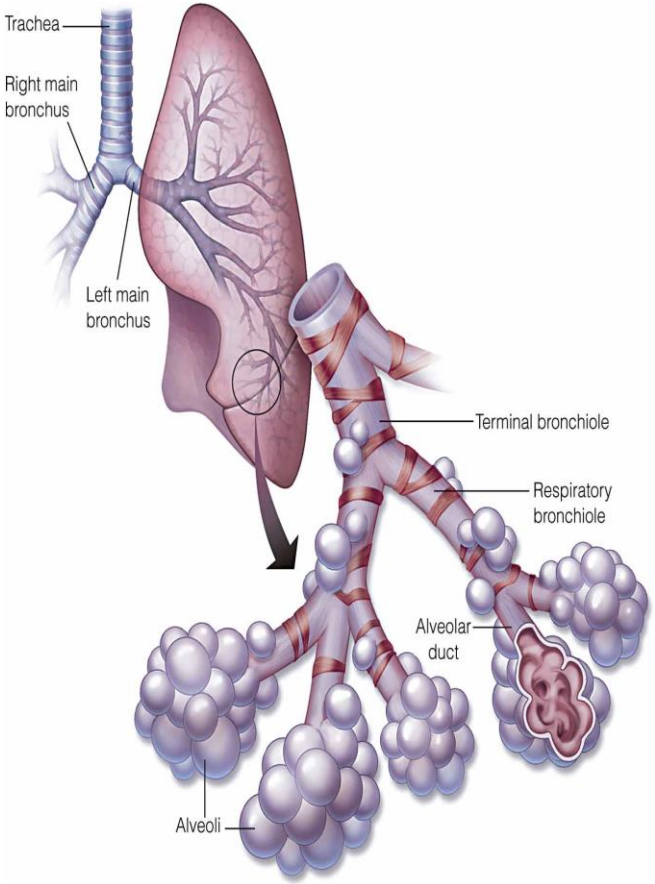
Lung Diseases…three families

- Prevalence of lung disease depends on the population, but in general we have three families:
  1. obstructive is 70%,
- 2. restrictive is 20-25% and
- 3. vascular the rest 5-10%

Introduction

- Bronchial asthma and COPD (chronic obstructive pulmonary disease) are obstructive pulmonary diseases that affected millions of people all over the world
- Asthma is a serious global health problem with an estimated 300 million affected individuals
- COPD is the fourth leading cause of death in the world and further increases in its prevalence and mortality can be predicted



Pulmonary Pathology

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

COPD

1. Emphysema 2. Chronic bronchitis ±3. Bronchial asthma…only when it becomes chronic

1. ↑ Compliance: mainly in emphysema, due to destruction of the elastic fibers,
2. ↑ FRC:
3. . ↑ Airway R. more fluctuation during dynamic phases mainly in asthma.

Smoking inhibits cilia → accumulation of mucus → bacterial growth → chronic bronchitis.

Smoking induces hyperplasia of Goblet cells → excessive mucus secretion → bacterial growth → chronic bronchitis

Chronic bronchitis….excessive mucous production

Asthma….bronchiole constriction

Chronic Obstructive Pulmonary Disease

- **Chronic pulmonary emphysema**
  - infection (secretions)
  - Obstruction→ turbulence → wheezes
  - loss of parenchyma…loss of surface area available for diffusion …hypoxemia…hypoxia
  - **Consequences**

    - high airway resistance

    - decreased diffusing capacity

    - pulmonary hypertension…increase pulmonary vascular resistance

Pathology

Resistance to airflow

- Lumen
- excessive secretions
- obstruction due to aspiration

– Airway
  - contraction of smooth muscle
  - hypertrophy of bronchial wall

– outside of airway
  - destruction of the elastin fibers

The work of Breathing:

$W = \Delta P \times \Delta V$

Normally 0.5 L X 5 cm H_2O = 0.25 J……*One Joule is equal to = 10 L X cm H_2O = J*

50% of the work of breathing is used to expand the lungs and 50% to expand the chest wall.

The work of breathing is used to overcome:

1) Elastic forces (70%) (Contribution to the total work of breathing): They are under static (no-flow conditions). Two types:

A) Elastic fibers (one third)

B) Surface tension (two thirds).

2) Non elastic forces (30%) (Only present during the dynamic phase of breathing). Again two types:

A) 20% is the tissue viscous resistance, it occurs only during tissue movement. It is frictional R which resists a change in shape. It always opposes motion (during inspiration and during expiration)

B) 80% is due to air way resistance:

$T_{Total} = P_{Elastic} + P_{Nonelastic}$

$P_{Elastic}$: elastic recoil P

$P_{Nonelastic}$: Is the pressure to overcome resistance to airflow.

When no air movement takes place $T_{Total} = E_{Elastic}$

Always remember Ohm's law: Flow is directly proportional to the driving force and inversely proportional to the resistance
Flow = pressure difference / resistance = $\Delta P/R$….
What is the ΔP? It is the pressure difference between the two opposite ends of the airways: ($P_{alv} - P_{atm}$)
If R is large then ΔP must be large too in order to keep air flow constant.
Boyle's law: The pressure and the volume of a gas are inversely related if the temperature is constant.
$R_{airways}$ resides mainly in large airways. In contrast, the small airways have small tiny diameter, but large cross sectional area, thus they offer little resistance to airflow.

The French physician Jean Leonard Marie **Poiseuille's**

$$V = (\Delta P)/ \pi r^4/8\eta l$$

***The most important point to remember is R is inversly proportional to $1/ r^4$

Small change in "r" results in huge change in R.

Air flow = $(P_{atm} - P_{alv})/R$

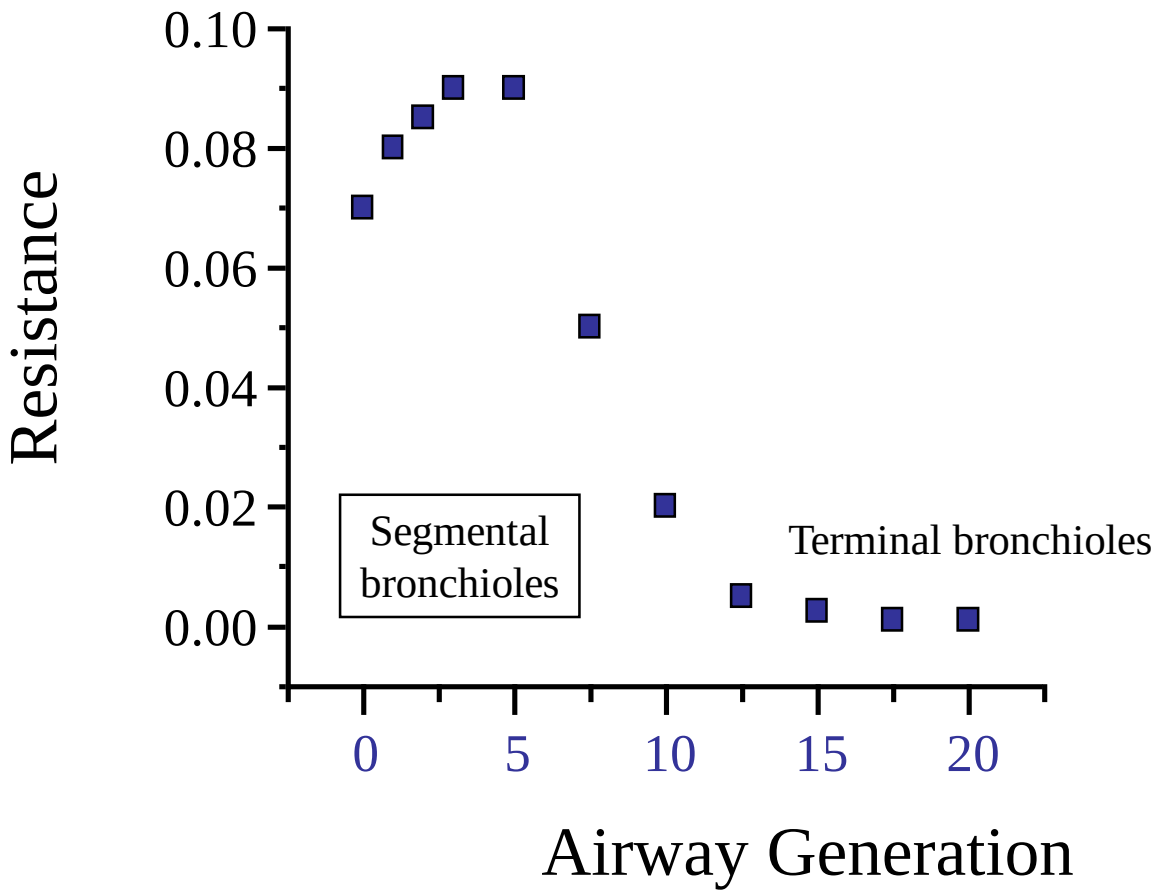
Remember the four Take home messages: Discussed In the lecture

1. Normally: R is small and negligible
2. Normally: R resides in large airways not in the small ones
3. Small airways participate in the increase in R disease condition.
4. R, when increased is Manifested mainly during expiration rather than during inspiration.

40-50% of airway R resides in the upper airways (larynx and above).
40% in the trachea and up to the first seven generations.. The medium size bronchi (2-4 mm in diameter) around the forth generation are the site for greatest R in the bronchial tree (excluding the upper airways)….. High velocity of air flow because less cross sectional area …see <u>next slide please</u>
Only 10-20% in small airways.
Beyond generation 15th R is almost zero.

In contrast to vascular system, where the branches have more cross sectional area than the original. In bronchial tree, cross sectional area start increasing from generation 4-5 and further. This observation is figured out from the velocity of air flow. It is increasing in the first few branches and then decreases. When it reaches terminal bronchioles it is less than 1% of the velocity at trachea.
The Ppl forms the environment for small airways. Transmural P (ΔP pressure across airway wall or across alveolar wall) is greater during inspiration, which makes airway open. In expiration transmural P is less $\rightarrow$ more R to air flow during expiration

Airway Resistance

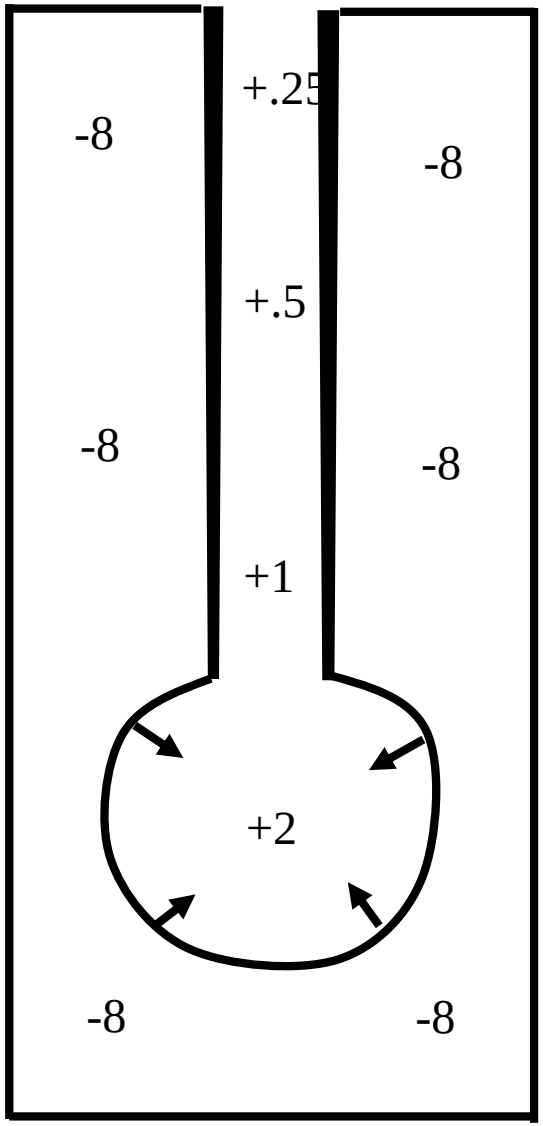


Ventilation

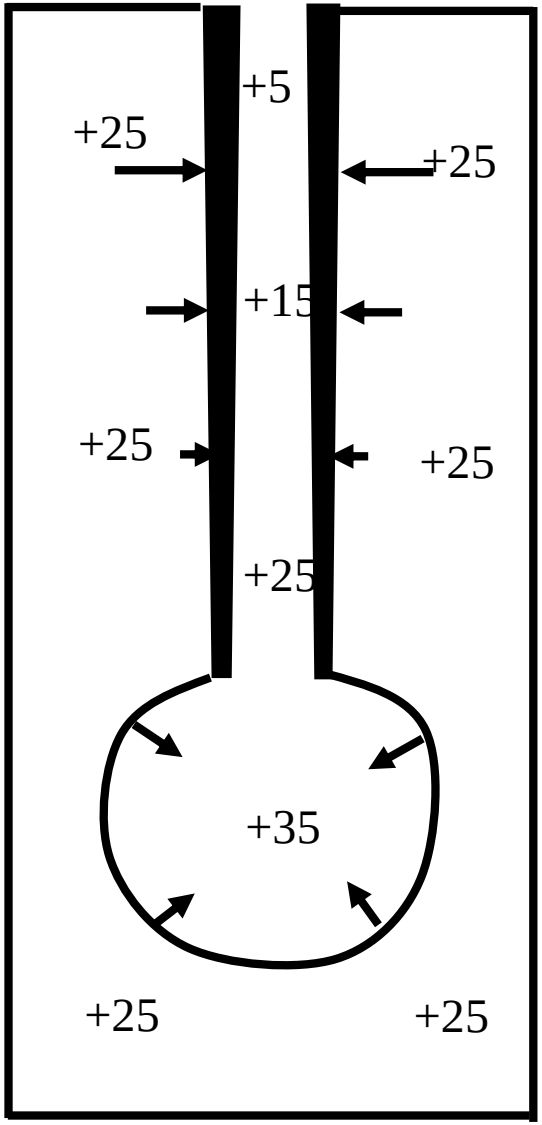
FACTOR	AFFECTED BY	MEDIATED BY
Length of the system	Constant; not a factor	
Viscosity of air	Usually constant; humidity and altitude may alter slightly	
Diameter of airways		
Upper airways	Physical obstruction	Mucus and other factors
Bronchioles	Bronchoconstriction	Parasympathetic neurons (muscarinic receptors), histamine, leukotrienes
	Bronchodilation	Carbon dioxide, epinephrine (β_2-receptors)

Pulmonary Disorders (continued)

- **Emphysema:**
  - **Is Chronic progressive condition**
    - **Alveolar tissue is destroyed leading to decrease surface area available for diffusion**
    - **Decreases ability of bronchioles to remain open during expiration…bcz of destruction of elastic fibers which keep small airways open,,,obstruction comes from ouside**
    - **Cigarette smoking stimulates macrophages and leukocytes to secrete protein digesting enzymes that destroy tissue.**



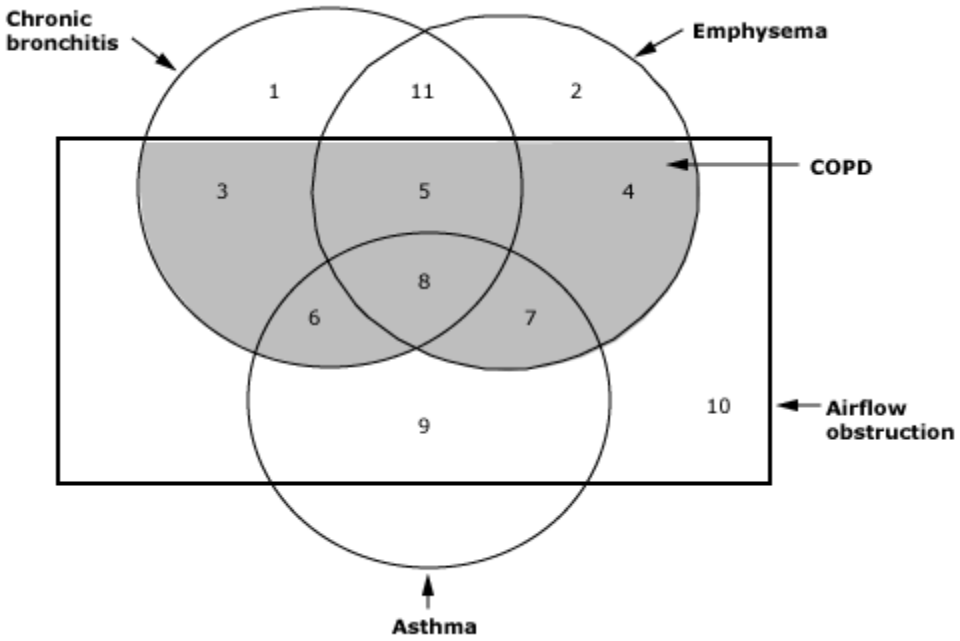
Passive Expiration



Forced Expiration

Control of Bronchiolar Diameter

- Nervous
  - Sympathetics
    - β_2 receptors dilate (salbutamol, dobutamine, albuterol, fenoterol, terbutaline).
  - Parasympathetics
    - Acetylcholine constrict bronchioles
- Humoral
  - Histamine, acetylcholine >> Constrict
  - Adrenergic (β agonists) >> Relax


Chronic bronchitis
Emphysema
1
11
2
COPD
3
5
4
8
6
7
10
Airflow obstruction
9
Asthma

This nonproportional Venn diagram shows subsets of patients with chronic bronchitis, emphysema, and asthma (black circles). The subsets defined as COPD are shaded gray. Subset areas are not proportional to actual relative subset sizes. Asthma is, by definition, associated with reversible airflow obstruction; **in variant asthma, special maneuvers may be necessary to make the obstruction evident**. Patients with asthma whose airflow obstruction is completely reversible (subset 9) are not considered to have COPD. In many cases it is virtually impossible to differentiate patients with asthma whose airflow obstruction does not remit completely from persons with chronic bronchitis and emphysema who have partially reversible airflow obstruction with airway hyperreactivity. Thus, patients with unremitting asthma are classified as having COPD (subsets 6, 7 and 8). Chronic bronchitis and emphysema with airflow obstruction usually occur together (subset 5), and some patients may have asthma associated with these two disorders (subset 8). Individuals with asthma exposed to chronic irritation, as from cigarette smoke, may develop chronic productive cough, a feature of chronic bronchitis (subset 6). Such patients are often referred to in the United States as having asthmatic bronchitis or the asthmatic form of COPD. **Persons with chronic bronchitis or emphysema without airflow obstruction (subsets 1, 2 and 11) are not classified as having COPD**. In order to emphasize that cough and sputum are abnormal, individuals with these symptoms and normal lung function were classified as GOLD Stage 0, at risk, in the original GOLD classification [1]. This stage was deleted in the 2006 revision because of uncertainties about whether it is progressive [2]. Patients with airway obstruction due to diseases with known etiology or specific pathology, such as cystic fibrosis or obliterative bronchiolitis (subset 10), are not generally included in the definition of COPD.

1. Data from: Global initiative for chronic obstructive lung disease (GOLD). Workshop report: Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease: Update 2005.

2. Data from: Global initiative for chronic obstructive lung disease (GOLD). Workshop report: Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease: Update 2006.

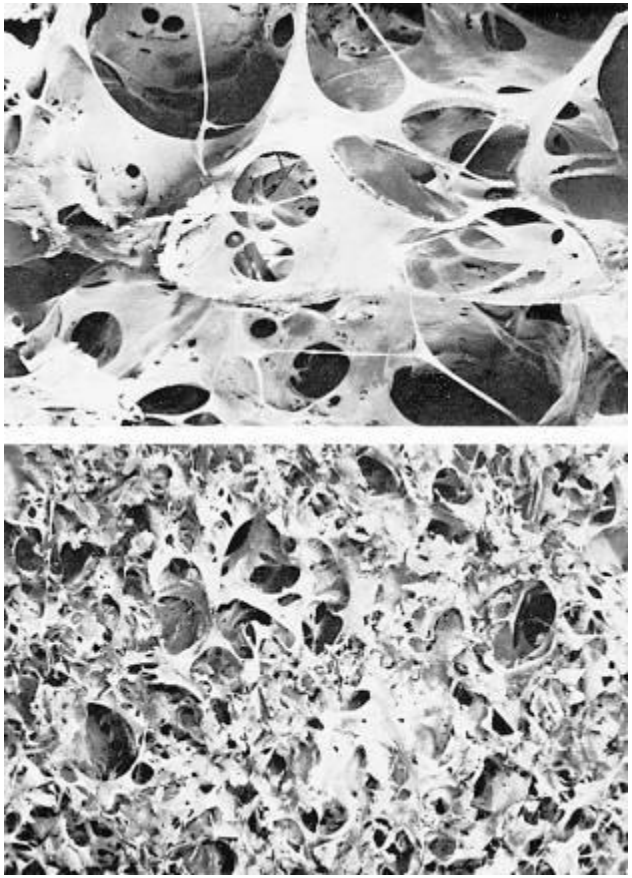
Pursed Lip Breathing in COPD patients

Collapse of your airways on expiration, as your lungs are getting smaller as you breathe out. This is a particularly serious problem in people with Emphysema, as the elastic supporting lung structure helping to keep the airways open is deficient.

Pursed Lip Breathing simply imposes a slight obstruction to expiration air flow at the mouth, which generates a back pressure throughout the airways, and therefore a stenting effect to help prop open the airways and assist expiration and lung emptying. It must be emphasized, the amount of pressure supplied by you by pursing your lips together must, as usually described, be "minimal," or "gentle."

Restrictive Diseases

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



Emphysematous Lung

Normal Lung

Figure 42-4

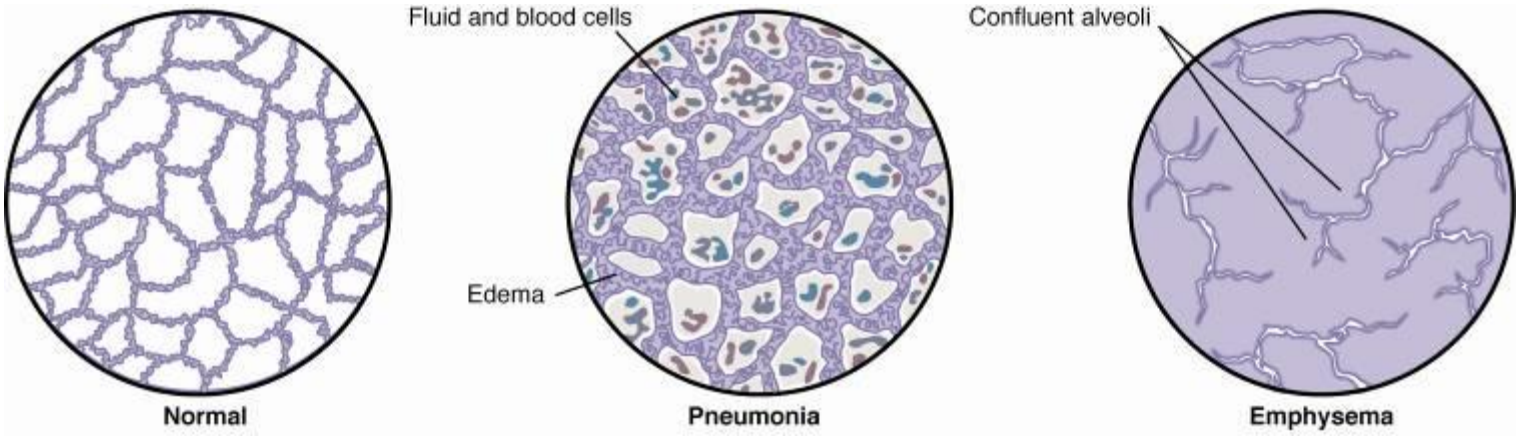

Fluid and blood cells
Edema
Confluent alveoli
Normal
Pneumonia
Emphysema

Figure 42-5

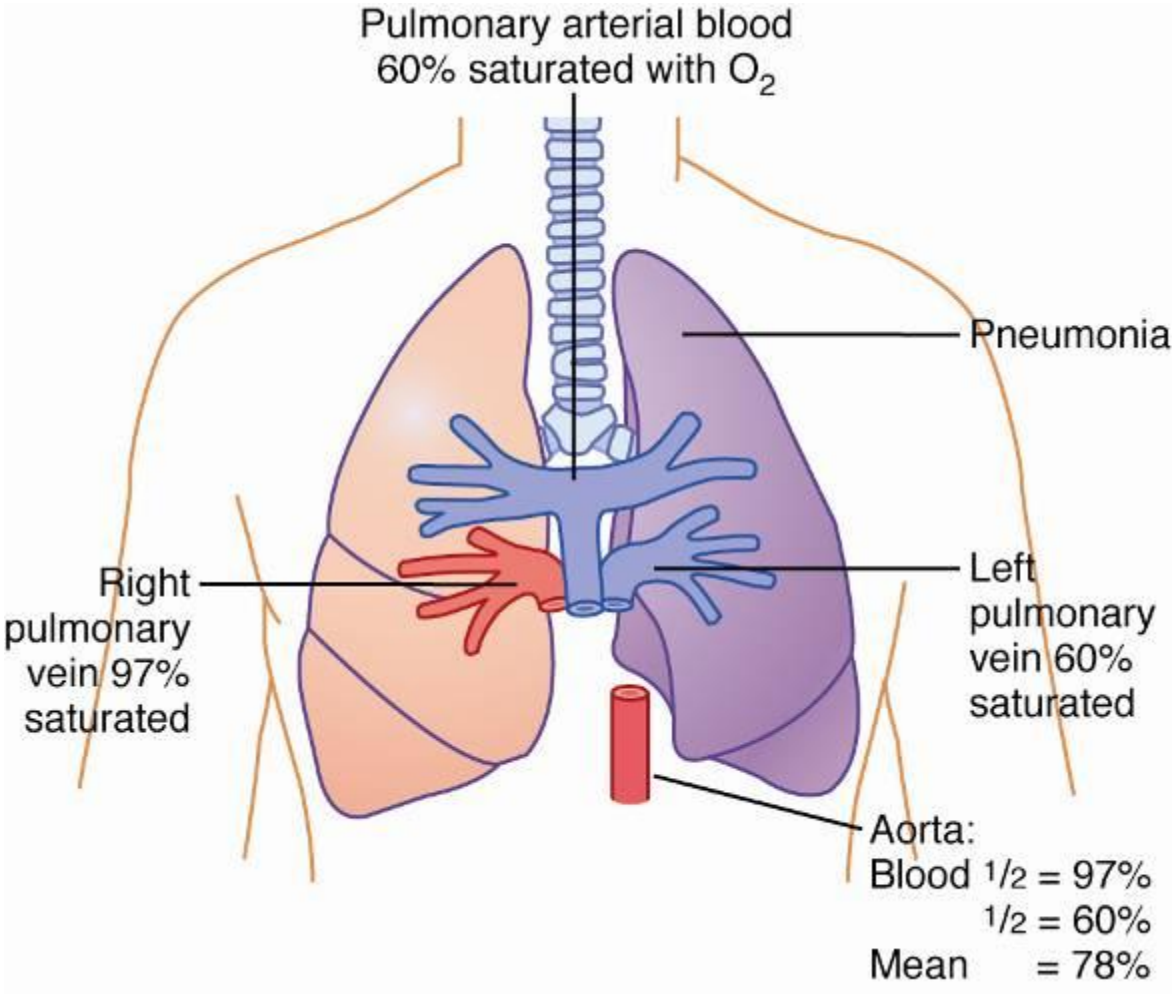

Pulmonary arterial blood
60% saturated with O_2
Pneumonia
Right
pulmonary
vein 97%
saturated
Left
pulmonary
vein 60%
saturated
Aorta:
Blood 1/2 = 97%
1/2 = 60%
Mean = 78%

Figure 42-6

Pathology

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

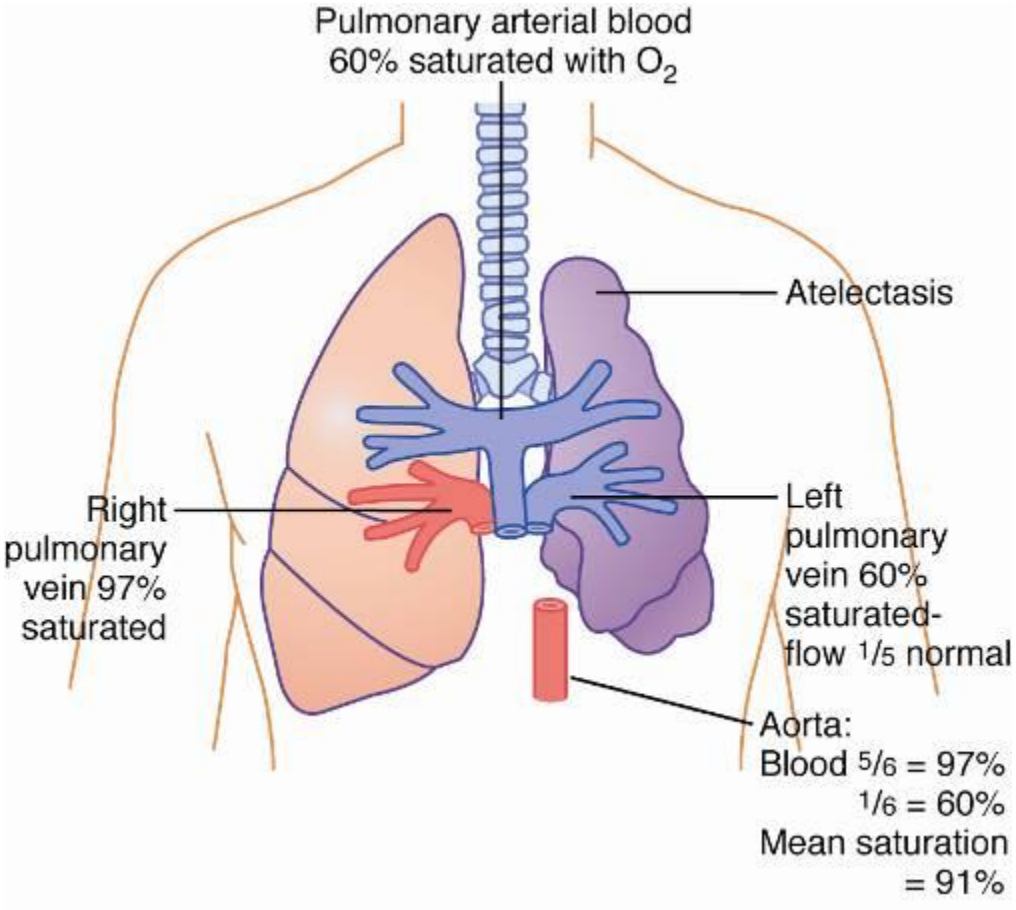
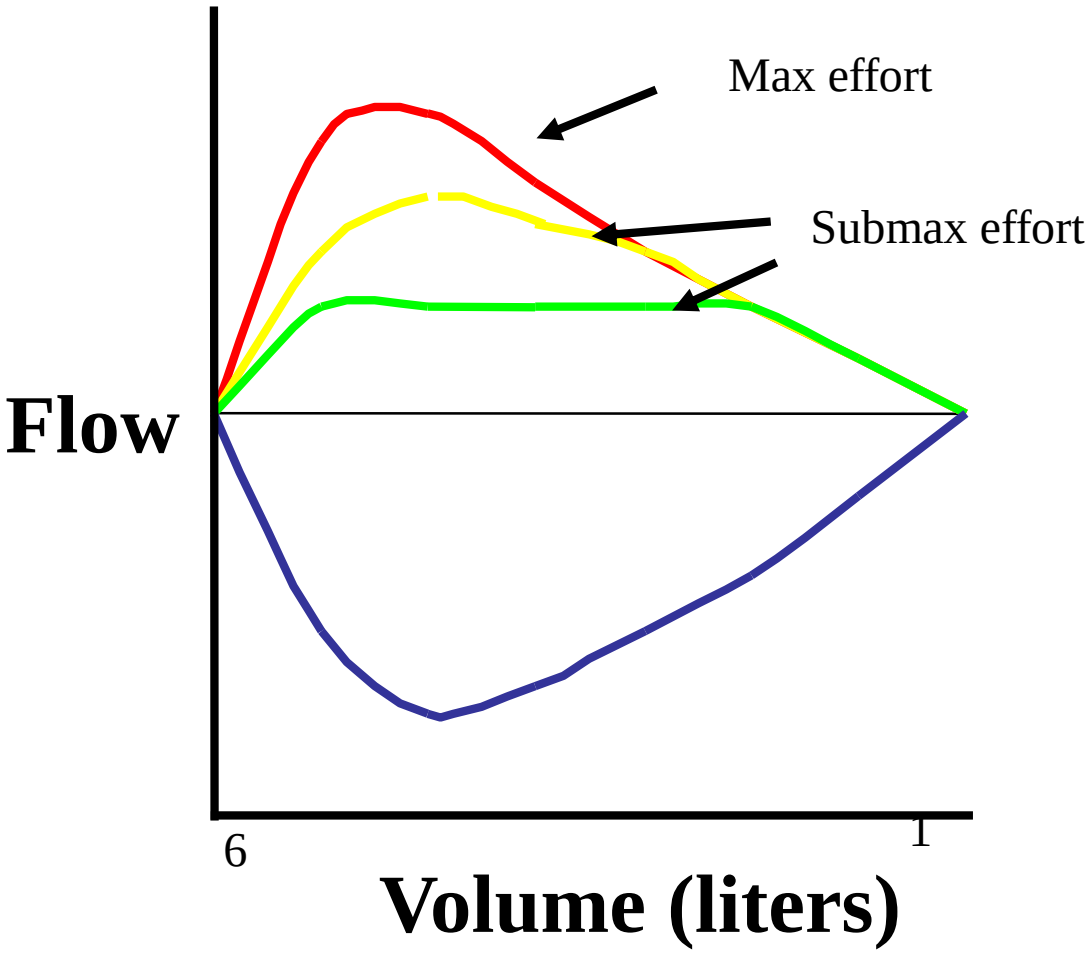


Figure 42-7

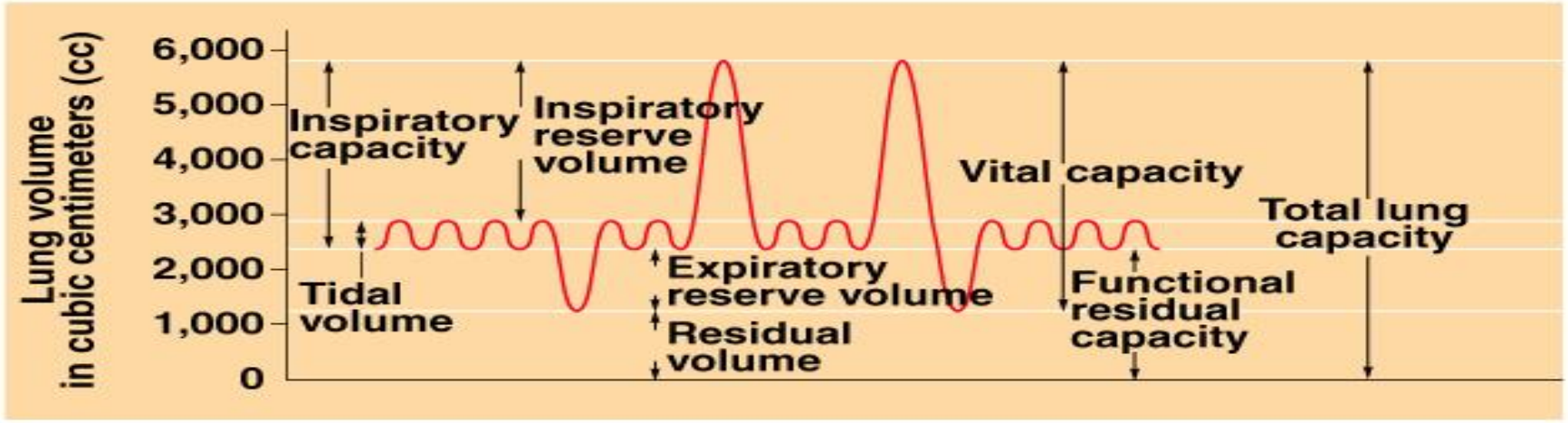
- **About Pulmonary Function Tests in Obstruction: Go to the e-learning videos**
- Spirometry provides an objective assessment of airflow obstruction and is important in staging asthma severity. It should be done on initial diagnosis of asthma, after treatment is started and symptoms have stabilized, 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 β_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**
- In the next slide is an example of a volume-time curve. It shows the amount of air expired from the lungs as a function of time.

Flow-volume Curve



Pulmonary Function Tests

- 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



Terms Used to Describe Lung Volumes and Capacities

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

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

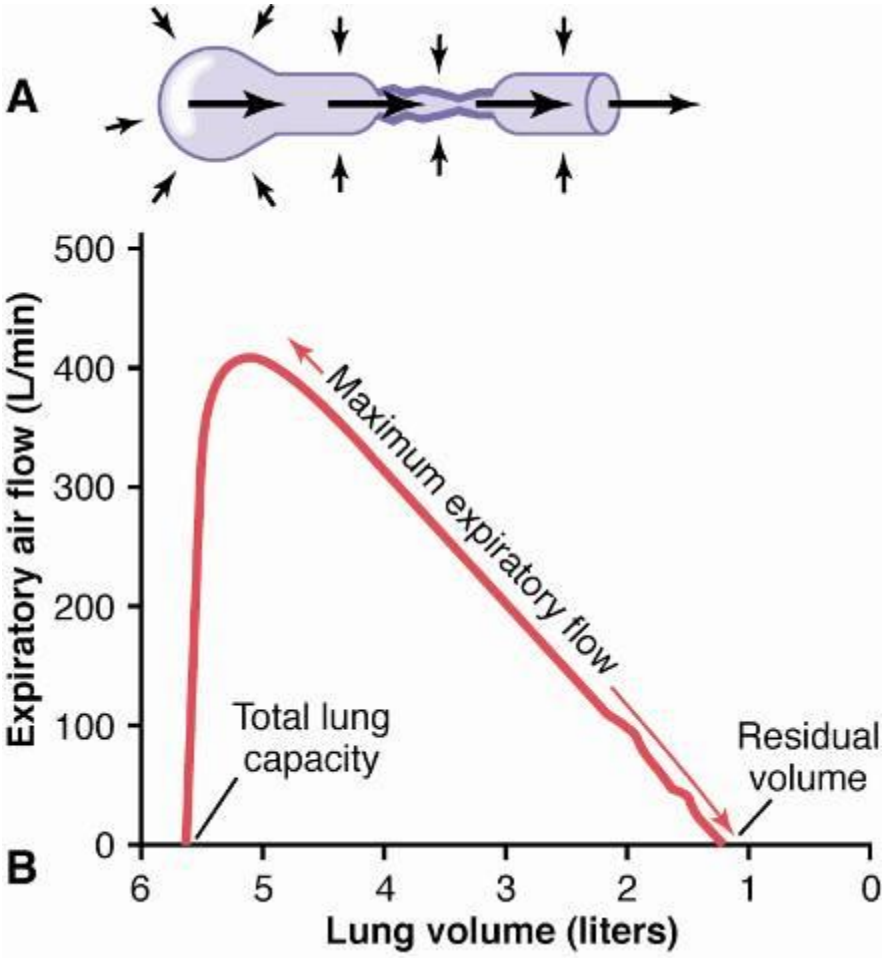

A
B
Expiratory air flow (L/min)
500
400
300
200
100
0
Maximum expiratory flow
Total lung capacity
Residual volume
6
5
4
3
2
1
0
Lung volume (liters)

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

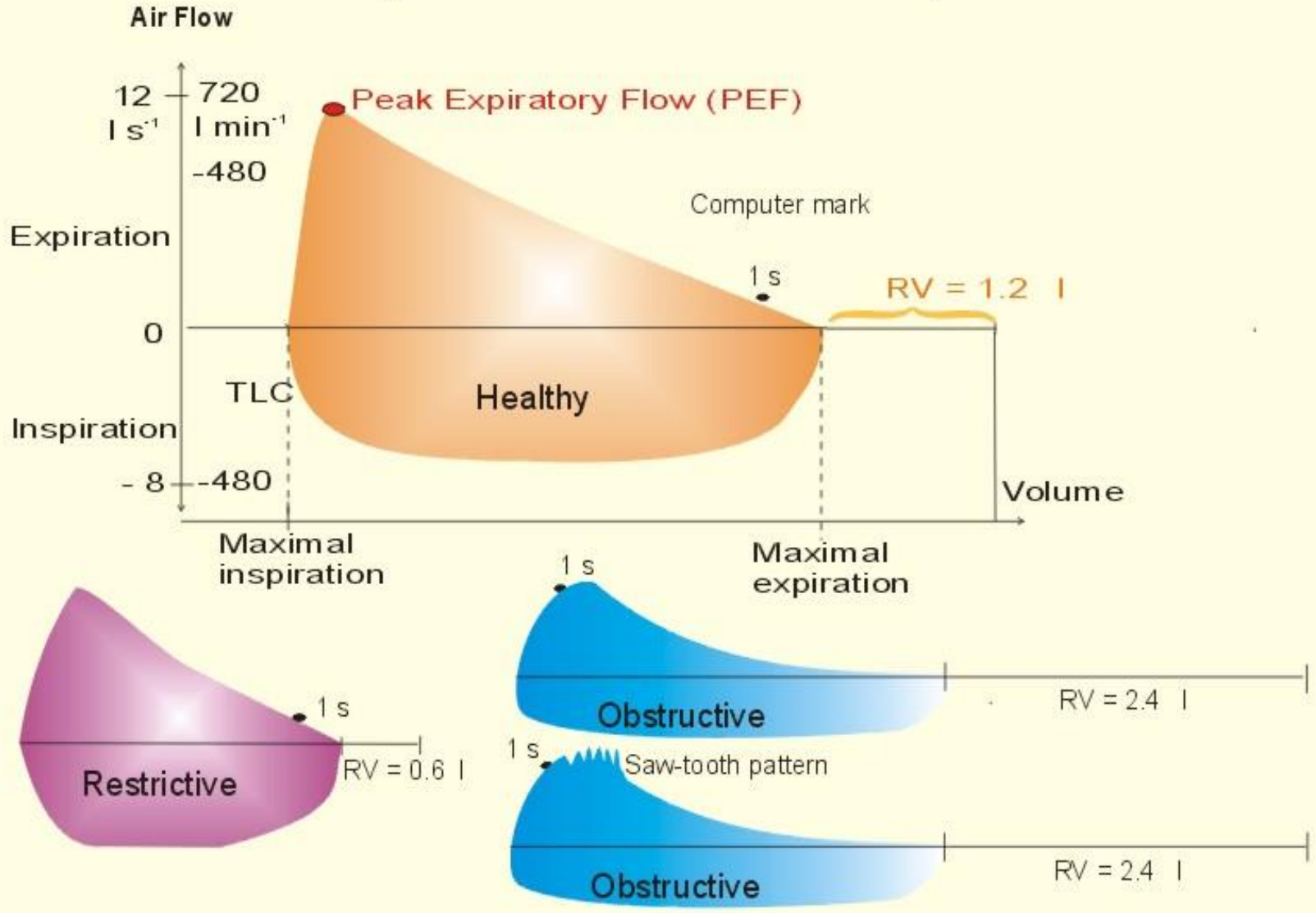


Fig. 13-6

KMc

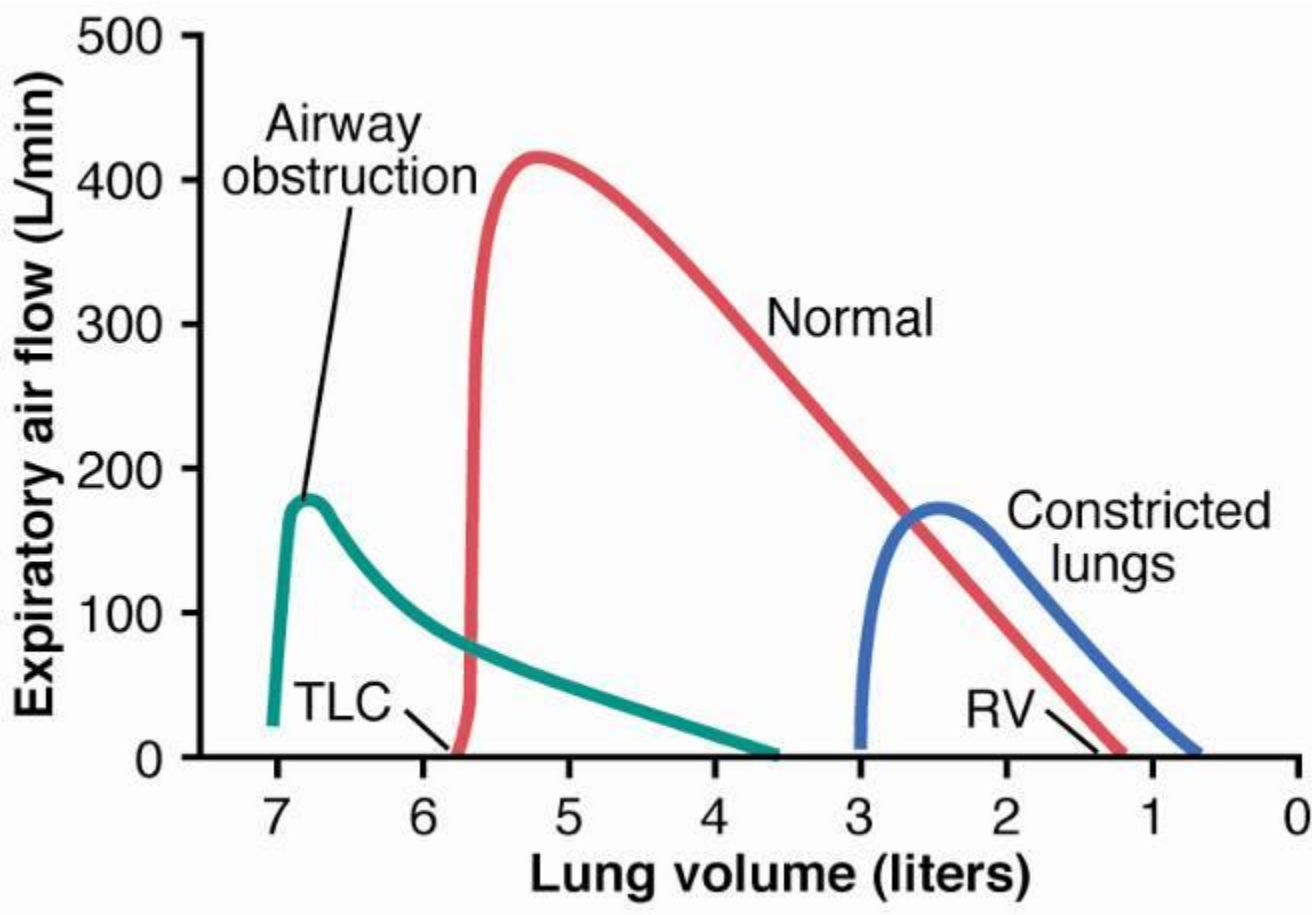

Expiratory air flow (L/min)
500
400
300
200
100
0
Airway obstruction
Normal
Constricted lungs
TLC
RV
7
6
5
4
3
2
1
0
Lung volume (liters)

Figure 42-2

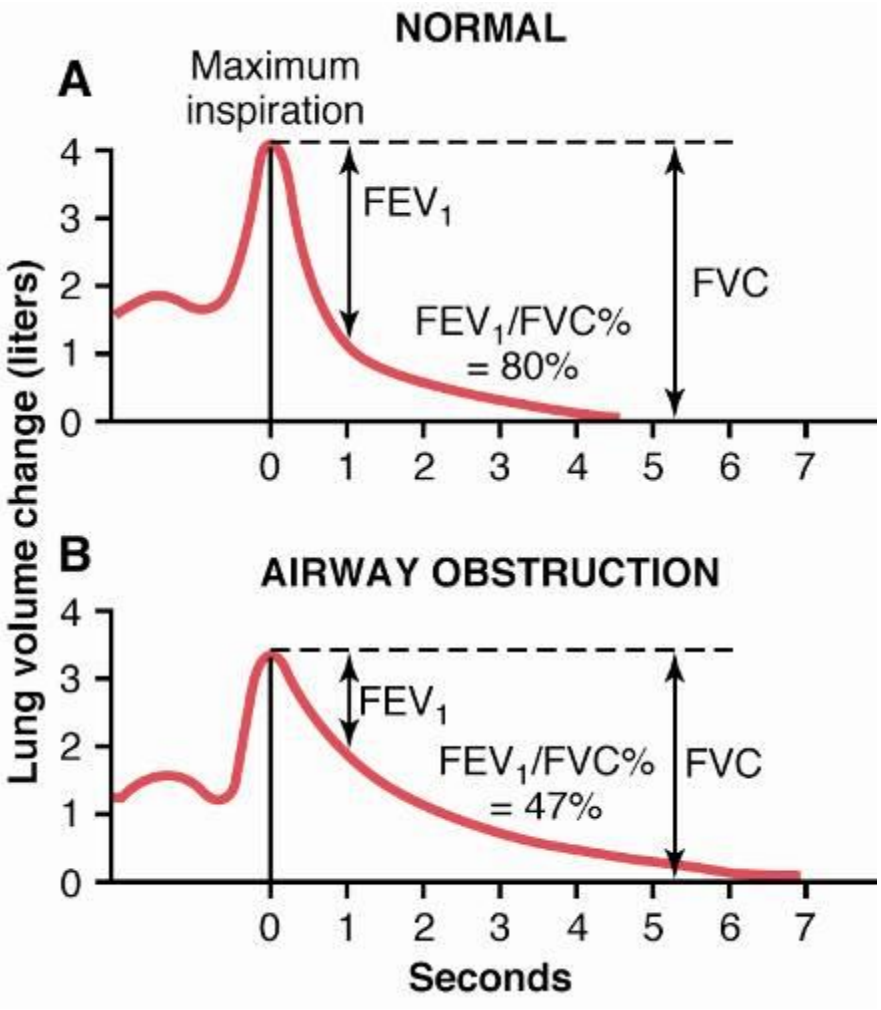

NORMAL
A
Maximum inspiration
FEV1
FVC
FEV1/FVC% = 80%
B
AIRWAY OBSTRUCTION
FEV1
FEV1/FVC% = 47%
FVC
Lung volume change (liters)
0 1 2 3 4
0 1 2 3 4 5 6 7
Seconds

Figure 42-3

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

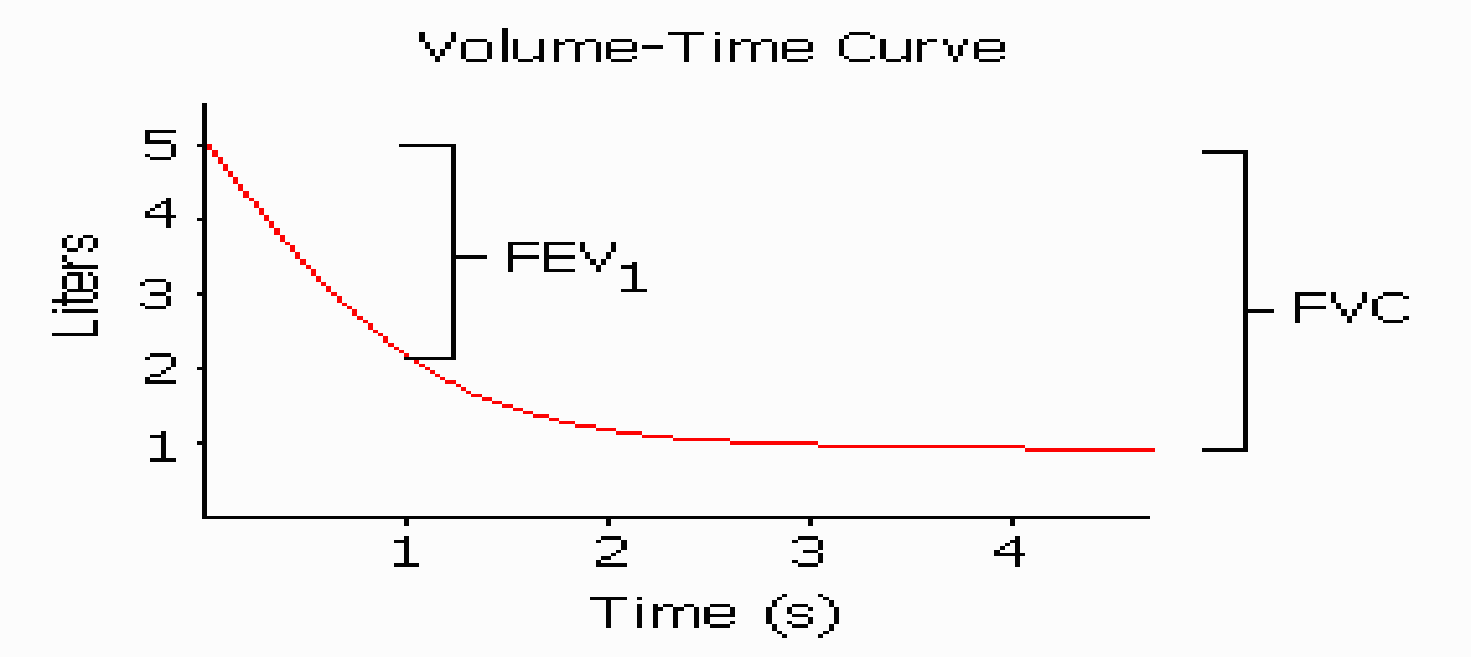
FEV1 (Forced Expiratory Volume in 1 Second) -- This is the volume of air expired in the first second during maximal expiratory effort. The FEV1 is reduced in both obstructive and restrictive lung disease. The FEV1 is reduced in obstructive lung disease because of increased airway resistance. It is reduced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

Chronic Obstructive Pulmonary Disease

Staging of COPD based on FEV_1
GOLD: **G**lobal **I**nitiative of chronic obstructive **L**ung **D**isease

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

	FEV_1 compared to predicted for age/ gender/ height
GOLD Stage I	$FEV_1 \geq 80\%$
GOLD Stage II	$50\% \leq FEV_1 < 80\%$
GOLD Stage III	$30\% \leq FEV_1 < 50\%$
GOLD Stage IV	$FEV_1 < 30\%$



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 or sometimes more than normal.

Staging of COPD based on FEV_1

GOLD: **G**lobal **I**nitiative of chronic obstructive **L**ung **D**isease

FEV_1 compared to predicted for age/ gender/ height

GOLD Stage I

$FEV_1 \geq 80\%$

GOLD Stage II

$50\% \leq FEV_1 < 80\%$

GOLD Stage III

$30\% \leq FEV_1 < 50\%$

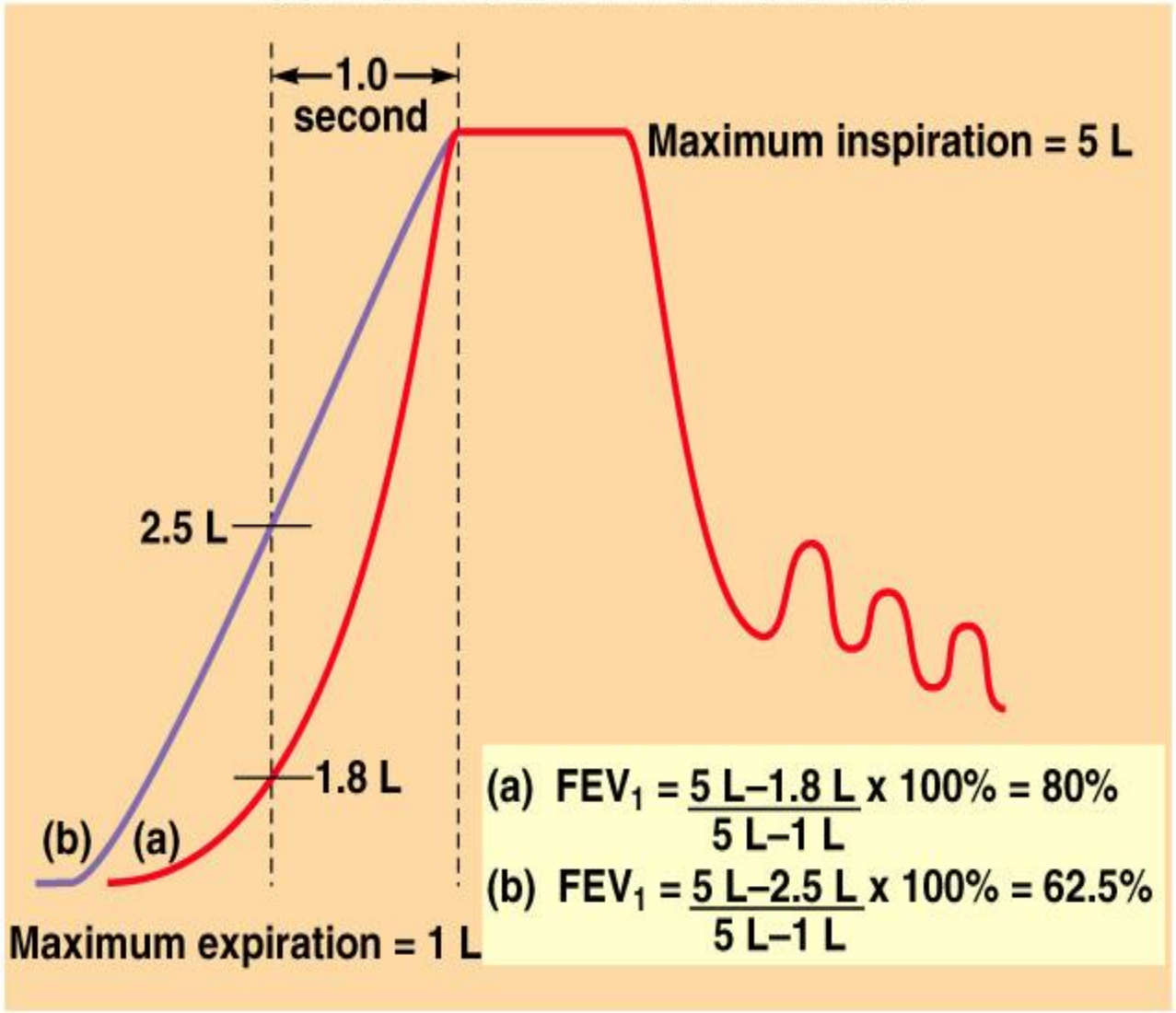
GOLD Stage IV

$FEV_1 < 30\%$

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%.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



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*

Closing capacity

Closing capacity
= the lung volume at which the small airways in the lung first start to close
--> Impairs gas exchange and increase venous admixture
--> Decrease PaO_2

Closing capacity
= RV + closing volume

Variation of closing capacity

Closing capacity increases with age

FRC does not change with age

In erect position, closing capacity = FRC = 40% of VC at 66 y.o.

In supine position, closing capacity = FRC at 44 y.o.

Measurement of closing volume

Closing volume is measured with single breath nitrogen test

A single breath of 100% O_2 from residual volume

Slow expiration with a rapid nitrogen analyzer

Late in expiration when airway closure starts to occur, expired [N_2] starts to rise about the plateau.

Closing volume = the volume expired, from the start of this rise to the end of maximal expiration

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

- 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

PaO_2

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

The normal range is 80 to 100 mm Hg.

SaO_2

The arterial oxygen saturation.

The normal range is 95% to 100%.

$PaCO_2$

The amount of carbon dioxide dissolved in arterial blood.

The normal range is 35 to 45 mm Hg.

HCO_3^-

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

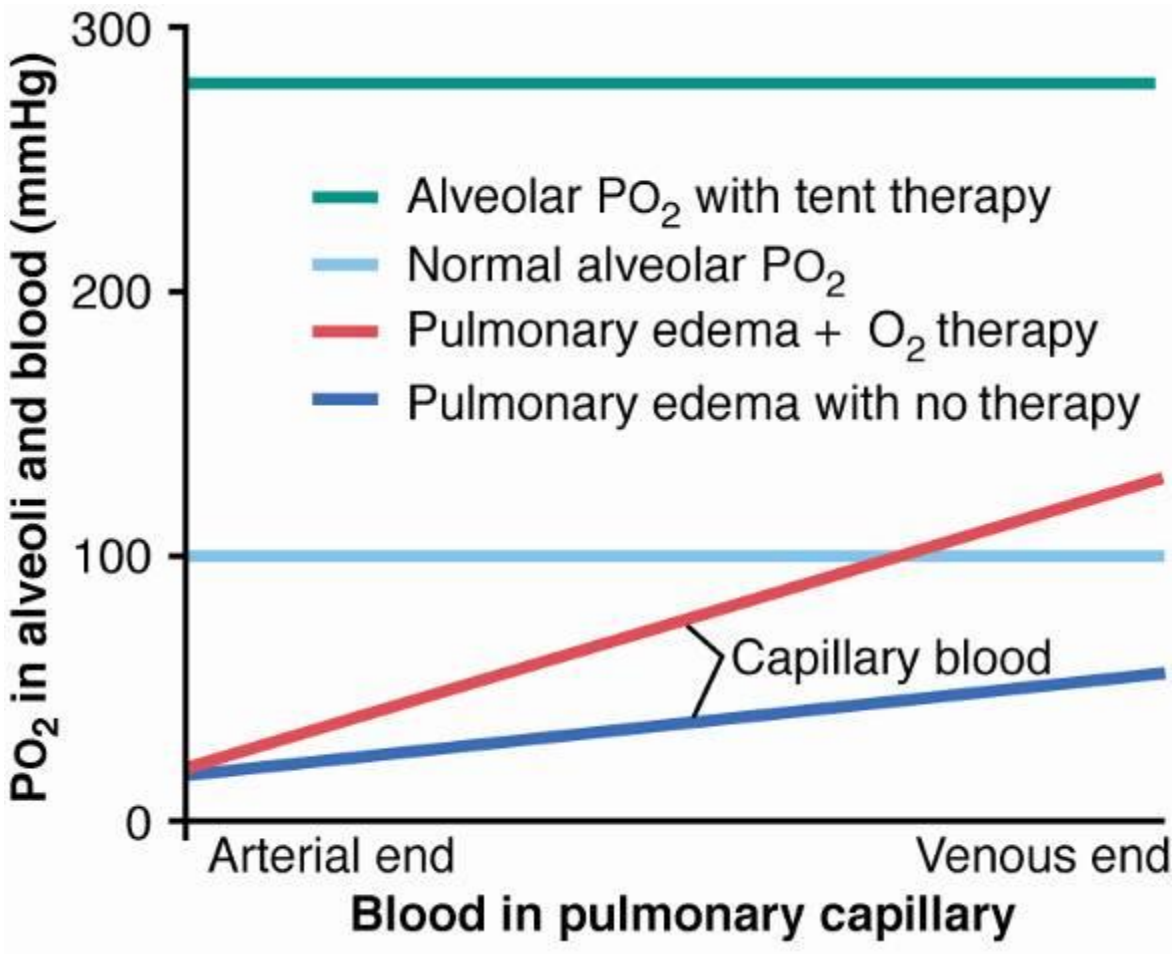

300
200
100
0
PO_2 in alveoli and blood (mmHg)
Alveolar PO_2 with tent therapy
Normal alveolar PO_2
Pulmonary edema + O_2 therapy
Pulmonary edema with no therapy
Capillary blood
Arterial end
Venous end
Blood in pulmonary capillary

Figure 42-8

THANK YOU

Next Time…

- Compliance