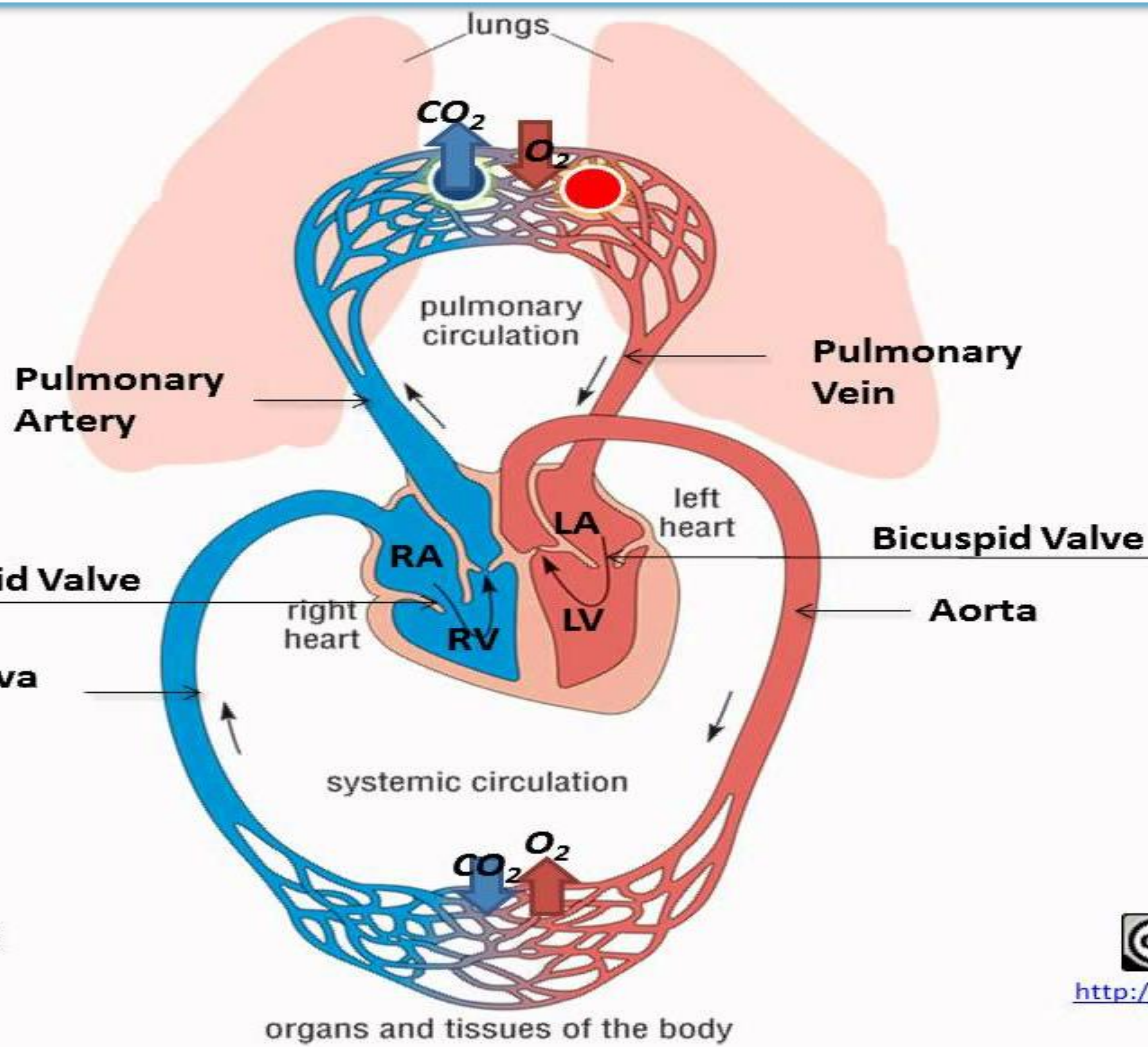
RS MODULE
PHYSIOLOGY (LECTURE 8)

PULMONARY CAPILLARY DYNAMICS

BY
Associate Professor
Dr. Fatma Farrag Ali

Pulmonary and Systemic Circulation

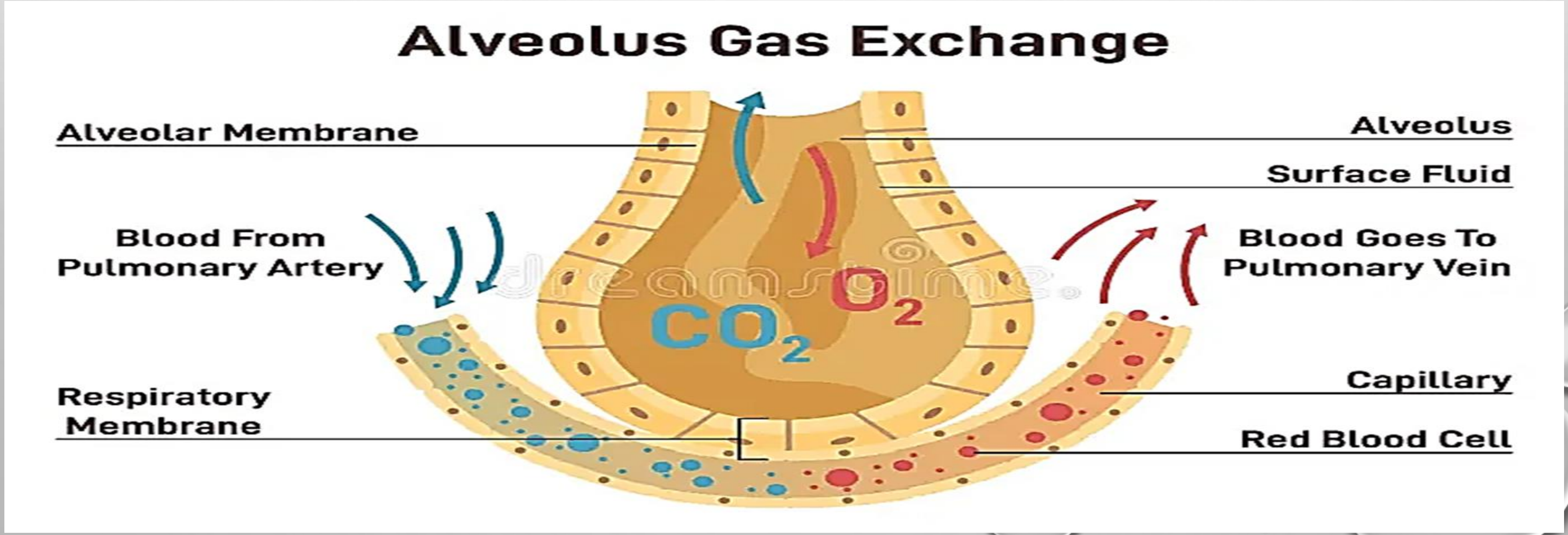


RA=Right atrium
RV=Right Ventricle
LA=Left Atrium
LV=Left Ventricle

http://

Characters of Pulmonary (i.e. Respiratory) Membrane

- **Very thin**, allowing for **efficient gas exchange.**
- **Large** total **surface area** of about **60 m^2** (in males).
- This **air-blood barrier** is composed of alveolar and capillary walls.



Pulmonary Circulation

Characteristics

The pulmonary vasculature has **unique** characteristics that set it apart from the rest of the vascular system.

These properties relate directly to the physiologic function of the respiratory system.

Pressures in the pulmonary circulation are **much lower than in** the systemic circulation.

- Normal pulmonary arterial pressure = **25** mmHg systolic / 8-**10** mmHg diastolic (average: 15 mmHg).
- Normal pulmonary capillary pressure is 7 mmHg (lowest capillary pressure in the body)

Resistance in pulmonary circulation is **much lower than in** the systemic circulation.

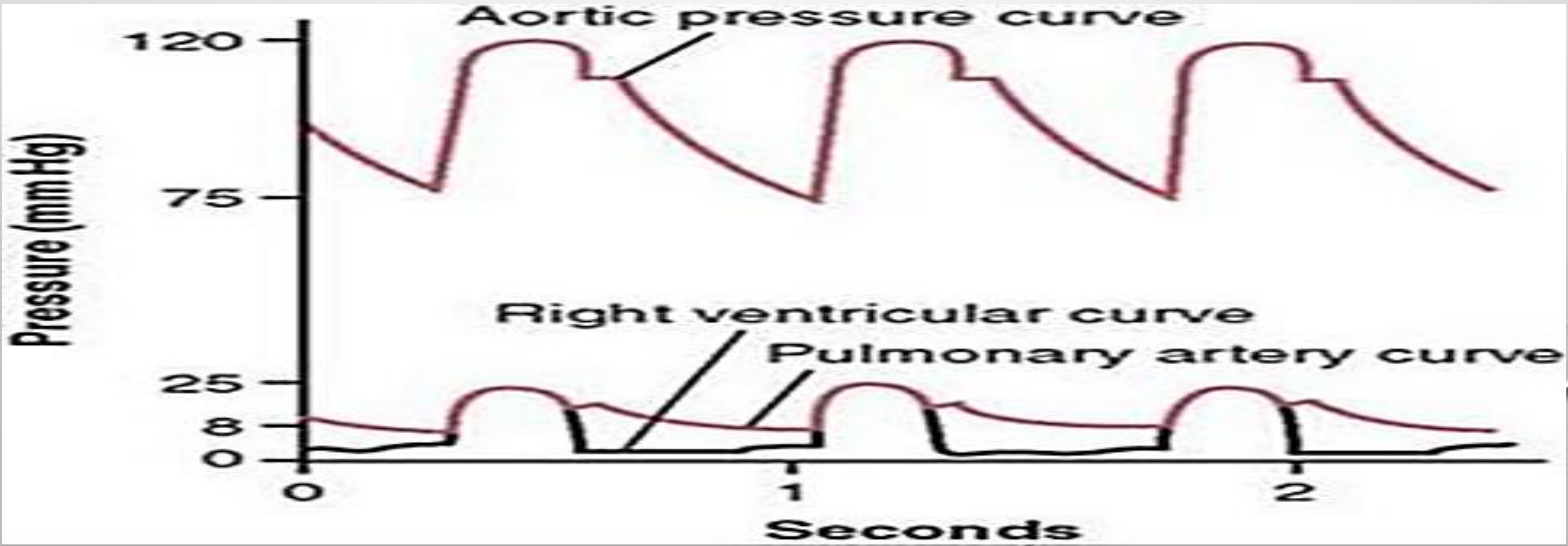
PULMONARY CAPILLARY DYNAMICS

Pressures in the Pulmonary System

Pressure Pulse Curve in the Right Ventricle and pulmonary artery.

Right ventricle pressures

These curves are contrasted with the much higher aortic pressure curve. The systolic pressure in the right ventricle of the normal human being averages about 25 mm Hg, and the diastolic pressure averages about 0 to 1 mm Hg, values that are only one fifth those for the left ventricle.



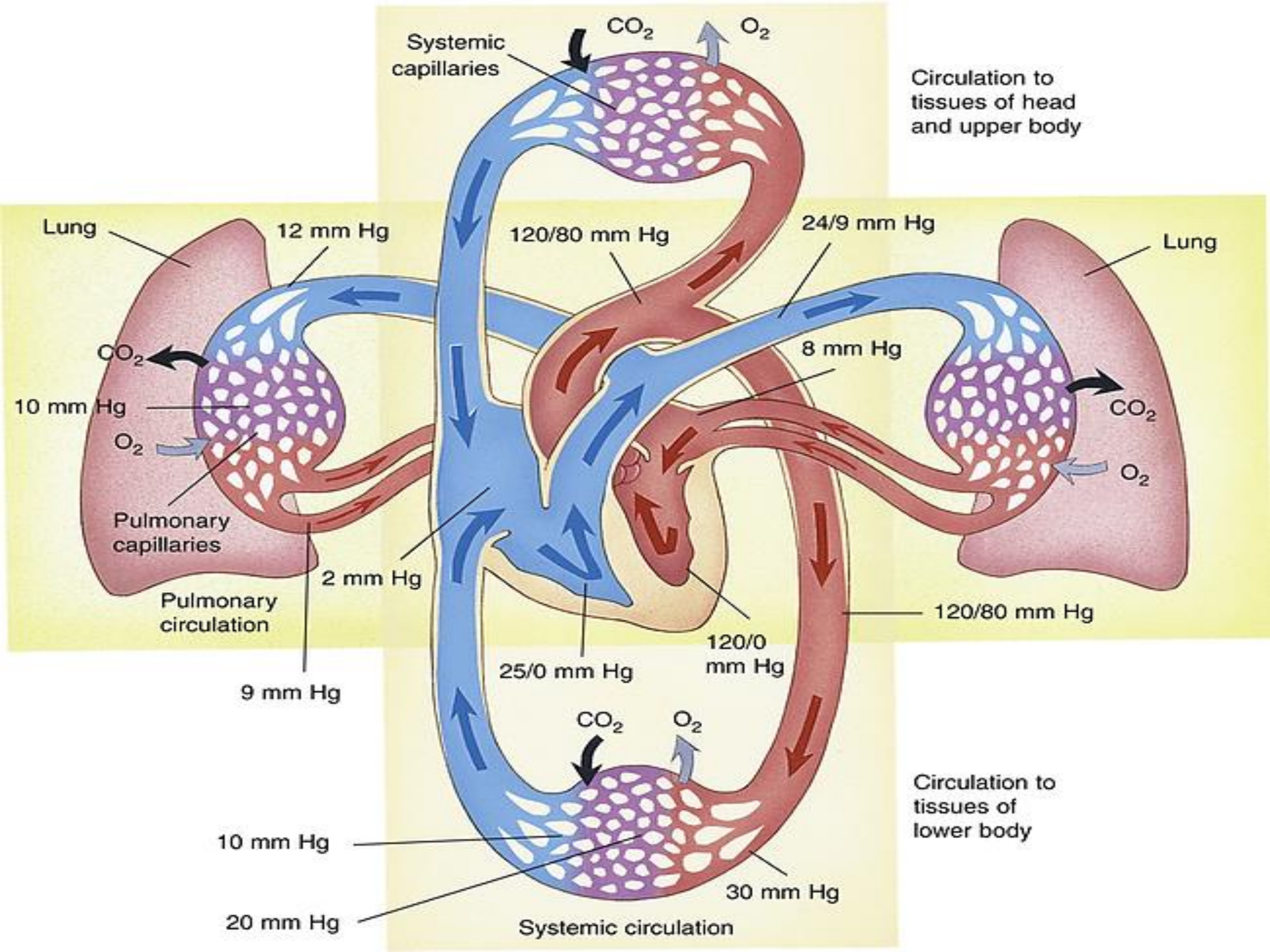
Pressures in the Pulmonary Artery.

During ***systole,*** the pressure in the pulmonary artery is essentially equal to the pressure in the right ventricle (25 mmHg). However, after the pulmonary valve closes at the end of systole, the ventricular pressure falls suddenly, whereas the pulmonary arterial pressure falls more slowly as blood flows through the capillaries of the lungs.

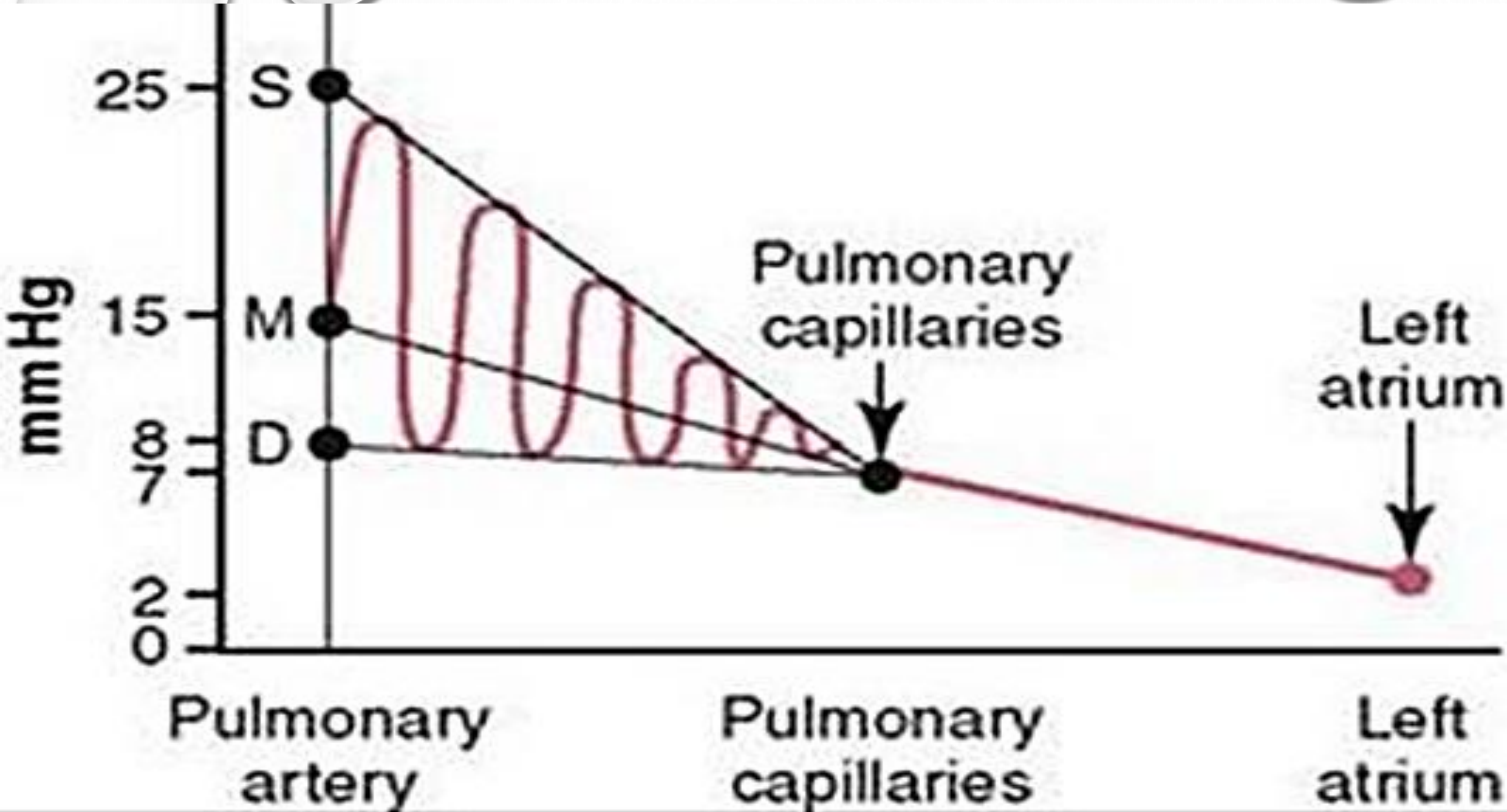
The **systolic** pulmonary arterial pressure averages about **25 mm Hg** in the normal human being, the **diastolic** pulmonary arterial pressure is about **8 mm Hg**, and the **mean** pulmonary arterial pressure is **15 mm Hg**.

Pulmonary Capillary Pressure.

Pulmonary capillary pressure is about 7 mm Hg.



Systemic capillaries
CO_2
O_2
Circulation to tissues of head and upper body
Lung
12 mm Hg
120/80 mm Hg
24/9 mm Hg
Lung
CO_2
8 mm Hg
10 mm Hg
O_2
CO_2
O_2
Pulmonary capillaries
2 mm Hg
Pulmonary circulation
120/80 mm Hg
120/0 mm Hg
25/0 mm Hg
9 mm Hg
CO_2
O_2
Circulation to tissues of lower body
10 mm Hg
30 mm Hg
20 mm Hg
Systemic circulation

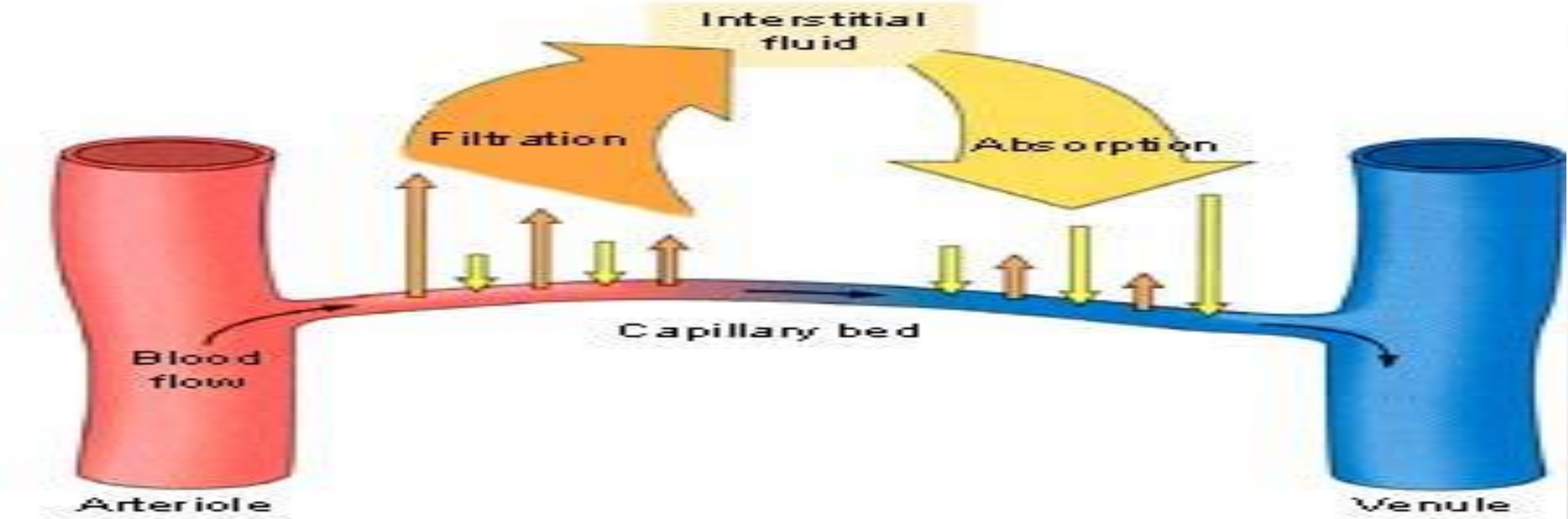


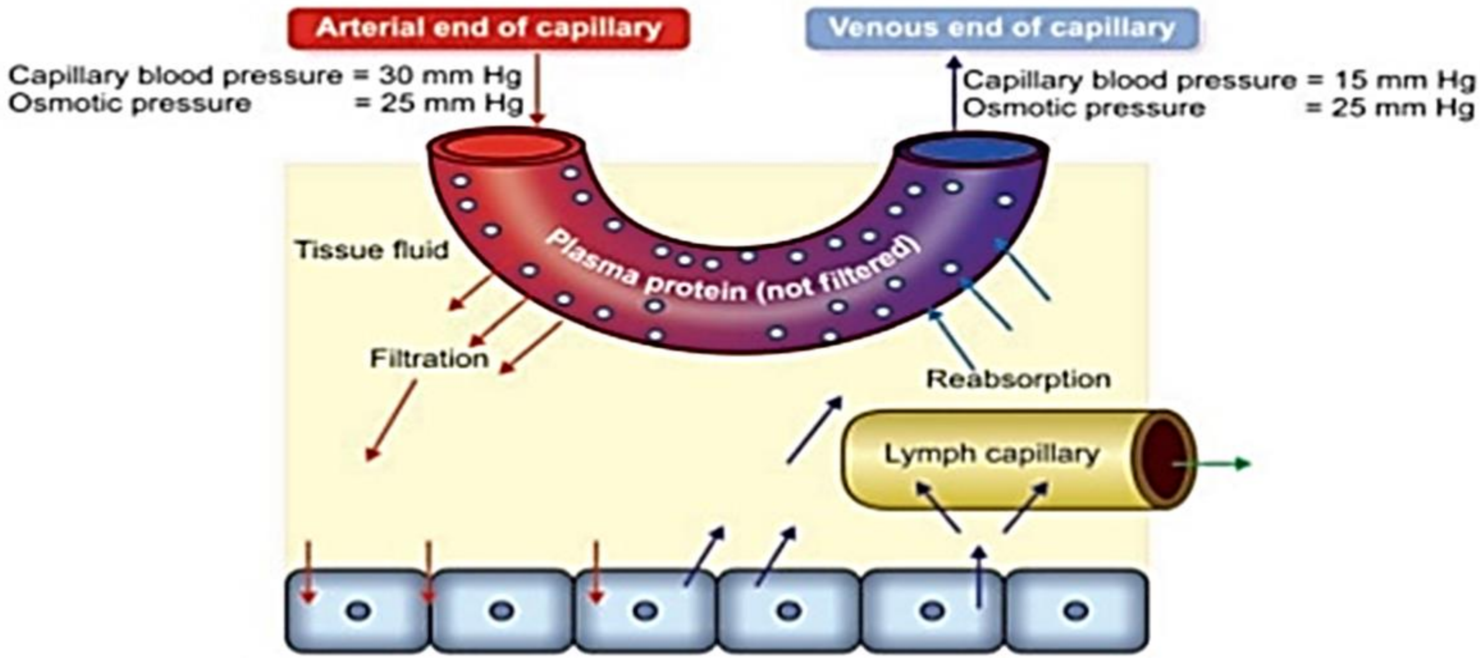
Pressures in the different vessels of the lungs. S, systolic ; D, diastolic; M, mean.

Length of Time Blood Stays in the Pulmonary Capillaries.

- when the cardiac output is normal, blood passes through the pulmonary capillaries in about **0.8 second**.

- When the cardiac output increases, this can shorten to as little as 0.3 second. The shortening would be much greater were it not for the fact that additional capillaries, which normally are collapsed, open up to accommodate the increased blood flow. Thus, in only a fraction of a second, blood passing through the alveolar capillaries becomes oxygenated and loses its excess carbon dioxide.


Interstitial fluid
Filtration
Absorption
Blood flow
Capillary bed
Arteriole
Venule


Arterial end of capillary
Venous end of capillary
Capillary blood pressure = 30 mm Hg
Osmotic pressure = 25 mm Hg
Capillary blood pressure = 15 mm Hg
Osmotic pressure = 25 mm Hg
Tissue fluid
Plasma protein (not filtered)
Filtration
Reabsorption
Lymph capillary

Determinants of Net Fluid Movement across Capillaries

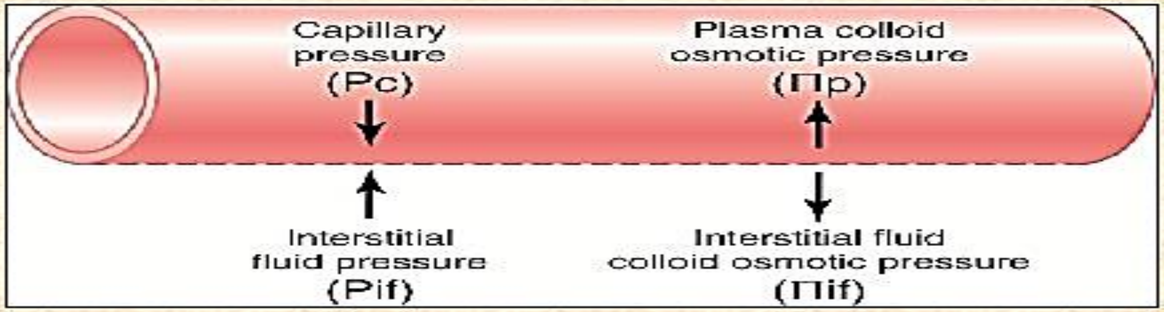


Figure 16-5; Guyton and Hall

- *Plasma colloid osmotic pressure* (π c)- opposes filtration causing osmosis of water inward through the membrane
- *Interstitial fluid colloid pressure* (π if) promotes filtration by causing osmosis of fluid outward through the membrane

$$NP = Pc - \pi c - Pif + \pi if$$

Capillary Exchange of Fluid in the Lungs, and Pulmonary Interstitial Fluid Dynamics

The dynamics of fluid exchange across the lung capillary membranes are *qualitatively* the same as for peripheral tissues. However, *quantitatively,* there are important differences, as follows:

1. **The pulmonary capillary pressure is low, about 7 mm Hg**, in comparison with a considerably higher functional **capillary pressure in the peripheral tissues**.
2. The pulmonary capillaries are relatively leaky to protein molecules, so that the **colloid osmotic pressure of the pulmonary interstitial fluid is about 14 mm Hg**, in comparison with less than half this value in the peripheral tissues.

Capillary Exchange of Fluid in the Lungs, and Pulmonary Interstitial Fluid Dynamics

3. The interstitial fluid pressure in the lung is slightly more negative than that in the peripheral tissue. (This has been measured in two ways: by a micropipette inserted into the pulmonary interstitium, giving a value of about –5 mm Hg, and by measuring the absorption pressure of fluid from the alveoli, giving a value of about **–8 mm Hg**.)

4. The **plasma colloid osmotic pressure of pulmonary capillaries** is about **28 mmHg**.

Forces tending to cause movement of fluid outward from the pulmonary capillaries and into the pulmonary interstitium (**filtering forces**):

	mm Hg
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 pulmonary capillaries (**absorbing forces**):

Plasma colloid osmotic pressure of pulmonary capillaries = 28 mmHg

TOTAL INWARD FORCE 28

Thus, the normal outward forces are slightly greater than the inward forces, providing **a net filtration pressure** at the pulmonary capillary membrane; this can be calculated as follows:

	mm Hg
Total outward force	+29
Total inward force	−28
Net Filtration Pressure	**+1**

This filtration pressure causes a slight continual flow of fluid from the pulmonary capillaries into the interstitial spaces, and except for a small amount that evaporates in the alveoli, this **fluid is pumped back to the circulation through the pulmonary lymphatic system.**

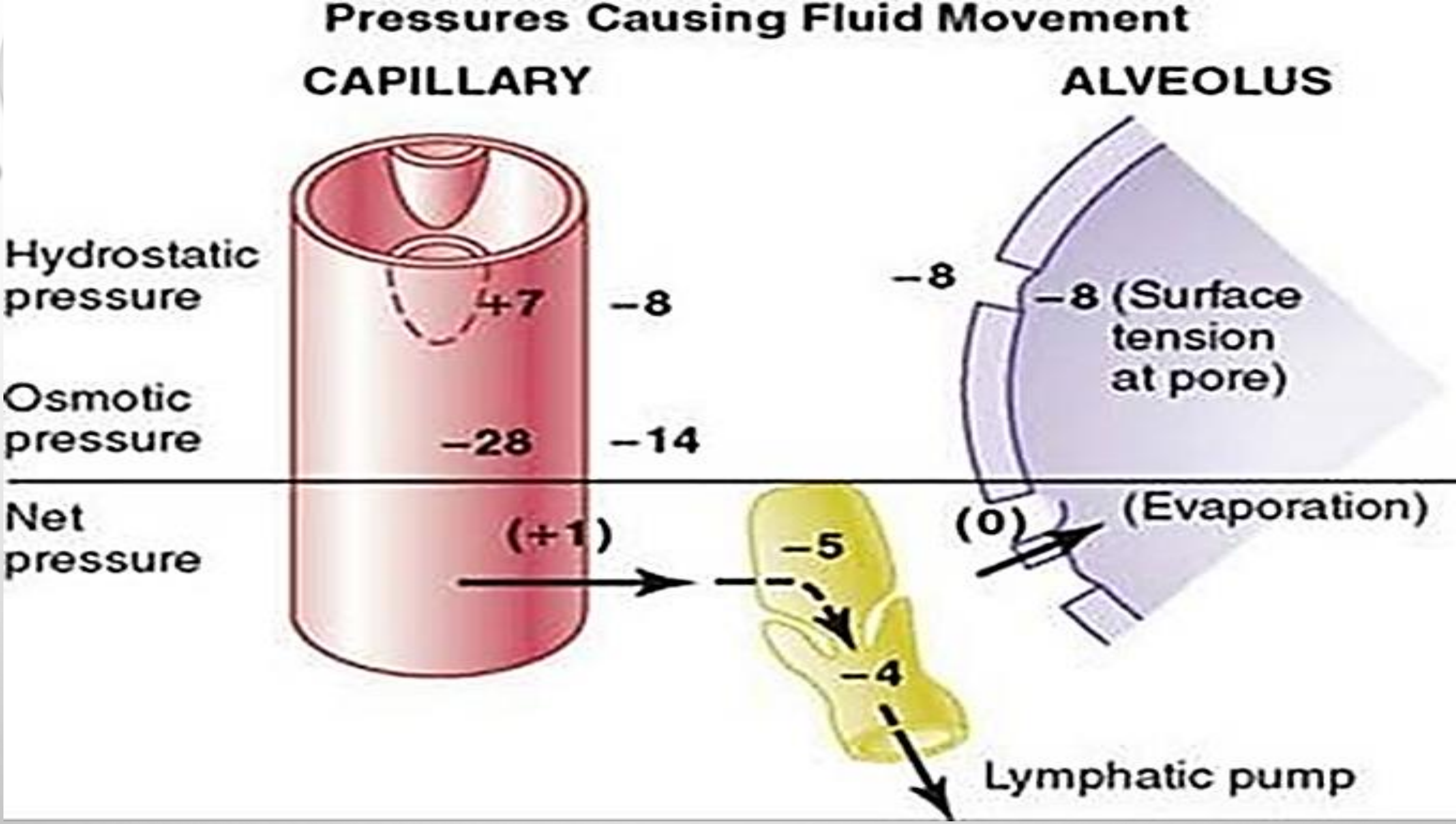


Figure. Hydrostatic and osmotic forces at the capillary *(left)* and alveolar membrane *(right)* of the lungs. Also shown is the tip end of a lymphatic vessel *(center)* that pumps fluid from the pulmonary interstitial spaces.

Negative Pulmonary Interstitial Pressure and the Mechanism for Keeping the Alveoli "Dry."

why the alveoli do not normally fill with fluid?

- ✓ The **pulmonary capillaries** and the **pulmonary lymphatic system** normally maintain a slight negative pressure in the interstitial spaces.
- ✓ It is clear that whenever extra fluid appears in the alveoli, it will simply be sucked mechanically into the lung interstitium through the small openings between the alveolar epithelial cells.
- ✓ Then, the excess fluid is either carried away through the pulmonary lymphatics or absorbed into the pulmonary capillaries.
- ✓ Thus, under normal conditions, the alveoli are kept "dry," except for a small amount of fluid that leaks from the epithelium onto the lining surfaces of the alveoli to keep them moist.

Pulmonary Edema

- **The most common causes of pulmonary edema are:**

1. Left-sided heart failure or mitral valve disease, with consequent great increases in pulmonary venous pressure and pulmonary capillary pressure and flooding of the interstitial spaces and alveoli.

2. Damage to the pulmonary blood capillary membranes caused by infections such as pneumonia or by breathing noxious substances such as chlorine gas or sulfur dioxide gas. Each of these causes rapid leakage of both plasma proteins and fluid out of the capillaries and into both the lung interstitial spaces and the alveoli.

"Pulmonary Edema Safety Factor."

Low pulmonary capillary pressure

in the human being, whose normal plasma colloid osmotic pressure is 28 mm Hg, the pulmonary capillary pressure must **rise** from the normal level of **7 mm Hg** to more than **28 mm Hg** to cause pulmonary edema, giving an **acute safety factor against pulmonary edema of 21 mm Hg**.

Rapidity of Death in Acute Pulmonary Edema.

When **the pulmonary capillary pressure rises** even slightly **above the safety factor level**→, **lethal pulmonary edema can occur within hours,** or **even within 20 to 30 minutes** if the **capillary pressure rises 25 to 30 mm Hg above the safety factor level.** Thus, in **acute left-sided heart failure,** in which the pulmonary capillary pressure occasionally does rise to 50 mm Hg, **death frequently occurs afterwards in less than 30 minutes from acute pulmonary edema.**

Safety Factor in Chronic Conditions.

When the **pulmonary capillary pressure remains elevated chronically** (for at least 2 weeks), **the lungs become** even **more resistant** to **pulmonary edema** because:

- **The lymph vessels expand greatly**, increasing their capability of **carrying fluid away from the interstitial spaces** perhaps as much as **10-fold**. Therefore, in patients with **chronic mitral stenosis**, pulmonary capillary pressures of 40 to 45 mm Hg have been measured without the development of lethal pulmonary edema.


THANK YOU