LECTURE-5
VENTILATION PERFUSION RATIO

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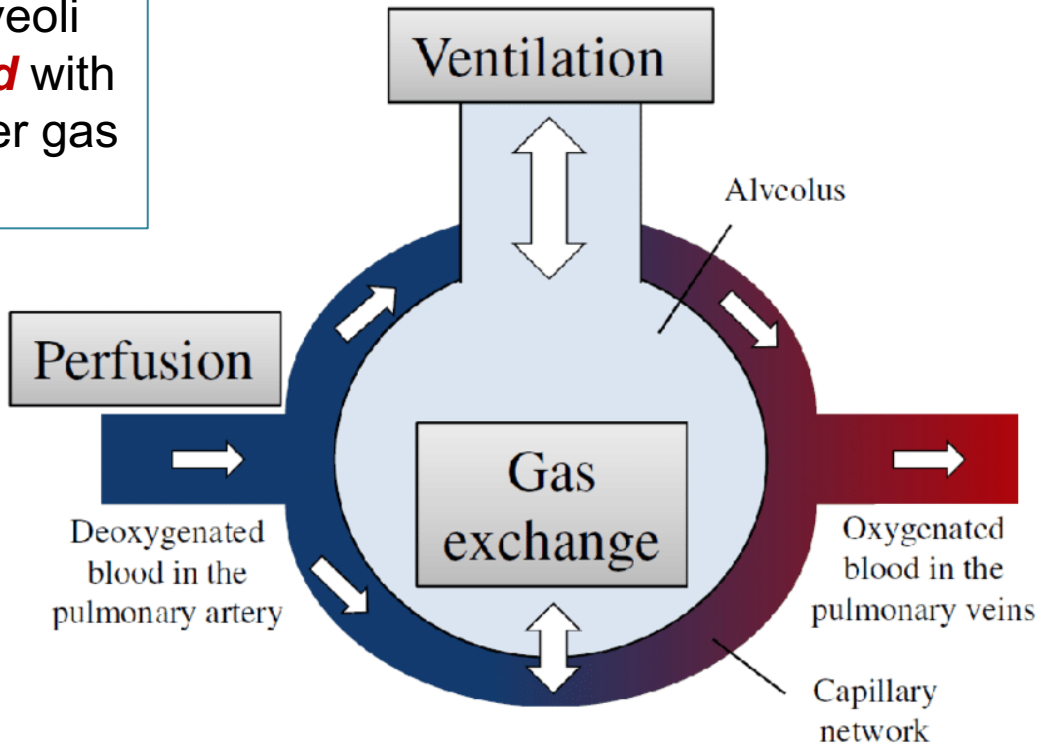
Objectives

- Recognize the high pressure and low pressure circulations supplying the lung.
- Identify the meaning of the physiological shunt in the pulmonary circulation.
- State the different lung zones according to the pulmonary blood flow.
- Define the V/Q ratio and its regional variation.
- Explain the clinical significance of the V/Q ratio
- Describe the abnormal patterns of the V/Q ration vice, shunt and dead space patterns.

Introduction

For normal gas exchange to occur, ***ventilated*** alveoli must also be ***perfused*** with blood to achieve proper gas exchange.



Ventilation

Perfusion

Introduction

If alveolus is ***ventilated*** but ***NOT perfused***

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PO_2 = 104mmHg
PCO_2 = 40mmHg

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PCO_2 = 40mmHg

PO_2 = 104mmHg
PCO_2 = 40mmHg

PO_2 = 40mmHg
PCO_2 = 45mmHg

Wasted ventilation

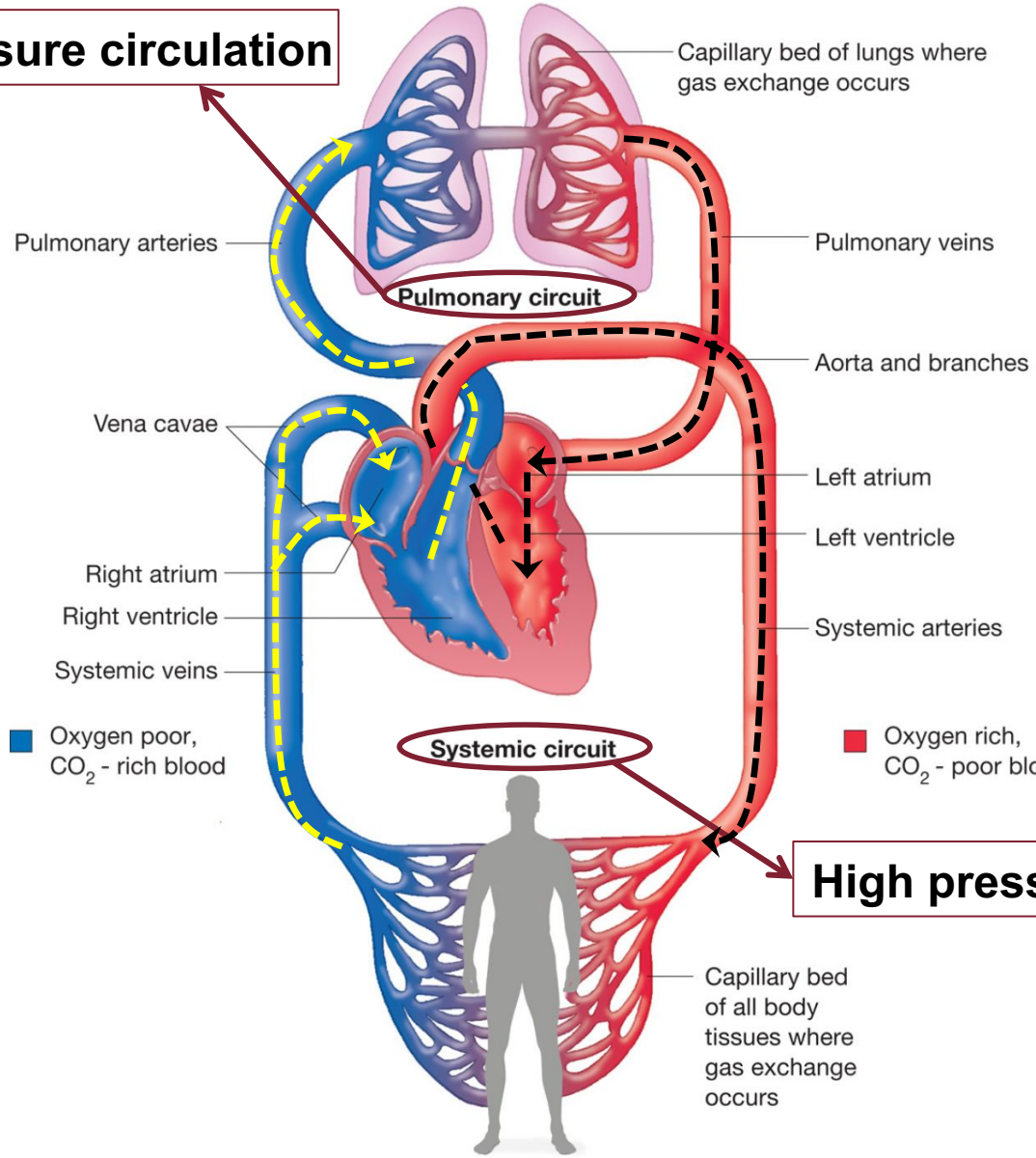
Wasted ??

We talked a lot about ventilation in previous lectures, so why don't we discuss "Pulmonary Perfusion"

Circuitry

Low pressure circulation

Why??



High pressure circulation

Why??

Blood Supply of the Lung

The lung has dual blood supply

Pulmonary Circulation

Starts at Rt atrium → Rt ventricle → Pulmonary art. → Capillaries → Pulmonary veins → Lt atrium.

Supplies ***deoxygenated*** blood to lungs to become oxygenated.

100% of CO

Low pressure, high flow circulation.

Bronchial Circulation

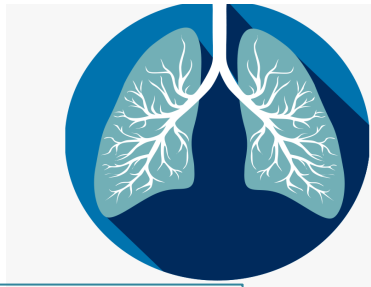
Starts from Aorta → Bronchial arteries → capillaries → Bronchial veins which drain either into pulmonary veins (i.e. Lt atrium) or right atrium.

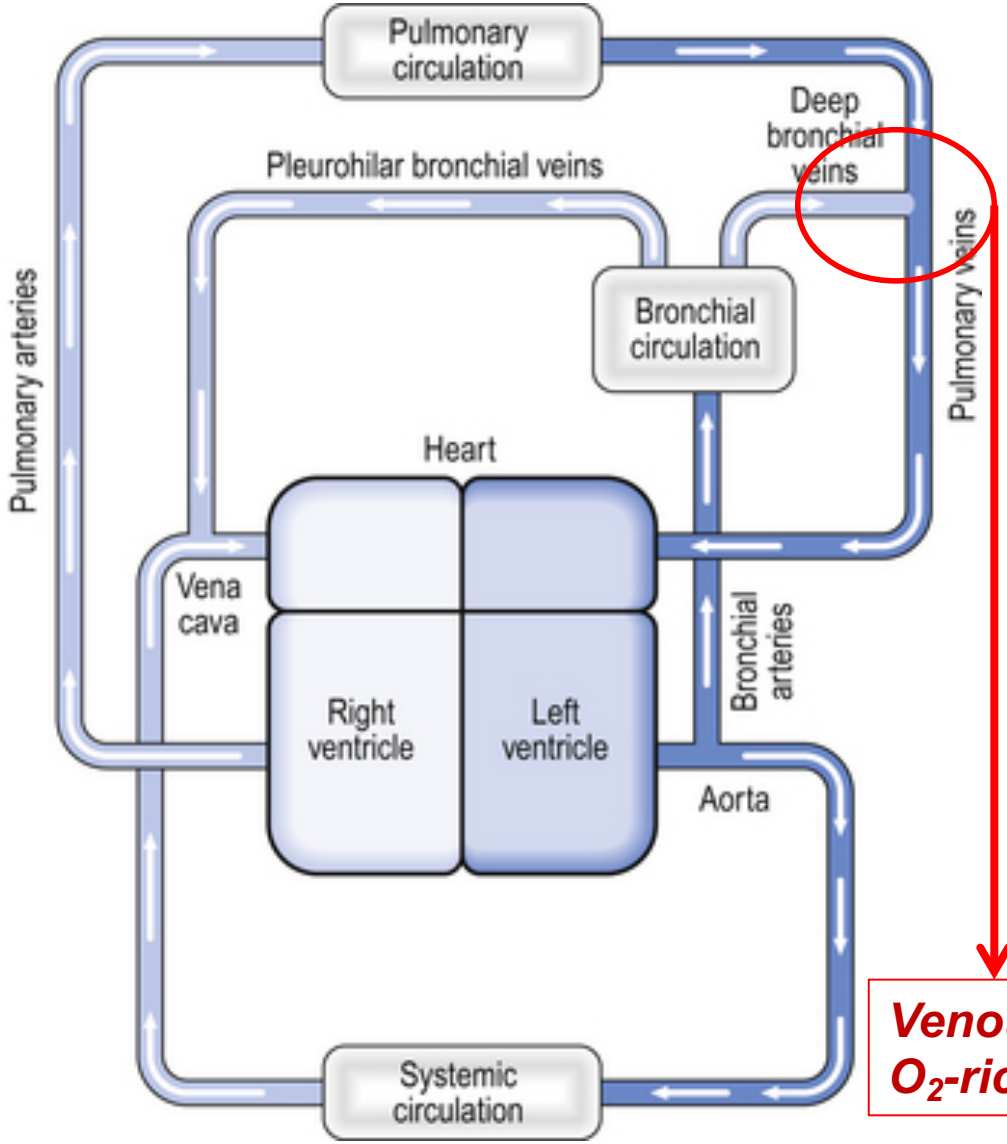
Supplies ***oxygenated*** blood to lung tissue.

Approximately 1-2% of CO

High pressure, low flow circulation.

Bronchial Circulation



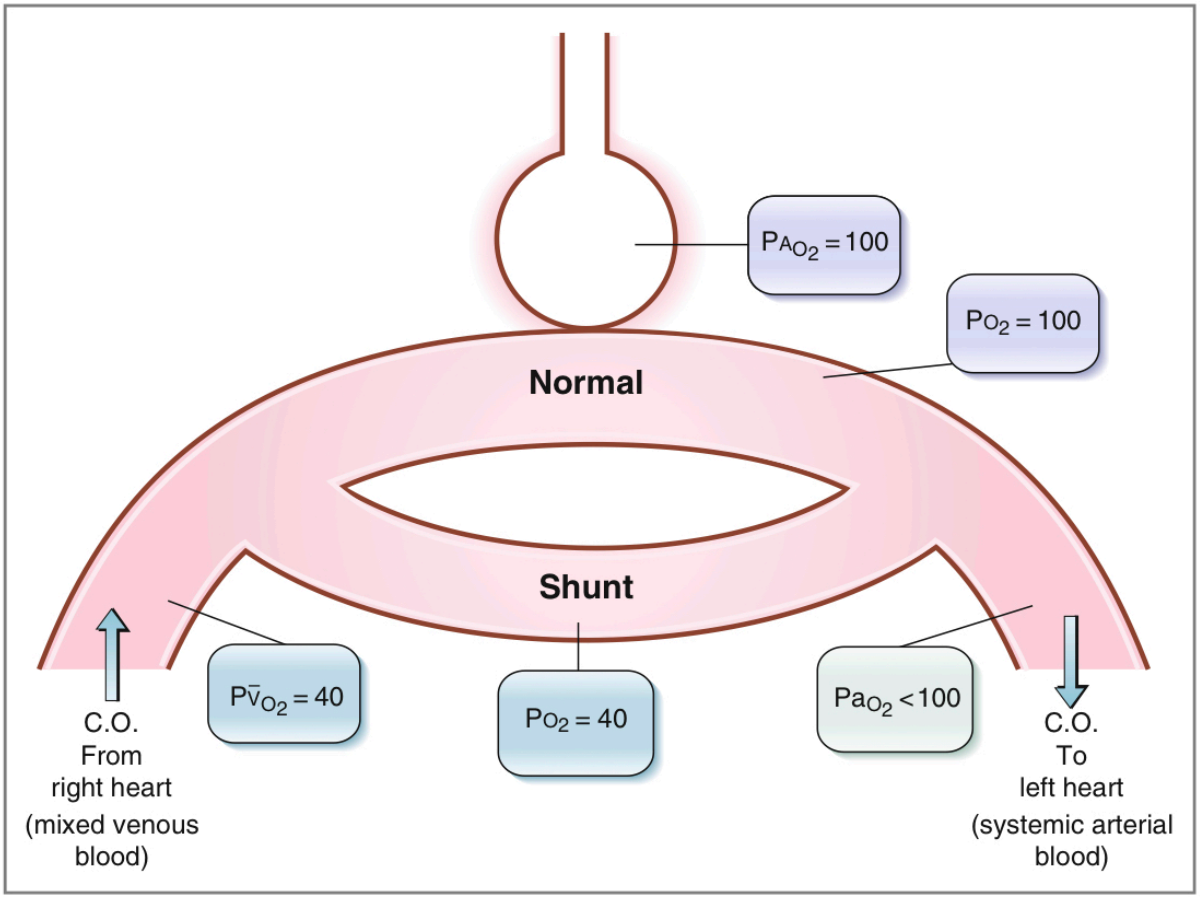


Supplies O_2-rich blood to lung tissue. After lung tissue extracts the needed O_2, $^2/_3$ of the resultant deoxygenated blood drains into pulmonary veins (which carry O_2-rich blood to the Lt atrium) causing ***venous admixture*** of deoxygenated blood with newly oxygenated blood coming from the pulmonary circulation.

Venous blood enters the O_2-rich pulmonary vein

Anatomic Rt-to-Lt Shunt

Right-to-Left Shunt



Normally, deoxygenated blood should pass to the lungs to get oxygenated. If deoxygenated blood bypasses the lungs and enters the left side of the circulation → "***Rt-to-Lt shunt***"

Pulmonary Perfusion

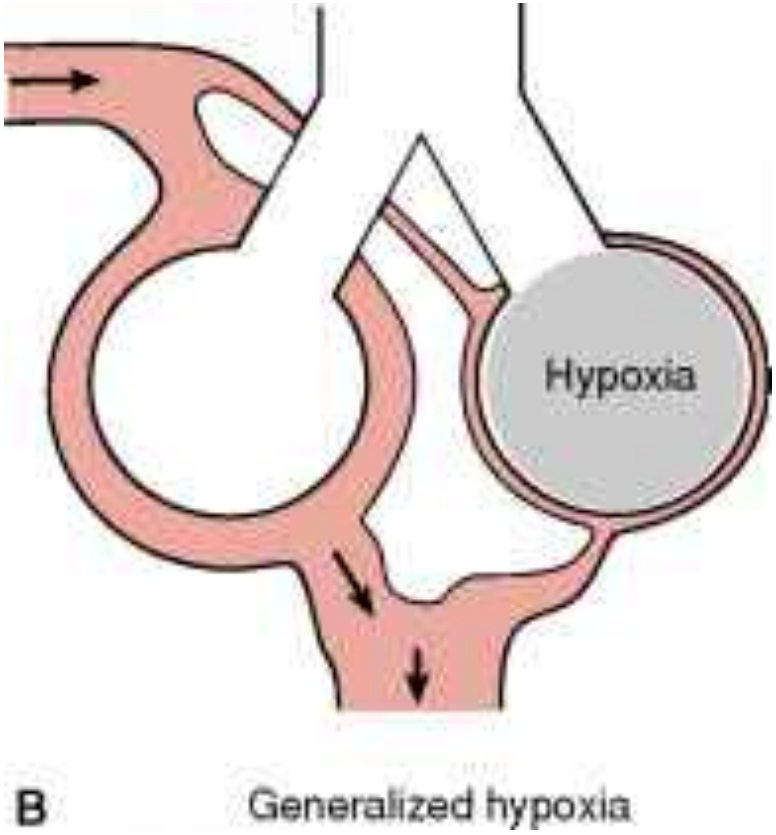
- Pulmonary perfusion refers to the blood flow through the lung that supplies deoxygenated blood to the lung to be oxygenated.
- This means “pulmonary circulation”.
- From now on we will focus on pulmonary circulation.

Pulmonary Blood Flow

- ***Pulmonary perfusion or pulmonary blood flow is affected by several factors:***

1. Alveolar oxygenation.
2. Hydrostatic pressure gradient (the effect of gravity).
3. And other factors that will not be discussed.

Alveolar Oxygenation



↓ in alveolar PO_2
(PO_2 < 73mmHg)

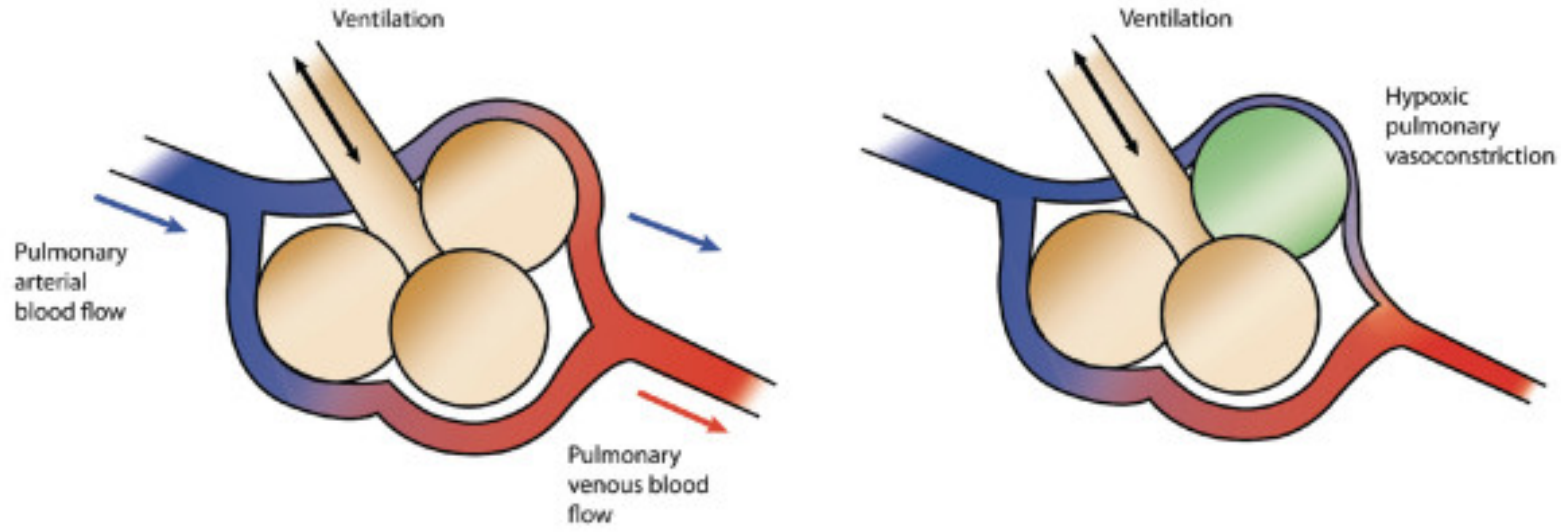
↓

Vasoconstriction of the vessels surrounding the hypoxic alveolus

This causes blood to flow to areas of the lungs that are better aerated

N. B. This is opposite to the effect observed in systemic vessels

Alveolar Oxygenation



Hypoxic pulmonary vasoconstriction. The left frame shows normal alveolar ventilation and perfusion. In the right frame, reduced ventilation (thus O_2 tension) in the alveolus (green) leads to a reduced perfusion because of the hypoxic pulmonary vasoconstriction mechanism.

The Hydrostatic Pressure Gradient

- In the upright position, the pressure of blood is not the same around the body… ***Why?***
- Due to weight of the blood column, the effect of gravity.
- For each cm distance above or below the heart the pressure changes 0.77mmHg.

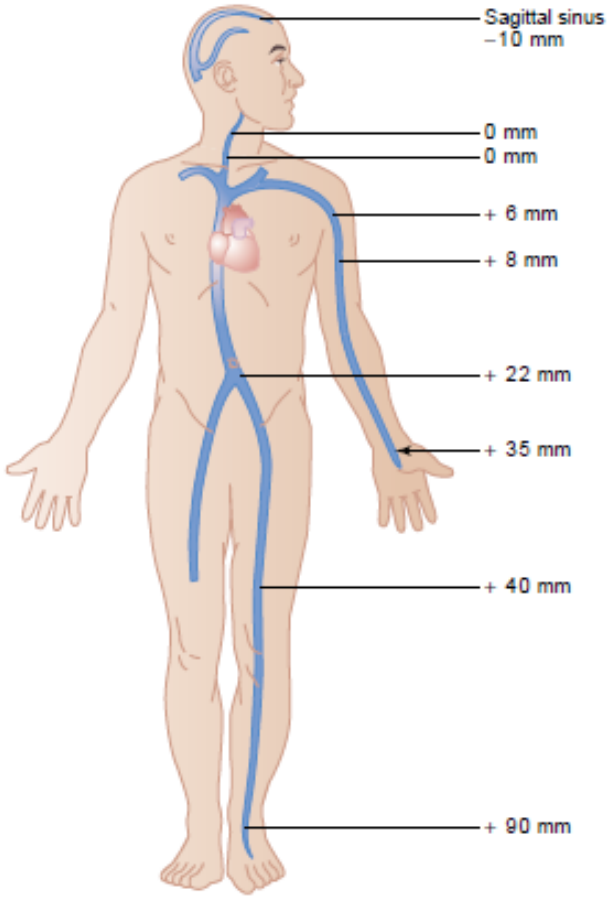
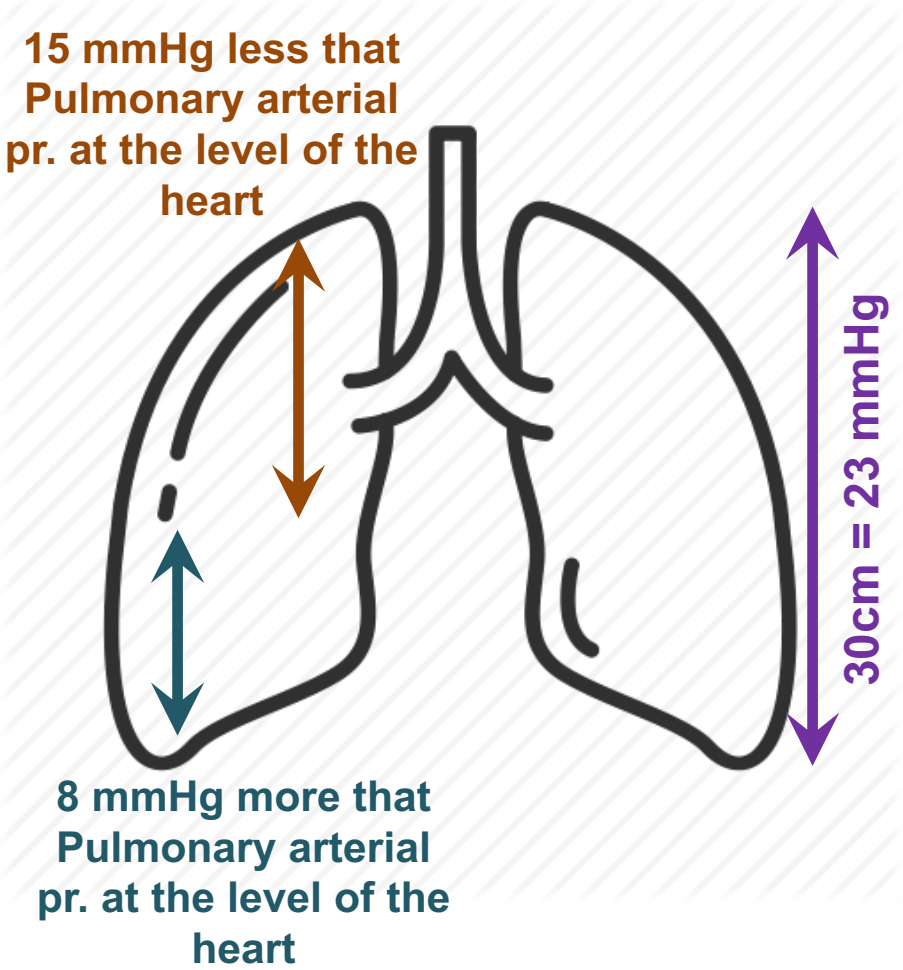


Figure 15–10

Effect of gravitational pressure on the venous pressures throughout the body in the standing person.

The Hydrostatic Pressure Gradient in the Lung

- The same effect happens in the lung.
- The distance between apex and base of lung ≈ 30cm.. Which means 23mmHg pressure difference between apex and base of the lung.
- 15mmHg above the heart and 8mmHg below the heart.



Regional Differences in Pulmonary Blood Flow

- The variation in arterial & venous pressures in the upright posture causes regional differences in blood flow.
- Base has more blood flow than apex in the upright posture.

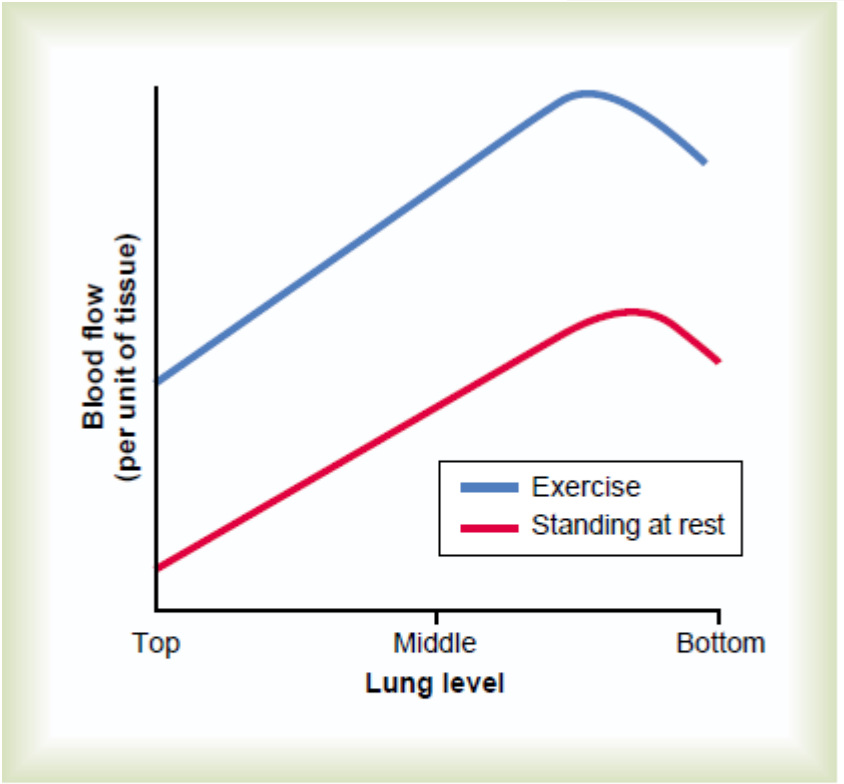


Figure 38–3

Blood flow at different levels in the lung of an upright person *at rest* and *during exercise*. Note that when the person is at rest, the blood flow is very low at the top of the lungs; most of the flow is through the bottom of the lung.

Perfusion Zones of the Lung

- Classically, the lung has been divided into 3 different zones:
  - ***Zone 1***: No blood flow.
  - ***Zone 2***: Intermittent blood flow.
  - ***Zone 3***: Continuous blood flow.

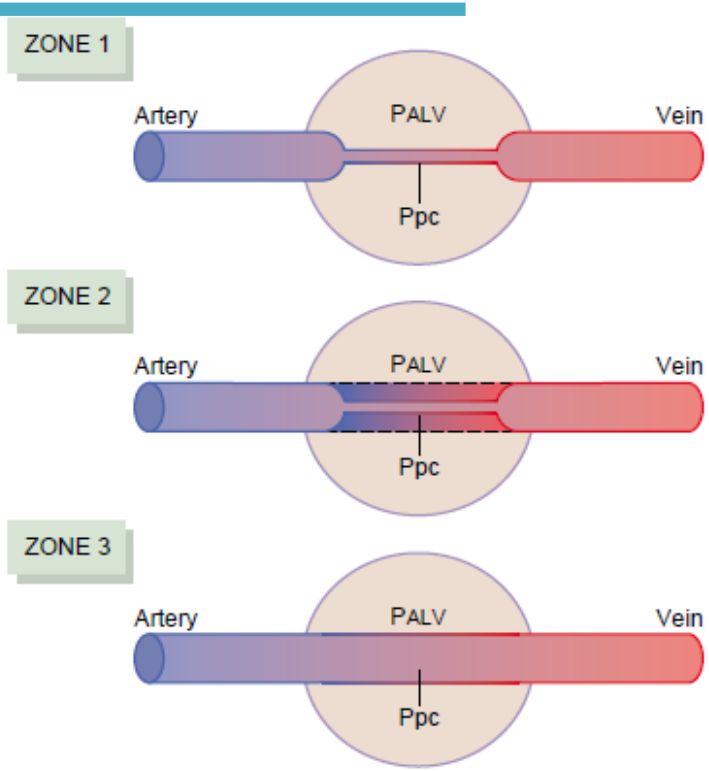


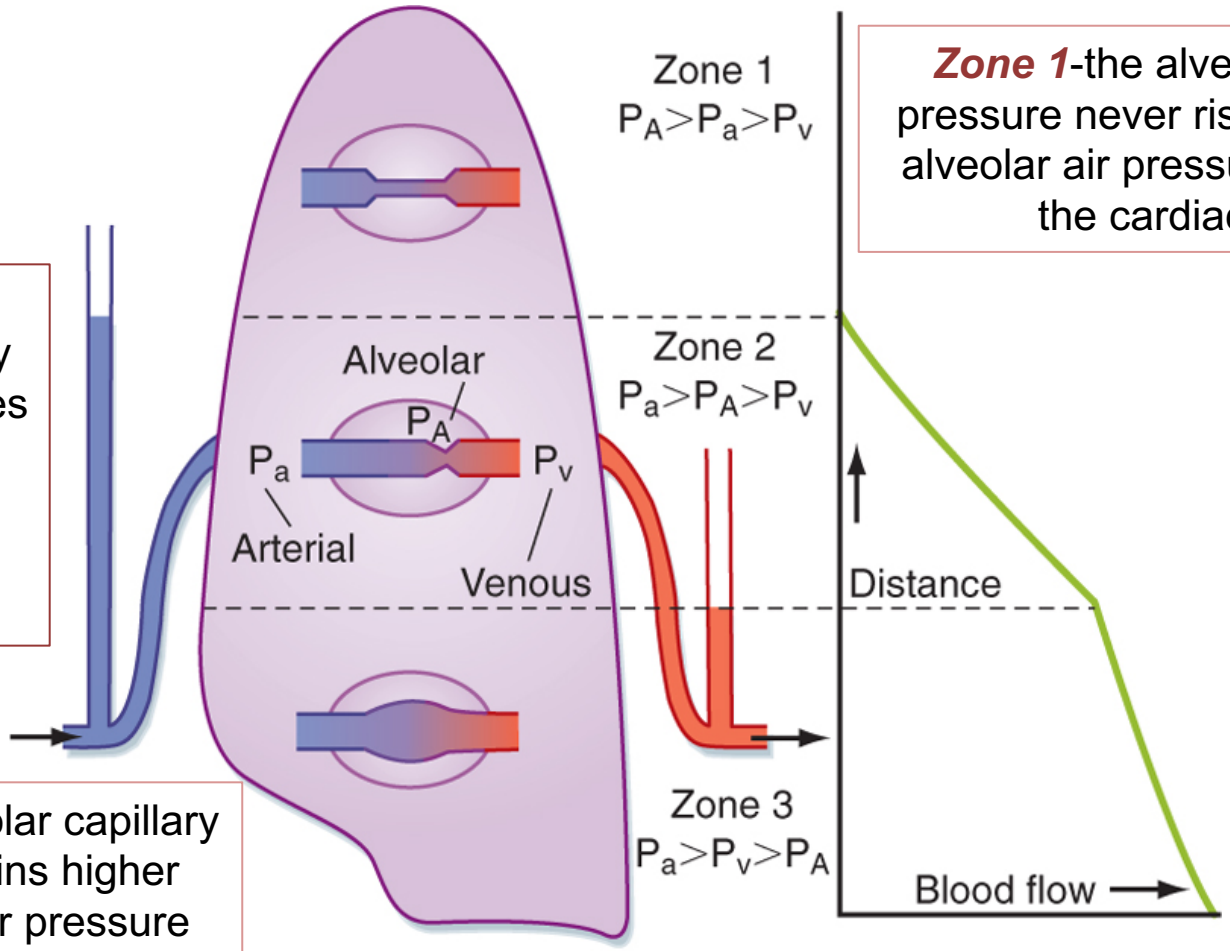
Figure 38–4

Mechanics of blood flow in the three blood flow zones of the lung: *zone 1, no flow*—alveolar air pressure (PALV) is greater than arterial pressure; *zone 2, intermittent flow*—systolic arterial pressure rises higher than alveolar air pressure, but diastolic arterial pressure falls below alveolar air pressure; and *zone 3, continuous flow*—arterial pressure and pulmonary capillary pressure (Ppc) remain greater than alveolar air pressure at all times.

Perfusion Zones of the Lung

Zone 1-the alveolar capillary pressure never rises higher than alveolar air pressure throughout the cardiac cycle.

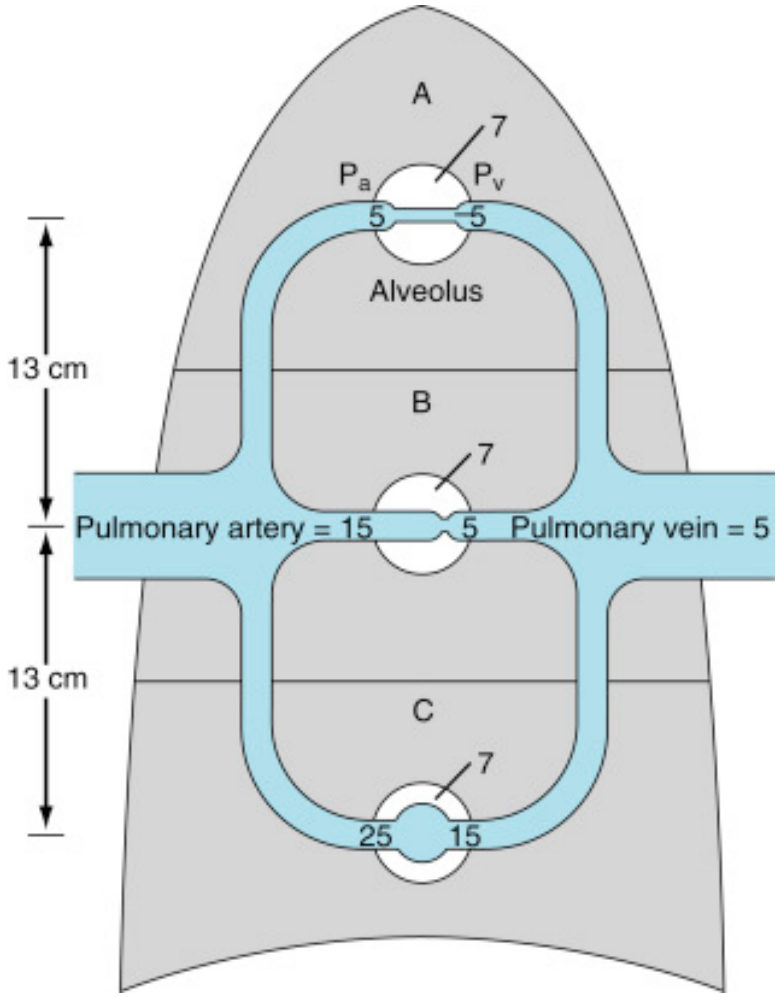
Zone 2-the alveolar capillary pressure becomes higher than alveolar air pressure only during systole.



Zone 3-the alveolar capillary pressure remains higher than alveolar air pressure throughout the cardiac cycle.

Perfusion Zones of the Lung

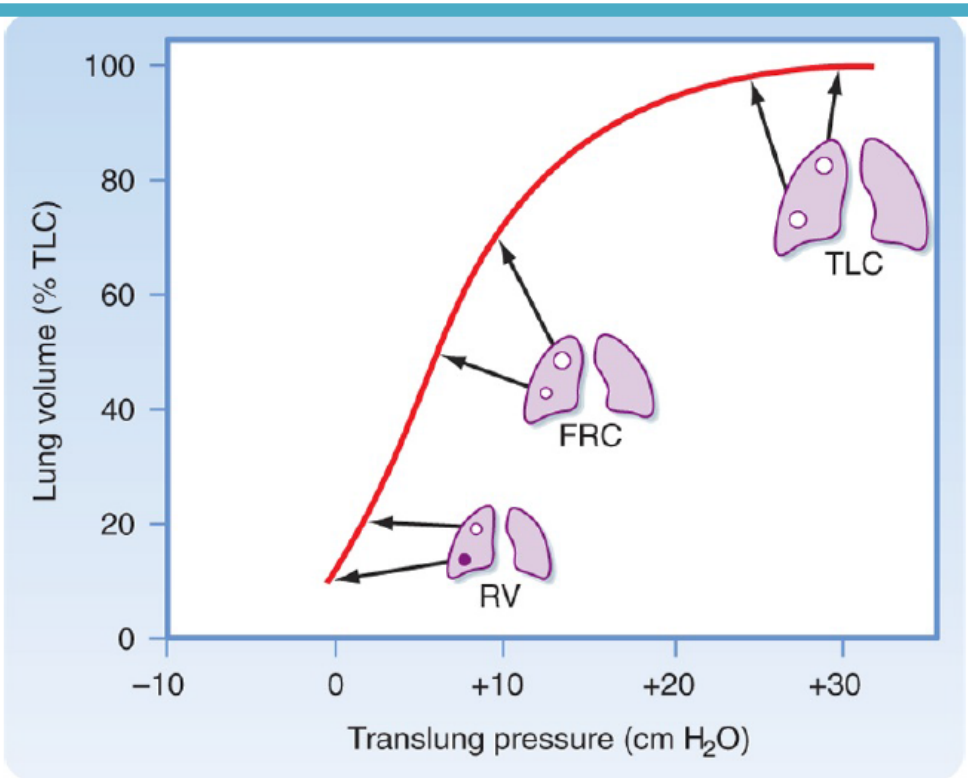
- Zone 1 is not normally seen in the lung.. ***When can zone 1 be seen in the lung?***
- Normal lungs have only zones 2 & 3;
  - Zone 2 at the apices.
  - Zone 3 in all lower areas.
- Zone 2 blood flow begins in the normal lung about 10cm above the midlevel of the heart and extends from there to the top of the lungs.
- ***What happens in a person who is lying down?***



What about ventilation?!!

Is it affected by gravity as well?

Regional Differences in Pulmonary Ventilation



Regional distribution of lung volume, including alveolar size and location on the pressure volume curve of the lung at different lung volumes. Because of suspension of the lung in the upright position, the pleural pressure (Ppl) and translung pressure (PL) of units at the apex will be greater than those at the base. These lung units will be larger at any lung volume than units at the base. The effect is greatest at residual volume (RV), is less at functional residual capacity (FRC), and disappears at total lung capacity (TLC). Note also that because of their location on the pressure-volume curve, inspired air will be differentially distributed to these lung units; the lung units at the apex are less compliant and will receive a smaller proportion of the inspired air than the lung units at the base, which are more compliant (i.e., reside at a steeper part of the pressure-volume curve).

Ventilation/Perfusion Ratio (V/Q Ratio)

- It is the ratio of alveolar ventilation to pulmonary blood flow per minute.
- The alveolar ventilation at rest (4.2 L/min)
- The pulmonary blood flow is equal to right ventricular output per minute (5L/min)

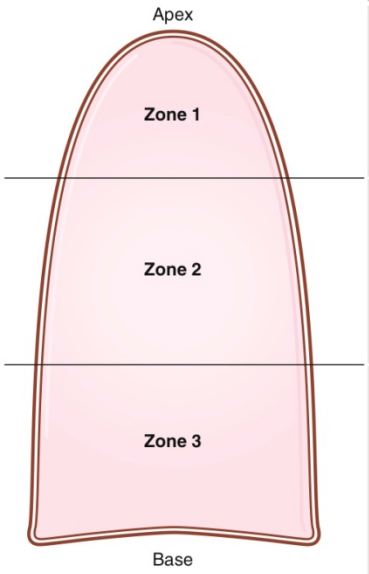
V/Q ratio= 4.2/5 = 0.84

- Alveolar ventilation is 80% of the value for pulmonary blood flow if the tidal volume and cardiac output are normal.

Variation in V/Q in the zones of the lung

- V/Q is uneven in the three zones.
- At the apex V/Q ratio = 3
- At the base V/Q ratio=0.6
- The apex is more ventilated than perfused and the base is more perfused than ventilated.
- During exercise the V/Q ratio becomes more homogenous among different parts of the lung.

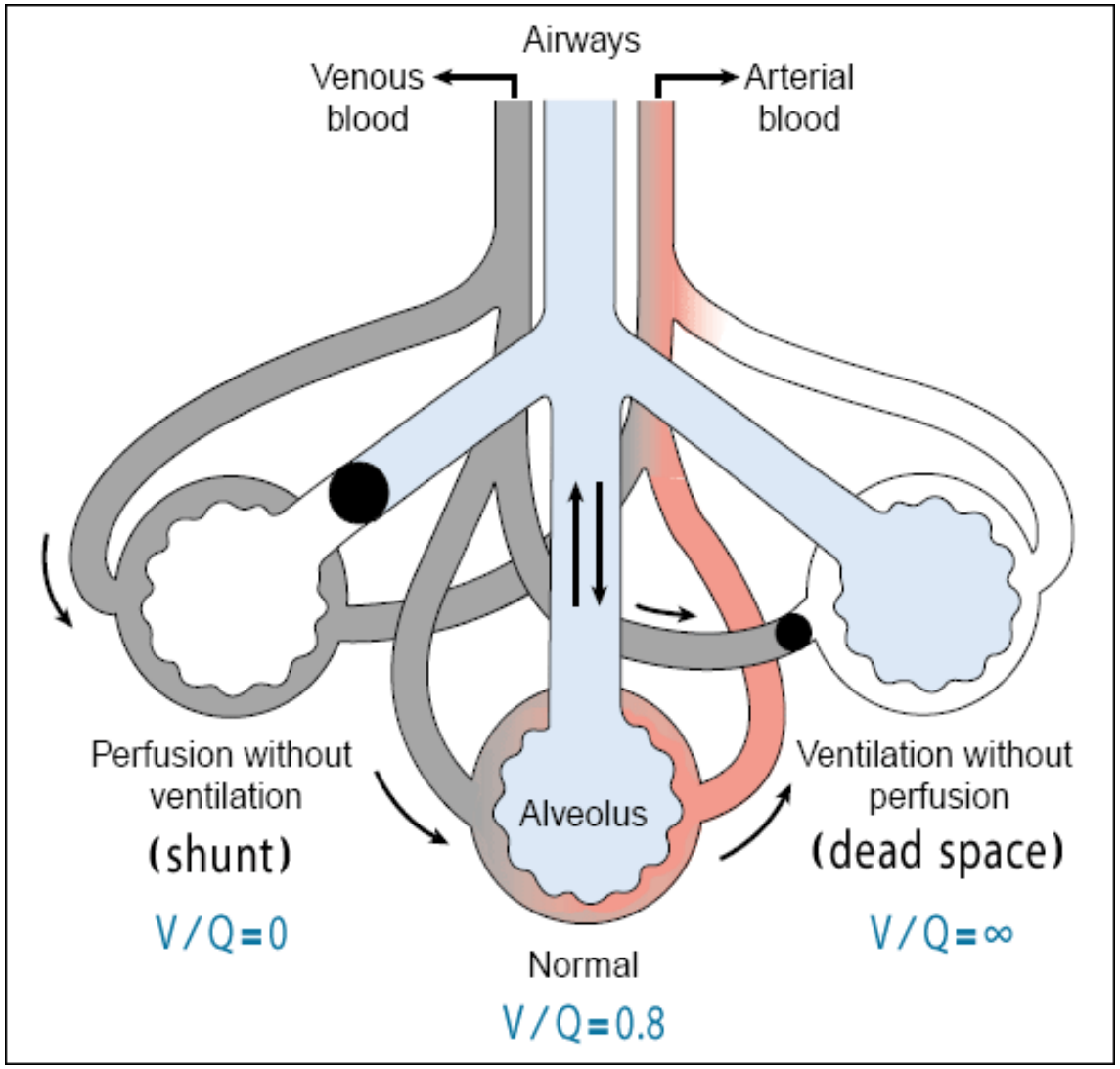
V̇/Q̇ DISTRIBUTION IN THE LUNG



	Blood Flow ($\dot{Q}$)	Alveolar Ventilation ($\dot{V}$)	$\frac{\dot{V}}{\dot{Q}}$	Pa_{O_2}	Pa_{CO_2}
Zone 1	Lowest	Lower	Highest (3.0)	Highest (130 mm Hg)	Lower (28 mm Hg)
Zone 2	–	–	–	–	–
Zone 3	Highest	Higher	Lowest (0.6)	Lowest (89 mm Hg)	Higher (42 mm Hg)

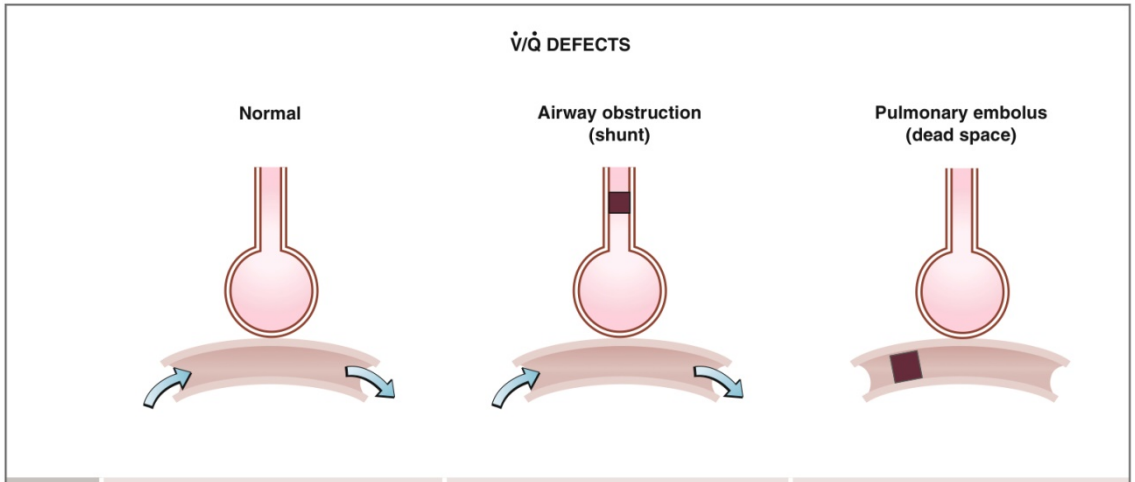
Figure 5-27 Variation in ventilation/perfusion (V̇/Q̇) in the three zones of the lung. The effects of regional differences in V̇/Q̇ on Pa_{O_2} and Pa_{CO_2} also are shown.

V/Q Ratio



- The main function of this ratio is to determine the state of oxygenation in the body.
- Apex V/Q ratio = 3 (moderate degree of physiologic or normal dead space).
- Base V/Q ratio= 0.6 (represent a physiologic or normal shunt).
- Any mismatch in the ratio can result in hypoxia.

Abnormalities in V/Q Ratio



$\dot{V}/\dot{Q}$	0.8	0	∞
$P_{A_{O_2}}$	100	—	150
$P_{A_{CO_2}}$	40	—	0
Pa_{O_2}	100	40	–
Pa_{CO_2}	40	46	–

Figure 5-30 **Effect of ventilation/perfusion ($\dot{V}/\dot{Q}$) defects on gas exchange in the lungs.** With airway obstruction, the composition of systemic arterial blood approaches that of mixed venous blood. With pulmonary embolus, the composition of alveolar air approaches that of inspired air.

- Changes in V/Q ratio can be caused by changes in ventilation or perfusion or both.
- In airway obstruction: alveolar ventilation is affected (shunt).
- In pulmonary embolism: perfusion is affected (dead space).