
بسم الله الرحمن الرحيم

THE PULMONARY CIRCULATION-2

Dr Zubia Shah

Learning Objectives

- Describe the consequences of **hypoxic pulmonary vasoconstriction** on the distribution of **pulmonary blood flow**.
- Describe the pulmonary **capillary dynamics**.
- Describe the development of **pulmonary edema**.

Effect of Decreased Alveolar Oxygen on Alveolar & Pulmonary Blood Flow

- When alveolar O_2 falls **below 70%** of normal (PO_2 below 73mmHg)
- → **constriction** of vessels
- →↑ **vascular resistance** more than 5 times → distributing blood flow

Low Oxygen levels - mechanism

Vasoconstrictor release **↓ Vasodilator (NO)**

TABLE 13-4 Effects of Local Changes in O_2 on the Pulmonary and Systemic Arterioles

Vessels	EFFECT OF A LOCAL CHANGE IN O_2	
	Decreased O_2	Increased O_2
Pulmonary Arterioles	Vasoconstriction	Vasodilation
Systemic Arterioles	Vasodilation	Vasoconstriction

Mechanism of Pulmonary Vasoconstriction due to Hypoxia

Hypoxia →

Inhibition of O_2 sensitive K+ channels in pulmonary vascular smooth muscle cell membranes →

Depolarization of cell membrane & activation of Calcium channels → vasoconstriction

Effect of Left Heart Failure on Pulmonary Pressure

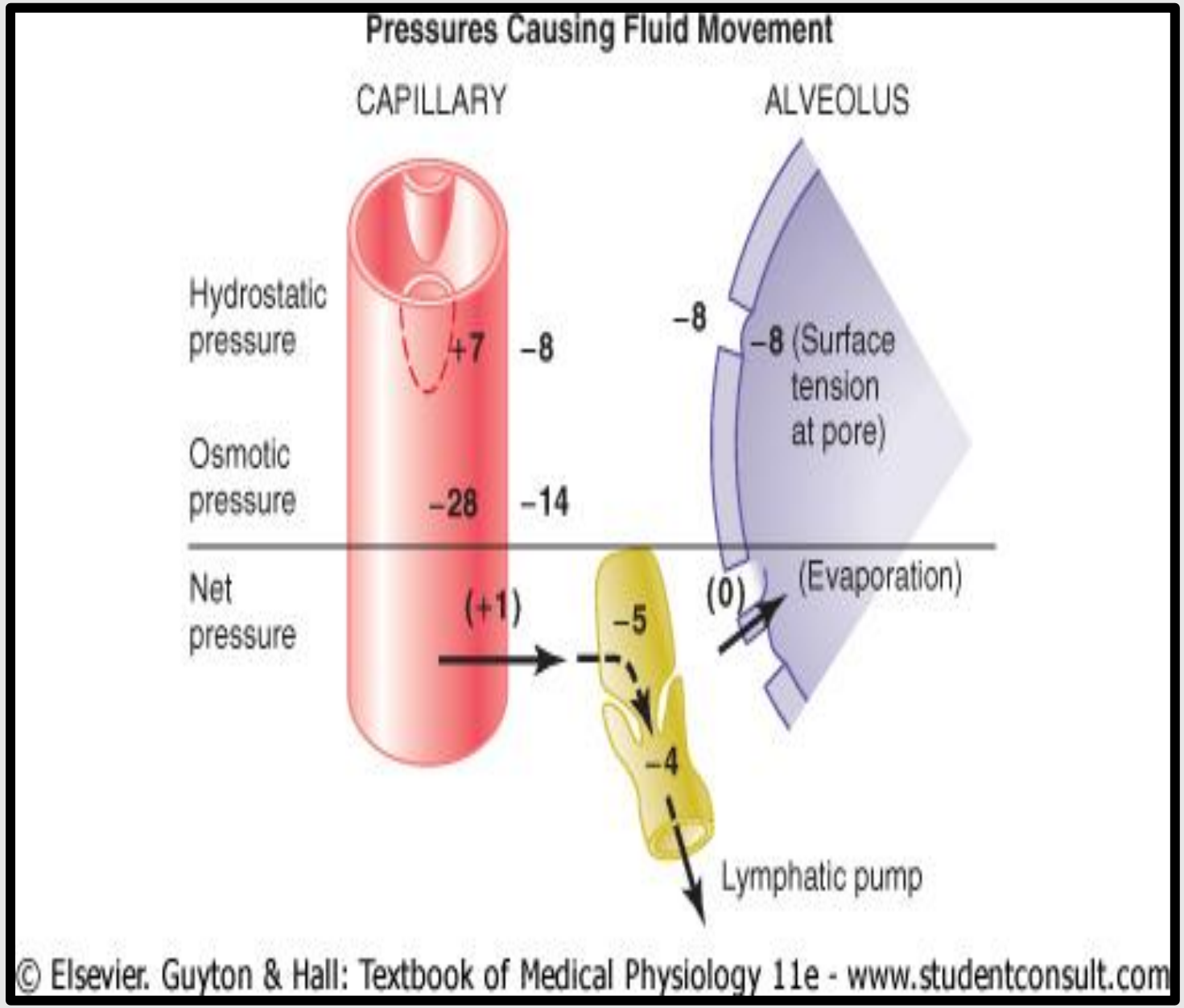
- In healthy person Left atrial pressure(1-5 mmHg)never rises above **+6mmHg**
- When ↑ **to 7-8 mmHg** → ↑ in Pulmonary Arterial Pressure
- **Above 30mmHg → Pulmonary Edema**

Pulmonary Capillary Dynamics

Pulmonary Capillary Pressure = 7 mm Hg

With Normal cardiac output, blood passes through the pulmonary capillaries in about 0.8 second

When the cardiac output increases, this time can shorten to as little as 0.3 second



Hydrostatic & Osmotic Forces At Capillary And Alveolar Level

Capillary Fluid Dynamics

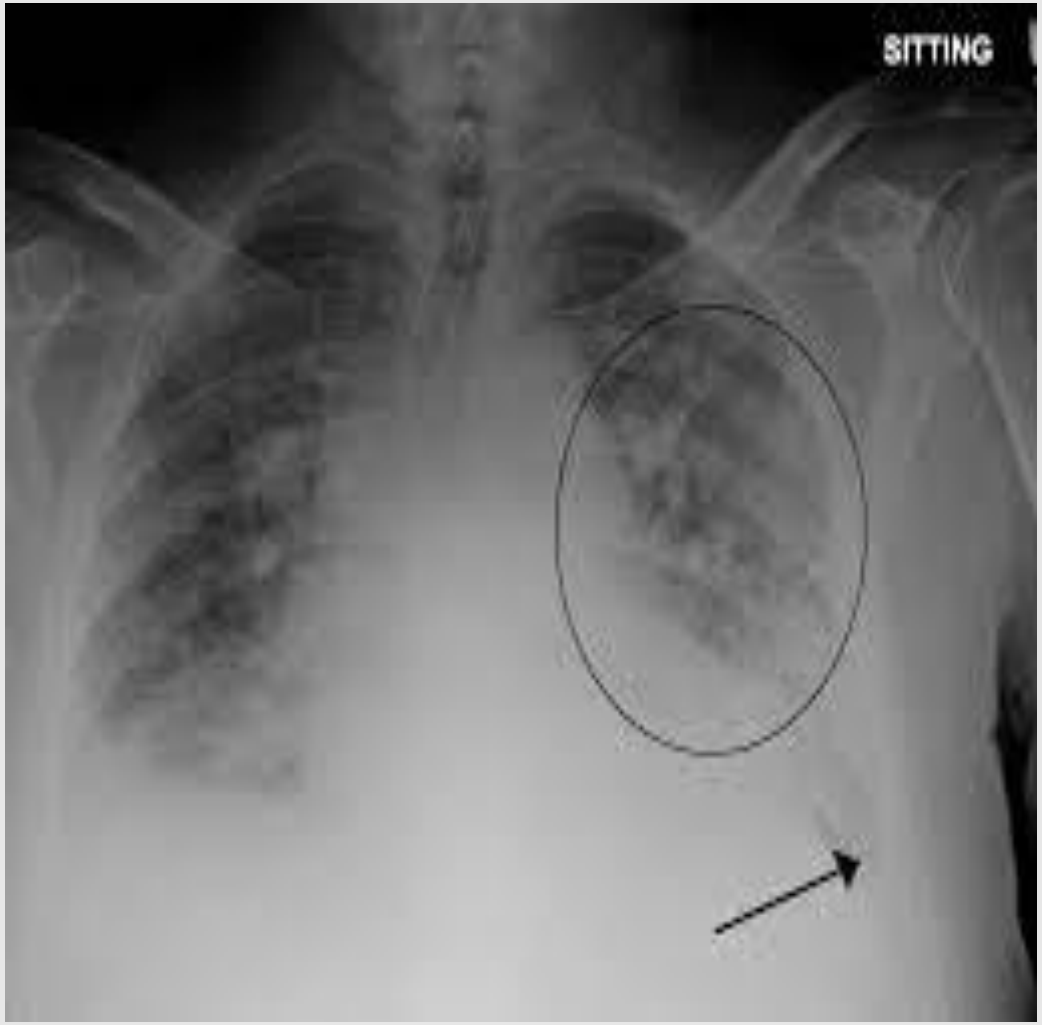
	mm Hg
Forces tending to cause movement of fluid outward from the capillaries and into the pulmonary interstitium:	
Capillary pressure	7
Interstitial fluid colloid osmotic pressure	14
Negative interstitial fluid pressure	8
TOTAL OUTWARD FORCE	29
Forces tending to cause absorption of fluid into the capillaries:	
Plasma colloid osmotic pressure	28
TOTAL INWARD FORCE	28

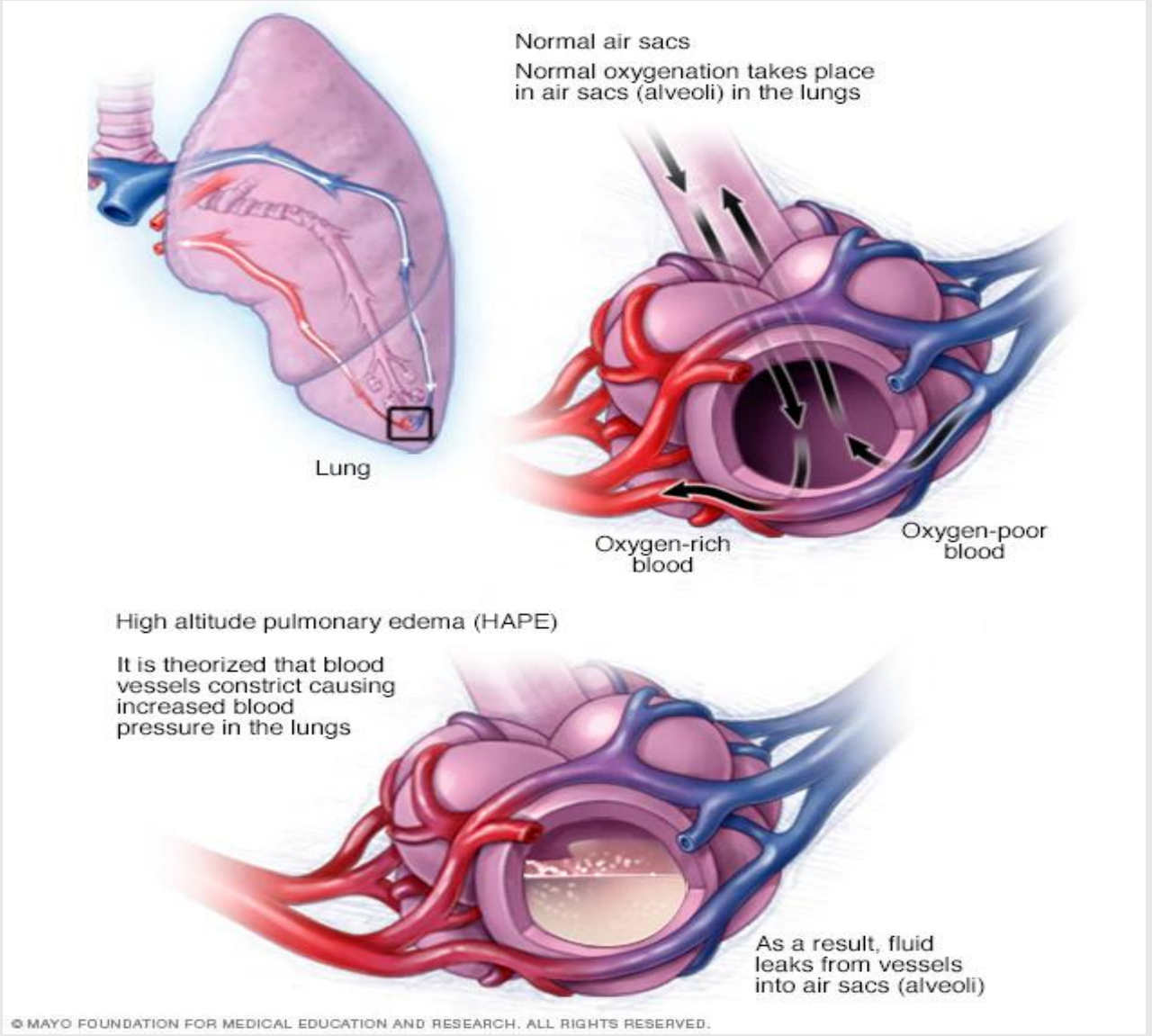
Mechanism for Keeping the Alveoli "Dry

Extra fluid in alveoli is sucked into the lung interstitium because of negative interstitial pressure

The excess fluid is then carried away through the pulmonary lymphatics

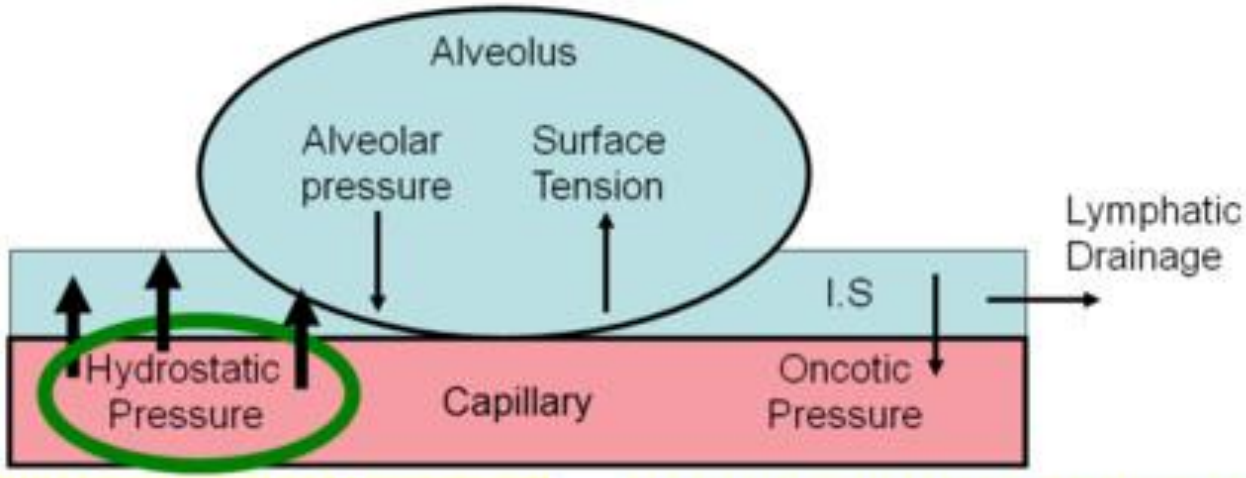
In normal state, the alveoli are "Dry," except for a small amount of fluid to keep them moist


SITTING


Normal air sacs
Normal oxygenation takes place in air sacs (alveoli) in the lungs
Lung
Oxygen-rich blood
Oxygen-poor blood
High altitude pulmonary edema (HAPE)
It is theorized that blood vessels constrict causing increased blood pressure in the lungs
As a result, fluid leaks from vessels into air sacs (alveoli)
© MAYO FOUNDATION FOR MEDICAL EDUCATION AND RESEARCH. ALL RIGHTS RESERVED.

Pulmonary Edema

Pulmonary Edema



Hydrostatic pressure is high (25 mm Hg)

Oncotic pressure normal (25 mm Hg)

Pulmonary edema – increased hydrostatic pressure

- Pulmonary hypertension in COPD
- Hypoxic vasoconstriction at altitude
- Increased central venous pressure – mitral stenosis

Causes of Pulmonary Edema

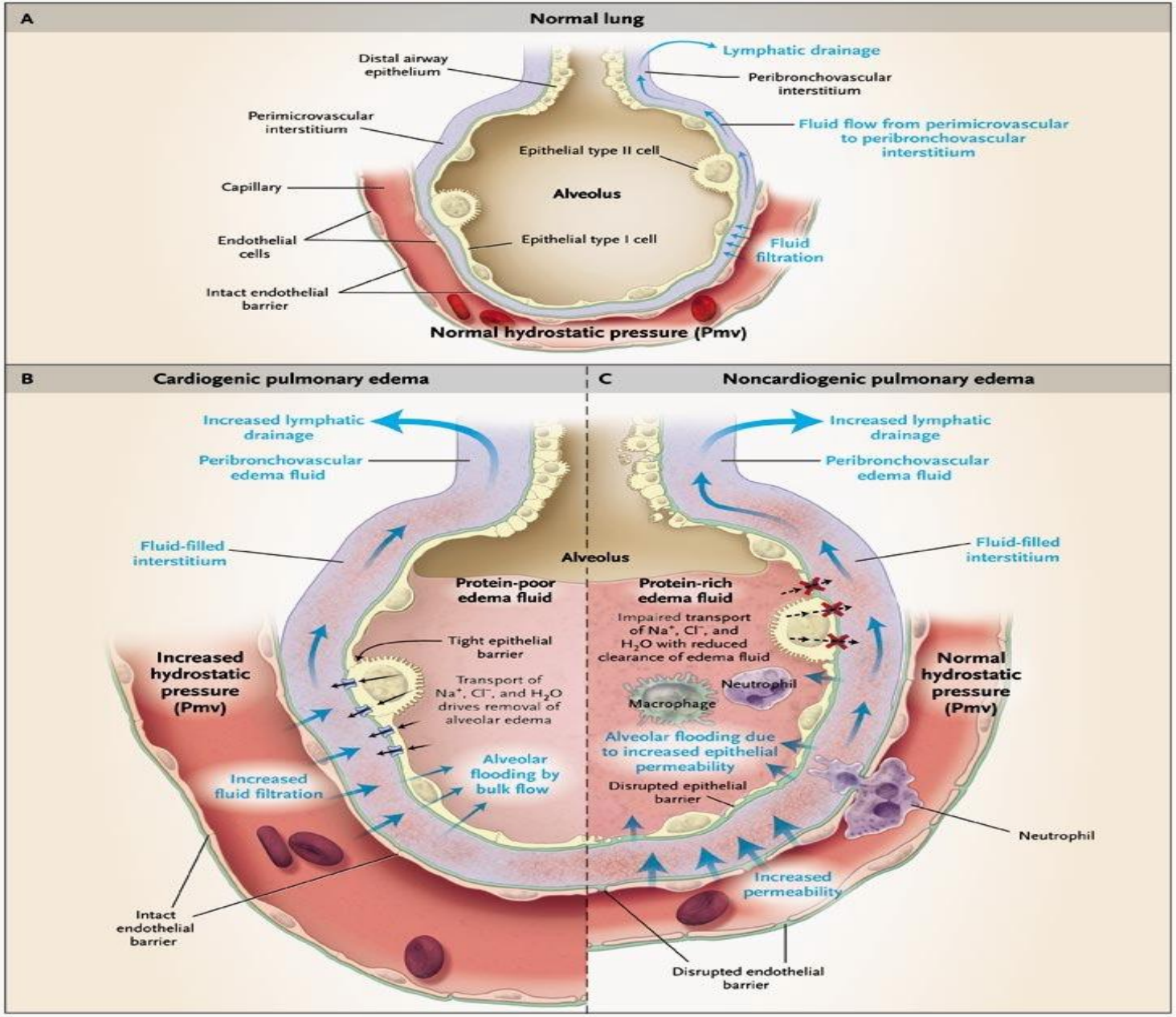
1. **Left-sided heart failure or Mitral Valve disease**

2. Damage to the Pulmonary capillary membranes caused by infections such as pneumonia or noxious substances such as chlorine gas or sulfur dioxide gas

rapid leakage of both plasma proteins and fluid out of the capillaries and into both the lung interstitial spaces and the alveoli

Normal Lung

Pulmonary Edema



Negative Pressure Pulmonary Edema: *Pathophysiology*

Authors:
Mackenzie Gault
Reviewers:
Arsalan Ahmad
Melinda Davis*
** MD at time of publication*

Airway Obstruction
Involuntarily biting ET tube or laryngospasm most common

↓ ventilation to lungs

Hypoxia

Detected by peripheral chemoreceptors

Sympathetic stimulation

Patient tries to inspire forcefully against obstruction

Highly negative intrathoracic pressure

Acute ↑ in systemic venous return to right heart

↑ pulmonary blood volume

↑ pulmonary arterial + capillary pressure

↓ pulmonary interstitial pressure

↑ trans-capillary pressure gradient

Fluid pushed out of pulmonary capillaries into the interstitium

Negative Pressure Pulmonary Edema:
Fluid in lungs caused by highly negative intrathoracic pressure

Fluid surrounds alveoli

CXR: diffuse bilateral infiltrates

↓ diffusion of alveolar O_2 into pulmonary capillaries

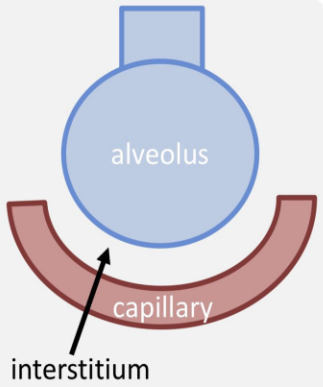
↓ PO_2
↓ O_2 Sats

If *severe*: pressure and fluid build-up damages capillary and alveolar walls

Fluid & red blood cells from capillaries enter alveoli and are coughed up

Frothy pink sputum

Notes:
ET tube: Endotrachial tube
Laryngospasm: spasm of vocal cords; may occur on extubation
CXR: Chest X-Ray



Vol of plasma filtered through capillaries exceeds the amount that can be taken away by the lymphatics → increasing the distance between alveoli and capillaries and thus impairing gas exchange

Published **September 1, 2019** on www.thecalgaryguide.com

Effect of Posture In A Person with Pulmonary Edema

Upright Posture Fluid tends to accumulate in basal portions of lungs allowing unimpeded gas exchange in apical portions

In Recumbent position edema fluid distributes evenly through lung tissue → greater impairment in gas exchange with difficulty in sleeping

Patients become Hypoxic and not hypercapnic because oxygen is less soluble in water than CO_2

Pulmonary Edema Safety Factor

Pulmonary capillary pressure (7mmHg) normally must rise to a value more than the **colloid osmotic pressure (28mmHg)** of the plasma inside the capillaries before significant pulmonary edema will occur

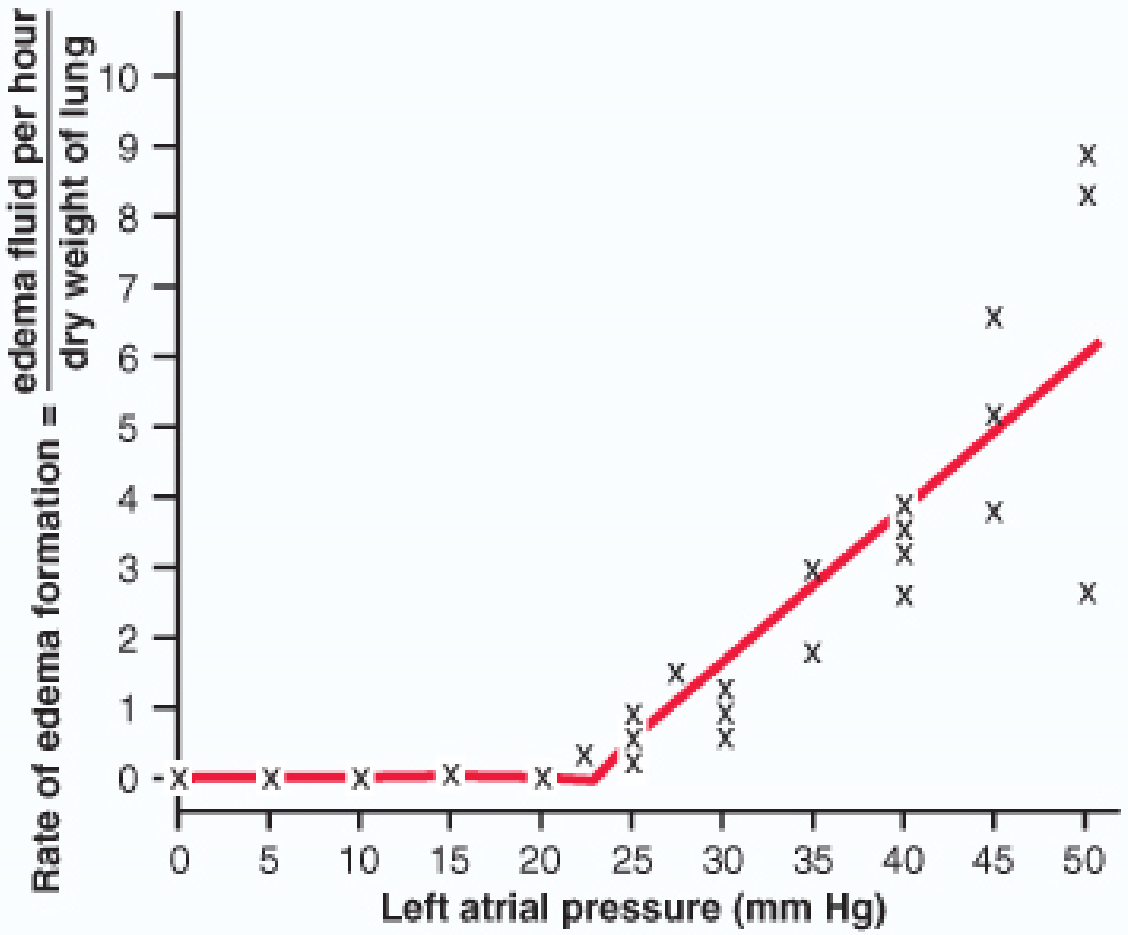
So Acute Safety Factor against Pulmonary Edema of 21mmHg

Safety Factor In Chronic Conditions

- **High Chronic Capillary Pressure** (for at least 2 weeks)

lungs become resistant to pulmonary edema as lymphatics expand → 10-fold ↑ carrying of fluid away from the interstitial spaces

- **In chronic mitral stenosis**, pulmonary capillary pressures of 40 to 45 mm Hg have been measured without the development of lethal pulmonary edema

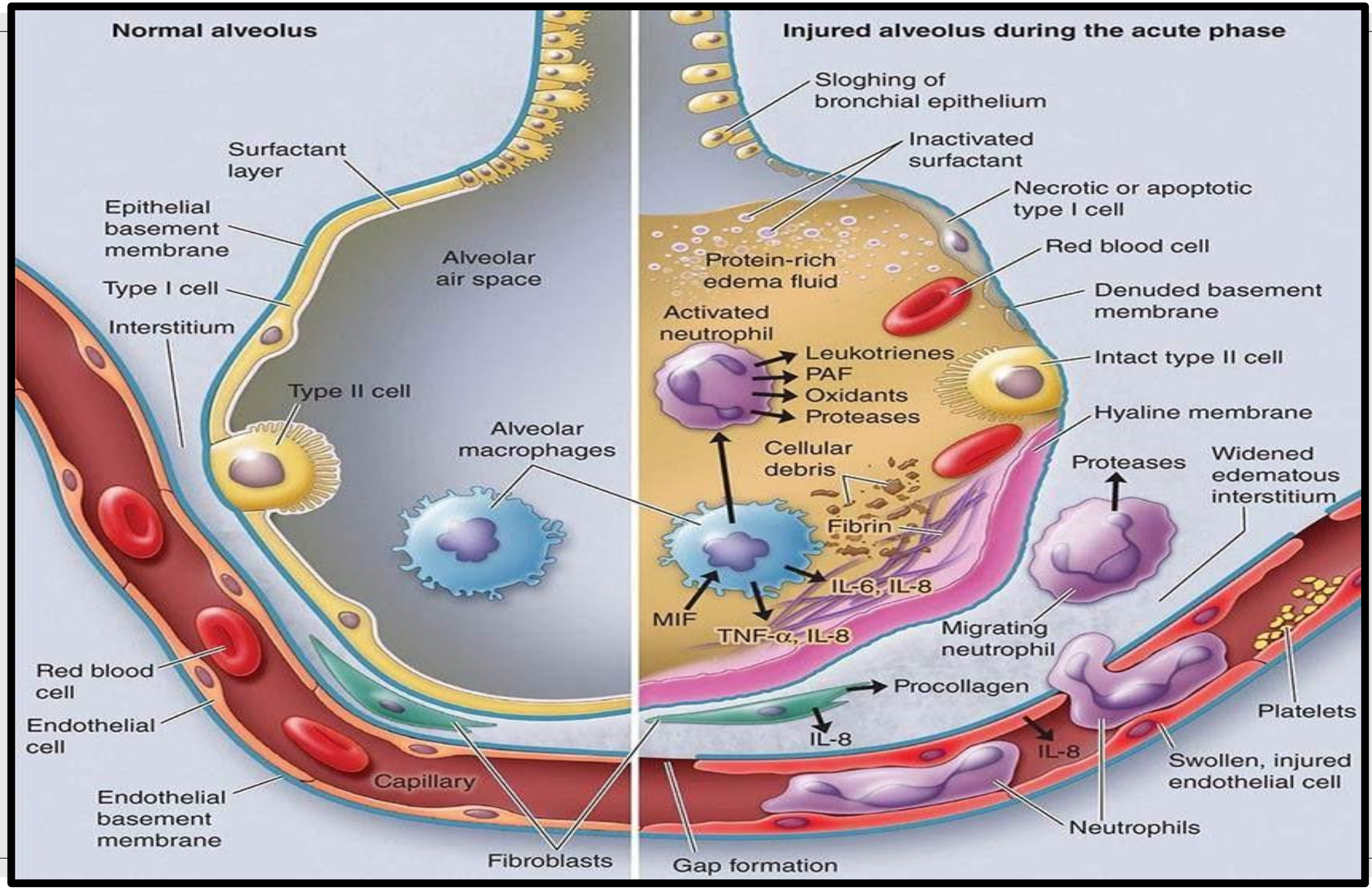


Effect of Elevated left Atrial Pressure On Rate of Fluid Loss In Lung Tissues

Acute Pulmonary Edema & Death

- If the **capillary pressure rises 25 to 30 mm Hg** above the safety factor level→ lethal pulmonary edema can occur within hours, or even within 20 to 30 minutes

- In **Acute left-sided heart failure** the pulmonary capillary pressure can rise to 50 mm Hg → death may in less than 30 minutes due to acute pulmonary edema


Normal alveolus
Surfactant layer
Epithelial basement membrane
Type I cell
Interstitium
Alveolar air space
Type II cell
Alveolar macrophages
Red blood cell
Endothelial cell
Capillary
Endothelial basement membrane
Fibroblasts
Injured alveolus during the acute phase
Sloghing of bronchial epithelium
Inactivated surfactant
Necrotic or apoptotic type I cell
Red blood cell
Protein-rich edema fluid
Denuded basement membrane
Activated neutrophil
Leukotrienes
PAF
Oxidants
Proteases
Intact type II cell
Hyaline membrane
Cellular debris
Fibrin
Proteases
Widened edematous interstitium
IL-6, IL-8
MIF
TNF-α, IL-8
Migrating neutrophil
Procollagen
Platelets
IL-8
IL-8
Swollen, injured endothelial cell
Neutrophils
Gap formation

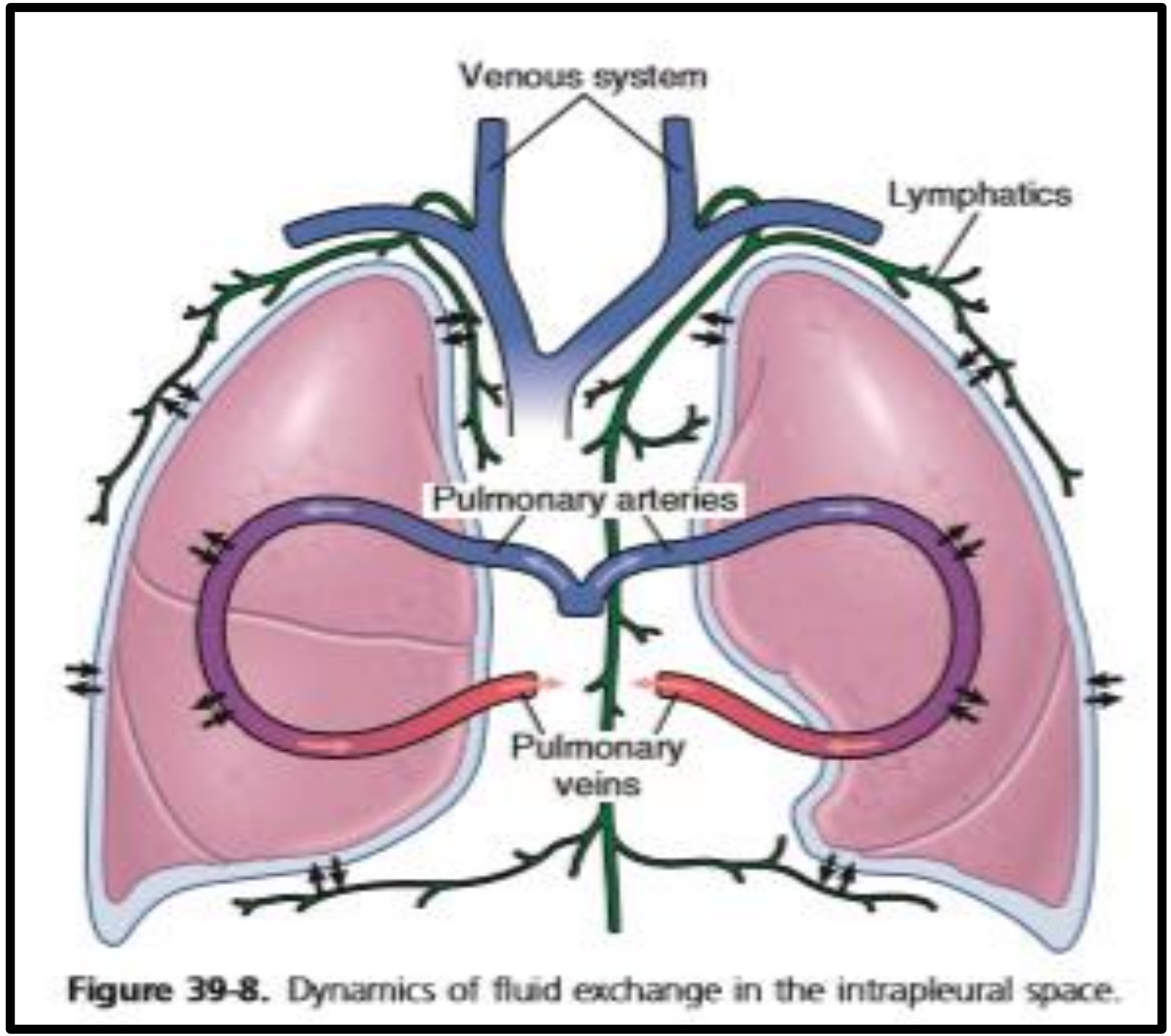


Figure 39-8. Dynamics of fluid exchange in the intrapleural space.

Fluid In Pleural Cavity

- Pleural space is a potential space with only a few ml of pleural fluid
- Excess is drained by lymphatics

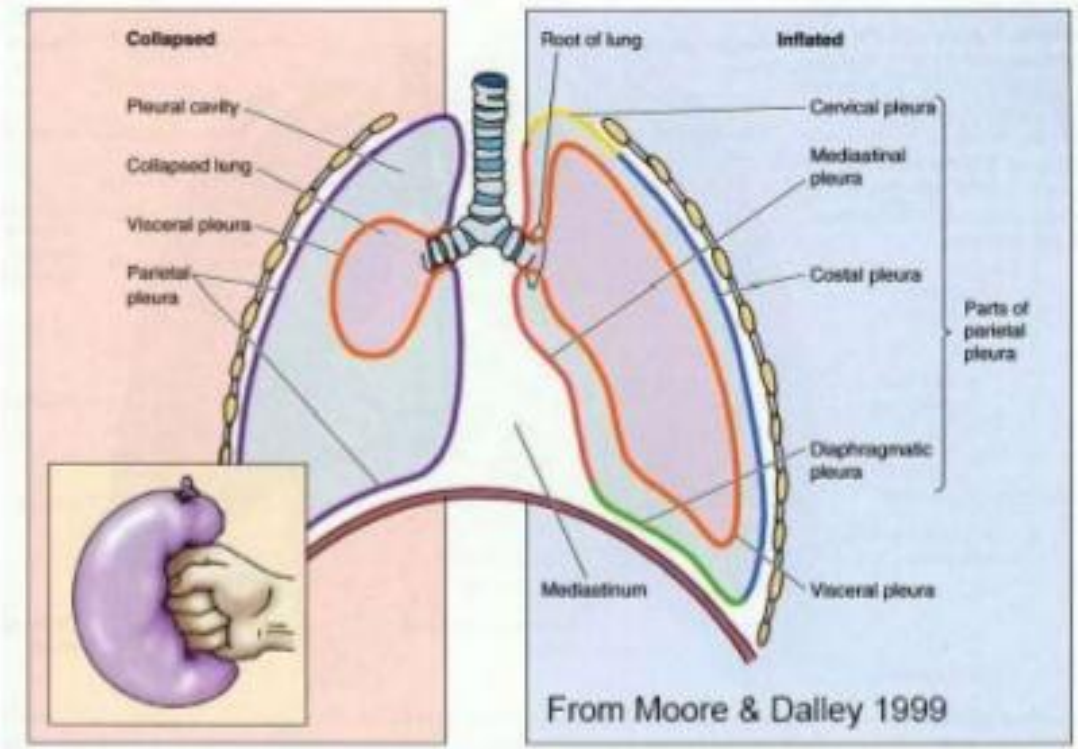
Negative Pressure In Pleural Fluid

Negative pressure in pleural space is due to pumping of fluid from the space by the lymphatics

the normal collapse tendency of the lungs is about −4 mm Hg

Actual pressure is usually about −7 mm Hg, which is a few millimeters of mercury more negative than the collapse pressure of the lungs keeping the lungs pulled out

Pleura and Pleural Cavity



Pleura

- Mesothelial lining of each hemithorax
- Derived from embryonic coelomic lining
- Visceral pleura: lung
- Parietal pleura: wall
  - Costal
  - Diaphragmatic
  - Mediastinal
  - Cervical

Pleural Cavity

- Potential space between visceral & parietal pleura
- Capillary layer of serous fluid produced by mesothelium
  - Reduces friction
  - Surface tension provides cohesion between lung and thoracic wall

Types of Pleural Effusion

Transudative	Exudative
◦ Congestive heart Failure ◦ Cirrhosis ◦ Nephrotic Syndrome	◦ Infectious Disease ◦ Pulmonary disease ◦ Radiation

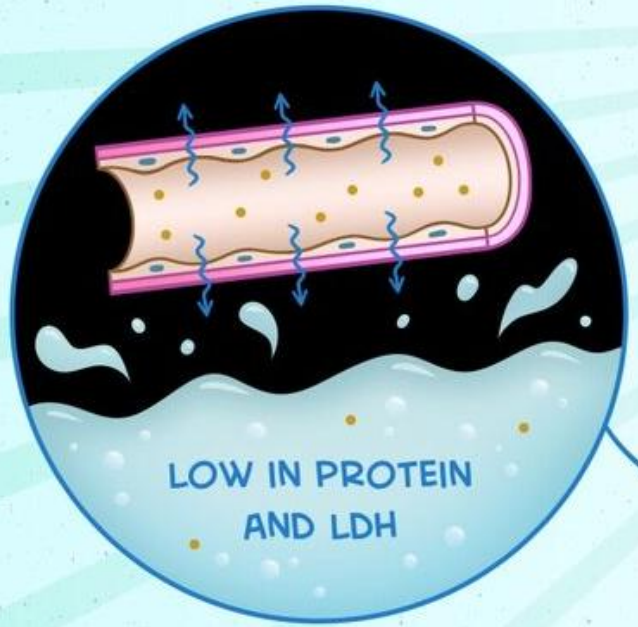
PLEURAL EFFUSION

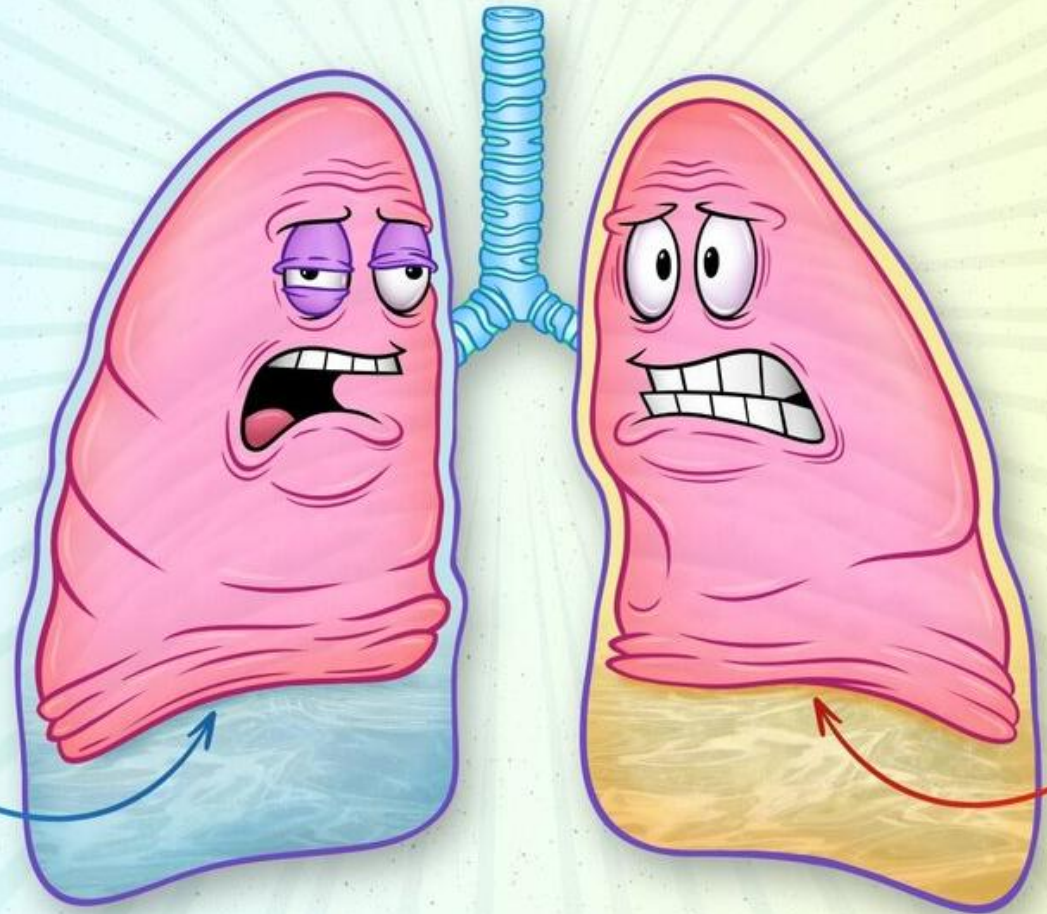
ACCUMULATION OF FLUID WITHIN THE PLEURAL SPACE

TRANSUDATIVE

OCCURS DUE TO INCREASED HYDROSTATIC PRESSURE OR LOW PLASMA ONCOTIC PRESSURE

E.G., CHF, CIRRHOSIS, NEPHROTIC SYNDROME, PE, HYPOALBUMINEMIA

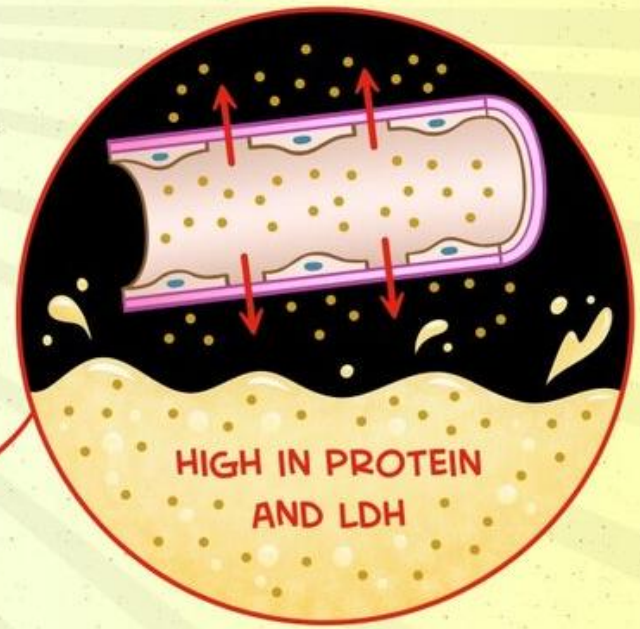




EXUDATIVE

OCCURS DUE TO INFLAMMATION AND INCREASED CAPILLARY PERMEABILITY

E.G., PNEUMONIA, CANCER, TB, VIRAL INFECTION, PE, AUTOIMMUNE



Causes of Pleural Effusion

- **Blockage of lymphatic** drainage from the pleural cavity
- **Cardiac Failure**
- **Marked decrease in colloid osmotic pressure**
- **Infection/ Inflammation** of pleural membranes → ↑ permeability of capillary membranes

References

- Guyton & Hall Physiology
- Ganong's Review of Medical Physiology
- Sherwood Physiology


Thank
you!