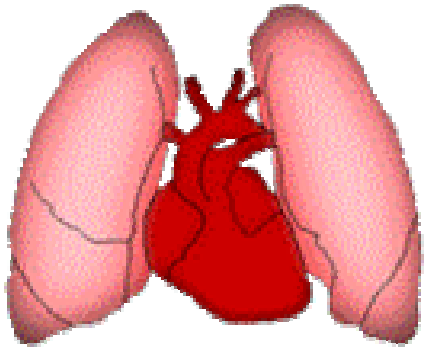
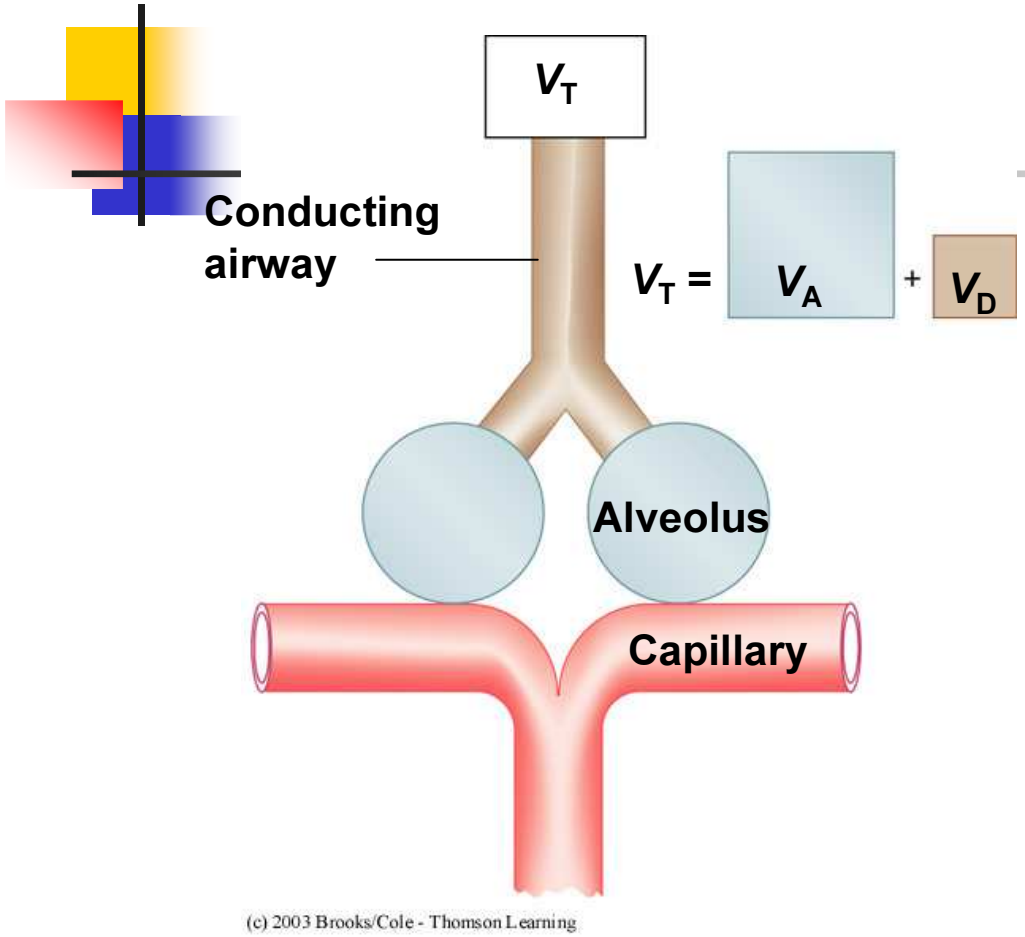
Respiration



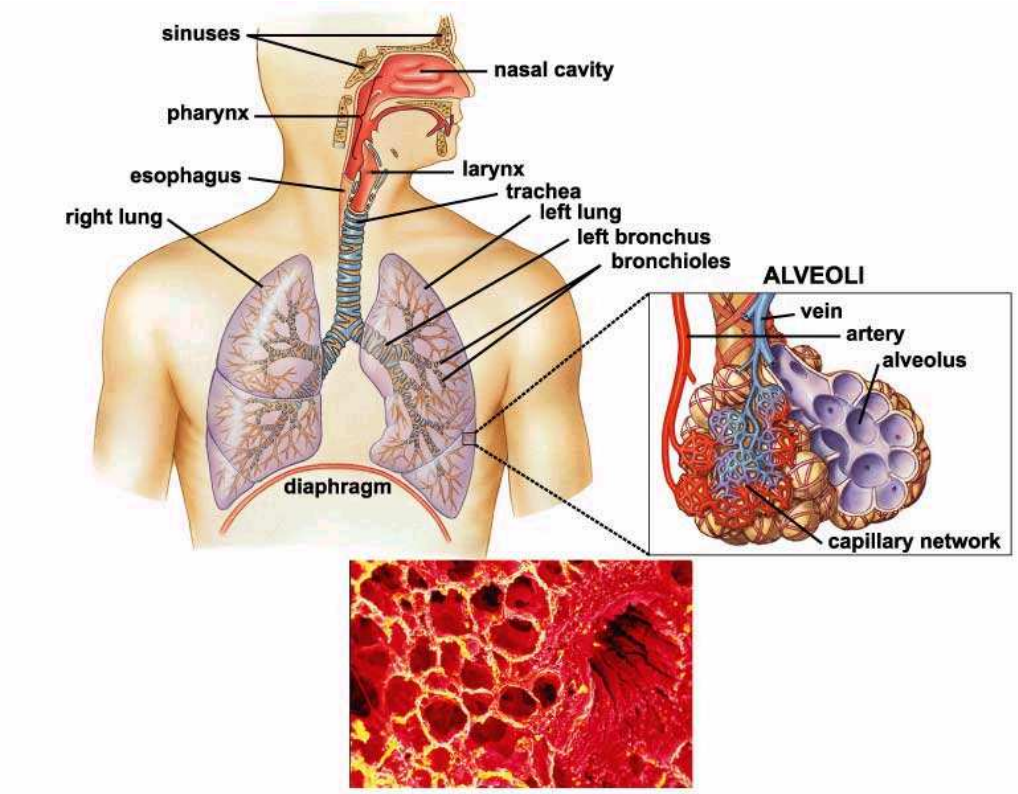
Minute ventilation = breathing rate x tidal volume



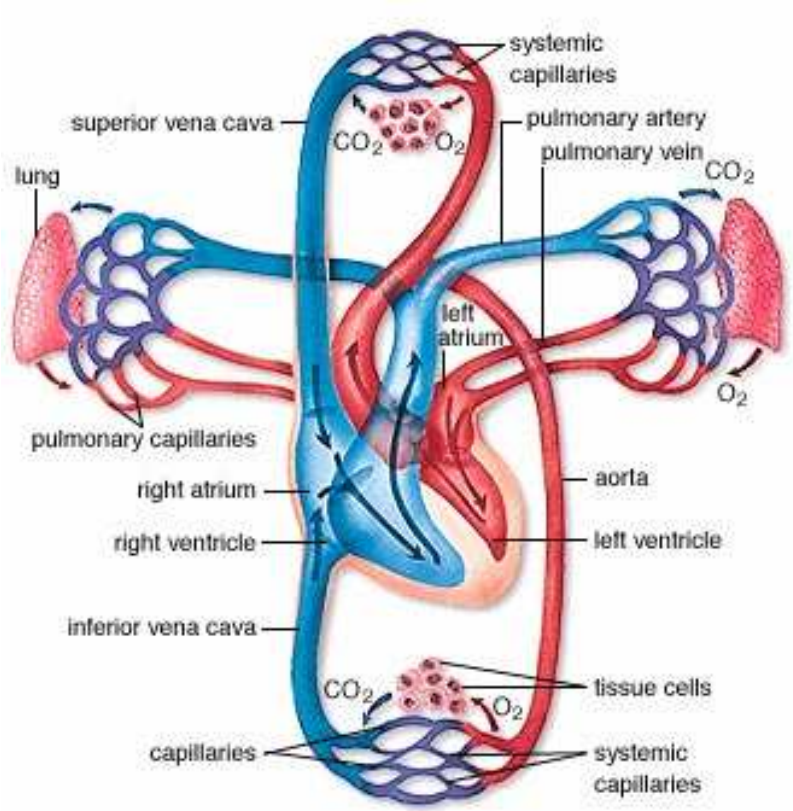
Dead space volume (about 0.15 L) does not reach alveoli.

Alveolar ventilation = (tidal volume - dead space volume) x breathing rate

Pulmonary blood flow



Pulmonary circulation - characteristics

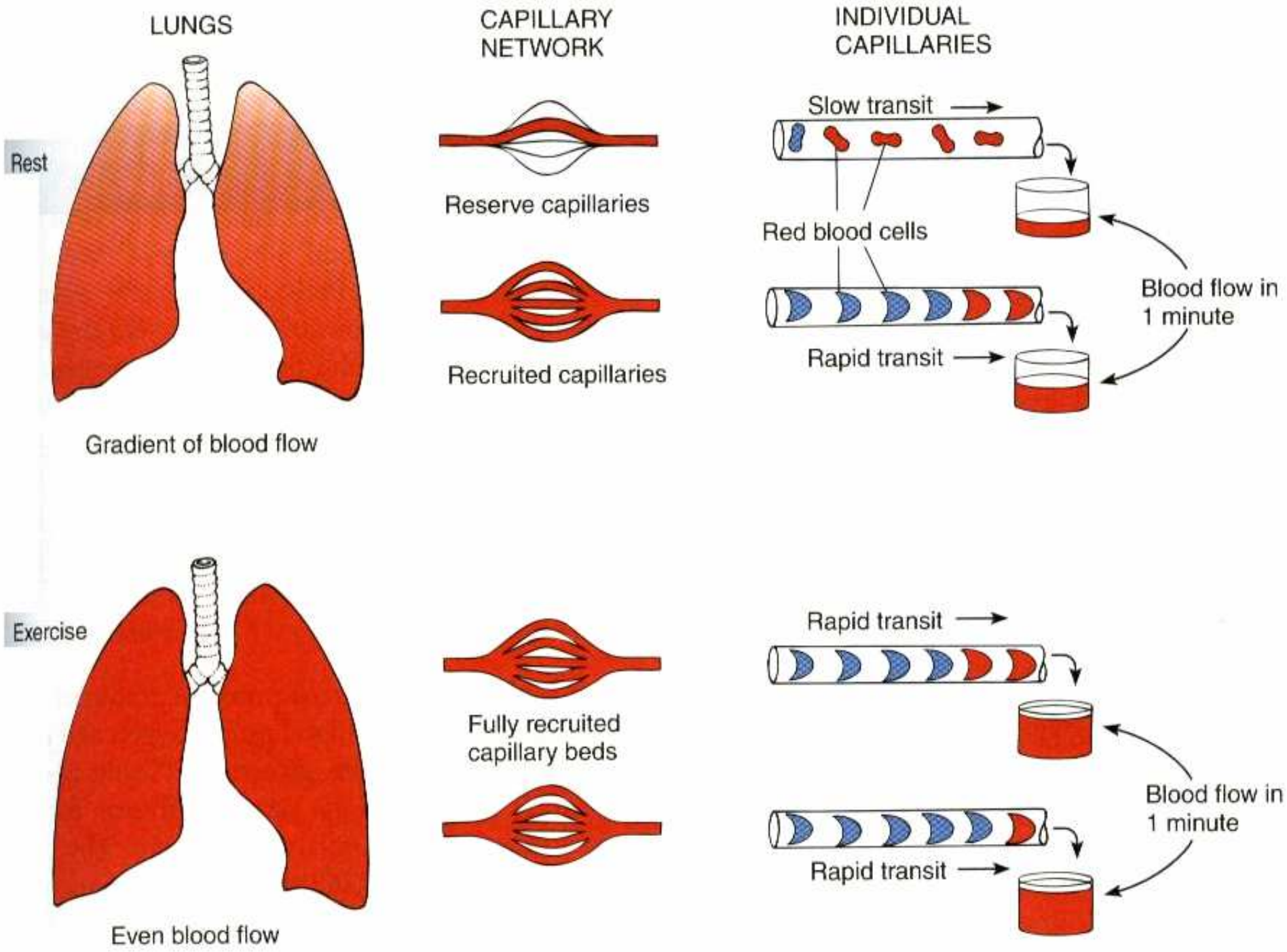


- Vessels thin and distensible (low resistance)
- Low pressure: SPAP 25mmHg; DPAP 8mmHg
- Mean PAP 15mmHg

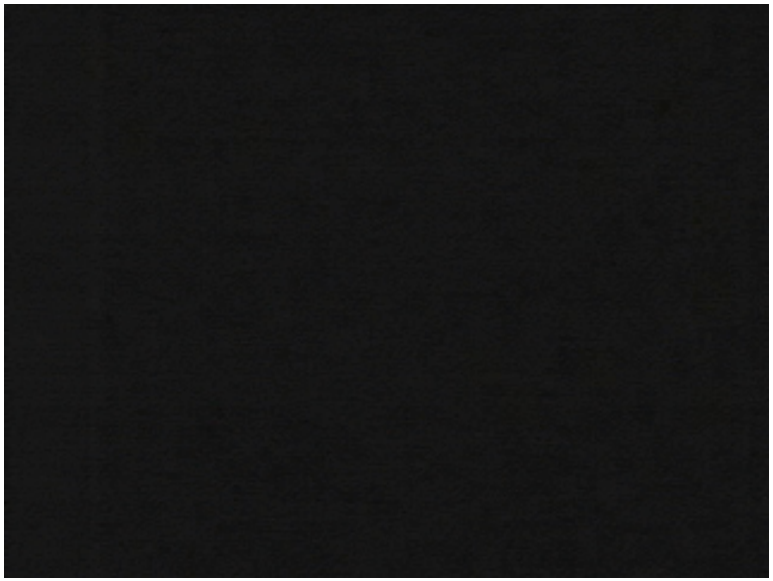
Systemic circulation: SAP 120mmHg, DAP 80mmHg, MAP 100mmHg

MAP=1/3 (SP-DP) + DP

- Blood flow equal to cardiac output
- During exercise PBP rises slightly – why?
- What happens during acute left ventricle failure?


LUNGS
CAPILLARY NETWORK
INDIVIDUAL CAPILLARIES
Rest
Reserve capillaries
Recruited capillaries
Slow transit
Red blood cells
Blood flow in 1 minute
Rapid transit
Gradient of blood flow
Exercise
Fully recruited capillary beds
Rapid transit
Blood flow in 1 minute
Rapid transit
Even blood flow

Pulmonary blood flow during exercise

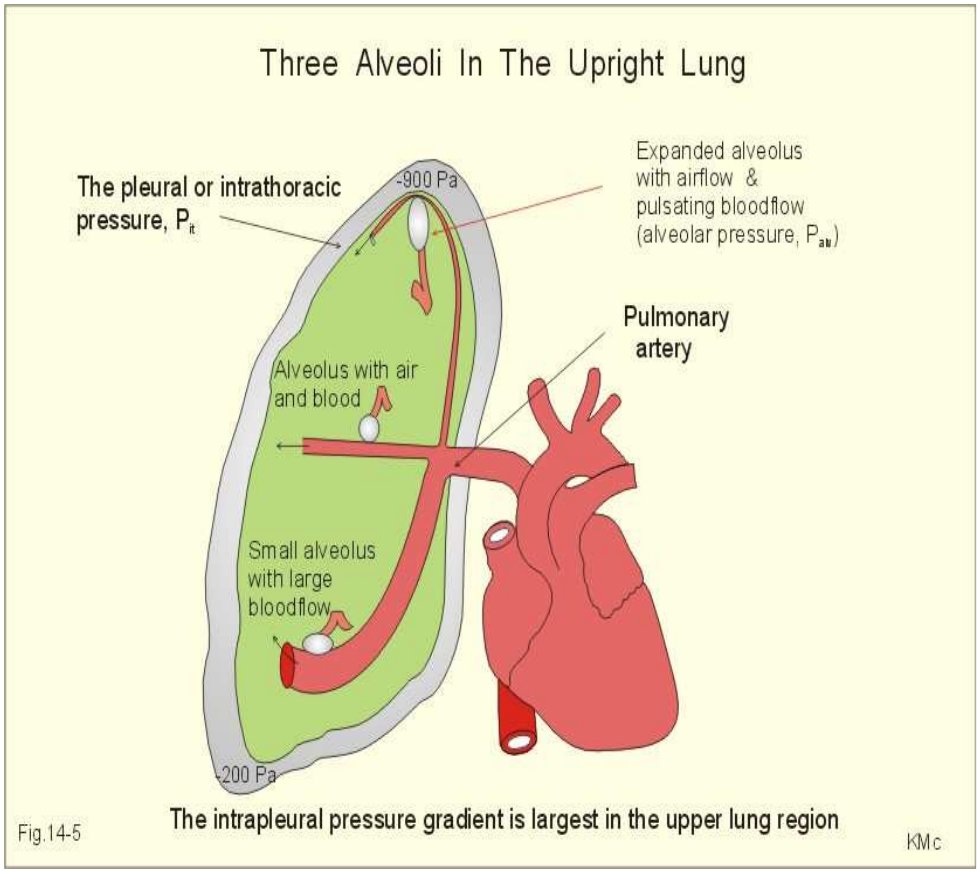


- During exercise PAP rises slightly – *why?*
- Pulmonary blood flow during exercise rises 4-7x:

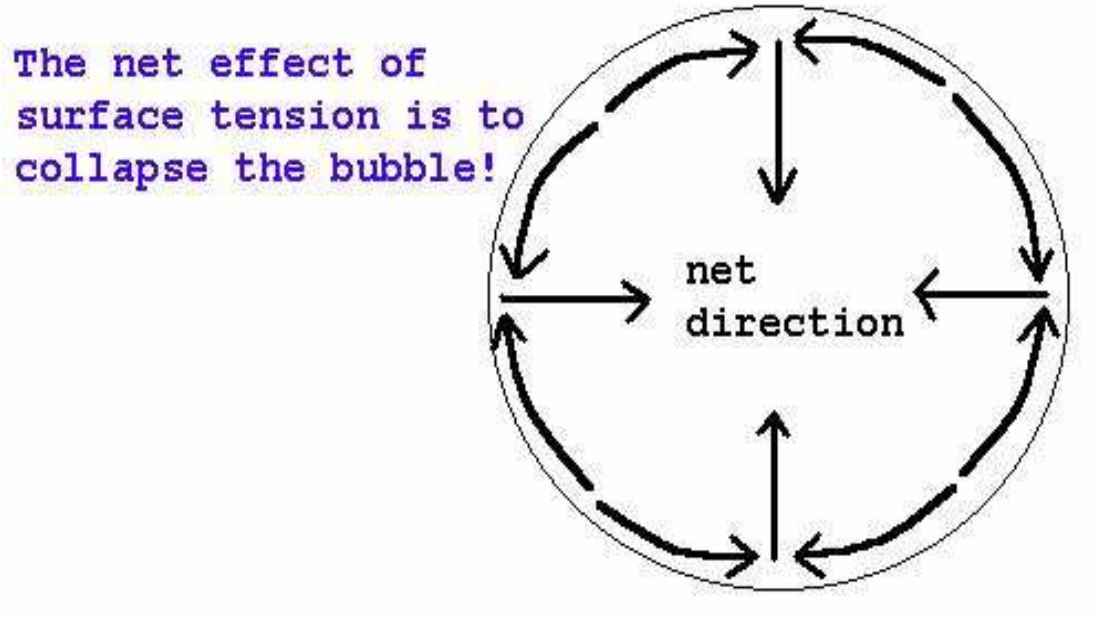
- ↑ number of open capillaries
- distension of all capillaries
- slight ↑ in pulmonary arterial pressure (preventing pulmonary edema)

Pulmonary circulation - characteristics

- Pulmonary blood pressures in the upper portion of the lung are about 15mmHg less than at the level of heart
- Blood flow through the apical part of the lung is intermittent (flow during systole and cessation of flow during diastole)
- In the lower parts of lungs blood flow is continuous



Surface tension



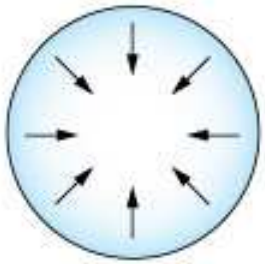
All of the water molecules in the walls of the bubble are trying to move closer to one another. Surface tension, or the attraction between water molecules, is trying to collapse the bubble

- Surface tension – molecular force created at gas-liquid interface; reflects the attractive force between liquid and gas molecules
- Because alveoli are spherical, the surface tension produces a force that pulls inward

Laplace's Law: the inward pressure exerted within a bubble varies directly with the surface tension within the bubble and inversely with the radius of the bubble

(in other words, the smaller the bubble, the greater the inward pressure trying to collapse the bubble)

(a) Pressure is greater in the smaller bubble.



Larger bubble
r = 2
T = 3
P = (2 × 3)/2
P = 3

Smaller bubble
r = 1
T = 3
P = (2 × 3)/1
P = 6

P = pressure trying to collapse the bubble

T = surface tension of water

r = radius of the bubble

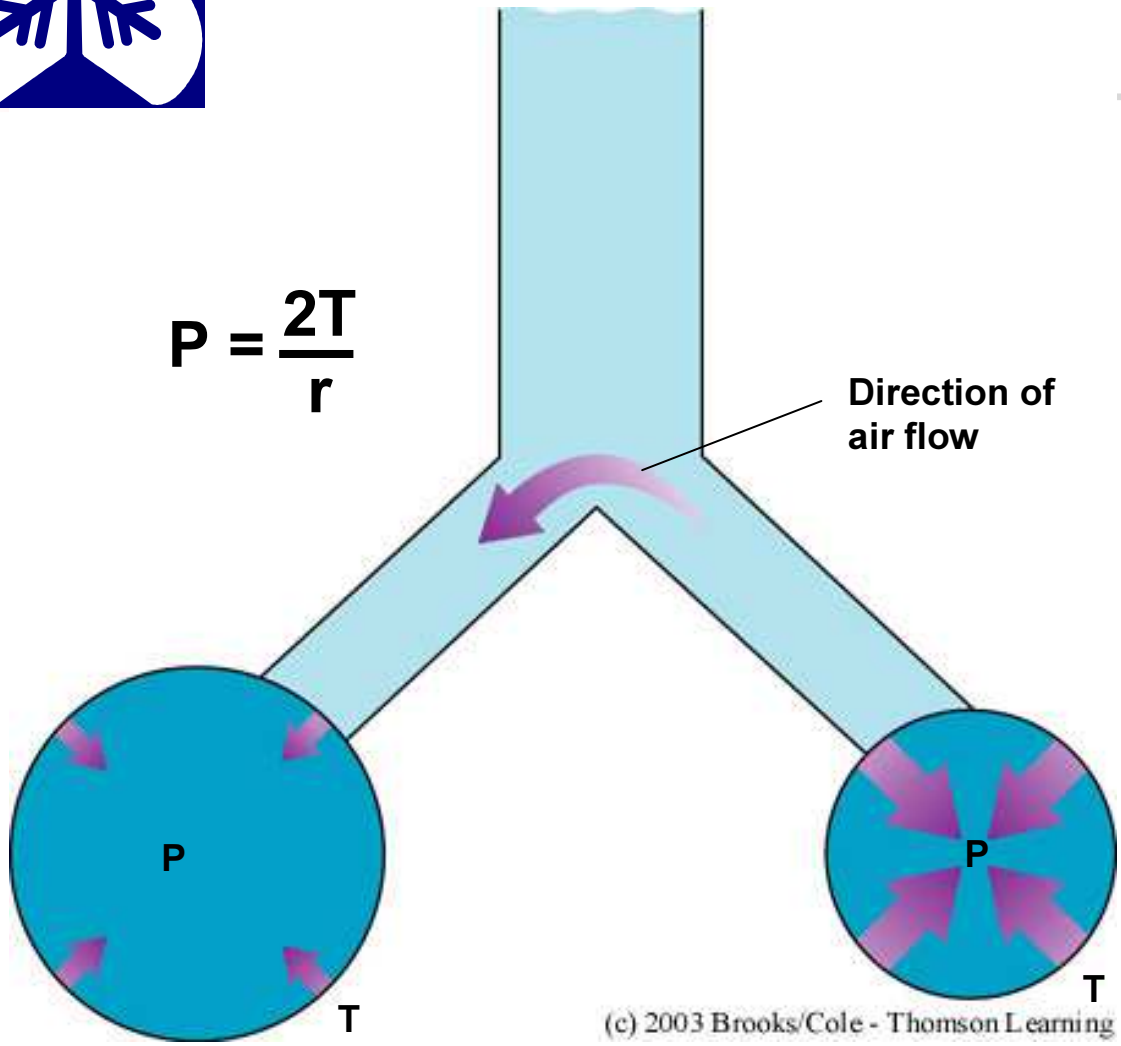
$$P = \frac{2T}{r}$$

(b) Surfactant reduces surface tension (T). Pressure is equalized in the large and small bubbles.

r = 2
T = 2
P = (2 × 2)/2
P = 2

r = 1
T = 1
P = (2 × 1)/1
P = 2

Surface tension tends to collapse alveoli, with the strongest force on small ones

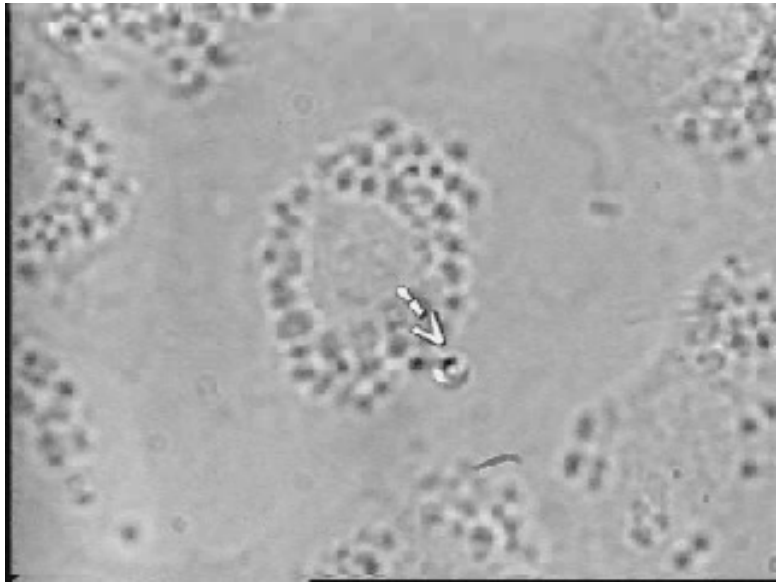


Surfactant promotes alveolar stability by lowering surface tension proportionately more in small alveoli

Without surfactant alveoli with larger diameter would be overinflated and smaller would become unstable and tend to collapse.

The phenomenon of collapsing alveoli is called atelectasis

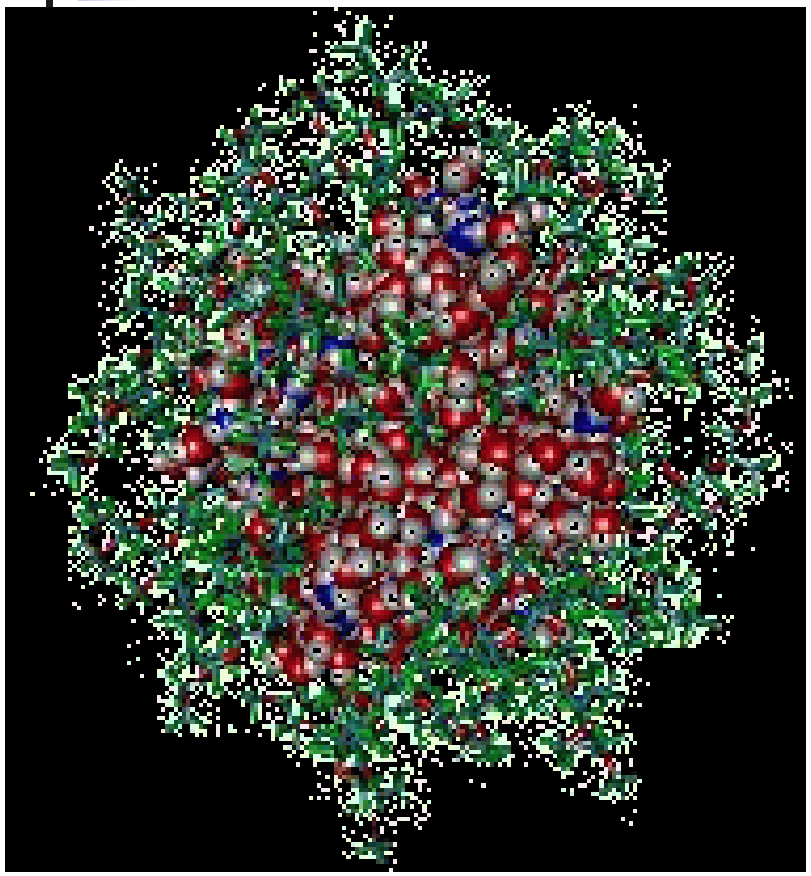
Surfactant



demonstration of the (visco-) elastic properties of pulmonary surfactant

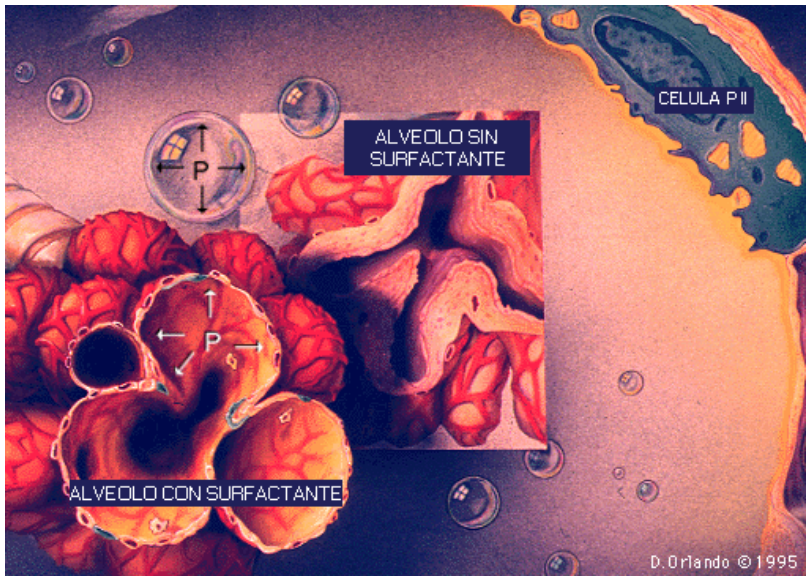
- lowers surface tension
- increases lung compliance *(facilitates breathing with minimal effort)*
- prevents movement of fluid into alveolus
- stimulates lung host defence system
- alveoli that vary in diameter can coexist

Surfactant - composition



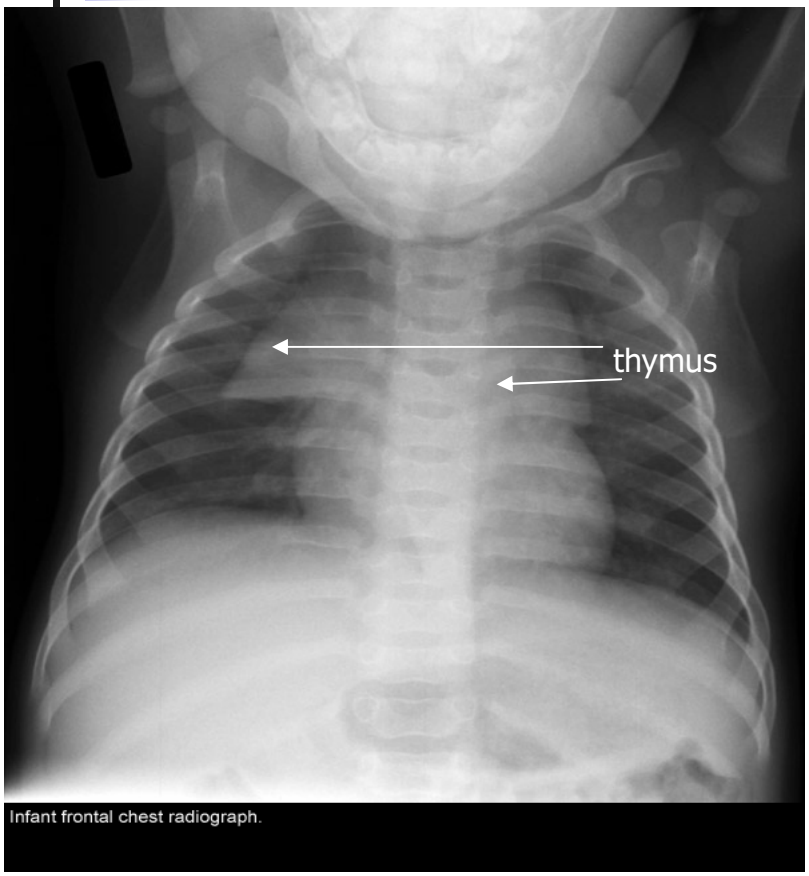
- 10% proteins
- 10% neutral lipids
  - mostly cholesterol
- 80% phospholipids
  - dipalitoylphosphatidylcholine (60%)
  - Phosphatidyl glycerol/ethanolamine/inositol (20%)

Surfactant



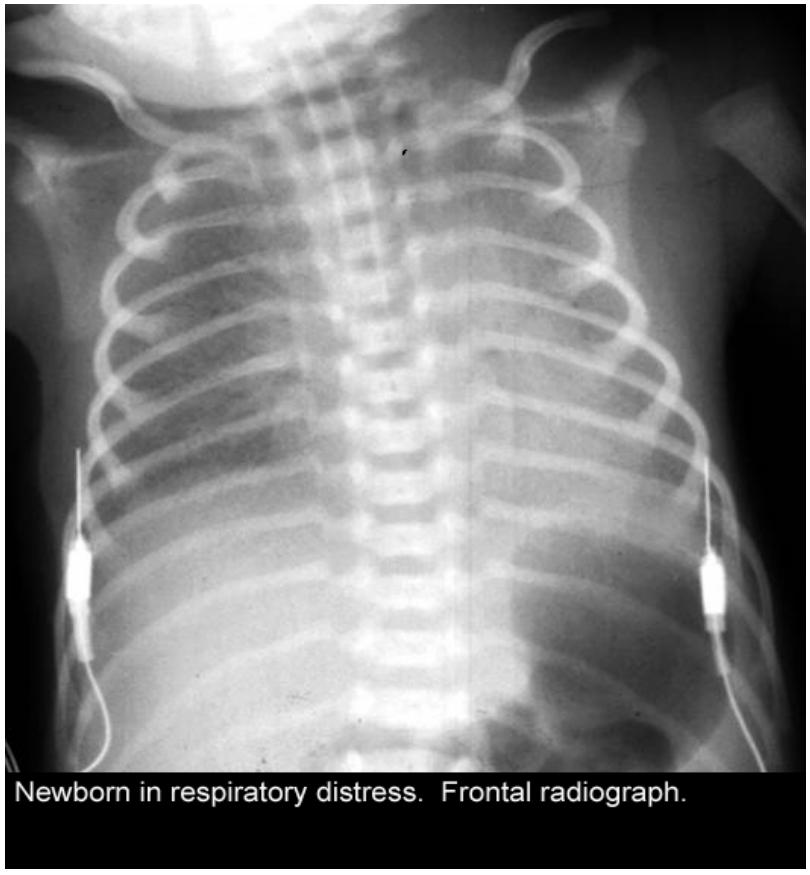
- secreted between 6th and 7th months of gestation
- secretion stimulated by cortisol, thyroid h-ns, vagus stimulation
- good sources of phospholipids are soybean, corn and egg yolks

Respiratory Distress Syndrome (RDS)



Infant frontal chest radiograph.

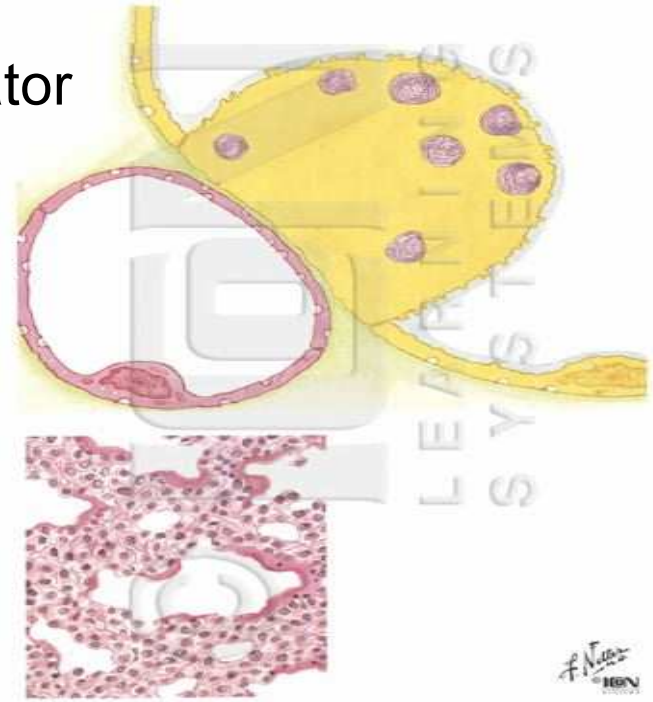
Normal infant frontal chest


Newborn in respiratory distress. Frontal radiograph.

Relatively low lung volume, ground glass appearance (hazy) to lungs. Nasotracheal tube in trachea.

Hyaline Membrane Disease (HMD = Insufficient Surfactant in the Newborn); *also known as Respiratory Distress Syndrome (**RDS**)*

- Alveolar collapse (atelectasis) may occur if there is not enough surfactant in the lungs of the neonate
- Treatment: surfactant molecules + O_2 (with a vaporizer in an incubator for several days)
- Some of these infants may require ventilator assisted oxygenation → production of oxygen-derived free radicals
- Free radicals → bronchpulmonary dysplasia (BPS; epithelial hyperplasia) + inactivation of surf. *(several months of RDS)*
- → „vicious circle”



Loss of surfactant function

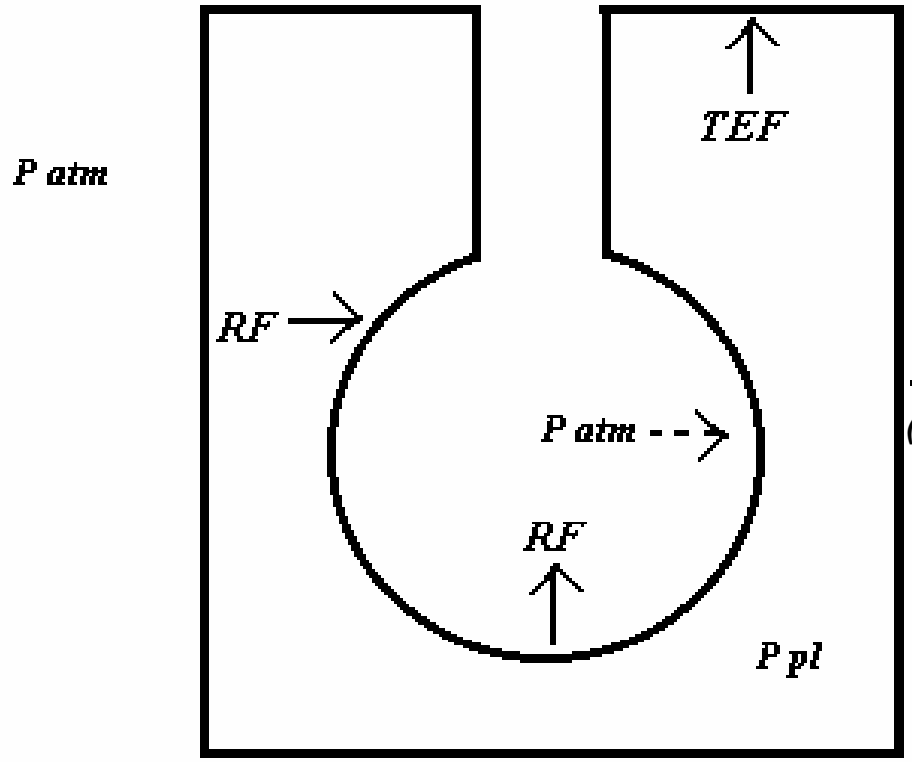
Inhibition

- by serum proteins (albumin), fibrinogen, bilirubin, and degradation products

Inactivation

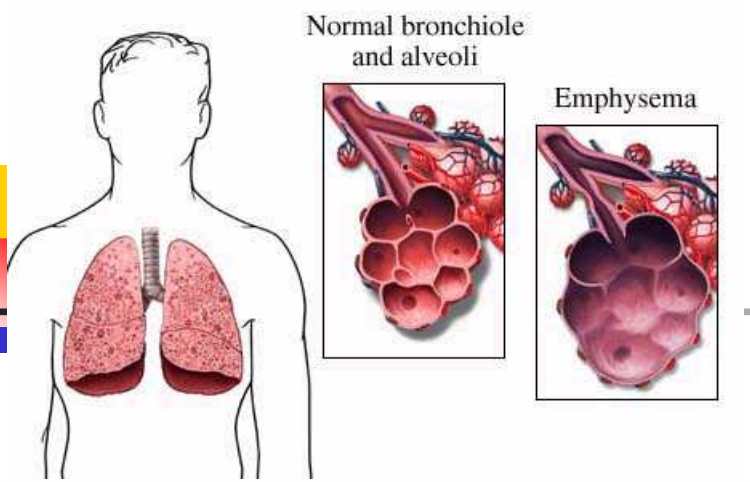
- by oxygen radicals and enzymes (phospholipases)

Negative intrapleural pressure



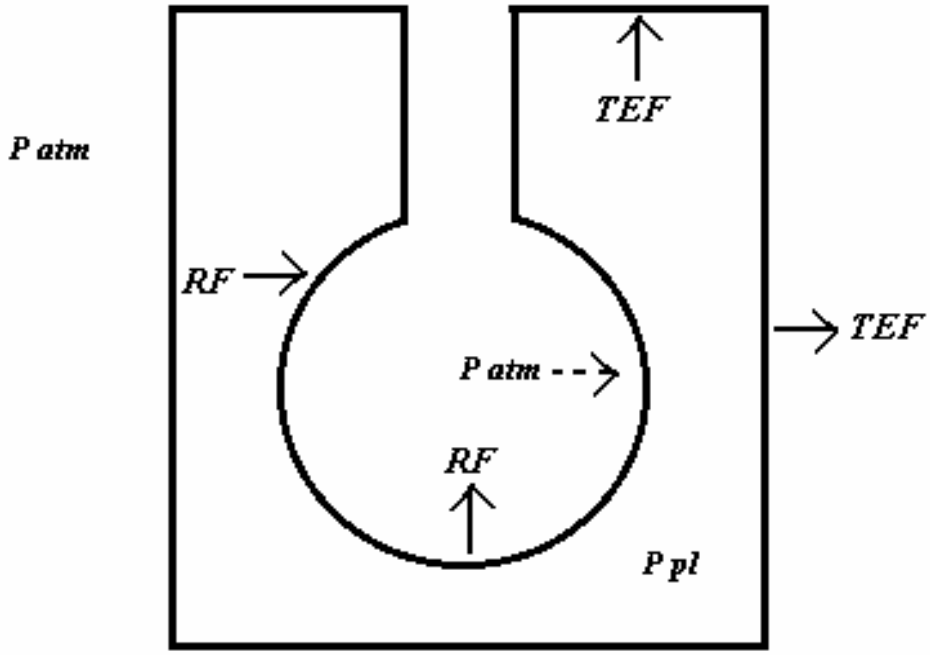
- Ppl = Patm - RF
- **retractive forces (RF)** due to:
  - surface tension
  - elastic forces of alveolus

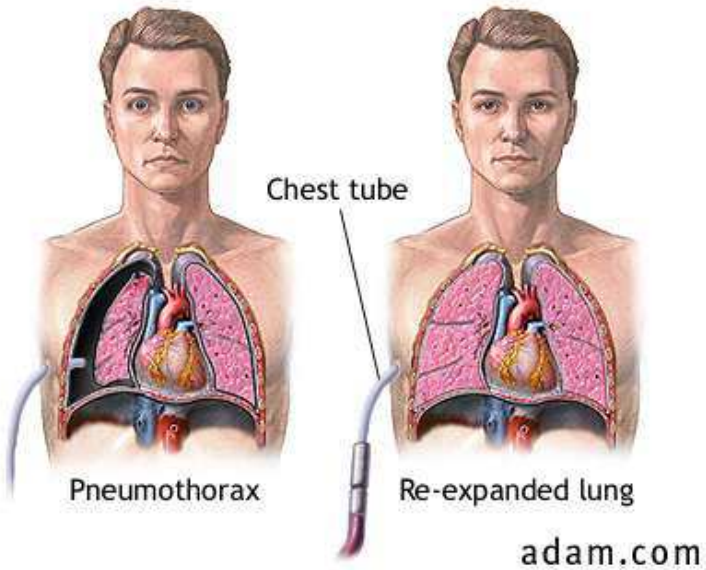
RF = elastic resistance



Emphysema

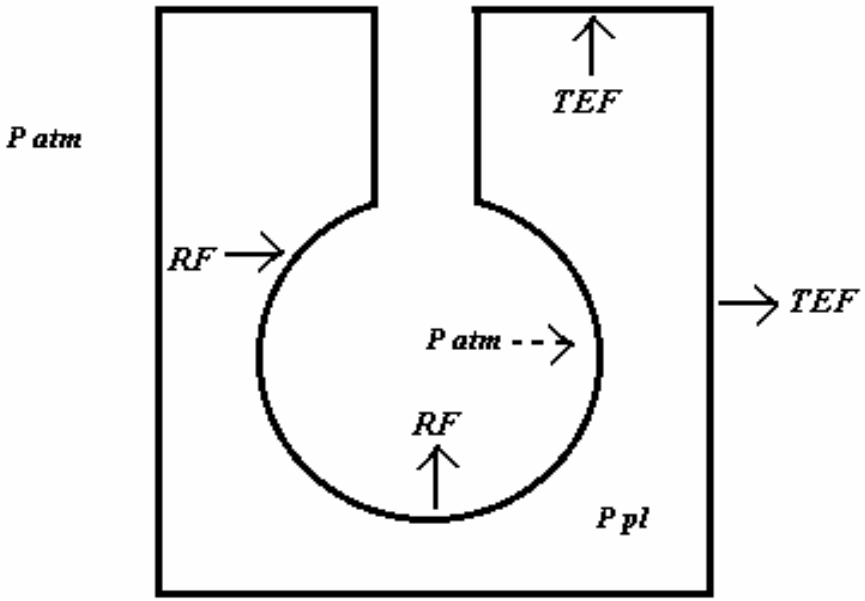
- Ppl = Patm - RF
- destruction of elastic fibers
- ↓ RF
- Intrapleural pressure is less negative (during expiration may be positive and higher than atmospheric!)
- ↓ transpulmonary pressure
- What is the effect of ↓ RF?

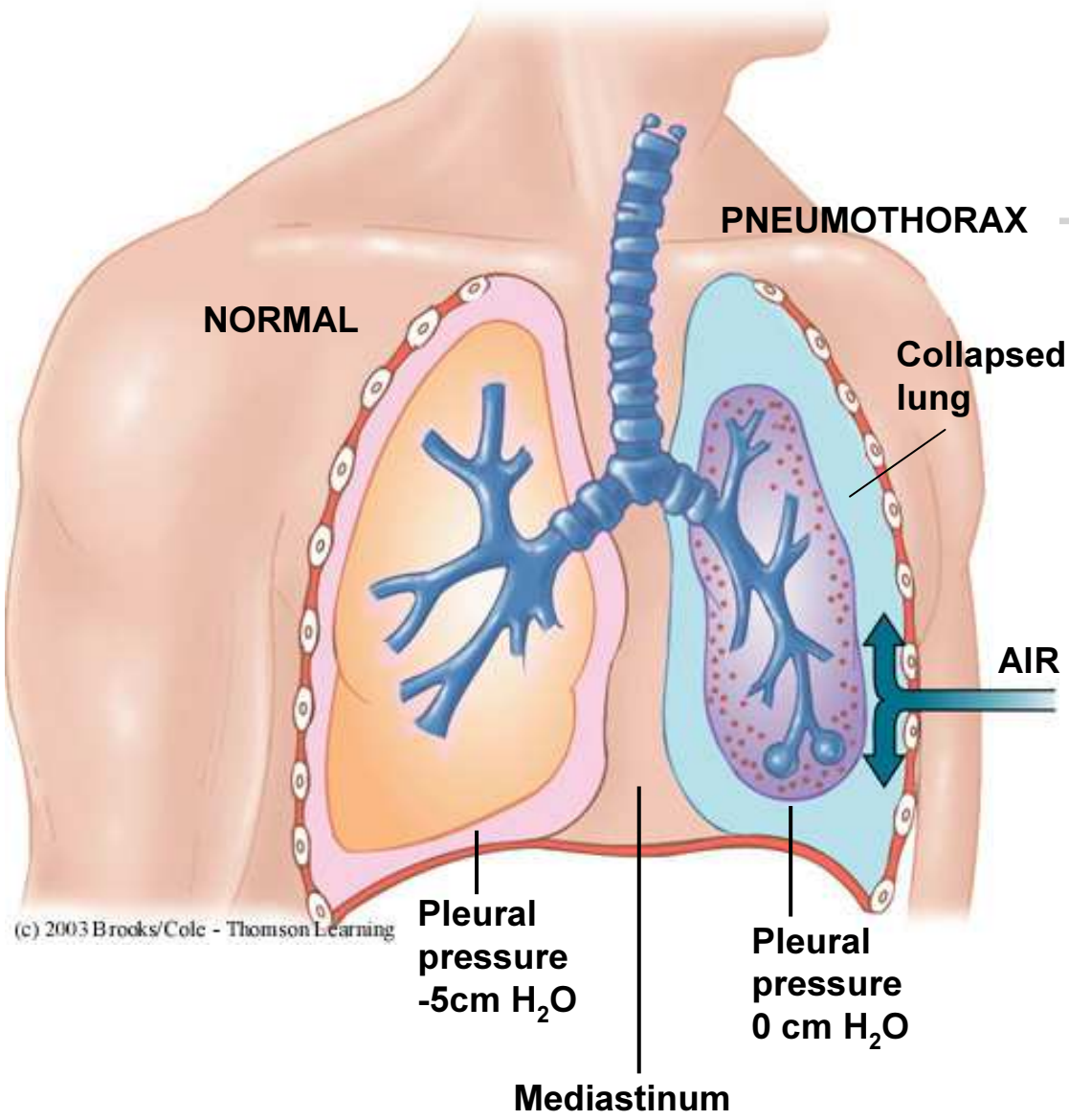




Pneumothorax

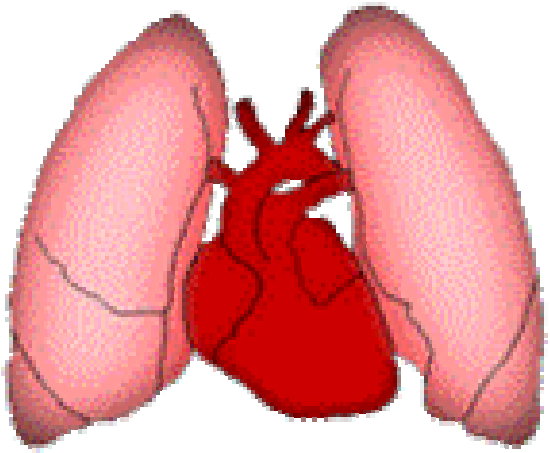
- Ppl = Patm - RF
- Punctured thoracic wall or/and airways (lung) wall
- Ppl=Patm
- What is the effect of pneumothorax?





Pneumothorax→ alveolar collapse (atelectasis)

Pulmonary resistance



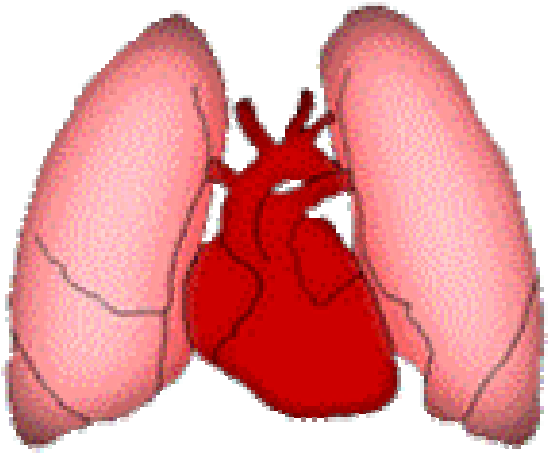
Pulmonary resistance

- Elastic – retractive forces:
  - surface tension
  - elastic forces
- Non-elastic:
  - airway resistance (AWR)
  - tissue resistance (friction)
- Inertia due to acceleration of moving air

AWR during inspiration vs. expiration

- AWR decreases during inspiration:
  - expansion of lungs pulls the airway wall
  - positive pressure in the airways is higher than negative intrapleural pressure
  - less impulses from Vagus

Lung compliance



Lung compliance

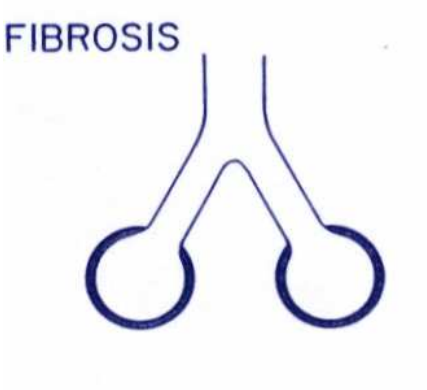
- Relatively small changes in pressure are needed to inflate the lung
- This is due to distensibility of the lung
- This distensibility is termed lung compliance (or pulmonary compliance)

What is the effect of surfactant on:

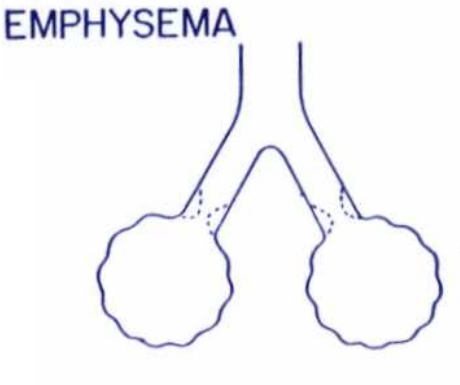
- lung compliance?
  - pulmonary elastic resistance?

What is the lung compliance:

- in fibrosis?



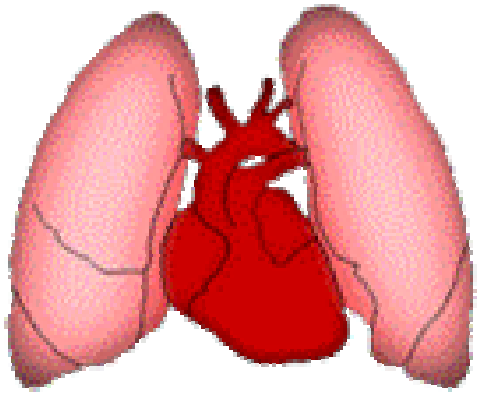
- in emphysema?



Partial pressures of O_2 and CO_2

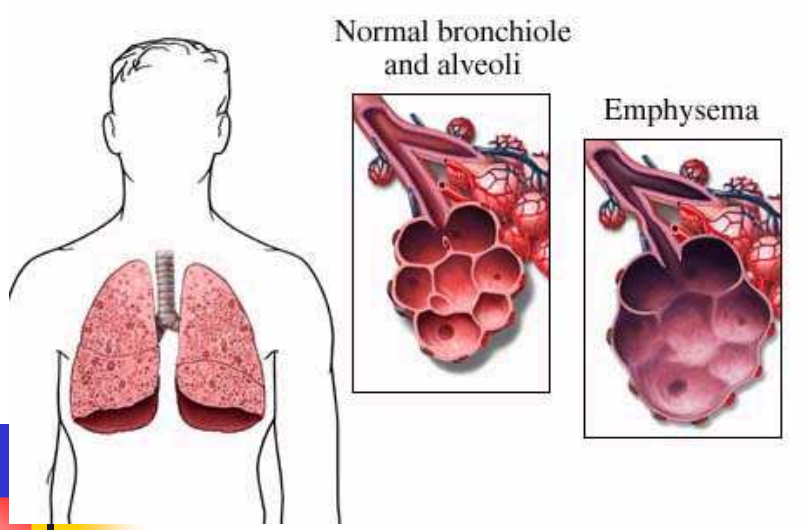
[mmHg]	Atmosphere	Expired air	Alveolar air	Oxygenated blood	Deoxygenated blood
pO2	159	120	104	**100**	**40**
pCO2	0.3	27	40	**40**	**45**

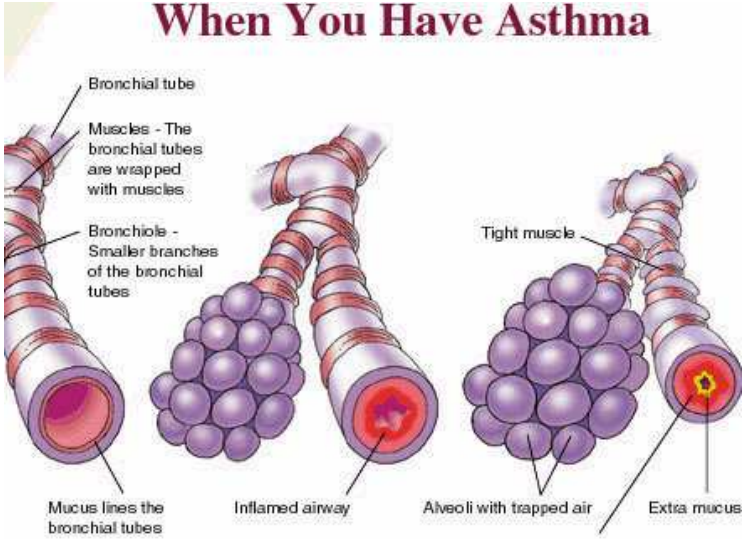
Obstruction vs. restriction



An obstructive disease blocks part of the airway, thus air can not get into the lungs, as shown on the left

An incomplete obstruction will also increase the airway resistance (AWR), and slow down both the inspiration and expiration



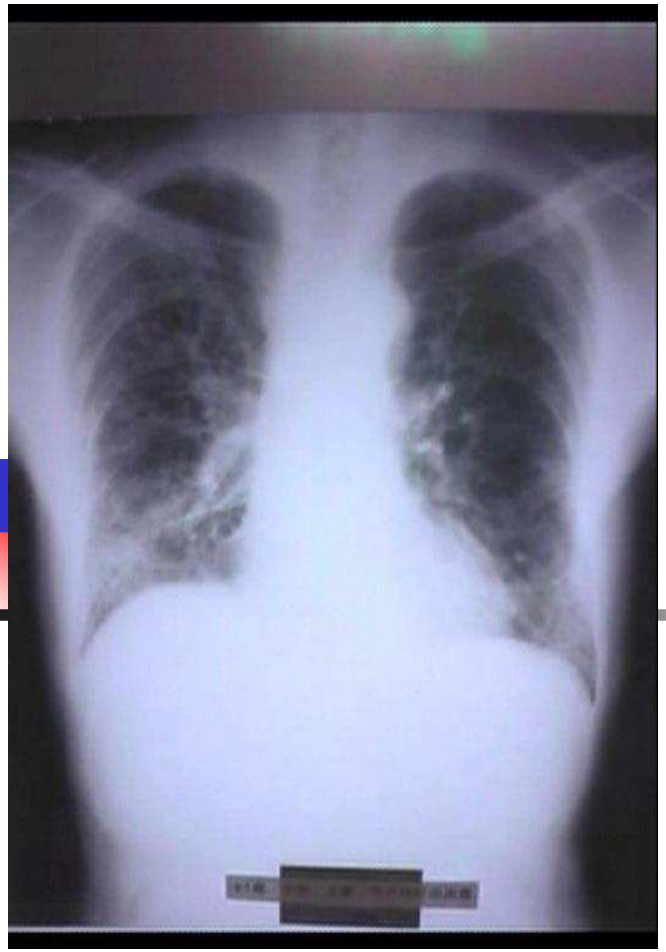


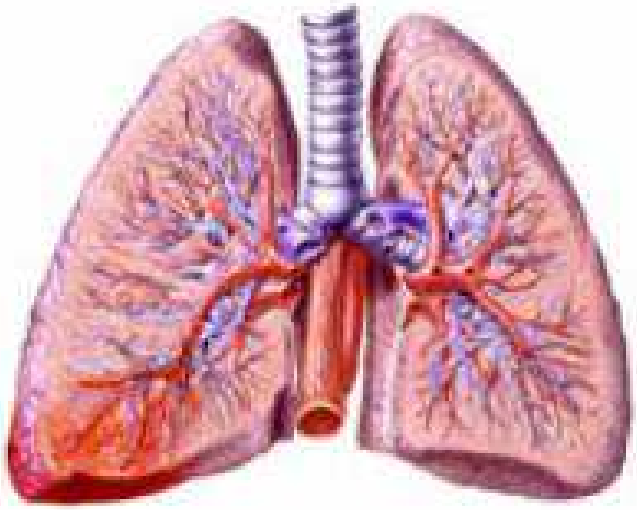
Obstructive lung disease

(emphysema, asthma, chronic bronchitis)

A restrictive disease is like a lock on the chest cage or the elastic tissue of the lungs, which limits the expansion of the lung, thus interferes with respiration

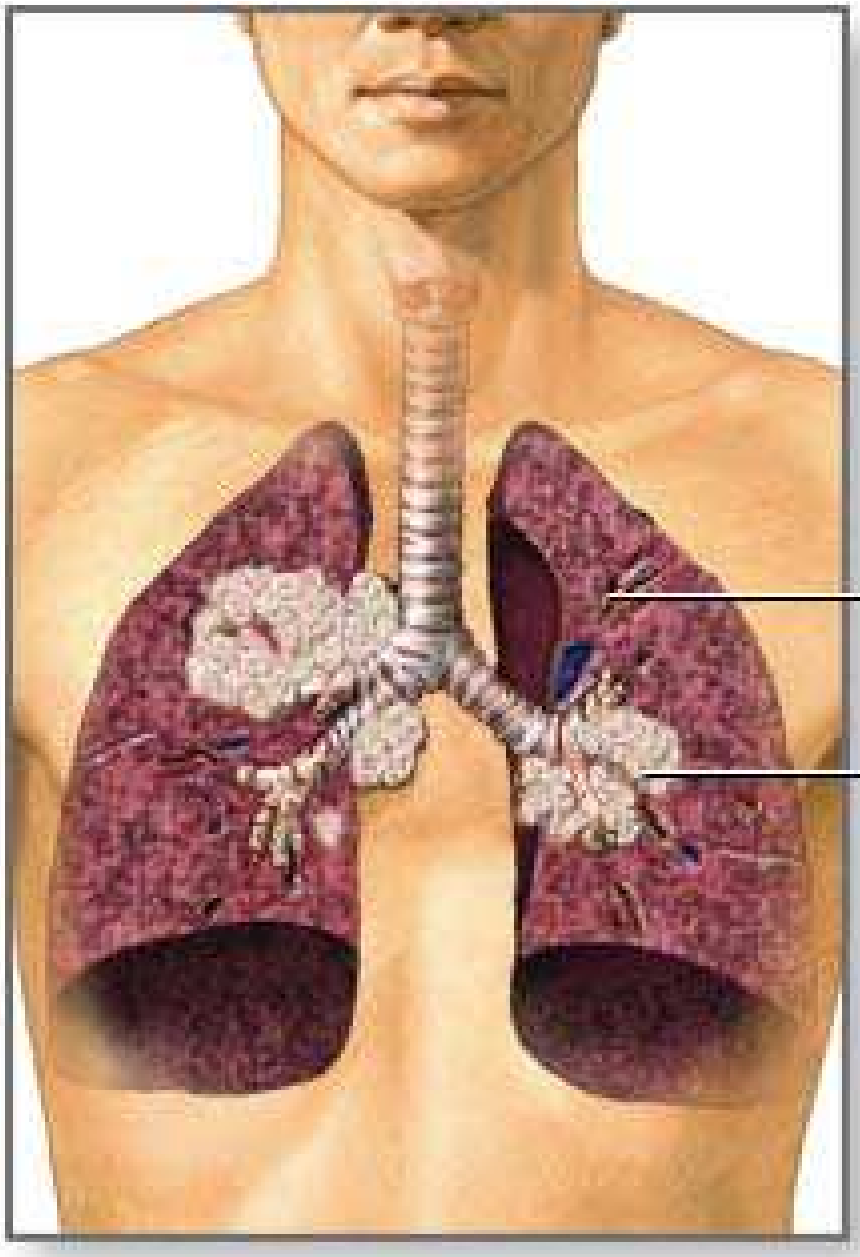
It does not increase the airway resistance, but limits the lung volume from increasing





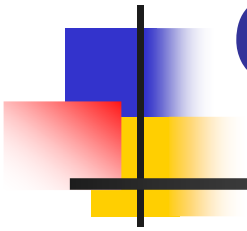
Restrictive lung disease

(e.g. interstitial lung disease, respiratory muscle weakness, thoracic cage deformities)

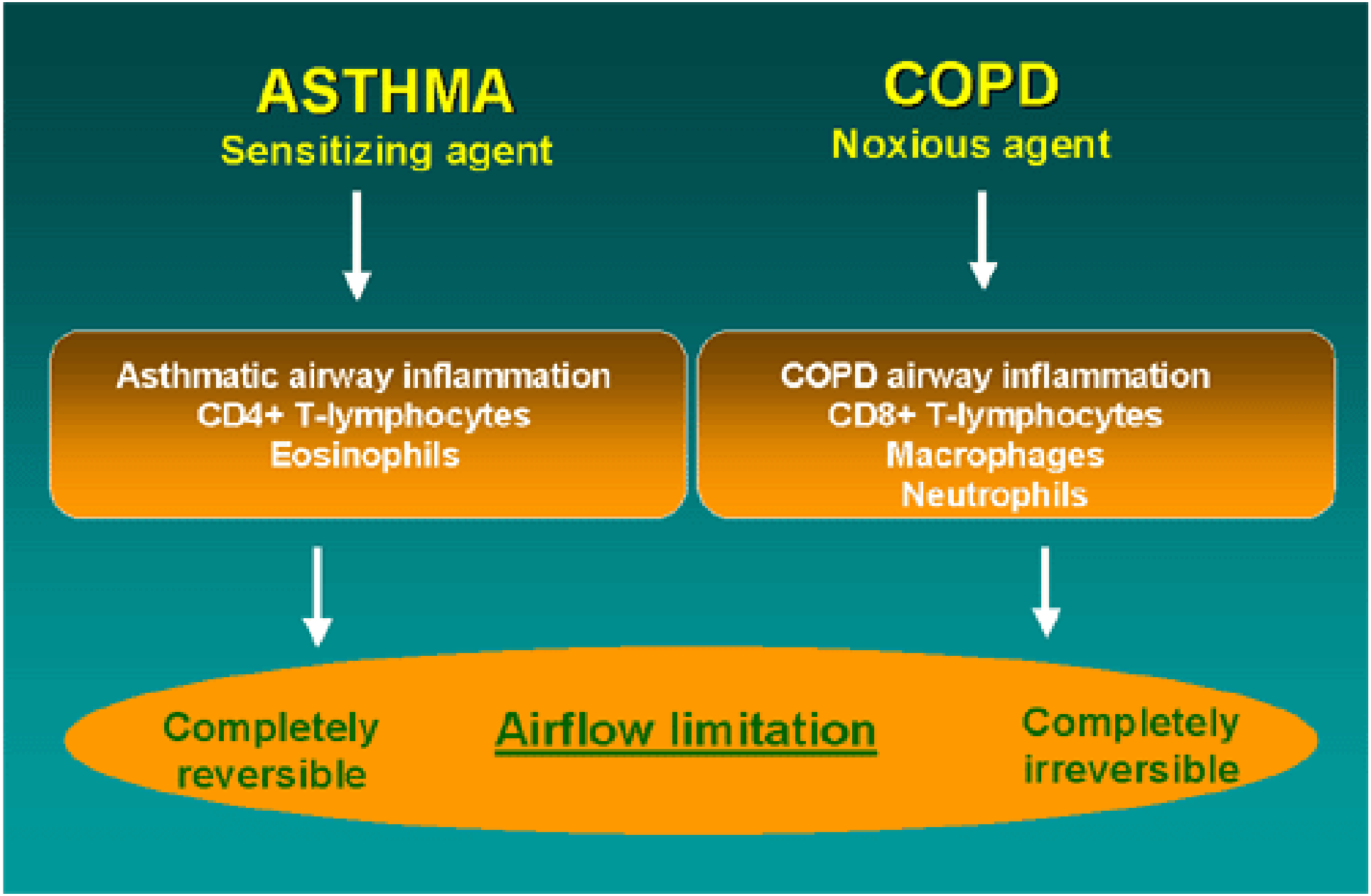


1. **What is the type of presented lung disease?**
2. **Predict changes of pulmonary resistance**

A.D.A.M.

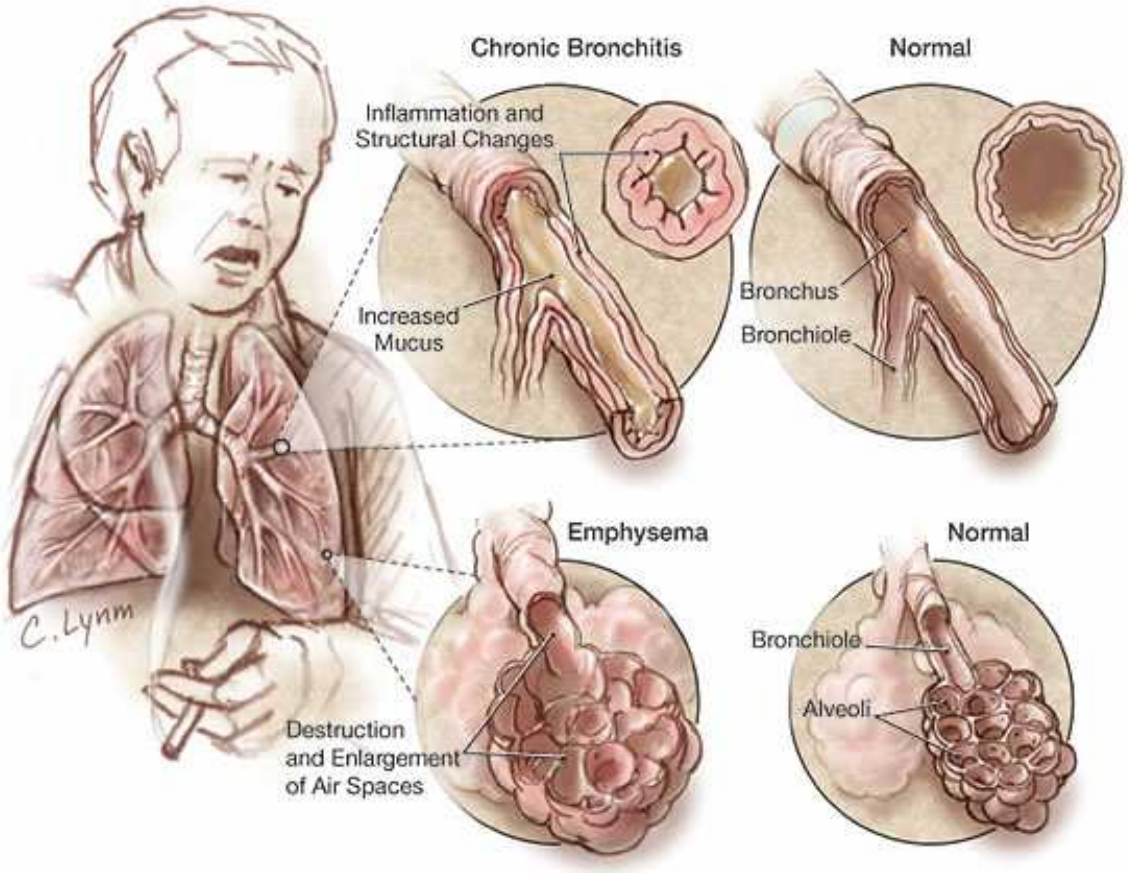


Obstructive lung diseases


ASTHMA
Sensitizing agent
COPD
Noxious agent
Asthmatic airway inflammation
CD4+ T-lymphocytes
Eosinophils
COPD airway inflammation
CD8+ T-lymphocytes
Macrophages
Neutrophils
Completely reversible
Airflow limitation
Completely irreversible

COPD - Chronic obstructive pulmonary disease is a term used to describe 2 related lung diseases: chronic bronchitis and emphysema.

Major cases of COPD

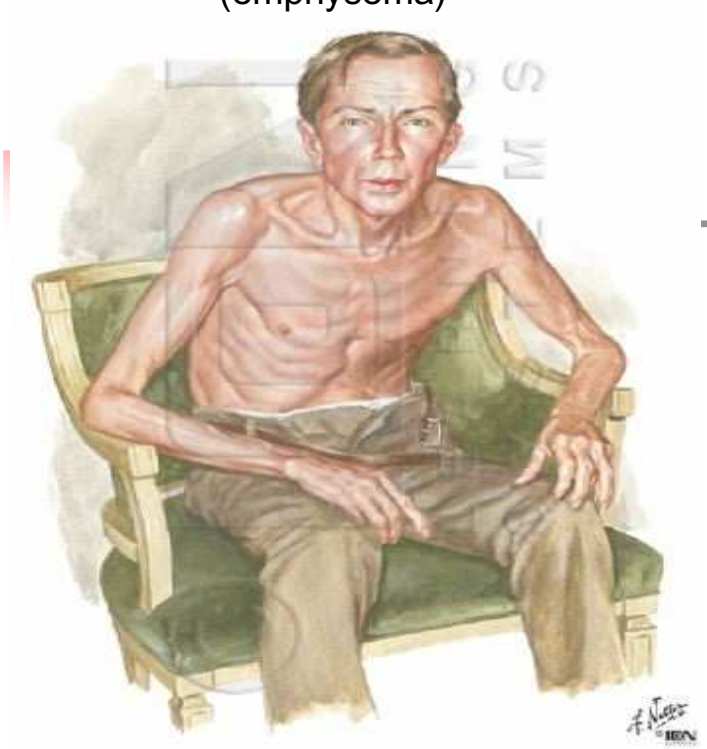


- Active or passive smoking
- Exposure to other irritants and pollution
- Genetic conditions: antitrypsin defficiency
- Severe lung infections

COPD

Pink puffer

(emphysema)



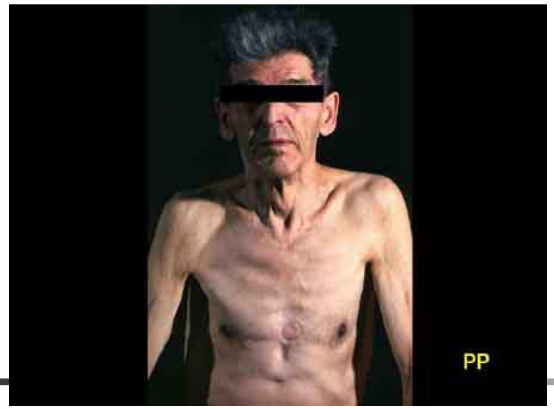
1. A pink puffer is typically thin and breathes with pursed lips. A pink puffer has tachypnoeic (increased respiratory rate) and experiences breathing difficulty.
2. Arterial bood gas results show less hypoxemia than blue bloaters, and no carbon dioxide retention
3. Prognosis for pink puffers is better than for blue bloaters.

Blue bloater

(chronic bronchitis)

1. A blue bloater has a history of cough with sputum for 3 months to one year or more. A blue bloater experiences cyanosis due to a decrease in sufficient amounts of oxygen reaching the blood. Ankles and legs may be swollen and distention in the neck veins may be apparent.
2. Arterial bood gas results show evidence of hypoxemia, carbon dioxide retention, and compensated respiratory acidosis.

COPD



Predominant emphysema

- severe dyspnea
- cough after dyspnea starts
- scant sputum
- less frequent infections
- risk for terminal resp insufficiency episode
- PaCO2 35-40 mmHg
- PaO2 65-75 mmHg
- hematocrit 35-45%
- Cor pulmonale rare

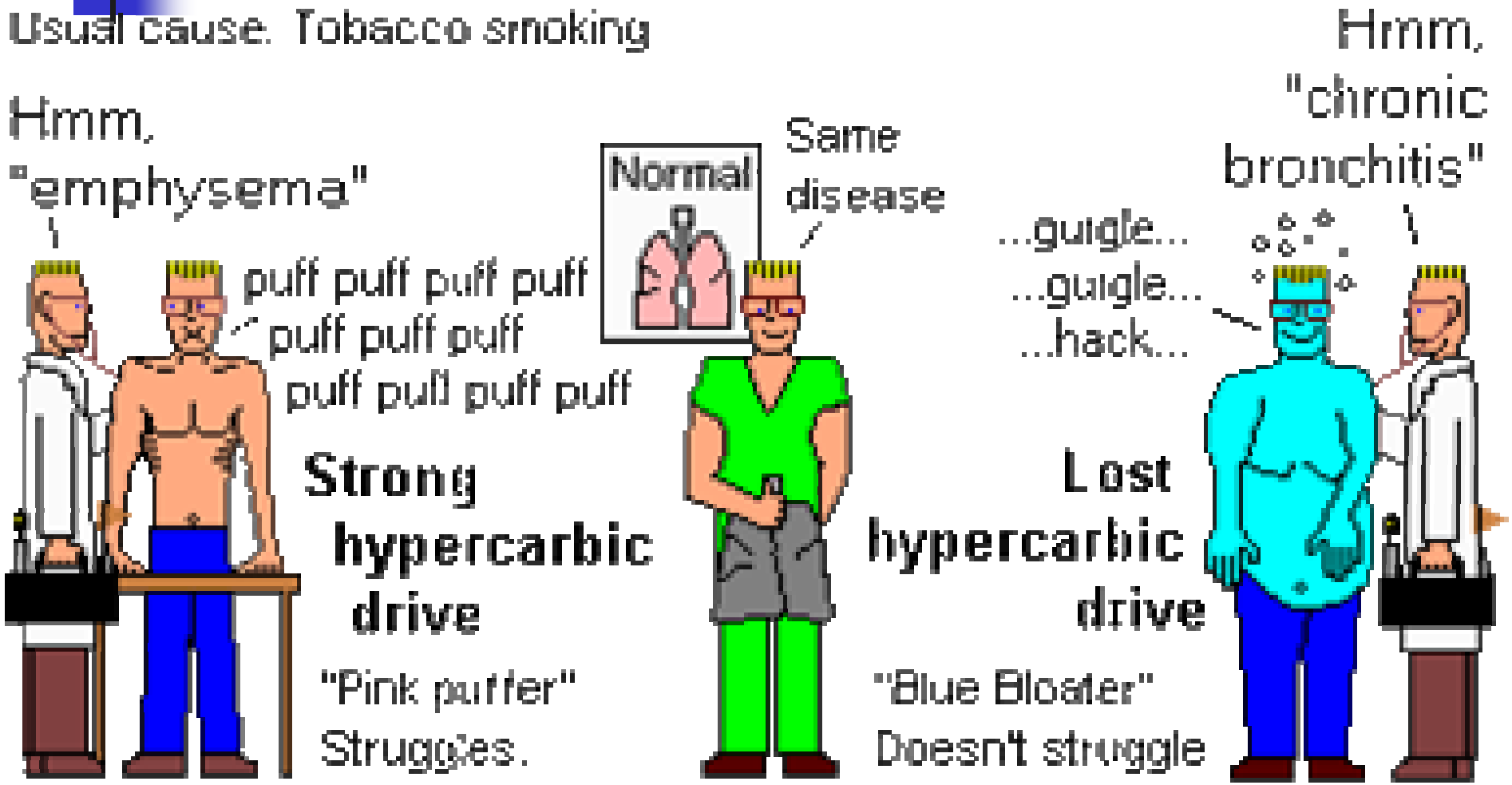
Predominant chronic bronchitis

- mild dyspnea
- cough before dyspnea starts
- copius, purulent sputum
- more frequent infections
- repeat resp insufficiency episodes
- PaCO2 50-60 mmHg
- PaO2 45-60 mmHg
- hematocrit 50-60%
- Cor pulmonale common

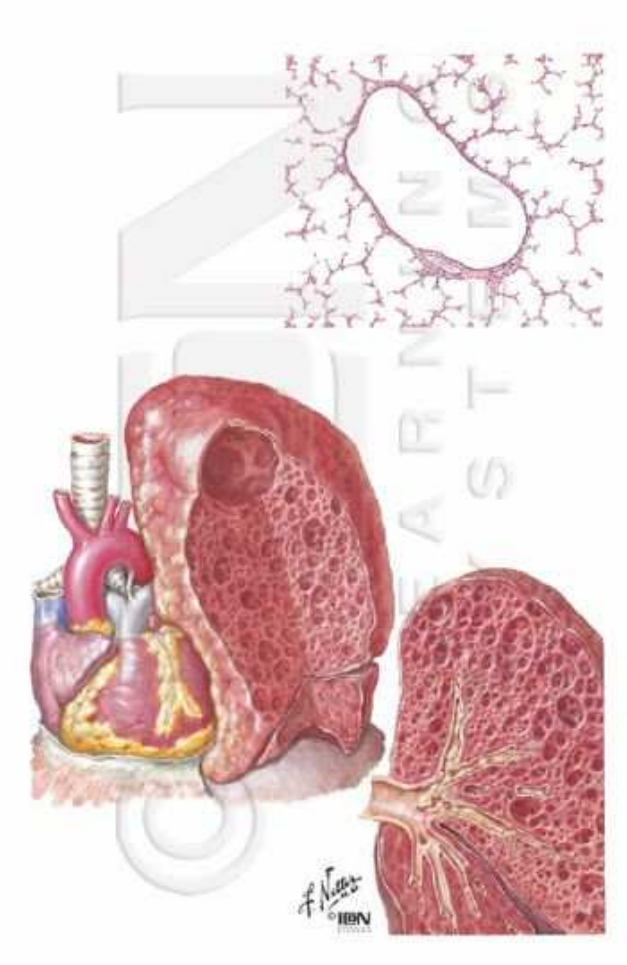
Emphysema

The fundamental problem is the loss of the lung's elastic recoil, causing the respiratory bronchioles to collapse upon expiration.

Usual cause: Tobacco smoking



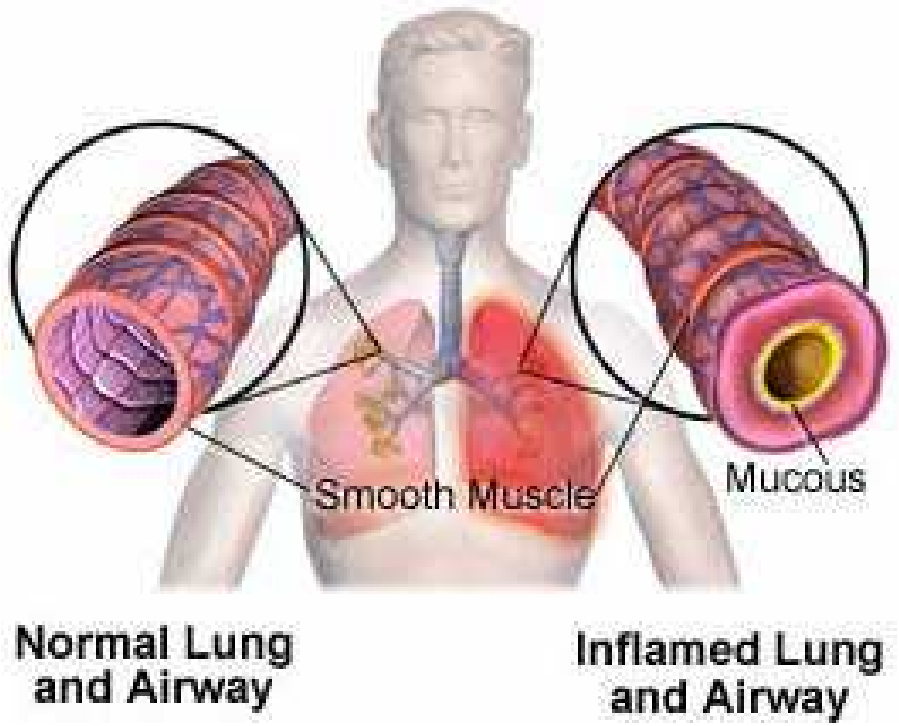
Emphysema



1. Chronic inflammation (eg. smokers)
   - chronic obstruction
   - „air trap” and overstretch of alveoli
   - destruction of the alveolar walls
2. Congenital

Asthma

- Airway inflammation (the airways in the lungs become red, swollen and narrow)
- Bronchoconstriction (the muscles that encircle the airways tighten or go into spasm)



1. Triggers irritate the airways and result in bronchoconstriction.
2. Inducers cause both airway inflammation and airway hyperresponsiveness and hence are recognized as causes of asthma.

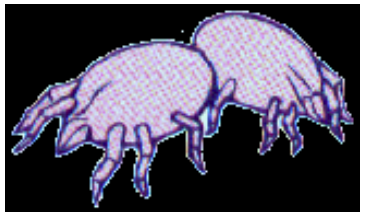
Triggers

- Cold air
- Dust
- Strong fumes
- Exercise
- Inhaled irritants
- Emotional upsets
- Smoke

Inducers

Most common allergens include:

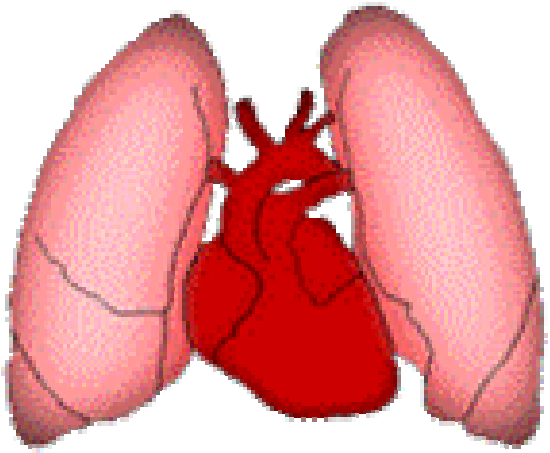
- pollen (grasses, trees and weeds)
- animal secretions (cats and horses tend to be to the most allergen causing)
- molds
- house dust mites



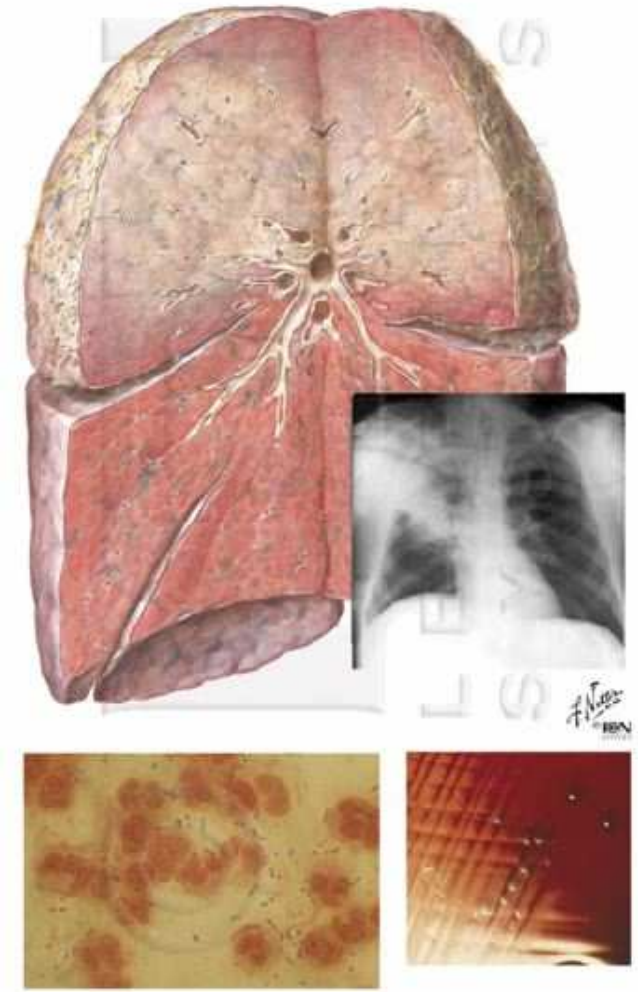
Asthma

- What type of therapeutic agent is used by asthmatics?

Pneumonia, atelectasis, fibrosis,

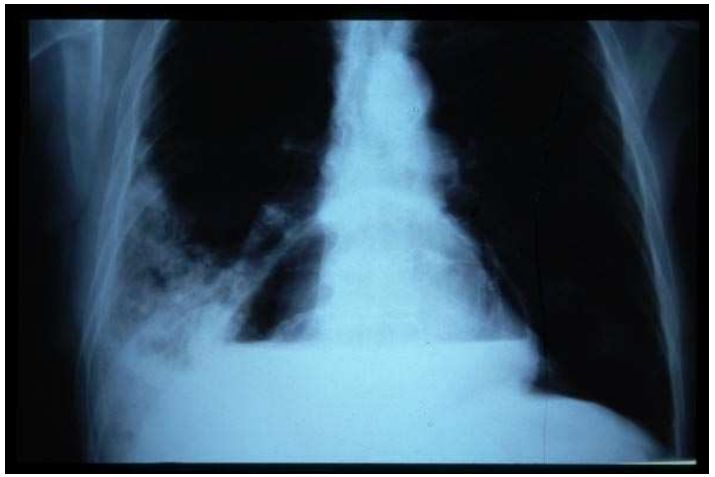


Pneumonia – pulmonary membrane is highly porous and inflammed; alveoli filled with fluid and cellular debris

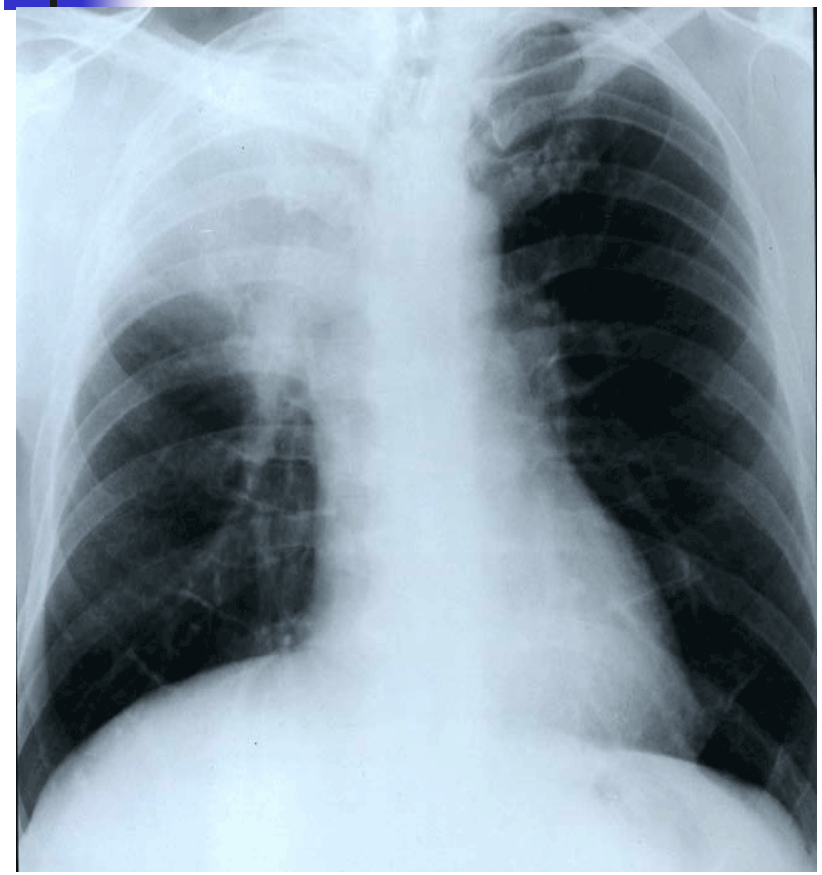


Pneumococcal pneumonia

- The total surface area of the respiratory membrane?
- V_A/Q?
- Blood pCO_2 and pO_2?



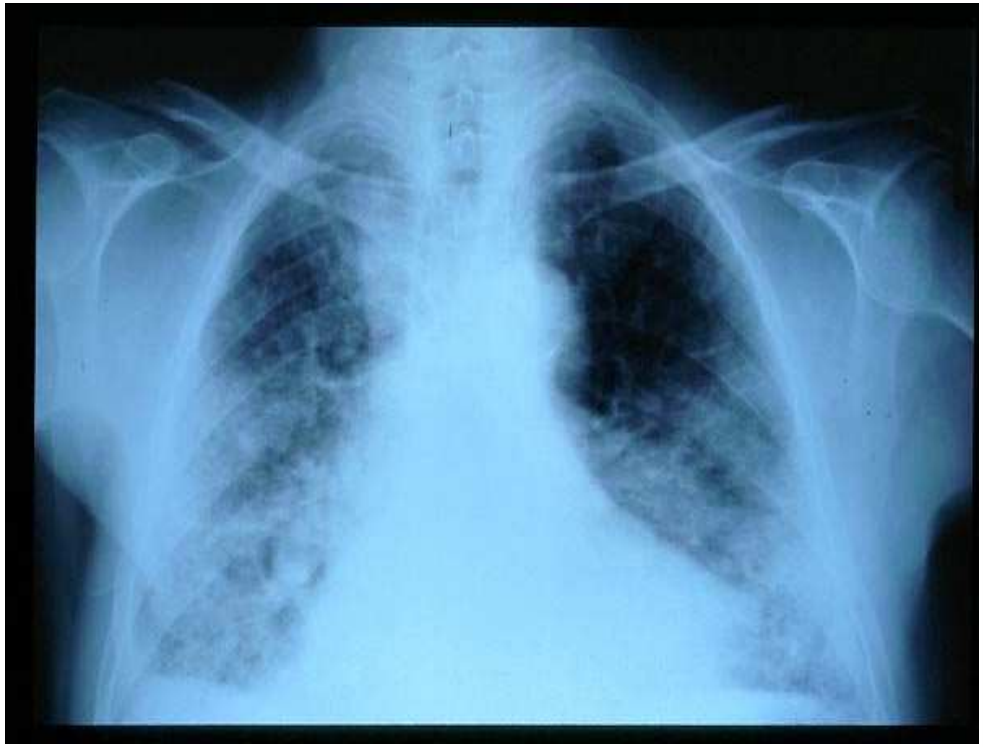
Atelectasis – collapse of the alveoli



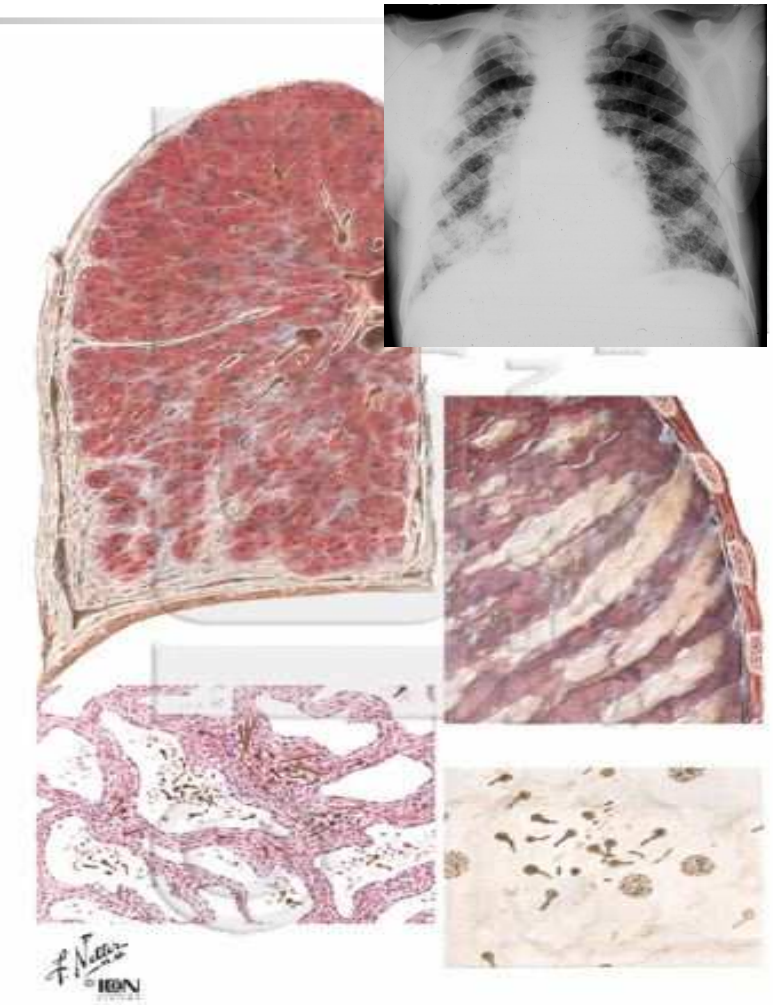
Right upper border is obliterated by a white opacity in the right upper lobe (silhouette sign) and the right hilum is elevated in relation to the left

- Atelectasis may be an acute or chronic condition.
- In acute atelectasis, the lung has recently collapsed and is primarily notable only for airlessness. Injury, surgery.
- In chronic atelectasis, the affected area is often characterized by a complex mixture of airlessness, infection, widening of the bronchi

Pulmonary fibrosis

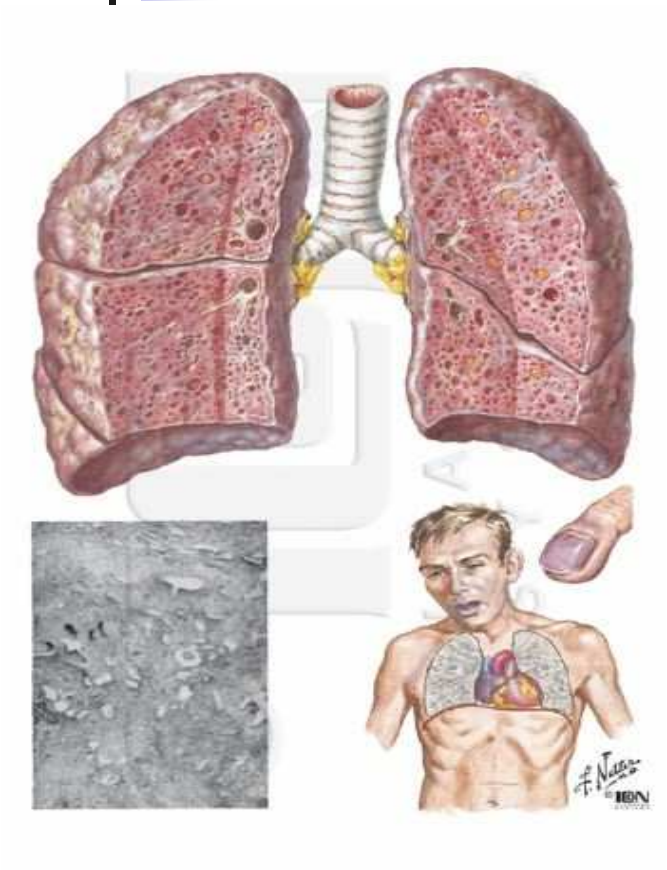


Idiopathic fibrosis

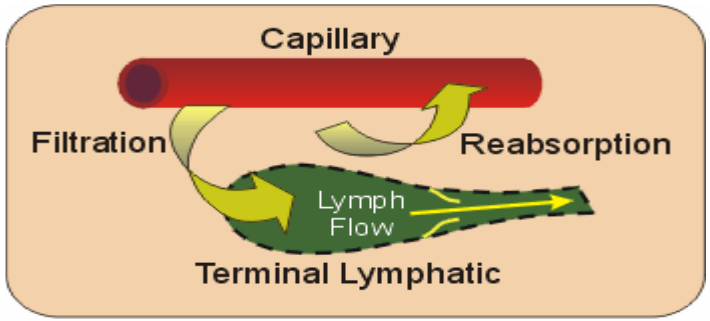


Asbestosis

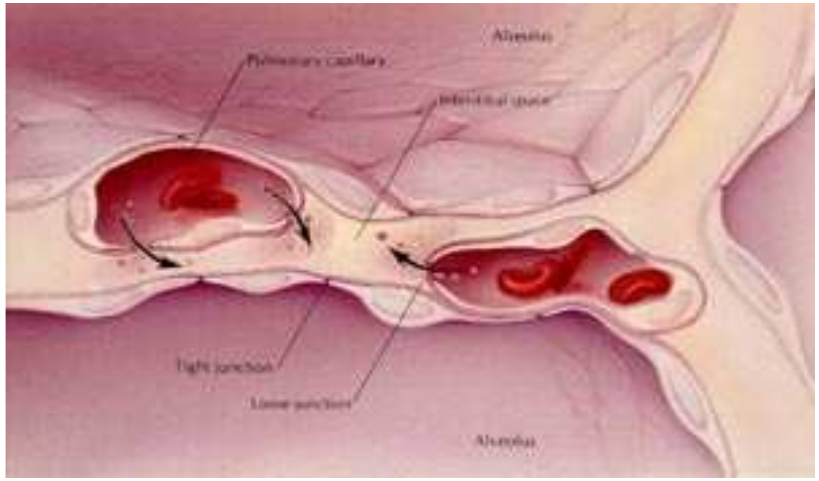
Pulmonary fibrosis

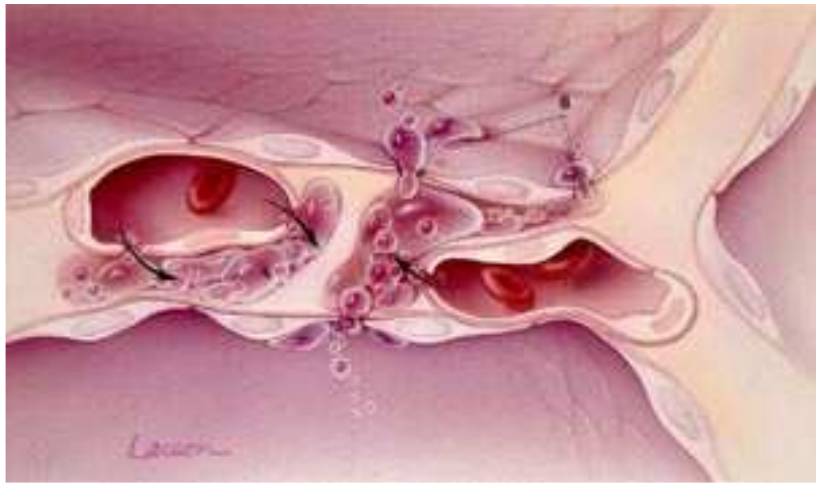


means scarring throughout the lungs; can be caused by many conditions including chronic inflammatory processes, infections, environmental agents, exposure to ionizing radiation, and certain medications.



The interstitial volume (bounded area) depends upon the rates of filtration, reabsorption, lymph flow, and the compliance of the interstitial compartment.



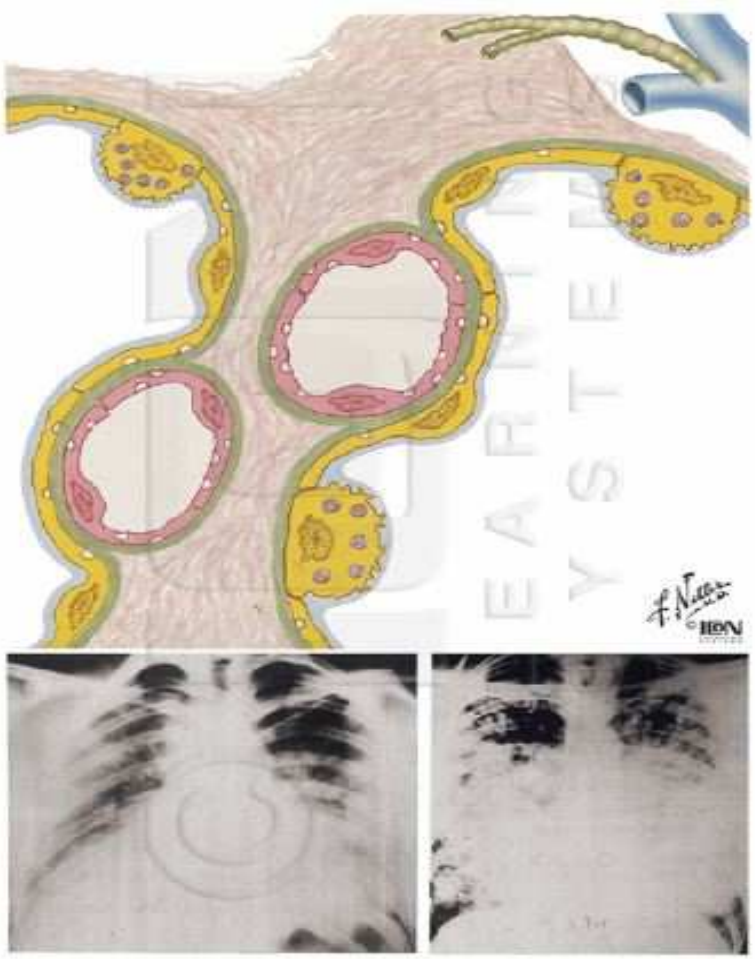


Pulmonary edema

1. Pulmonary edema begins with an increased filtration through the loose junctions of the pulmonary capillaries.

2. As the intracapillary pressure increases, normally impermeable (tight) junctions between the alveolar cells open, permitting alveolar flooding to occur.

Pulmonary edema (1) heart problems (2) other reasons eg. pneumonia, exposure to certain toxins and medications, and exercising or living at high elevations.

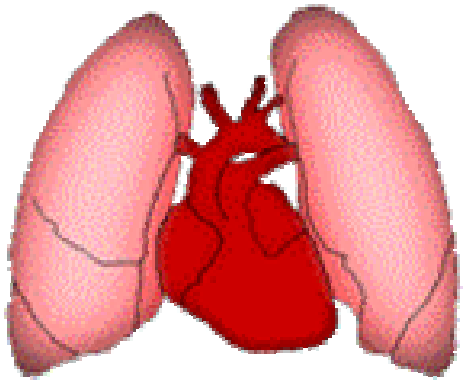


- Pulmonary capillary pressure must rise to a value at least equal to the colloid osmotic pressure (28mmHg) of the plasma

Partial pressures of O_2 and CO_2

[mmHg]	Atmosphere	Expired air	Alveolar air	Oxygenated blood	Deoxygenated blood
pO2	159	120	104	**100**	**40**
pCO2	0.3	27	40	**40**	**45**

Ventilation-perfusion ratio



Ventilation-Perfusion Coupling

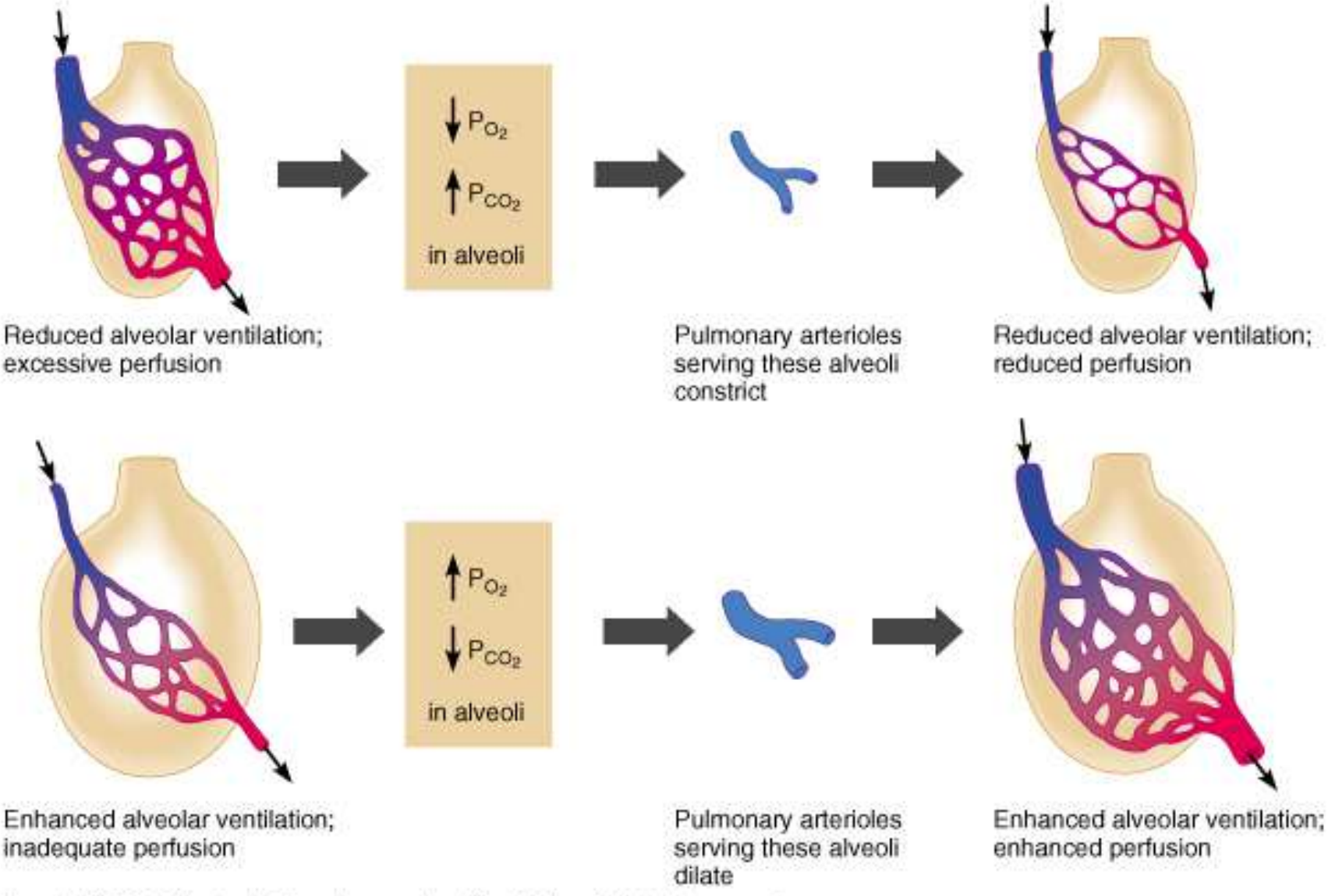
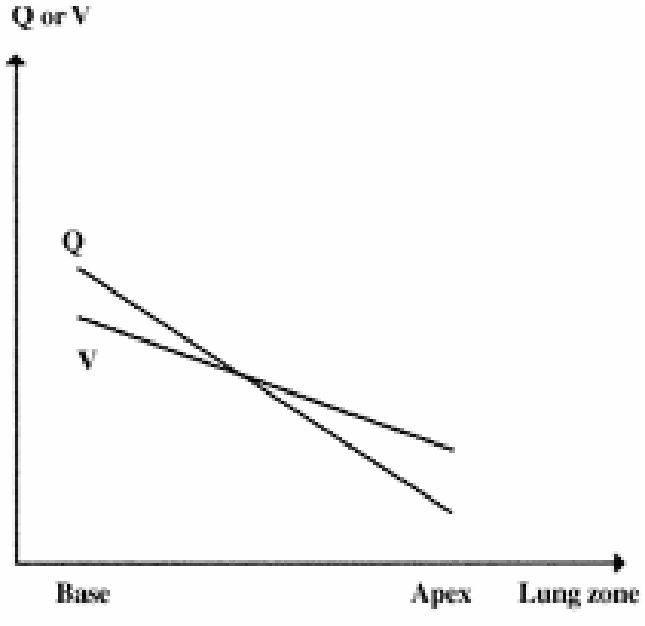


Figure 21.19

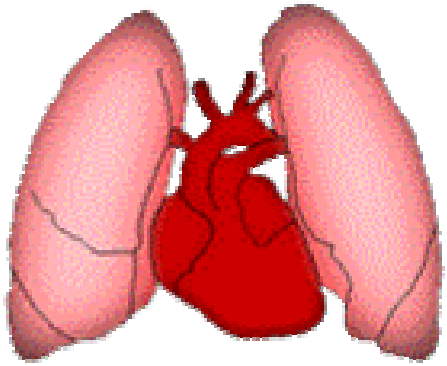
Total ventilation-perfusion ratio $\dot{V}_A/\dot{Q}$ (minute alveolar ventilation of 4600ml/min to minute pulmonary blood flow of 5400ml/min) accounts to about **0.8-1.2**

- In lower portions of lungs = 0.55
- Both blood flow and ventilation are greater
- Blood flow is increased considerably more than is ventilation



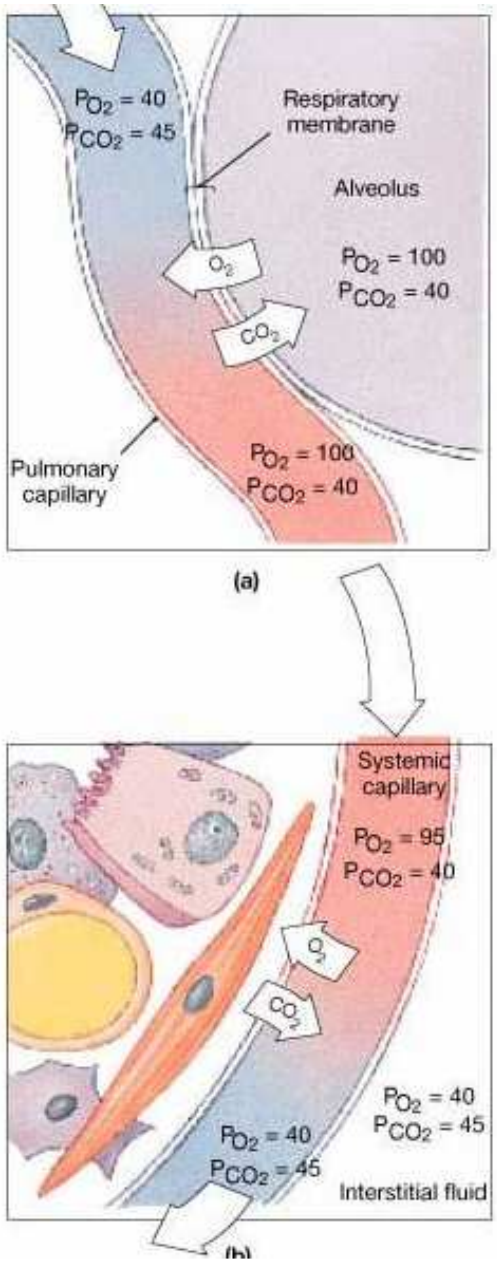
- In upper portions of lungs = 2.2
- Blood flow and ventilation are much less than in the lower parts
- Blood flow is decreased considerably more than is ventilation

Alveolar dead space and physiologic shunt



Alveolar dead space

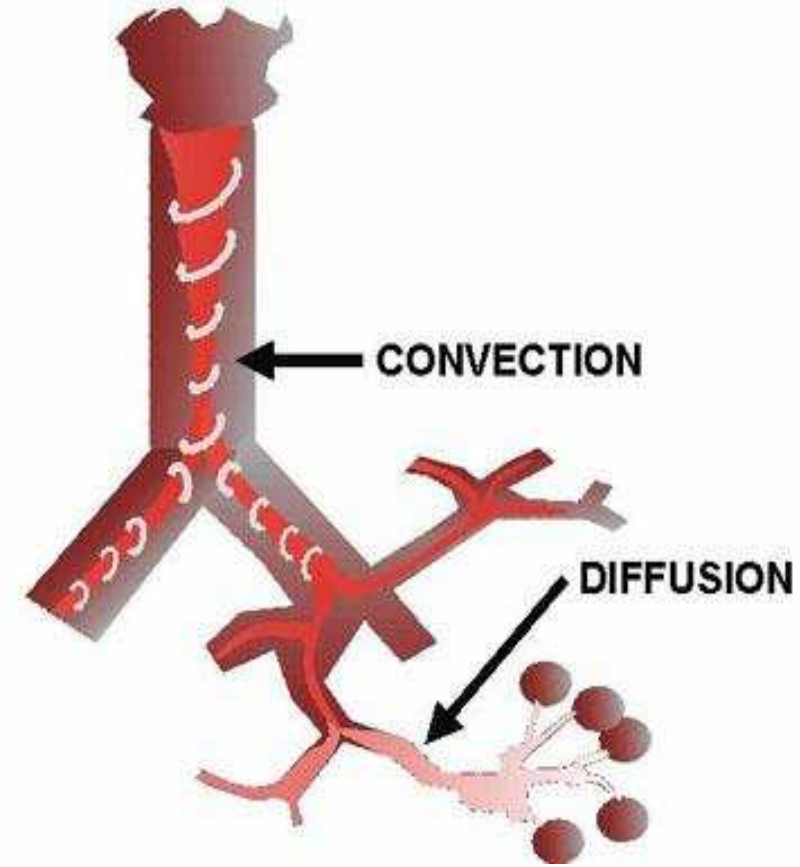
- At the top of the lung there is far more available O_2 in the alveoli than can be transported away by flowing blood
- thus the ventilation is said to be wasted



Physiologic shunt

- In the bottom of the lung slightly to little ventilation in relation to blood flow occurs
- therefore some part of blood does not become oxygenated (5%)
- Pulmonary shunt= physiologic shunt+anatomic shunt

Dead space is the portion of each tidal volume that does not take part in gas exchange



- Anatomic dead space is the total volume of the conducting airways from the nose or mouth down to the level of the terminal bronchioles, and is about **150 ml** on the average in humans

Physiologic dead space

Physiologic dead space =

anatomic d.s. + alveolar d.s.

Physiologic dead space =1-2L

- Physiologic dead space includes all the non-respiratory parts of the bronchial tree included in anatomic dead space, but also factors in alveoli which are well-ventilated but poorly perfused and are therefore less efficient at exchanging gas with the blood

Bohr and Haldane effects

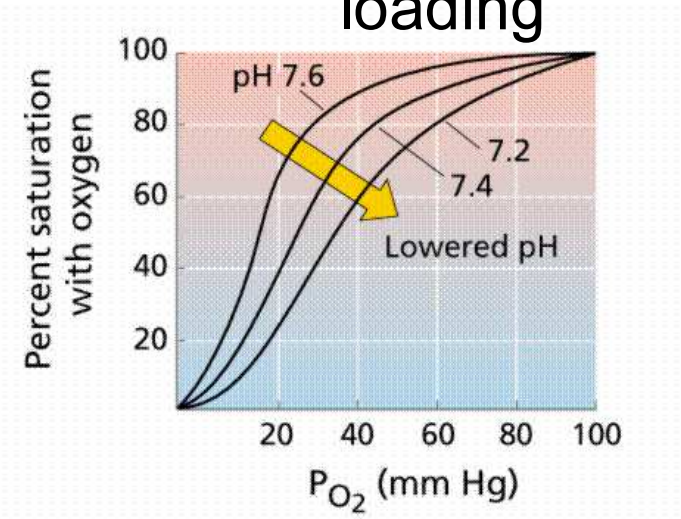
Bohr effect

- Tissue:

- ↑ CO2 loading (↓pH) facilitates O2 unloading

- Lungs:

- ↓ level of CO2 (CO2 unloading) facilitates O2 loading



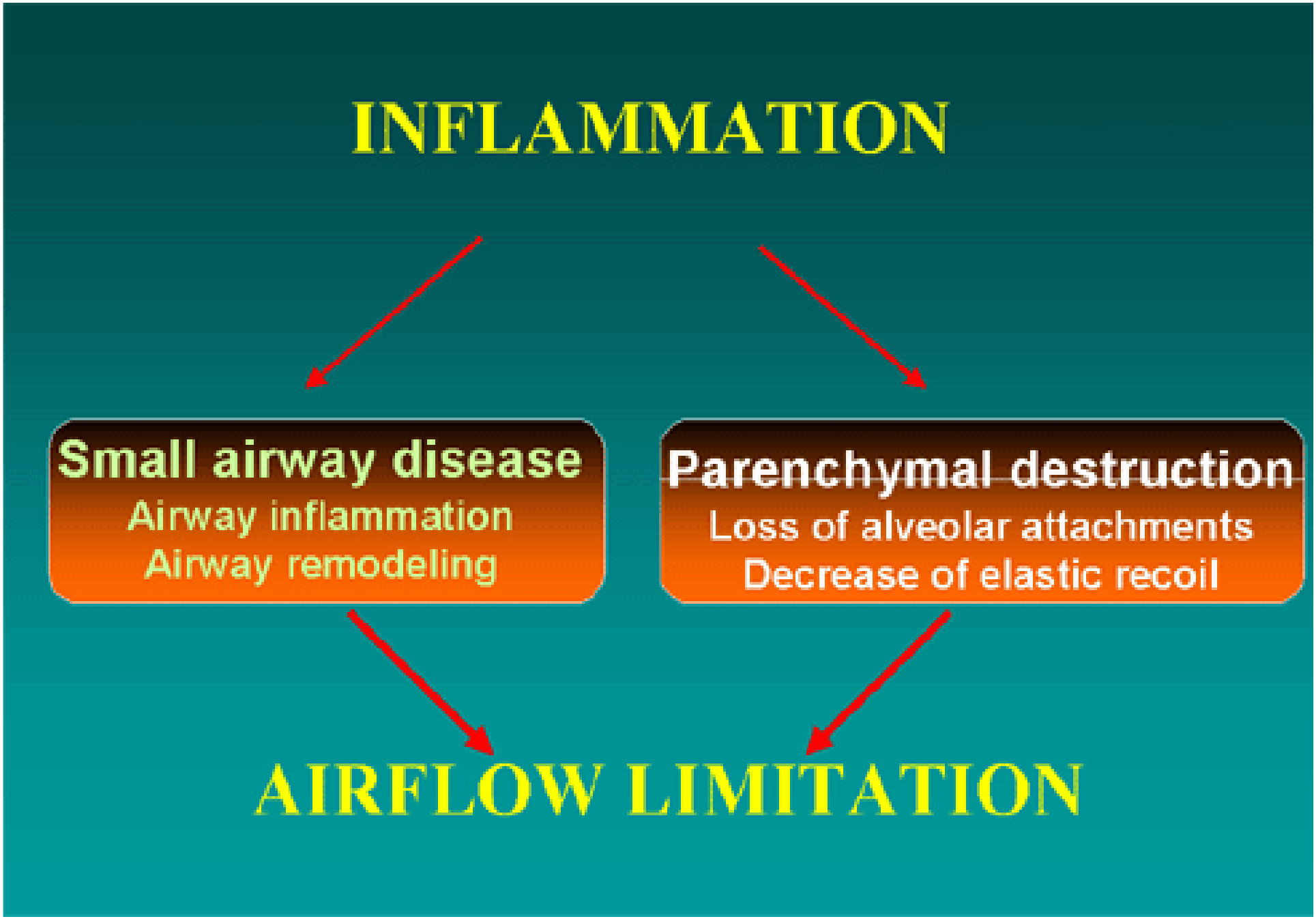
Haldane effect

- Tissue:

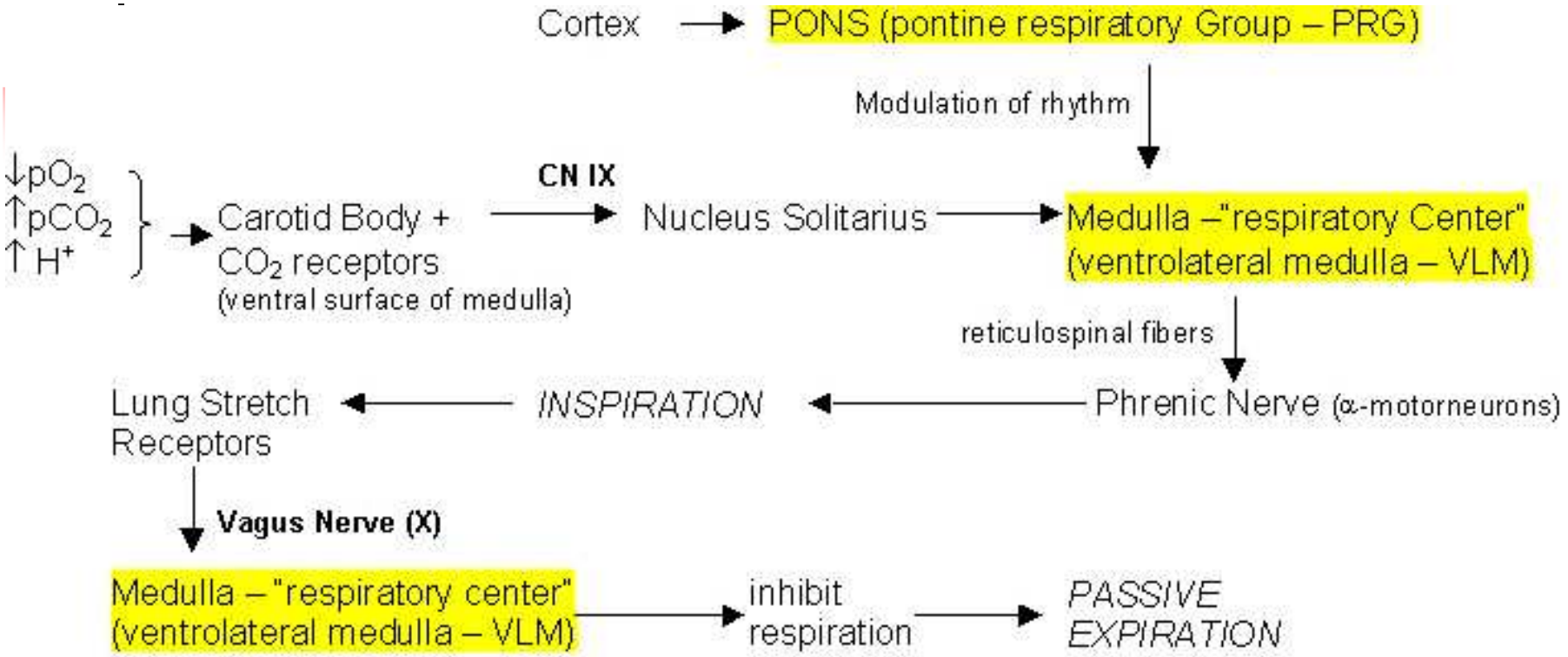
  - O2 unloading (↓level of HbO2) facilitates CO2 loading

- Lungs:

  - O2 loading (↑level of HbO2) facilitates CO2 unloading


INFLAMMATION
Small airway disease
Airway inflammation
Airway remodeling
Parenchymal destruction
Loss of alveolar attachments
Decrease of elastic recoil
AIRFLOW LIMITATION

Neural respiratory control



Carotid body: located @ bifurcation of common carotid artery. Chemoreceptor response is carried by glossopharyngeal (CN IX) in response to ↓ O_2, ↑ CO_2, ↑ H^+ (↓pH)