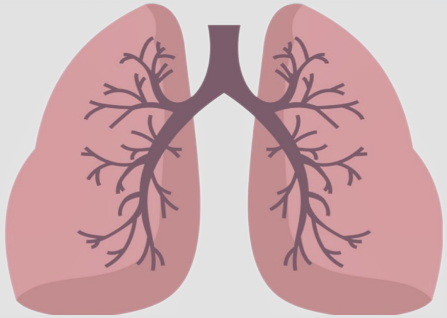
Ventilation, Perfusion, Ratio.



Respiratory Block

Physiology 439 team work

- Black: in male / female slides
- Red : important
- Pink: in female slides only
- Blue: in male slides only
- Green: notes
- Gray: extra information
- Textbook: Guyton + Linda

Editing file

@Physiology_439

Objectives :

01 Recognize the high pressure and low pressure circulations supplying the lung.

02 Identify the meaning of the physiological shunt in the pulmonary circulation.

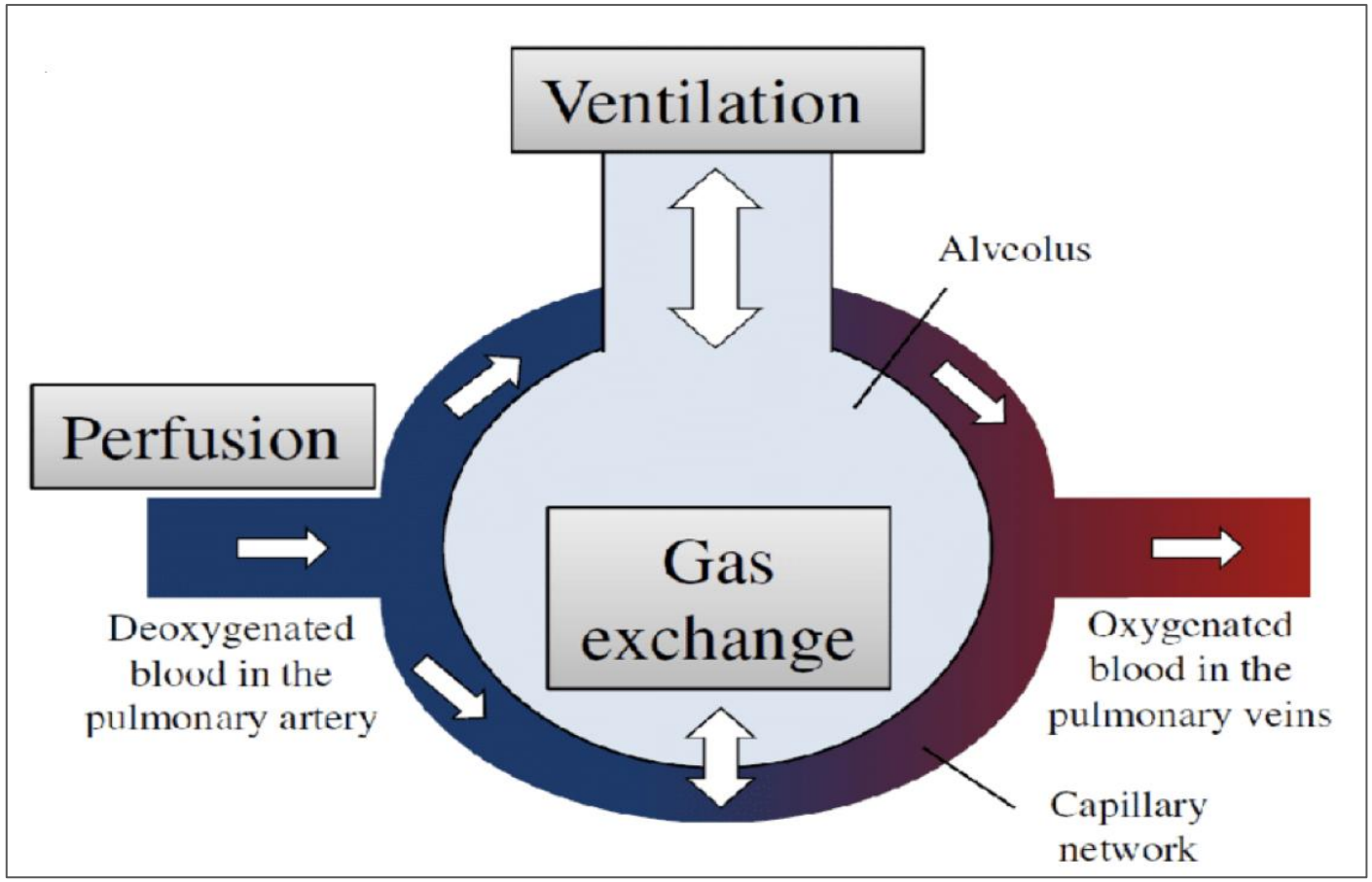
03 State the different lung zones according to the pulmonary blood flow.

04 Define the V/Q ratio and its regional variation.

05 Explain the clinical significance of the V/Q ratio

06 Describe the abnormal patterns of the V/Q ration vice, shunt and dead space patterns.

Only in girls slide



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

The lung has dual blood supply

Pulmonary Circulation

Low pressure, high flow circulation supplies venous blood from all parts of the body to the alveolar capillaries where oxygen (O2)is added and carbon dioxide (CO2) is removed.

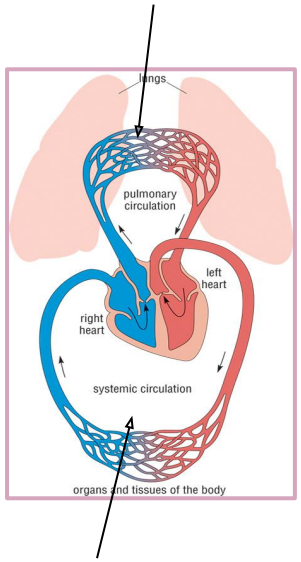
Supplies deoxygenated blood to lungs to become oxygenated.

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

100% of CO

The pulmonary artery (which receives blood from the right ventricle) and its arterial branches carry blood to the alveolar capillaries for gas exchange, and the pulmonary veins then return the blood to the left atrium to be pumped by the left ventricle through the systemic circulation.

Low pressure circulation



High pressure circulation

Bronchial Circulation

High pressure, low flow circulation supplies systemic arterial blood to the trachea, the bronchial tree (including the terminal bronchioles), the supporting tissues of the lung, and the outer coats (adventitia) of the pulmonary arteries and veins.

.

Supplies oxygenated blood to lung tissue. (Supplies O2-rich blood to lung tissue)

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

Approximately 1-2% of CO

The bronchial arteries, which are branches of the thoracic aorta, supply most of this systemic arterial blood at a pressure that is only slightly lower than the aortic pressure.

Only in boys slides

Shunts

A shunt:
refers to a portion of the pulmonary blood flow that bypasses the alveoli(no gas exchange).

Physiological shunt:
bronchial blood flow bypasses the alveoli and coronary blood flow(2%).

From Guyton:
whenever V/Q is below normal,there is inadequate ventilation to provide the O2 needed to fully oxygenate the blood flowing through the alveolar capillaries.Therefore, a certain fraction of the venous blood passing through the pulmonary capillaries not become oxygenated.This Fraction is called shunted blood.Also,some additional blood flows through bronchial vessels rather than through alveolar capillaries,normally about 2 percent of the cardiac output,this, too is oxygenated shunted blood.
The total quantitative amount of shunted blood per minute is called the physiological shunt.

Example of abnormal shunt:
defects in the wall of the ventricles(will not be treated by high oxygen supply but useful diagnostic tool).

Anatomic 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 → "Right -to-Left shunt"

So, What Exactly happen?

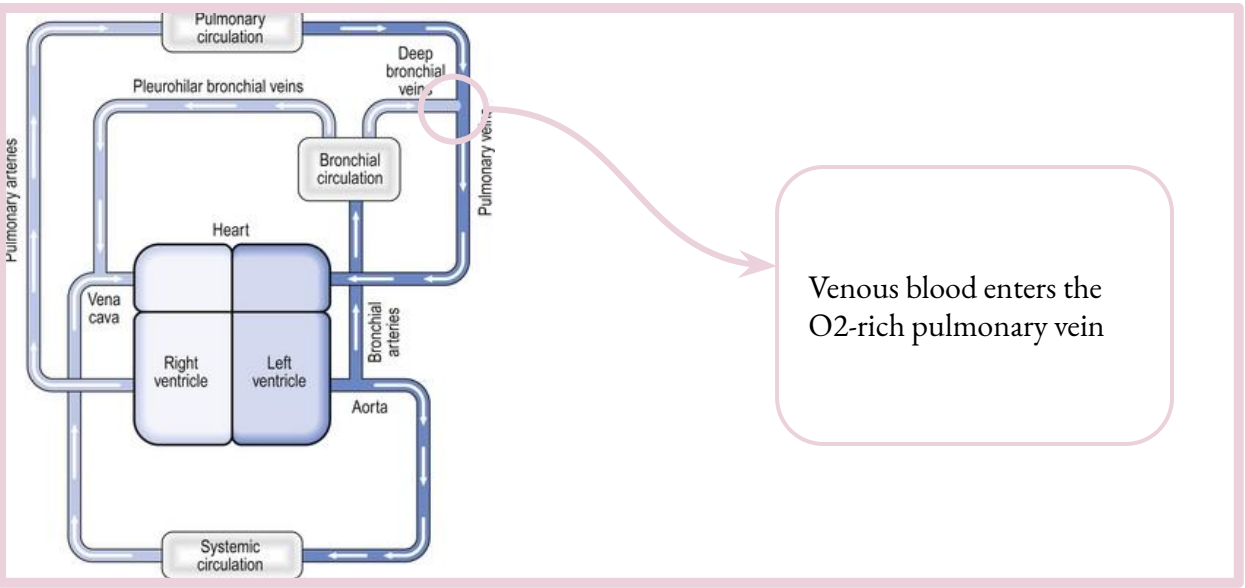
After lung tissue extracts (used) the needed O2 (the O2 which carry by bronchial artery) , ⅔ of the resultant deoxygenated blood drains into pulmonary veins (which carry O2-rich blood to the Lt atrium) causing venous admixture of deoxygenated blood with newly oxygenated blood coming from the pulmonary circulation.

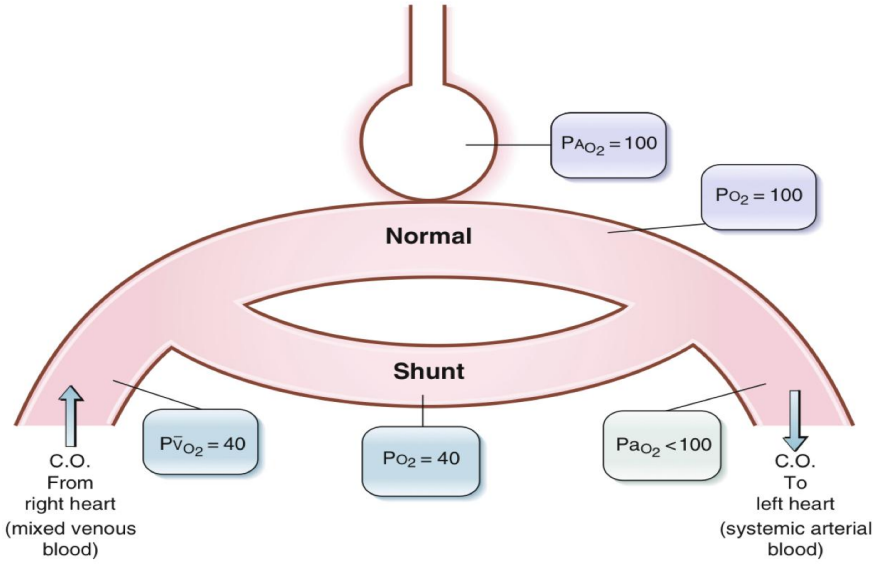
In other word,

-Blood also flows to the lungs through small bronchial arteries amounts to 1-2 percent of the total cardiac output,this bronchial arterial blood is oxygenated blood, supplies the supporting tissues of the lungs, including the connective tissue, septa, and large and small bronchi.

-After this bronchial blood passes through the supporting tissues, it empties into the pulmonary veins and enters the left left atrium,rather than passing back to the right atrium.

-So,The flow into the left atrium and the left ventricular output are about 1 to 2 percent greater than that of the right ventricular output.





Pulmonary Perfusion
“pulmonary blood flow”

Definition

the blood flow through the lung that supplies deoxygenated blood to the lung to be oxygenated.
This means “pulmonary circulation”

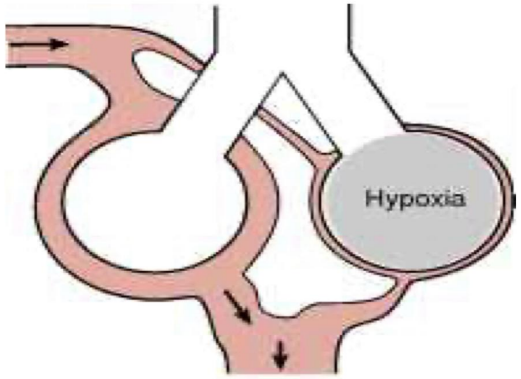
Pulmonary perfusion or pulmonary blood flow is affected(Regulated) by several factors ***include***

Alveolar oxygenation.
The major factor regulating pulmonary blood flow is the partial pressure of O2 in alveolar gas,PAo2.
Will discuss in next slides

Hydrostatic pressure gradient
(the effect of gravity)

Alveolar oxygenation

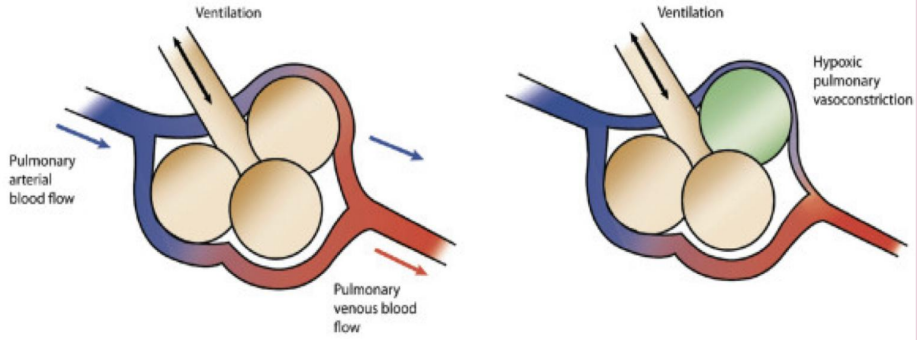
Helpful video,click here



↓ In Alveolar Po2
(Po2<73,70mmHg)

produce pulmonary vasoconstriction
-Vasoconstriction of the vessels surrounding the hypoxic alveolus
This causes blood to flow to areas of the lungs that are better aerated
-adaptive mechanism: Blood flow is directed away from poorly ventilated region.

This is opposite to the effect observed in systemic vessels



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.

1- High altitude,PAo2 is reduced which produced global vasoconstriction.
2- Fetal pulmonary blood flow circulation is about 15%of cardiac output due to global vasoconstriction.

The Hydrostatic Pressure Gradient

The Hydrostatic Pressure Gradient in the body

In the upright position
the pressure of blood is not the same around the body
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.
بمعنى كل ما طلعنا فوق قل الضغط بمقدار 0.77
وكل مانزلنا تحت زاد الضغط بمقدار 0.77

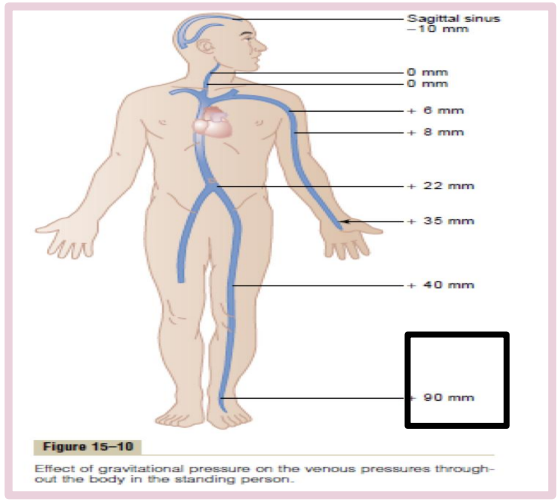


Figure 15–10
Effect of gravitational pressure on the venous pressures throughout the body in the standing person.

The highest blood flow In the foot

The Hydrostatic Pressure Gradient in the lung

The same effect happens in the lung.

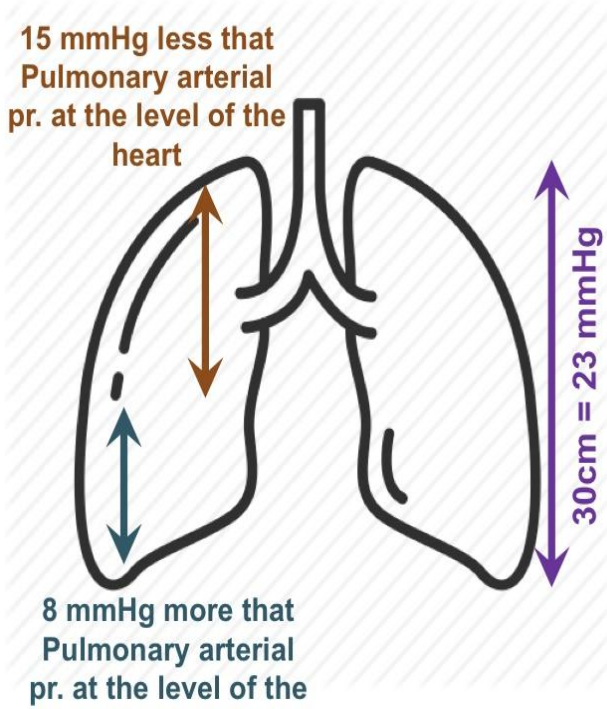
The distance between apex and base of lung ≈ 30cm in other word The lowest point in the lungs is normally about 30 cm below the highest point Which means 23mmHg pressure difference between apex and base of the lung ,15mmHg above the heart and 8mmHg below the heart.

due to the gravitational effect,The pulmonary arterial pressure in the uppermost portion of the lung of a standing person is about 15 mm Hg less than the pulmonary arterial pressure at the level of the heart, and the pressure in the lowest portion of the lungs is about 8 mm Hg greater.

Such pressure differences have profound effects on blood flow through the different areas of the lungs. This effect depicts blood flow per unit of lung tissue at different levels of the lung in the upright person.

In the standing position at rest, there is little flow in the top of the lung but about five times as much flow in the bottom

In supine position, blood flow is nearly uniform.



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.

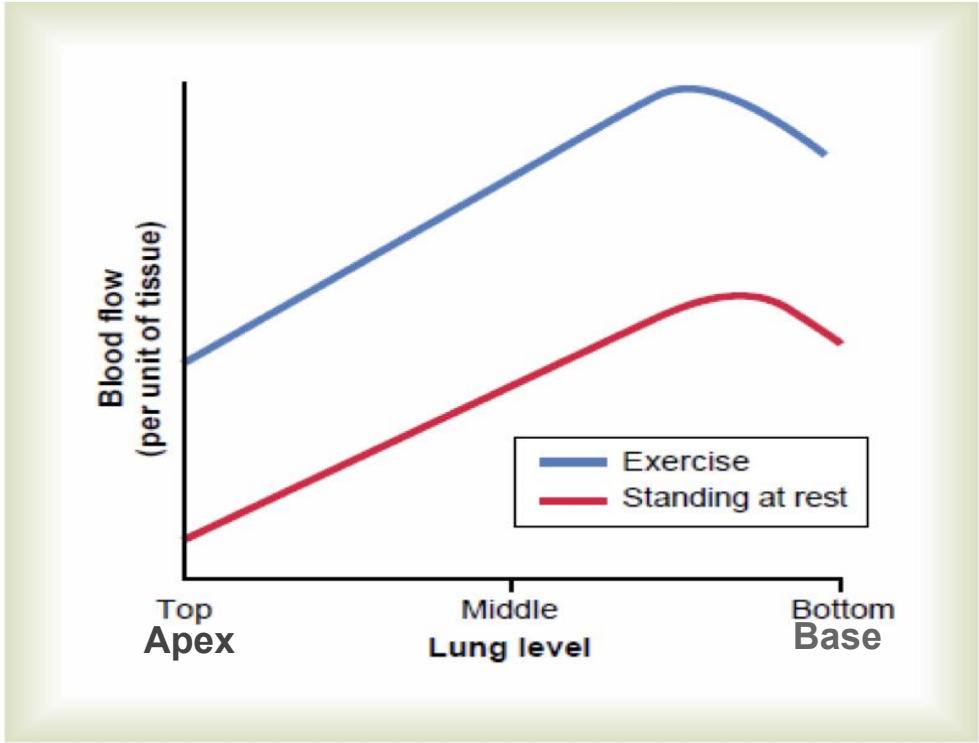


Figure 38–3

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** during during all portions of the cardiac cycle because the local alveolar capillary pressure never rises higher than the alveolar air pressure during any part of the cardiac cycle.

- Zone 2: **Intermittent blood** flow only during the peaks of pulmonary arterial pressure because the systolic pressure is then greater than the alveolar air pressure, but the diastolic pressure is less than the alveolar air pressure.

- Zone 3: **Continuous blood flow** because the alveolar capillary pressure remains greater than alveolar air pressure during the entire cardiac cycle

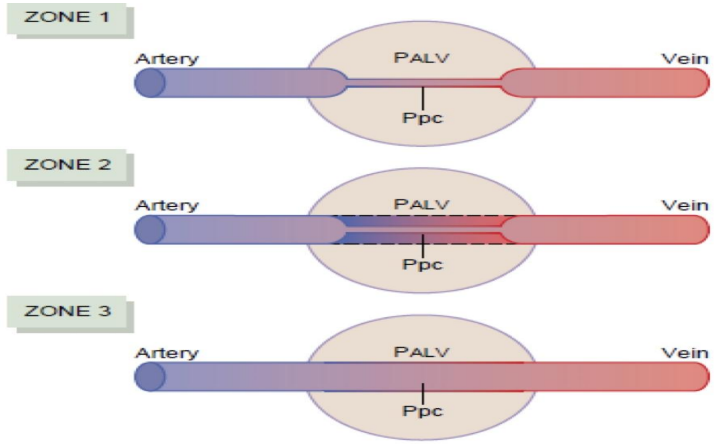
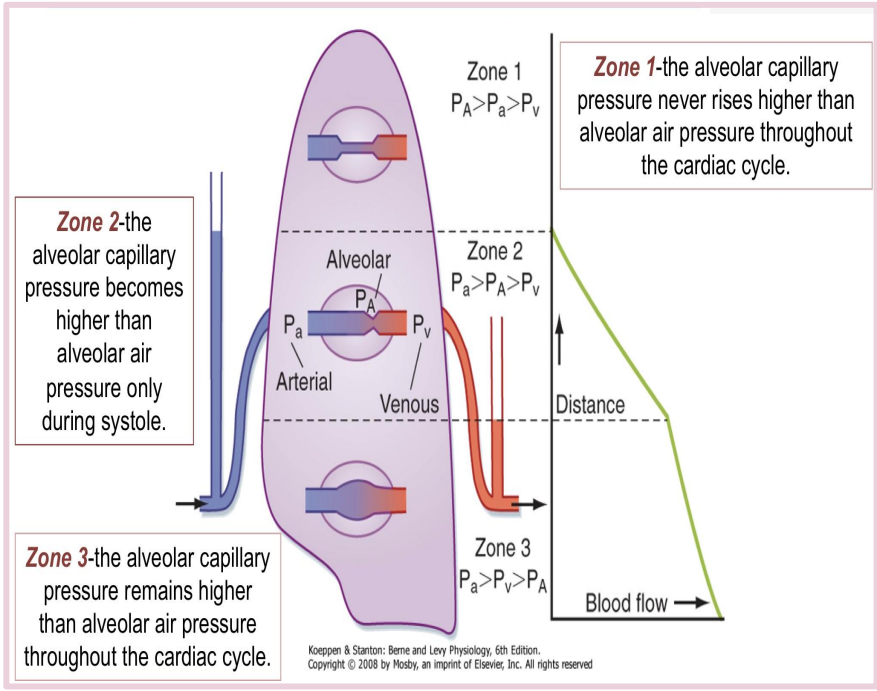


Figure 38–4

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.



Cont.Perfusion Zones of the Lung

Zone 1 is not normally seen in the lung

From linda:

This situation can occur if arterial blood pressure is decreased as a result of hemorrhage or if alveolar pressure is increased because of positive pressure ventilation.(explained by girls Dr)

Positive pressure ventilation

يدخل هواء بشكل كبير جدًا في ال alveoli فيزيد الضغط فيها ف بالتالي بتتأثر ال capillaries اللي حولها

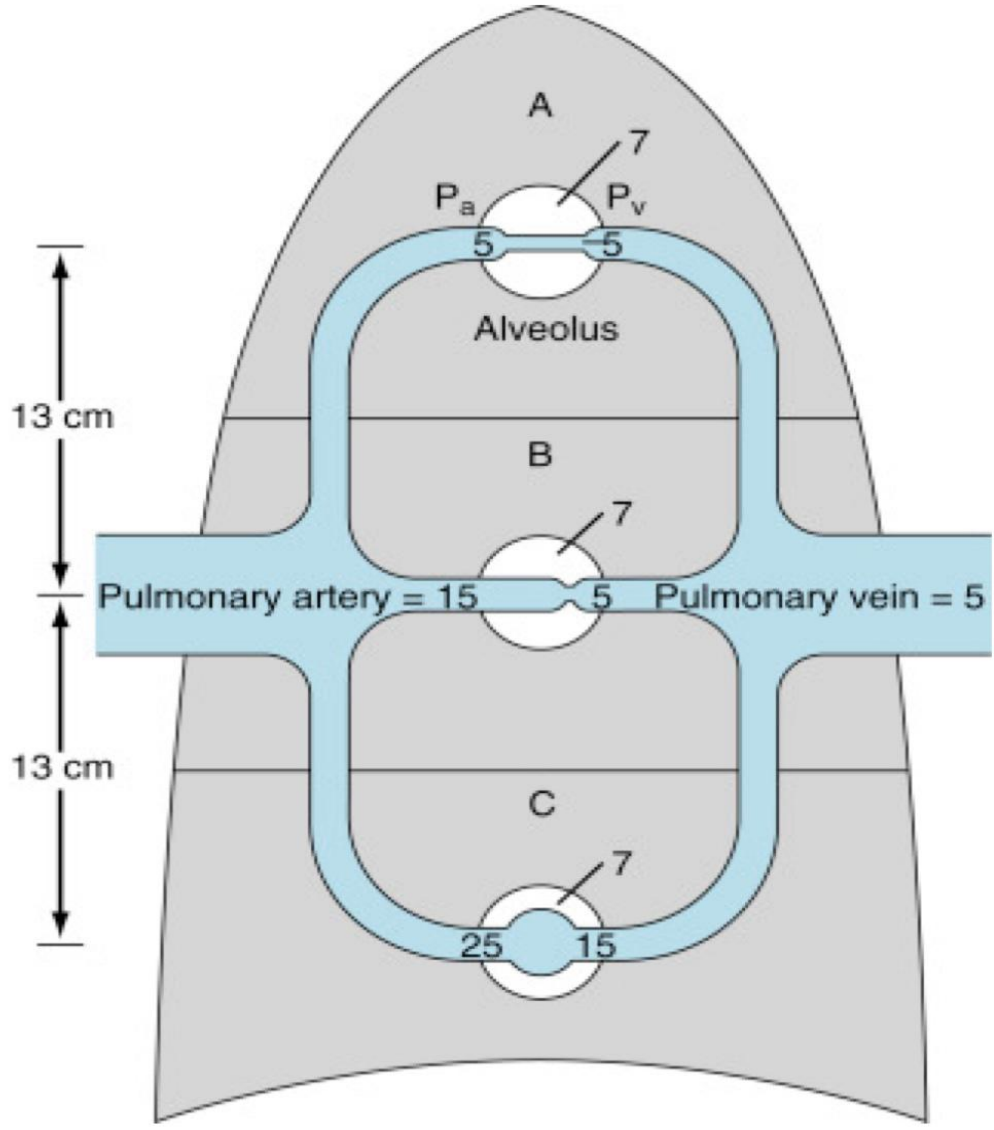
Normal lungs have only zones 2 & 3

Zone 2 at the apices.

- Zone 3 in all lower areas.

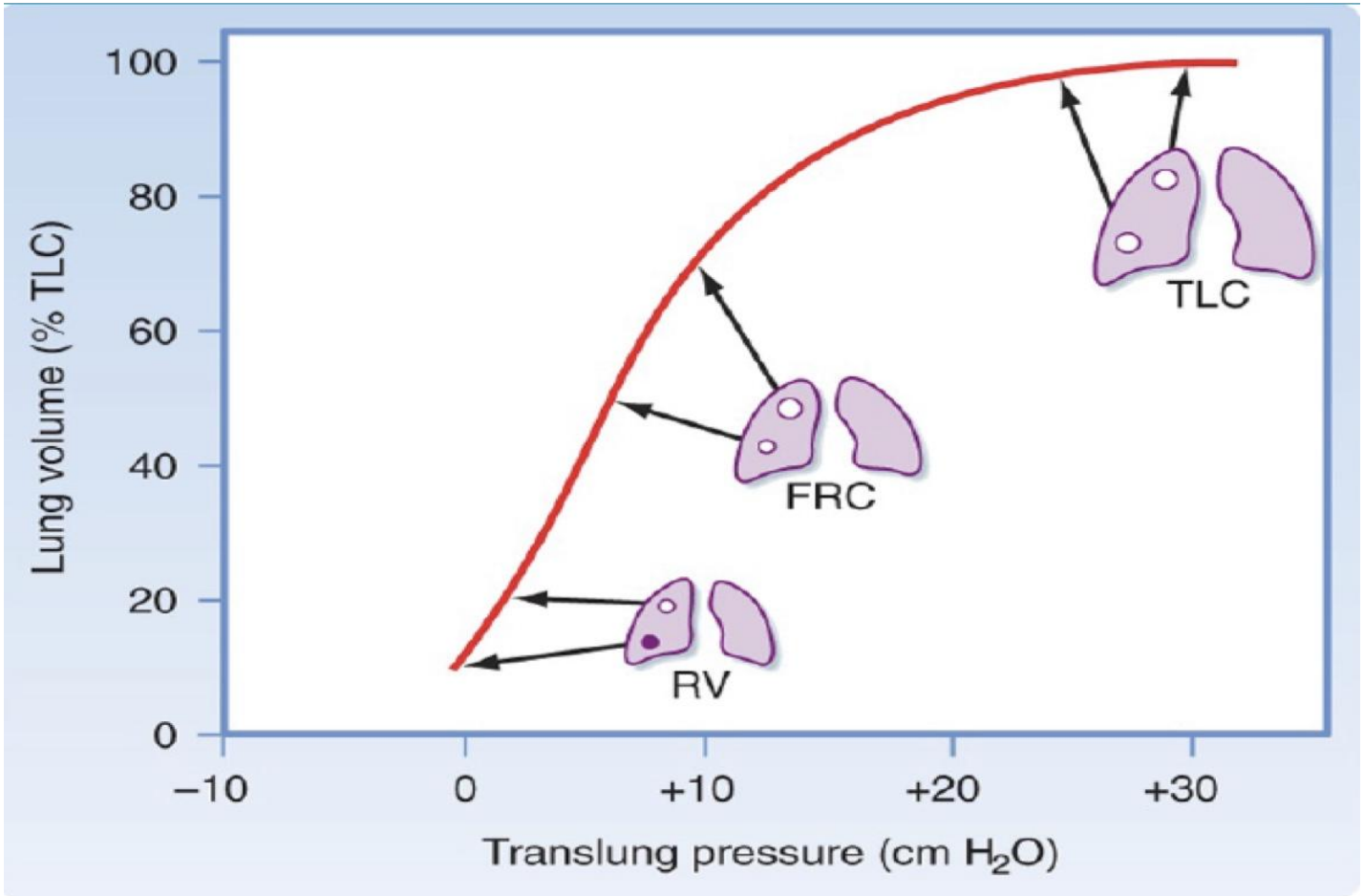
¾ of our lungs are zone 3

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.



In girls slides only

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 Ventilation = respiratory rate (RR) X tidal volume (TV)

The pulmonary blood flow is equal to right ventricular output per minute= 5L/min

V/Q ratio = 4.2/5 = 0.84 — معناته ان 80% من الwell ventilated alveoli are perfused

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

Any mismatch in the ratio can result in hypoxia.

The main function of this ratio is to determine the state of oxygenation in the body.

V/Q is uneven*غير متطابق* in the three zones

At the apex V/Q ratio = 3 (moderate degree of physiologic dead space)
The apex is more ventilated than perfused

At the base V/Q ratio=0.6 (represent a physiologic or normal shunt)
the base is more perfused than ventilated

During Exercise and laying flat in bed the V/Q ratio becomes more homogenous among different parts of the lung.

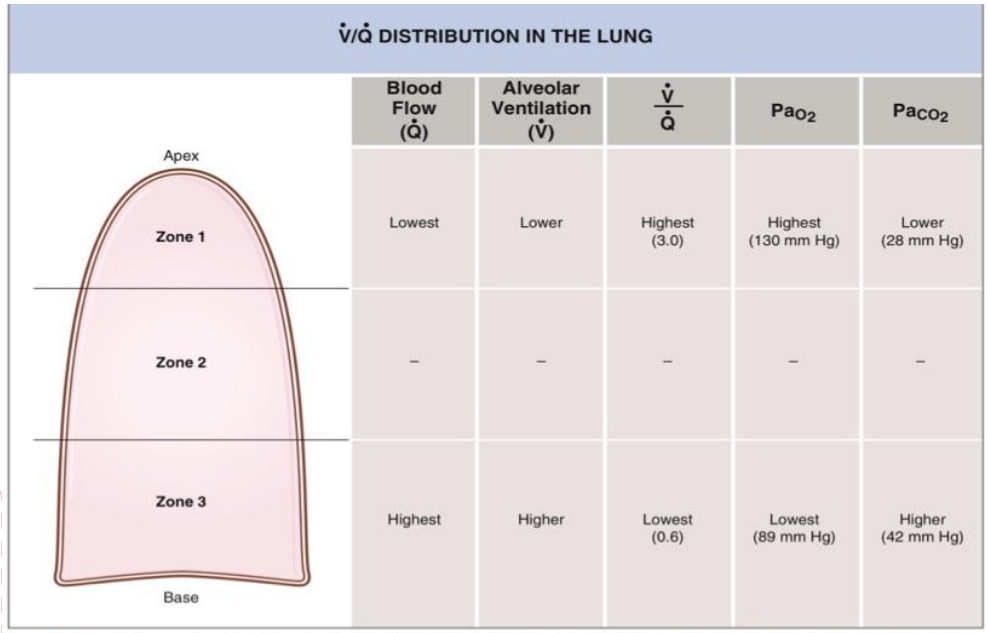
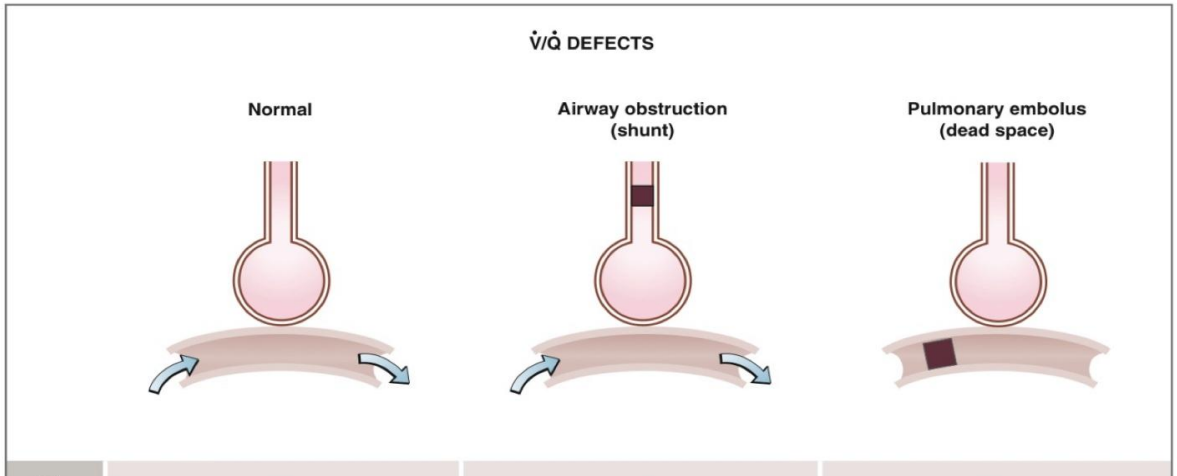


Figure 5-27 **Variation in ventilation/perfusion (V̇/Q̇) in the three zones of the lung.** The effects of regional differences in V̇/Q̇ on Pa_{O_2} and Pa_{CO_2} also are shown.

Abnormalities in V/Q Ratio



V̇/Q̇	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 (V̇/Q̇) 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).

Extra,helpful Graph

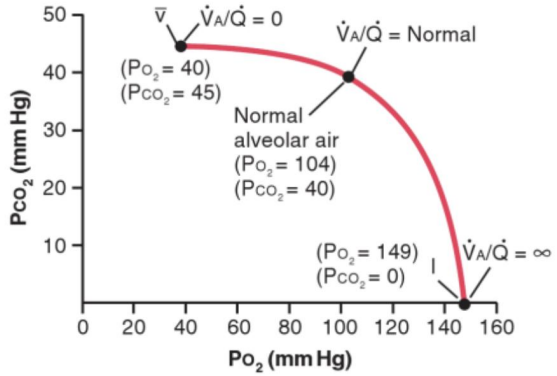


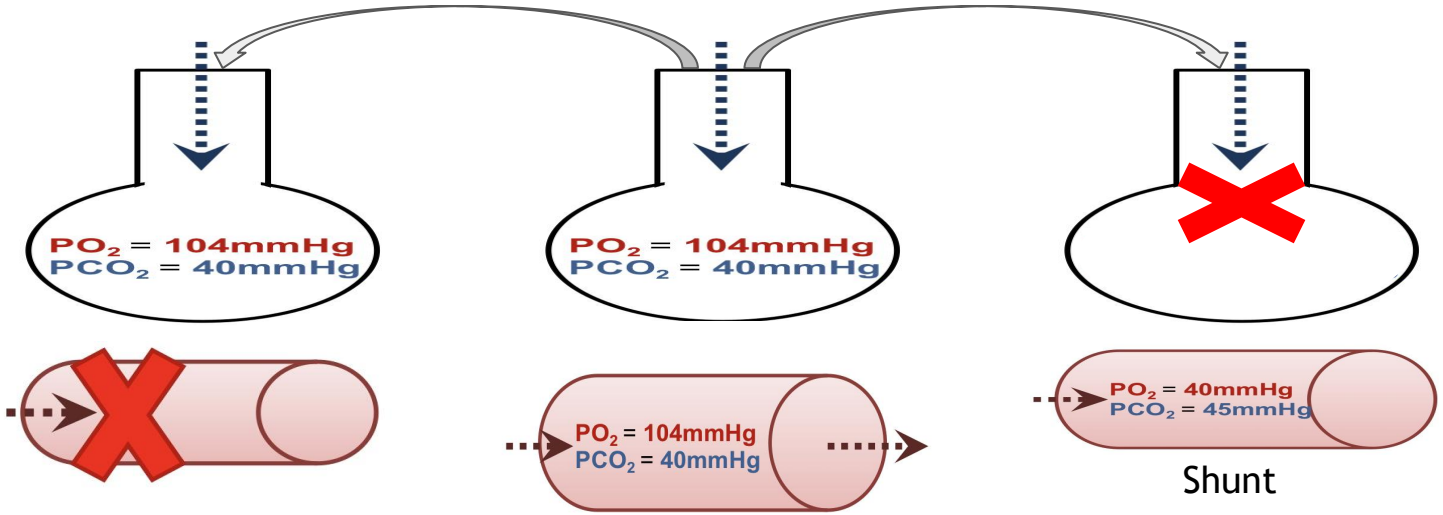
Figure 40-11. Normal partial pressure of oxygen (P_{O_2})–partial pressure of carbon dioxide (P_{CO_2}) ventilation-perfusion ($\dot{V}_A/\dot{Q}$) ratio (P_{O_2}-P_{CO_2}, $\dot{V}_A/\dot{Q}$) diagram.

Only in girls slide

Cont.Abnormalities in V/Q Ratio

If alveolus is ventilated but NOT perfused

If alveolus is perfused but NOT ventilated



Wasted ventilation

Shunt

When V/Q is more than normal this is called **Physiologic dead space** (when the ventilation of some of the alveoli is great but the alveolar blood flow is low, ventilation of these alveoli is wasted).

When the V/Q ratio is less than normal this is called physiologic shunt (a certain fraction of the venous blood is passing through the pulmonary capillaries without being oxygenated i.e shunted blood).

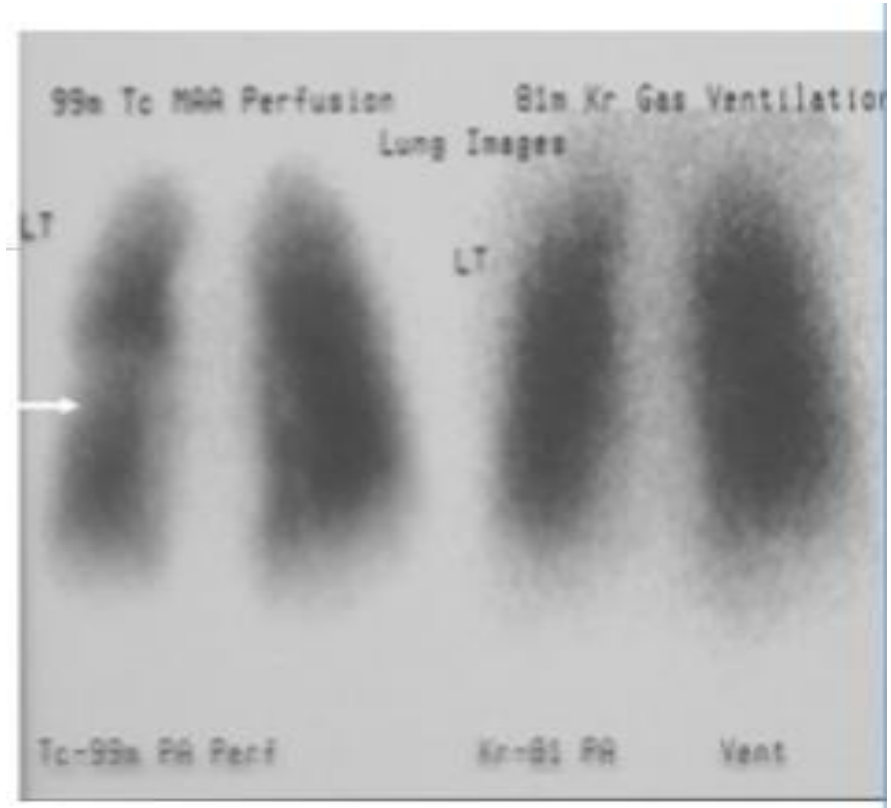
Only in girls slide

Cont.Abnormalities in V/Q Ratio

In Chronic Obstructive Lung disease (COPD).

-because of bronchial obstruction in some areas and destruction of the alveolar septa in other areas with patent alveoli those people has some areas of the lung exhibit serious
physiologic shunt and other areas serious physiologic dead space.

-COPD is the most prevalent cause of pulmonary disability today, lung effectiveness as a gas exchange organ may decrease to 10%



Ventilation- Perfusion Lung Scan

Summary

Pulmonary Circulation

Starts at Right atrium → Right ventricle → Pulmonary art. → Capillaries → Pulmonary veins → Left atrium.

Bronchial Circulation

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

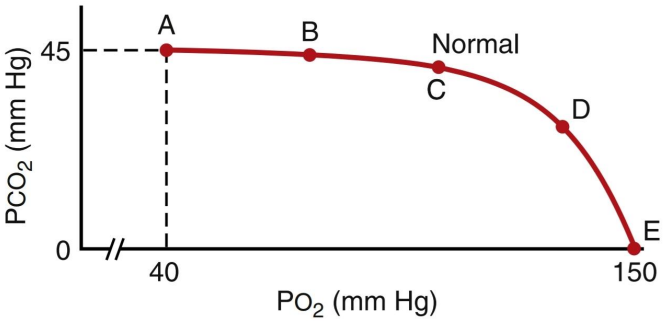
A shunt: refers to a portion of the pulmonary blood flow that bypasses the alveoli(no gas exchange)
Physiologic shunt: bronchial blood flow bypasses the alveoli and coronary blood flow(2%).

In airway obstruction: alveolar ventilation is affected (shunt).
In pulmonary embolism: perfusion is affected (dead space).

The main function of V/Q ratio is to determine the state of oxygenation in the body

Quiz

Questions 1 and 2



1. A 67-year-old man has a solid tumor that pushes against an airway, partially obstructing airflow to the distal alveoli. Which point on the V/Q line of the O2-CO2 diagram above corresponds to the alveolar gas of these distal alveoli?

A)A **B)**B **C)** C **D)** D **E)** E

2. A 55-year-old man has a pulmonary embolism that completely blocks the blood flow to his right lung. Which point on the V/Q line of the O2-CO2 diagram above corresponds to the alveolar gas of his right lung?

A)A **B)**B **C)** C **D)** D **E)** E

3. What happens when perfusion to an alveolus is reduced relative to ventilation?

A) PO2 rises and CO2 falls in alveoli.
B) PO2 falls in the alveoli and CO2 rises.
C) PO2 and CO2 in the alveolus falls
D) PO2 and CO2 in the alveolus rises.

---

4. What could possibly cause the left ventricular output to be greater than that of the right ventricular output?

A) Bronchial artery
B) Coronary artery
C) Right to left shunt (in the walls of the ventricles)
D) All of the above

1)B 2)D 3)A 4)D

SAQ

1. **Compare the ventilation/perfusion ratio between the apex and the base of the lung?**

2. **What is the relationship between the alveolar air pressure and alveolar capillary pressure?**

1.In the apex: the V/Q ratio is high (3) because the alveolar ventilation is low but the perfusion is lower which will cause the ratio to be higher than normal.
In the base: the V/Q ratio is low (0.6) because the alveolar ventilation is high but the blood perfusion is higher which will cause the ratio to be lower than normal.

2.If the alveolar air pressure is higher than the capillary pressure there won't be blood flow or little flow (Zone 1)
If alveolar air pressure is less than the capillary pressure the blood will flow continuously. (Zone 3)

Team leaders :

TeiF Almutiri | Abdulaziz Alkraida

Team Members

- Mishal Althunayan
- Basel Fakeeha
- Ibrahim altamimi
- Abdulaziz Alsuhaim
- Mohammad alkathiri
- Basam alasmari
- Morshed Alharbi
- Ahmad Al Khayat
- Mohammod alghedan
- Nawaf alghamdi
- Raed alntaifi
- Homoud alghadeb
- Mishal alhamed
- Musab alamri
- Fayez altbaa
- Khalid altowijeri
- Mohammed alsalman
- Renad Alhomaidi
- Aseel alshehri
- Noura abdulaziz
- Yasmin Al Qarni
- Alaa Alsulmi
- Farah Albakr
- Muneerah alsadhan
- Sarah alobaid
- Farrah alsaid
- Noura almsaud
- Hessah alalyan
- Rema alhdleg
- Raghad alsweed
- Raghad asiari
- Ghadah alouthman
- Haya alanazi
- Asma alamri
- Rania Almutiri
- Yara alasmari

Reviewed by

- Ghadah alouthman
- homoud Algadheb

Contact us

The subleader:
Sarah alQhtani