

Physiology of the Respiratory System

Obstructive and Restrictive Pulmonary Processes

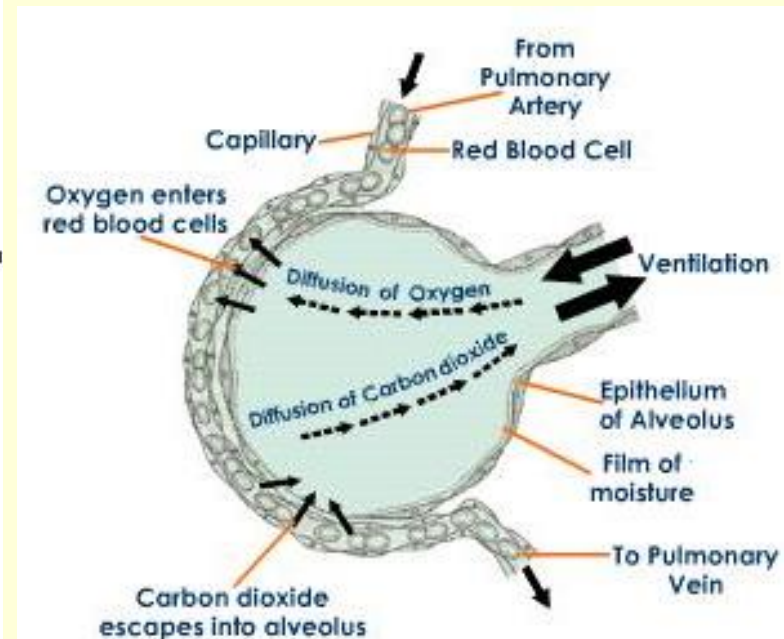
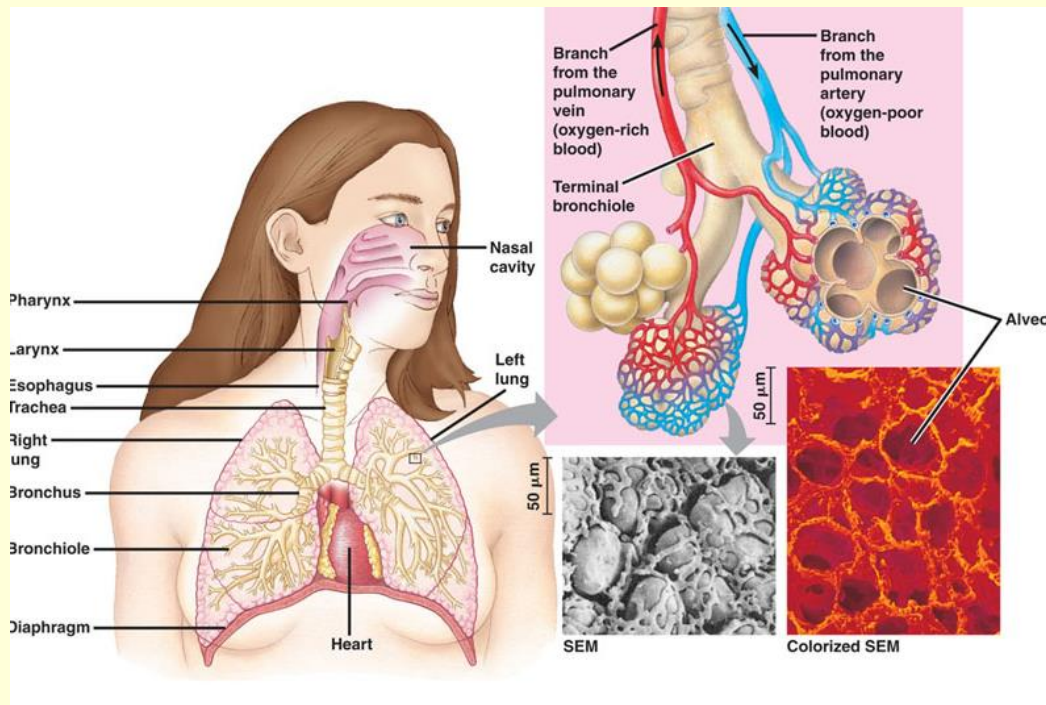
lecture from Physiology and Pathophysiology II

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Respiratory System

- O₂ supply to the tissues via the blood
- regulation of the acid-base balance via the CO₂ concentration in the blood



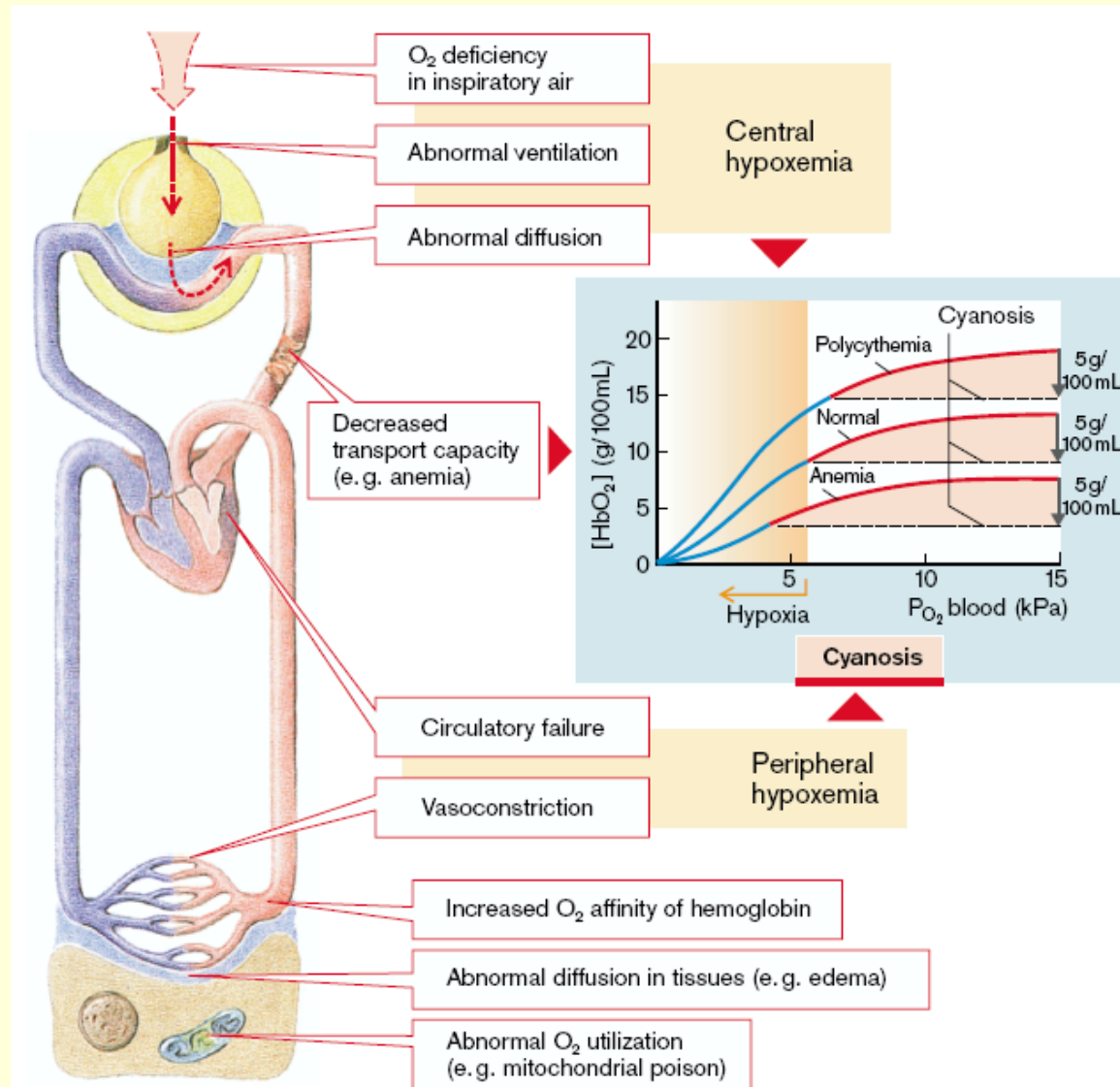
Changes in O₂ Concentration

HYPOXEMIA

- decreased oxygen content of the blood
- it leads to reduction of oxygen supply to tissue below physiological levels –

HYPOXIA

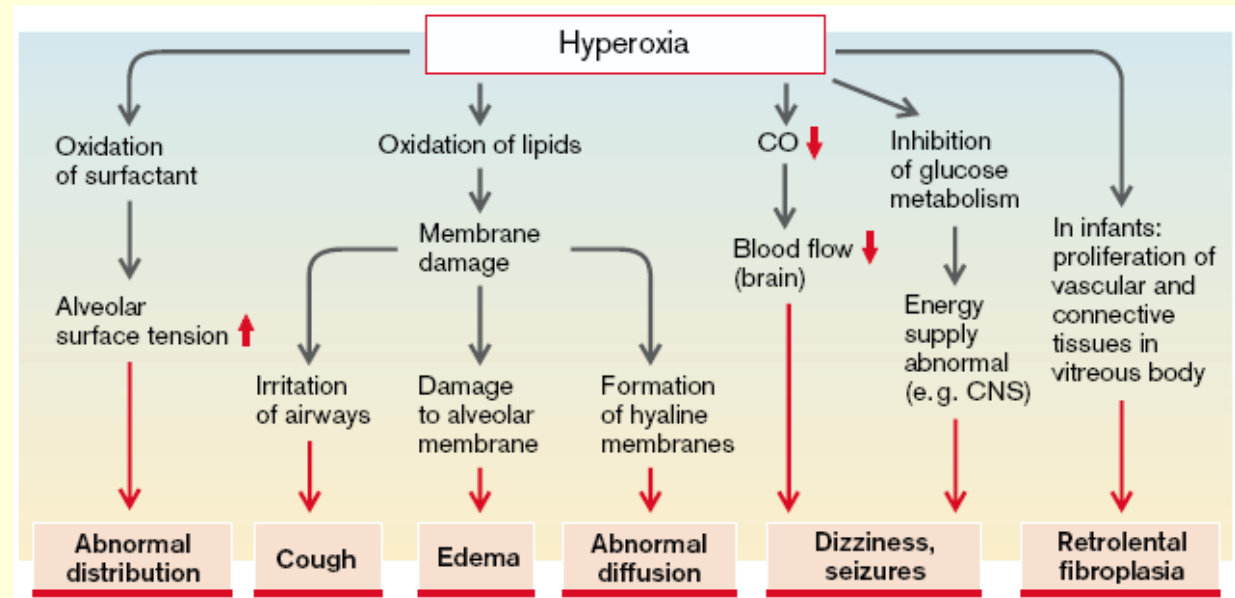
- due to insufficient delivery of oxygen (low PaO₂)
- or inability to utilise oxygen (normal PaO₂)



Changes in O₂ Concentration

HYPEROXEMIA

- increased oxygen content of the blood
- therapy of CO intoxication (hyperbaric oxygenotherapy)



Cyanosis

- refers to the bluish colour of skin, nails, lips and mucous membranes caused by a higher concentration of **deoxygenated hemoglobin** in the capillaries
- the onset of cyanosis is **50 g/L** of deoxygenated hemoglobin in the blood

- CNS disorders
- bronchial tree and lung disorders
 - hypoventilation
 - abnormal pulmonary diffusion
- circulatory failure



Changes in CO₂ Concentration

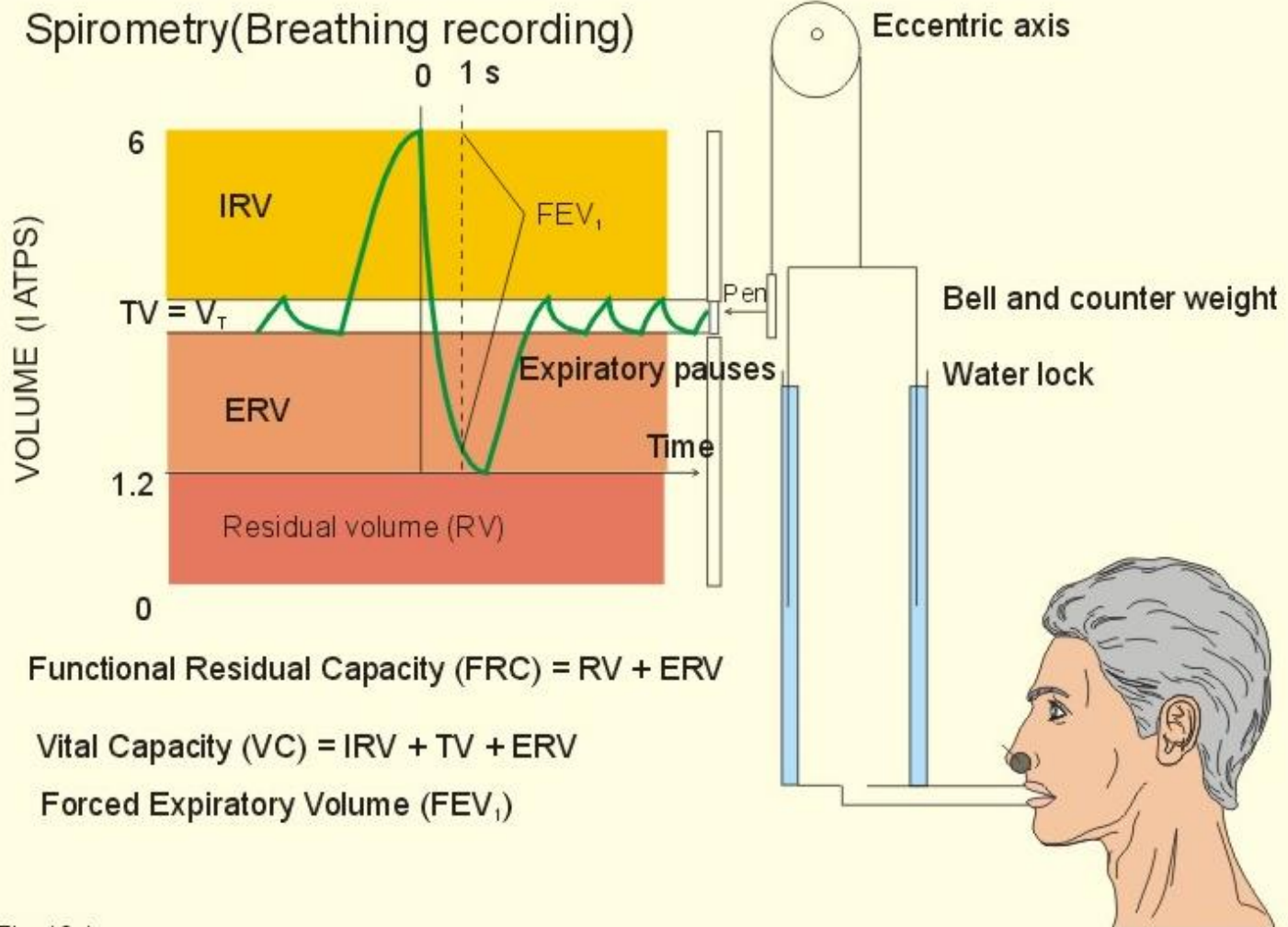
HYPERCAPNIA

- increased concentration of carbon dioxide (CO₂) in the blood
- hypoventilation
 - brain strokes
 - overdose of drugs (opiates)

HYPOCAPNIA

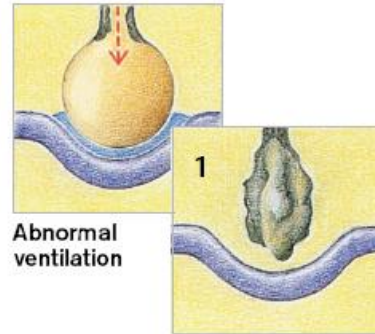
- a state of reduced carbon dioxide in the blood
- caused by hyperventilation

Spirometry

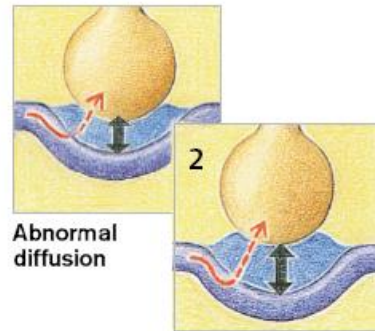


Pathophysiology of Respiration

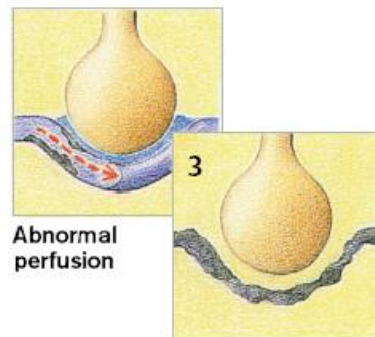
VENTILATION



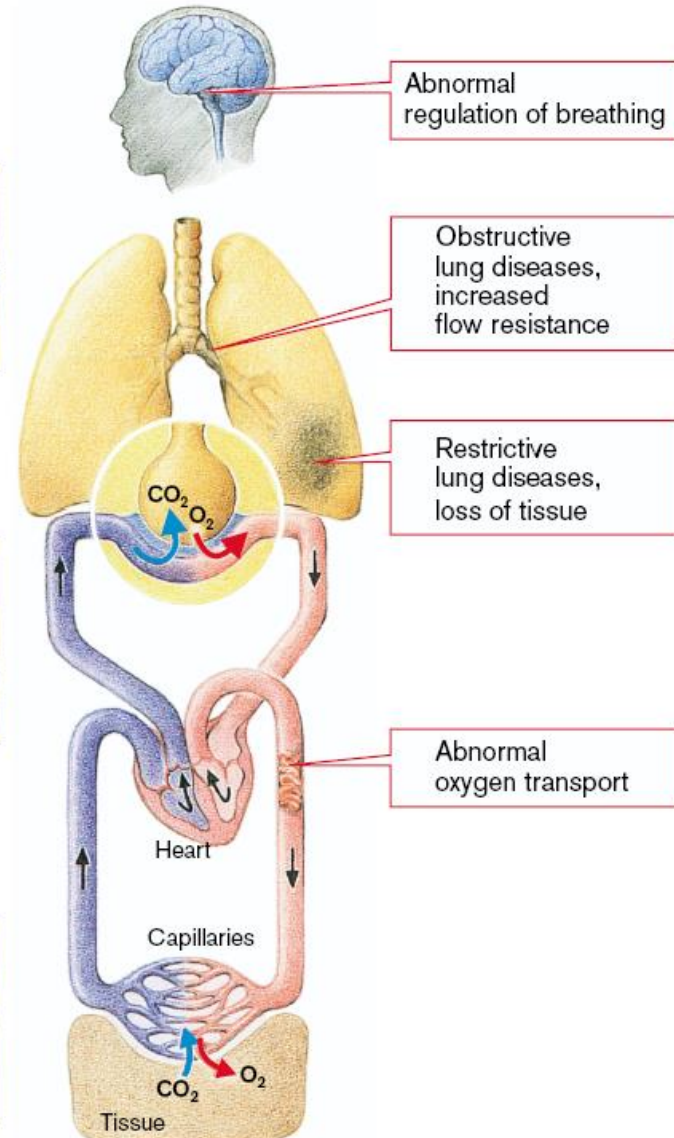
DIFFUSION



PERFUSION



DISTRIBUTION



Diffusion Abnormalities

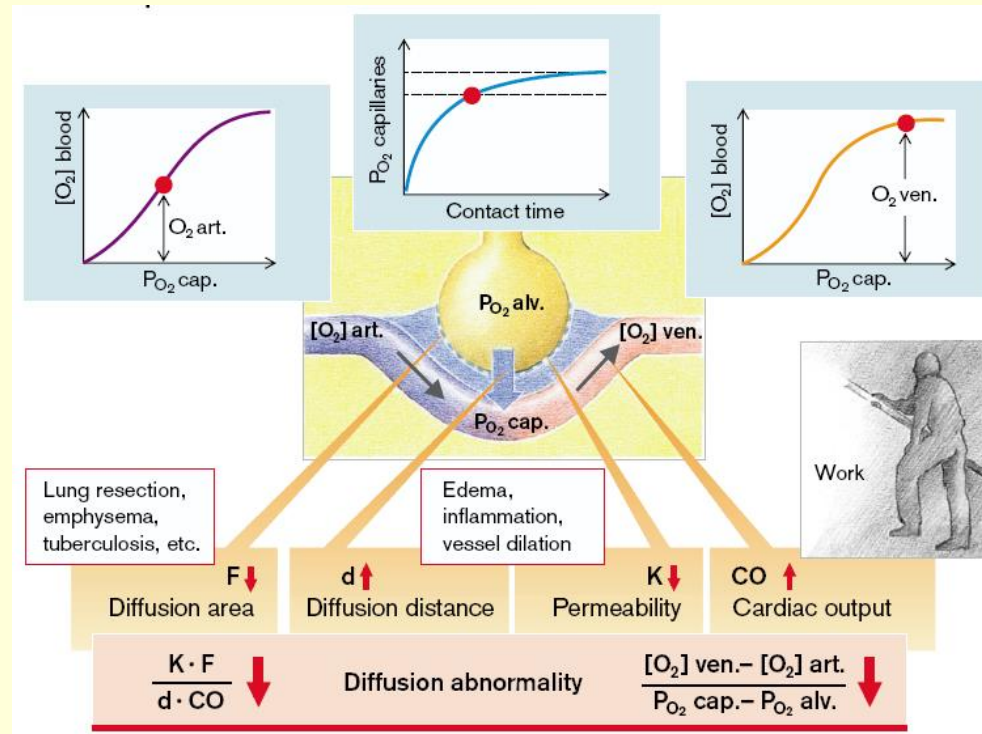
- primarily affects O_2 transport
- hypoxemia stimulates respiratory centre
- hyperventilation \longrightarrow hypocapnia

INCREASED DISTANCE

- lung fibrosis
- edema
- inflammatory processes

DECREASED DIFFUSION AREA

- TBC
- emphysema
- lung resection



Distribution Abnormalities

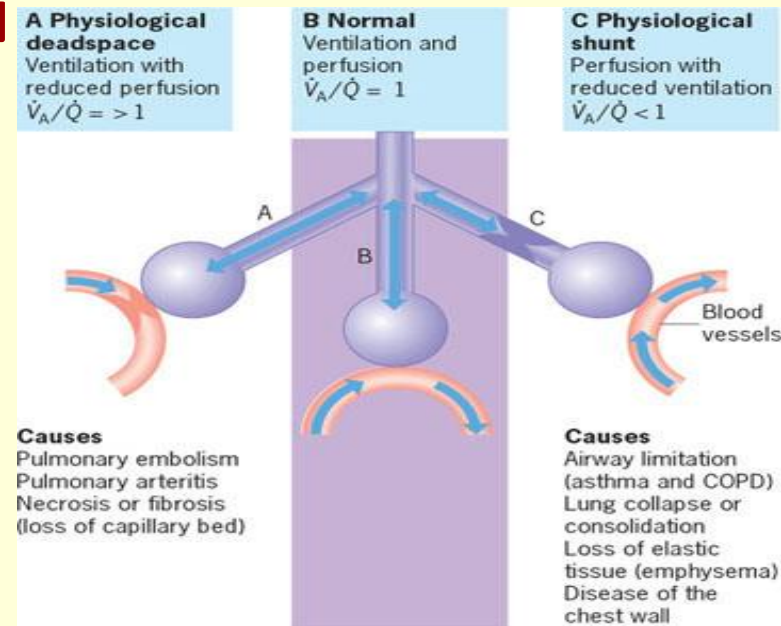
- **VENTILATION** – air that reaches the lungs
- **PERFUSION** – blood that reaches the lungs
- **V/Q ratio = VENTILATION/PERFUSION**
- normal V/Q ratio is 4/5 or 0.8

IMPAIRED PERFUSION

- area with no perfusion = **dead space**
- **high V/Q ratio**
 - pulmonary embolism

IMPAIRED VENTILATION

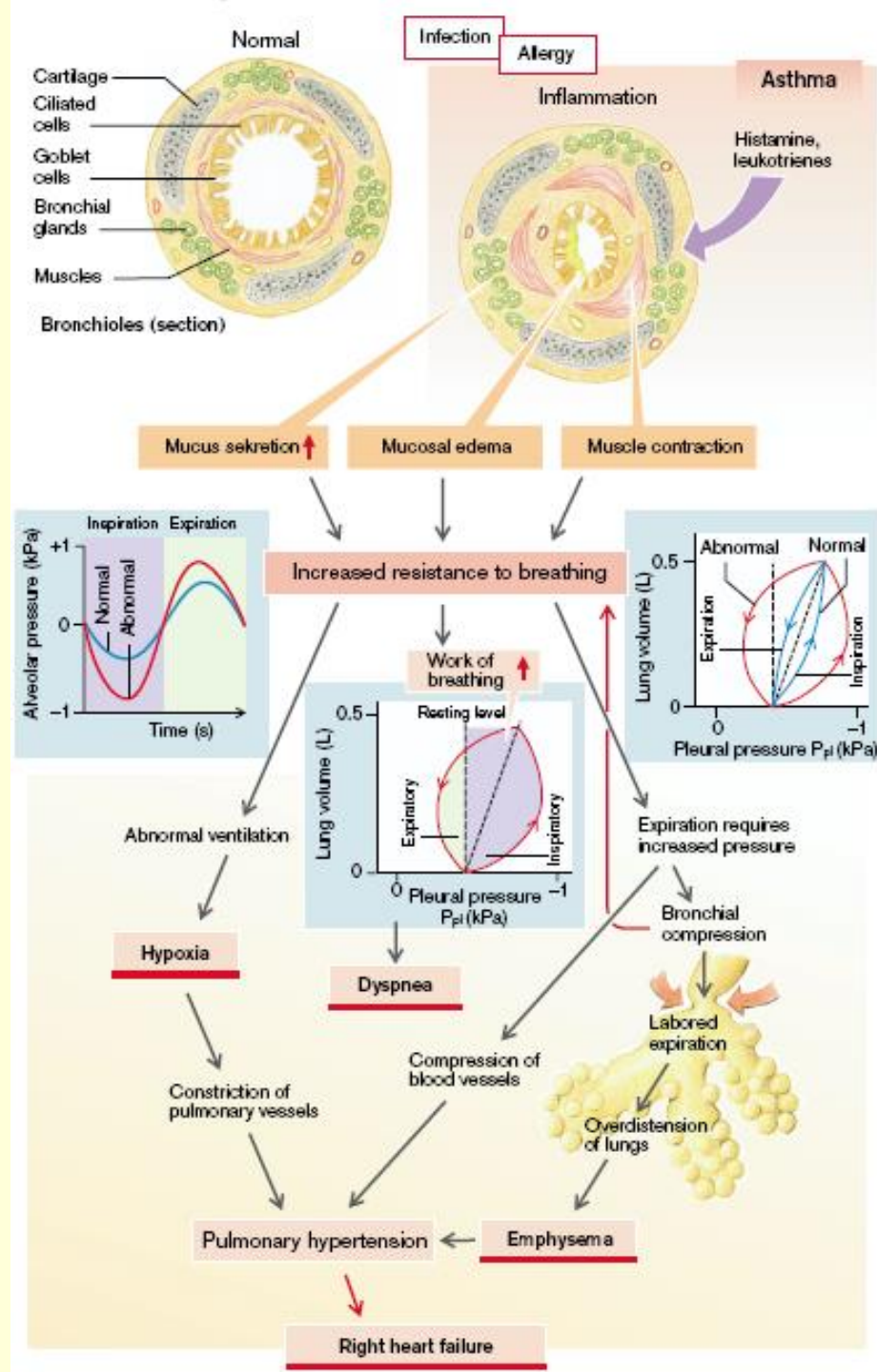
- **low V/Q ratio** – cause of low arterial partial pressure of oxygen (paO_2)
 - chronic bronchitis, asthma and acute pulmonary edema



Obstructive Lung Diseases

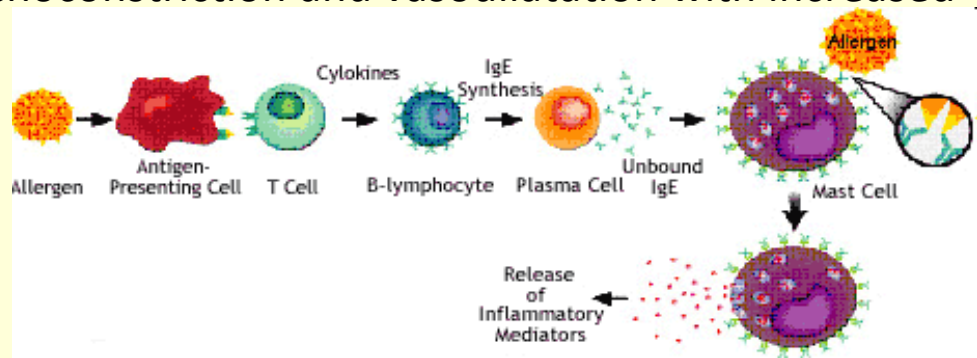
- respiratory diseases characterized by airway obstruction

- **ASTHMA**
- **CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)**
 - EMPHYSEMA
 - CHRONIC BRONCHITIS
- **CYSTIC FIBROSIS**



Bronchial Asthma

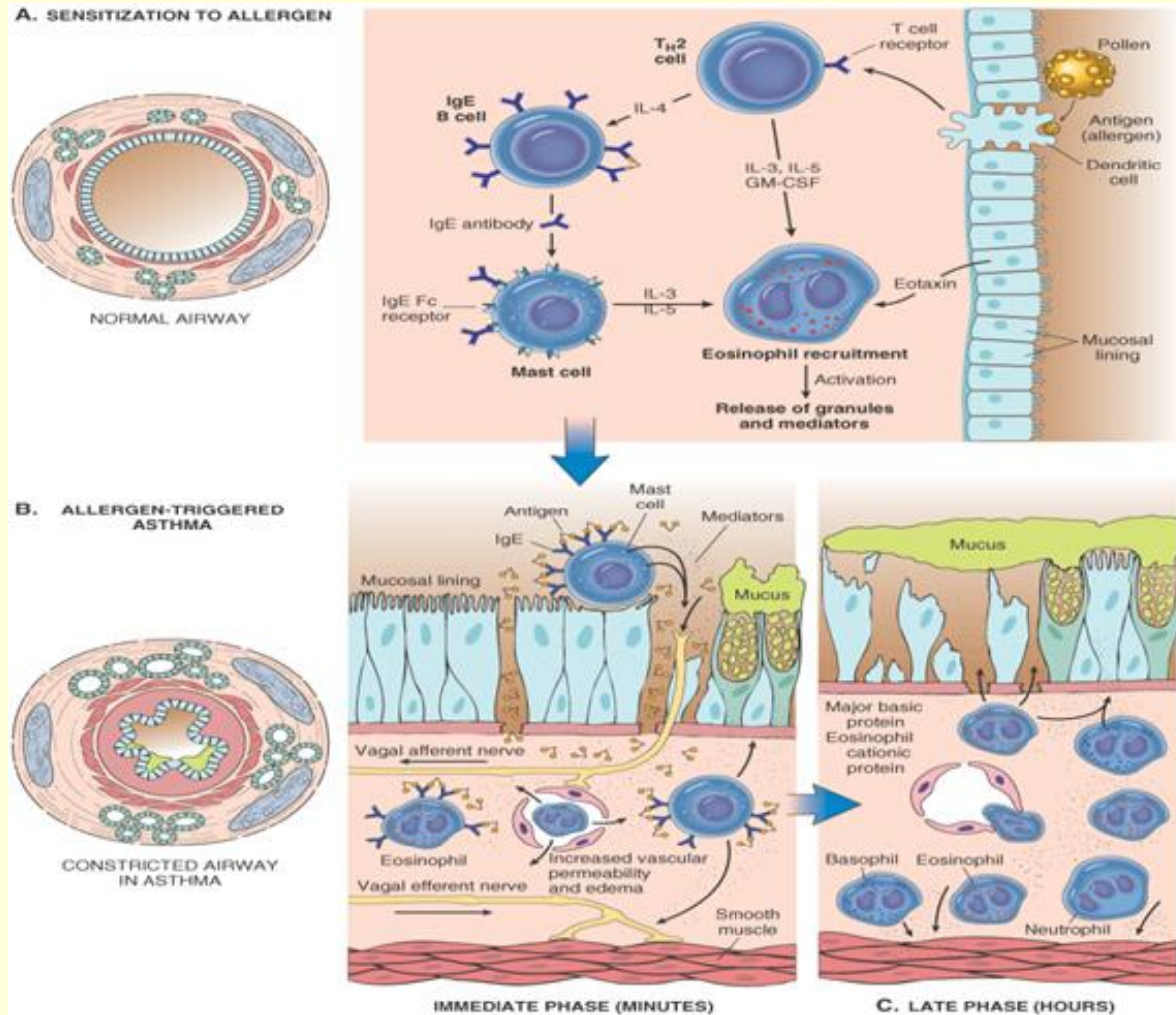
- an acute airflow obstruction caused by bronchoconstriction, edema and mucous production resulting from an allergic or hypersensitive reaction
- caused by a specific allergen
 - house-dust mites, pollen grains, moulds and domestic pets
- **eosinophils** recognise the allergen and B-lymphocytes release allergen-specific **IgE Ab**
- **the allergen-IgE complex** is bound to IgE-receptors on the surface of mast cells, eosinophils and basophils, hereby, **mediators** of anaphylactic reactions are released from the mast cell granules
 - **leukotrienes**: strong bronchoconstrictors, mucosal inflammation with edema
 - **prostaglandin D2**: bronchoconstriction and vasodilatation with increased capillary permeability



Symptoms of Bronchial Asthma

- wheezing (during expiration)
- cough
- shortness of breath
- chest tightness

- symptoms often worsen at night or in the early morning, or in response to exercise or cold air

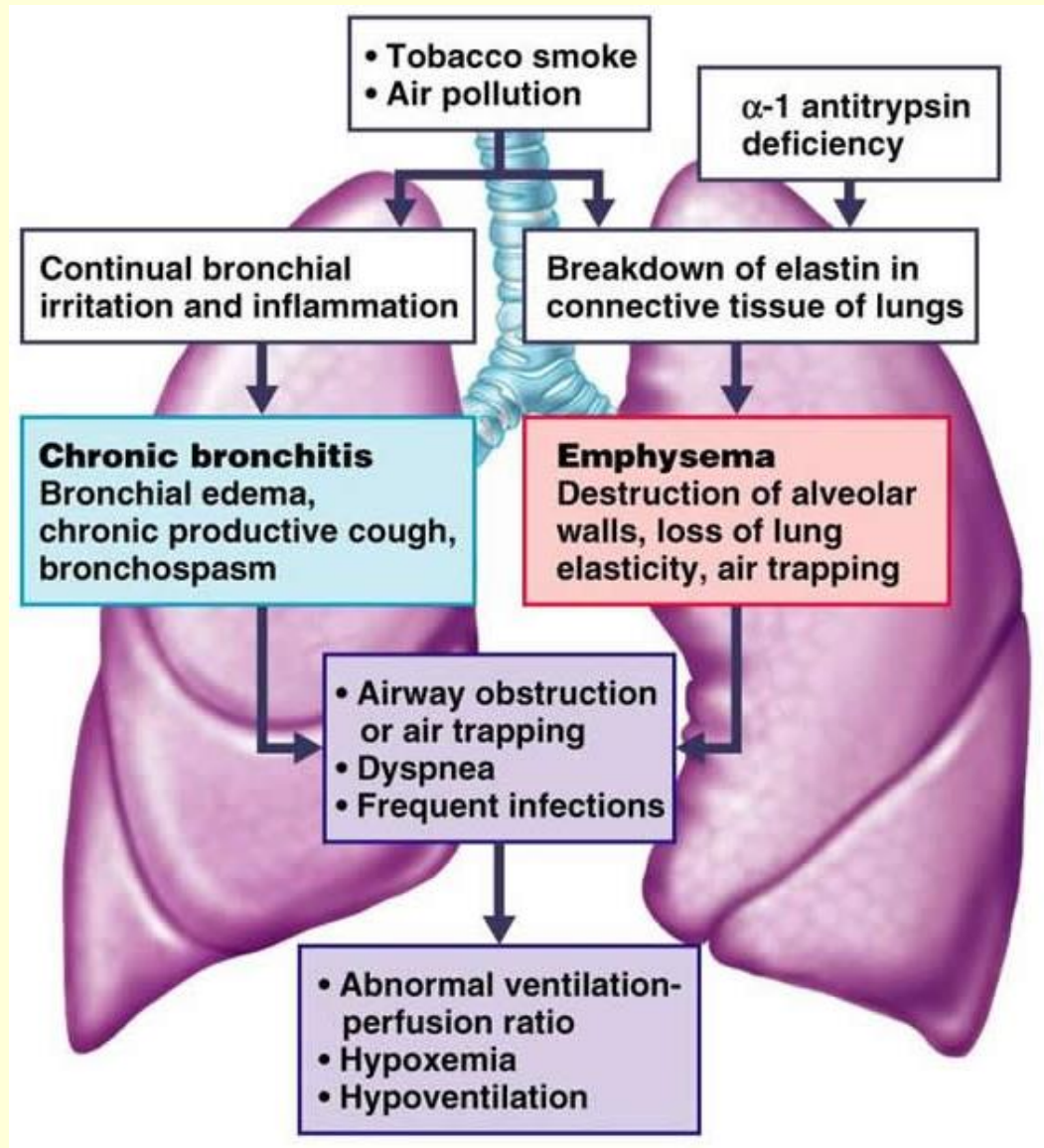


Chronic Obstructive Pulmonary Disease (COPD)

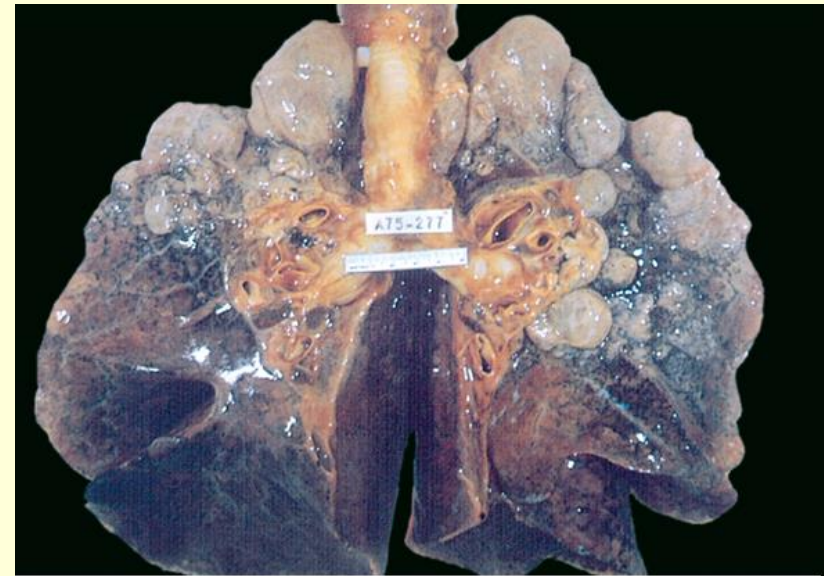
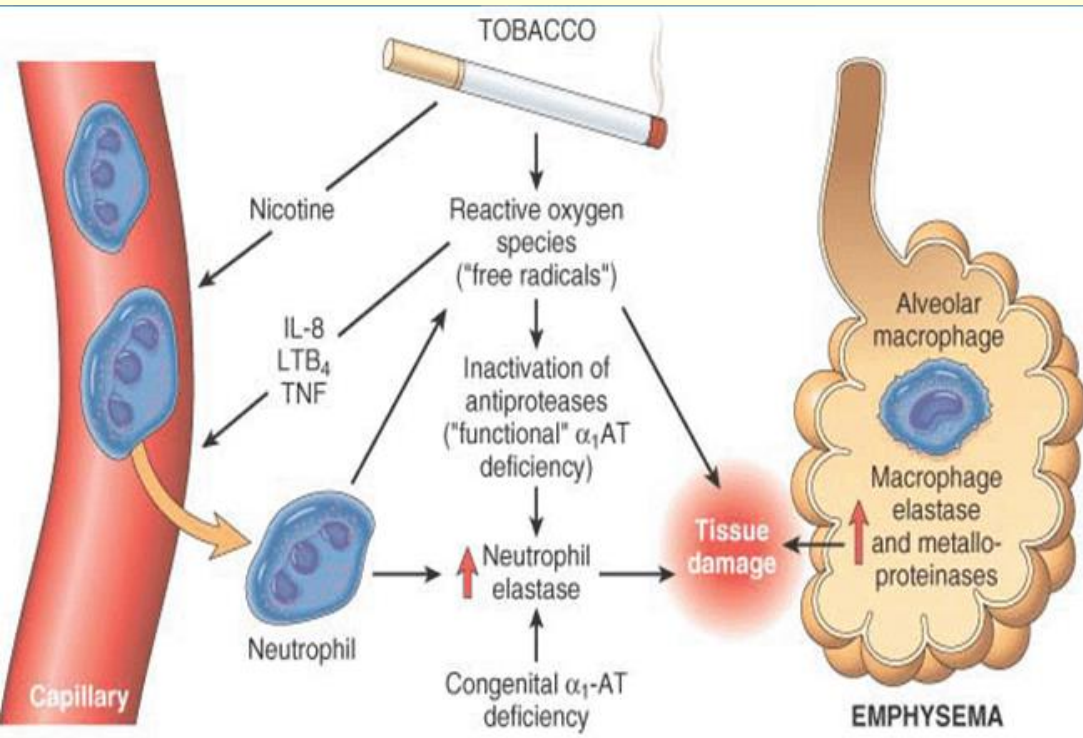
- refers to **chronic bronchitis** and **emphysema**
- limitation of the airflow causing shortness of breath, chronic cough and frequent respiratory infections
- noxious gases, tobacco smoking

- **CHRONIC BRONCHITIS**
 - inflammation and swelling of the lining of the airways that leads to narrowing and obstruction of the airways
 - production of mucous (sputum)
- **EMPHYSEMA**
 - in the alveoli, the inflammatory process causes destruction of alveolar walls and permanent enlargement of the alveoli
 - air becomes "trapped" in the alveoli and reduces the ability of the lung to shrink during exhalation
 - acute exacerbations

Chronic Obstructive Pulmonary Disease

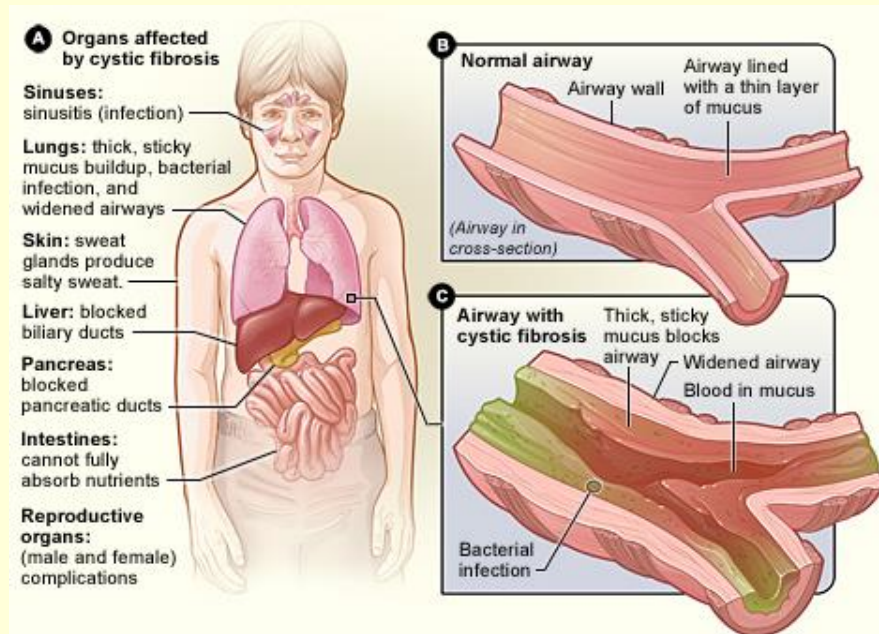


Emphysema



Cystic Fibrosis

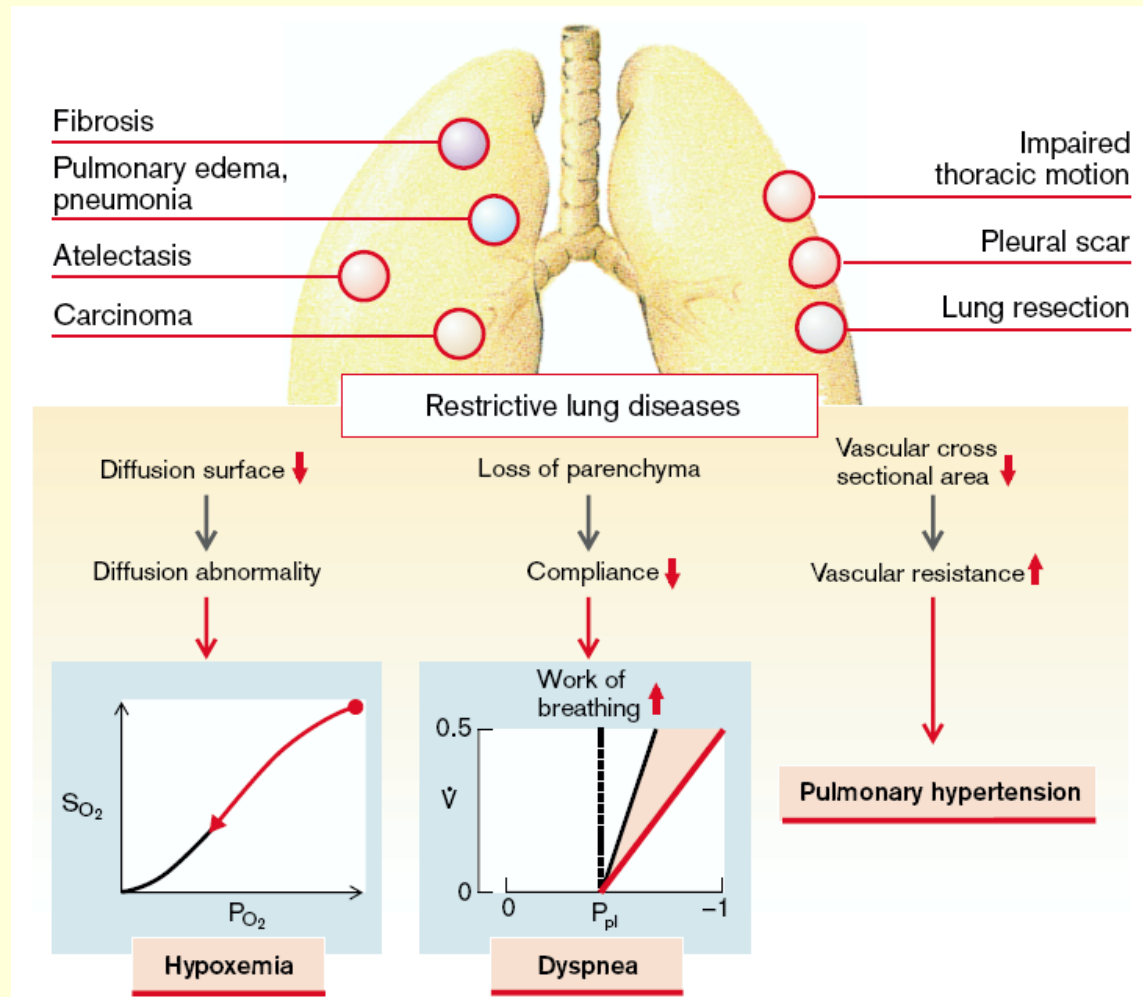
- genetically transmitted chronic obstructive disease characterized by exocrine secretion of **thick, copious mucus in the respiratory, GIT and reproductive tracts**
- **bronchial obstruction** results in ineffective airway clearance, which causes mucus stasis
- it leads to **infection**, commonly with *Pseudomonas aeruginosa* or *Staphylococcus*
- permanent parenchymal damage results as bronchial walls are destroyed and the bronchioles become dilated



Restrictive Lung Diseases

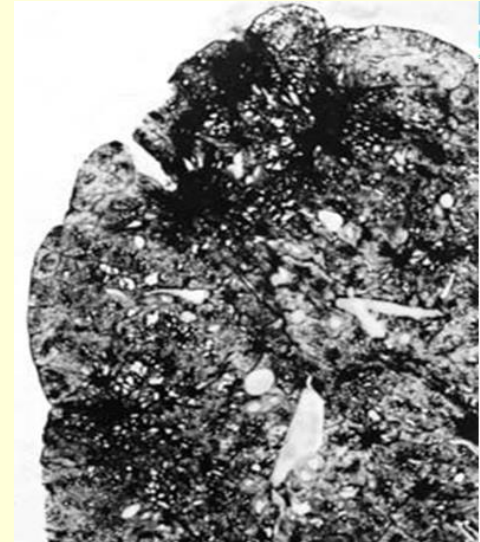
- the distensibility of the lungs (compliance) is decreased
- reduction of the diffusion area
- gaseous exchange impairment

- PNEUMOTHORAX
- PNEUMOCONIOSES
- ARDS
- PULMONARY EDEMA
- TBC
- PNEUMONIAS



Pneumoconiosis

- **ANTHRACOSIS** (coal dust)
 - **SILICOSIS** (crystalline silica dust)
 - **ASBESTOSIS** (asbestos)
 - **SIDEROSIS** (iron oxides)
 - **BYSSINOSIS** (cotton)
-
- particles from 1 to 5 μm reach the distal airways
 - the alveolar macrophages mediate an **inflammatory response** and initiate fibroblast proliferation and collagen deposition
 - reduction of the diffusion area

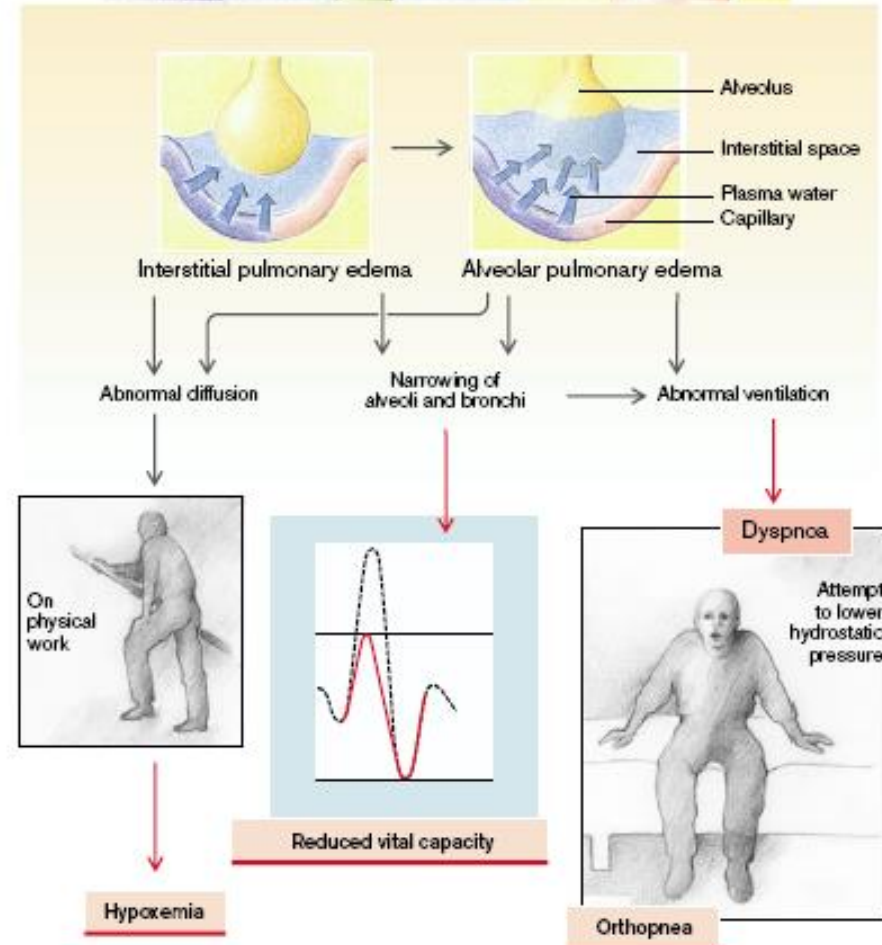
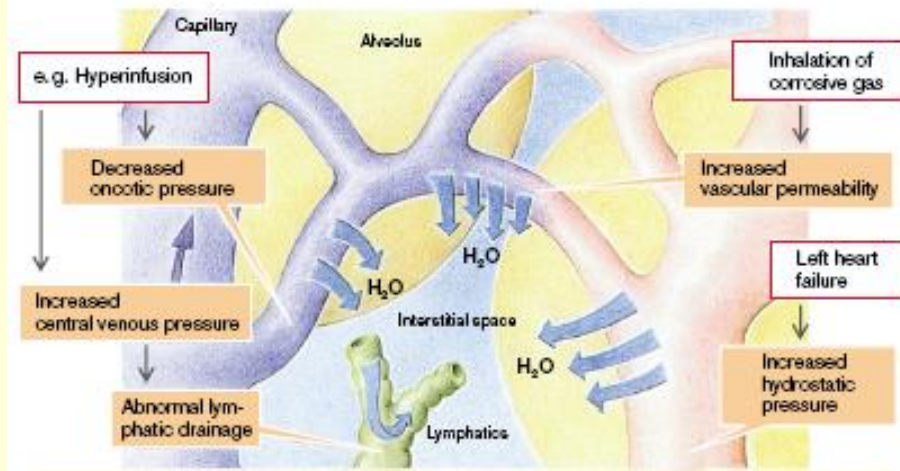


MESOTHELIOMA DUE TO ASBESTOS EXPOSURE



Pulmonary Edema

- left heart failure
- inhalation of corrosive gases
- hyperhydratation
- shock
- multiorgan failure



Acute Respiratory Distress Syndrome (ARDS)

- reaction to lung injury/inflammation leading to an impaired gas exchange with the systemic release of mediators causing **inflammation, hypoxemia** and frequently resulting in **multiple organ failure**
- increased permeability of the alveolar-capillary membrane permits fluid and protein to move from the vessels into the interstitium and alveoli, causing **pulmonary edema**
- **inactivation of surfactant**, alveolar surface tension increases
- alveoli become lined with **hyaline membranes**, compromising the diffusion of respiratory gases
- accumulation of fluid, impaired diffusion, which causes **hypoxemia**



RESPIRATORY DISTRESS

ARDS

Phase 1

In *phase 1*, injury reduces normal blood flow to the lungs. Platelets aggregate and release histamine (H), serotonin (S), and bradykinin (B).



Phase 2

In *phase 2*, those substances—especially histamine—inflame and damage the alveolocapillary membrane, increasing capillary permeability. Fluids then shift into the interstitial space.



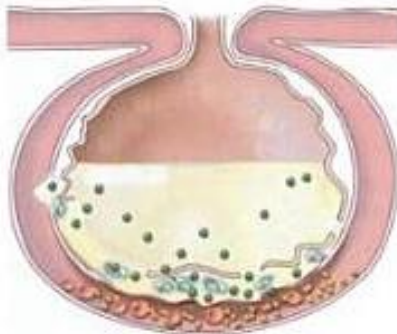
Phase 3

In *phase 3*, as capillary permeability increases, proteins and fluids leak out, increasing interstitial osmotic pressure and causing pulmonary edema.



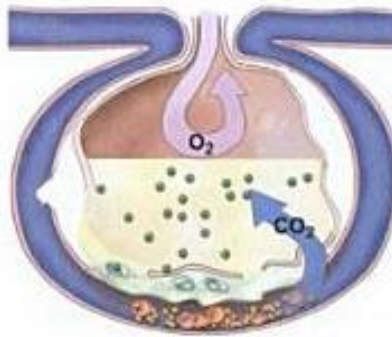
Phase 4

In *phase 4*, decreased blood flow and fluids in the alveoli damage surfactant and impair the cell's ability to produce more. As a result, alveoli collapse, impeding gas exchange and decreasing lung compliance.



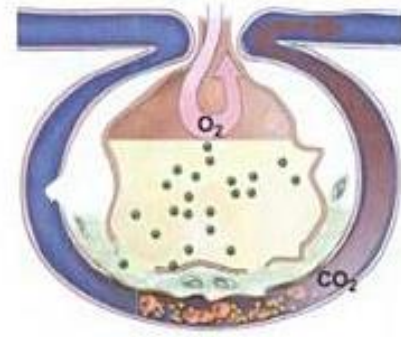
Phase 5

In *phase 5*, sufficient oxygen can't cross the alveolocapillary membrane, but carbon dioxide (CO₂) can and is lost with every exhalation. Oxygen (O₂) and CO₂ levels decrease in the blood.



Phase 6

In *phase 6*, pulmonary edema worsens, inflammation leads to fibrosis, and gas exchange is further impeded.



Pneumonia

- inflammatory process in lung tissue
- bacteria
 - *Streptococcus pneumoniae*
 - *Staphylococcus aureus*
 - *Haemophilus influenzae*
- viruses
 - flu viruses
 - coronaviruses
 - adenoviruses
- cough
- chest pain
- fever
- dyspnoea

