PHYSIOLOGY OF RESPIRATION

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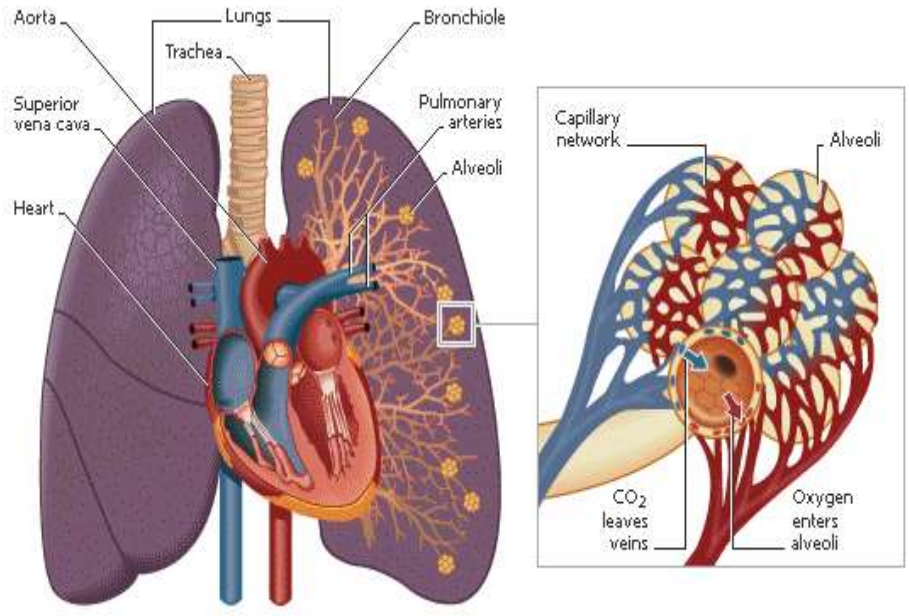
Physiological Anatomy of Respiratory System

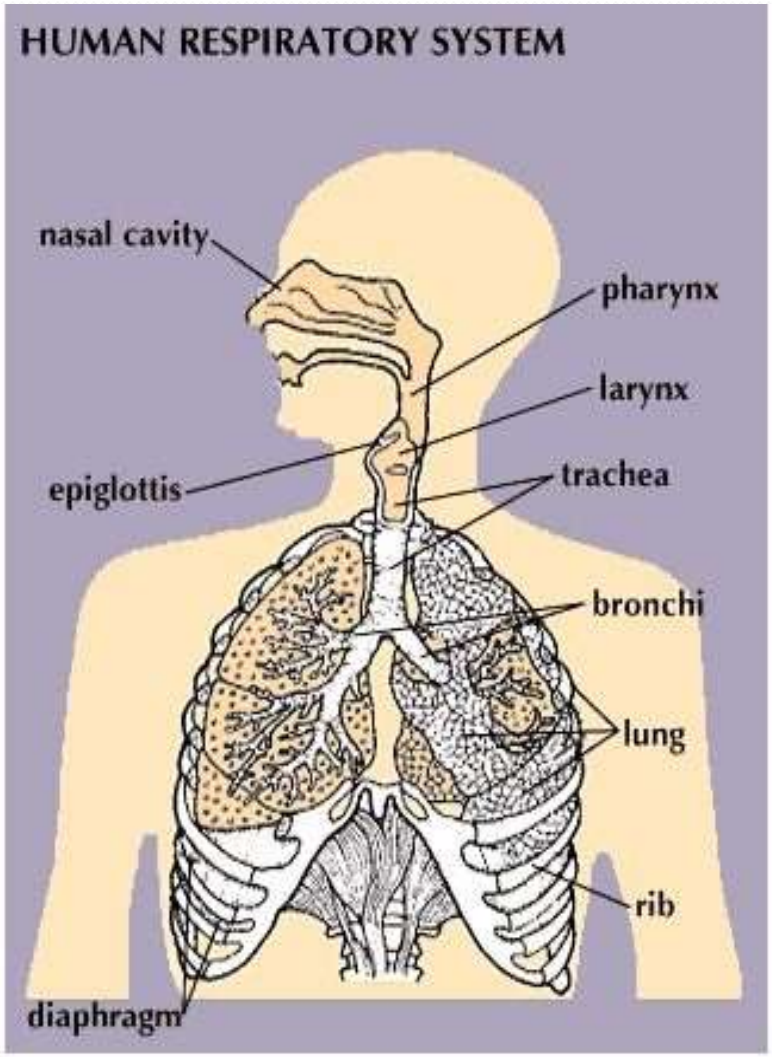
- The respiratory system consists of the **nasal cavity**, **pharynx**, **larynx**, **trachea**, **bronchi**, and **lungs,** which is whole together called as the Respiratory Tract..

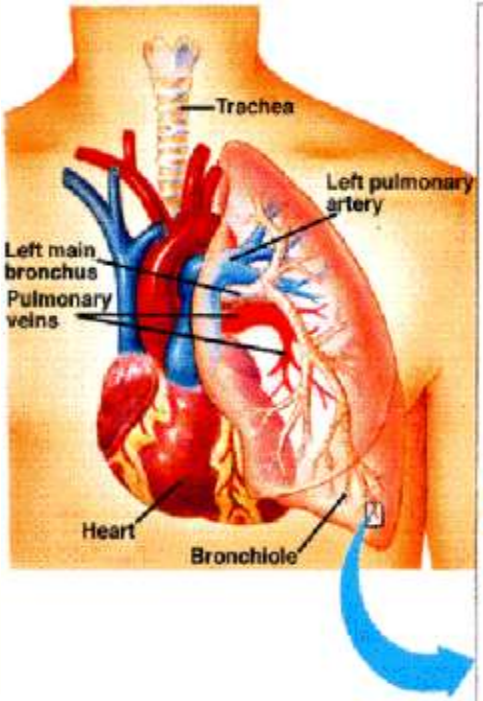
- Upper respiratory tract refers to: Nasal cavity, pharynx, and associated structures.

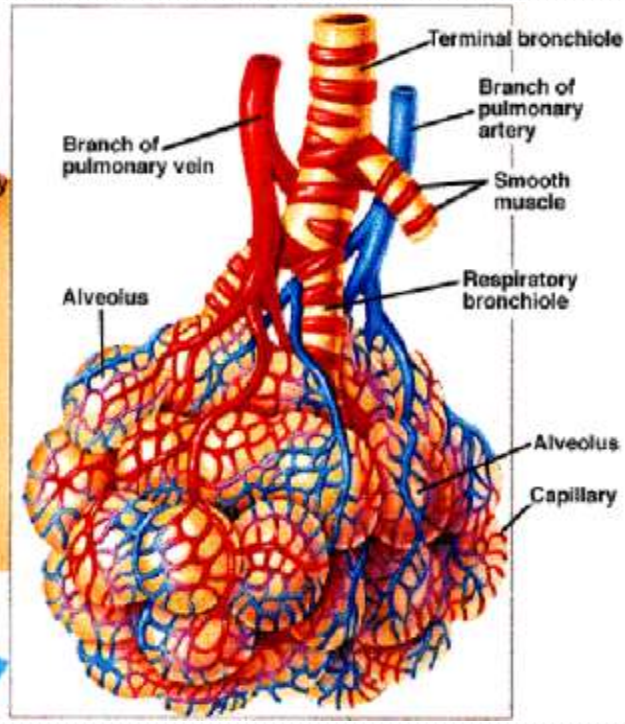
- Lower respiratory tract refers to: Larynx, trachea, bronchi, and lungs.



The Lungs & Alveoli



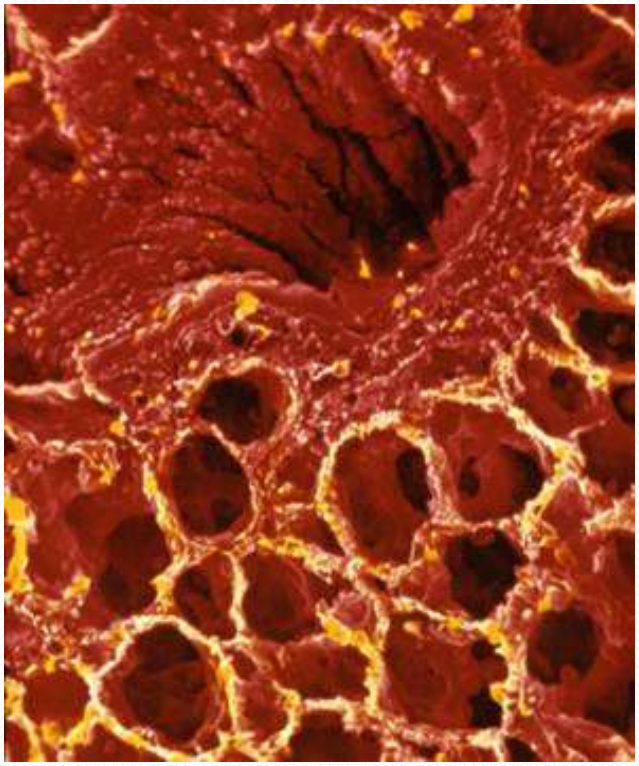




- Respiratory Unit

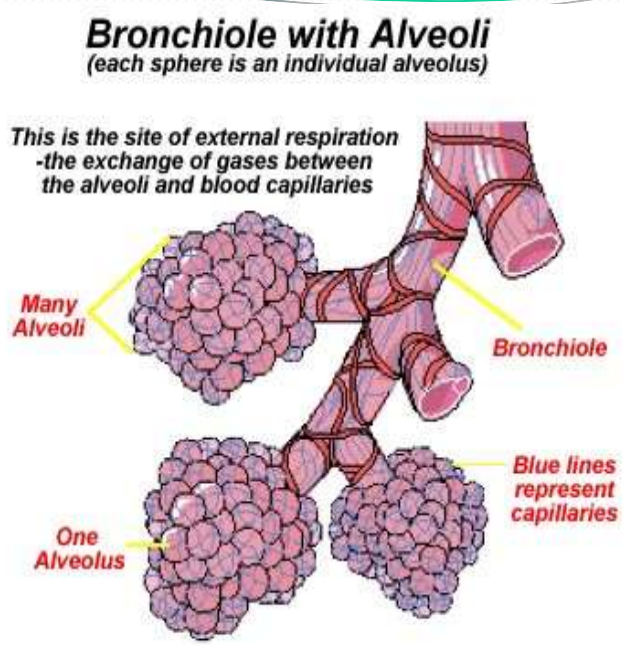
  Respiratory unit is the terminal portion of the Respiratory Tract. It includes:

- 1. Respiratory Bronchioles
- 2. Alveolar Ducts
- 3. Antrum
- 4. Alveolar Sacs
- 5. Alveoli (Human beings have a thin layer of about 700 million alveoli within their lungs. Which is crucial for respiration, exchanging O_2 & CO_2 with the surrounding blood capillaries.)



Microscopic Structure of Alveoli

- Types of Respiration
- 1. External Respiration:
- Exchange of O2 & CO2
- Between lungs & blood.



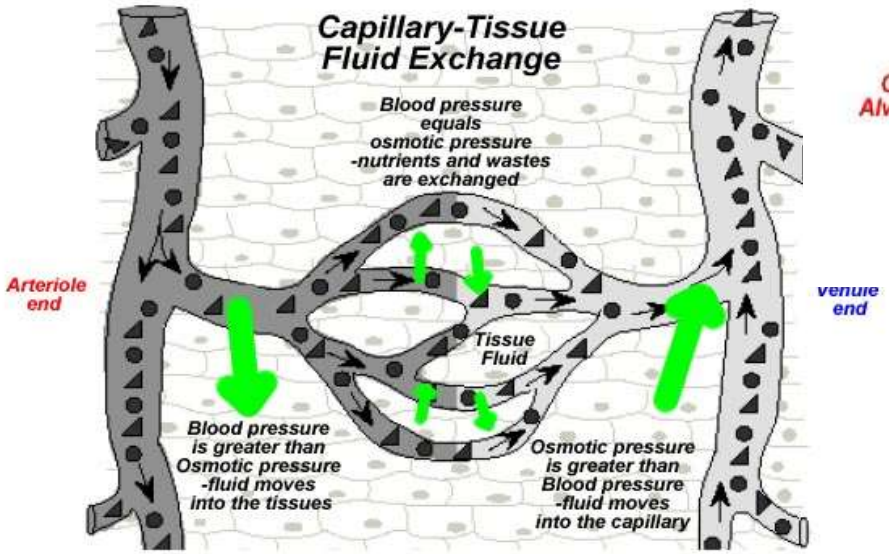
External Respiration
(Reactions)

$Hb + O_2 \longrightarrow HbO_2$

$HbCO_2 \longrightarrow Hb + CO_2$

$HHb \longrightarrow Hb + H^+$

$H^+ + HCO_3^- \longrightarrow H_2CO_3 \xrightarrow{\text{carbonic anhydrase}} H_2O + CO_2$



Internal respiration occurs in the capillaries
Internal Respiration Reactions

$HbO_2 \longrightarrow Hb + O_2$

$Hb + CO_2 \longrightarrow HbCO_2$

$CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} H_2CO_3 \longrightarrow H^+ + HCO_3^-$

$H^+ + Hb \longrightarrow HHb$

2. Internal Respiration:
Exchange of gases
between blood & tissues.

- Respiratory Functions:
- 1. Pulmonary Ventilation
- 2. Diffusion of O_2 and CO_2 between the alveoli & the blood.
- 3. Transportation of O_2 & CO_2 in the blood & body fluids to & fro from the body's tissue cells.
- 4. Regulation of Ventilation.

- Non- Respiratory Functions:
- 1. Olfaction, Vocalization
- 2. Defense Mechanism
- 3. Anticoagulant Function
- 4. Regulation of Body Temperature & Acid Base Balance
- 5. Maintenance of Water balance
- 6.Secretion of ACE Angiotensin Converting Enzyme

Mechanism of Respiration

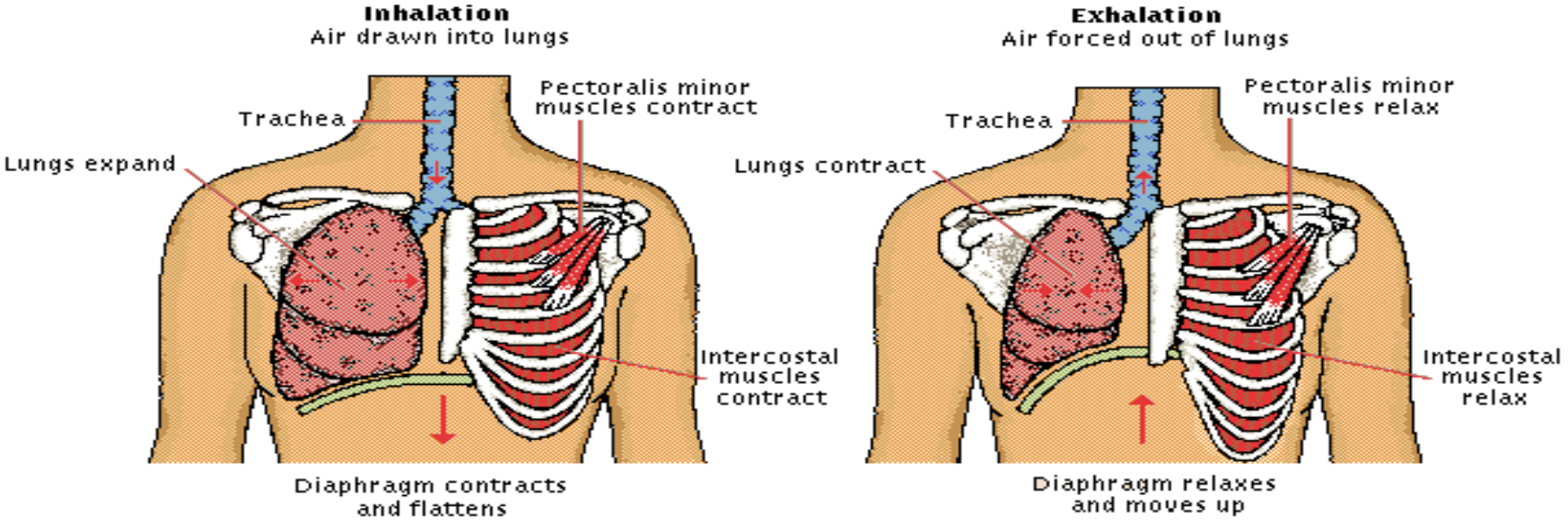
- Muscles of Respiration

i. Primary Inspiratory: Diaphragm

ii. Accessory Inspiratory: Sternomastoid, Scaleni, Anterior Serrati, Elevators of Scapula & Pectorals

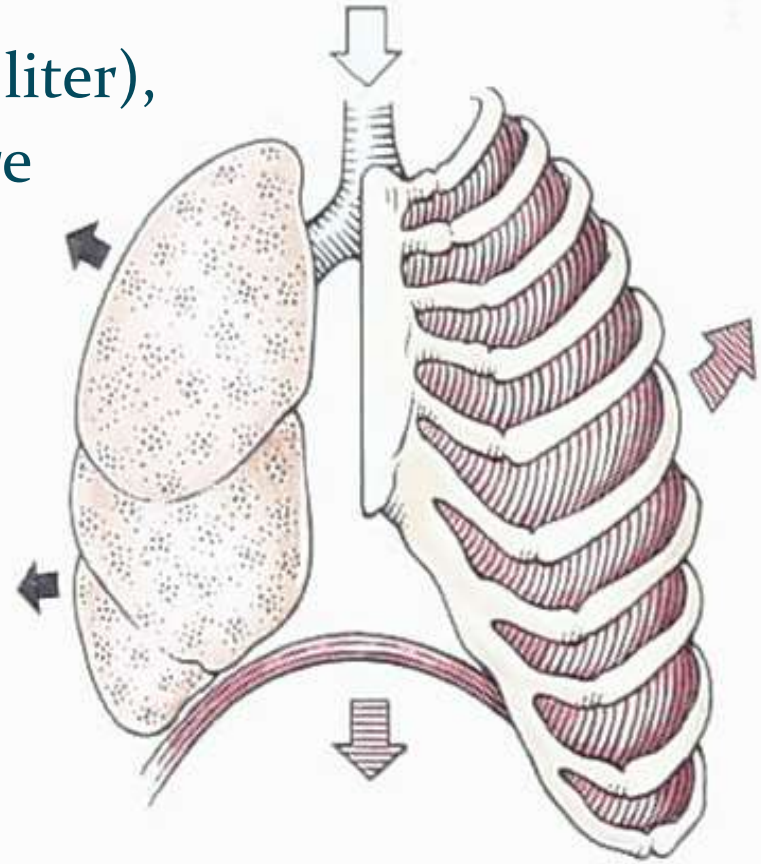
iii. Primary Expiratory: Internal Intercostal muscles

iv. Accessory expiratory: Abdominal muscles Inspiration

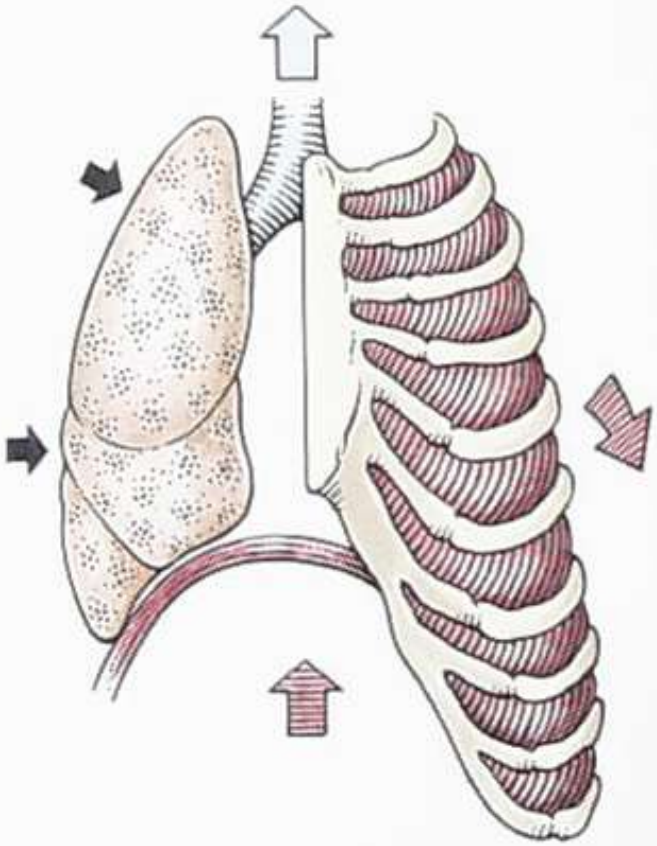


- Inspiration
- 1. Diaphragm muscle contracts, increasing thoracic cavity size in the superior-inferior dimension
- 2. External intercostal muscles contract, expanding lateral & anterior-posterior dimension
- 3. INCREASED volume (about 0.5 liter), DECREASED pulmonary pressure (-1 mm Hg),air rushes into lungs to fill alveoli
- Deep/forced inspirations – as during exercise and pulmonary disease

  * scalenes, sternocleidomastoid, pectorals are used for more volume expansion of thorax.



- Expiration
- 1. Quiet expiration (exhalation) - simple elasticity of the lungs DECREASES volume INCREASED pulmonary pressure -> movement of air out of the lungs
- 2. Forced expiration - contraction of abdominal wall muscles (i.e. obliques & transversus abdominus) further DECREASES volume beyond relaxed point ----> further INCREASE in pulmonary pressure ---> more air moves out.



- Movements of Thoracic Cage

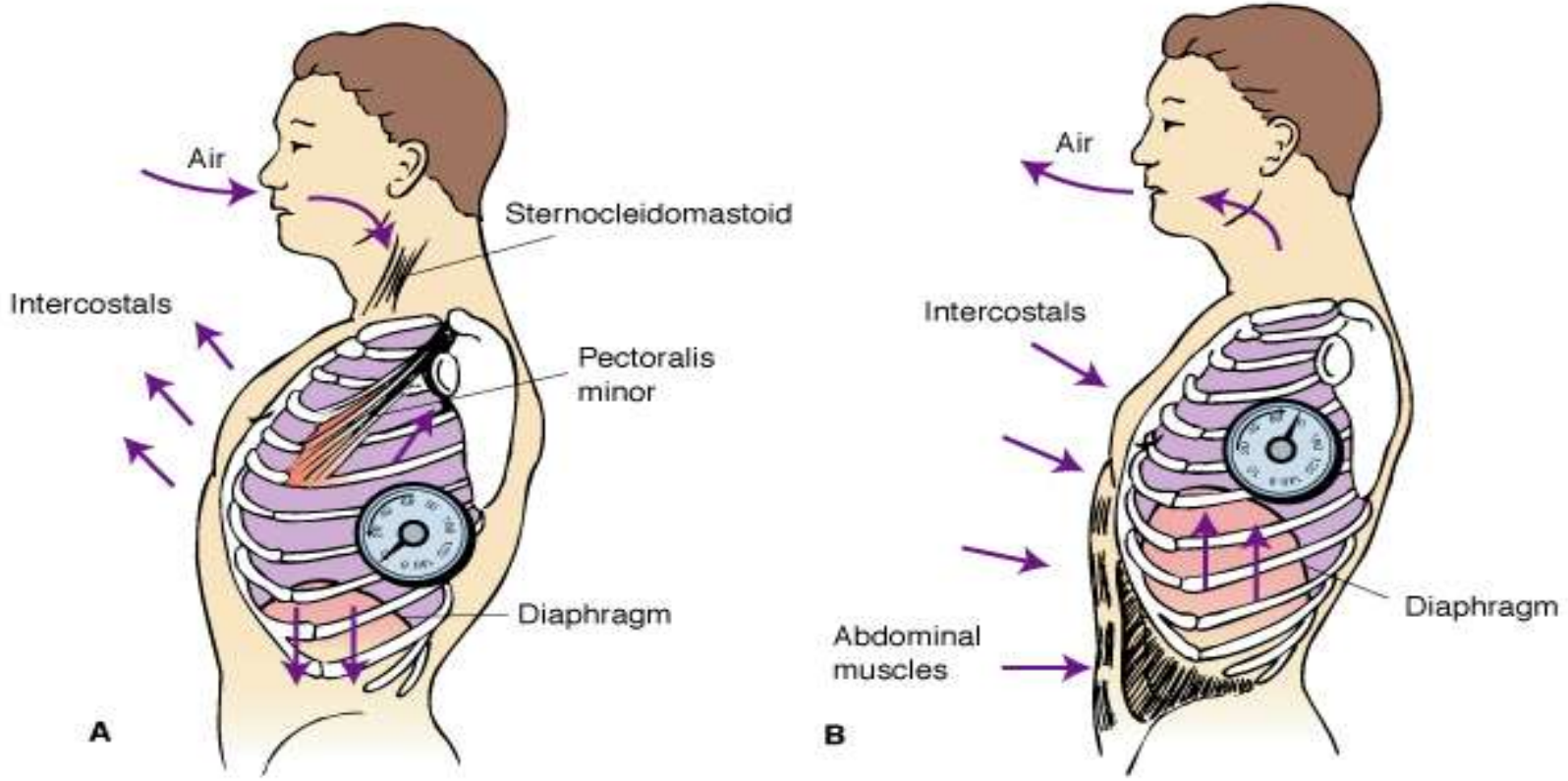


Figure 20-2 Ventilation and thoracic pressure changes. (A) Inspiration. (B) Expiration.

- Movements of Lungs

Factors holding lungs AGAINST the thorax wall:

i. Surface tension holding the "visceral" and "parietal" pleura together.

ii. Intrapulmonary pressure is ALWAYS slightly greater than intrapleural pressure by 4 mm Hg.

iii. Atmospheric pressure acting on the lungs.

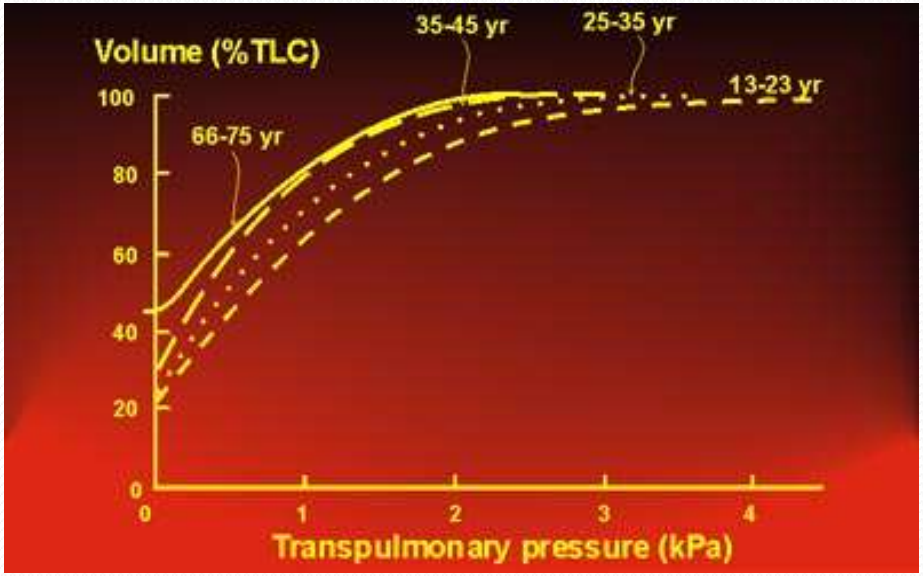
a) Atelectasis (collapsed lung) - hole in pleural "balloon" causes equalization of pressure and collapse of the lung.

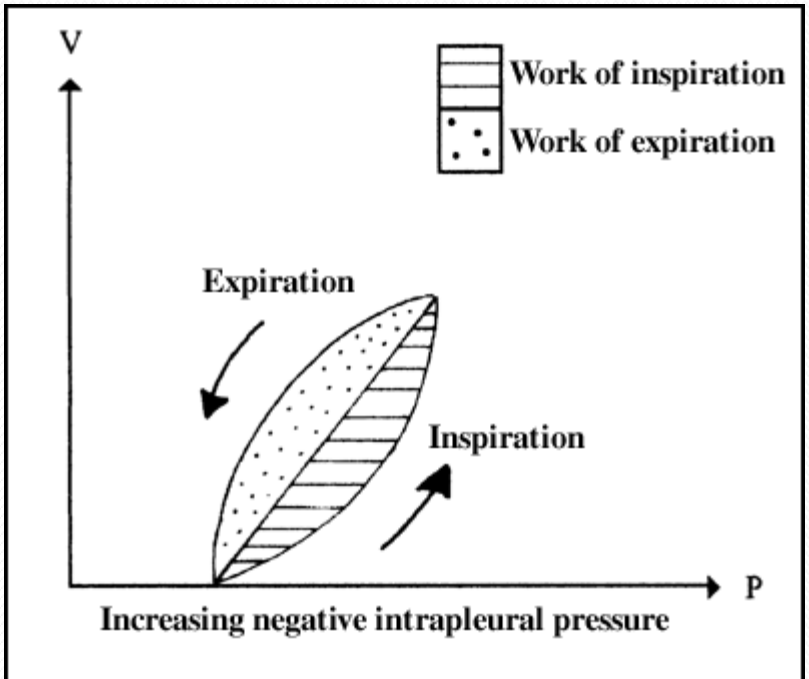
b) Pneumothorax - abnormal air in the intrapleural space, can lead to collapsed lung.

Factors facilitating lung movement AWAY from thorax wall

i. Elasticity of lungs allows them to assume smallest shape for given pressure conditions.

ii. Fluid film on alveoli allows them to assume smallest shape for given pressure conditions.





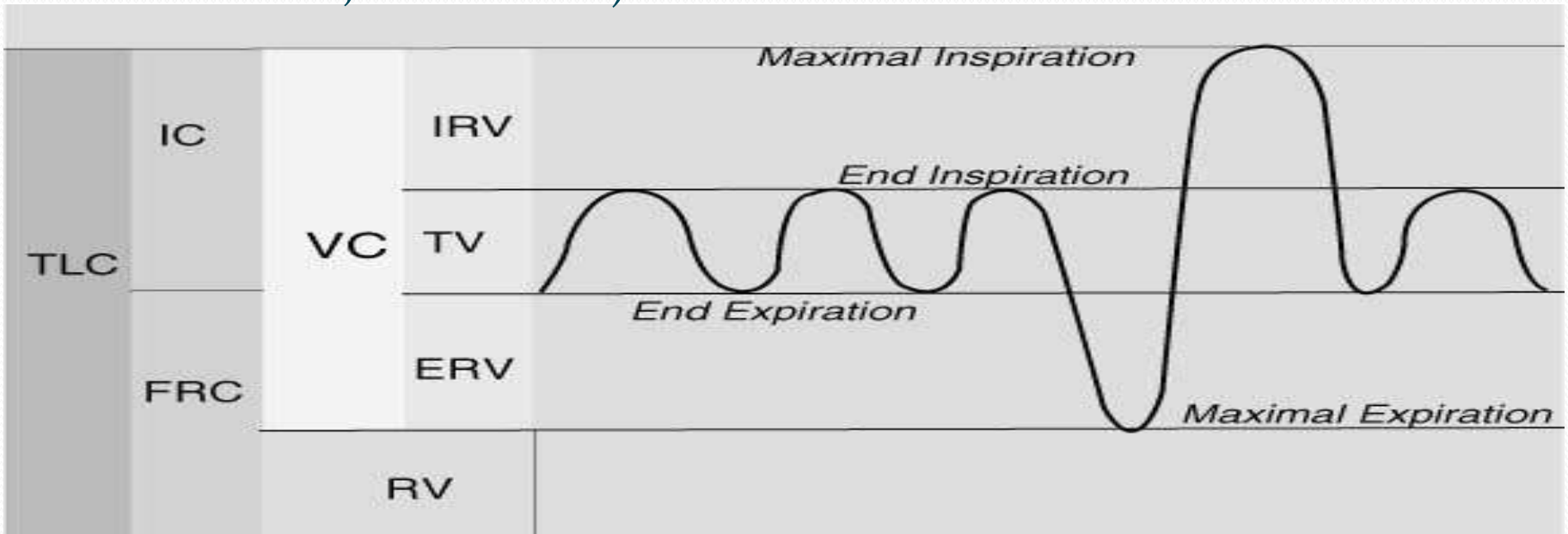
Pulmonary Volumes, Capacities & Function Tests

A. Respiratory Volumes

- 1. Tidal volume (TV) - normal volume moving in/out (0.5 L).
- 2. Inspiratory reserve volume (IRV) - volume inhaled AFTER normal tidal volume when asked to take deepest possible breath (2.1-3.2 L).
- 3. Expiratory reserve volume (ERV) - volume exhaled AFTER normal tidal volume when asked to force out all air possible (1.- 2.0 L).
- 4. Residual volume (RV) - air that remains in lungs even after totally forced exhalation (1.2 L).

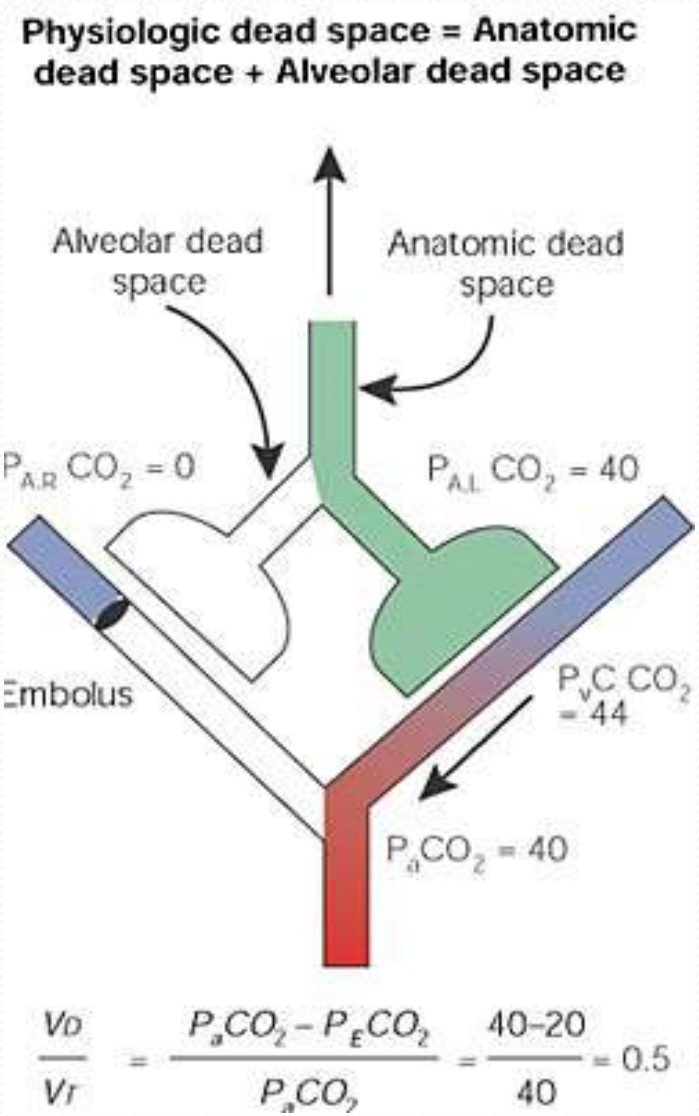
B. RespiratoryCapacities

- 1. Inspiratory capacity (IC) = TV + IRV (MAXIMUM volume of air that can be inhaled).
- 2. Functional residual capacity (FRC) ERV + RV (all non-tidal volume expiration).
- 3. Vital capacity (VC) = TV + IRV + ERV (TOTAL volume of air that can be moved).
- 4. Total lung capacity (TLC) = TV + IRV + ERV + RV (the SUM of all volumes; about 6.0 L).



C. Dead Space

- 1. Anatomical dead space – all areas where gas exchange does not occur (all but alveoli).
- 2. Alveolar dead space – non-functional alveoli.
- 3. Total dead space – Anatomical + Alveolar.



D. Pulmonary FunctionTests

- 1. Spirometer - measures volume changes during breathing.

  a. Obstructive pulmonary disease - increased resistance to air flow (bronchitis or asthma).

  b. Restrictive disorders - decrease in Total Lung Capacity (TB or polio) .

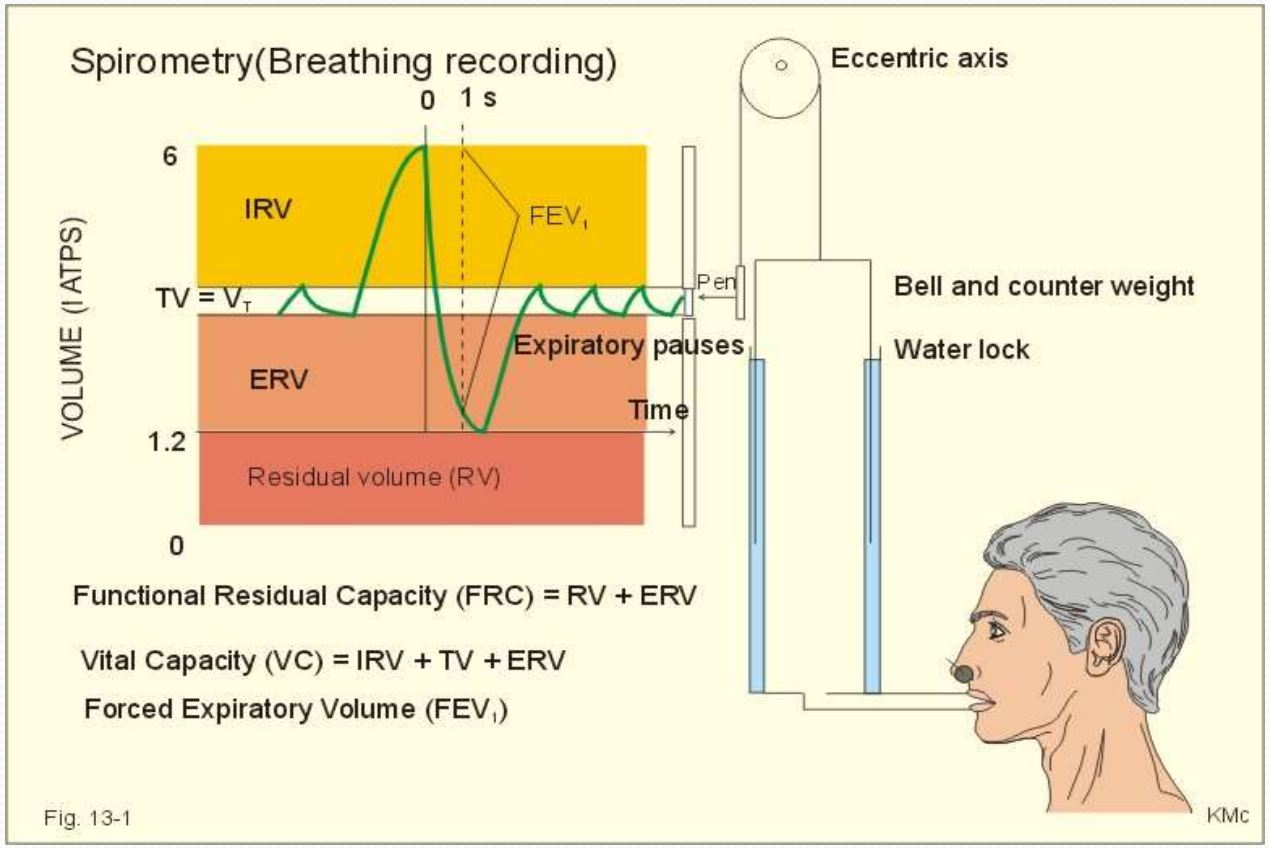
- 2. Minute respiratory volume (MRV) - total volume flowing in & out in 1 minute (resting rate = 6 L per minute).
- 3. Forced vital capacity (FVC) - total volume exhaled after forceful exhalation of a deep breath.
- 4. Forced expiratory volume (FEV) - FEV volume measured in 1 second intervals (FEV_1...).

E. Alveolar Retention Rate

- AVR = Breath Rate X (TV - Dead space)

  (Normal) AVR = 12 /minute X (500 ml – 150 ml)

  (Normal) AVR = 4.2 L/min



Spirometer

Transport of Gases

- Transport of O_2:

  i) As simple solution (3% i.e. 0.3ml/100ml)

  ii) In Combination with Hb (97%)

- Transport of CO_2:

  i) As dissolved form (7%)

  ii) As carbonic Acid (Negligible)

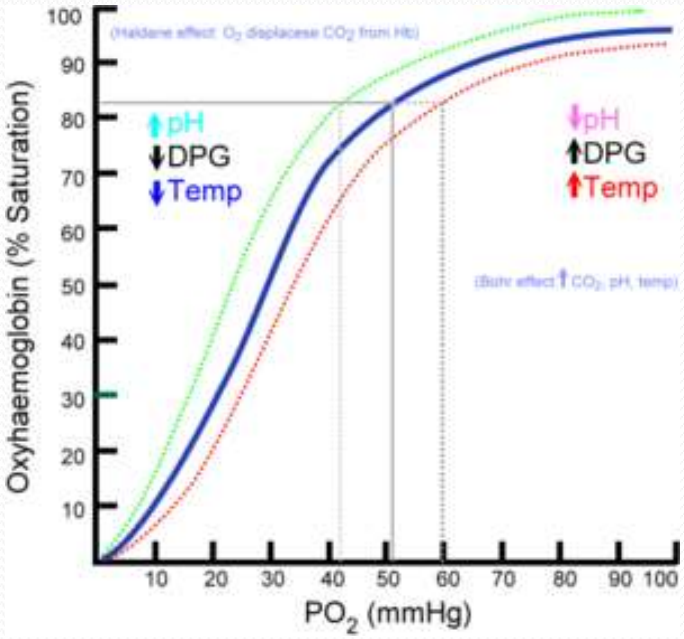
  iii) As Bicarbonate (63%)

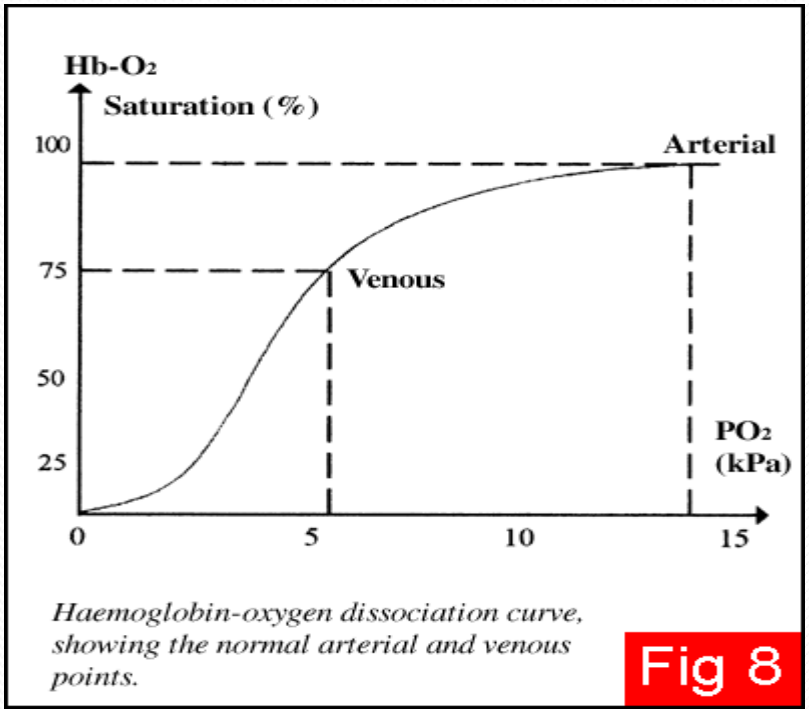
  iv) As Carbamino Compounds (30%)

- Oxygen Dissociation Curve

1. Oxygen-hemoglobin dissociation curve

- a. 104 mm (lungs) - 100% saturation (20 ml/100 ml)
- b. 40 mm (tissues) - 75% saturation (15 ml/100 ml)
- c. right shift - Decreased Affinity, more O_2 unloaded
- d. left shift- Increased Affinity, less O_2 unloaded





Haemoglobin-oxygen dissociation curve, showing the normal arterial and venous points.

Fig 8

A. Effects of Temperature

1. HIGHER Temperature ⟶ Decreased Affinity (right)
2. LOWER Temperature ⟶ Increased Affinity (left)

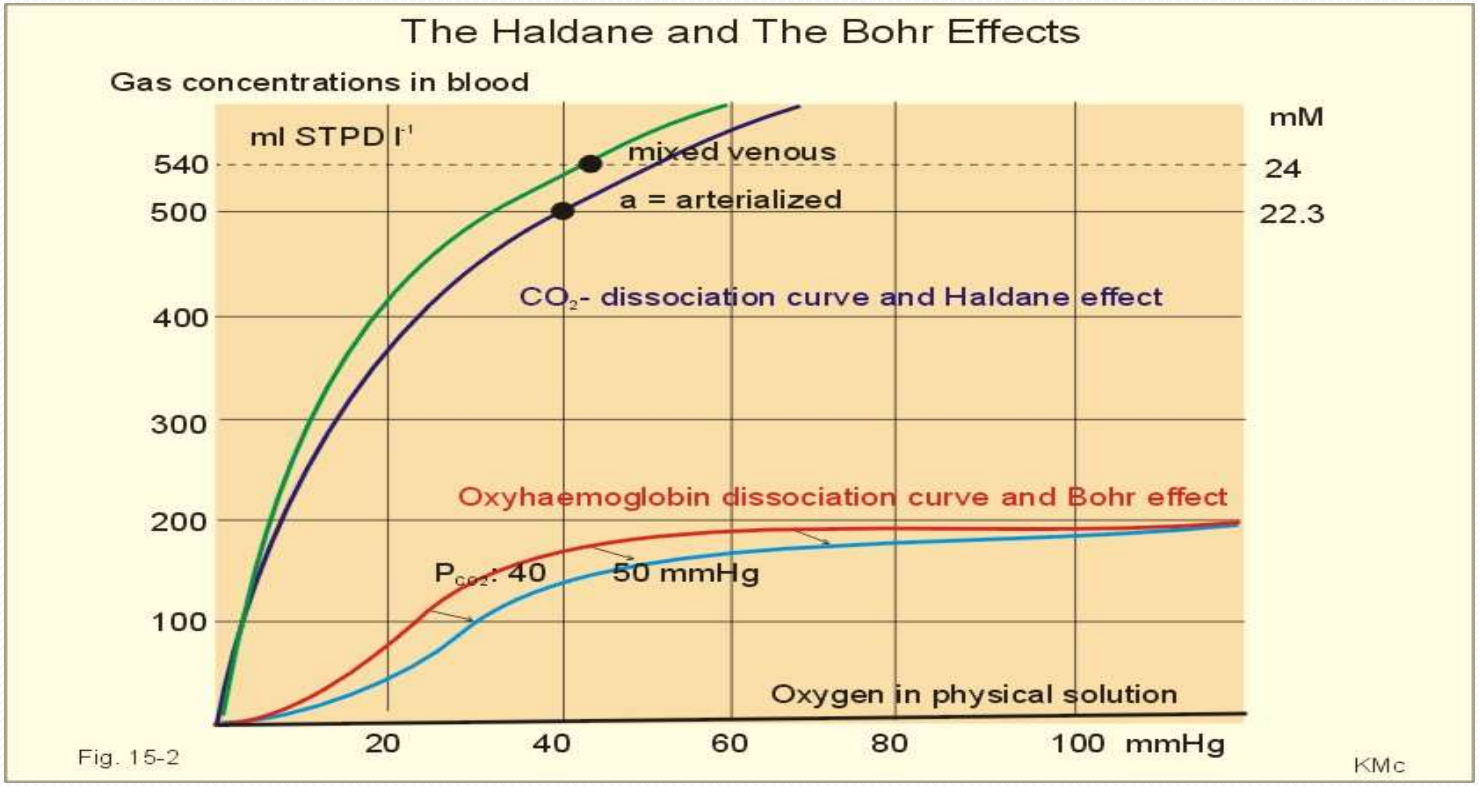
B. Effects of pH (Acidity)

1. HIGHER pH⟶Increased Affinity (left)
2. LOWER pH ⟶Decreased Affinity (right) "Bohr Effect“

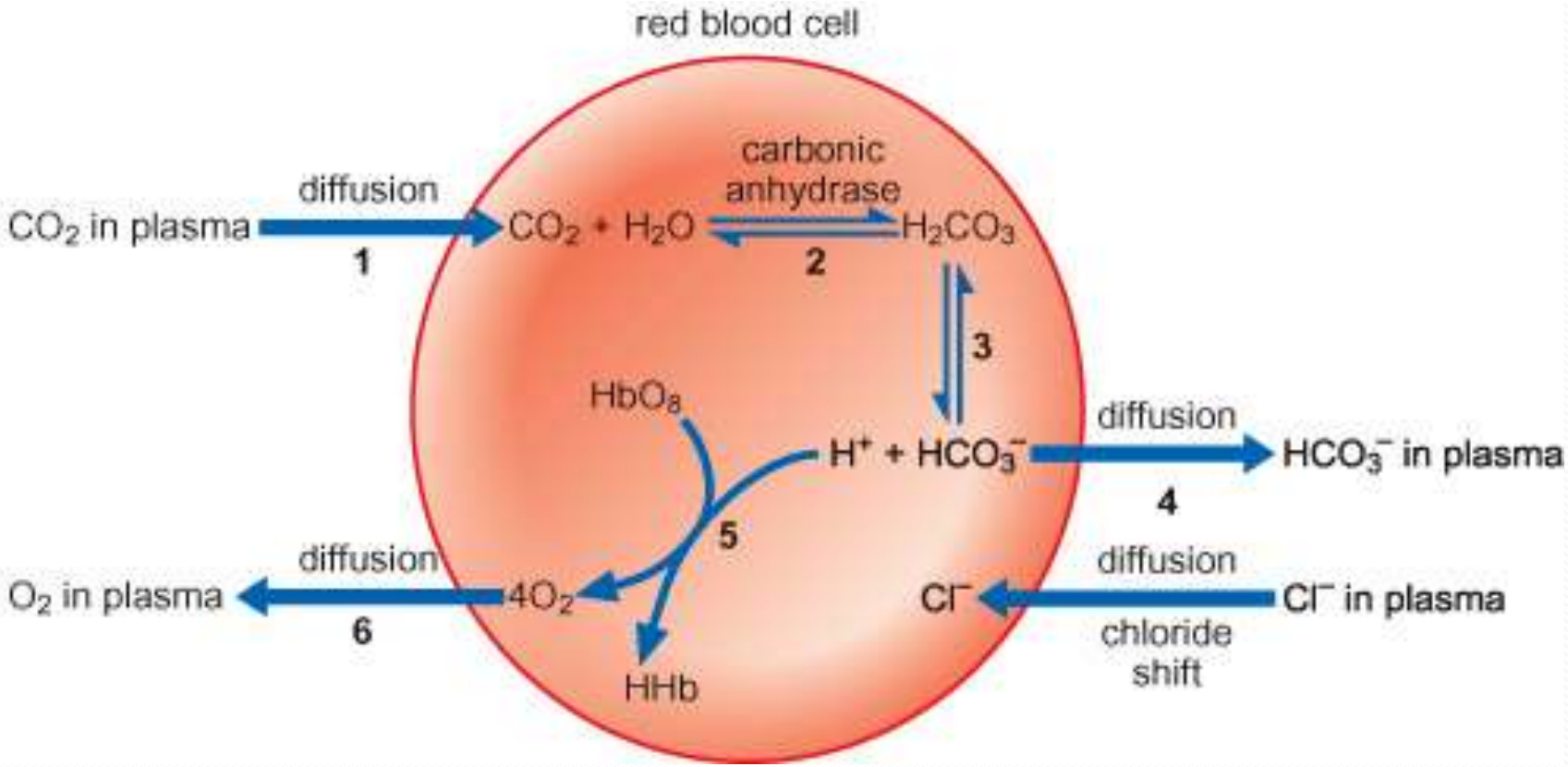
C. Effects of Diphosphoglycerate (DPG)

1. DPG - produced by anaerobic processes in RBCs
2. HIGHER DPG > Decreased Affinity (right)
3. Thyroxine, testosterone, epinephrine, NE - increase RBC metabolism and DPG production, cause RIGHT shift.

- Carbon Dioxide Dissociation Curve
- Bohr Effect - Formation of Bicarbonate (through Carbonic Acid) leads to LOWER pH (H+ increase), and more unloading of Ox to tissues. Since Hb "buffers" to H^+, the actual pH of blood does not change much.



- Chloride Shift - Chloride ions move in opposite direction of the entering/leaving Bicarbonate, to prevent osmotic problems with RBCs



Exchange of Gases

A. External Respiration (Air & Lungs)

1. Partial Pressure Gradients & Solubilities

a. Oxygen: alveolar (104 mm) ---> blood (40 mm)

b. Carbon Dioxide: blood (45 mm) ----> alveolar (40 mm) (carbon dioxide much more soluble than oxygen)

2. Alveolar Membrane Thickness (0.5-1.0 micron) very easy for gas to diffuse across alveoli

b. Edema - increases thickness, decreases diffusion

3. Total Alveolar Surface Area for Exchange

a. Total surface area healthy lung = 145 sq. Meters

b. Emphysema - decreases total alveolar surface area

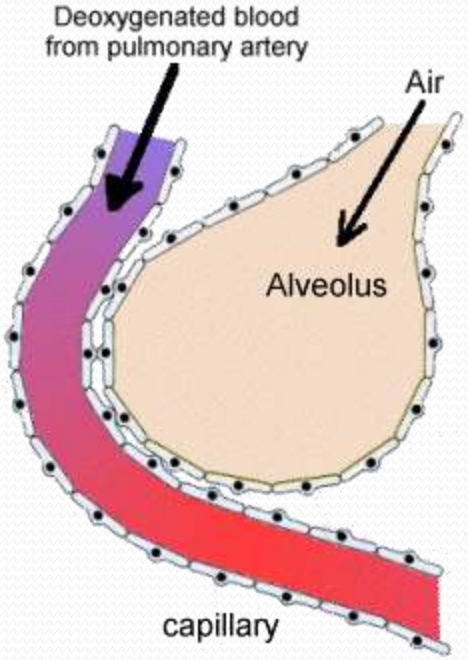
4. Ventilation-Blood Flow Coupling

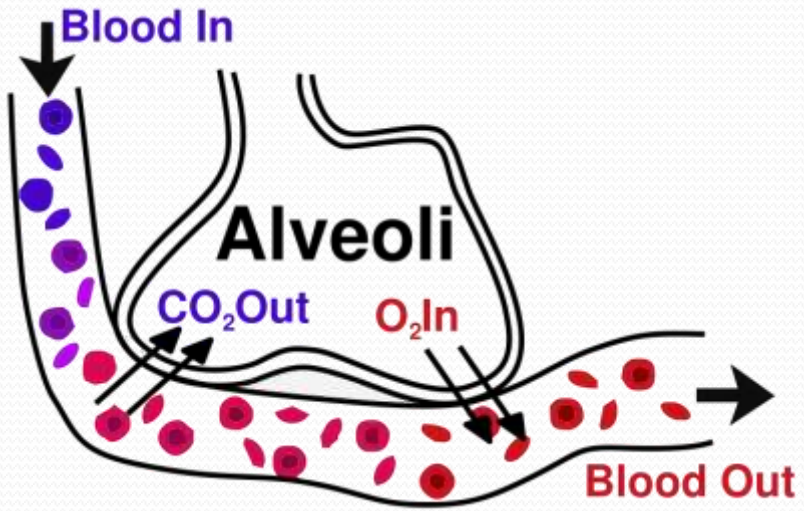
Low O_2 in alveolus ⟶ vasoconstriction

High O_2 in alveolus ⟶ vasodilation

High CO_2 in alveolus ⟶ dilate bronchioles

Low CO_2 in alveolus ⟶ constrict bronchioles





B. Internal respiration (Blood & Tissues)

- 1. Oxygen: blood (104 mm) ⟶tissues (40 mm)
- 2. Carbon Dioxide: tissues (>45 mm)⟶ blood (40 mm)

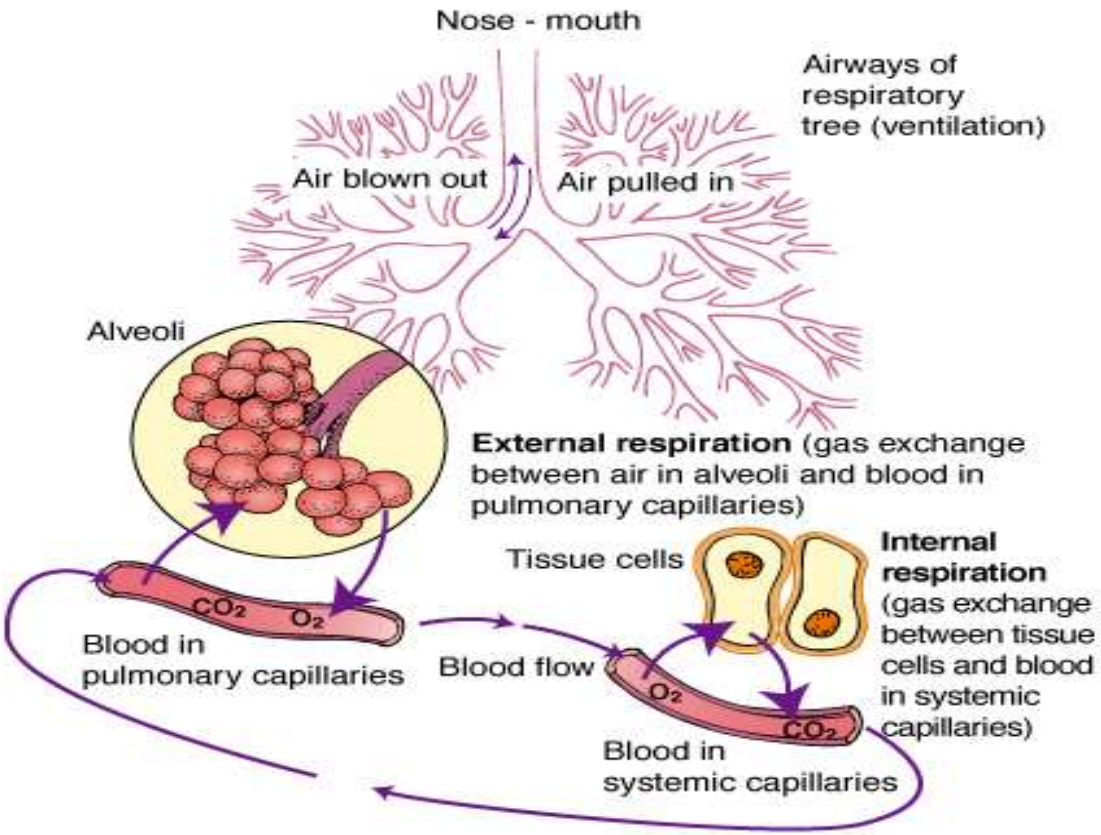


Figure 20-1 External and internal respiration.

Regulation of Respiration

Nervous Mechanism

A. Medullary Respiratory

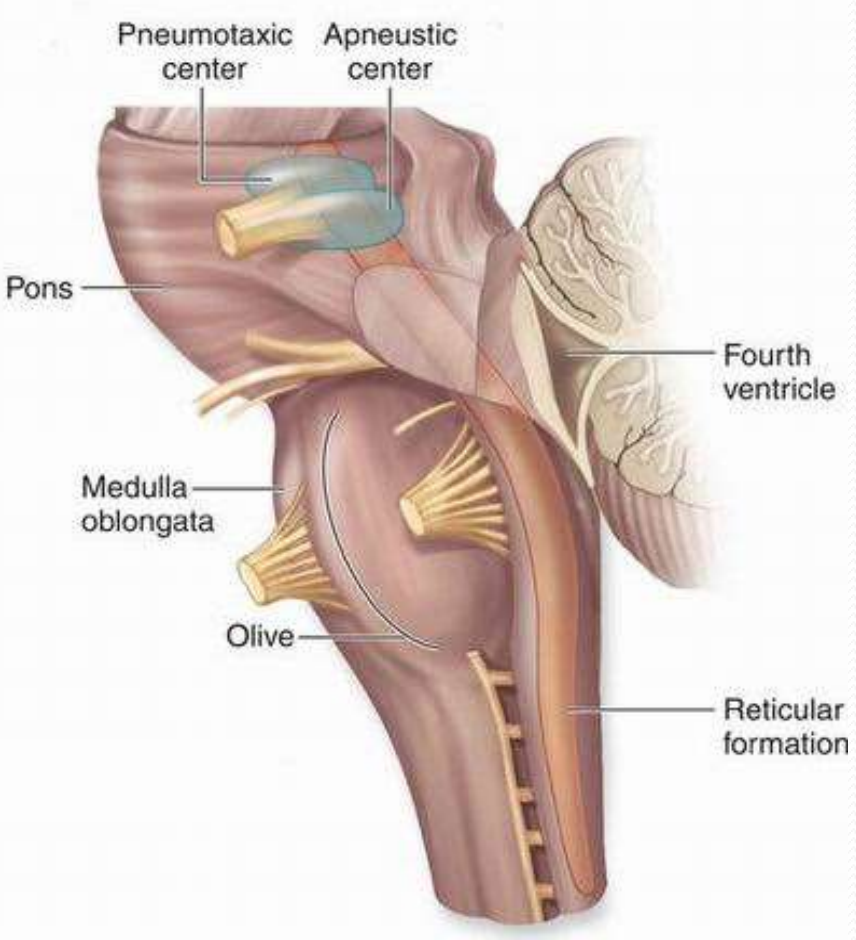
- **Inspiratory Center (Dorsal Resp Group - rhythmic breathing**
- Phrenic nerve, Intercostal nerves , diaphragm + external intercostals

- **Expiratory Center (Ventral Resp Group - forced expiration)**
- Phrenic nerve, Intercostal nerves, Internal intercostals + abdominals (expiration)

1. Eupnea - normal resting breath rate (12/minute)
2. Drug overdose - causes suppression of Inspiratory Center

B. Pons Respiratory Centre

- 1. Pneumotaxic center - slightly inhibits medulla, causes shorter, shallower, quicker breaths
- 2. Apneustic center – stimulates the medulla, causes longer, deeper, slower breaths



C. Control of Rate & Depth of Breathing

- 1. Breathing rate - stimulation/inhibition of medulla.
- 2. Breathing depth - activation of inspiration muscles.
- 3. Hering-Breuer Reflex - stretch of visceral pleura that lungs have expanded (vagal nerve).

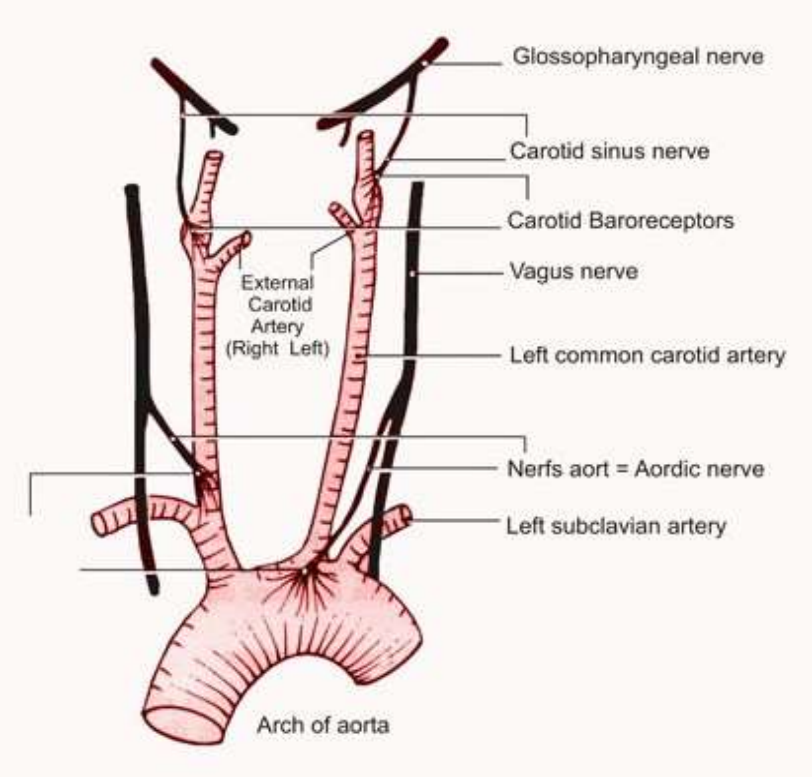
D. Hypothalamic Control - emotion + pain to the medulla

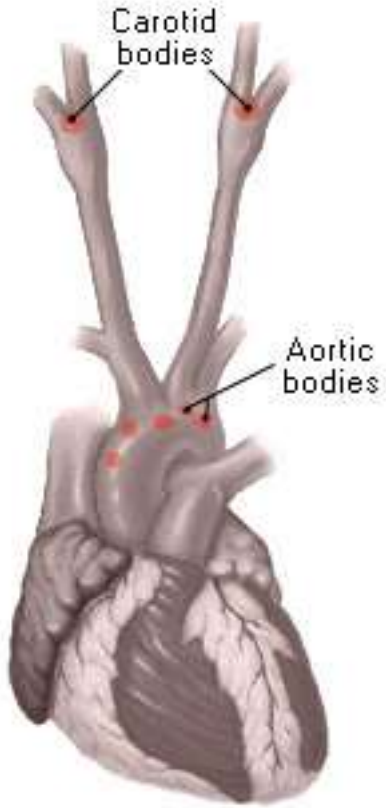
E. Cortex Controls (Voluntary Breathing) - can override medulla as during singing and talking

Chemical Mechanism

A. Chemoreceptors

- 1. Central chemoreceptors - located in the medulla
- 2. Peripheral chemoreceptors - large vessels of neck



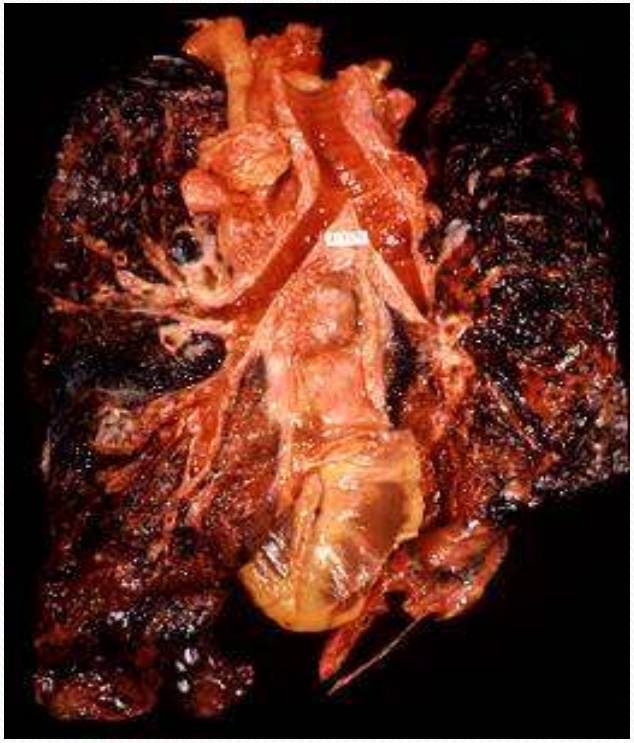


B. Overview of Chemical Effects

Chemical	Breathing Effect
• Increased CO_2 (more H^+)	Increase
• Decreased CO_2 (less H^+)	Decrease
• Slight decrease in O_2	Effects CO_2 system
• Large decrease in O_2	Increases ventilation
• Decreased pH (more H+)	Increase
• Increased pH (less H+)	Decrease

Applied Aspects

- Lung Cancer
  1. Non- Small Cell Lung Cancer
     - Squamos cell Carcinoma
     - Adenocarcinoma
     - Large Cell Carcinomas
  2. Small Cell Lung Cancer

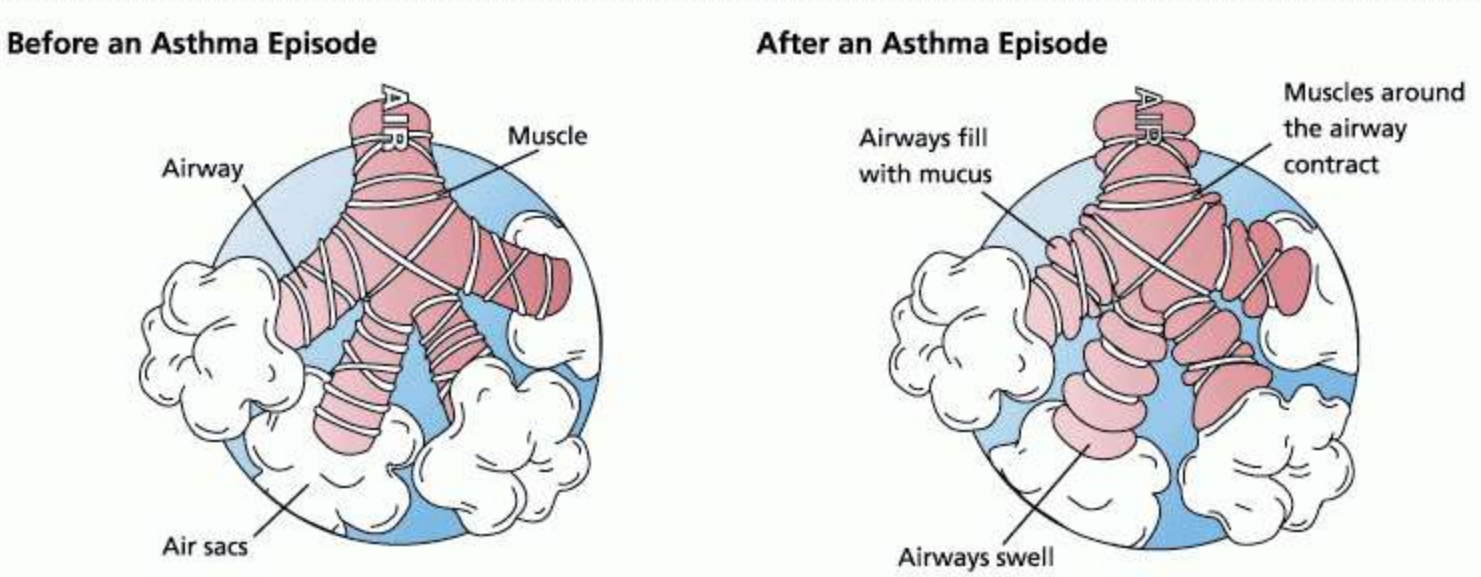


- Symptoms
  - Constant Chest Pain
  - Shortness of Breath
  - Wheezing
  - Recurring lung infections such as Pneumonia or Bronchitis
  - Blood or Rust coloured Sputum

- Risk Factors
  - Smoking, Second hand smoke, Smoking Marijuna cigarettes
  - Recurring inflammation such as TB & Pneumonia
  - Asbestos exposure, Talcum powder
  - Cancer causing agents like Arsenic, Vinyl Chloride, Nickel Chromates, Uranium, Coal, Ethers
- Diagnosis
  - Chest X-ray, Bronchoscopy
  - Sputum Cytology, Mediastinoscopy
  - Needle biopsy
- Treatment
  - Surgery : Segmental or Wedge Resection, Lobectomy, Pneumonectomy
  - Radiation therapy
  - Chemotherapy

Chronic Obstructive Pulmonary Diseases(COPD)

1. Asthma
   - Asthma is a chronic, inflammatory lung disease involving recurrent breathing problems. The characteristics of asthma are three airway problems:
   - Obstruction, Inflammation, Hyper-responsiveness

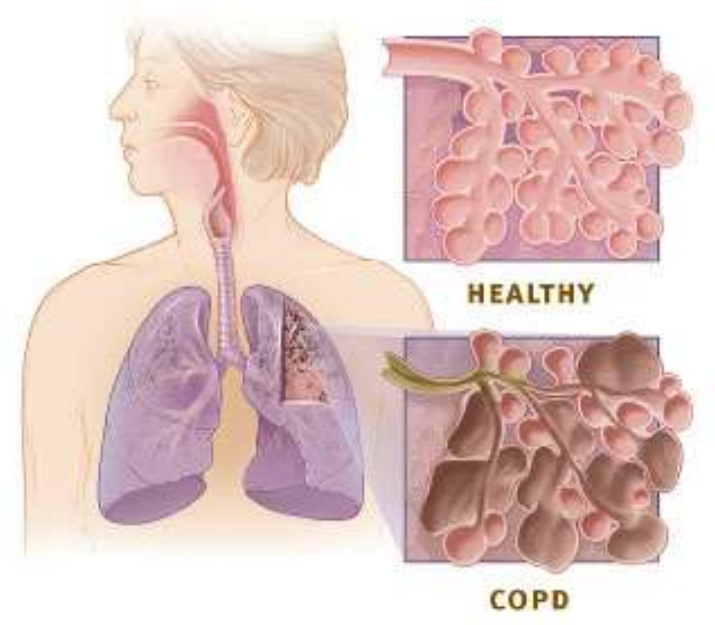


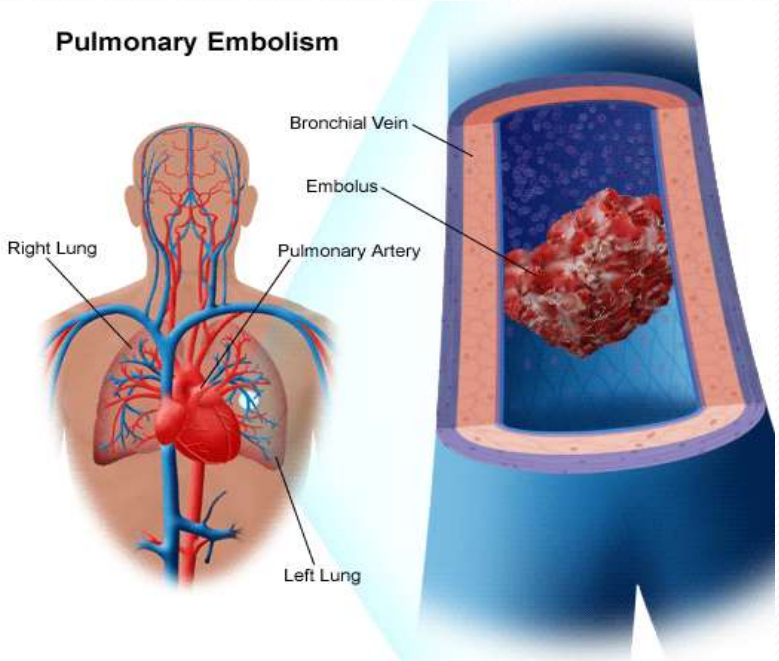
2. Chronic Bronchitis

Chronic bronchitis is a long-term inflammation of the bronchi, which results in increased production of mucous, as well as other other changes.

3. Pulmonary Embolism

Pulmonary embolism, a severe and life-threatening condition, is the blocking of the pulmonary artery by foreign matter such as:
a blood clot (thrombus) or pieces of it, Fat, Air, Tumor tissue





Cystic Fibrosis

Cystic fibrosis is an inherited disease characterized by an abnormality in the glands that produce sweat and mucus. It is chronic, progressive, and may be fatal.

Symptoms

- Thick mucus that accumulates in lungs and intestines, which can cause:
- Malnutrition, Poor growth, Frequent respiratory infections, Breathing difficulties, Lung disease.

Diagnosis

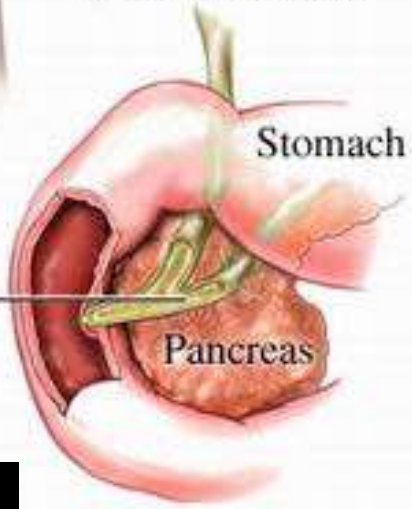
- Chemical tests, Chest x-rays, Lung function tests, Sputum cultures, Stool evaluations.

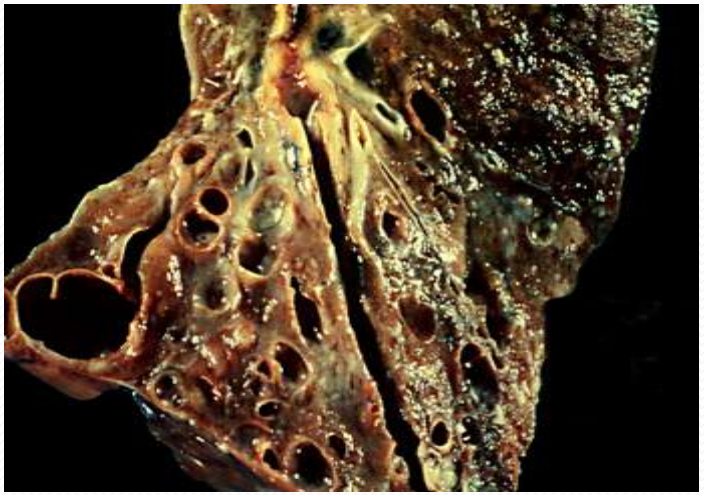
Treatment

- Physical therapy, Exercise to loosen mucus, stimulate coughing and improve overall physical condition, Medications to reduce mucus and help breathing

Cystic Fibrosis

Mucus blocks air sacs (alveoli) in the lungs



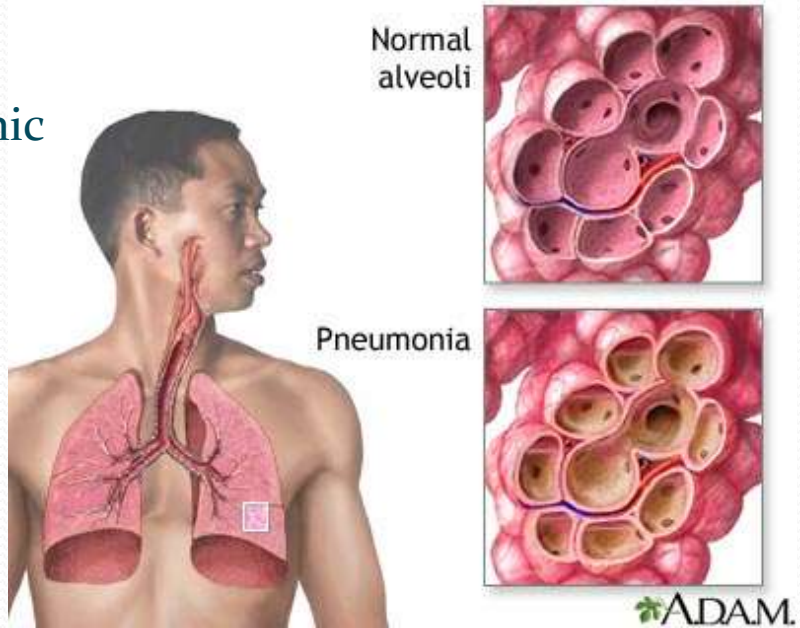


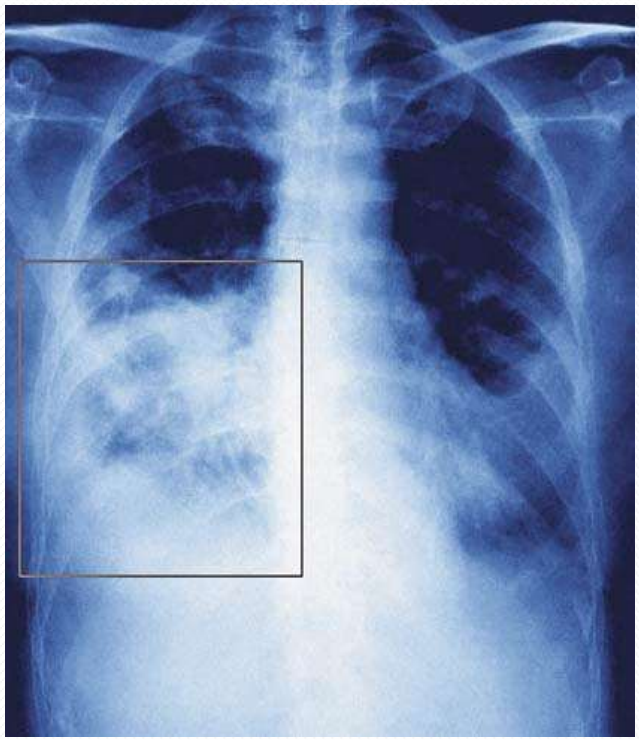
❑ Pneumonia

- Pneumonia is an inflammation of the lungs caused by bacteria, viruses or chemical irritants. It is a serious infection or inflammation in which the air sacs fill with pus and other liquid.
- **Lobar pneumonia** affects one or more sections (lobes) of the lungs.
- **Bronchial pneumonia** (or bronchopneumonia) affects patches throughout both lungs.

➢ Types

- Bacterial
- Viral
- Pneumonic





Symptoms

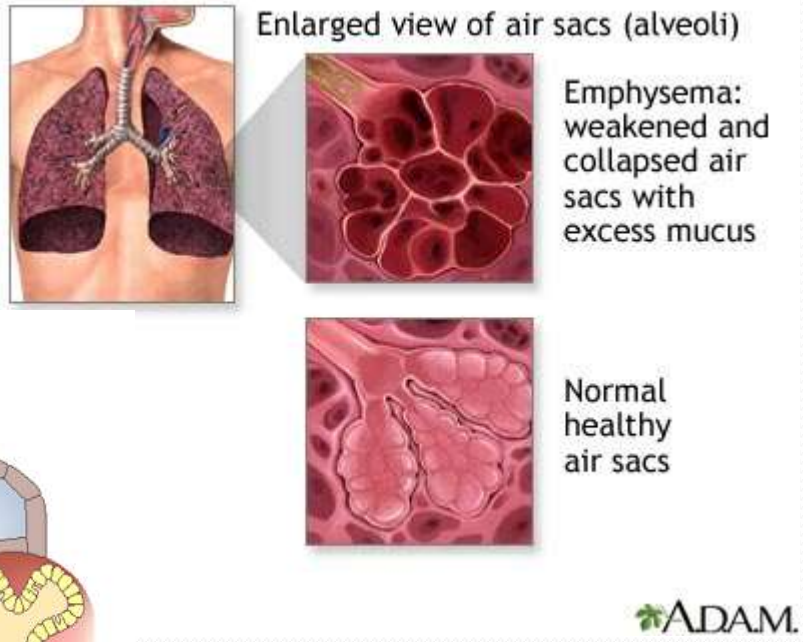
- Shaking chills, High temperature
- Chattering teeth,
- Severe chest pain, Cough that produces rust-colored or greenish mucus, Heavy perspiring
- Rapid pulse, Rapid breathing, Bluish color to lips and nail beds, Confused mental state or delirium

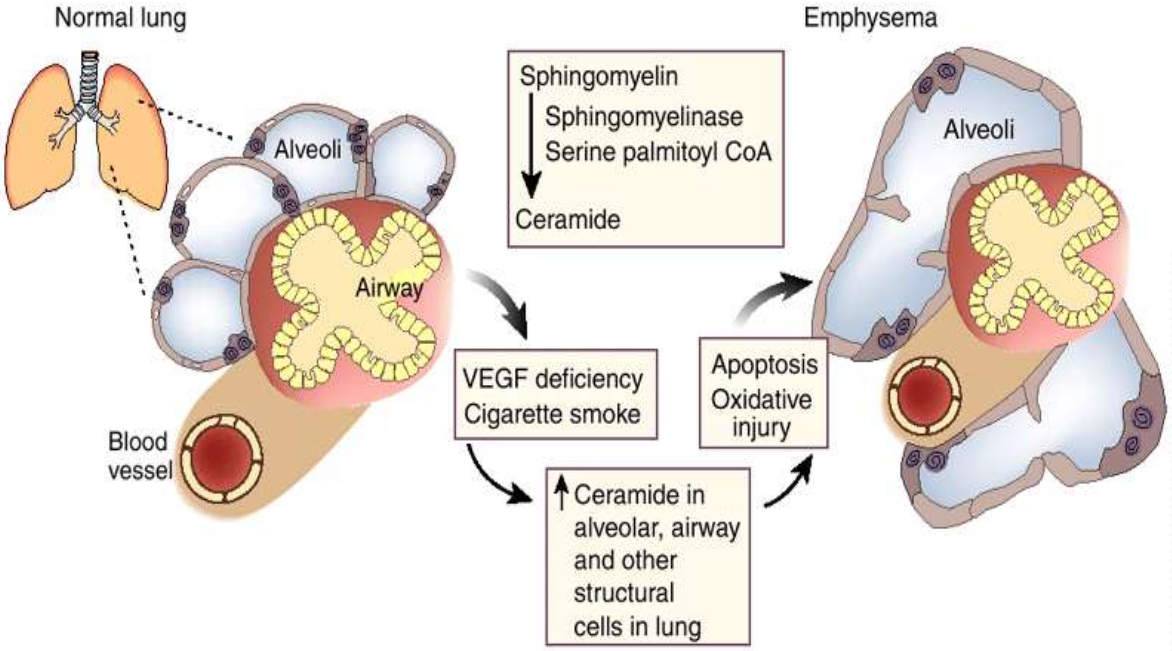
Treatment

- Treatment may include antibiotics for bacterial pneumonia. Antibiotics may also speed recovery from mycoplasma pneumonia and some special cases. There is no clearly effective treatment for viral pneumonia, which usually heals on its own.
- Other treatment may include appropriate diet, oxygen therapy, and pain and cough medication.

Pulmonary Emphysema

- Emphysema is a chronic lung condition in which **alveoli**, or air sacs, may be:
- Destroyed, Narrowed, Collapsed
- Stretched, Over-inflated





Symptoms

Early symptoms of pulmonary emphysema may include:

- Cough & Shortness of breath

Other symptoms may include:

- Fatigue, Sleep problems
- Anxiety, Depression
- Heart problems, Weight loss

Treatment

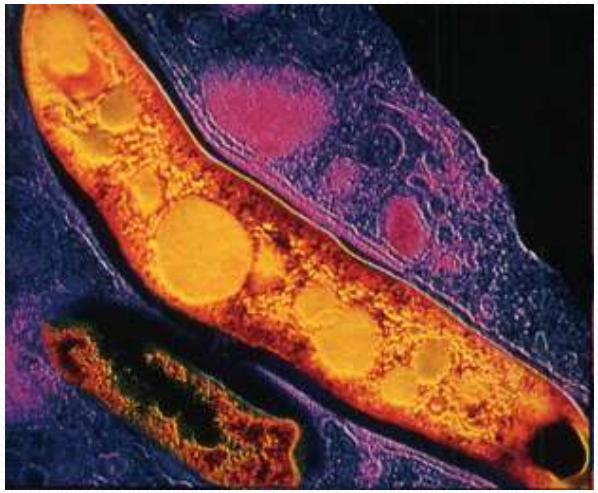
- Quitting smoking
- Antibiotics for bacterial infections, Oral medications
- Bronchodilators and other inhaled medications
- Exercise -- including breathing exercises to strengthen the muscles used in breathing as part of a pulmonary rehabilitation program to condition the rest of the body
- Oxygen supplementation from portable containers
- Lung reduction surgery to remove damaged area of the lung
- Lung transplantation

Tuberculosis

Tuberculosis (TB) is a chronic bacterial infection that usually infects the lungs, although other organs are sometimes involved.
TB is primarily an airborne disease.

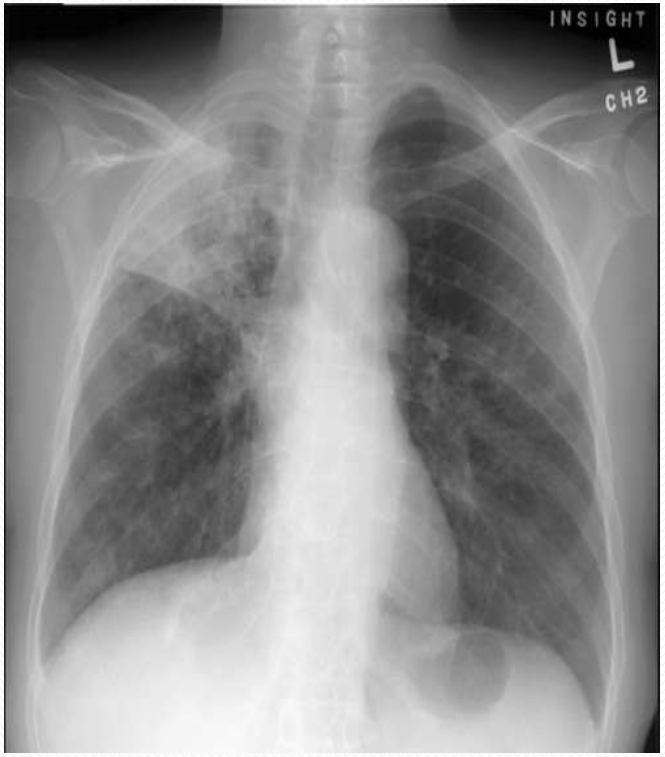
Symptoms

- Cough that will not go away
- Fatigue
- Loss of appetite, loss of weight
- Fever, night perspiring
- Coughing blood

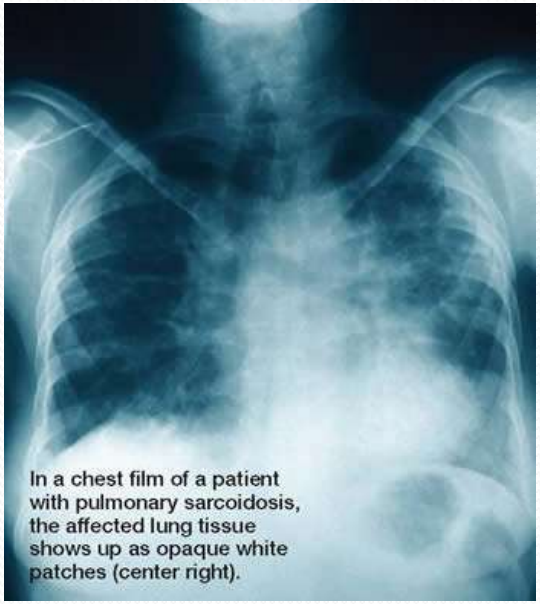


Mycobacterium Tuberculosis

- Diagnosis
  - TB Skin tests
  - X-Rays
  - Sputum Tests
- Treatment
  - Short-term hospitalization
  - Medications



- Other Diseases
  - Acute Bronchitis
  - Influenza
  - Interstitial Lung Diseases
    - Bronchiolitis
    - Alveolitis
    - Vasculitis
  - Pulmonary Hypertension
  - Sarcoidosis



Sarcoidosis

THANK YOU