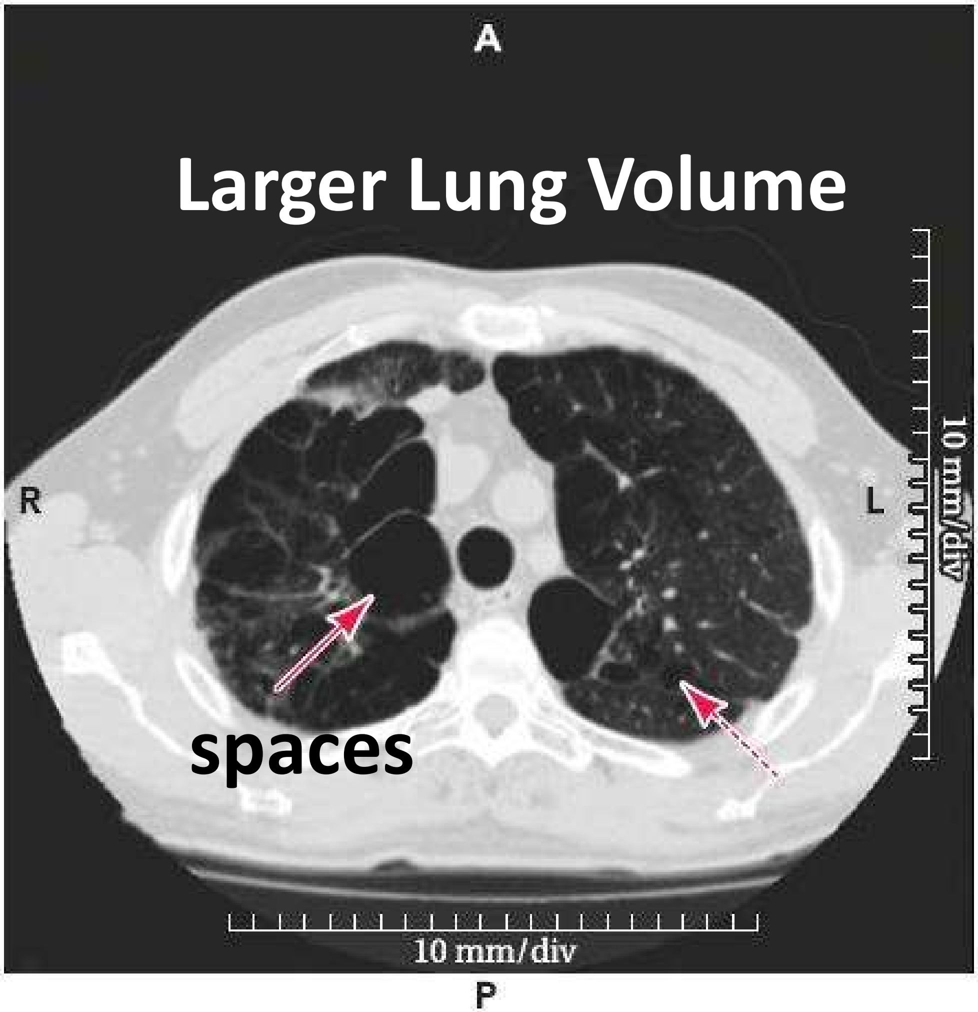
- PEFR reduced
- TLC increased
- RV increased
- FRC increased



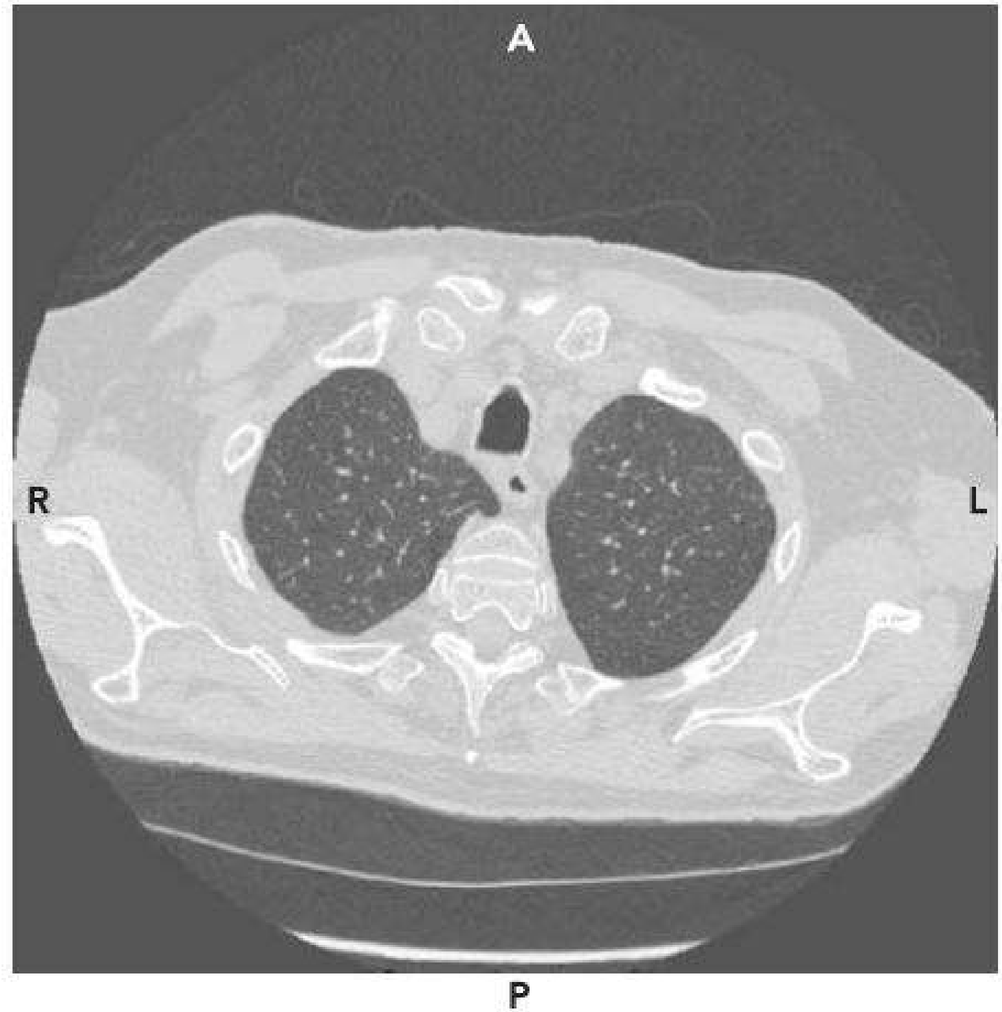
- Extent of changes depends on amount of R_{AW} increase and if coexisting Emphysema

Emphysema vs. Normal

Advanced Emphysema



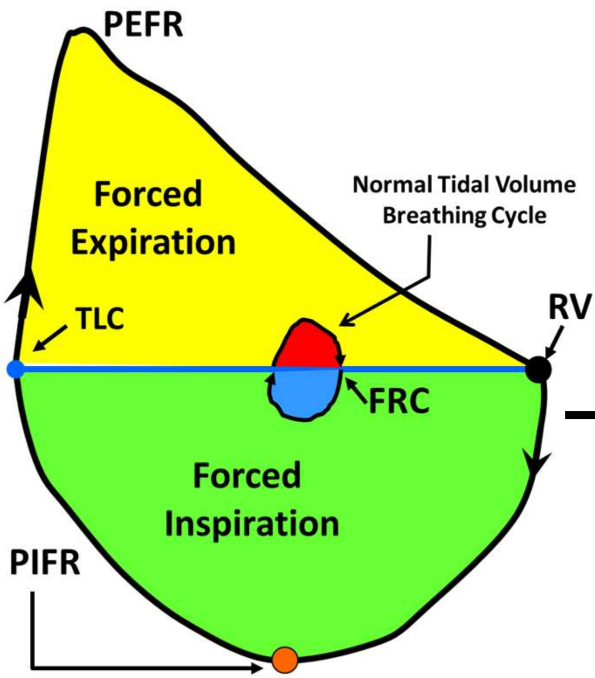
Normal Lung



White specs are blood vessels: low in Emphysema

Interactive Questions

What Determines PIFR



Lung P_{REC} ↑

WHY → Stretching the spring increases restoring force
→ So inward force tending to close alveoli increases

WHY → Moving closer to chest zero stress expansion
→ So outward force tending to expand lung diminishes

Chest Force ↓

WHY → Airway diameter increases with increasing volume
→ So airway resistance decreases

R_{AW} ↓

PIFR value depends on balance of combined factors

Restrictive Lung Disease

Restrictive Diseases: *Restricts Lung Expansion*

Factors → "PAINT"

SITE → CAUSES

Pleural → Scarring or Effusion or fibrosis etc

Alveolar → Edema or Hemorrhage

Interstitial → Interstitial Lung Disease or Fibrosis

Neuromuscular → ALS
(Amyotrophic lateral sclerosis)

Thoracic/Extra-thoracic →Obesity or Ascites

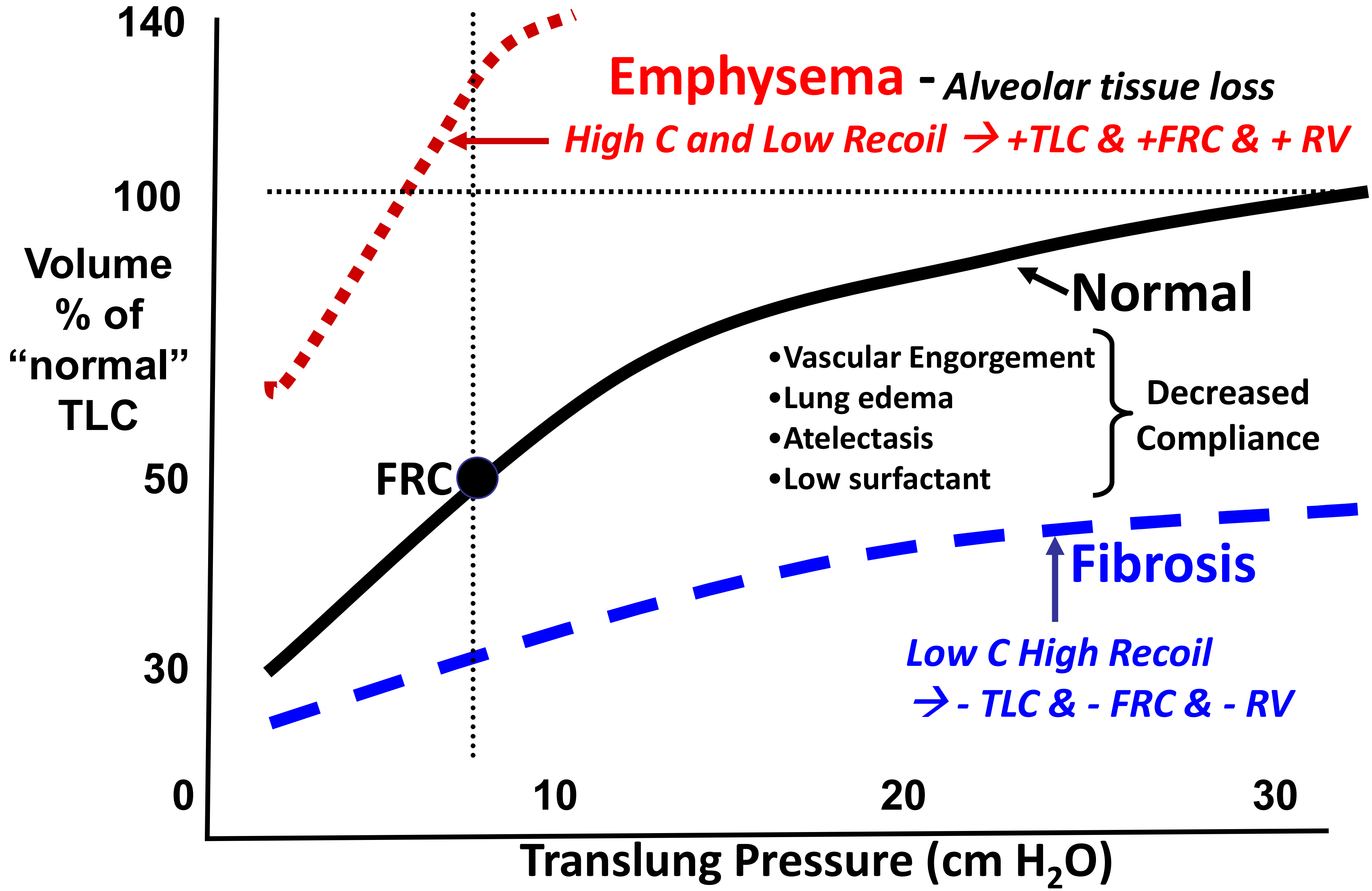
Example Conditions

- Interstitial Fibrosis
  + alveolar fibrous tissue
  Lung becomes stiffer
  (-) compliance
  Inspiration more difficult

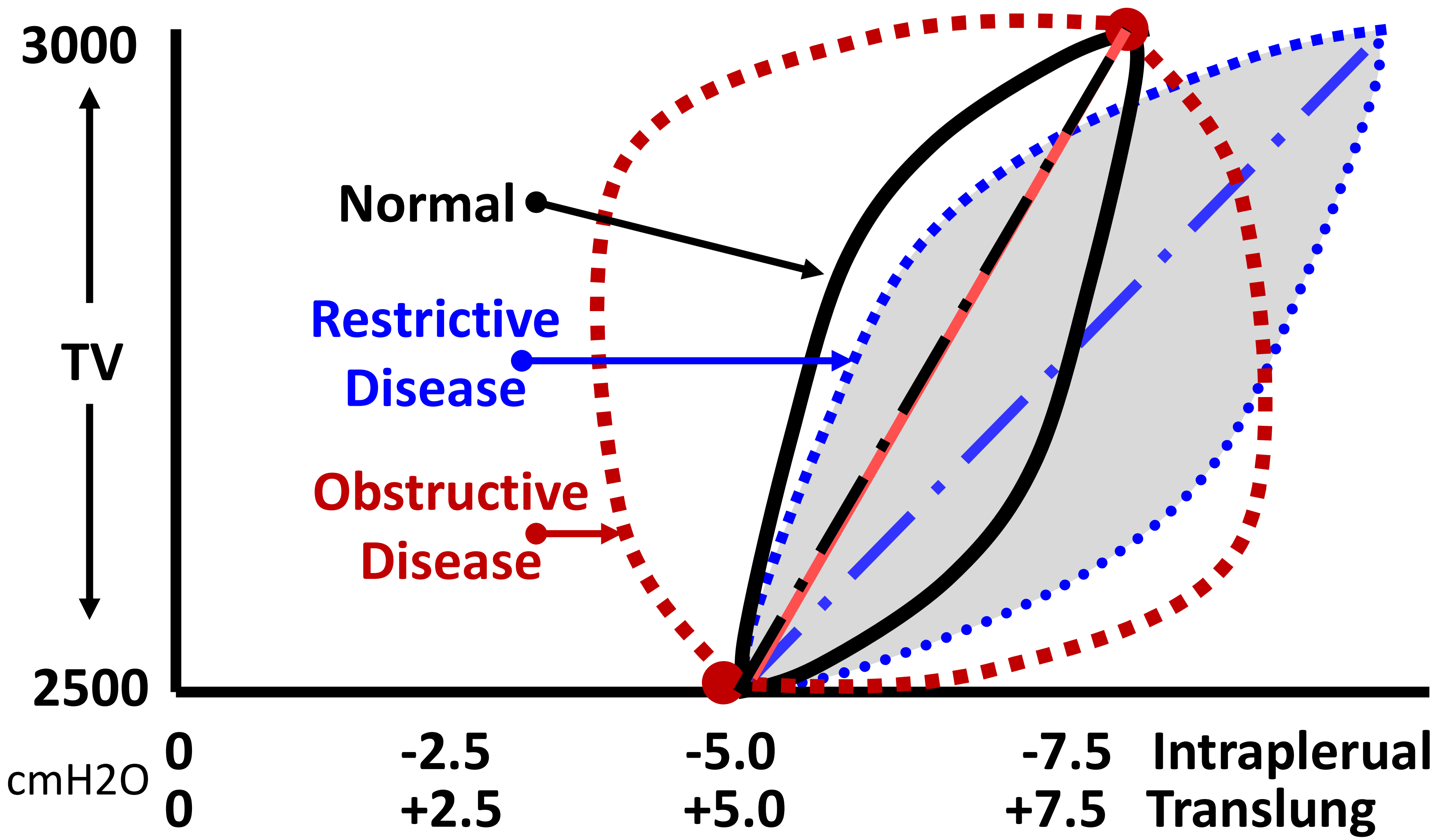
- Allergic Alveolitis
  Alvoli Wall Thickens
  (-) compliance

- Pleural Effusion
  Intrapleural Fluid buildup:
  (-) compliance
  Pleural fibrosis & + rigidity:
  (-) compliance

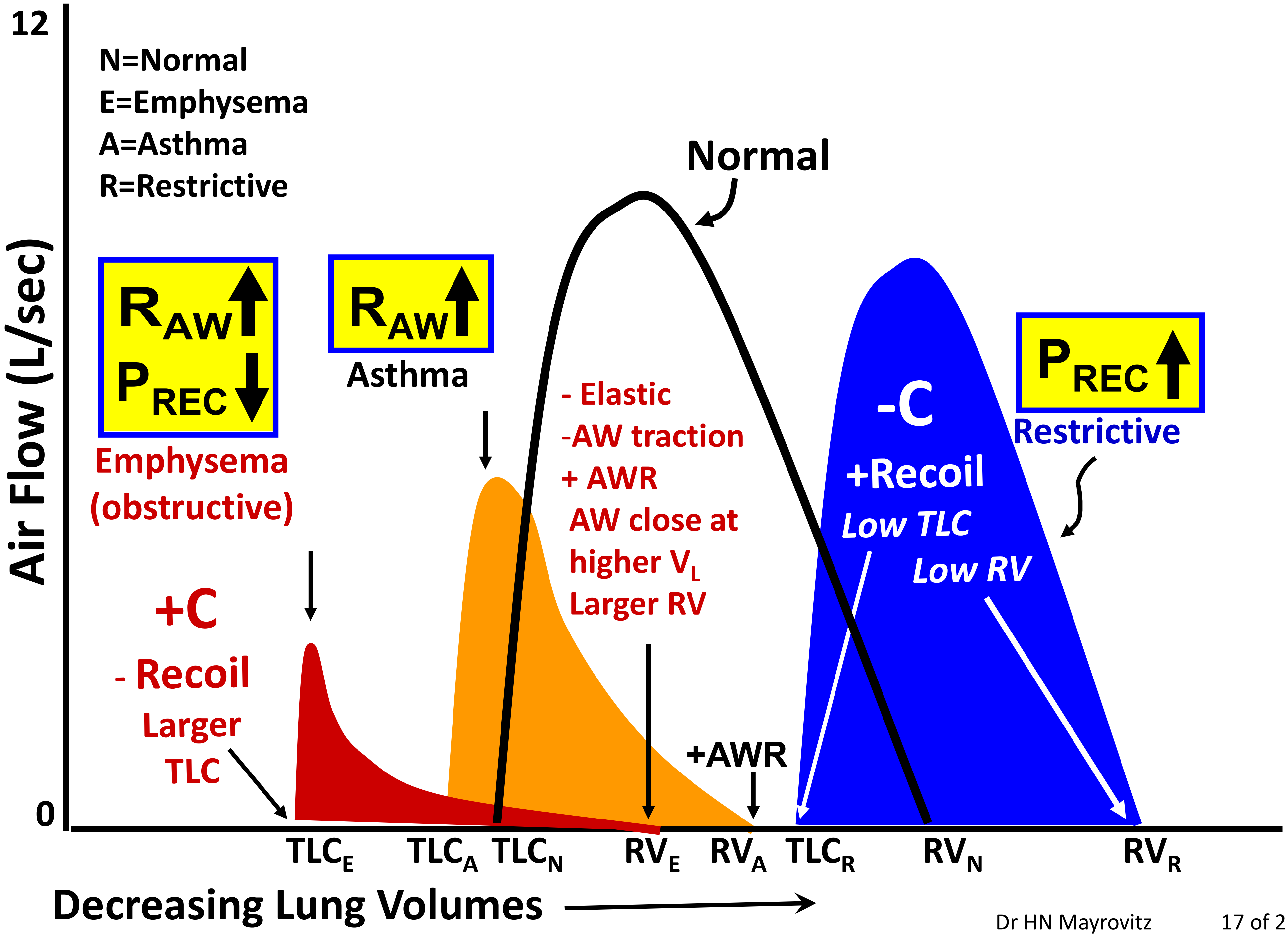
Obstructive vs. Restrictive Compliance Abnormalities



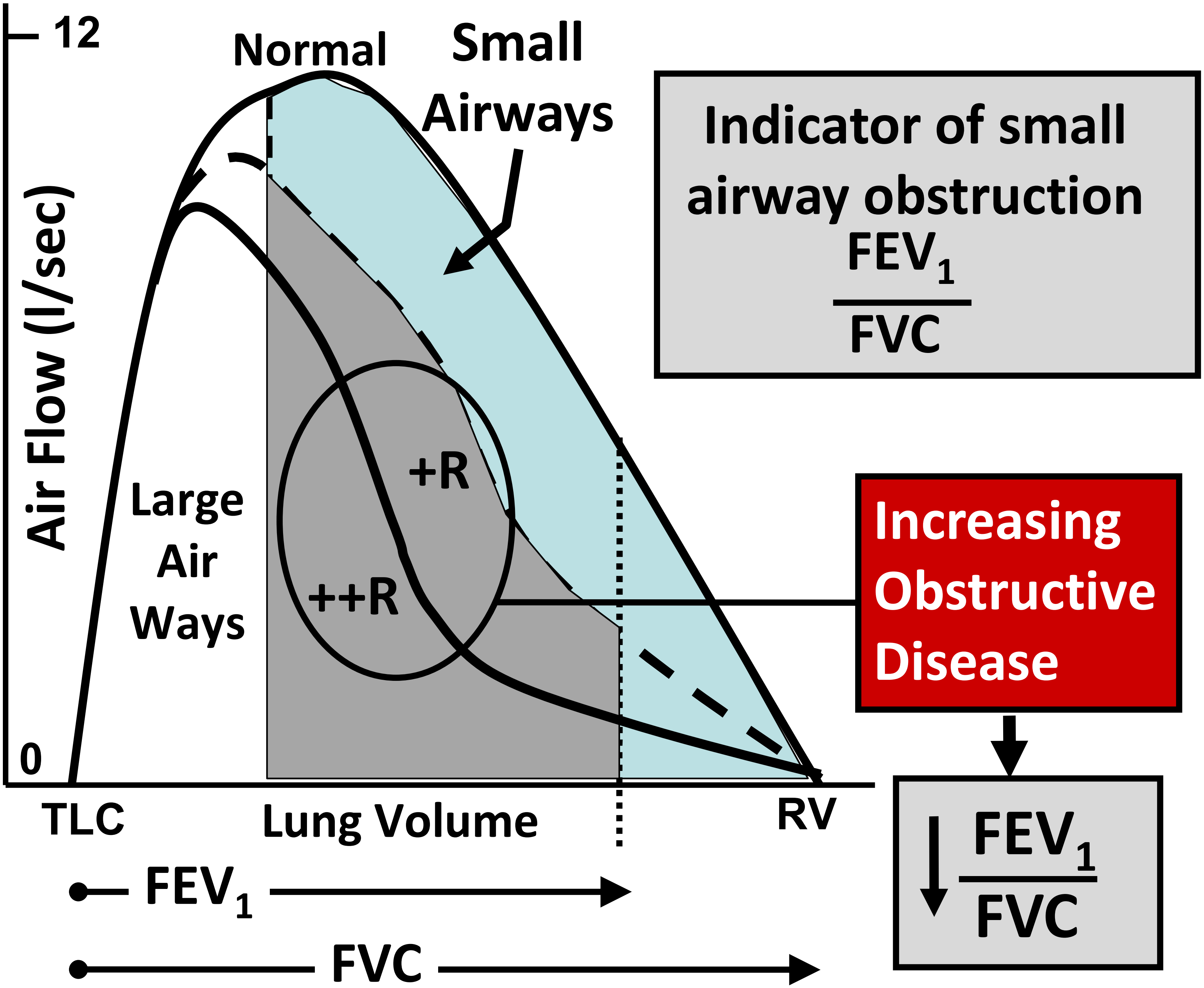
Differential Effects on Lung Dynamic Work



Differential Forced Expiratory Flow-Volume Patterns



Forced Expiratory *Volume-Time* Test



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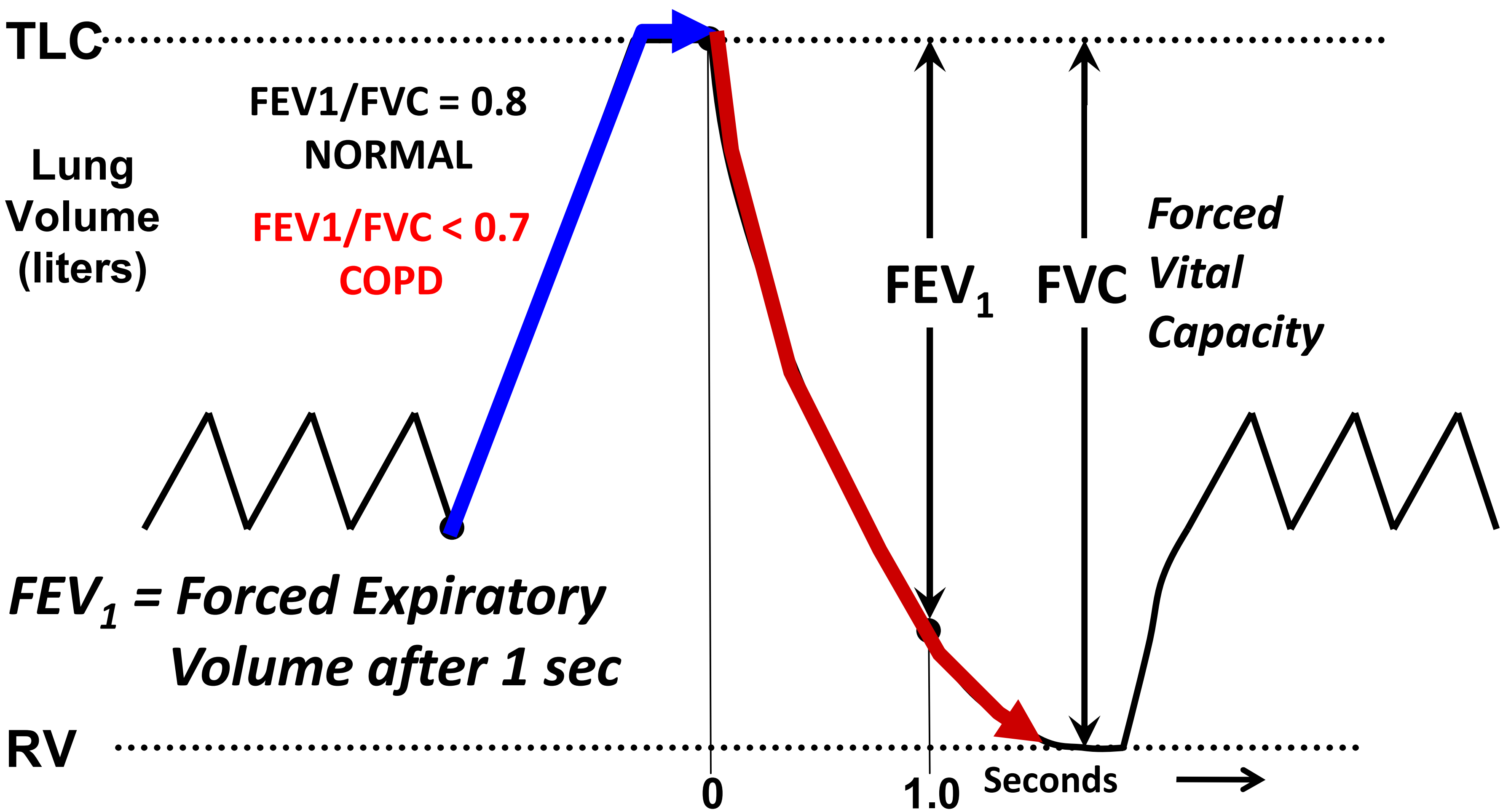


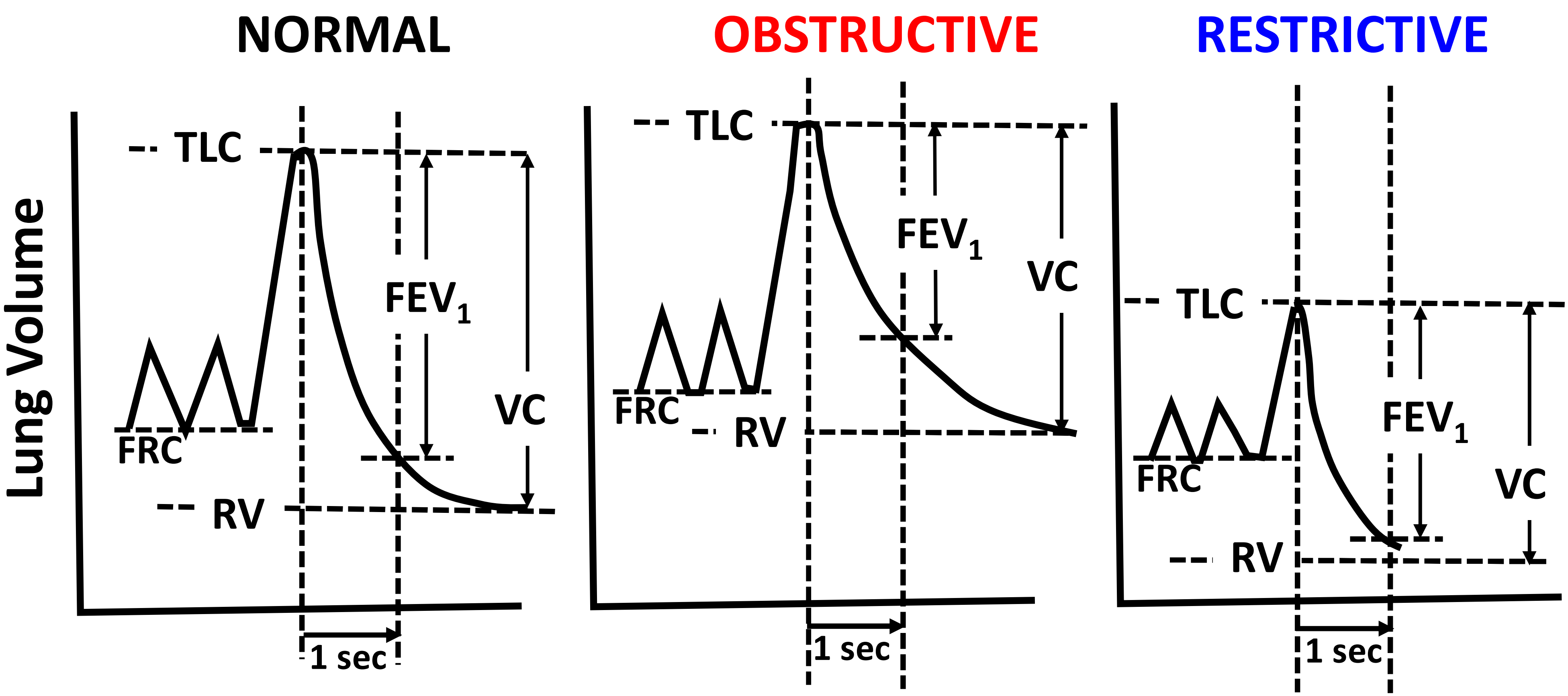
Factors and Reference Ranges
To be considered for "Normal"

- Gender → Male > Female
- Age → Younger > Older
- Height → Taller > Shorter

	Mild	Moderate	Severe	Very Severe
FEV_1 (% predicted)	≥ 80%	50% to <80%	30% to <50%	<30%
	Stages of COPD (All have (FEV1/FVC) < 0.7			

Differential Forced Expiratory *Volume-Time* Test

Normal-Obstructive-Restrictive



FEV_1/VC	**FEV_1/VC**	**FEV_1/VC**
~0.8	**Reduced**	**Normal or Elevated**

http://www.cdc.gov/niosh/topics/spirometry/RefCalculator.html

Total Work (O2 Cost) is Minimum at some TV x RR

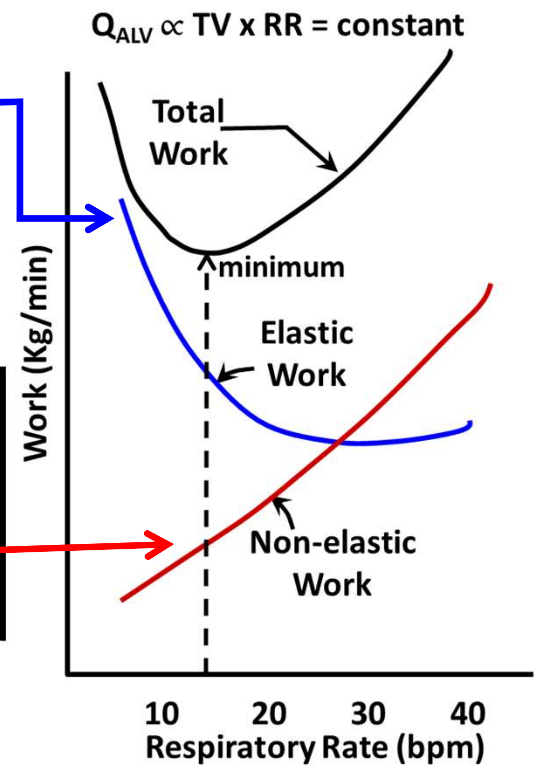
WORK COMPONENTS

Elastic work to expand lung (W_E) ~ 1/Compliance

- **Larger TV → more W_E since C decreases with V**
- **Larger TV → less relative ADS (ADS/TV is less/breath)**
- **For same alveolar ventilation W_E decreases with +RR**

Nonelastic (W_{NE} ~ Resistance)

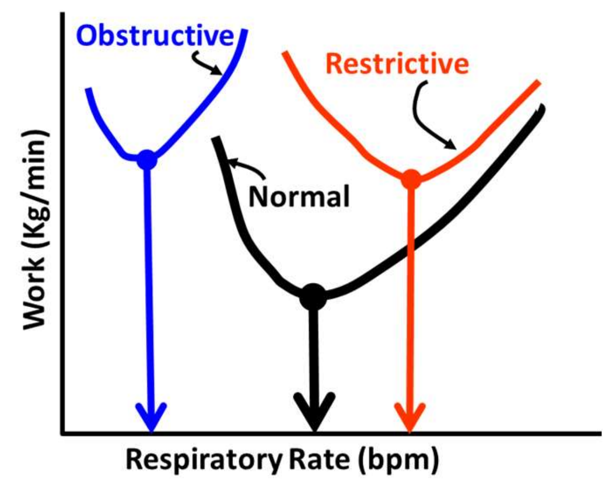
- **Energy is LOST to overcome airway and tissue resistances**
- **Larger RR → Larger dV/dt → Larger W_{NE}**
- **For same alveolar ventilation W_{NE} increases with +RR**



Total Work minimum at some RR

Two Clinical Points:

- **Obstructive Disease: "slow and deep"**
- **Restrictive Disease: "rapid and shallow"**



Hyperinflation: Quick Summary

Static Hyperinflation (*At rest*)

Inward recoil pressure reduced → + End Expiratory Lung Volume (EELV)

Chronic Obstructive Pulmonary Disease (COPD) especially moderate to severe EMPHYSEMA → Loss of elastic tissue → - recoil pressure
Generally, increase in Total Lung Capacity (TLC)

Dynamic Hyperinflation (*Exercise*)

Start inhalation before full exhalation completed

Potentially all levels of COPD including ASTHMA
→ Temporary and Variable in extent
→ Can occur with no maintained increase in TLC

Main Factors Determining Extent:

1) Degree of airflow limitation
2) time available for exhalation (ΔT)

Dynamic Hyperinflation – "Air Trapping"

Can occur with any increase in airway R (Airflow Limitation)

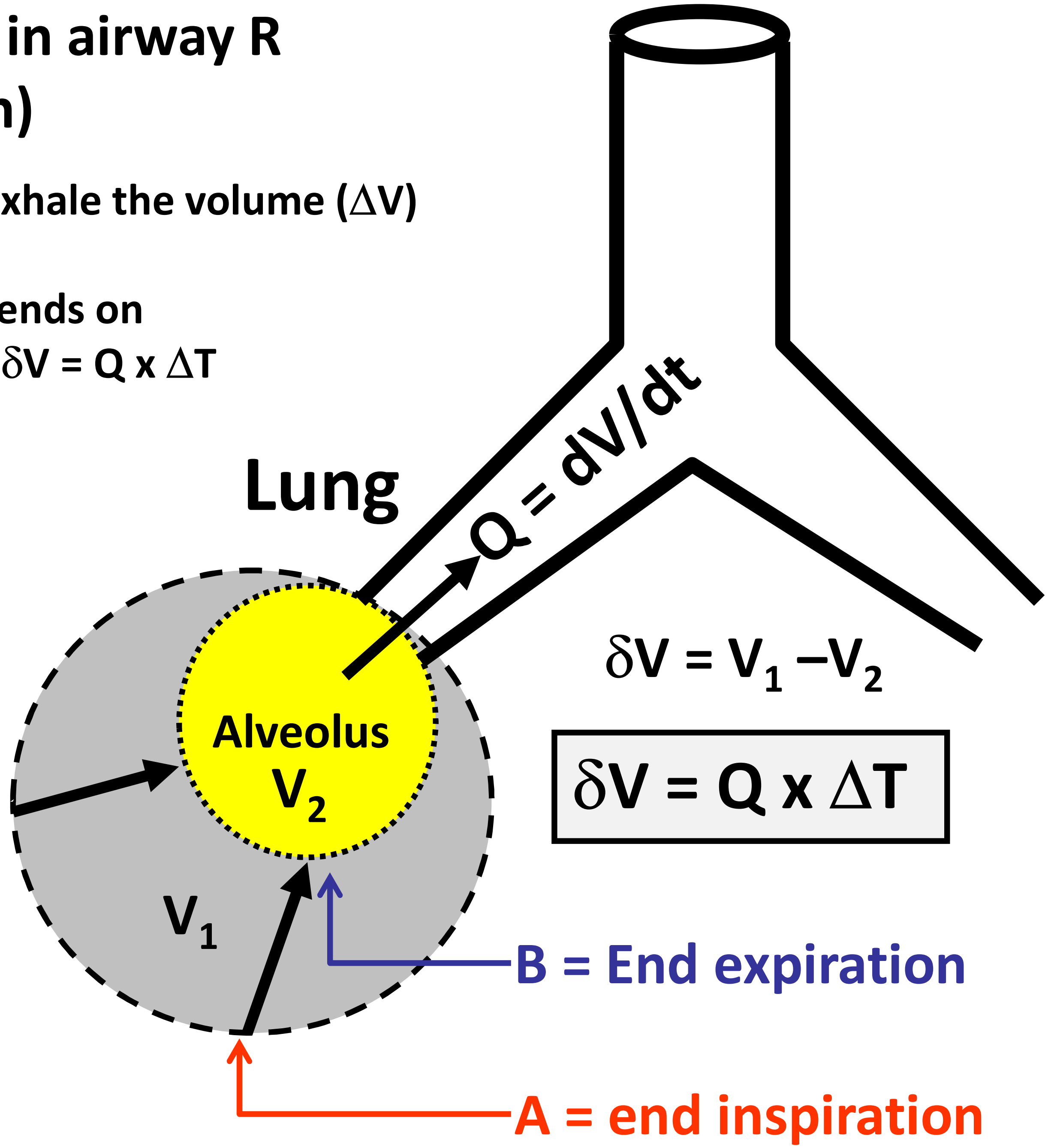
- To prevent "air trapping" need to exhale the volume (ΔV) that was just inhaled (TV)
- Volume actually removed (δV) depends on the air flow Q and the time (ΔT) as $\delta V = Q \times \Delta T$

$\uparrow R$ & $\downarrow P_{Recoil} \Rightarrow \downarrow Q$

So TIME needed for exhalation $\uparrow$

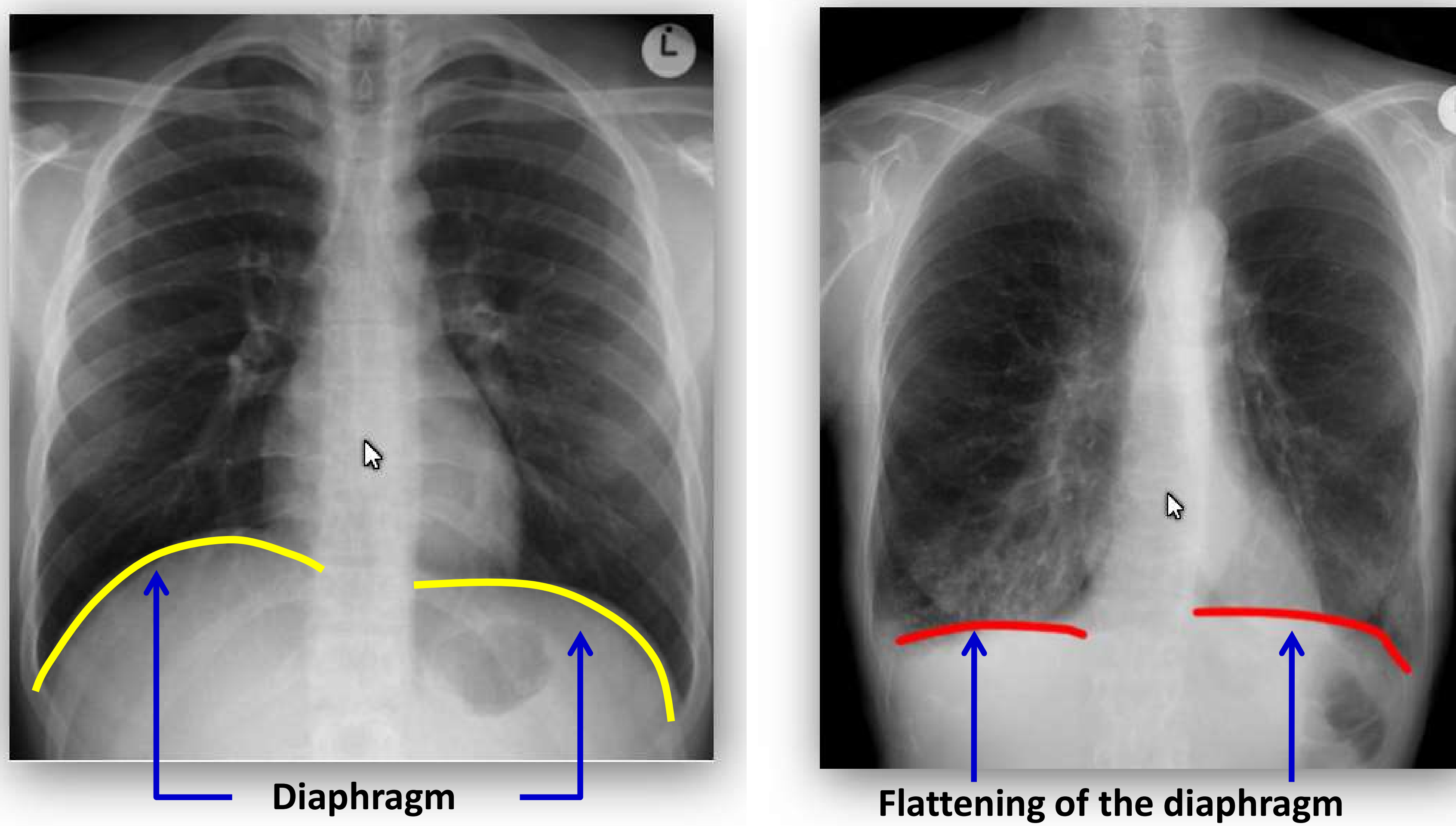
$\Downarrow$

If next inspiration starts prior to expiration to true FRC then air trapping!



Hyperinflation

Normal | **Hyperinflated**



Chronic Obstructive Pulmonary Disease (COPD)

Especially moderate to severe EMPHYSEMA

- **Loss of elastic tissue**
- **Reduced recoil pressure**
- **Increased end expiratory lung volume**
- **Increase Total Lung Capacity (TLC)**

Dynamic Hyperinflation – Effects Summary

- May occur at rest but often manifest if increased ventilation demand
- Increased respiratory rate (RR) further shortens available exp time
- Further air trapping results and TV begins to be limited by now

  diminishing inspiratory capacity (IC) due to rising FRC
- Inspiratory muscle load increases → greater recoil at elevated volume
- Increased FRC reduces the mechanical advantage of inspiratory m.
- Increased work of inspiration and oxygen cost of breathing
- Increasing amounts of dyspnea

10 Short Interactive Review Questions

1. If lung compliance decreases, what is the effect on the work of inspiration?
2. If surfactant production is low or absent, what will be the effect on work of inspiration?
3. What is the name given to lung volume at the end of quiet expiration?
4. As you inspire does intrapleural pressure increase or decrease?
5. As you inspire does translung pressure increase or decrease?
6. Is total respiratory compliance greater on less than lung compliance?
7. What are the components of airway-alveolar time constant?
8. During a normal respiration cycle, when is the air flow zero?
9. A person with emphysema would have a high or low lung recoil pressure?
10. A person with interstitial fibrosis would have a high or low lung recoil pressure?

End Respiratory Physiology
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