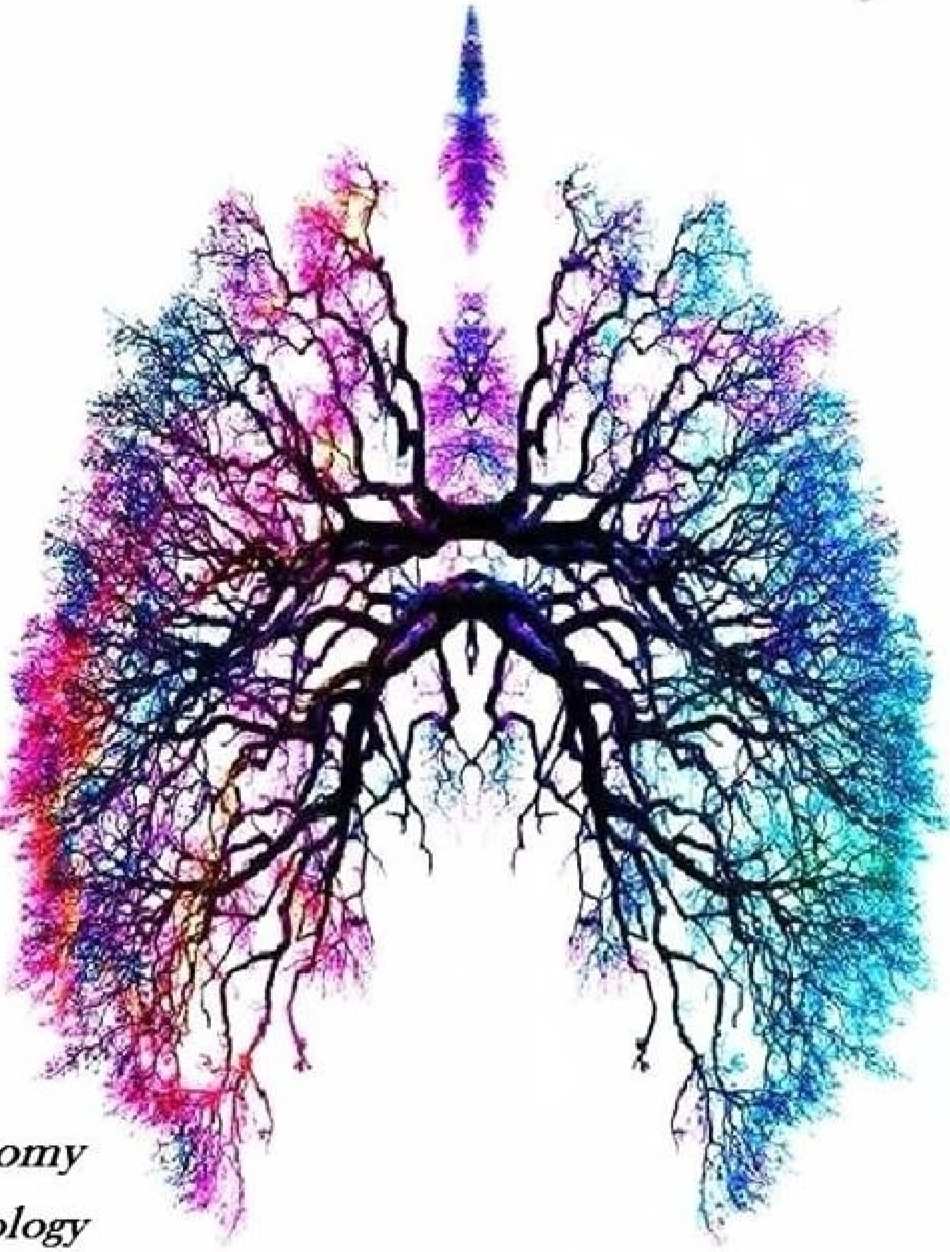
RESPIRATORY SYSTEM

Cover by: Aseel Khatib



- ○ Anatomy
- ○ Pathology
- ● Physiology
- ○ Pharmacology
- ○ Microbiology
- ○ PBL

Dr Name: Dr. Yanal Shafagoj
Lecture # 6

Sheet ☐
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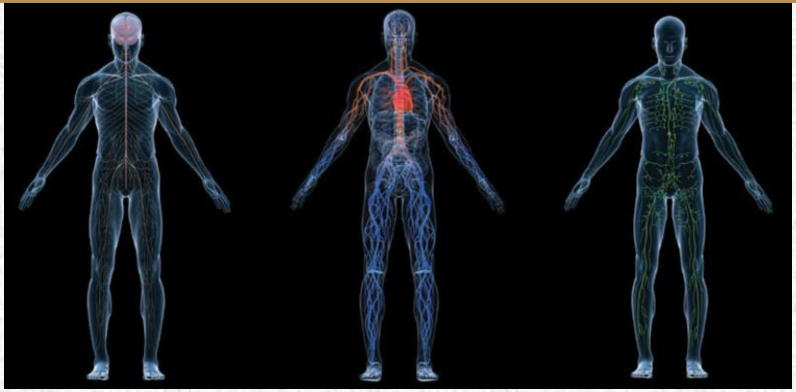
UNIT VII

GUYTON AND HALL *Textbook of*

Medical Physiology

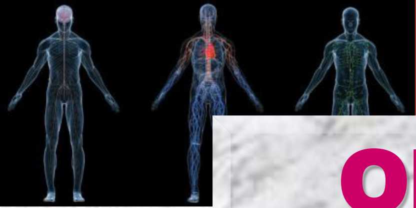
TWELFTH EDITION



Chapter 38:

Pulmonary Circulation, Pulmonary Edema, Pleural Fluid

Slides by Robert L. Hester, PhD



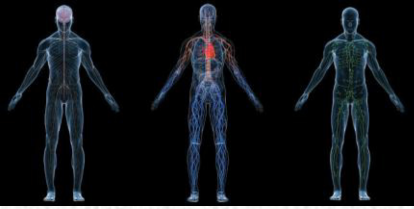
Objectives

- Describe the pulmonary circulation
- Describe the pulmonary blood pressures
- List the factors that affect diffusion
- Explain the factors that affect O_2 and CO_2 diffusion
- Composition of air in the respiratory pathway
- Describe the lung zones of perfusion
- Explain how the lungs accommodate extra flow
- Describe the Ventilation/Perfusion ratio

Two circulations in the respiratory system

- **Bronchial Circulation**
  - Arises from the aorta.
  - Part of systemic circulation (oxygenated).
  - Receives about 1-2% of left ventricular output.
  - Supplies the supporting tissues of the lungs, including the connective tissue, septa, and bronchi.
  - It empties into the pulmonary veins and eventually into left atrium
  - The blood flow into left side is greater by 2%

- **Pulmonary Circulation**



PULMONARY BLOOD FLOW

- Pulmonary Pressures
  - Pulmonary artery pressure
    - systolic 25 mmHg
    - diastolic 8 mmHg
    - mean 15 mmHg
    - capillary 7 mmHg
- Left Atrial and Pulmonary Venous Pressures = 2 (1-5) mm Hg (estimated)
- *Pulmonary wedge pressure* = 5 mm Hg (usually its 2 to 3 mm Hg greater than the left atrial pressure)

Reasons Why Pressures Are Different in Pulmonary and Systemic Circulations

- Gravity and Distance:
  - Distance above or below the heart adds to, or subtracts from, **both** arterial and venous pressure
  - Distance between Apex and Base affected by gravity

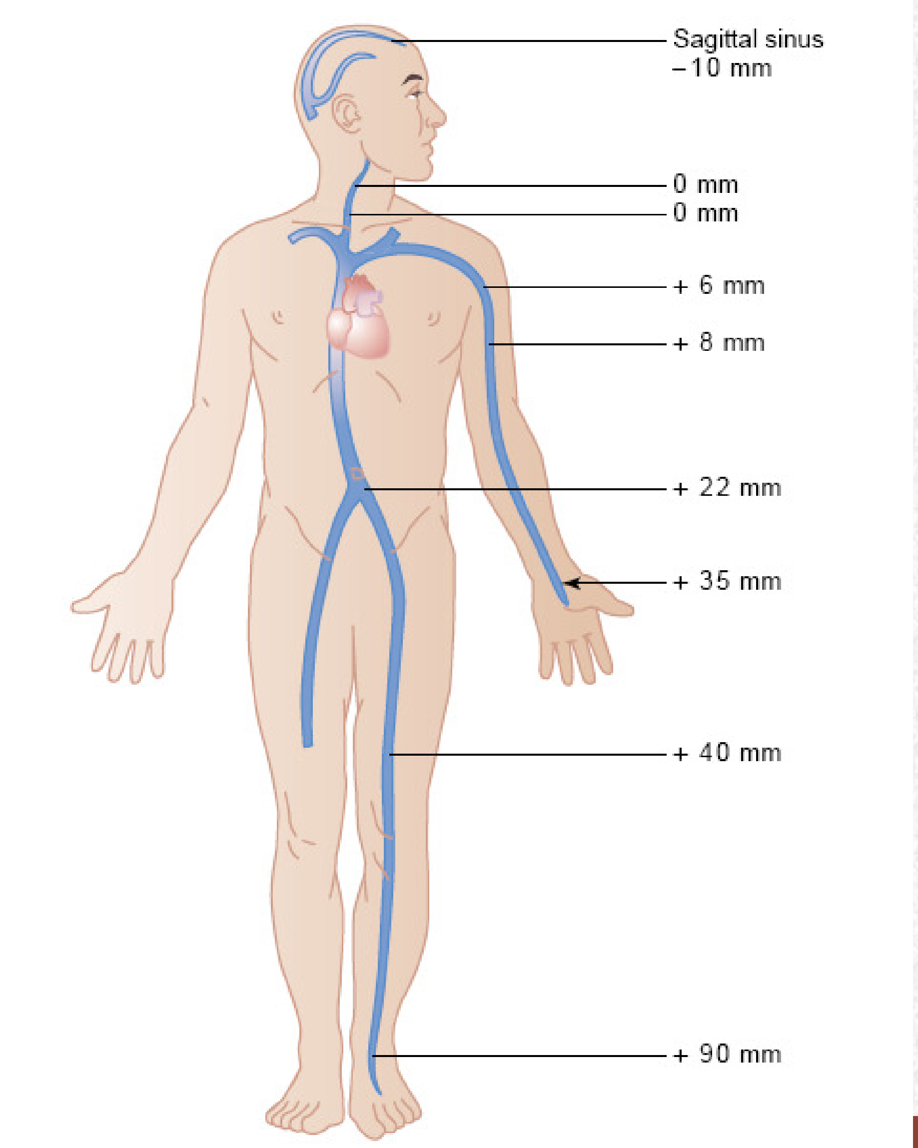
Systemic

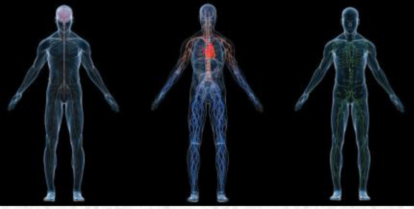
Aorta	100 mmHg
Head	50 mmHg
Feet	180 mmHg

Pulmonary

Mean PA	15 mmHg
Apex	2 mmHg
Base	25 mmHg

Effect of hydrostatic pressure on venous pressure in the standing position

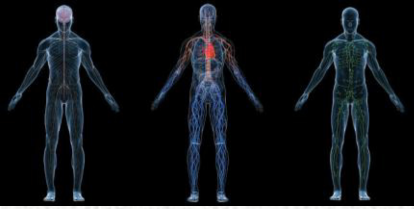




The composition of alveolar air reflects the harmony by which respiratory & cardiovascular systems are workin:(V/Q).

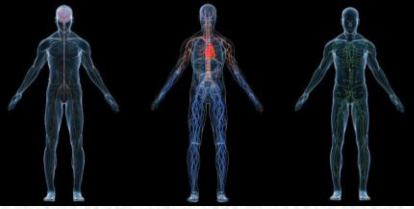
Pressure in the different areas of the lungs

- At the top, 15 mm Hg less than the pulmonary arterial pressure at the level of the heart
- At the bottom, 8 mm Hg greater than the pulmonary arterial pressure at the level of the heart.
- 23 mm Hg pressure difference between the top and the bottom of the lung
- These differences have effects on blood flow through the different areas of the lungs.



PULMONARY RESISTANCE TO FLOW

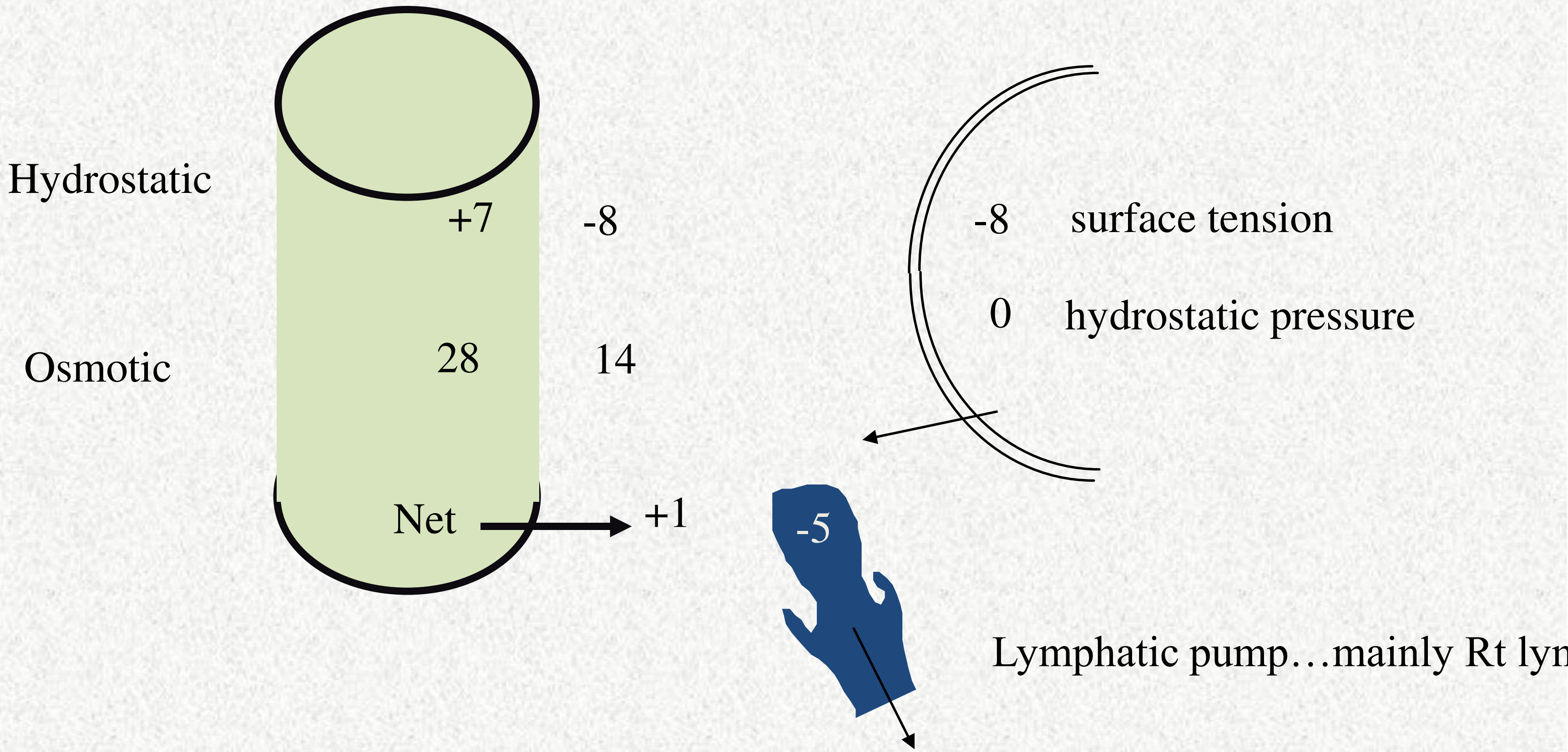
- Pressure drop of 12 mmHg
- Flow of 5 l/min
- Resistance 1/7 systemic circulation



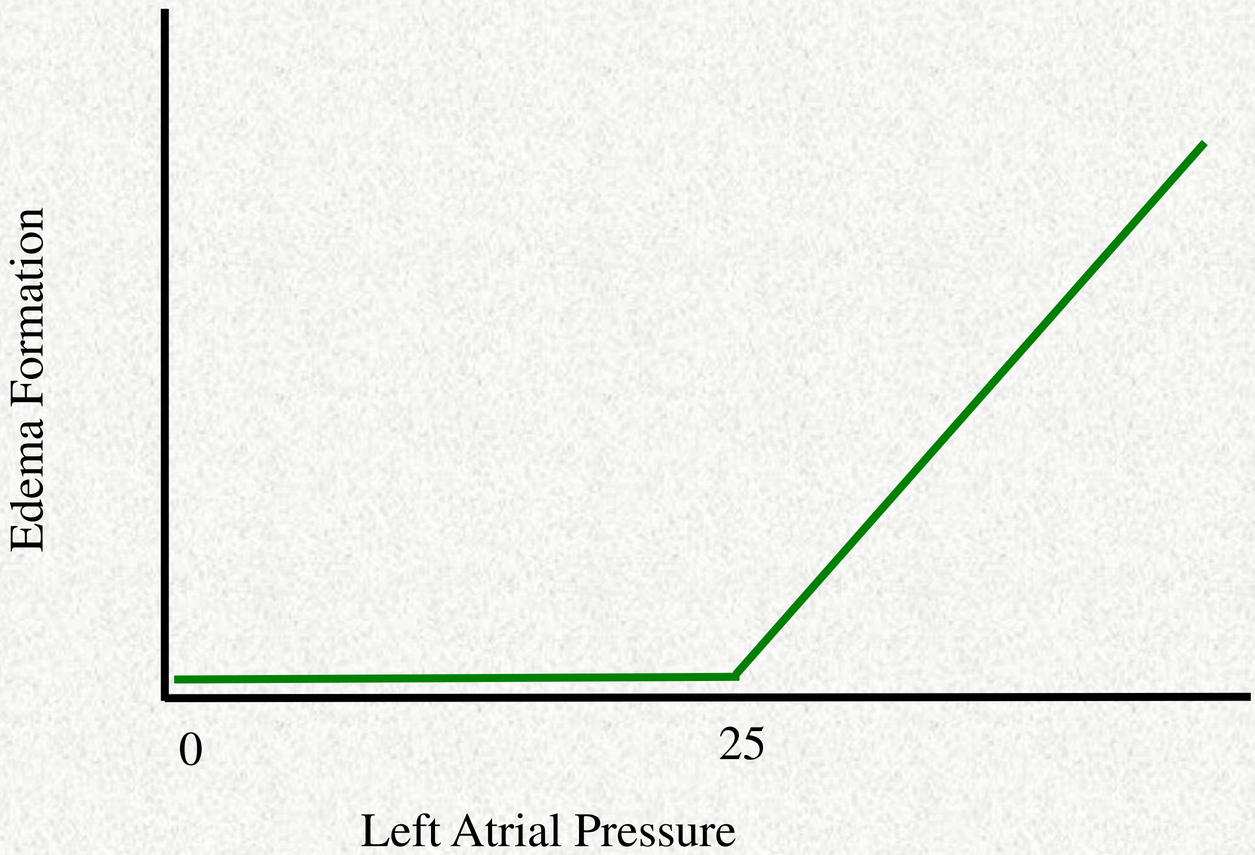
Pulmonary Capillary Dynamics

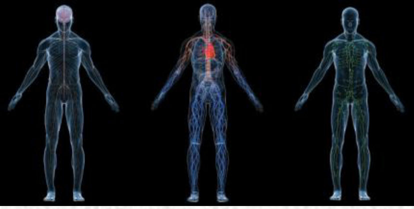
- **Outward Forces**
  - Pulmonary capillary pressure 7 mmHg
  - Interstitial colloid osmotic pressure 14 mmHg
  - Negative interstitial pressure 8 mmHg
  - **Total 29 mmHg**
- **Inward Forces**
  - Plasma osmotic pressure 28 mmHg
- **Net filtration pressure 1 mmHg**
- **Lymphatic vessels take care of this extra filtrate**
- There is plenty lymphatics which empty in the right lymphatic duct to prevent the occurrence of pulmonary edema. The left apex empties in the thoracic duct.

Pulmonary Capillary Dynamics



Heart Failure and Pulmonary Edema





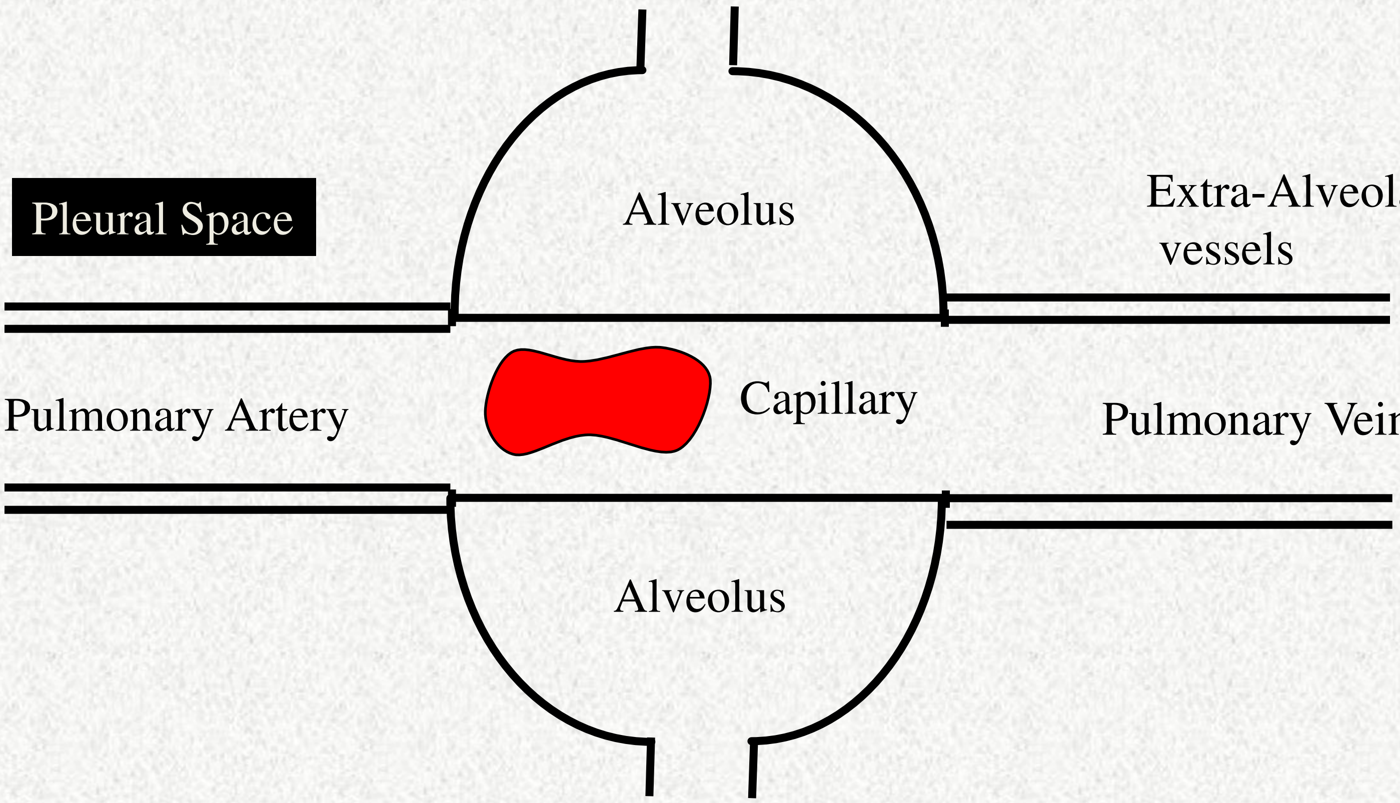
Pulmonary Edema

- Causes of pulmonary edema
  - – left heart failure
  - – damage to pulmonary membrane:
    infection or noxious gas such as , chlorine, sulfur dioxide
- Safety factor
  - – negative interstitial pressure
  - – lymphatic pumping
  - – decreased interstitial osmotic pressure

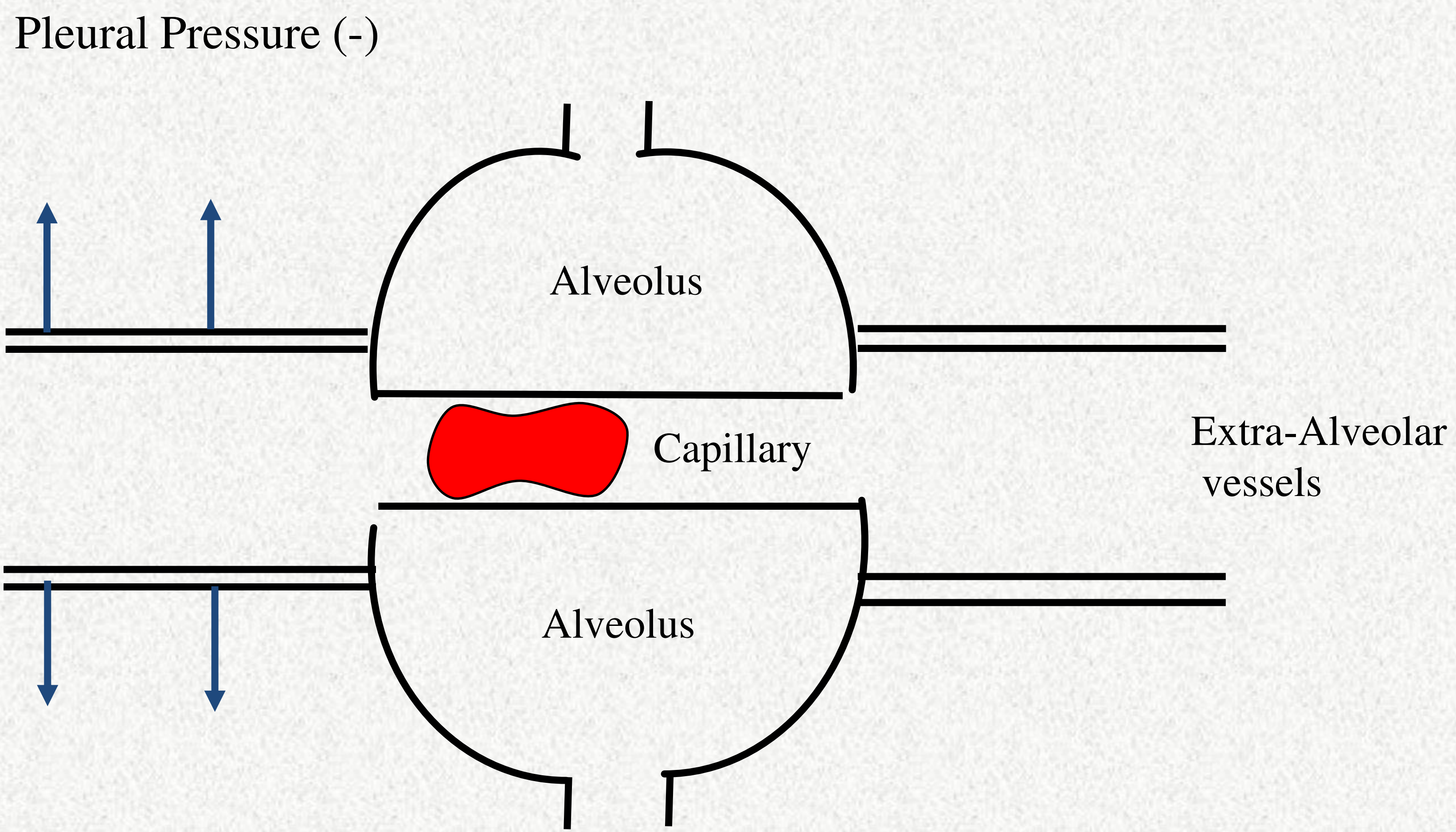
Three Zones of Pulmonary Blood Flow

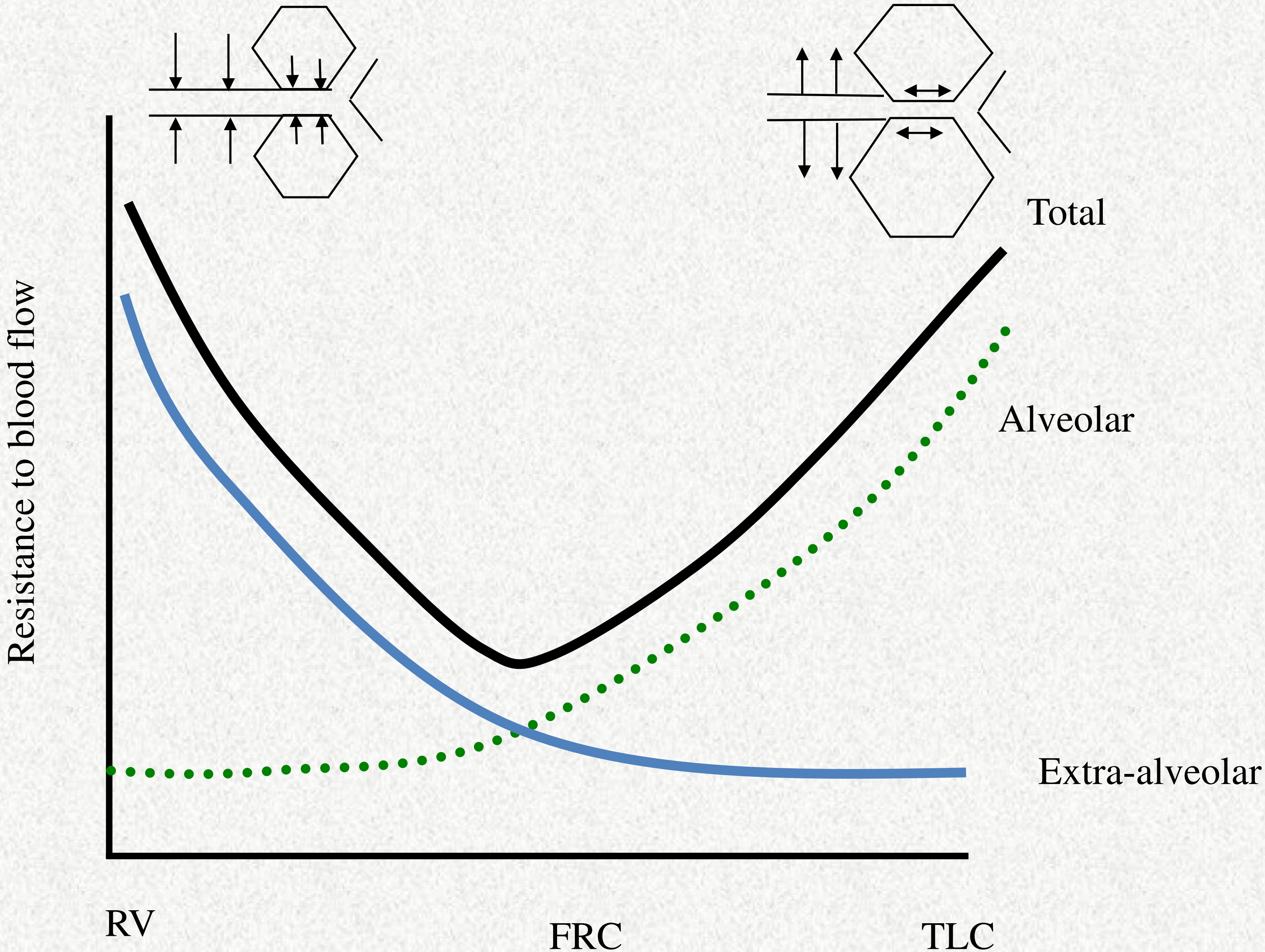
- The alveolar capillaries are distended by the blood pressure inside them and compressed by the alveolar air pressure on their outsides.
- If the alveolar air pressure (Palv) becomes greater than the pulmonary capillary blood pressure (Ppc), the capillaries will close and there is no blood flow.
- There are three possible *patterns* of blood flow (zones of pulmonary blood flow) under different normal and pathological lung conditions.

ALVEOLAR and "EXTRA-ALVEOLAR" VESSELS



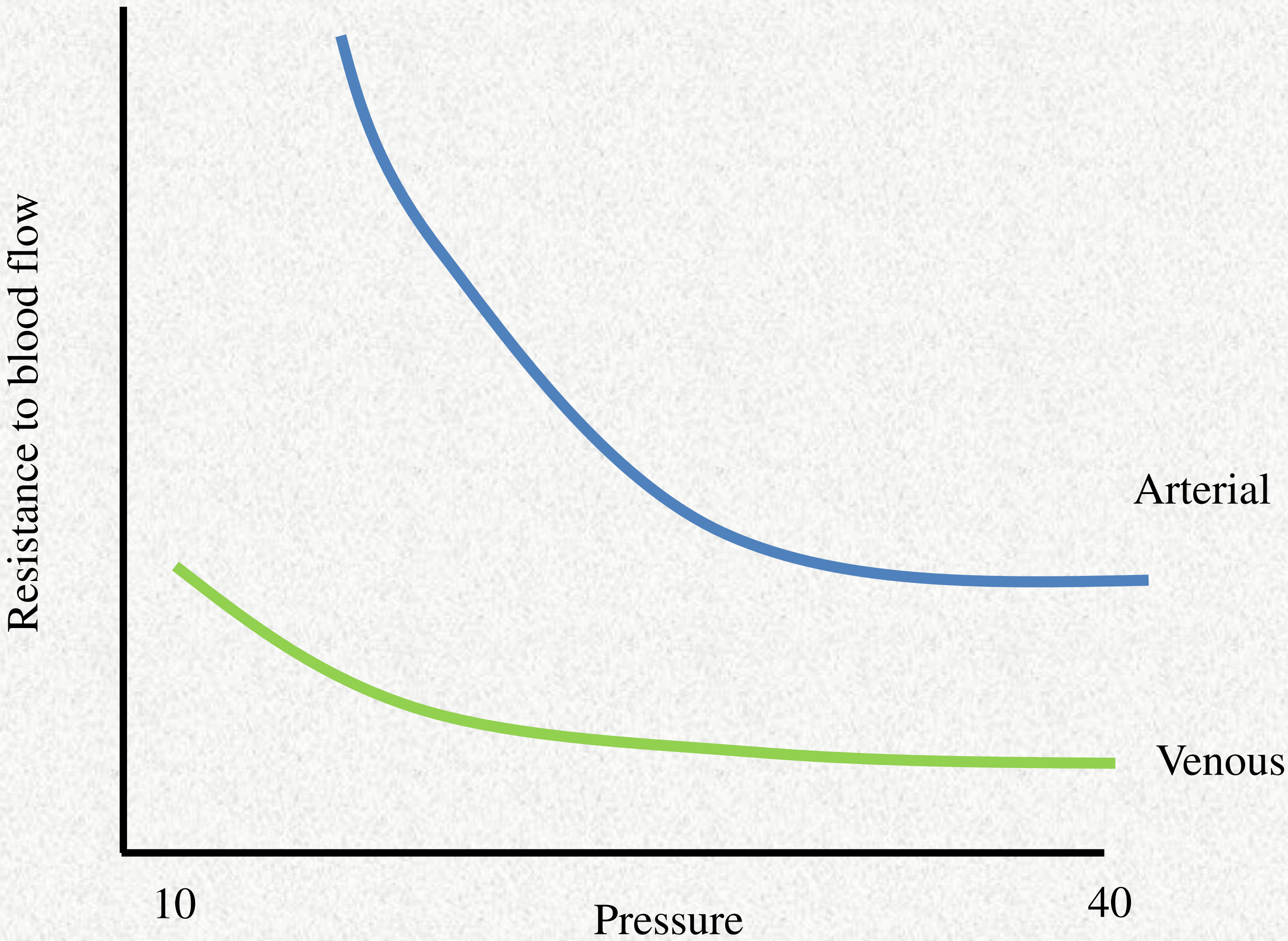
ALVEOLAR and “EXTRA-ALVEOLAR” VESSELS



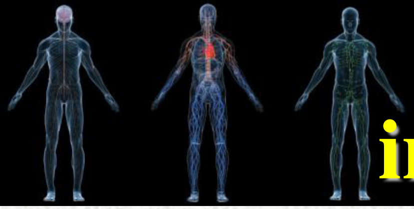


Resistance to blood flow
Total
Alveolar
Extra-alveolar
RV
FRC
TLC

Effect of Pressures on Blood Flow Resistance



Increasing pressure decreases resistance



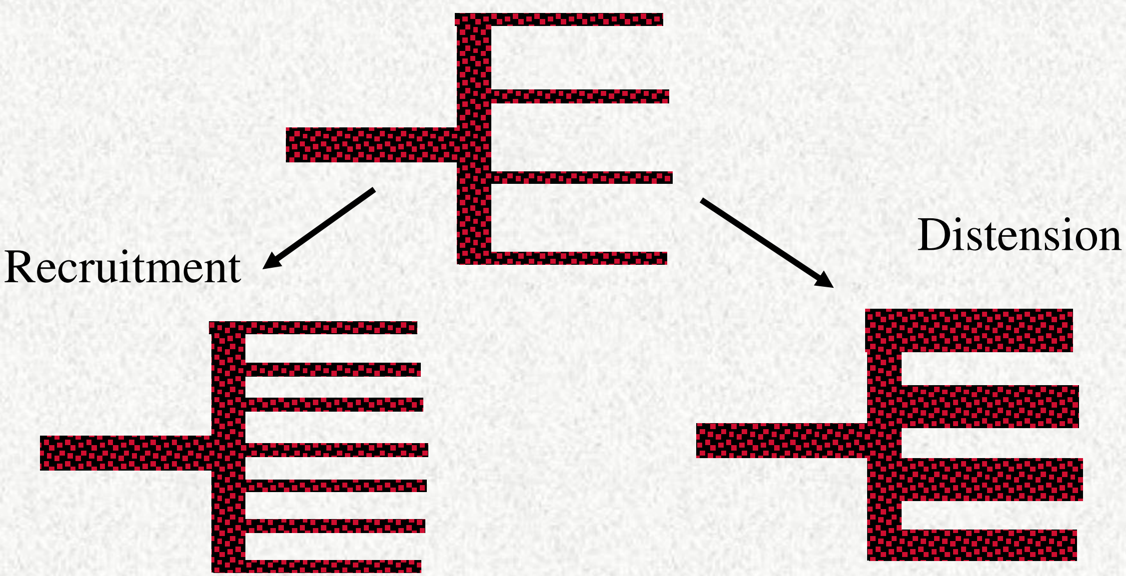
Recruitment and Distension increases Pulmonary blood flow

Pulmonary blood vessels are much more <u>compliant</u> than systemic blood vessels. Also the system has a remarkable ability to promote a <u>decrease in resistance</u> as the blood pressure rises.

***This achieved by two mechanisms*:**

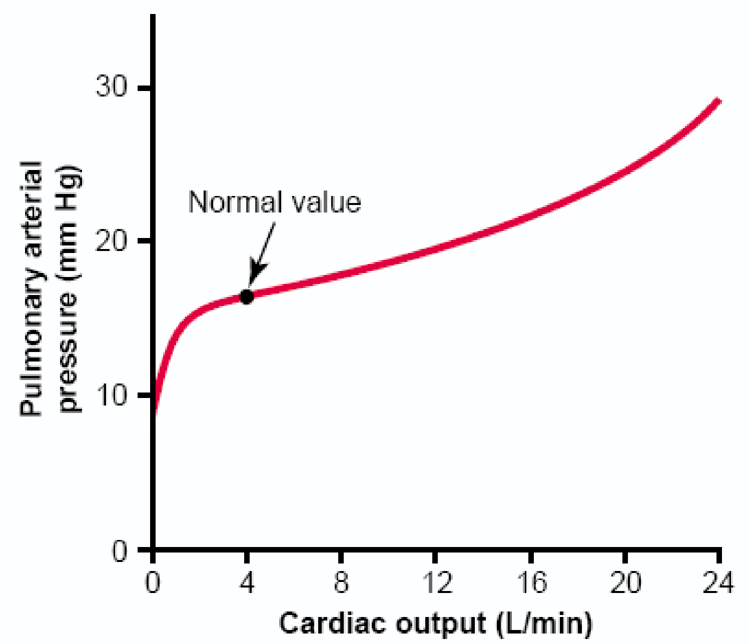
Recruitment: by increasing the number of open capillaries

Distension: by distending all the capillaries and increasing the rate of flow



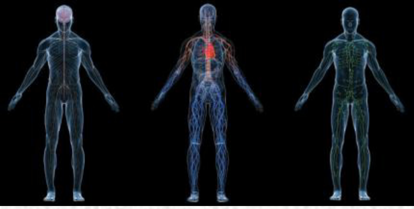
Effect of Increased Cardiac Output on Pulmonary Blood Flow and Pulmonary Arterial Pressure During Heavy Exercise

Recruitment and Distension decrease pulmonary vascular resistance, so that the pulmonary arterial pressure rises very little even during maximum exercise.



PULMONARY BLOOD FLOW

- Blood Volume
  - Approximately 450 ml
  - 190 ml in the arterial part
  - 190 ml in the venous part
  - 70 ml inside the capillaries
  - Can shift to systemic circulation



MEASUREMENT OF PULMONARY BLOOD FLOW

Fick Principle for cardiac output estimation

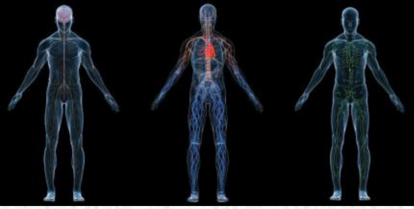
$$V_{O_2} = Q(Ca_{O_2} - Cv_{O_2})$$

V_{O_2} = Oxygen Consumption

Ca_{O_2} = Arterial Content

Q = Blood flow

Cv_{O_2} = Venous Content



MEASUREMENT OF PULMONARY BLOOD FLOW

$V_{O_2} = Q(Ca_{O_2} - Cv_{O_2})$

Ca_{O_2} = 20 ml O_2/100 ml blood

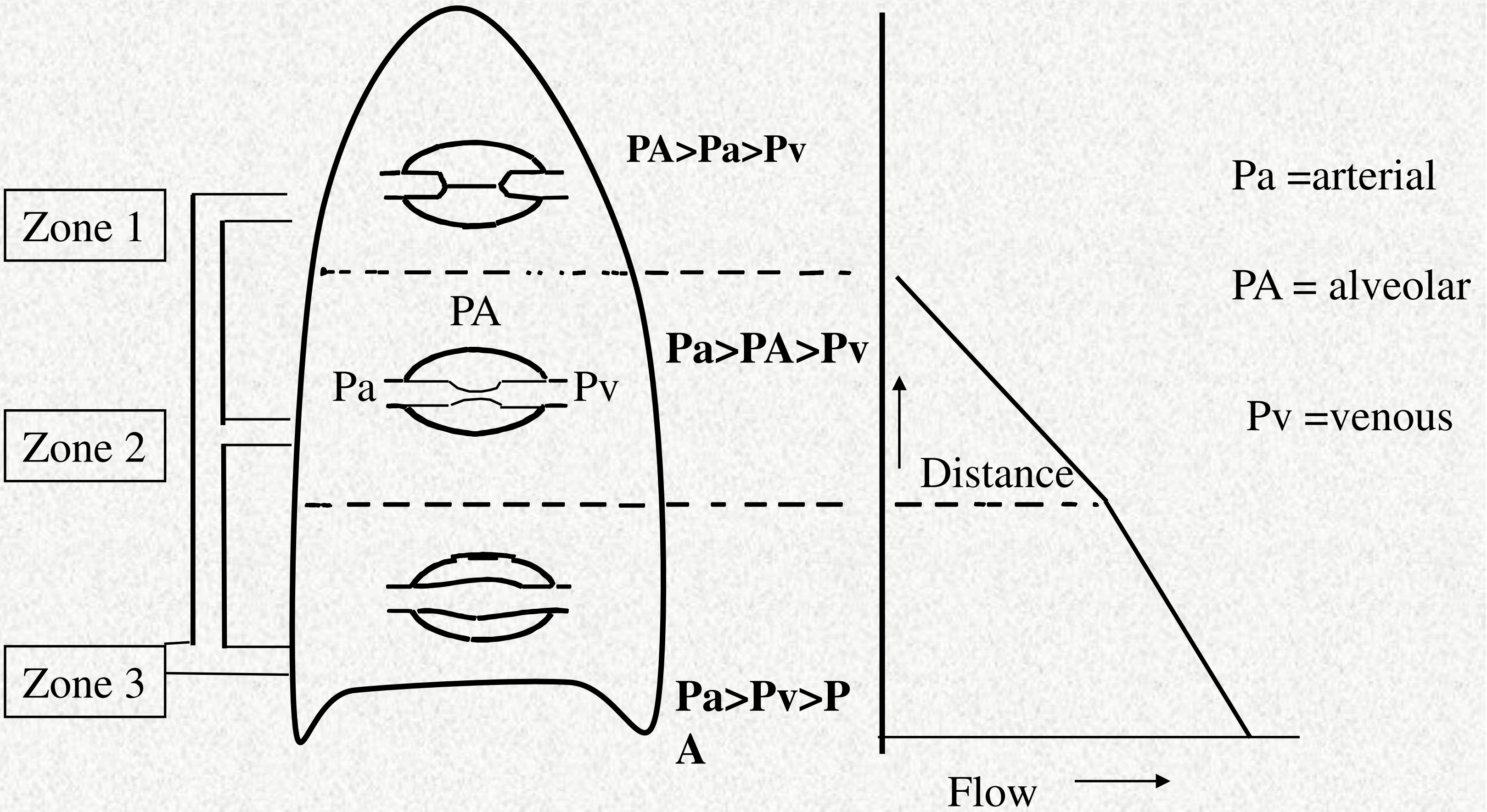
V_{O_2} = 250 ml/min

Cv_{O_2} = 15 ml O_2/100 ml blood

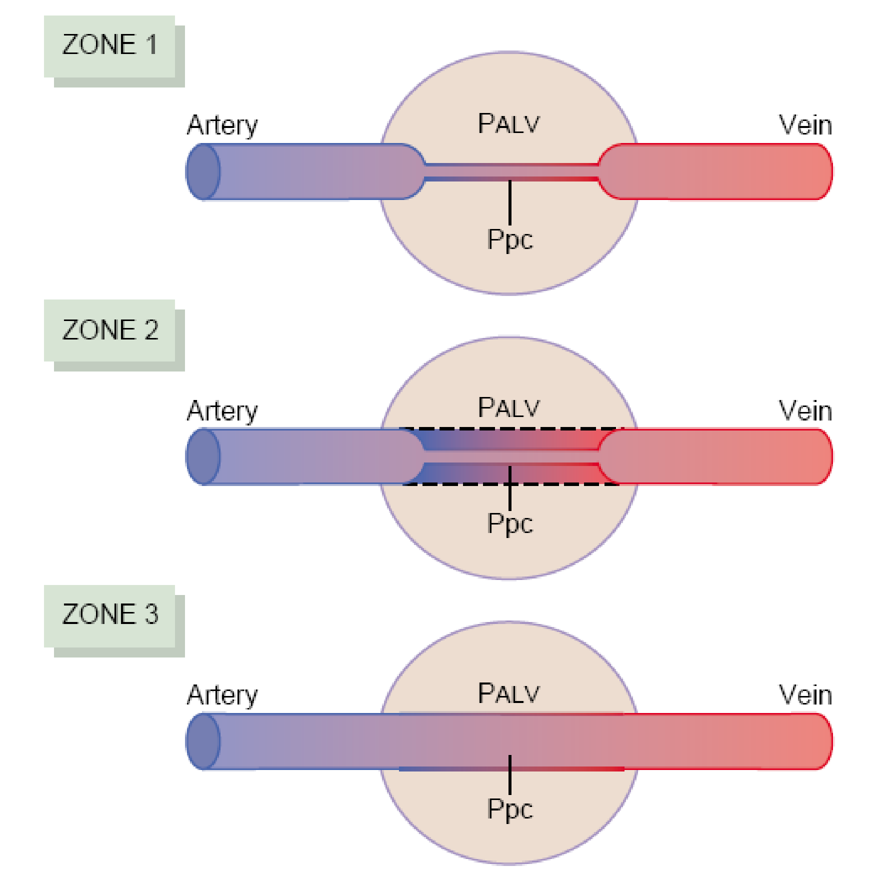
$$Q = \frac{250 \text{ ml } O_2/\text{min}}{(20-15) \text{ ml } O_2/100 \text{ ml blood}} = \frac{250 \text{ ml } O_2}{\text{min}} * \frac{100 \text{ ml blood}}{5 \text{ ml } O_2}$$

Q = 5000 ml blood /min

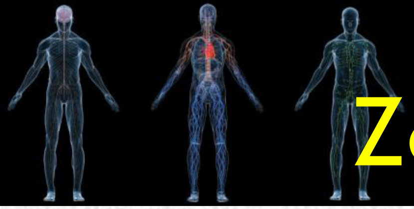
Hydrostatic Effects on Blood Flow



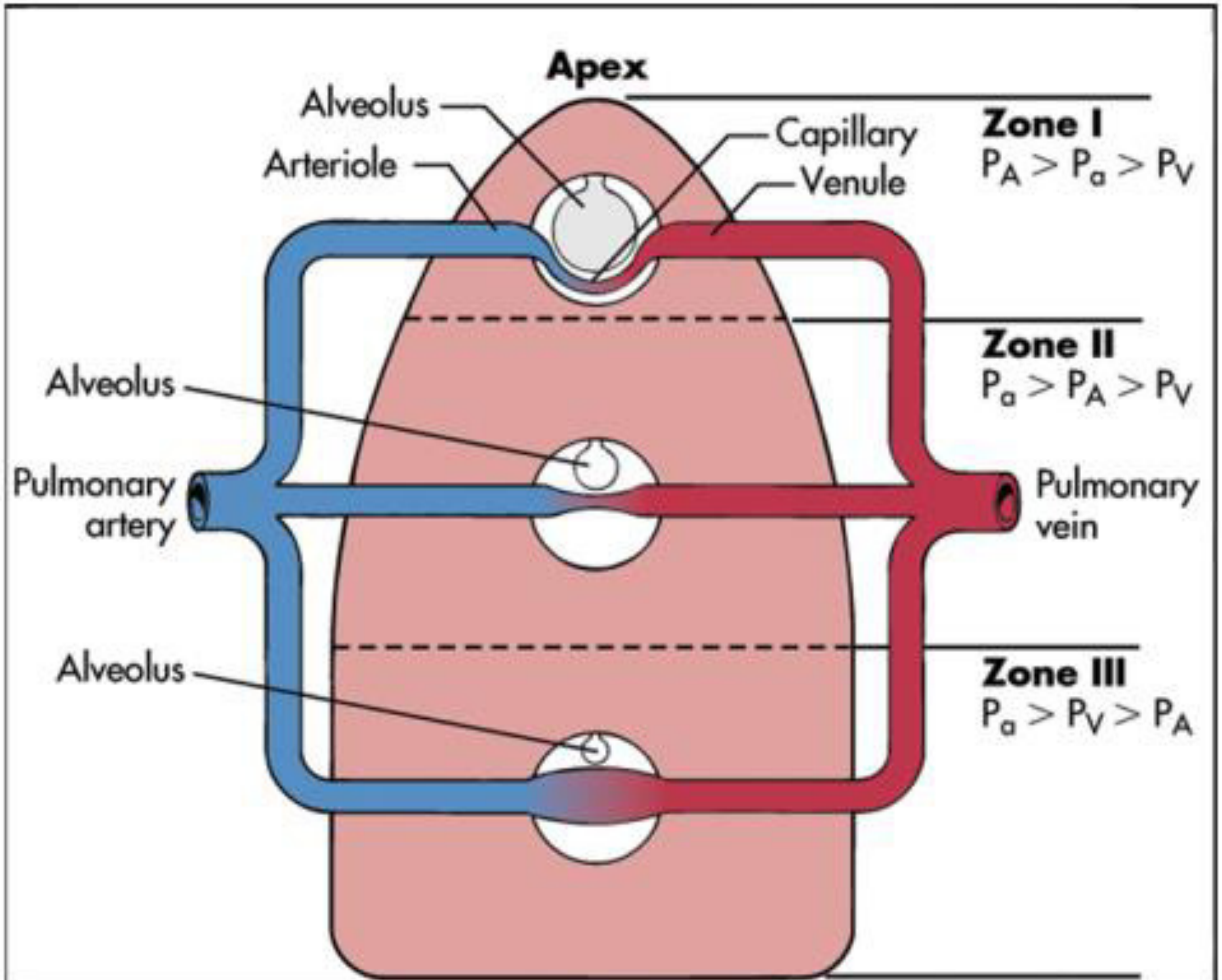
Zones of Pulmonary Blood Flow

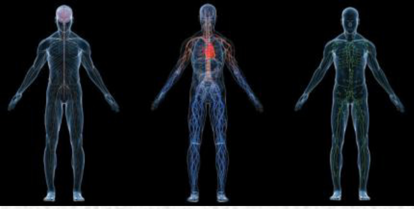


- *Zone 1:*
  - ***no flow***
  - alveolar air pressure (Palv) is higher than pulmonary arterial pressure (Ppc) during any part of cardiac cycle…This zone does not exist in human lung.
- *Zone 2:*
  - ***intermittent flow***
  - systolic arterial pressure higher than alveolar air pressure, but diastolic arterial pressure below alveolar air pressure.
- *Zone 3:*
  - ***continuous flow***
  - pulmonary arterial pressure (Ppc) remain higher than alveolar air pressure at all times.



Zones of Pulmonary Blood Flow

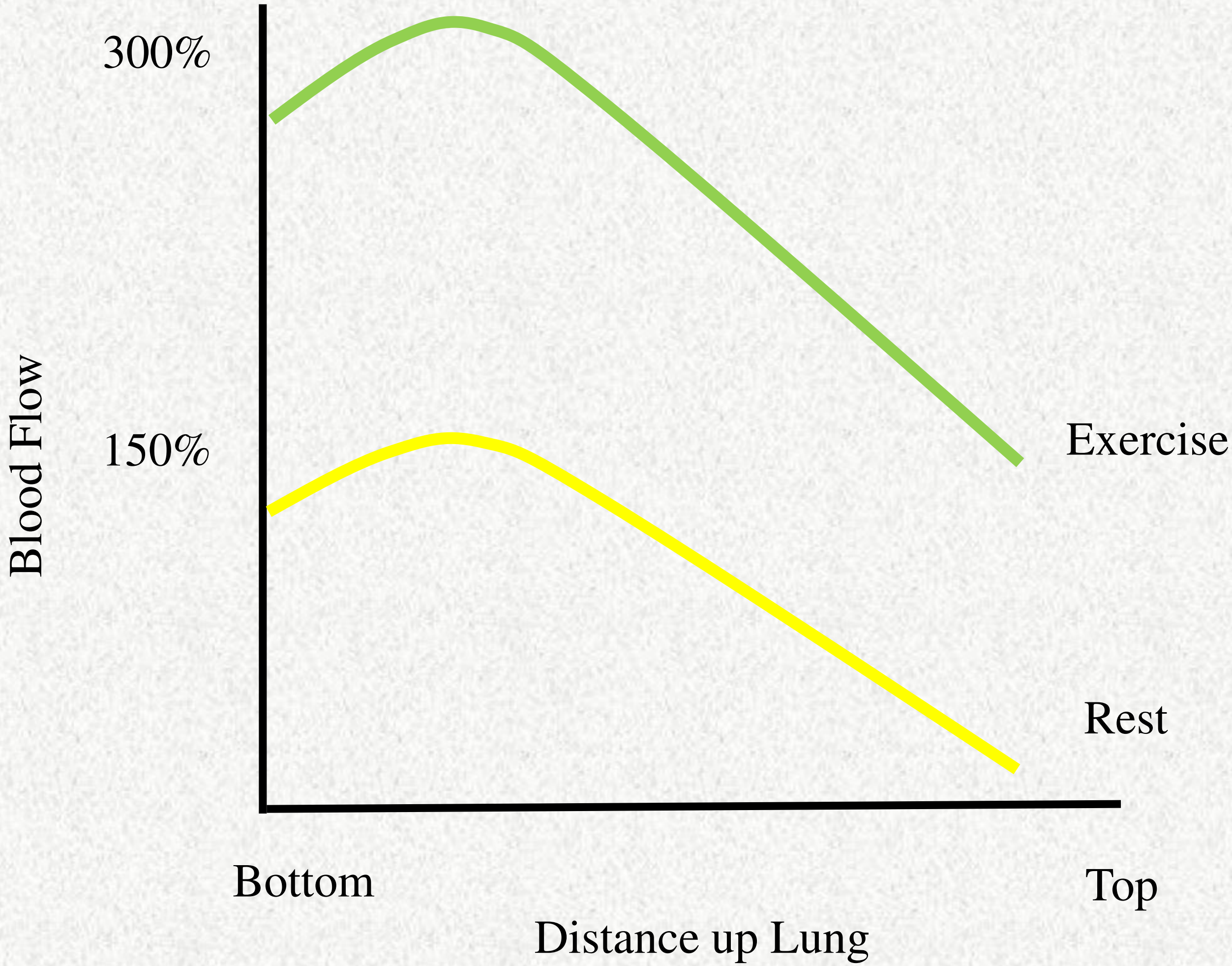




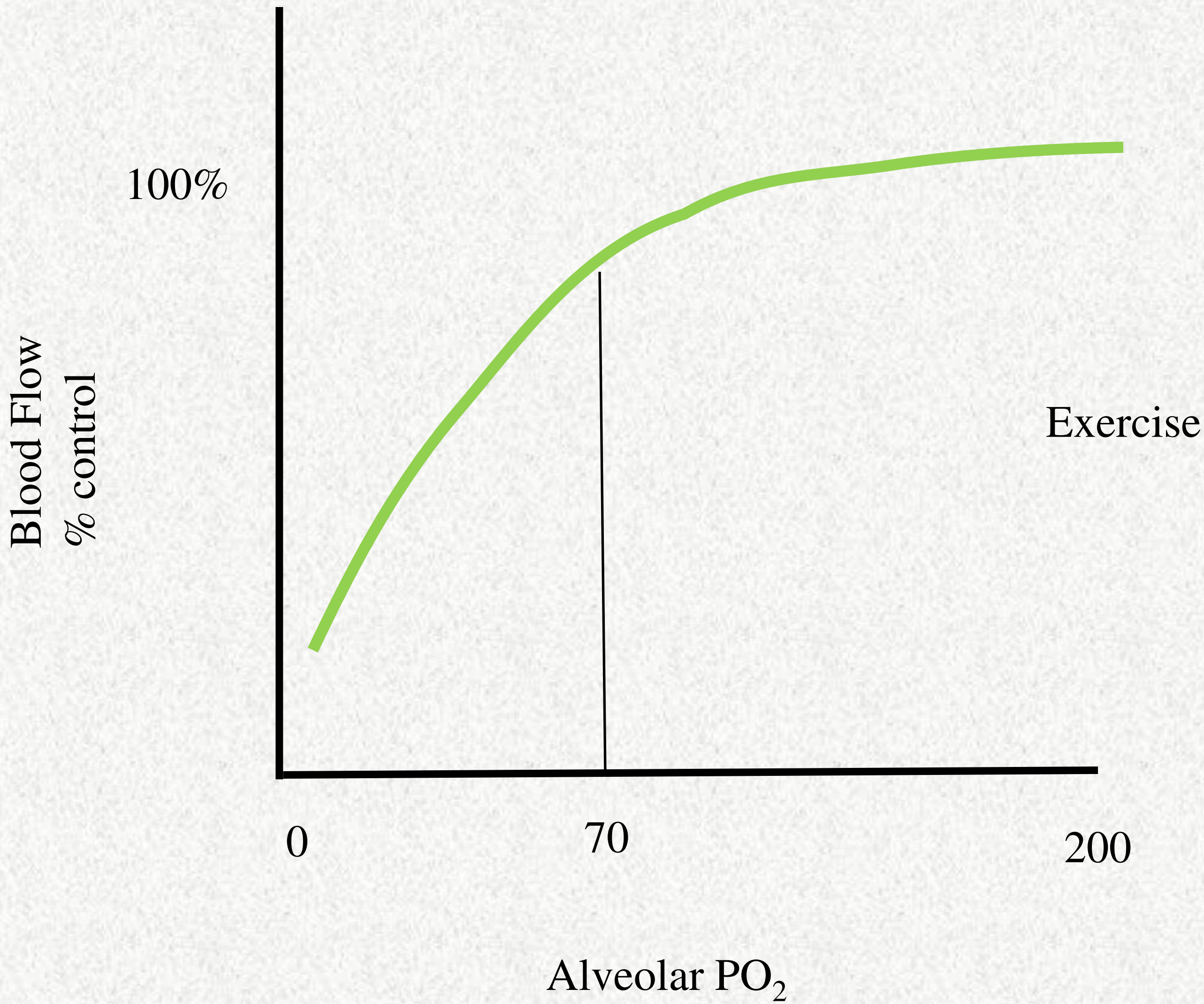
Zones of a normal lung

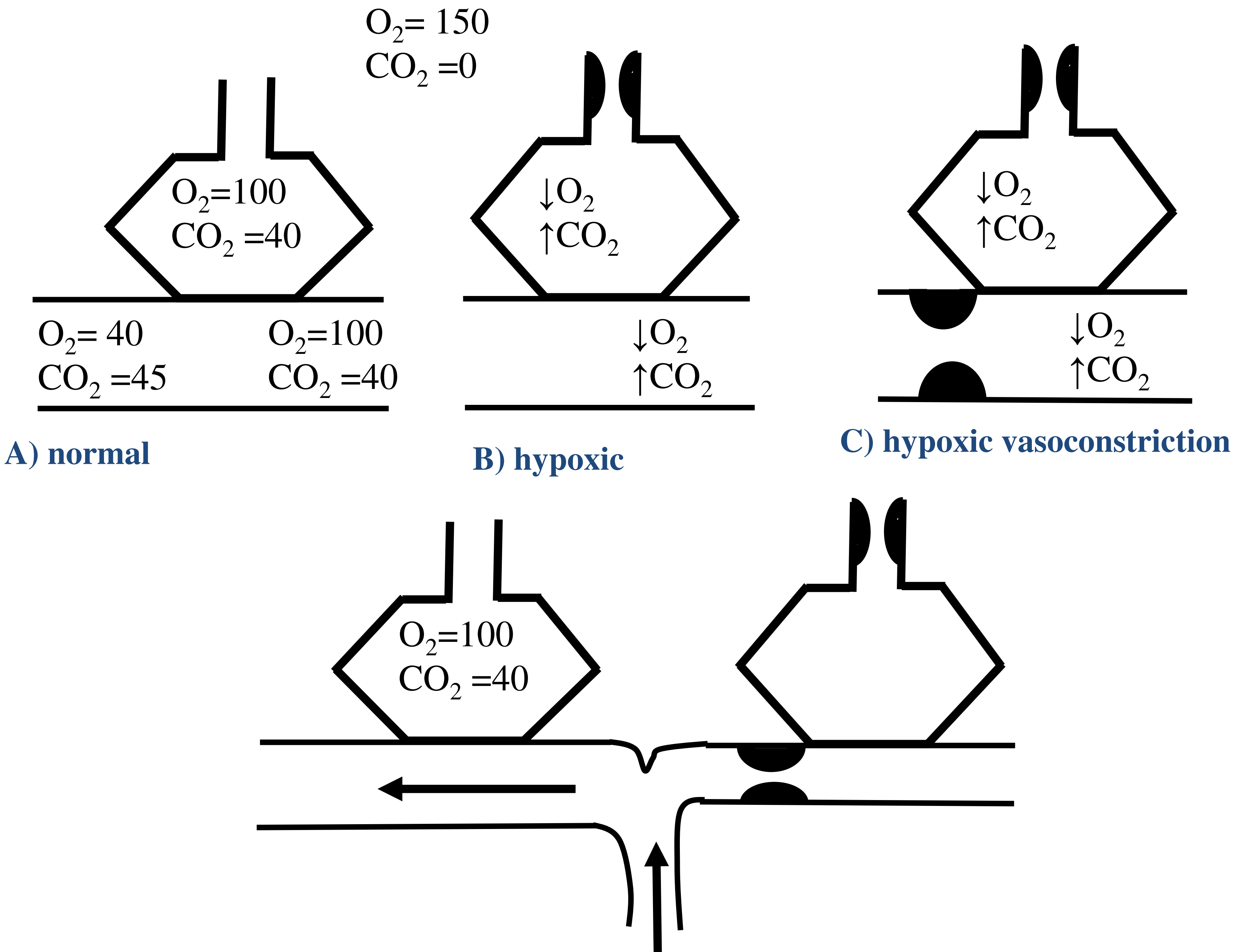
- Normally, the lungs have 2 zones for blood flow
  - zone 2 (intermittent flow) at the apices.
  - zone 3 (continuous flow) in all the lower areas.
- In normal lungs, Zone 2 begins 10 cm above the mid-level of the heart to the top of the lungs.

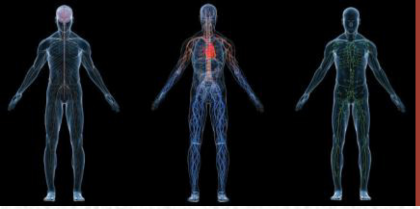
DISTRIBUTION OF BLOOD FLOW



EFFECT OF Po_2 ON BLOOD FLOW

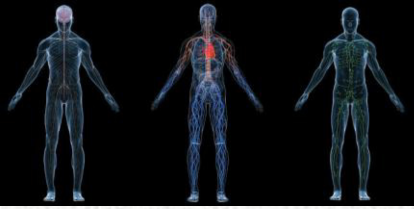



O2= 150
CO2 =0
O2=100
CO2 =40
O2= 40
CO2 =45
O2=100
CO2 =40
A) normal
↓O2
↑CO2
↓O2
↑CO2
B) hypoxic
↓O2
↑CO2
↓O2
↑CO2
C) hypoxic vasoconstriction
O2=100
CO2 =40



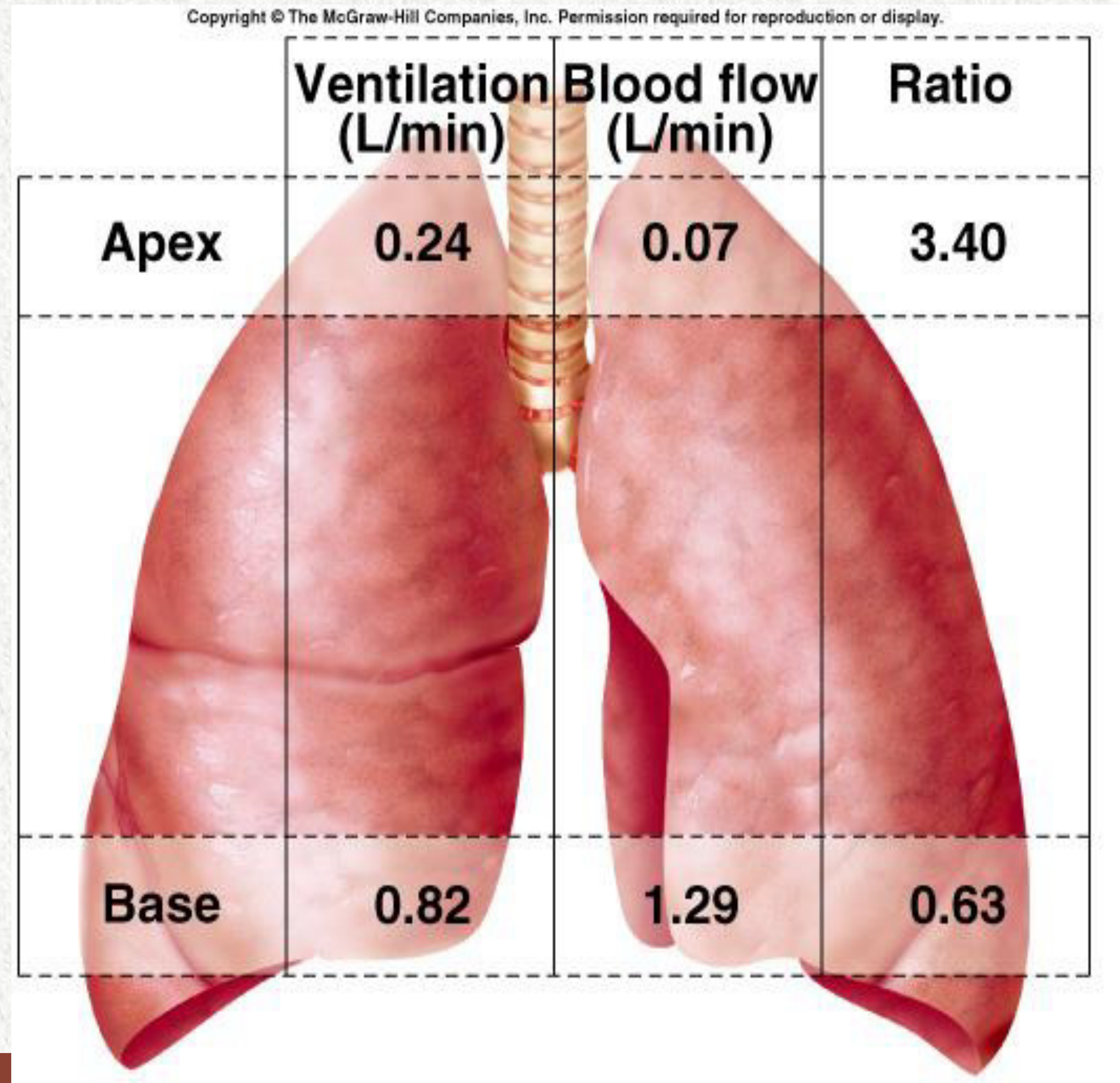
Pulmonary Circulation

- Rate of blood flow through the pulmonary circulation is = flow rate through the systemic circulation.
  - Driving pressure is about 10 mm Hg.
- Pulmonary vascular resistance is low.
  - Low pressure pathway produces less net filtration than produced in the systemic capillaries.
    - Avoids pulmonary edema.
- Autoregulation:
  - Pulmonary arterioles constrict when alveolar P_{O_2} decreases.
  - Matches ventilation/perfusion ratio.

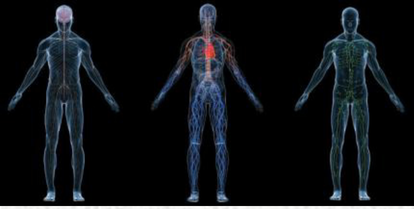


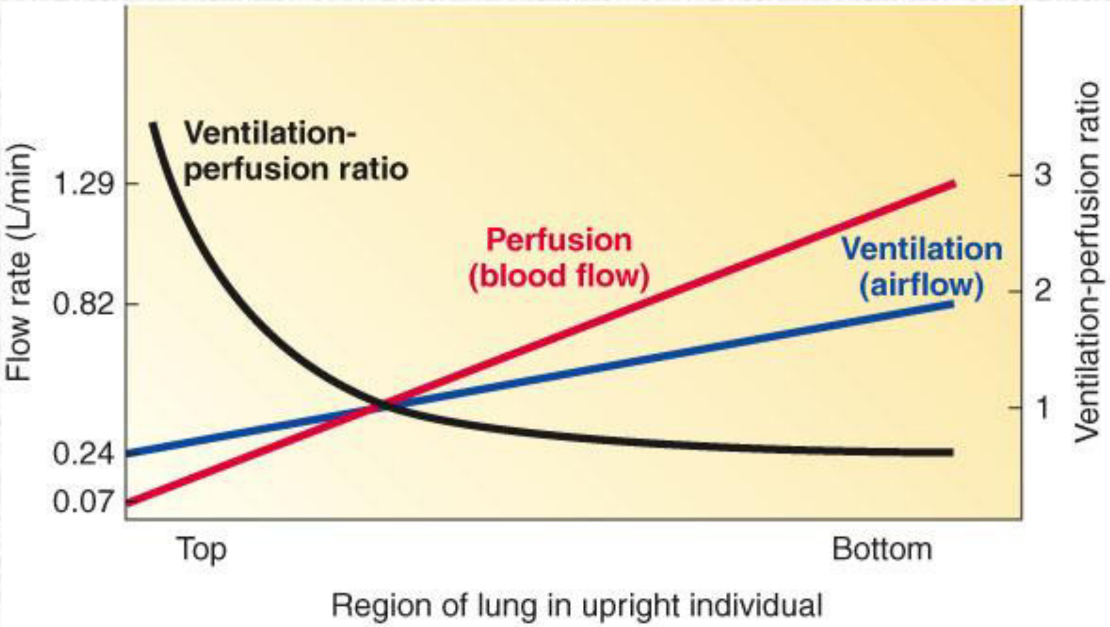
Lung Ventilation/Perfusion Ratios

- Functionally:
  - Alveoli at apex are underperfused (overventilated).
  - Alveoli at the base are underventilated (overperfused).



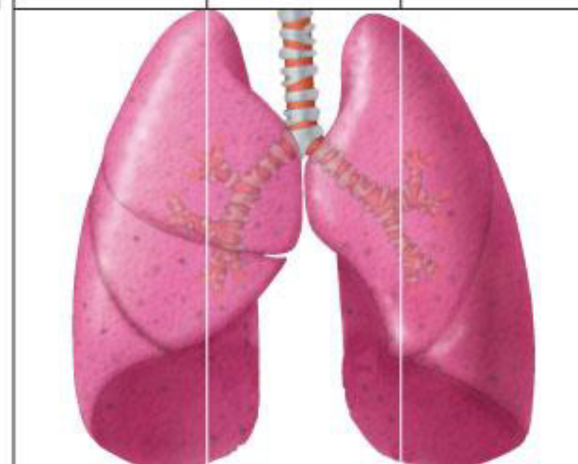
- V/Q is ↑ in:
- 1. pulmonary embolism.
- 2. emphysema.
- 3. cigarette smokers.
- 4. pulmonary hyperventilation
- Whenever V/Q ↑
- 1. alveolar dead space ↑.
- 2. mixed expired P_ECO_2 ↓.
- 3. mixed expired P_EO_2 ↑.





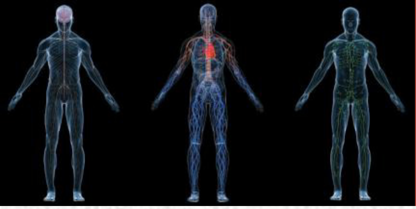
(a) Regional ventilation and perfusion rates and ventilation-perfusion ratios in the lungs

	Ventilation (airflow) (L/min)	Perfusion (blood flow) (L/min)	Ventilation-perfusion ratio
Top of lung	0.24	0.07	3.40
Bottom of lung	0.82	1.29	0.63

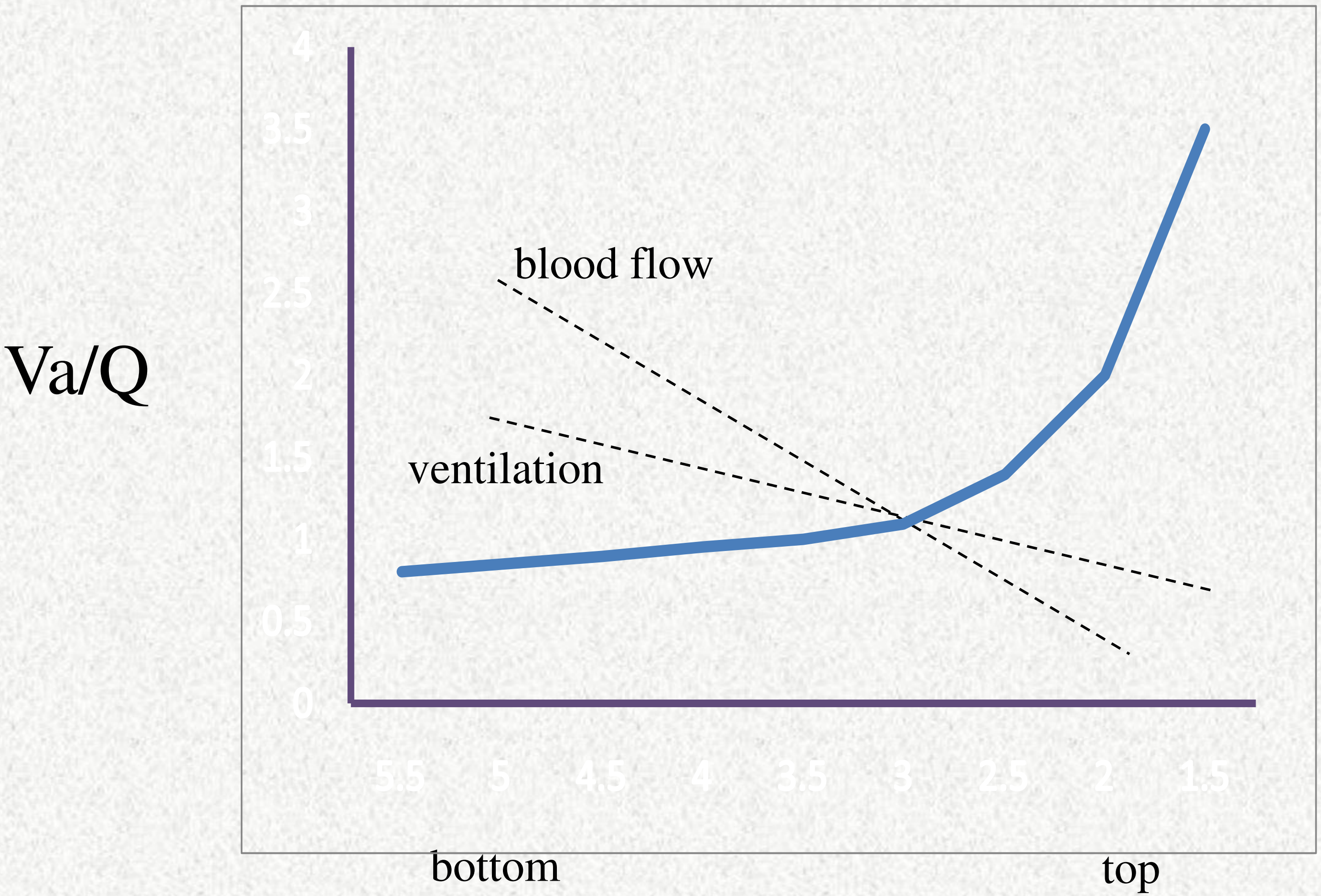


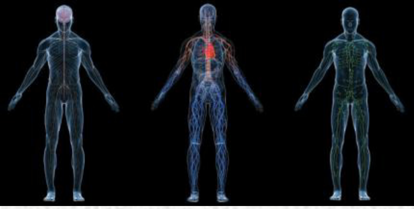
(b) Ventilation and perfusion rates and ventilation-perfusion ratios at top and bottom of lungs

Fig. 13-24, p. 485



Regional Gas Exchange





Question

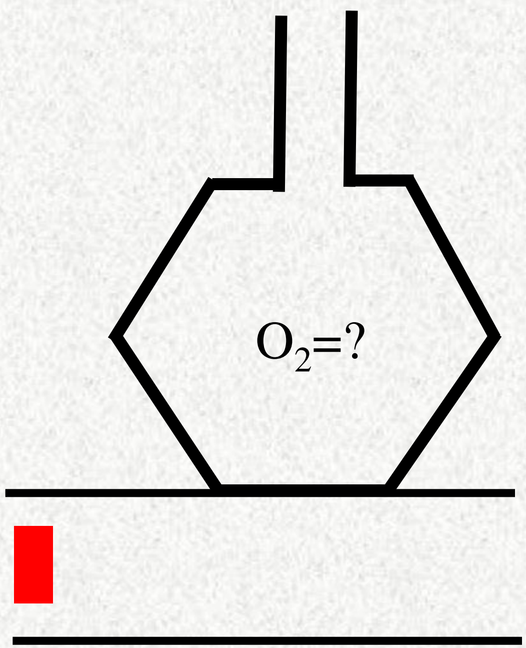
An alveoli that has normal ventilation and no blood flow (V/Q=0) has an alveolar PO_2 of

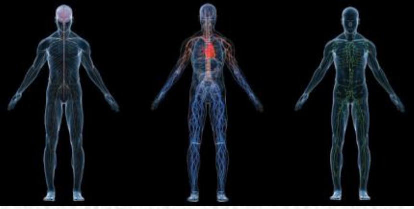
A. 40 mmHg

B. 100 mmHg

C. 149 mmHg

D. 159 mmHg





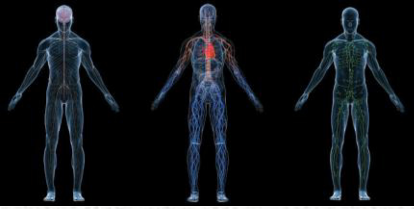
Ventilation/perfusion

- Relationship between adequate flow and adequate ventilation
- Defined as V/Q
- V/Q = (4 l/min)/ (5 l/min) = 0.8
- $Va/Q=8.63*R*(CA_{O_2}-CV_{O_2})/PA_{CO_2}$
- If there is no diffusion impairment then the Po_2 and Pco_2 between an alveolus and end capillary blood are usually the same.

Ventilation/Perfusion Ratios

- **The ratio of alveolar ventilation to pulmonary blood flow = 0.8 (4.2 L/min / 5 L/min blood flow).**

- When the ventilation (Va) is zero, but there is adequate perfusion (Q) of the alveolus, the Va/Q is **zero**.
- when there is adequate ventilation, but zero perfusion, the ratio Va/Q is **infinity**.
- At a ratio of either zero or infinity, there is no exchange of gases through the respiratory membrane of the affected alveoli

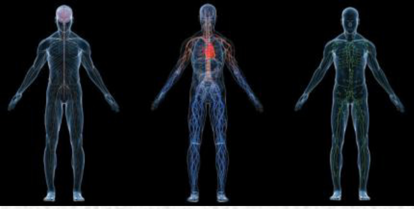


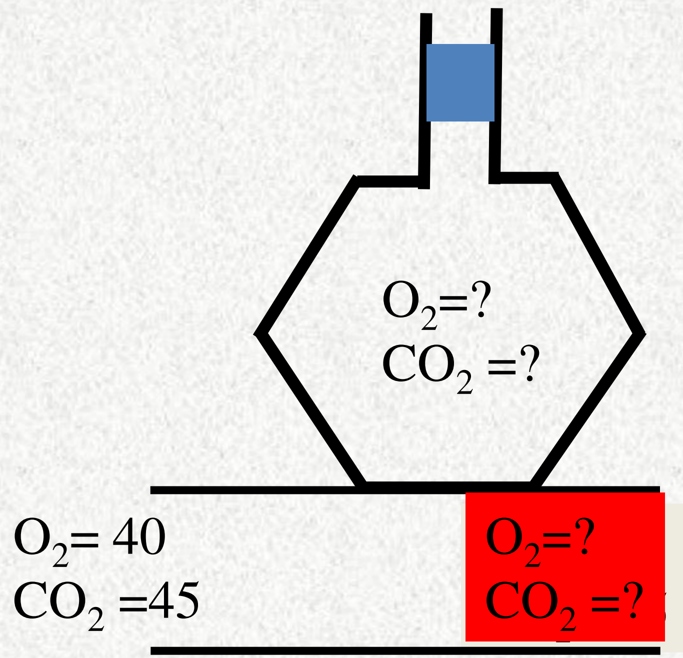
Movement of Air in and Out of Lungs

- Pleural Pressures
  - Resting -5 cm H_20
  - Inspiration -8 cm H_20
  - In the upright position at rest the basal intrapleural P is

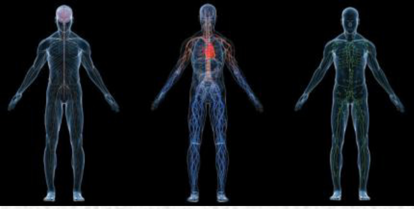
–2 mm Hg, while apical intrapleural P equals –7 mm Hg.

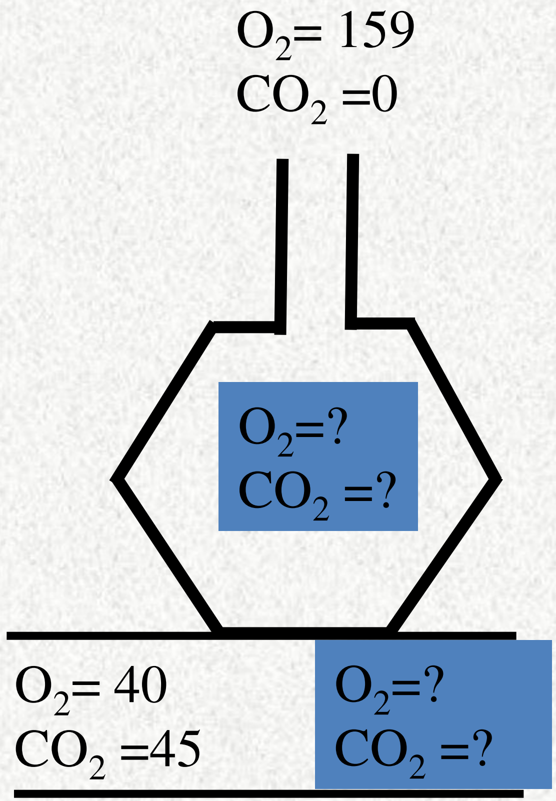
(1 cm H_20 ~ 0.7 mmHg)



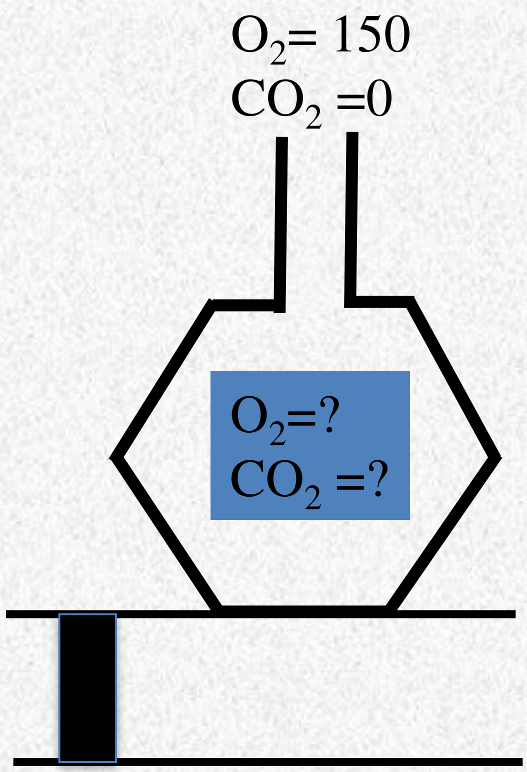


$$V/Q = 0$$

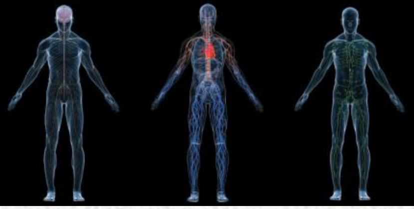


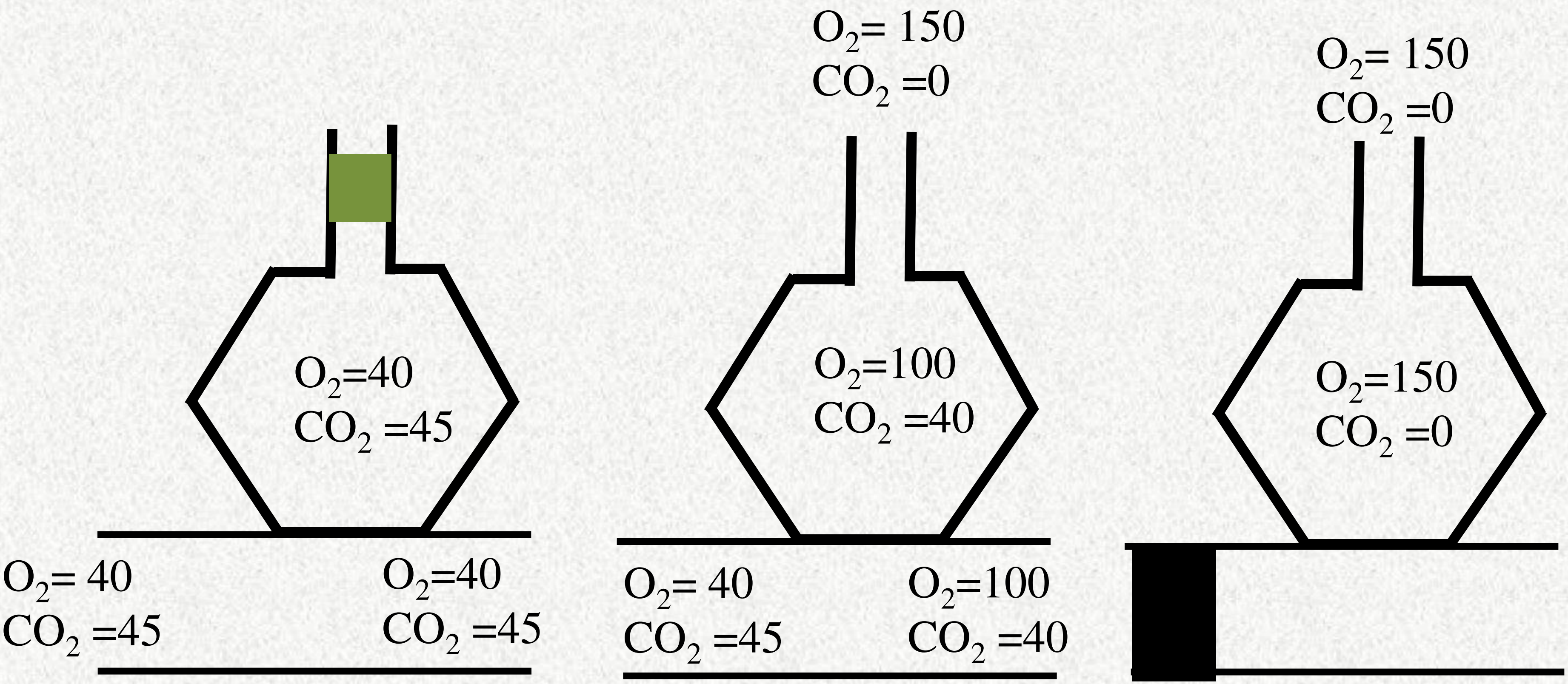


V/Q =0.8

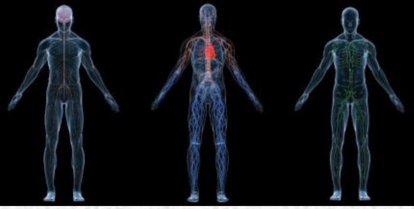


$$V/Q = \infty$$

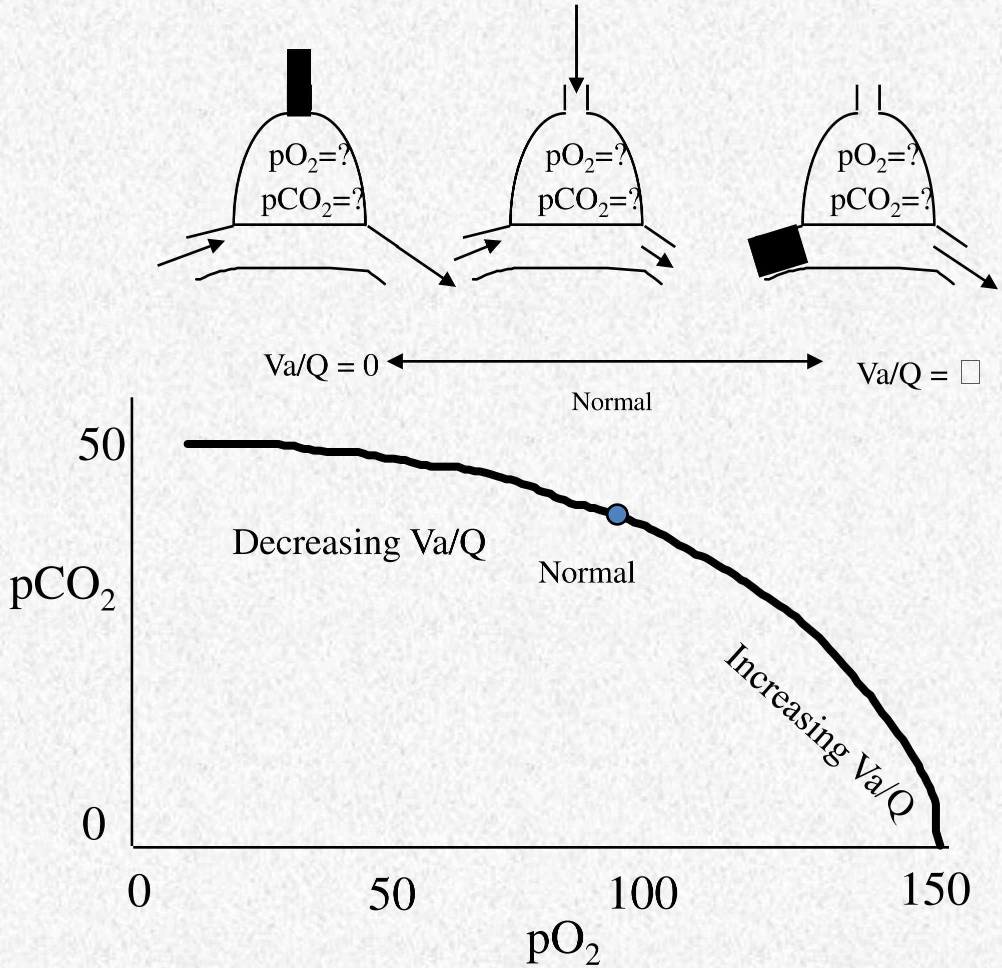




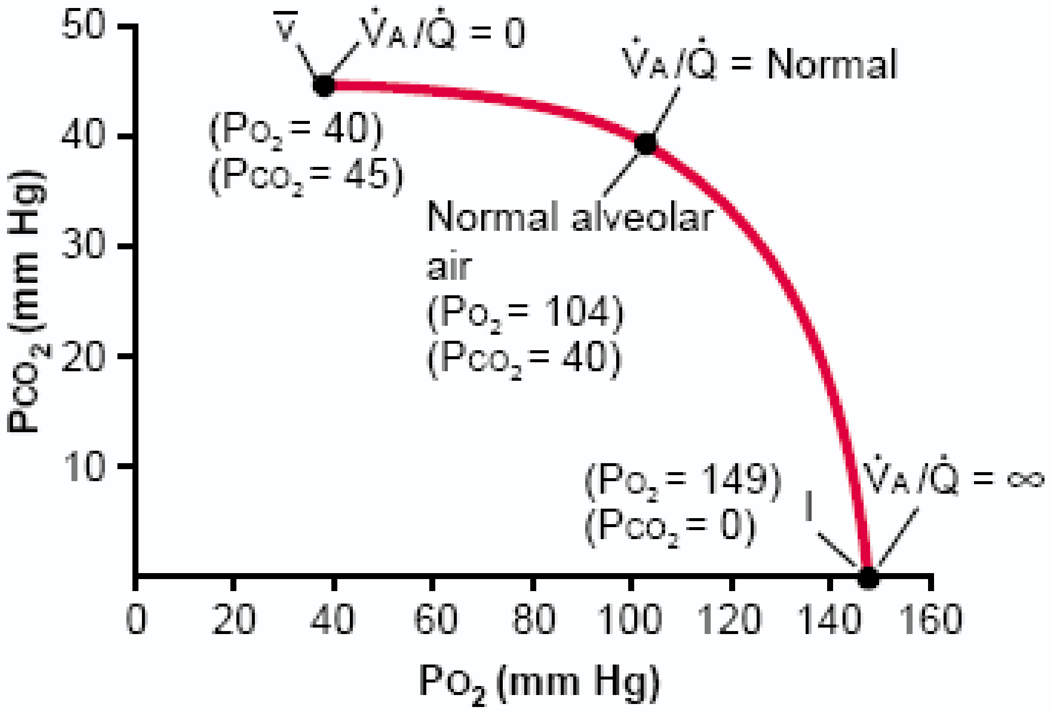
$V/Q = 0$ $V/Q =$ normal $V/Q = \infty$



Ventilation/perfusion



Ventilation/Perfusion Ratios



physiologic shunt:

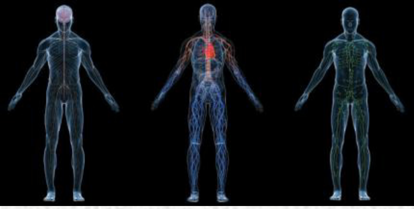
The total amount of shunted blood per minute.

physiologic dead space:

Alveolar + anatomical dead spaces

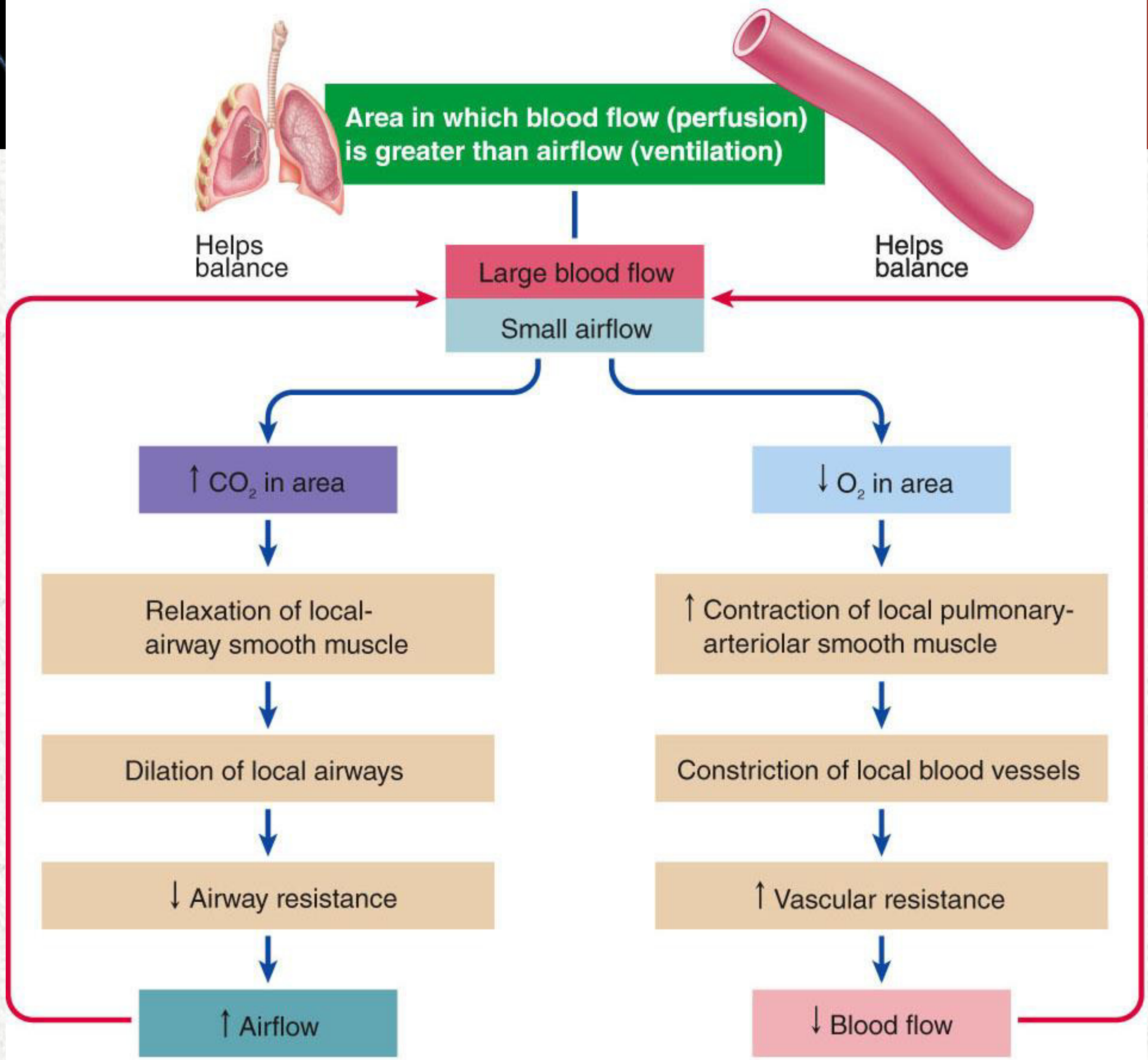
Abnormal VA/Q in the Upper and Lower Normal Lung.

- **Upper part of the lung**
  - Less blood flow and ventilation; but blood flow is considerably less than ventilation.
  - Therefore, Va/Q is 2.5 times higher than the normal value
  - This causes a moderate degree of *physiologic dead space.*
- **The bottom of the lung**
  - Slightly too little ventilation in relation to blood flow
  - Va/Q as low as 0.6 times the normal value.
  - A small fraction of the blood fails to become normally oxygenated, and this represents a *physiologic shunt*.
  - Assuming perfusion is adequate … hyperventilation makes alveolar air like atmospheric air …. Hypoventilation makes alveolar air like venous blood.



Ventilation/perfusion

- Physiologic shunt
  - Va/Q < normal
  - low ventilation
- Physiologic dead space
  - Va/Q > normal
  - wasted ventilation
- Abnormalities
  - Upper lung Va/Q 3 x normal
  - Lower lung Va/Q .5 x normal



(a) Local controls to adjust ventilation and perfusion to lung area with large blood flow and small airflow

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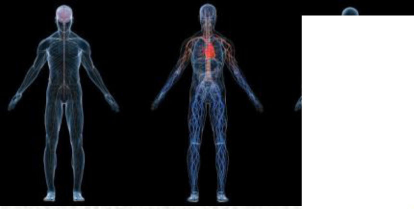

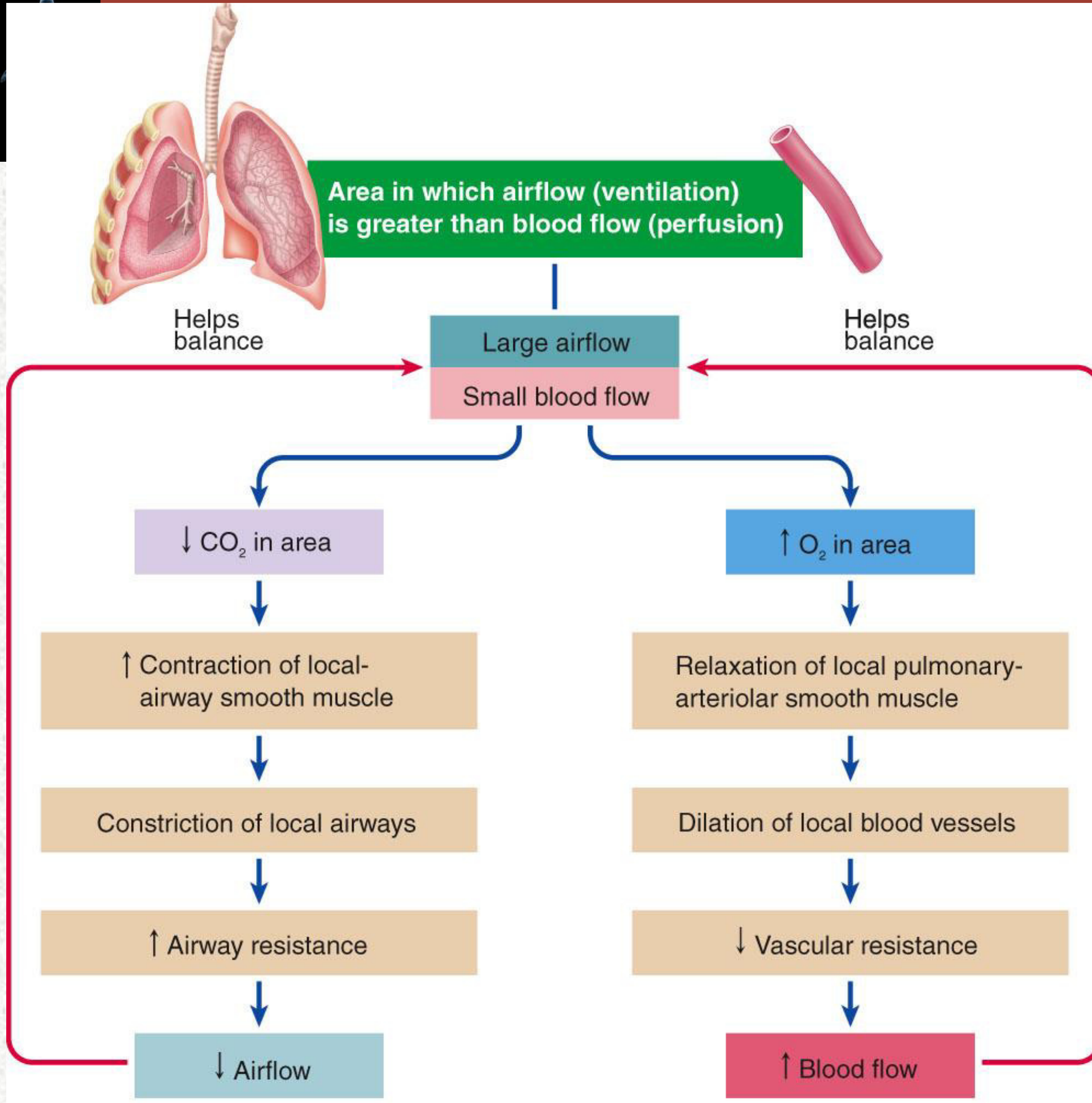

(b) Local controls to adjust ventilation and perfusion to a lung area with large airflow and small blood flow

Fig. 13-23b, p. 484