PATHOPHYSIOLOGY OF RESTRICITVE LUNG DISEASE

HINA VAISH

RESTRICITVE LUNG DISEASE

- RLD are a category of respiratory disease characterized by a loss of lung compliance causing incomplete lung expansion and increase lung stiffness.
- If the volume of air or gas is reduced the defect is restricitve. i.e. Inspiratory capacity of the lung is restricted to less than the predicted normal.

- Restricitve lung dysfunction may result from the many different diseases arising from the pulmonary system or any other body system.
- It can also result from trauma or therapeutic intervention such as radiation therapy or the use of certain drugs.
- If the origin is pulmonary than both lung compliance and diffusion capacity will decrease.

- In RLD both lung volumes and capacities are getting decreased.
- This occurs either because of :-

1) Alteration in lung parenchyma.
2) Disease of the pleura, chest wall or neuromuscular apparatus.

- Physiologically restrictive lung diseases are defined by reduced total lung capacity, vital capacity and functional residual capacity, but with preserved air flow.
- In case of restrictive disease total lung capacity should be less than 80% of the normal value.

Lung volumes & capacities	Effect of RLD
Tidal volume	Decreases
Inspiratory reserve volume	Decreases
Expiratory reserve volume	Decreases
Residual volume	Decreases/normal
Vital capacity	Decreases
Total lung capacity	Decreases
Functional residual capacity	Decreases
SPIROMETRY MEASURES	
FVC	Low
FEV_1	Decreases
FEV_1/FVC	Normal/high

- Restrictive lung diseases are divided into two group :-

1) Intrinsic lung diseases.(diseases of lung parenchyma)
2) Extrinsic lung diseases.(extra parenchymal diseases)

INTRINSIC LUNG DISEASES

- These diseases causes either :-

  -Inflammation and/or scarring of lung tissue.(Interstitial lung disease)

  OR

  -Fill the air spaces with exudate and debris.(Pneumonitis)

- This diseases are further classified on the basis of etiological factor.

EXTRINSIC LUNG DISEASE

- The chest wall, pleura, and respiratory muscles are the component of the respiratory pump.
- The disorder of these structures cause lung restriction and impair respiratory function.
- These are grouped as :

1) Neuromuscular diseases. Eg-myasthenia gravis & guillain barrie syndrome.
2) Non-muscular diseases of the chest wall. Eg- kyphosis & scoliosis

- Further RLD classified on the basis of etiological factor :-

1) PULMONARY CAUSES OF RLD :-

- Idiopathic Pulmonary Fibrosis
- Coal Worker's Pneumoconiosis
- Silicosis
- Asbestosis
- Pneumonia
- Pleural effusion
- Bronchogenic Carcinoma
- ARDS
- Sarcoidosis

2) CARDIOVASCULAR CAUSES OF RLD :-

- Pulmonary Edema
- Pulmonary Emboli

3) NEUROMUSCULAR CAUSES :-

- Spinal Cord Injury
- Amyotropic Lateral Sclerosis
- Poliomyelitis
- Gullian-Barre Syndrome
- Myasthenia Gravis
- Tetanus
- Duchenne's Muscular Dystrophy
- Other Muscular Dystrophies

4) MUSCULOSKELETAL CAUSES :-

- Diaphragmatic Paralysis or Paresis
- Kyphoscoliosis
- Ankylosing sponylitis

5) NUTRITIONAL AND METABOLIC CAUSES :-

- Obesity
- Diabetes Mellitus

6) CONNECTIVE TISSUE CAUSES :-
- Rheumatoid Arthritis
- Systemic Lupus Erythematosus
- Scleroderma
- Polymyositis
- Dermatomyositis

7) IMMUNOLOGIC CAUSES :-
- Goodpasture's Syndrome
- Wegener's Granulomatosis

8) REPRODUCTIVE CAUSES :-
- Pregnancy

9) TRAUMATIC CAUSES :-
- Crush Injuries
- Penetrating Wounds
- Thermal Trauma

10) THERAPEUTIC CAUSES :-
- Surgical Therapy
- Drug Therapy
- Radiation Therapy

PATHOGENESIS :

- There are 3 major aspects of pulmonary ventilation must be considered to understand the pathophysiology of RLD.

1) Compliance of both the lungs & chest wall.
2) Lung volumes and
3) Work of breathing

COMPLIANCE :-

- With RLD, chest wall or lung compliance or both decreases.
- Patient has to work hard to move air into the lungs
- Decrease lung compliance indicates stiffer lungs. So it requires greater transpulmonary pressure to expand the lung to a given volume in a person.
- If the amount of pressure to move air into the lung is constant , volume of air decreases in the person with decrease compliance.

LUNG VOLUMES :-

- Generally all the lung volumes and capacities are getting decreased.
- Because distensibility of lung decreases.
- TLC & VC are the 2 major spirometric measurement used in identification of RLD.
- Decrease in TLC & FRC are a direct result of a decrease in lung compliance.

WORK OF BREATHING :-

- As in RLD both compliance & volume decreases, work of breathing increases.
- Now, to minimize the work of breathing respiratory rate and tidal volume should be altered.
- Greater transpulmonary pressure is required to achieve a normal T.V, this results in increase WOB.
- Now to overcome decrease compliance the respiratory rate increases and thus additional effort is required which will lead to additional O_2 expenditure.
- Normally body uses less than 5% of O_2 consumption/min. i.e. 3-14mlO_2 / min to support WOB. But with RLD VO_2 (O_2 consumption/min) needed to support WOB can reach & exceed 25%.

SIGNS & SYMPTOMS :-

- SIGNS :
  - Tachypnea
  - Hypoxemia
  - Decreased lung volume
  - Decreased diffusion capacity
  - Decreased breath sounds
  - Pulmonary hypertension
  - Clubbing
  - Cynosis
- SYMPTOMS :
  - Dyspnea
  - Cough
  - Weight loss
  - Muscle wasting

PATHOPHYSIOLOGY

INTRINSIC LUNG DISEASES :

- Diffuse parenchymal disorders cause reduction in all lung volumes.
- This is produced by excessive elastic recoil of the lungs.
- Expiratory flows are reduced in proportion to lung volumes.
- Arterial hypoxemia is caused by ventilation/perfusion mismatch.
- Impaired diffusion of oxygen will cause exercise-induced desaturation.
- Hyperventilation at rest secondary to reflex stimulation.

EXTRINSIC LUNG DISEASES :

- Diseases of the pleura, thoracic cage, decreases the compliance of respiratory system.
- There is reduction in lung volumes.
- Secondarily, atelectasis occurs leading to V/Q mismatch ➲ hypoxemia.
- The thoracic cage and neuromuscular structures are a part of respiratory system.
- Any disease of these structures will cause restrictive disease and ventilatory dysfunction.

IDIOPATHIC PULMONARY FIBROSIS

SYNONYMS : cryptogenic fibrosing alveolitis, interstitial pneumonitis, and Hanman-Rich syndrome.

- It is an inflammatory process involving all the components of the alveolar wall that progresses to gross distortion of lung architecture.
- The components of the alveolar wall include the epithelial cells, the endothelial cells, the cellular and noncellular components of the interstitium, and the capillary network.
- These components are supported by the connective tissue framework made up of collagen and elastic fibers.

PATHOPHYSIOLOGY

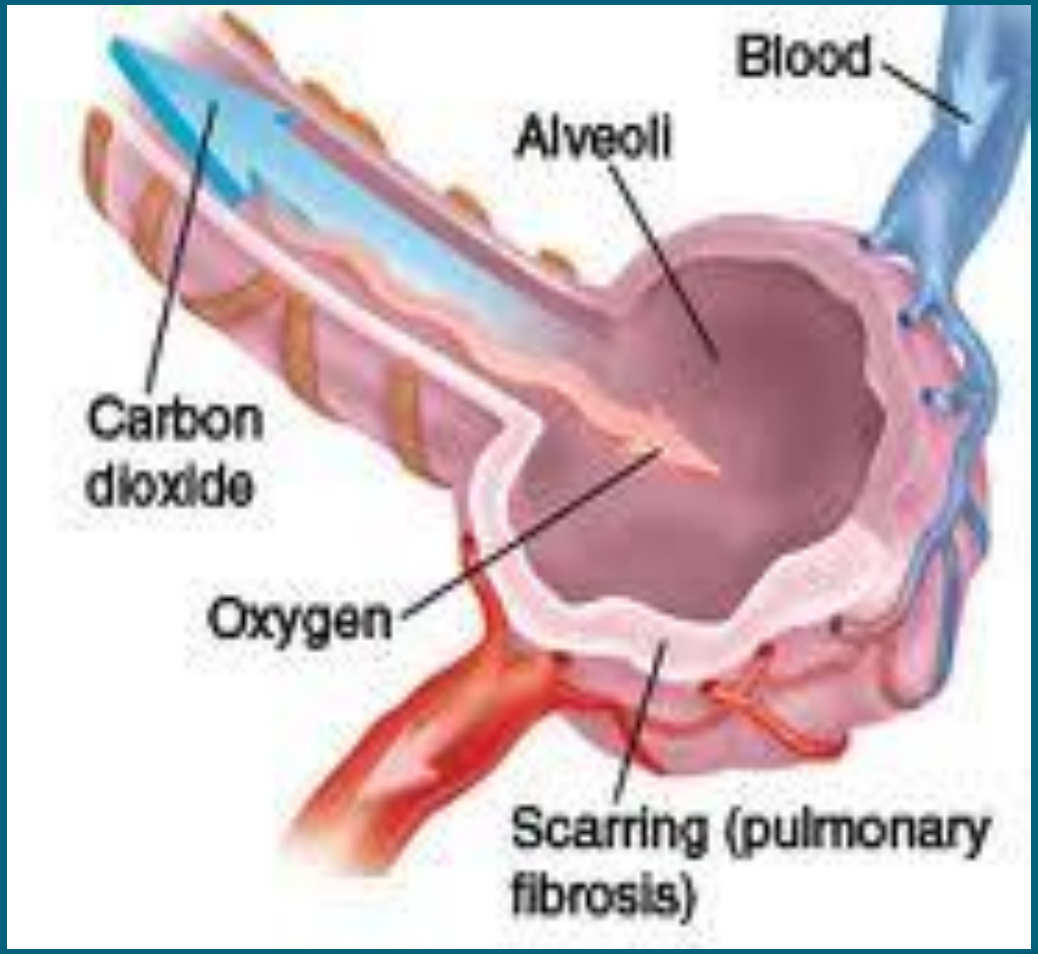
- Lung involvement in IPF shows patchy focal lesions scattered throughout both lungs.
- Followed by inflammatory changes and then scar and become fibrotic, distorting alveolar septa and the capillary network.
- Alveolar spaces become irregular in size and shape and there is significant progressive destruction of capillary bed.

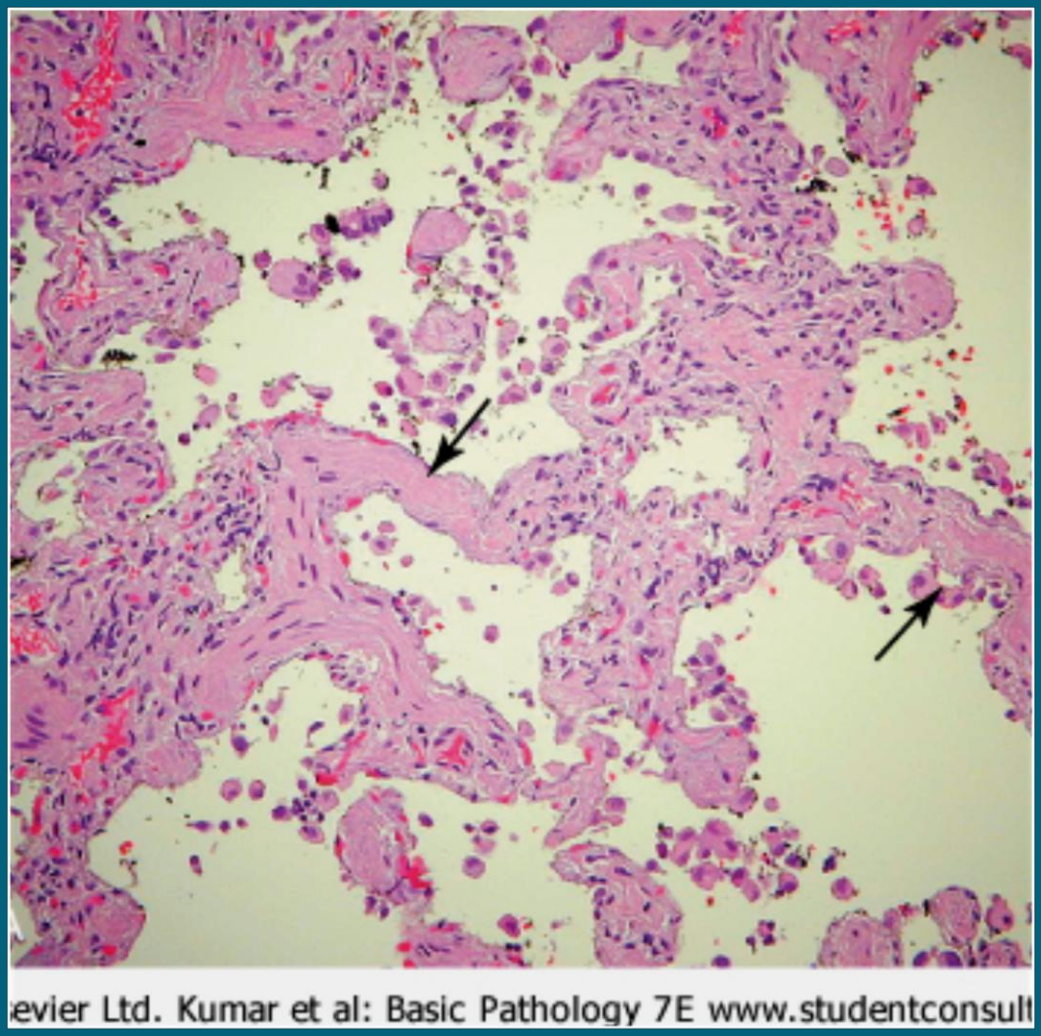
- Now these changes combine to cause,
  - decreased lung compliance
  - decreased lung volumes
  - increased V/Q mismatching
  - decreased surface area for gas exchange
  - decreased diffusion capacity
  - increased pulmonary arterial pressure
  - which increase the work of right ventricle
  - increased work of breathing
  - increased caloric requirement
  - decreased functional capacity.

- Two major pathologic component of IPF are :

1) inflamatory process in the alveolar wall.
   (sometimes called alveolitis)
2) scaring or fibrotic process secondary to active inflammation.

- Both of this components occurs simultaneously within the lung.


Blood
Alveoli
Carbon dioxide
Oxygen
Scarring (pulmonary fibrosis)

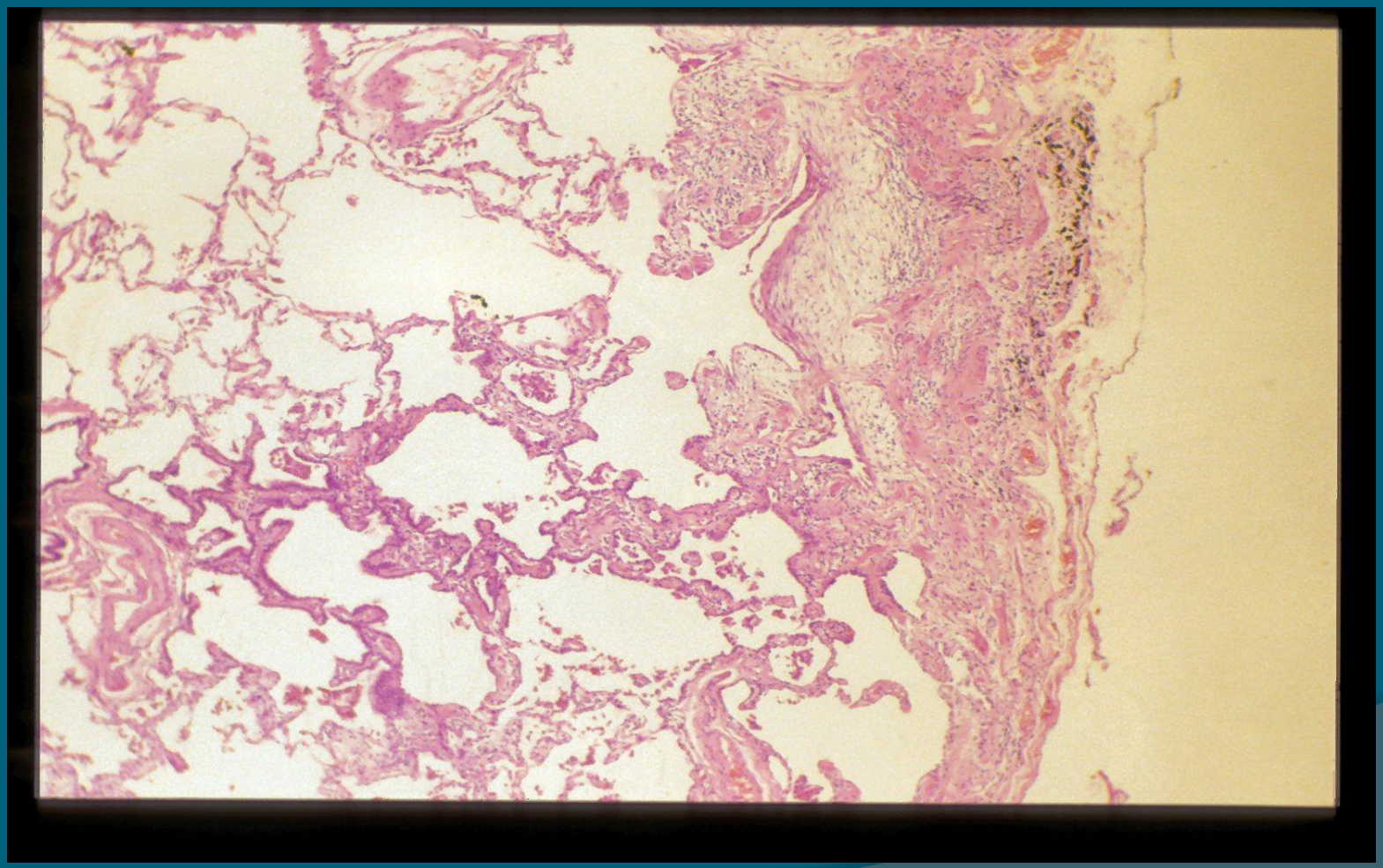


Idiopathic pulmonary fibrosis,The alveolar walls are thickened

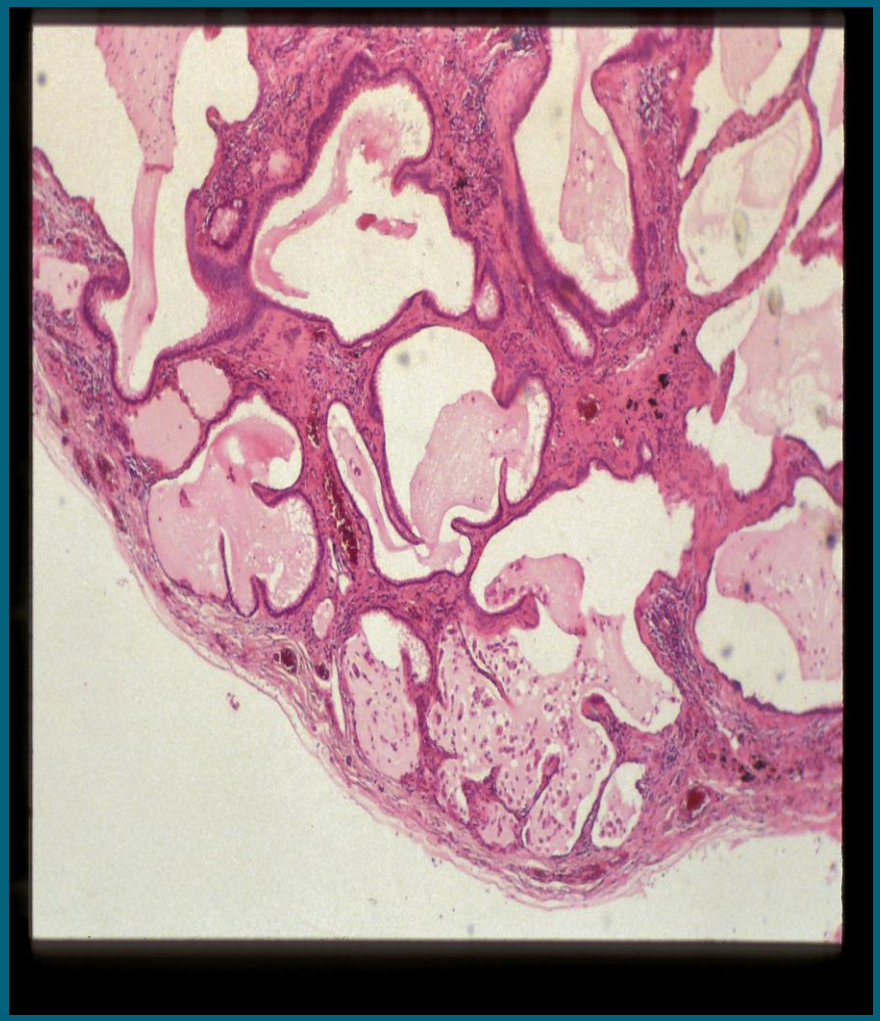
By fibrosis (arrows),In addition ,there is aspares interstitial infiltrate of

Mononuclear cells

Fibrosing alveolitis (early)



IPF (late – honeycombing)



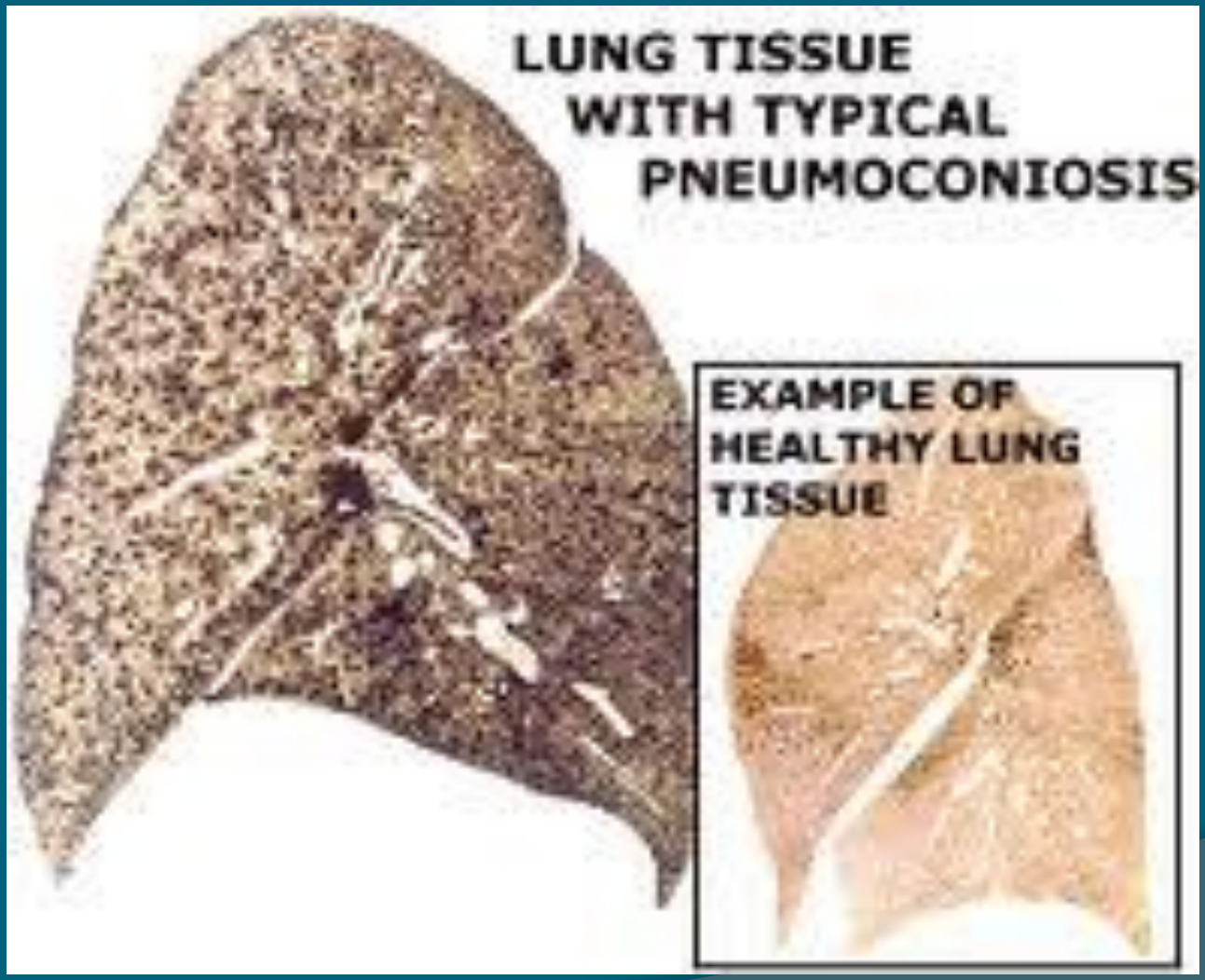
COAL WORKERS' PNEUMOCONIOSIS

- It is an interstitial lung disease, an occupational pneumoconiosis, caused by inhalation of coal dust. It is divided into simple CWP & complicated CWP
- It is caused by repeated inhalation of coal dust over a prolonged period of time i.e 10-12 yrs.
- Complicated CWP, sometimes called as progressive massive fibrosis occur only after longer exposure to coal dust.
- Antharcite coal is more hazardous than bituminous in the development of this disease.

PATHOPHYSIOLOGY

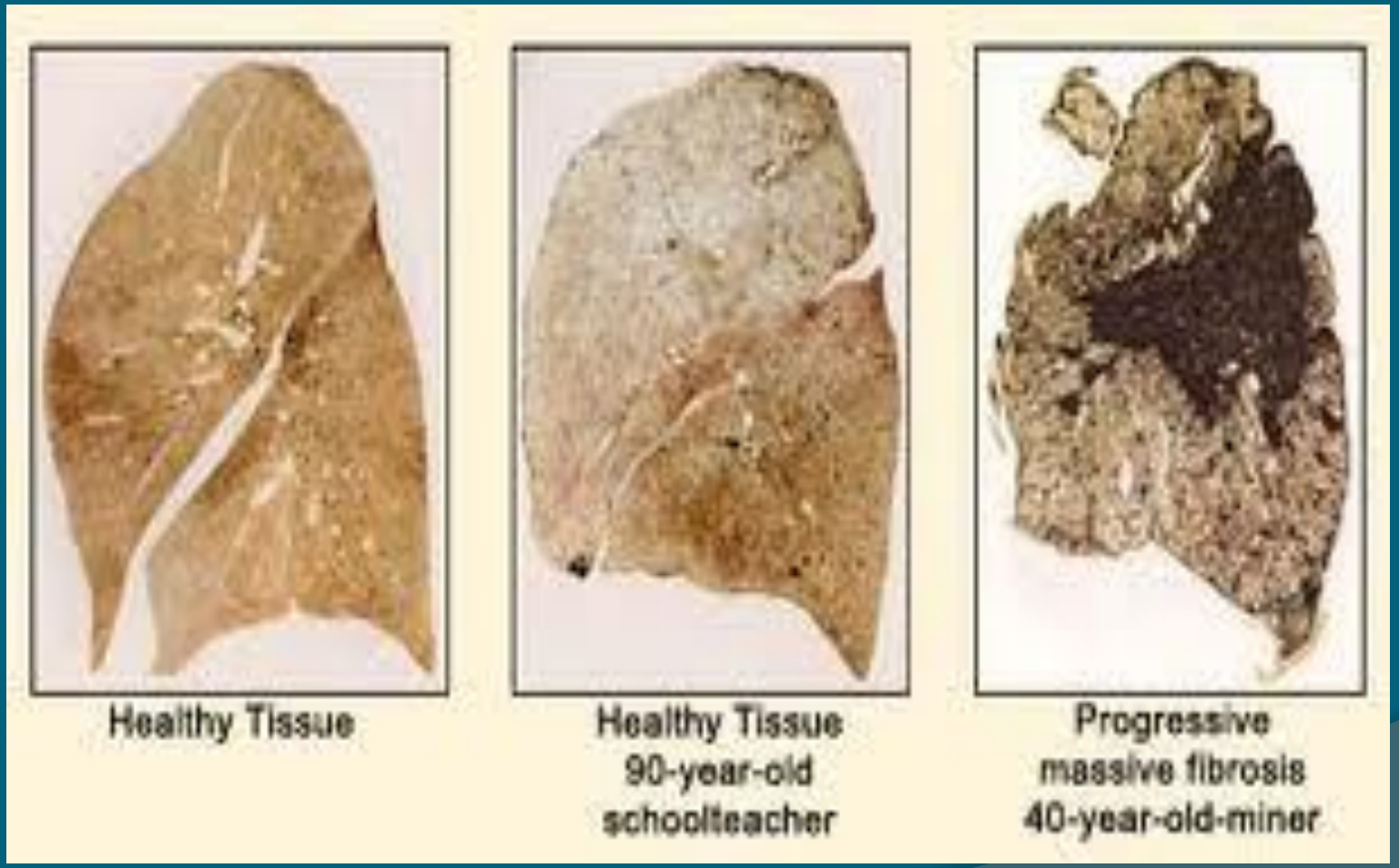
- Coal macules – focal collection of coal dust with little tissue reaction in terms of either cellular infilteration or fibrosis.
- These coal macules are located at the division of the respiratory bronchioles and are often associated with fibrotic emphysema.
- Lymph nodes are enlarged and homogeneously pigmented and are firm and not fibrotic.
- The pleural surface appear black owing to deposition of coal dust.
- Less than 5% cases progress to complicated CWP.

- The mechanism for the progression of simple to complicated CWP is unknown.
- It has been suggested simple CWP may progress, when it combines with infection, or silicosis, or tuberculosis or altered immunologic mechanism.
- Complicated CWP results in zones of dense fibrosis in the apical segments in one or both the lungs.
- These zones are made of dense, acellular, collagenous, black pigmented tissue.
- The normal lung parenchyma is completely replaced, and the blood vessels in that area show obliterative arteritis.
- These fibrous zone completely replace the entire upper lobe.


LUNG TISSUE
WITH TYPICAL
PNEUMOCONIOSIS
EXAMPLE OF
HEALTHY LUNG
TISSUE

Coal miner with progressive massive fibrosis (unstained)

BLACK LUNG DISEASE

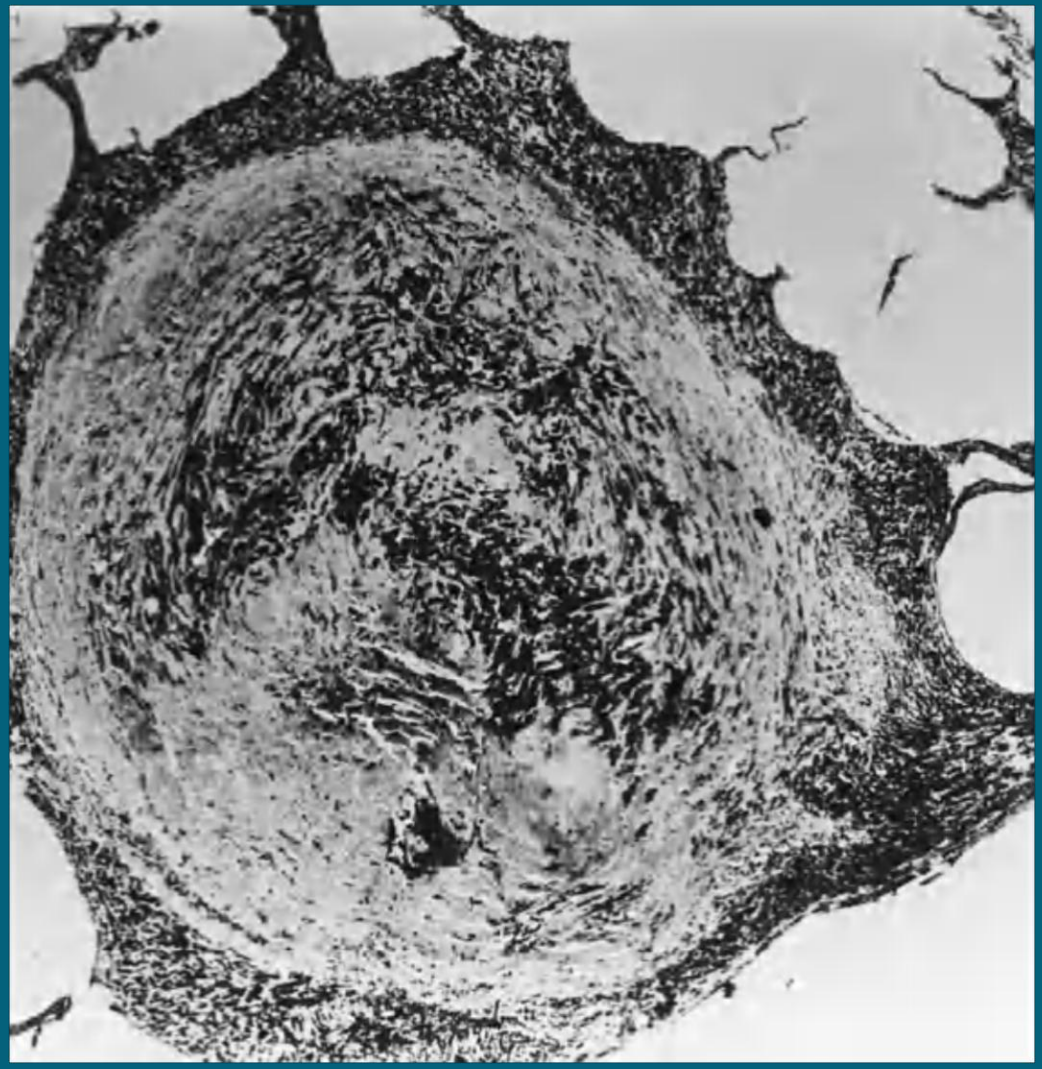

Healthy Tissue
Healthy Tissue
90-year-old
schoolteacher
Progressive
massive fibrosis
40-year-old-miner

SILICOSIS

- It is one of the occupational pneumoconisosis, is a fibrotic lung disease caused by the inhalation of the inorganic dust known as free or crystalline silicon dioxide.

PATHOPHYSIOLOGY

- Inhaled silica causes macrophages to enter the area to ingest these particles.
- But cytotoxic effect of silica destroy these macrophages.
- This process release lysosomal enzymes, which induces the progressive formation of collagen, which eventually become fibrotic.
- An other characteristic of silicosis is formation of acellular nodules composed of connective tissue called silicotic nodules.
- Initially this nodules are small but as the disease progress it becomes large.
- Silicosis normally affect the upper lobes of the lung more than lower lobes.



Lung pathology showing classic silicotic nodule.

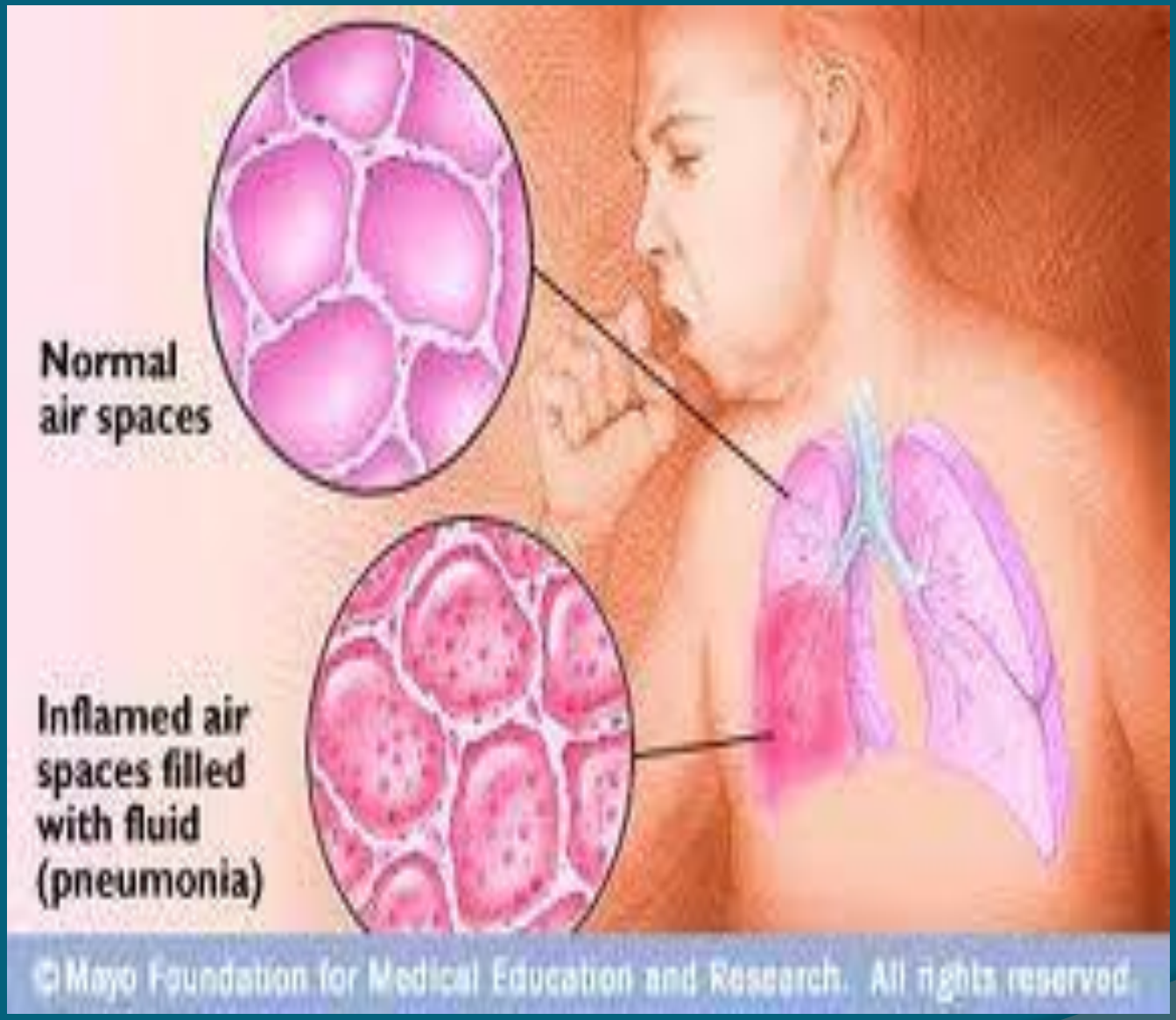
PNEUMONIA

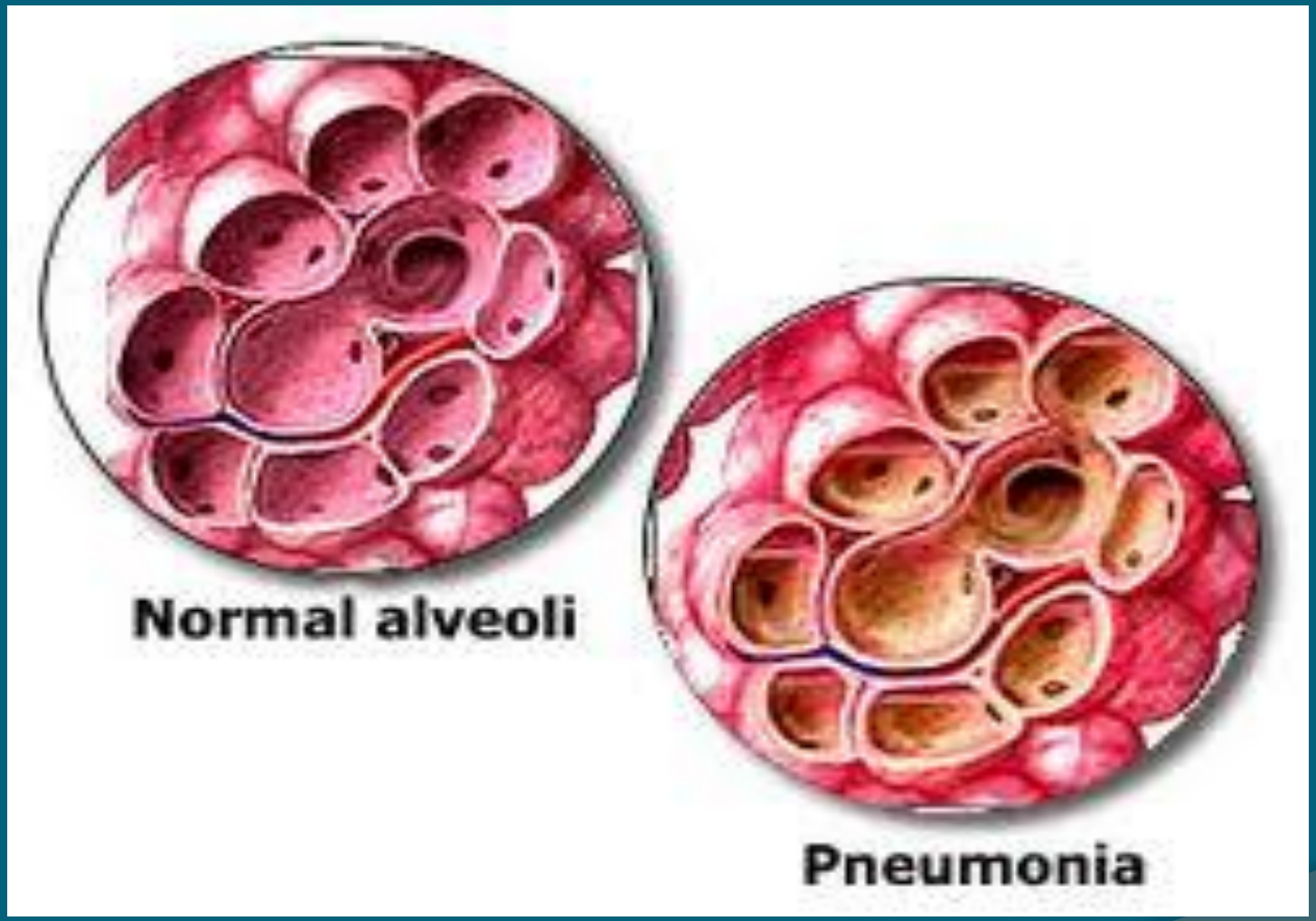
- It is a inflammatory process of the lung parenchyma.
- The disease may be classified anatomically as lobular, lobar, or segmental. Bilateral lobular pneumonia is termed bronchopneumonia.
- The commonest cause is infection by bacteria such as, streptococcus pneumoniae/pyogenes, staphylococcus pyogenes and klebsiella pneumoniae, mycoplasmal pneumoniae. Legionella pneumophilia causes pneumonia known as legionnaires disease.

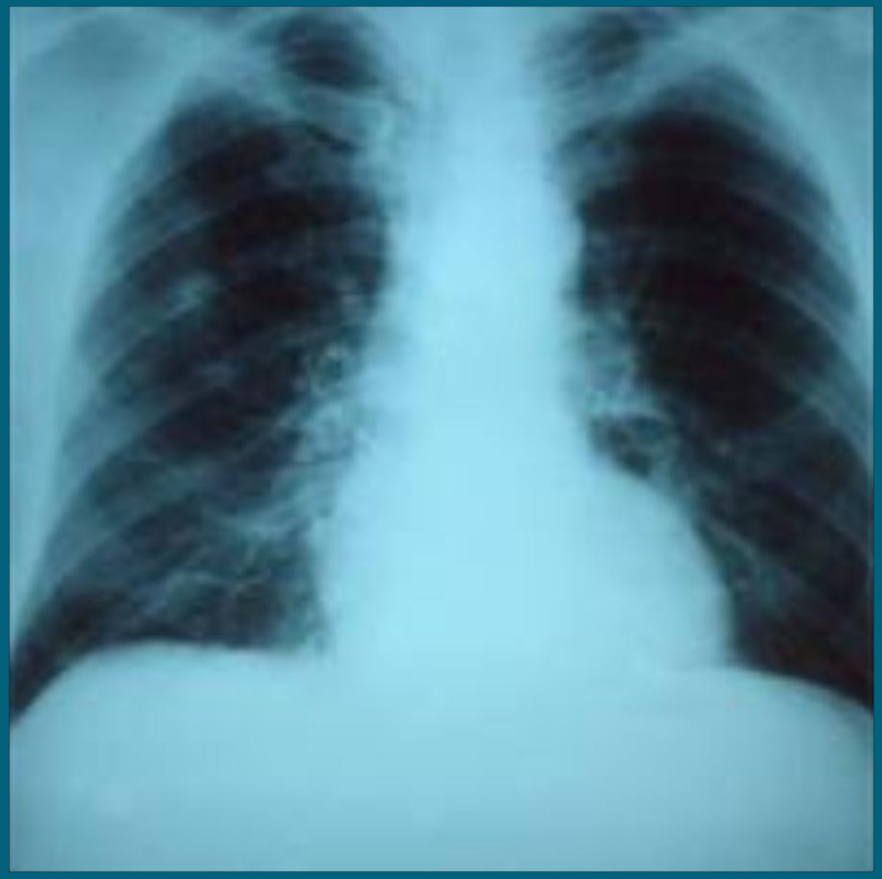
PATHOPHYSIOLOGY

- The most common route for infection leading to pneumonia are inhalation and aspiration.
- When the causative organism is bacteria, the first response will be outpouring of edema fluid.
- This is followed rapidly by the appearance of polymorphonuclear leuckocytes that are involved in active phagocytosis of the bacteria, and than fibrin is depositied in the inflamed area.
- Clinically, bacterial pneumonia usually has an abrupt onset and is characterized by lobar consolidation, high fever, chills, dyspnea, tachypnea, productive cough, pleuritic pain, and leukocytosis.

- When the causative agent is viral, the virus first localizes in respiratory epithelial cells and causes destruction of the cilia and mucosal surface, leading to loss of mucociliary function.
- If viral infection reaches the level of alveoli, there may be edema, hemorrhage, hyaline membrane formation, and possibly the development of adult respiratory distress syndrome.
- Primary viral pneumonia is a serious disease with diffuse infiltrates, extensive parenchymal injury, and severe hypoxemia.
- Clinically, viral pneumonia usually has an insidious onset and is characterized by patchy diffuse bronchopulmonary infiltrates, moderate fever, dyspnea, tachypnea, nonproductive cough, myalgia, and normal WBC count.


Normal
air spaces
Inflamed air
spaces filled
with fluid
(pneumonia)
©Mayo Foundation for Medical Education and Research. All rights reserved.


Normal alveoli
Pneumonia



This anteroposterior chest x-ray revealed right upper lobe **pneumonia**

ADULT RESPIRATORY DISTRESS SYNDROME

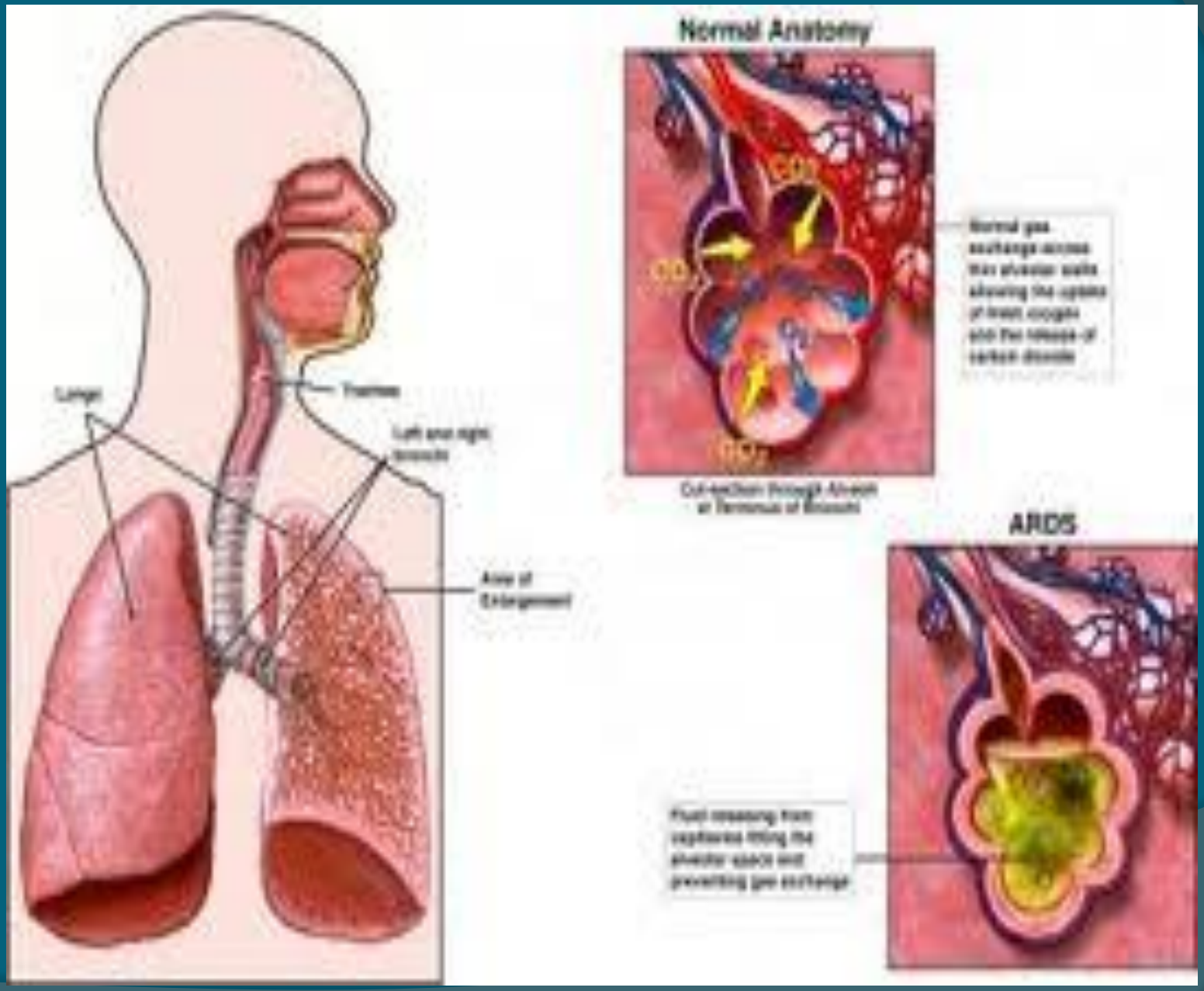
- ARDS is a clinical syndrome caused by acute lung injury and characterized by severe hypoxemia and increased permeability of the alveolar capillary membrane.

PATHOPHYSIOLOGY

- Primary pathologic change is increase permeability of the microvascular pulmonary membrane.
- This will allow excess fluid and plasma protein to move out of vascular channel.
- This fluid leak into the interstitial tisssue and then crosses the alveolar epithelium to fill the alveoli.

- The change from air-filled to fluid-filled organ leads to-
  - decrease in compliance of the lung & all lung volumes and capacities.
  - increase in work of breathing.
  - pulmonary vascular resistance is increased and intrapulmonary right-to-left shunt takes place.
  - V/Q mismatching is increased
  - gas exchange is reduced.
  - surfactant production is decreased.
- The significant atelectasis due to edema in the interstitial space leads to increase in pressure on the adjacent bronchioles and alveoli.

- Acute phase- ARDS resolve completely within few months.
- Sub-acute phase- as alveolar fibrosis and capillary obliteration develop within the lung, it leads to chronic restrictive lung dysfuntion.


Normal Anatomy
ARDS

PLEURAL EFFUSION

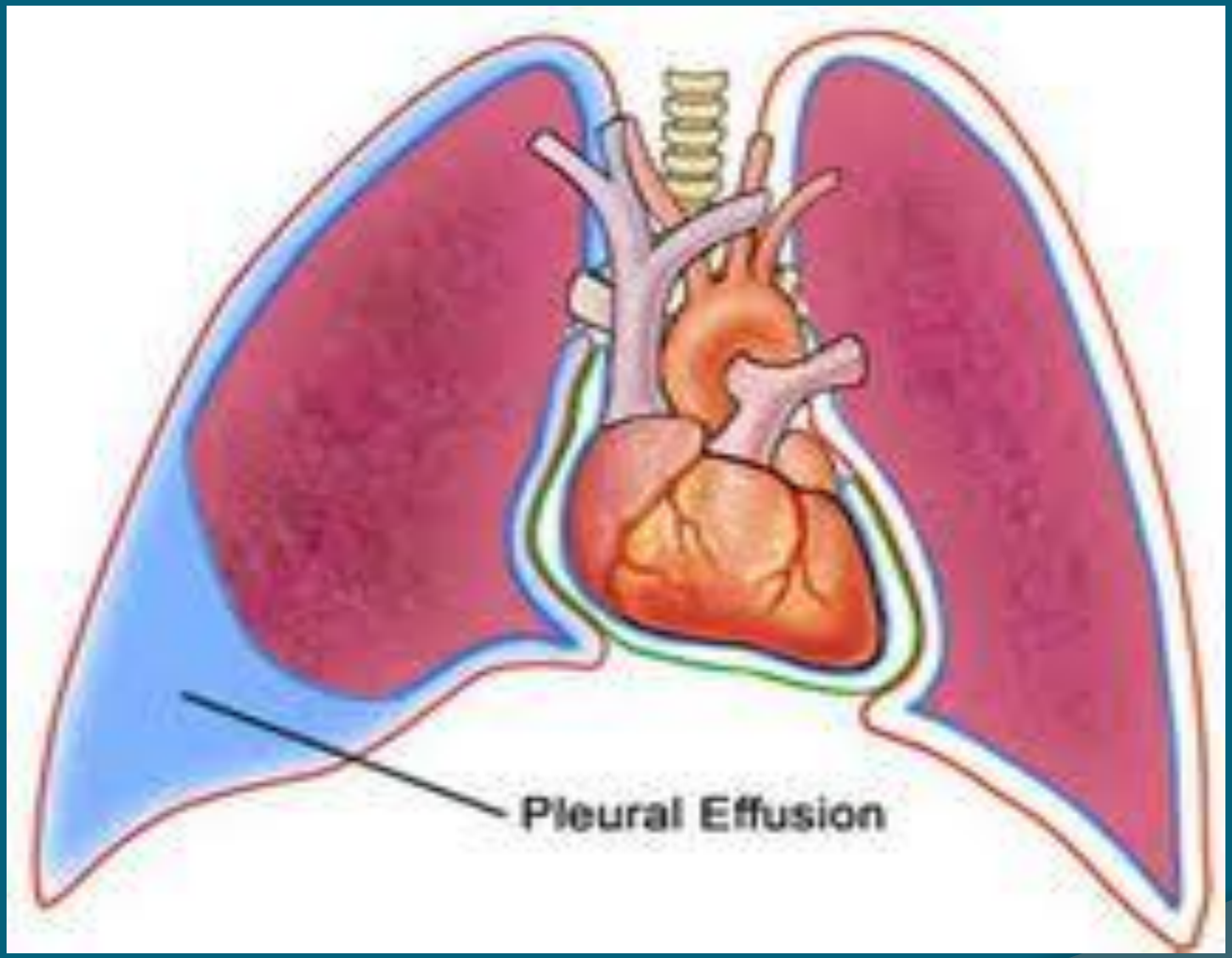
- It is the accumulation of the fluid within the pleural space.
- The fluid is transudate if it has a low protein content and accumulates owing to change in hydrostatic pressure within the pleural capillaries.
- The fluid is exudate if it has high protein content and accumulates because of change in permeability of pleural surfaces.

PATHOPHYSIOLOGY

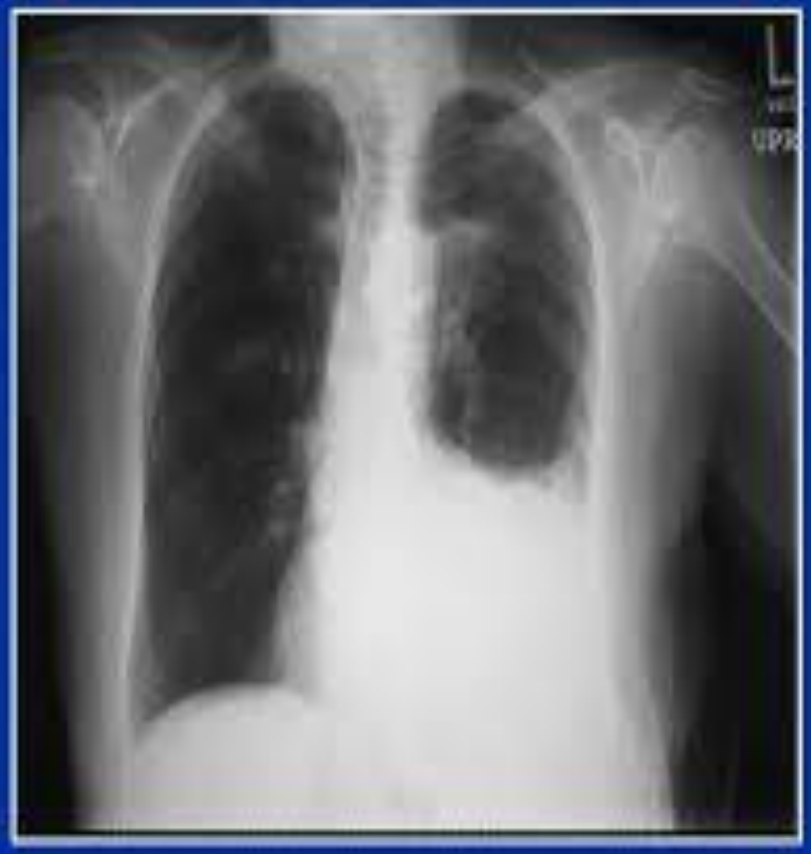
- The capillary in the parietal pleura receive blood via high pressure systemic arterial circulation.
- The capillary in the the visceral pleura receive blood via low pressure pulmonary circulation.
- Because of this pressure gradient fluid is constantly moving from parietal pleural capillaries to pleural space and is than reabsorbed into the visceral pleural capillaries.
- Approx 5-10 liters of fluid pass through pleural space each day using this route.
- Normally fluid formation and resorption are balanced and fluid donot accumulate in the pleural space.
- When this balanced is disrupted due to any cause it leads to accumulation of pleural fluid in the space and thus causes restriction in lung function by donot allowing the lungs to expand.

- Transudative pleural effusion are associated with an elevation in the hydrostatic pressure in the pleural capillaries.
- This is commonly due to left-sided heart failure, right-sided heart failure or both.
- Because of increase in hydrostatic pressure, more fluid is moved out of pleural capillaries and less fluid is reabsorbed.
- Therefore there is excess pleural fluid in pleural space, causing bilateral pleural effusions.
- Congestive heart failure is the most common cause of transudative pleural effusion.

- Exudative pleural effusions are associated with increase permeability of the pleural surfaces that allows protein and excess fluid to move into the pleural space.
- Therefore in exudative pleural effusion pleura is involved in pathologic process.
- Most commonly involved in inflammatory process or with neoplastic disease.
- Inflammatory process such as pneumonia, T.B, pulmonary emboli with infarction cause disruption of the normal pleural permeability.
- Cancer can also cause disruption of normal pleural permeability, either by direct extension of lung tumour in to pleural surface or indirectly tumour cells are spread via lymphatics.


Pleural Effusion

Chest X-Ray with Pleural Effusion on the Left



THANK YOU