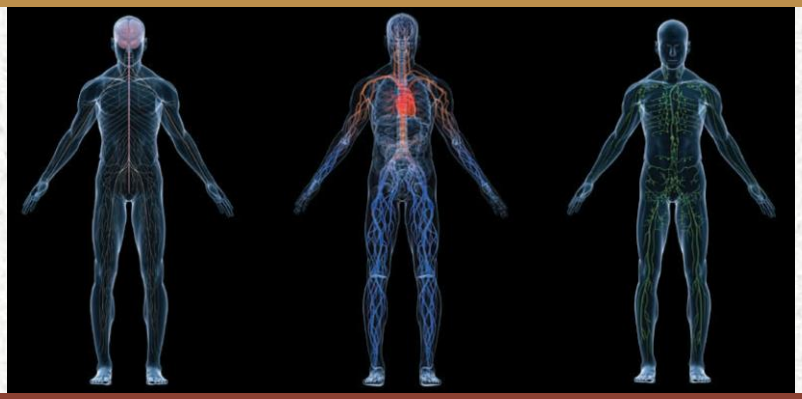
UNIT VII

GUYTON AND HALL *Textbook of*
# Medical Physiology
TWELFTH EDITION



Chapter 42:

## Respiratory Insufficiency—Pathophysiology, Diagnosis, Oxygen Therapy

**Slides by Robert L. Hester, PhD**

- **Prevalence of lung disease depends on the population, but in general obstructive is 70%, restrictive is 20-25% and vascular is 5-10%.** Only the latter cannot be screened for reliably with PFT's. An ideal screening test would identify every patient with a disease regardless of stage or severity (high sensitivity…No false negative) and exclude those without the disease (high specificity…no false positive). Spirometry measures the volume of air that a subject inspires and expires.

# Pulmonary Pathology

- Obstructive Diseases
  - Increased resistance to air flow
- Restrictive Diseases
  - Decreased expansion of the lungs

# Pathology

- Increased resistance to airflow
  - Lumen
    - excessive secretions
    - obstruction due to aspiration
  - Airway
    - contraction of smooth muscle
    - hypertrophy of bronchial wall
  - outside of airway
    - destruction of lung parenchyma

# Chronic Obstructive Pulmonary Disease

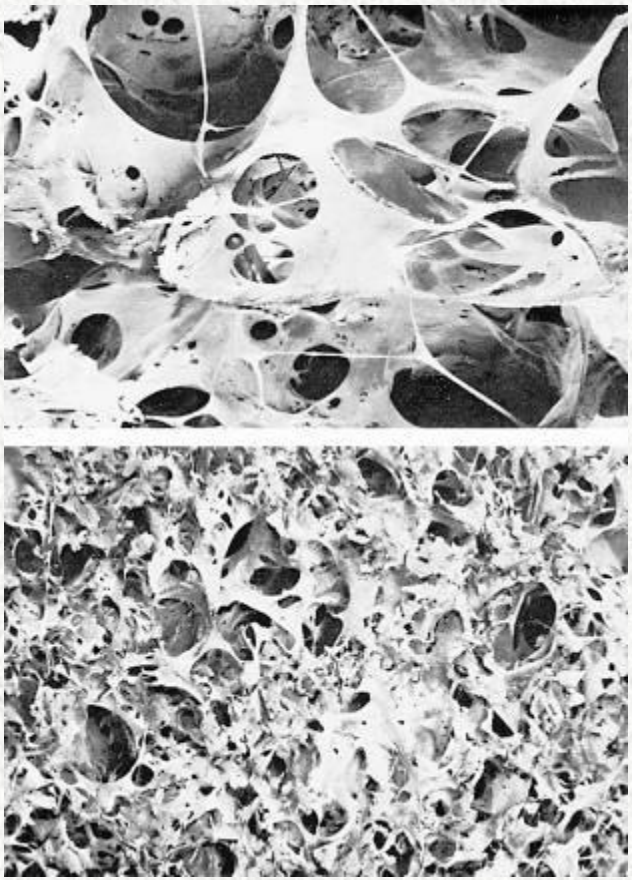
- Chronic pulmonary emphysema
  - infection (secretions)
  - obstruction
  - loss of parenchyma
- Consequences
  - high airway resistance
  - decreased diffusing capacity
  - pulmonary hypertension

# Chronic Obstructive Pulmonary Disease

- Chronic bronchitis
  - excessive mucous production
- Asthma
  - bronchiole constriction

# Restrictive Diseases

- Decreased expansion of the lungs
- Lung volumes
  - reduced VC, FRC, normal resistance
- Diffuse Interstitial Pulmonary Fibrosis
  - thick collagen deposits
- Pneumothorax



Emphysematous Lung

Normal Lung

Figure 42-4

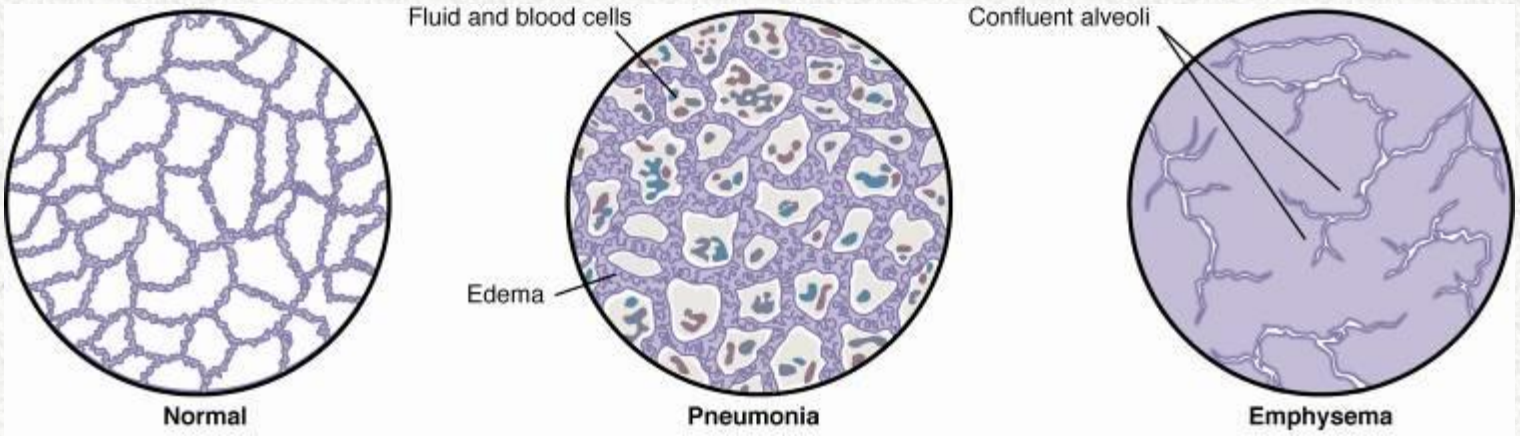



Figure 42-5

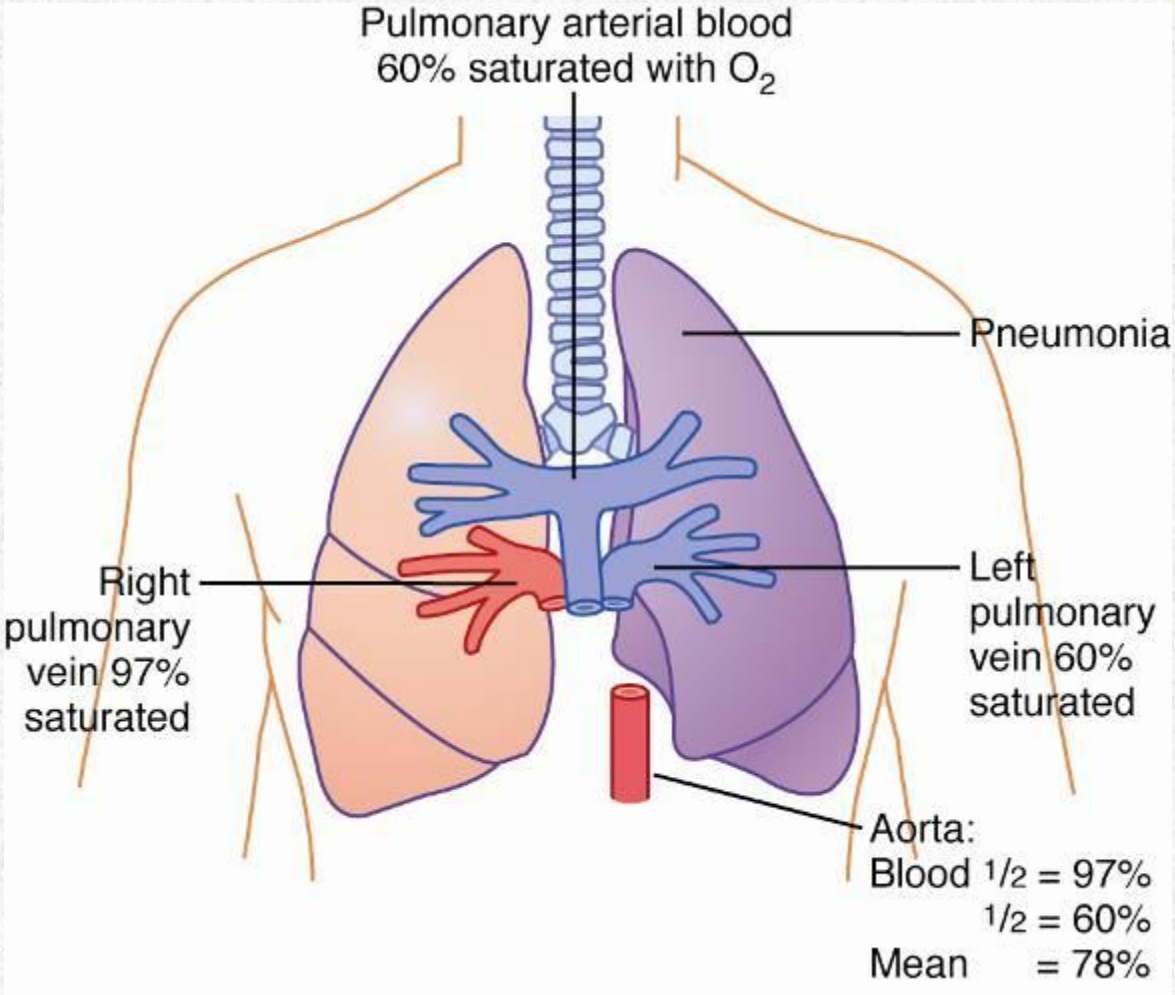



Figure 42-6

# Pathology

- Atelectasis
  - collapse of alveoli
    - airway obstruction
    - lack of surfactant

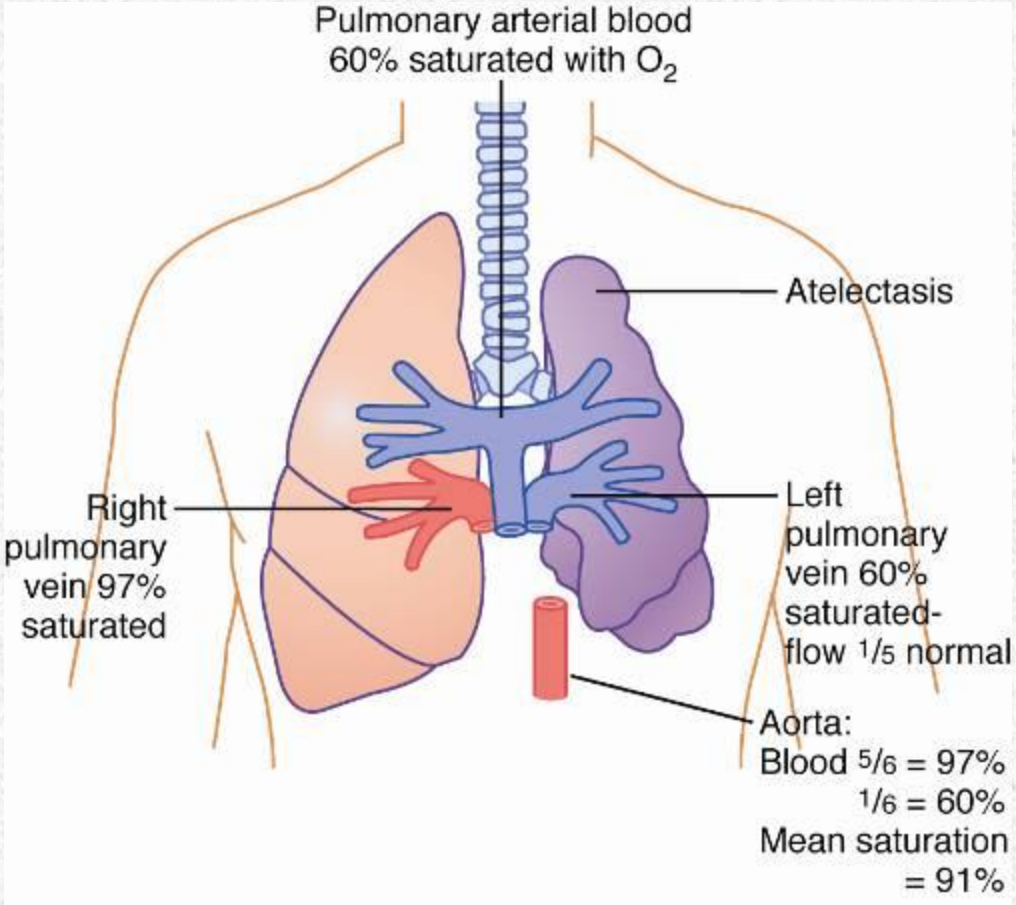
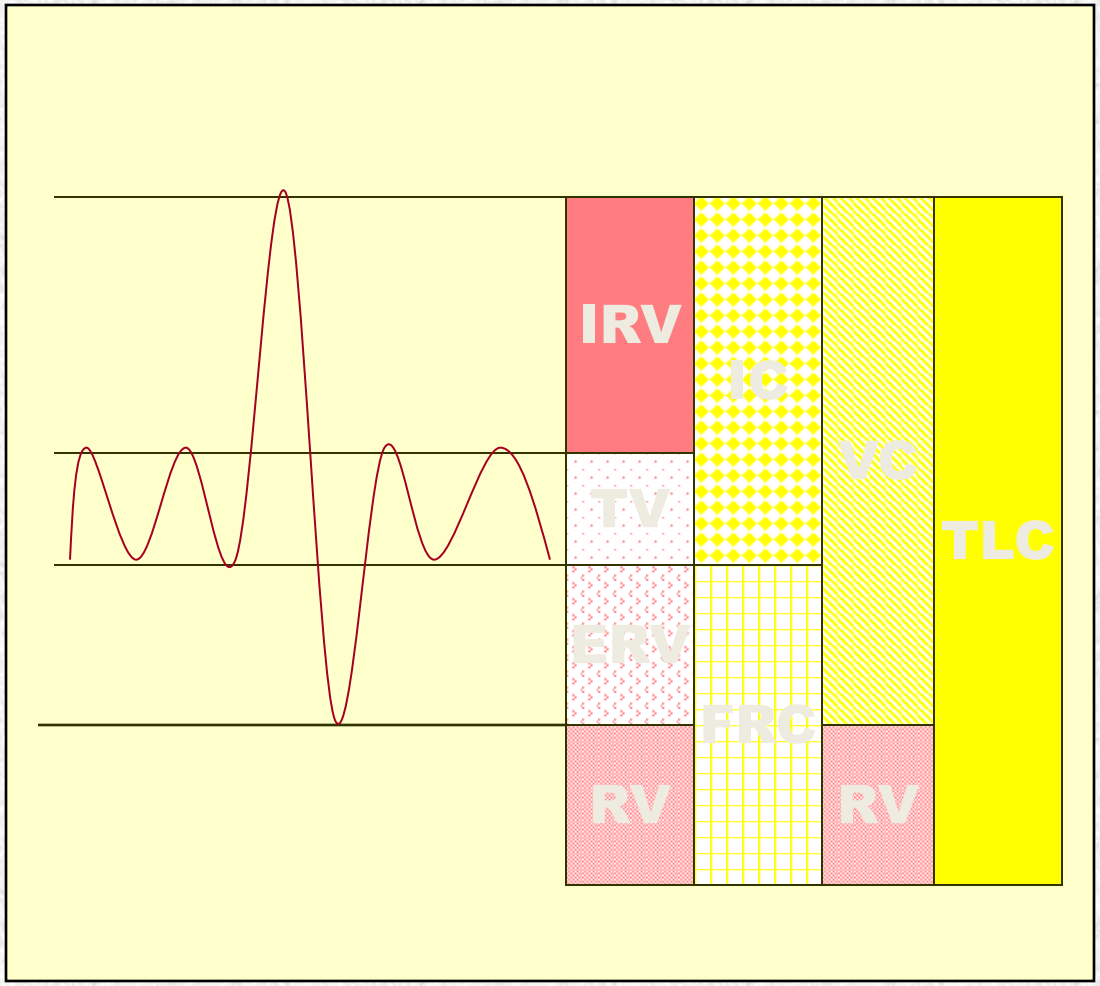



Figure 42-7

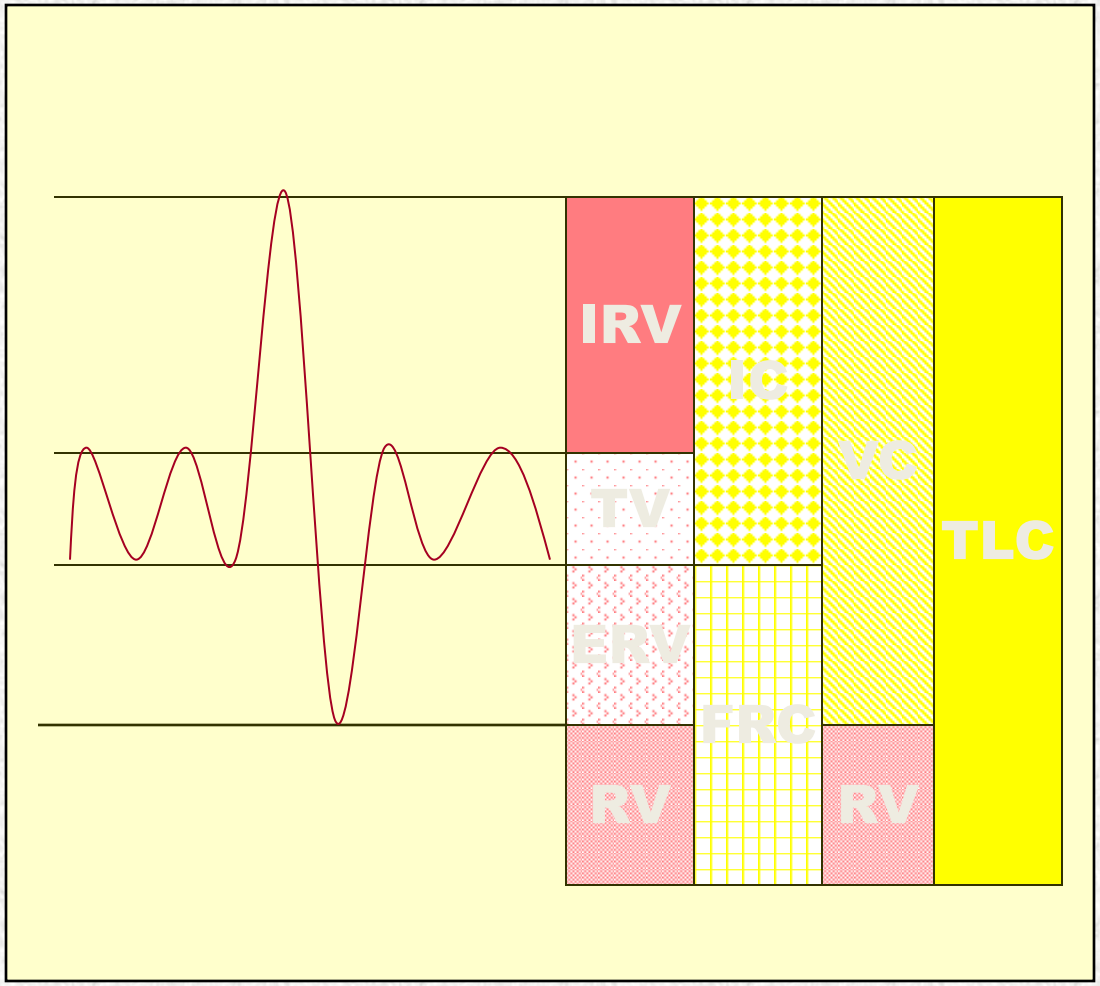
- **RESPIRATORY FAILURE**
- **When the lung cannot oxygenate the blood and cannot wash out $CO_2$.**
- Acute Respiratory Failure: **When arterial $PO_2$< 50 mmHg ± arterial $PCO_2$ > 50 mm Hg under resting condition at sea level when breathing room air**. It is based on ABGs. 1. Hypoxemic respiratory failure ($PCO_2$ is normal or even low) and 2. Hypercapnic ventilatory failure (both $PO_2$ and PCO2 are abnormal).

# Lung Volumes



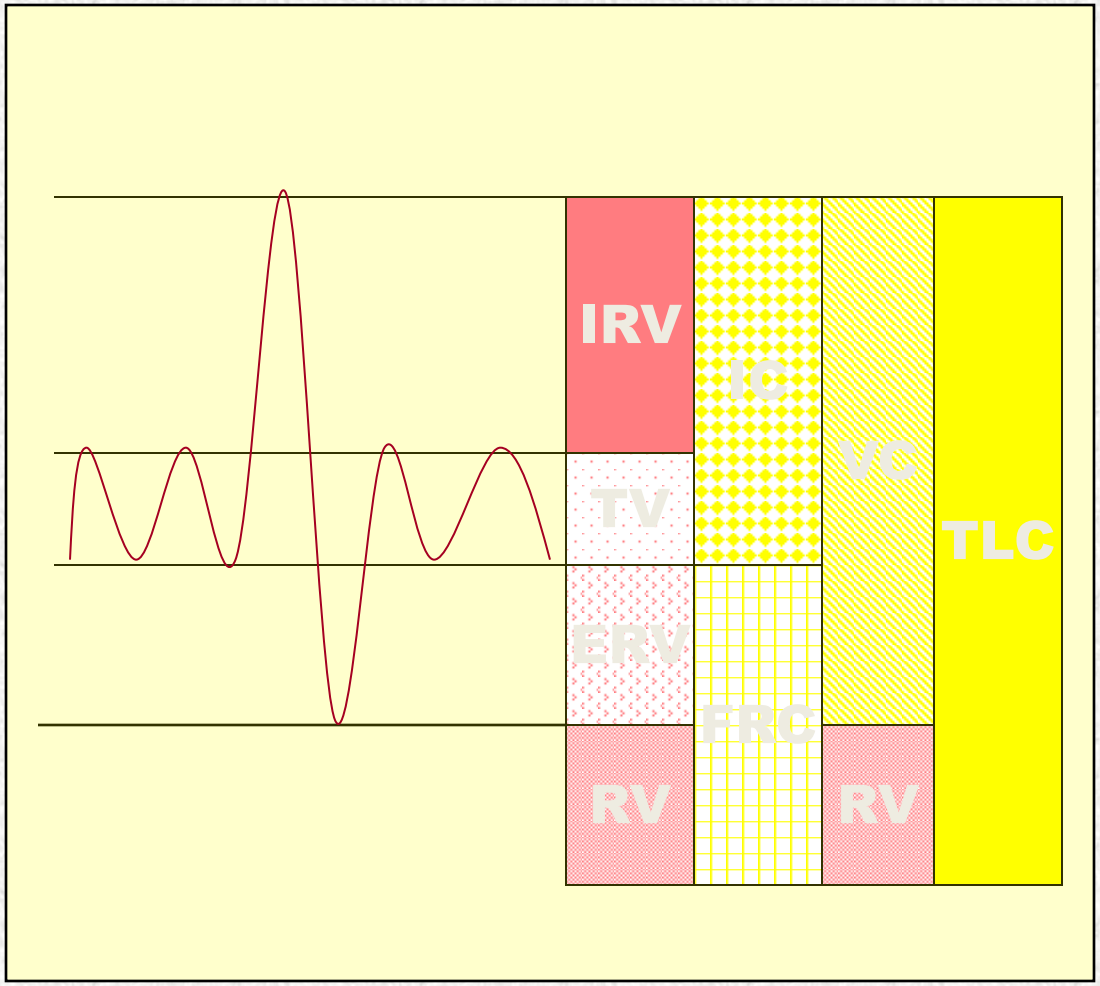

- 4 Volumes
- 4 Capacities
  - Sum of 2 or more lung volumes

# Tidal Volume (TV)



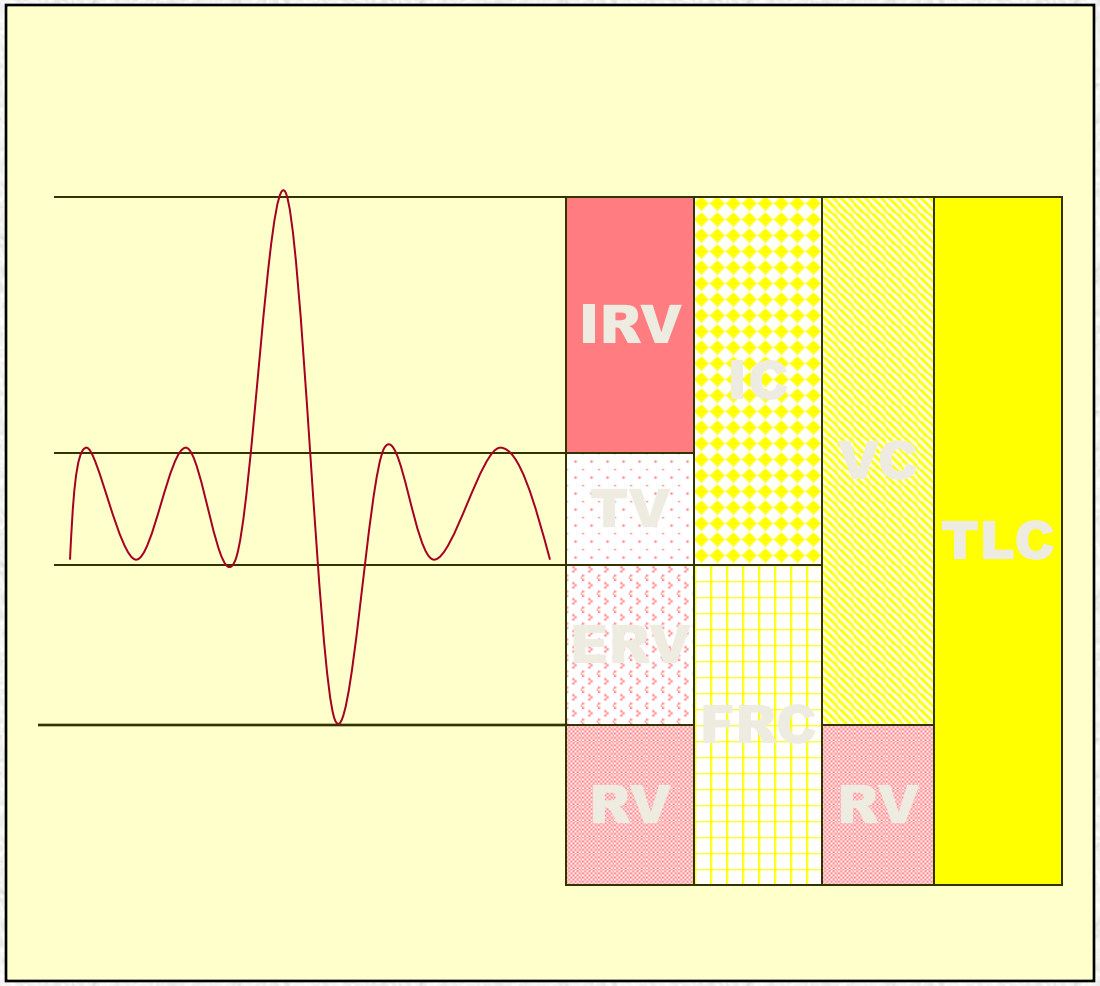

- Volume of air inspired and expired during normal quiet breathing

# Inspiratory Reserve Volume (IRV)



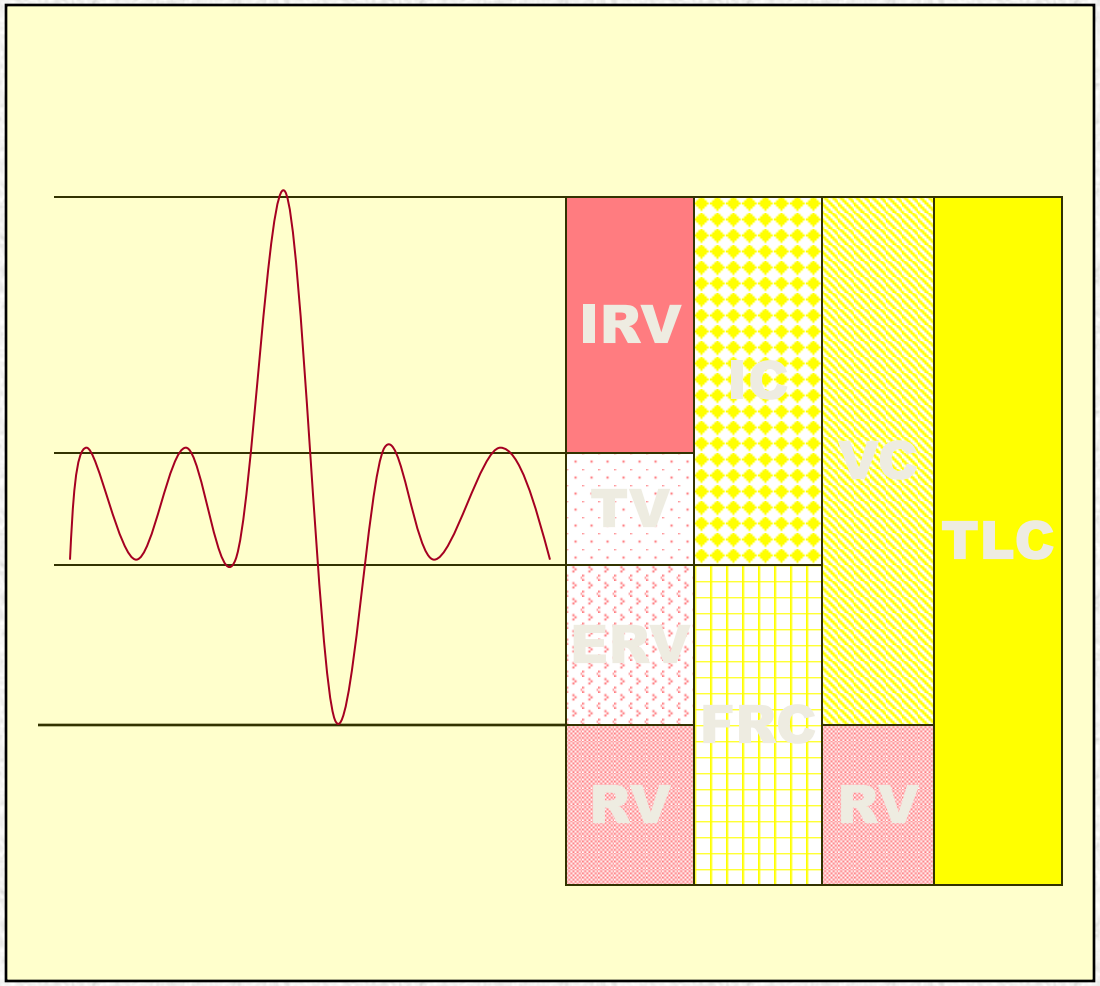

- The maximum amount of air that can be inhaled after a normal tidal volume inspiration

# iratory Reserve Volume (ERV)



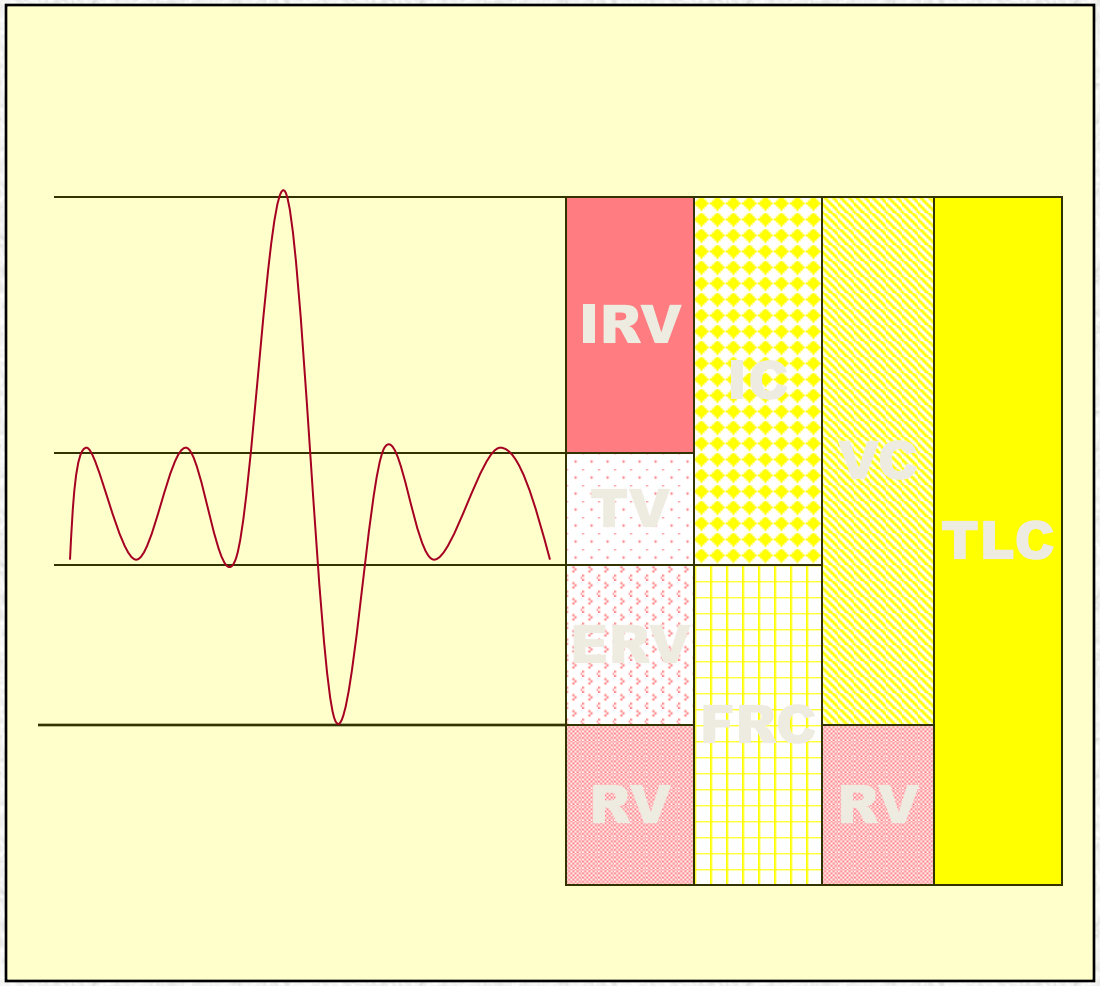

- Maximum amount of air that can be exhaled from the resting expiratory level

# Residual Volume (RV)



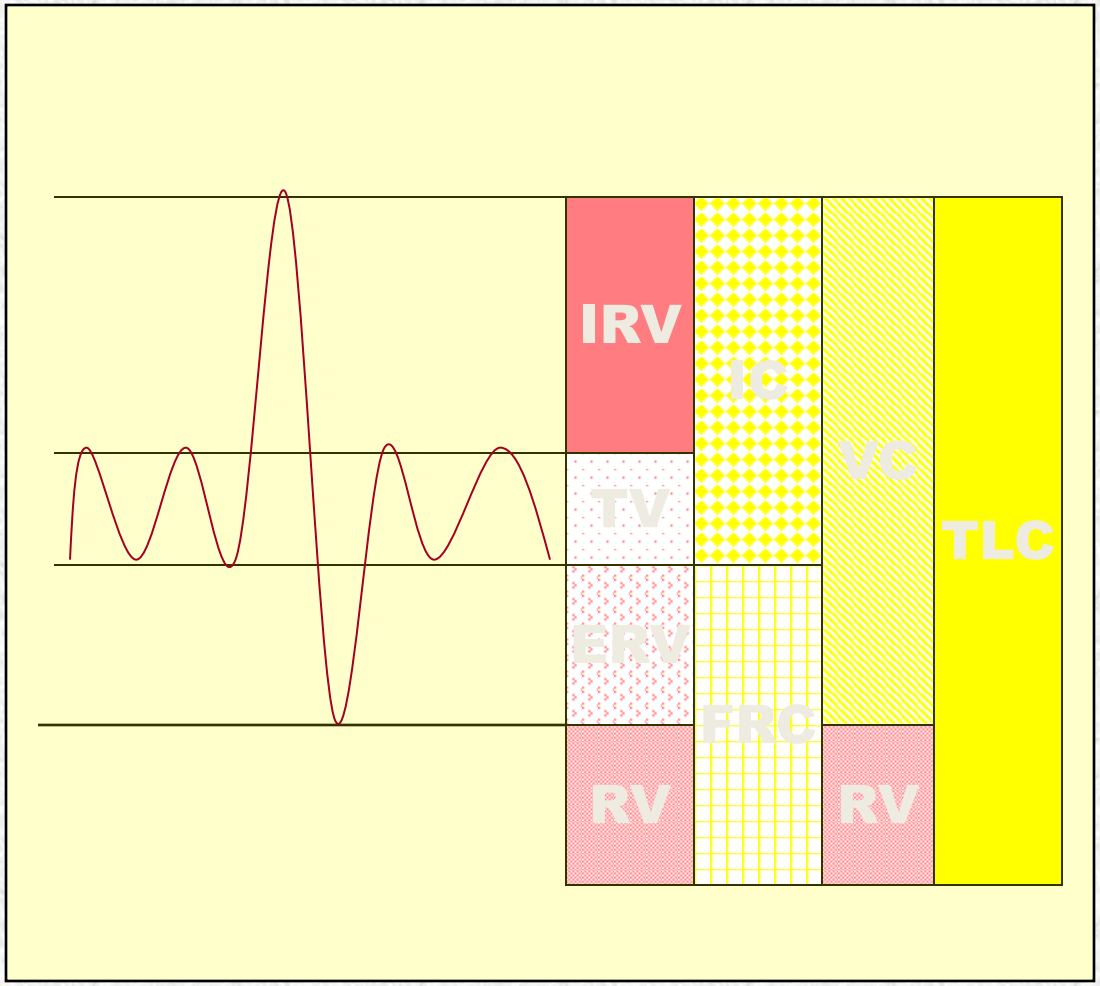

- Volume of air remaining in the lungs at the end of maximum expiration

# Vital Capacity (VC)



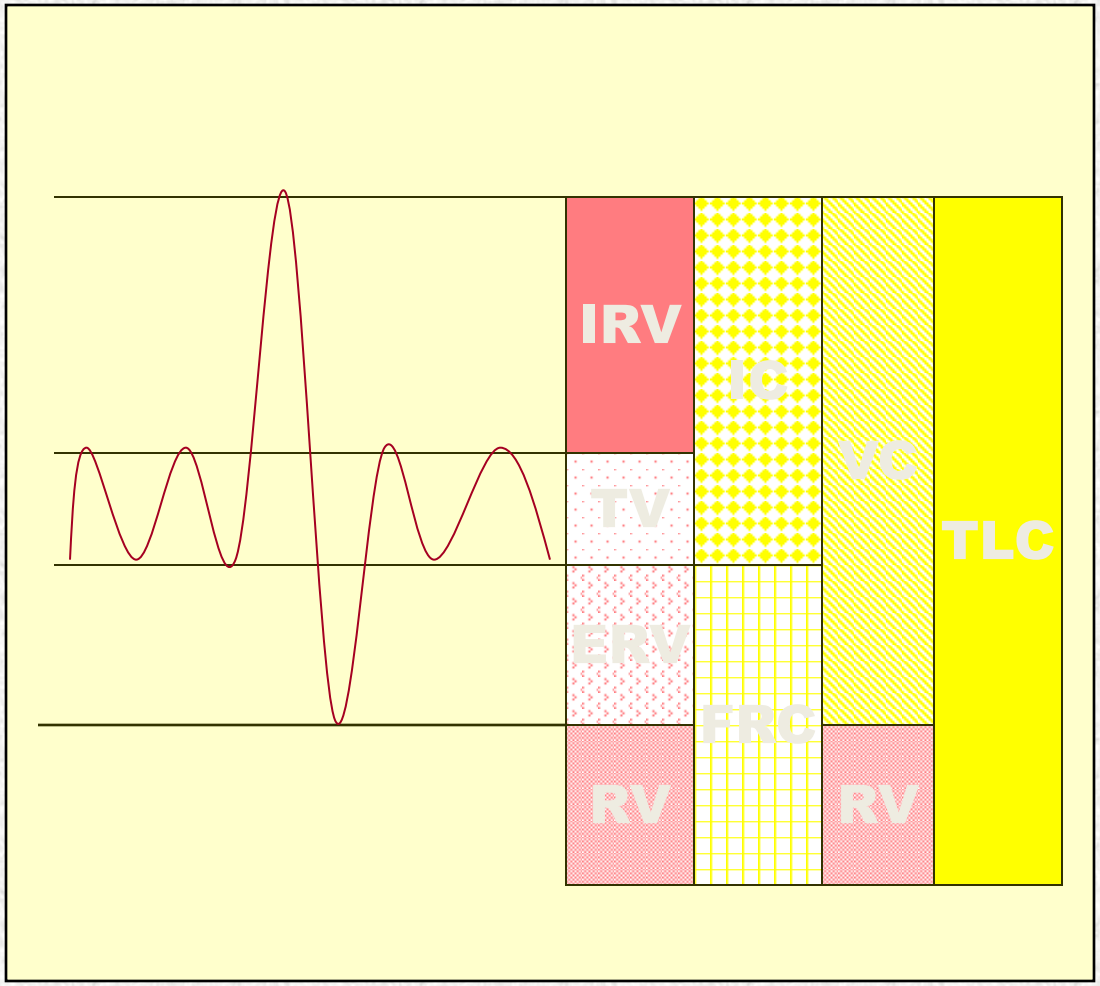

- Volume of air that can be exhaled from the lungs after a maximum inspiration
- FVC: when VC exhaled forcefully
- SVC: when VC is exhaled slowly
- VC = IRV + TV + ERV

# nspiratory Capacity (IC)



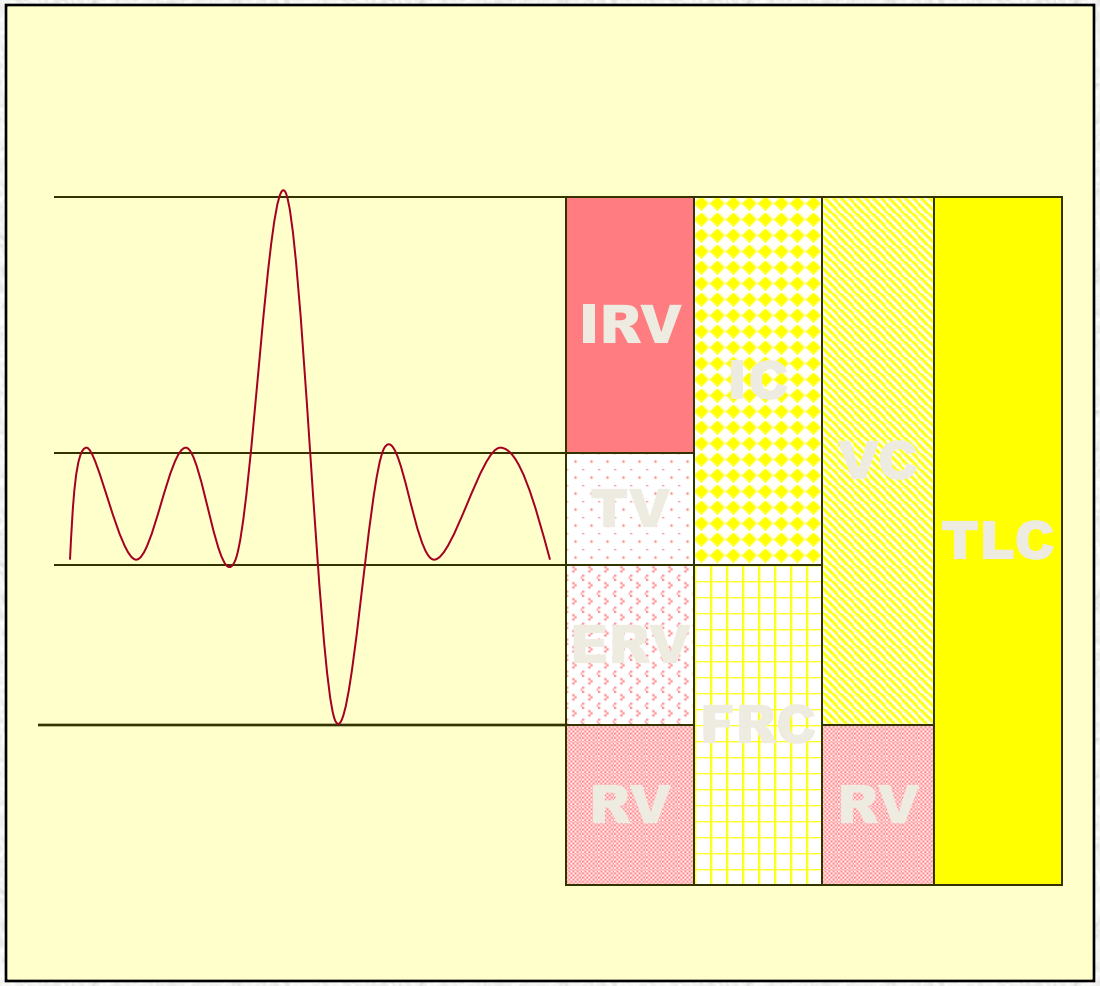

- Maximum amount of air that can be inhaled from the end of a tidal volume
- IC = IRV + TV

# ctional Residual Capacity (FRC)




- Volume of air remaining in the lungs at the end of a TV expiration
- The elastic force of the chest wall is exactly balanced by the elastic force of the lungs
- FRC = ERV + RV

# Total Lung Capacity (TLC)




- Volume of air in the lungs after a maximum inspiration
- TLC = IRV + TV + ERV + RV
  - Increased with obstructive disease
  - Decreased with restrictive disorders
  - Sum of the vital capacity and residual volume
  - Obtain RV by:
    - Body plethysmography
    - Nitrogen washout
    - Helium dilution

# lmonary Function Testing

- Process of having the patient perform specific inspiratory and expiratory maneuvers
- Important to be familiar with these tests and values even if you do not work in a PFT lab
- Used for the following:
  - Medical diagnosis
  - Surgery related evaluation
  - Disability evaluation
  - Public Health/Research
  - Studying the effects of exercise on the lungs

# lmonary Function Testing

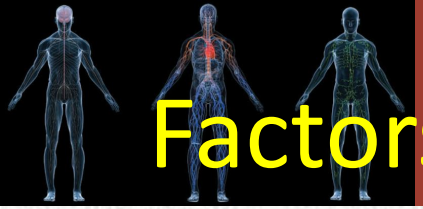
- Spirometry
- Lung volumes
- Diffusion capacity
- ABG

# Importance

- Patients and physicians have inaccurate perceptions of severity of airflow obstruction and/or severity of lung disease by physical exam
- Provides objective evidence in identifying patterns of disease

# Technique

- Have patient seated comfortably
- Closed-circuit technique
  - Place nose clip on
  - Have patient breathe on mouthpiece
  - Have patient take a deep breath as fast as possible
  - Blow out as hard as they can until you tell them to stop



# Factors that may affect results of ABG tests

*Hyperventilation* (rapid and deep breathing). This can cause lower than usual PaCO2 levels. While this is a symptom of several diseases, hyperventilation can also occur due to pain or anxiety.

Smoking. Tobacco smoke contains about 2,000 gases and chemicals. These toxins can interfere with test results.

Carbon monoxide inhalation. Carbon monoxide (CO) is a colorless, odorless, tasteless gas that is produced from the incomplete burning of fuels (e.g., from home furnaces, car engines and indoor barbecues). High CO levels in the body can cause CO poisoning and quickly lead to death. CO levels in the body will also affect an ABG test.

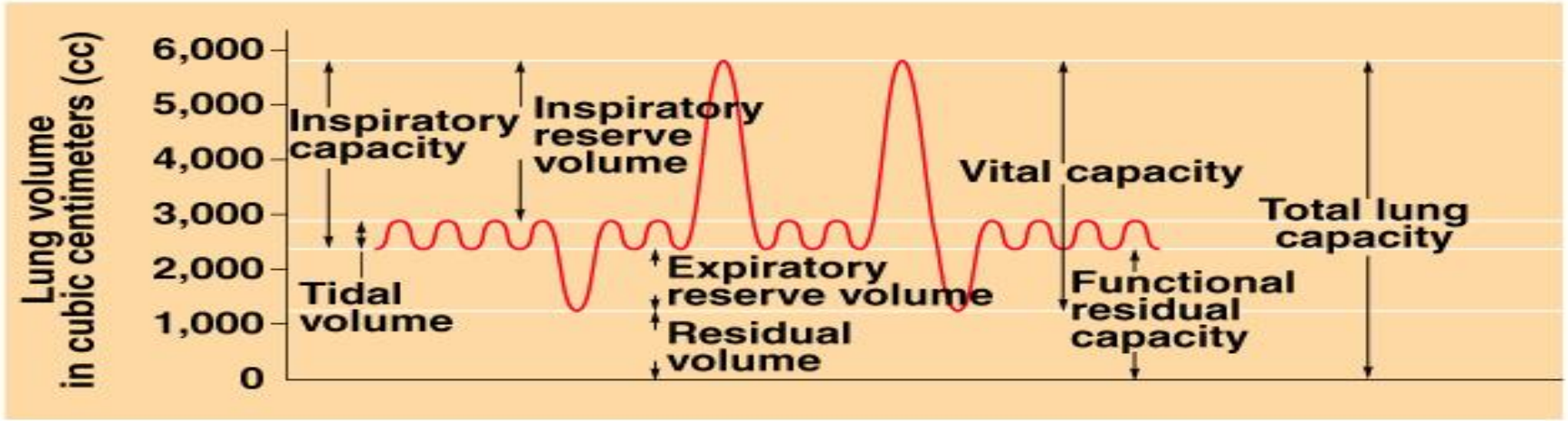
- **About Pulmonary Function Tests**
- Spirometry provides an objective assessment of airflow obstruction and is important in staging asthma severity. It should be done on initial diagnosis of asthma, after treatment is started and symptoms have stabilized, and every 1 to 2 years afterward. Spirometry is used to measure the rate of airflow during maximal expiratory effort after maximal inhalation. It can be useful in differentiating between obstructive and restrictive lung disorders. In asthma (an obstructive lung disorder) the forced expiratory volume in 1 second (FEV1) is usually decreased, **the forced vital capacity (FVC) is usually normal** and the ratio FEV1/FVC is decreased. In restrictive disorders the FEV1 and FVC are both decreased, leaving a normal FEV1/FVC.

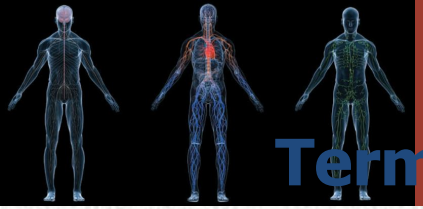
  Spirometry measurements are usually done before and after administration of a $\beta_2$ agonists (salbutamol, dobutamine, albuterol, fenoterol, terbutaline).. Reversibility with the use of a bronchodilator is defined as an increase in $FEV_1$ of 12% or 200 ml. **Patients with severe asthma may need a short course of oral steroid therapy before they demonstrate reversibility**.
- **Common Terms in Spirometry**
- Below is an example of a volume-time curve. It shows the amount of air expired from the lungs as a function of time.

**Classification: Obstructive or Restrictive or Mixed.  Clinical diagnosis cannot be made by spirometry; but is often supported or excluded. Obstruction and Restriction criteria**

# Pulmonary Function Tests

- Assessed by spirometry.
- Subject breathes into a closed system in which air is trapped within a bell floating in $H_20$.
- The bell moves up when the subject exhales and down when the subject inhales.





# Terms Used to Describe Lung Volumes and Capacities



## Table 16.3 Terms Used to Describe Lung Volumes and Capacities

| Term | Definition |
|---|---|
| *Lung Volumes* | The four nonoverlapping components of the total lung capacity |
| Tidal volume | The volume of gas inspired or expired in an unforced respiratory cycle |
| Inspiratory reserve volume | The maximum volume of gas that can be inspired during forced breathing in addition to tidal volume |
| Expiratory reserve volume | The maximum volume of gas that can be expired during forced breathing in addition to tidal volume |
| Residual volume | The volume of gas remaining in the lungs after a maximum expiration |
| *Lung Capacities* | Measurements that are the sum of two or more lung volumes |
| Total lung capacity | The total amount of gas in the lungs after a maximum inspiration |
| Vital capacity | The maximum amount of gas that can be expired after a maximum inspiration |
| Inspiratory capacity | The maximum amount of gas that can be inspired after a normal tidal expiration |
| Functional residual capacity | The amount of gas remaining in the lungs after a normal tidal expiration |

# Normal Flow Volume Responses

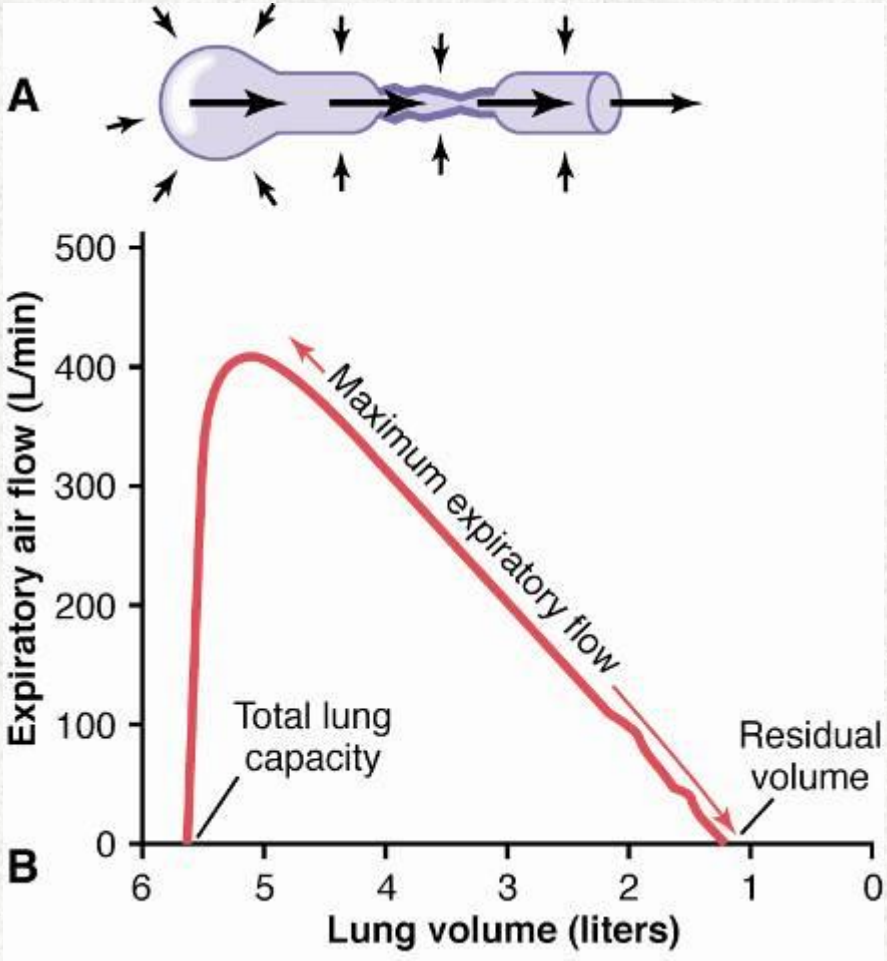



Figure 42-1

- At every lung volume there exists a maximal rate of flow which cannot be exceeded. When an individual tries to exceed his maximal flow rate, he forcefully contracts his abdominal muscles to increase his already positive pleural pressure. This increases the driving pressure for air flow from the alveoli to the mouth but also causes the bronchi (whose pressure lies somewhere between that in the alveoli and that at the mouth, but is less than pleural pressure) to collapse. Thus the airways become occluded and flow is slowed until the pressure difference across the airways drops a bit, the airways can reopen, and flow can continue.

# Dynamic Flow - Volume Loops

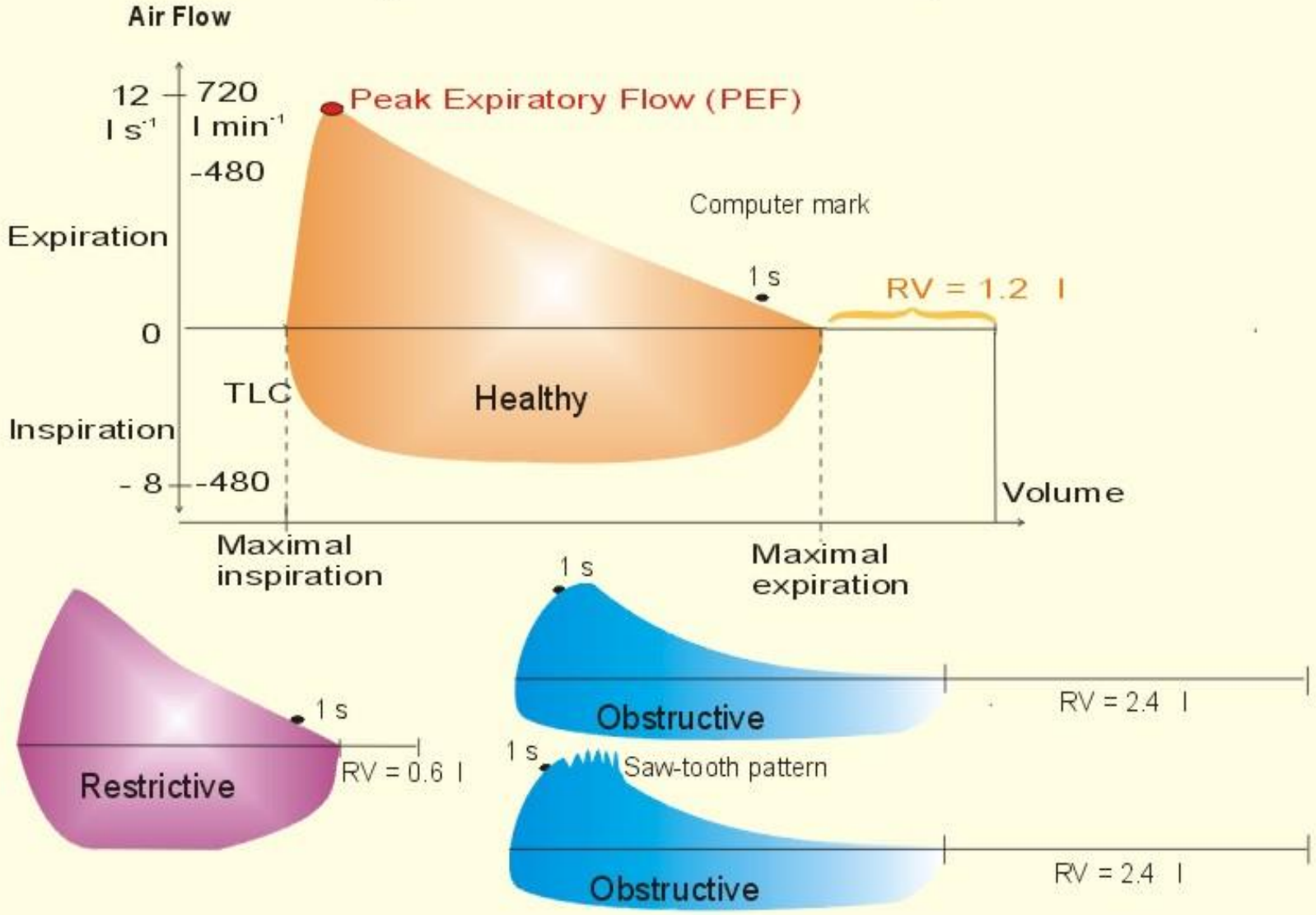



Fig. 13-6

KMc

# Abnormal Flow Volume Responses

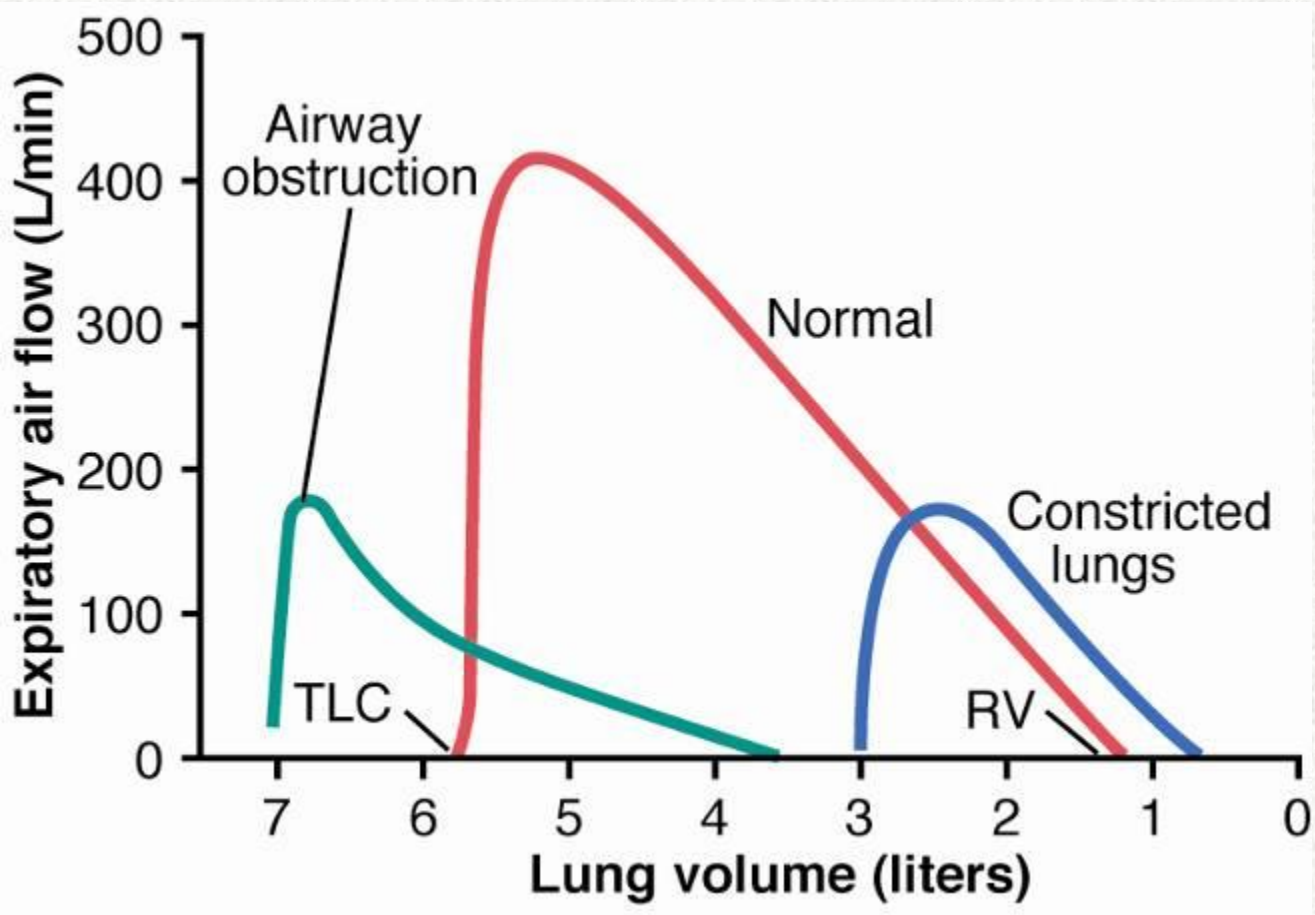



Figure 42-2

# Forced Expiratory Vital Capacity

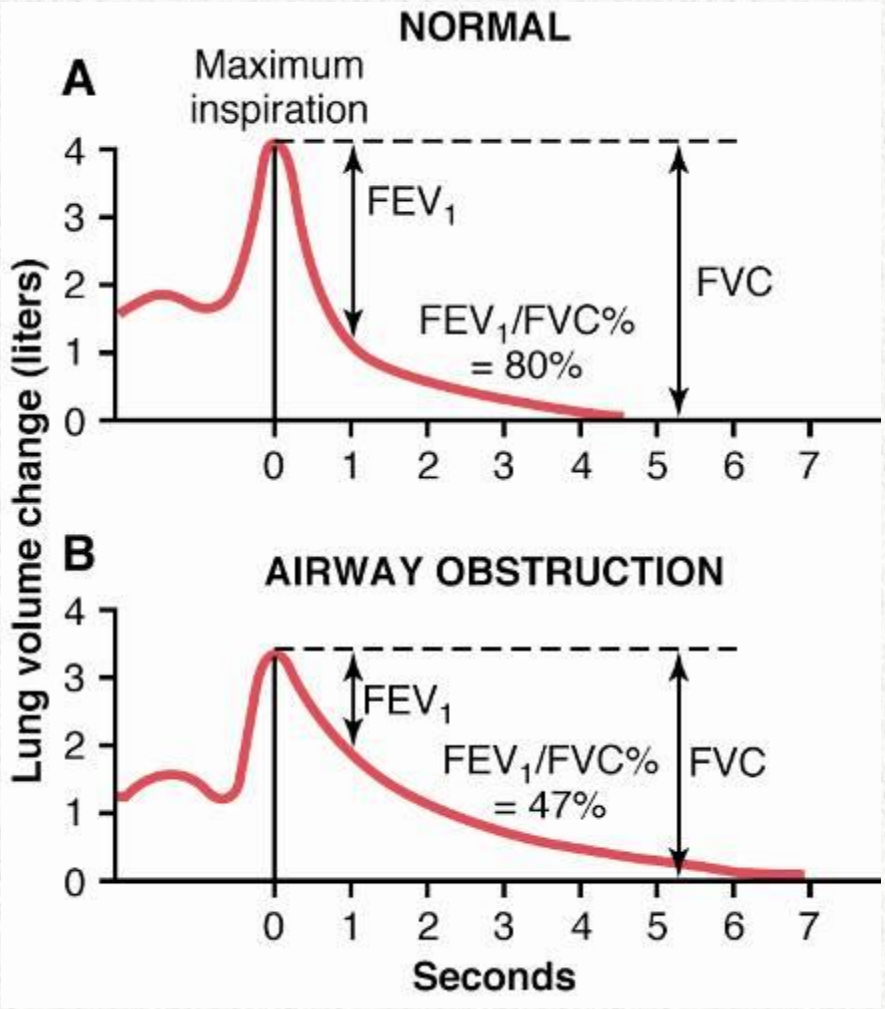



Figure 42-3

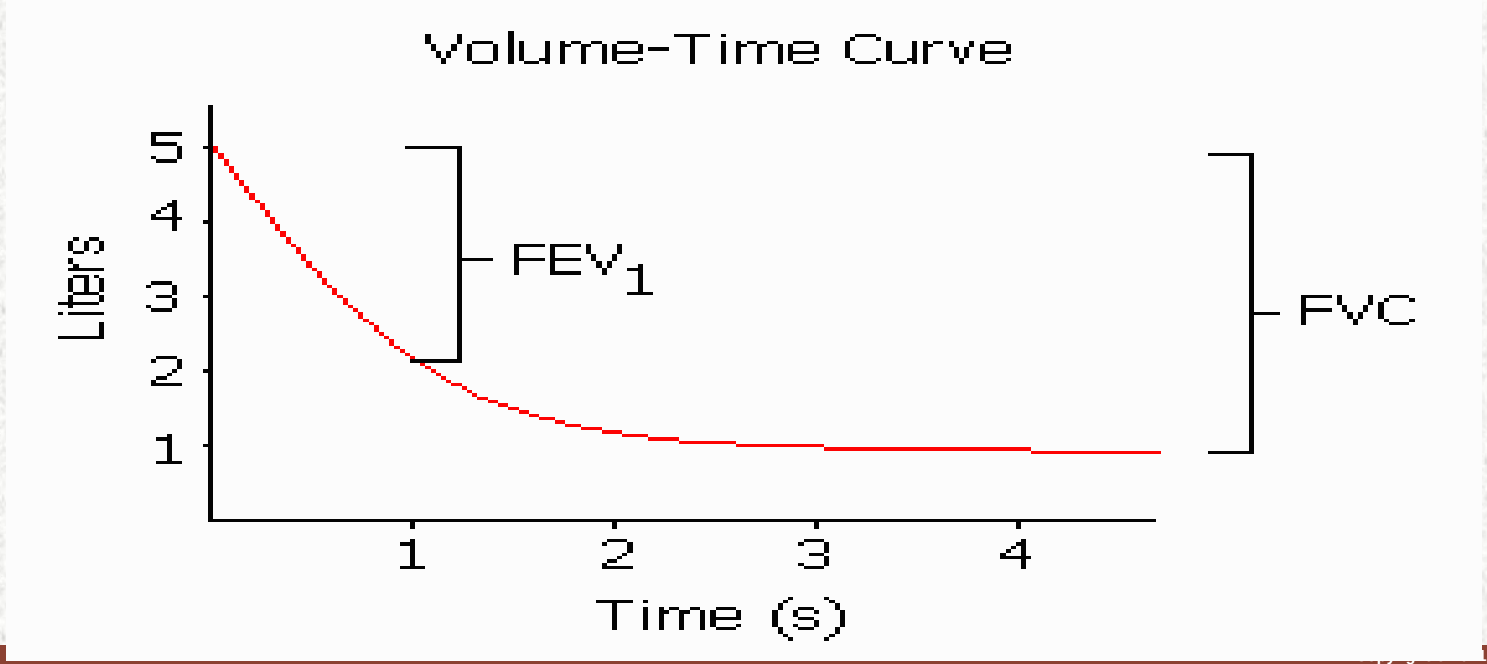
**Forced expiration curves are particularly useful because they are so reproducible.**

**FEV1 (Forced Expiratory Volume in 1 Second)** -- This is the volume of air expired in the first second during maximal expiratory effort. The FEV1 is reduced in both obstructive and restrictive lung disease. The FEV1 is reduced in obstructive lung disease because of increased airway resistance. It is reduced in restrictive lung disease because of the low vital capacity

# Chronic Obstructive Pulmonary Disease

$FEV_1$ values (expressed as a percentage of **predicted**) may classify the severity of the COPD

| |
|---|
| 60% - 79% predicted: MILD COPD |
| 40% - 59% predicted: MODERATE COPD |
| Less than 40% predicted: SEVERE COPD |

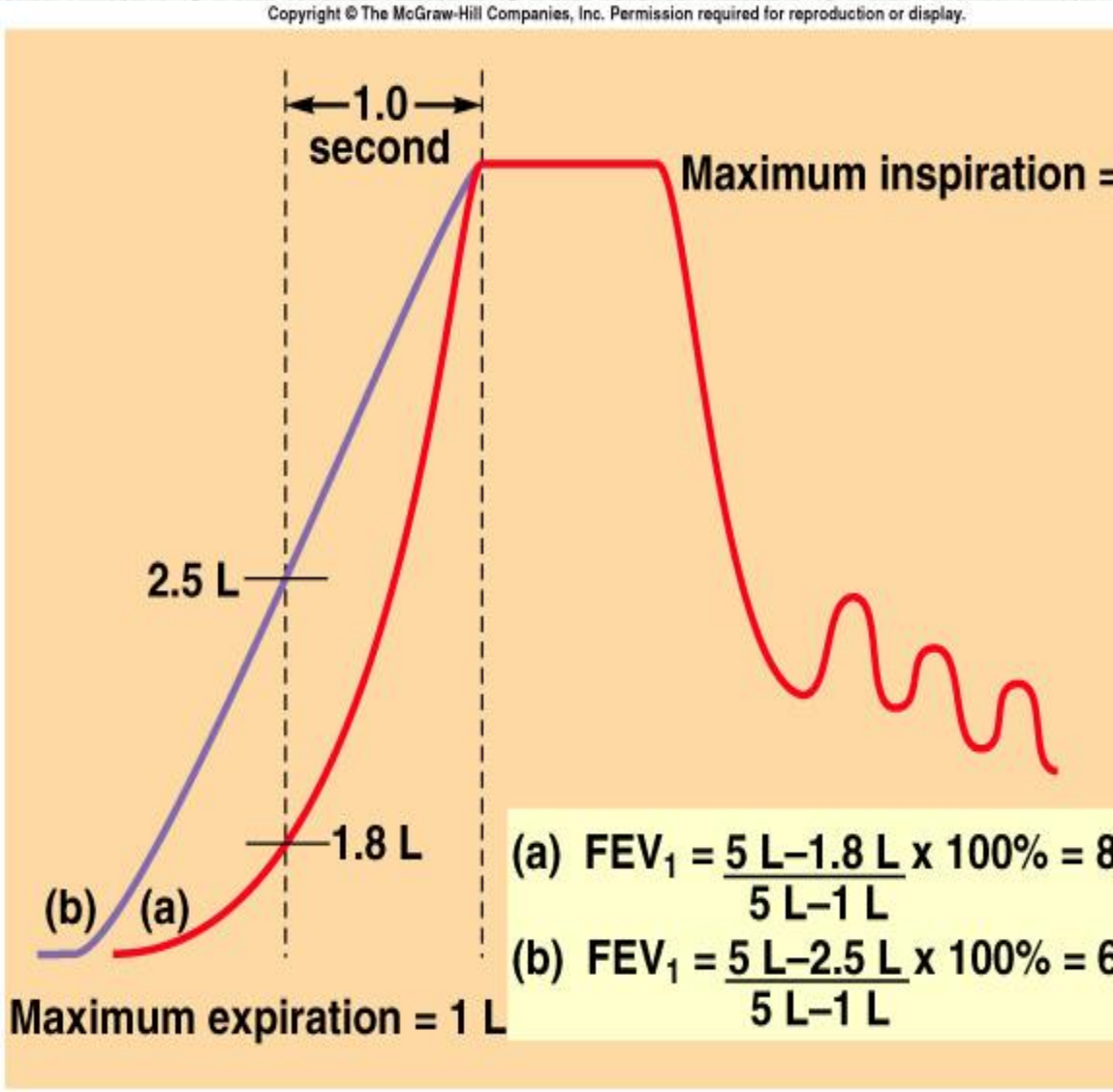


- **FEV1/FVC** -- This is the percentage of the vital capacity which is expired in the first second of maximal expiration. In healthy patients the FEV1/FVC is usually around 70%. In patients with obstructive lung disease FEV1/FVC decreases and can be as low as 20-30% in severe obstructive airway disease. Restrictive disorders have a near normal FEV1/FVC.

# Restrictive and Obstructive Disorders

- Restrictive disorder:
  - Vital capacity is reduced.
  - FVC is normal.
- Obstructive disorder:
  - Diagnosed by tests that measure the rate of expiration.
    - VC is normal.
    - $FEV_1$ is < 80%.





**Closing volume** (CV) *is the volume of air that can be exhaled after the gravitationally dependent airways have closed down. The point at which the closure begins during expiration is called the closing point which is normally reached near to residual volume. If its reached before the end of normal* $V_T$*, then the V/Q ratio falls sharply. By the mid-forties, CV equals FRC in the lying position and by the mid-sixties it equals FRC in the erect position. It increases in smokers, pulmonary congestion, pulmonary edema, chronic bronchitis, and excessive bronchial secretions. Any condition which interfere with diaphragmatic movement such as, tight clothing, obesity, pregnancy, ascites, phrenic paralysis, obesity, pneumothorax*

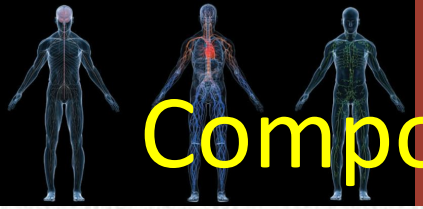
# ABG

- An **arterial blood gas** (**ABG**) is a blood test that is primarily performed using blood from an artery. It involves puncturing an artery with a thin needle and syringe and drawing a small volume of blood. The most common puncture site is the radial artery at the wrist, but sometimes the femoral artery or other sites are used. The blood can also be drawn from an arterial catheter.

- **$DL_{CO}$ (Diffusing Capacity of the Lung for Carbon Monoxide)** -- Carbon monoxide can be used to measure the diffusing capacity of the lung. The diffusing capacity of the lung is decreased in parenchymal lung disease and COPD (especially emphysema) but is normal in asthma.

| | Obstructive Pattern | Restrictive Pattern |
|---|---|---|
| RV | ↑ | ↓ |
| FRC | ↑ | ↓ |
| TLC | N ↑ | ↓ |
| VC | N ↓ | ↓ |
| FVC | N ↓ | ↓ |
| $FEV_{1.0}$ | ↓ | ↓ |
| $FEV_{1.0}/FVC$ | ↓ | N ↑ |
| MMFR | ↓ | N↓ |
| CV | ↑ | - |
| $P_aO_2$ | ↓ | N ↓ Exercise |
| $P_aCO_2$ | ↑ | N ↓ |
| pH | ↓ | N ↑ |

- The test is used to determine the pH of the blood, the partial pressure of carbon dioxide and oxygen, and the bicarbonate level. Many blood gas analyzers will also report concentrations of lactate, hemoglobin, several electrolytes, oxyhemoglobin, carboxyhemoglobin .



# Components of the Arterial Blood Gas

The arterial blood gas provides the following values:

**pH**

Measurement of acidity or alkalinity, based on the hydrogen (H+) ions present.

The normal range is 7.35 to 7.45

**PaO2**

The partial pressure of oxygen that is dissolved in arterial blood.

The normal range is 80 to 100 mm Hg.

**SaO2**

The arterial oxygen saturation.

The normal range is 95% to 100%.

**PaCO2**

The amount of carbon dioxide dissolved in arterial blood.

The normal range is 35 to 45 mm Hg.

**HCO3**

The calculated value of the amount of bicarbonate in the bloodstream.

The normal range is 22 to 26 mEq/liter

**B.E.**

The base excess indicates the amount of excess or insufficient level of bicarbonate in the system.

The normal range is –2 to +2 mEq/liter.

(A negative base excess indicates a base deficit in the blood.)

# Oxygen Therapy

- Atmospheric
- Hypoventilation
- impaired alveolar membrane
- anemia, abnormal hemoglobin
- inadequate tissue use

# Responses to Oxygen Therapy

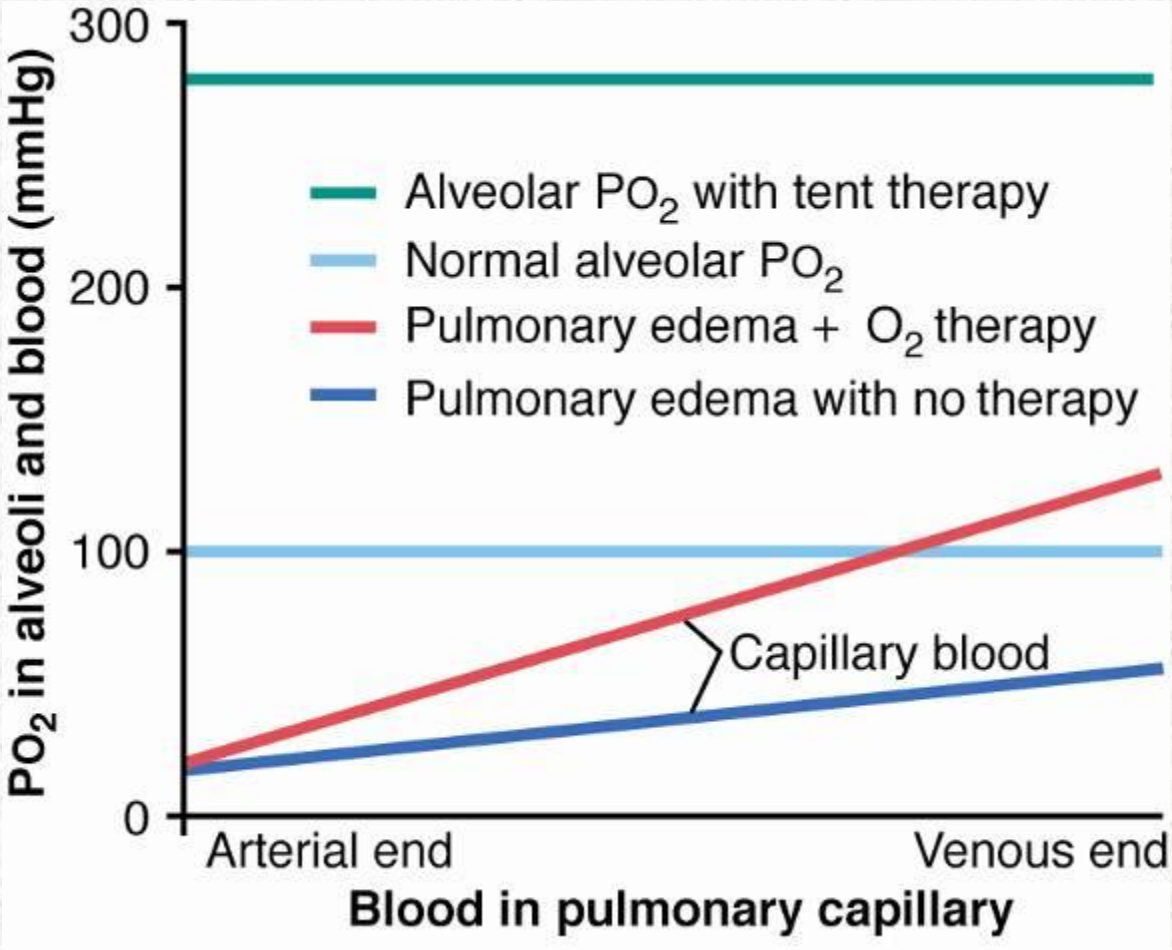



Figure 42-8

# THANK YOU