Hypoxia and cyanosis

Dr. Felwah Al-Zaid

MBBS, MSc, PhD

Objectives

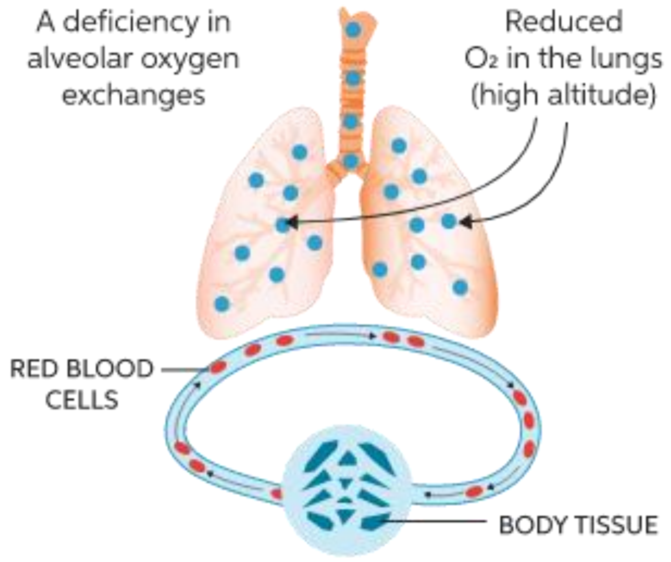
- **By the end of this lecture you should be able to:**
- Define hypoxia and list its various physiological and pathological causes.
- Outlines the treatment of hypoxia.
- Define hypercapnia and list its causes and manifestations.
- Define hypo and hyper-ventilation in terms of arterial PCO2 and PO2.
- Define cyanosis and its clinical presentation.

What is hypoxia?

- Hypoxia is defined as deficiency of oxygen in the tissue cells.

- It is classified into the following groups:-

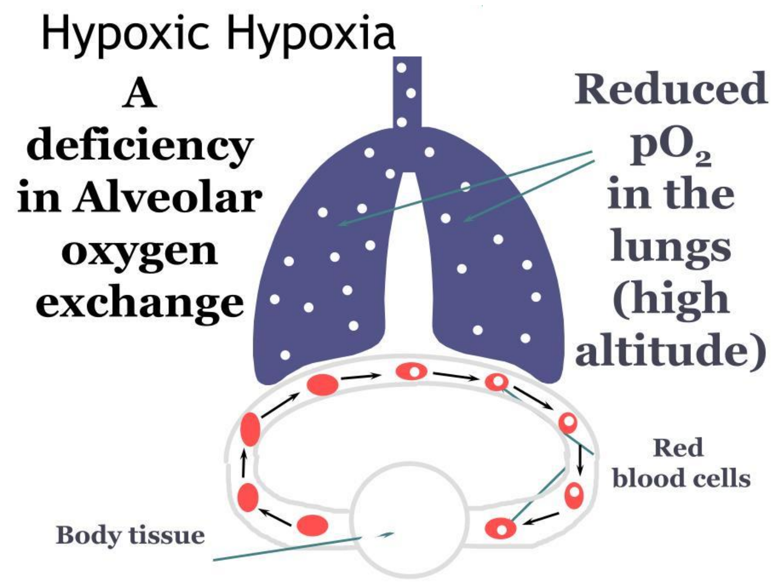
- **Hypoxic or arterial hypoxia**
- **Anemic hypoxia**
- **Stagnant hypoxia**
- **Histotoxic hypoxia**



What do we need for normal oxygenation?

- Oxygen in the air 20.8%.
- Action of chest wall and diaphragm.
- Patent respiratory passages.
- Elastic alveoli.
- Surfactant.
- Wall of alveoli and capillary.
- RBCs, haemoglobin.
- Adequate venous and arterial circulation.
- Capillary walls.
- Tissue fluid.
- Tissue cells.
- Mitochondria.

I-Hypoxic or arterial hypoxia



Reduced arterial PO2 it can be due to:

1- Inadequate blood oxygenation in the lung:

- O2 deficiency in the atmosphere (high altitudes, breathing in closed space).
- Hypoventilation (increase airway resistance / decreased pulmonary compliance).

2- Pulmonary disease:

- Alveolar hypoventilation
- Reduced respiratory membrane diffusion
- Right to left shunt
- Abnormal alveolar ventilation-perfusion ratio (including increased physiological dead space or physiological shunt).

II-Anemic hypoxia

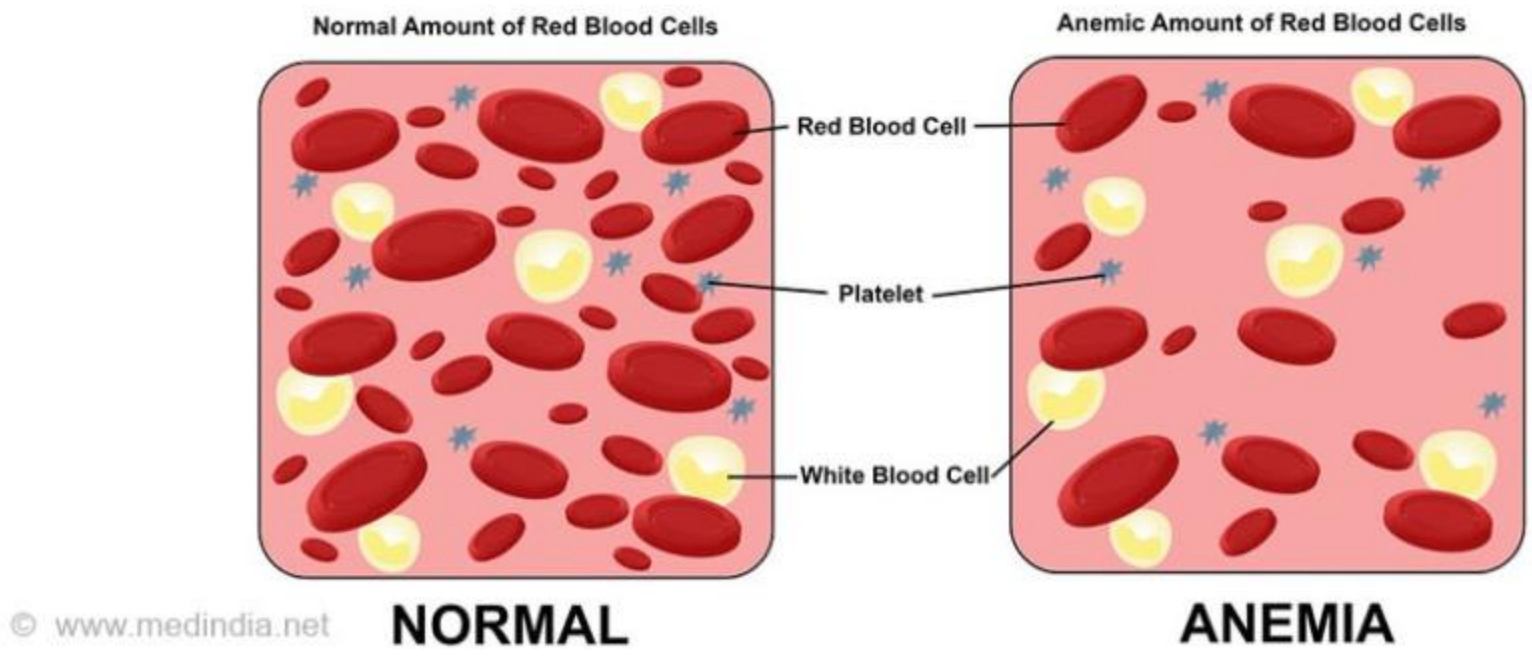
- It is caused by reduction in the oxygen carrying capacity of the blood, due to decreased amount of Hb or abnormal type of Hb which is unable to carry oxygen.
- The PO2 and % Hb-O2 is normal.

Causes:

1- Anemia

2-Abnormal Hb e.g:

- methemoglobin.
- carboxyhemoglobin.

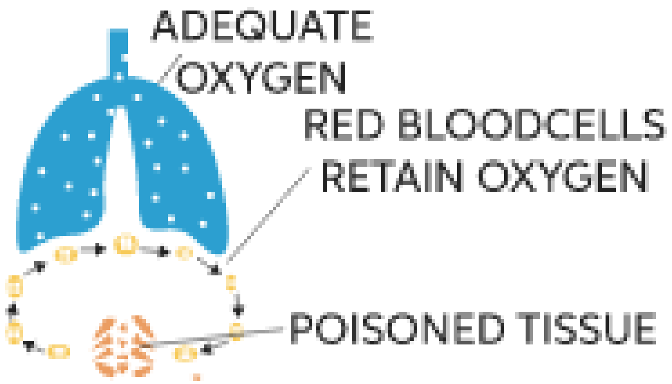


III-Stagnant hypoxia

- Caused by reduced blood flow through the tissues, so more and more oxygen is extracted from the blood, and due to slow circulation less oxygen is carried by the blood at the lung , leading to hypoxia.
- **Causes:**
- 1-General slowing of the circulation, as in heart failure and shock.
- 2-Local slowing e.g vasoconstriction, cold, arterial wall spasm.

IV- Histotoxic hypoxia

- Is defined as the inability of the tissues to use oxygen due to inhibition of the oxidative enzyme activity. e.g cyanide poisoning causing blockade of the cytochrome oxidase activity.
- Deficiencies of some of the *tissue cellular oxidative enzymes* or of other elements in the tissue oxidative system can lead to this type of hypoxia, e.g., *beriberi*, in which several important steps in tissue utilization of oxygen and the formation of CO_2 are compromised because of *vitamin B deficiency*.



What are the clinical effects of hypoxia?

- According to the degree of hypoxia it could lead to:

➢ Impairment of judgment.

➢ Inability to perform complex calculations.

➢ Headache, nausea, irritability, dyspnea, increased heart rate.

➢ Reduction in muscle working capacity.

➢ Eventually, coma and death may occur.

Sudden oxygen drop

- Sudden drop of oxygen to less than 20 mmHg (16,000 m) causes loss of consciousness in about 20 seconds, death in 4-5 min.

Treatment of hypoxia

- Improve the blood oxygen saturation:
- Target saturation in illness is 94-98%.
- In CO_2 retainer 88-92%.
- Adjunct airway.
- Upright posture.
- Oxygen therapy.
- Aids to ventilation.
- Spontaneous breathers CPAP (continuous positive airway pressure).
- Ventilated PEEP (positive end expiratory pressure).

Treatment of hypoxia by Oxygen

- O2 can be administered by :

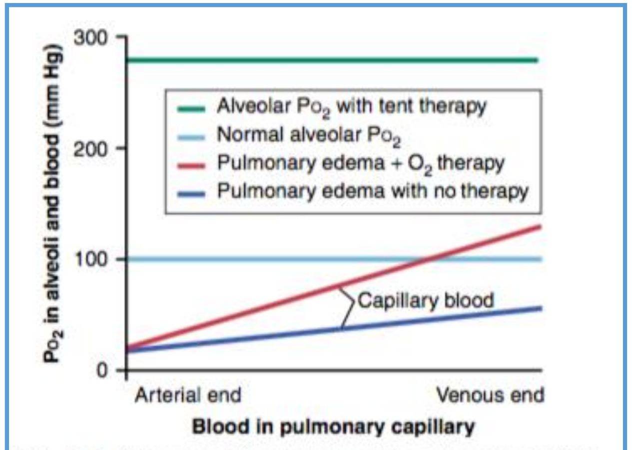
(1) Placing the patient's head in a "tent" that contains air fortified with O2.

(2) Allowing the patient to breathe pure O2 (100% O2) or high concentrations of O2 from a mask;

(3) Administering O2 through an intranasal tube.

- This is most useful in hypoxic hypoxia but of less value in other types of hypoxia .

- Histiotoxic hypoxia will not benefit from O2 therapy.



gure 43-8. Absorption of oxygen into the pulmonary capillary ood in pulmonary edema, with and without oxygen tent therapy.

Mechanical ventilation

- A mechanical ventilator is a machine that helps a patient breathe (ventilate) when they are having surgery or cannot breathe on their own due to a critical illness.
- The patient is connected to the ventilator with a hollow tube (artificial airway) that goes in their mouth and down into their main airway or trachea.

Indications of oxygen therapy

High O2 concentration 15 L/min:

- Cardiac arrest or resuscitation.
- Shock.
- Sepsis.
- Major trauma.
- Anaphylaxis.
- Carbon monoxide poisoning.

- **Moderate concentration O2 (10-15ml/min):**
- Acute asthma.
- Pneumonia.
- Lung cancer.
- Sickle cell crises.

Low oxygen: COPD and morbid obesity.

Hypercapnia

- Excess of CO_2 in body fluids, it usually occurs with hypoxia, PCO_2 increases above 52 mmHg, it decreases the PH.

- In circulatory deficiency, diminished flow of blood decreases CO_2 removal from the tissues, resulting in tissue hypercapnia in addition to tissue hypoxia.
- However, the transport capacity of the blood for CO_2 is three times higher that for O_2, and thus the resulting tissue hypercapnia is much less than the tissue hypoxia.
- In hypoxia caused by hypoventilation, CO_2 transfer between the alveoli and the atmosphere is affected as much as is O_2 transfer. Hypercapnia then occurs along with the hypoxia.

Features of hypercapnia

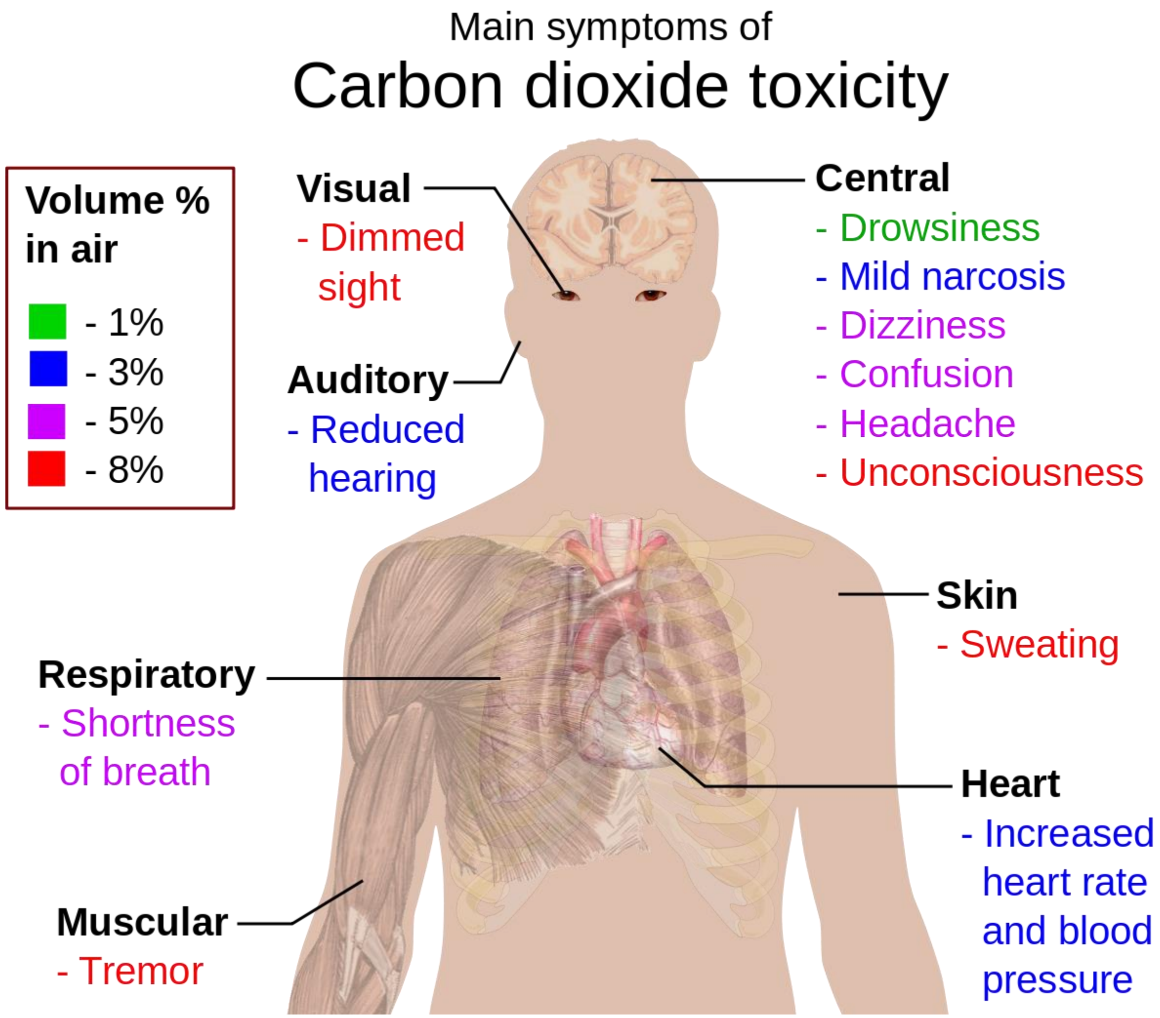
- Air hunger Dyspnea (At PCO_2 between 60-70 mmHg).
- Peripheral vasodilatation
- Sweating
- Warm extremities and bounding pulse
- Muscle twitching
- Headache, drowsiness and semi-coma (PCO_2 rises to 80 to 100 mm Hg).
- Papilledema (swelling of optic disc).

➢ Anesthesia and death can result when the PCO_2 rises to 120 to 150 mm Hg.

➢ At these higher levels of PCO_2, the excess CO_2 now begins to depress respiration rather than stimulate it, thus causing a vicious circle:

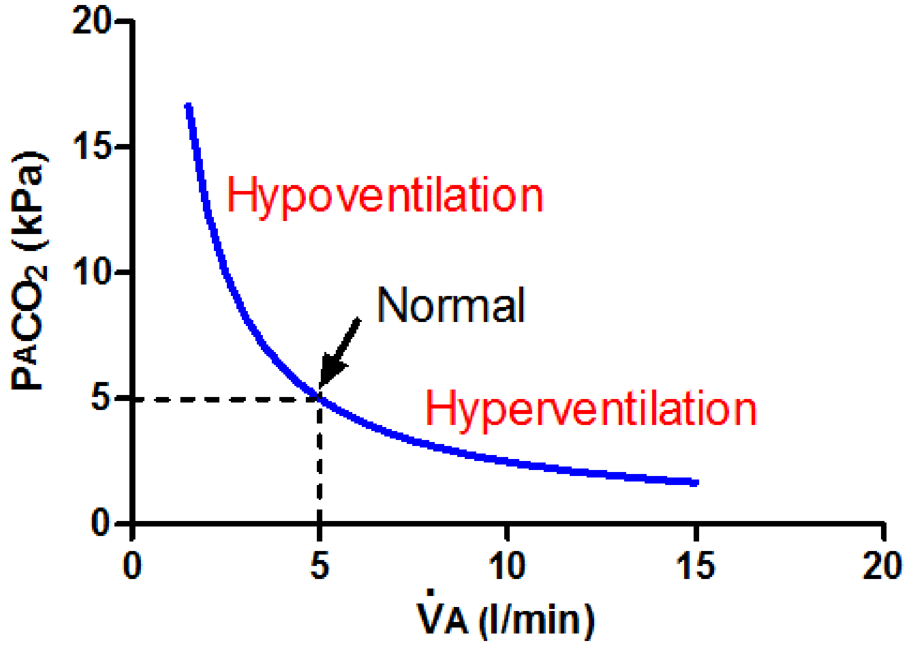
More CO_2 → further decrease in respiration → then more CO_2, and so forth—culminating rapidly in a respiratory death.

Signs and symptoms of hypercapnia



Hypo and hyper-ventilation

- **Hyperventilation** is excessive $\dot{V}A$ such that too much CO_2 is blown out of the body, not breathing too quickly as the word is commonly (mis)used.
- **Hypoventilation** is the opposite, you retain too much CO_2.



Cyanosis

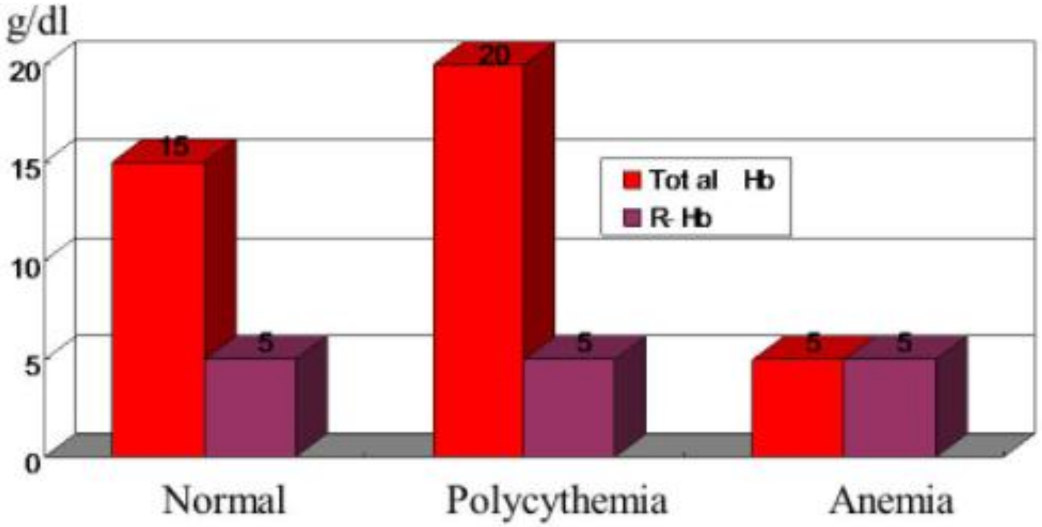
- Blue discoloration of the skin and mucus membrane due to more than 5 g/100 ml of reduced (deoxygenated) hemoglobin in the skin blood vessels especially the capillaries.
- Oxygen saturation (86-85%)
- This deoxygenated hemoglobin has an intense dark blue–purple color that is transmitted through the skin.
- Two types:

➢ **Central:** chest, neck, tongue, lips.

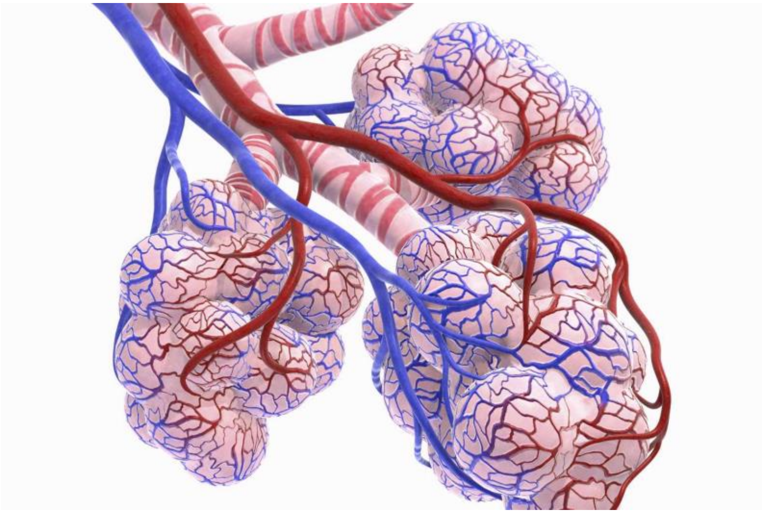
➢ **Peripheral:** finger, toes, tip of nose, ears.

Cyanosis

- A person with anemia almost never develop cyanosis due to low amount of Hb for 5 grams to be deoxygenated/100ml blood.
- Conversely, in a person with excess red blood cells, as in *polycythemia vera*, the great excess of available hemoglobin that can become deoxygenated leads frequently to cyanosis, even under otherwise normal conditions.



Ventilation perfusion (V/Q) Ratio



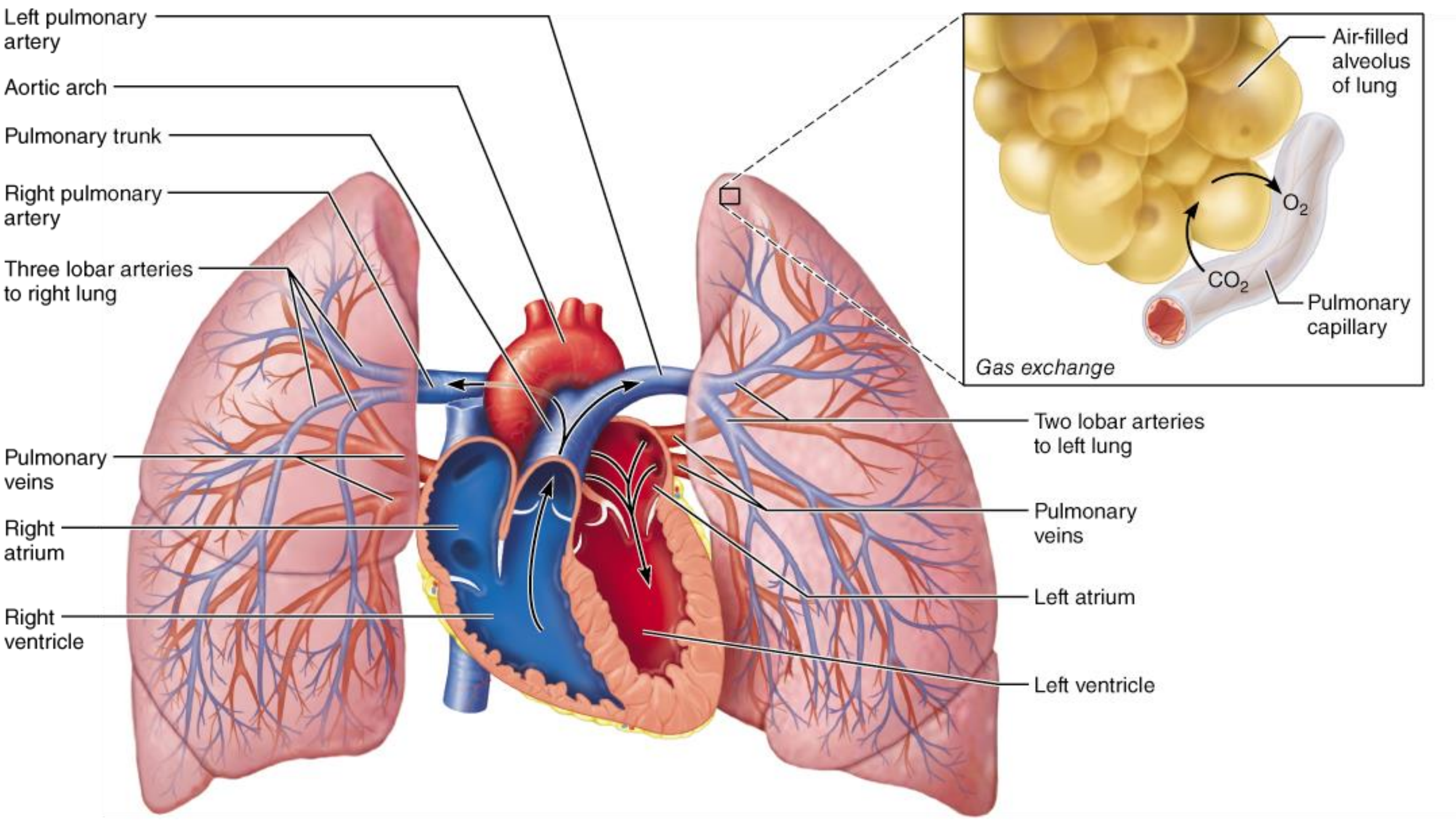
Dr. Felwah Al-Zaid

MBBS, MSc, PhD

Objectives

- **By the end of this lecture you will be able to:**
- Recognize the high pressure and the low pressure circulations supplying the lungs.
- 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 ratios vice, shunt and dead space patterns.

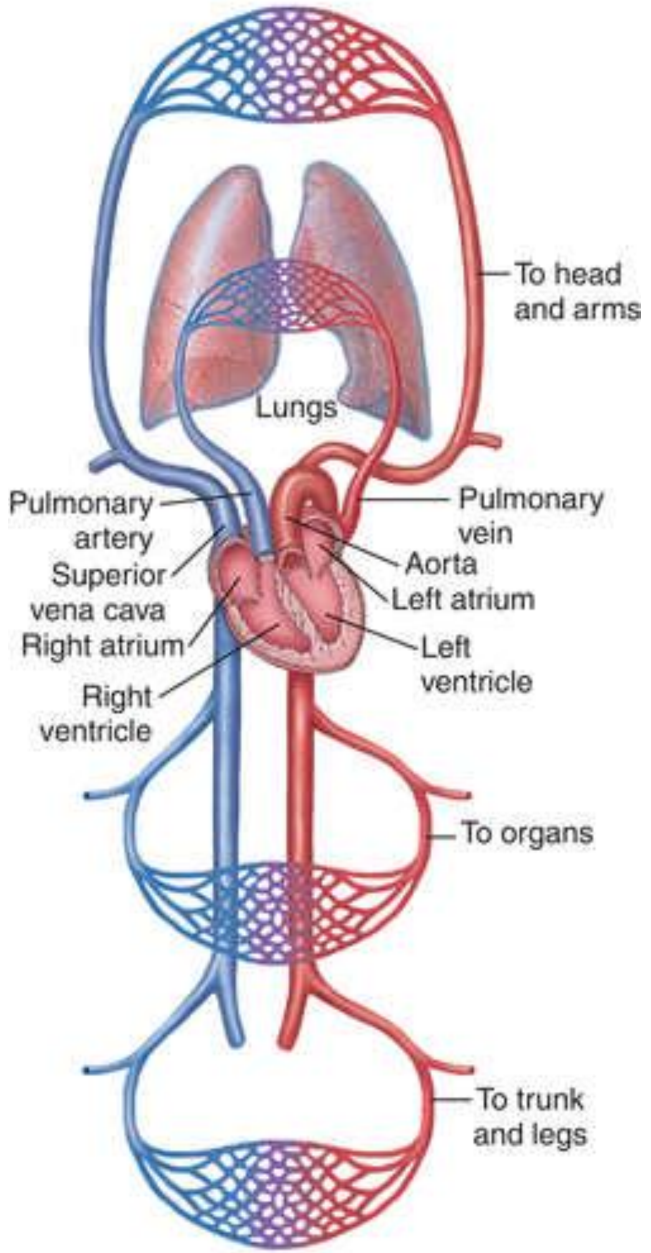
Pulmonary circulation



The pulmonary arterial system is shown in blue to indicate that the blood carried is oxygen-poor. The pulmonary venous drainage is shown in red to indicate that the blood transported is oxygen-rich.

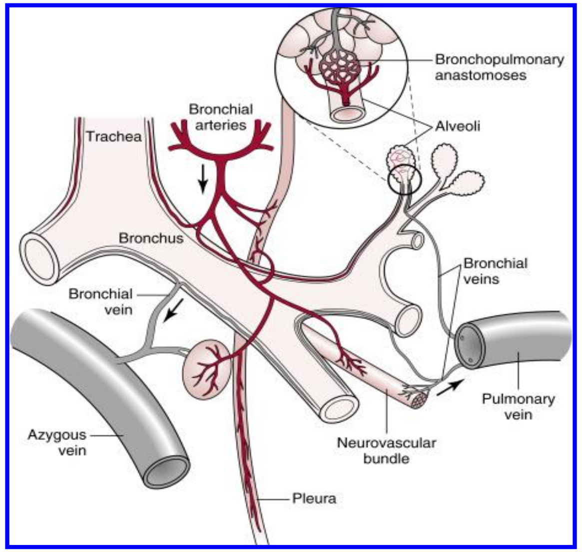
Blood volume of the lungs

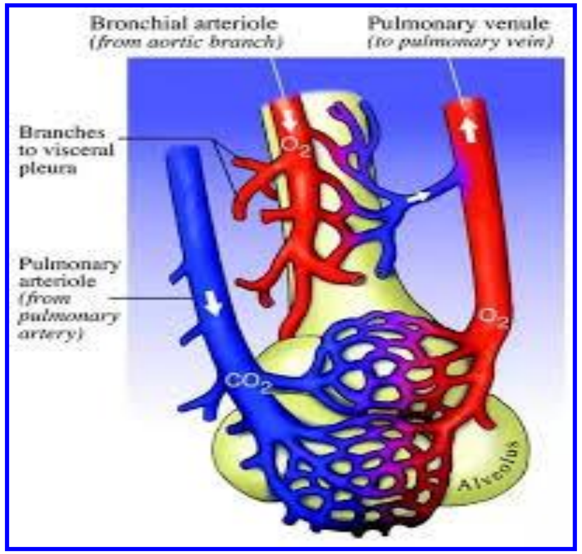
- 450 ml.
- 9% of total blood volume.
- Approximately 70 ml in pulmonary capillaries.
- Lungs serve as blood reservoir (100-250 ml).



Pulmonary Circulations

- **(1) The 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. **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.





Pulmonary Circulations

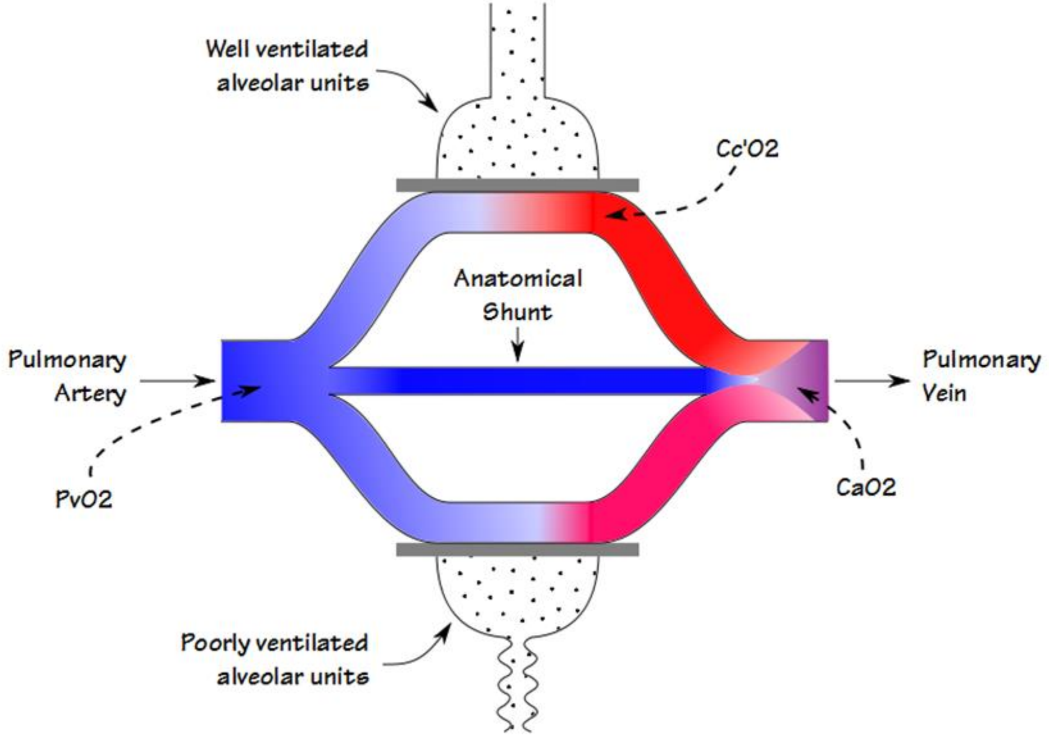
- **(2) The low-pressure, high-flow circulation** supplies venous blood from all parts of the body to the alveolar capillaries where oxygen (O2) is added and carbon dioxide (CO2) is removed. **The pulmonary artery** (which receives blood from the right ventricle) and its arterial branches *carry blood 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 though the systemic circulation.

Physiological shunt

It is defined as a diversion through which the venous blood is mixed with arterial blood.

1- Flow of deoxygenated blood from bronchial circulation into pulmonary veins without being oxygenated makes up part of normal physiological shunt.

2- Flow of deoxygenated blood from thebesian veins into cardiac champers directly.



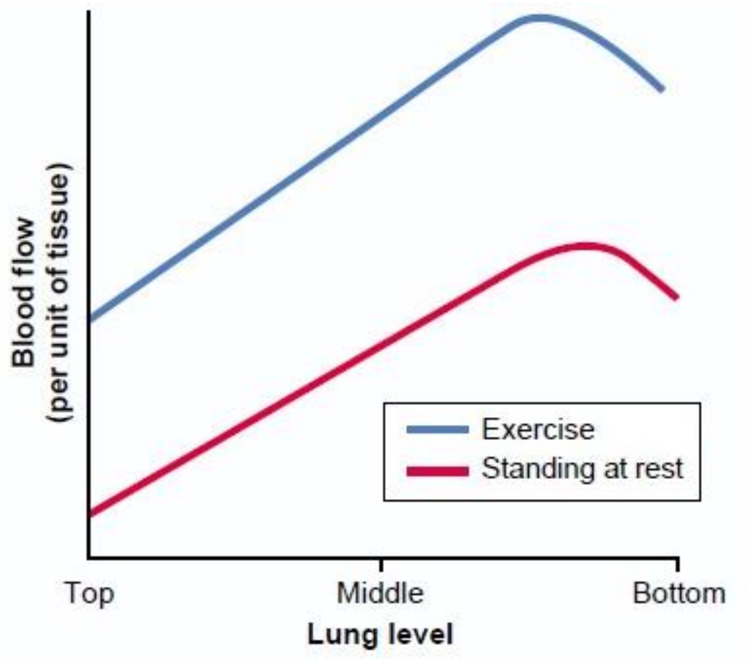
Physiological shunt results in venous admixture (mixing of oxygenated blood with deoxygenated blood).

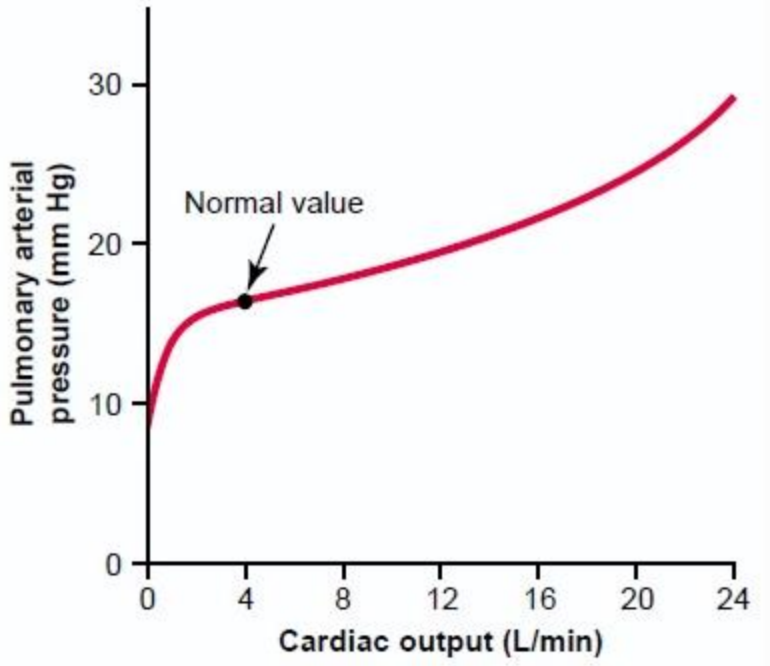
The physiological shunt

- The blood that flows to the lungs through small bronchial arteries is about 1% to 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 atrium, rather than passing back to the right atrium (Shunt blood).
- 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.

Factors regulating pulmonary blood flow

- Cardiac output.
- Decreased alveolar oxygen.
- Chemical factors, vasoconstrictor or dilator.
- Hydrostatic pressure.
- Physical activity.





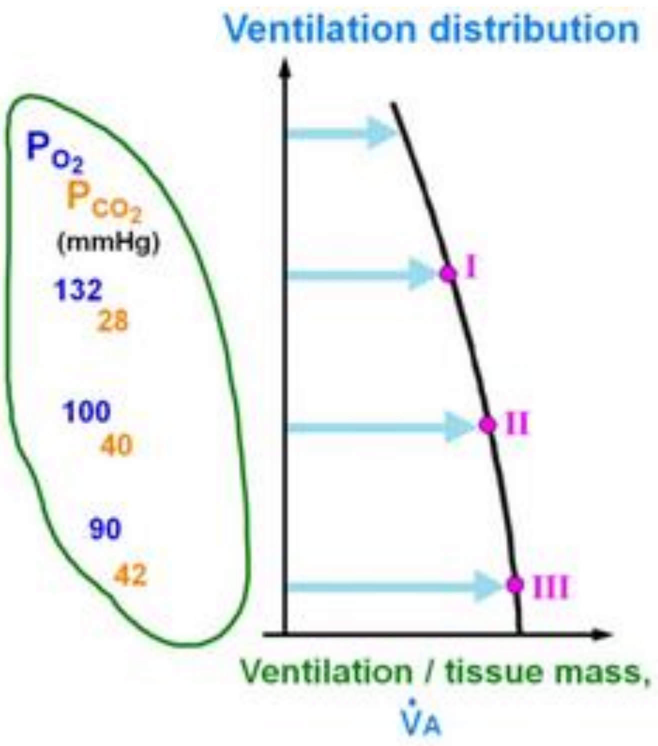
Effect of exercise on pulmonary blood flow and on mean pulmonary arterial pressure caused by increase cardiac output

Effect of hydrostatic pressure on regional pulmonary blood flow

- hydrostatic pressure is affected by gravity.
- The lowest point in the lungs is normally about 30 cm below the highest point, this represents a 23 mm Hg pressure difference, about 15 mm Hg of which is above the heart and 8 below it.
- 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. 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 as it determines blood flow per unit of lung tissue at different levels of the lung in the upright person.

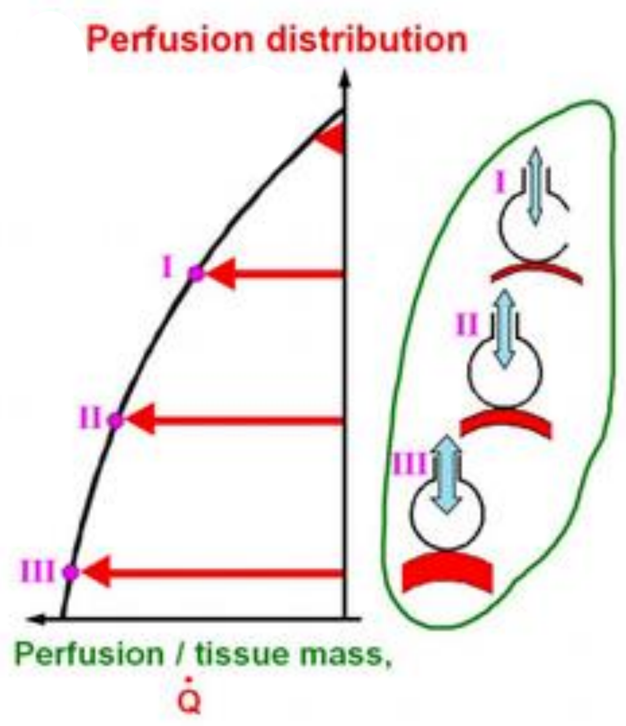
Distribution if ventilation

- The right lung is slightly better ventilated than the left.
- **In an erect patient** the bases of the lung are better ventilated. The weight of lung above compresses the lung below, improving the compliance of dependent lung whilst stretching the non-dependent lung.
  - This is only significant at low inspiratory flow rates.
  - The V/Q ratio in the bases is ~0.6.
  - The V/Q ratio in the apices is >3.
- **In a lateral position:**
  - The dependent lung is better ventilated in a spontaneously breathing patient.
  - The non-dependent lung is better ventilated in a ventilated patient.



Distribution of perfusion

- The pulmonary circulation is a low pressure circulation.
- Gravity therefore has a substantial effect on fluid pressure.
- Consequently, the distribution of blood throughout the lungs is uneven:
  - The **bases perfused better than the apices.**

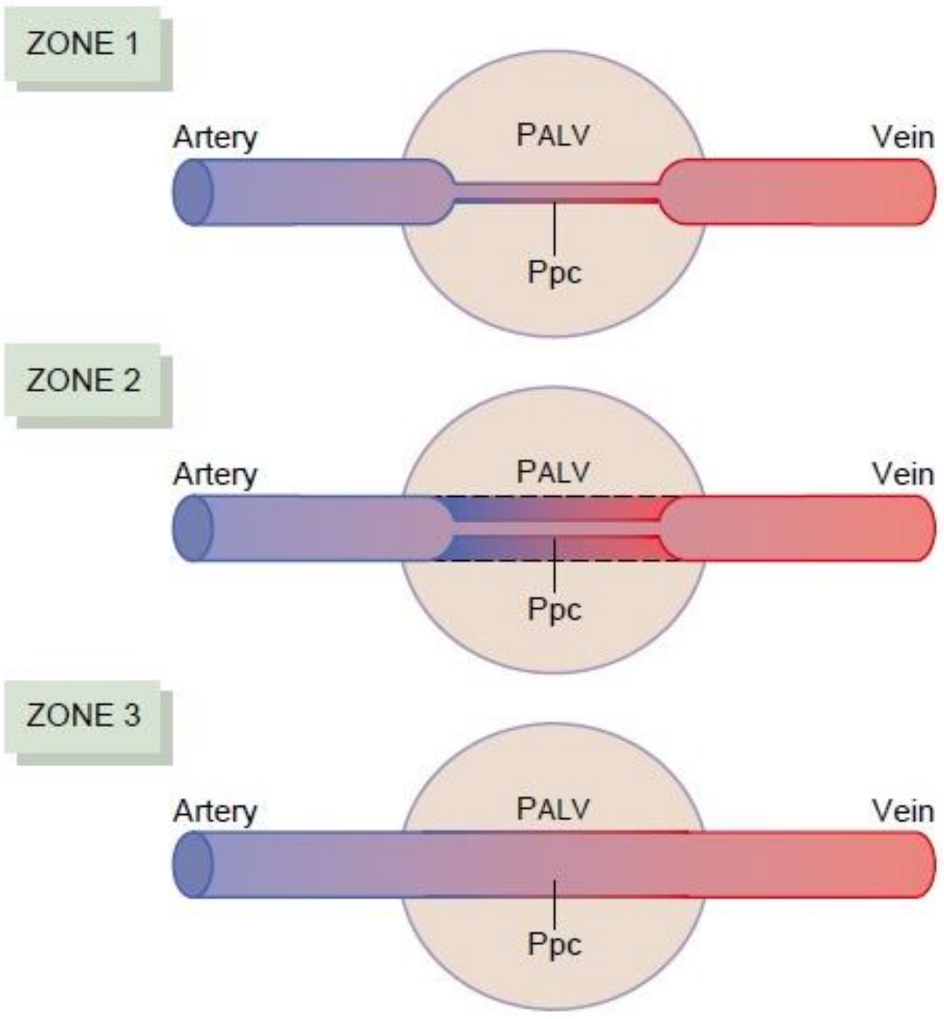


Effect of hydrostatic pressure gradient in the lungs on regional pulmonary blood flow

- **Zone 1** no blood flow during all portions of the cardiac cycle (alveolar pressure (PALV) is greater than arterial pressure).

- **Zone 2** intermittent blood flow only during peaks of pulmonary arterial pressure (systolic arterial pressure rises higher than alveolar air pressure but diastolic arterial pressure fall below alveolar pressure).

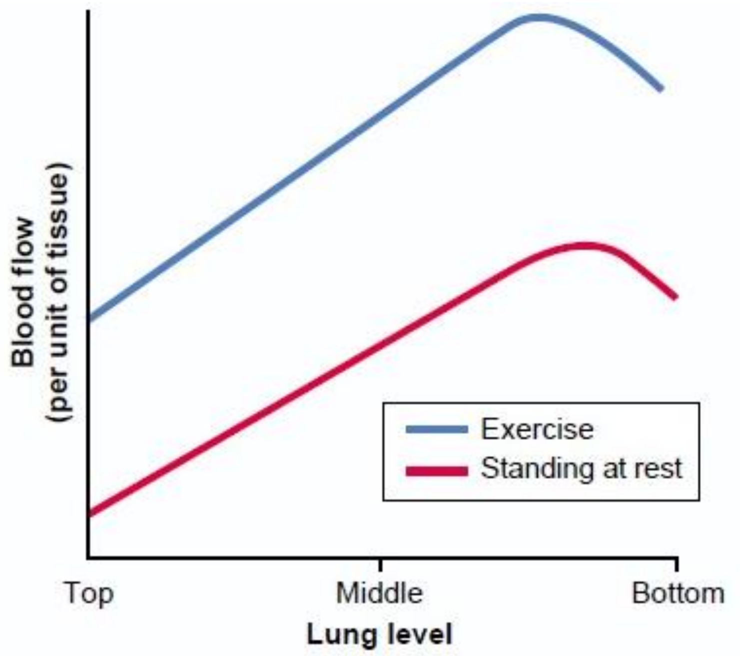
- **Zone 3** continuous flow (arterial pressure and pulmonary capillary pressure (Ppc) remain greater that alveolar air pressure at all times).



Normally lungs have zone 2 (apices) and zone 3 (in all the lower areas).

Exercise Increases Blood Flow Through All Parts of the Lungs.

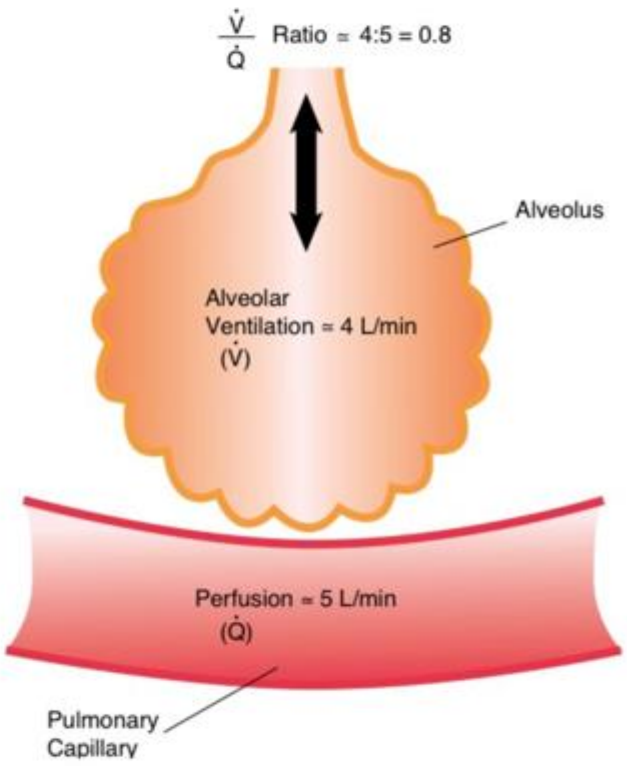
- In the standing position at rest, there is little flow in the top of the lung but about five times as much flow in the bottom.
- The blood flow in all parts of the lung increases during exercise.
- A major reason for increased blood flow is that the pulmonary vascular pressures rise enough during exercise to convert the lung apices from a zone 2 pattern into a zone 3 pattern of flow.



Ventilation –perfusion (V/Q) ratio

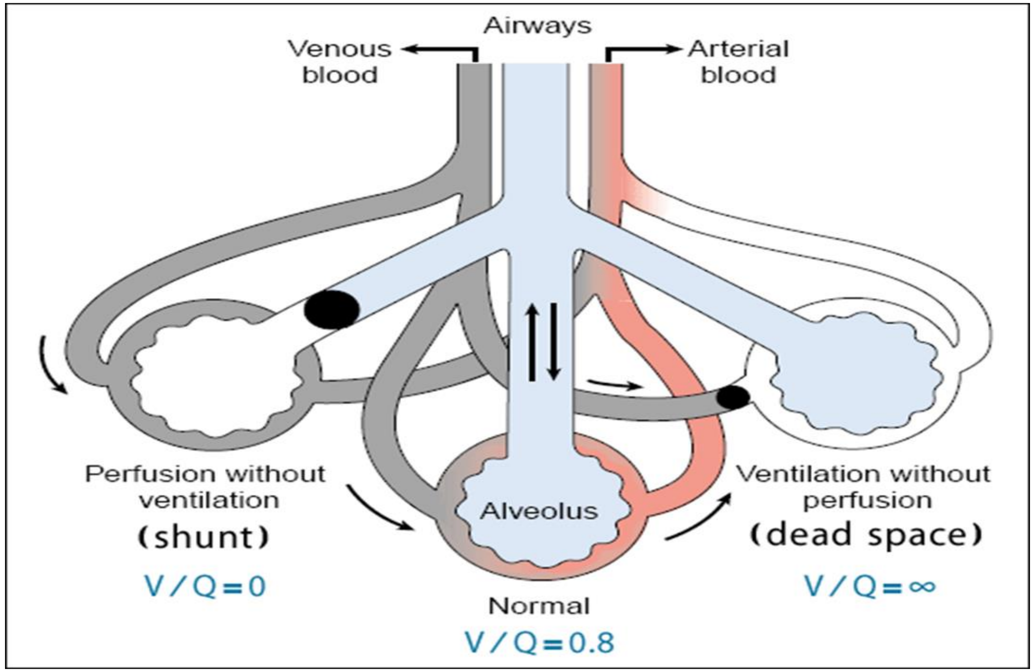
- It is the ratio of alveolar ventilation to pulmonary blood flow per minute.

- The alveolar ventilation (V) at rest (4.2 L/min).
- The pulmonary blood flow i.e. perfusion (Q) is equal to right ventricular output per minute (5L/min).
- So the normal V/Q ratio is = 4.2 / 5 = 0.84
- Therefore, exchange of O2 and CO2 through the respiratory membrane is nearly optimal, and alveolar PO2 is normally at a level of 104 mm Hg. Likewise, alveolar PCO2 is normally 40 mm Hg.



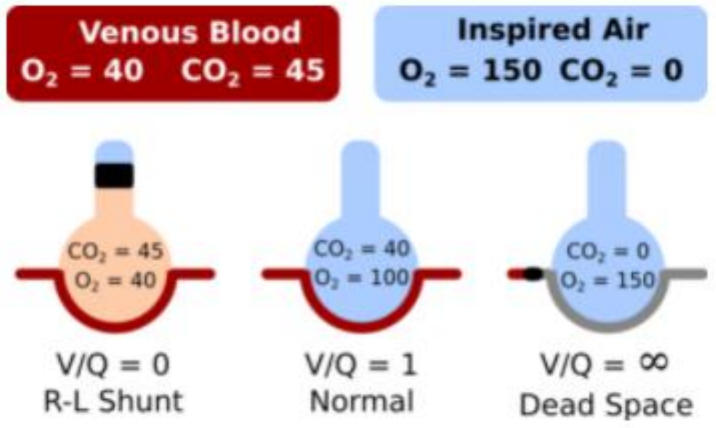
V/Q ratio mismatch

- A V/Q mismatch happens when part of your lung receives oxygen without blood flow or blood flow without oxygen.
- This happens if you have an obstructed airway, such as when you are choking, or if you have an obstructed blood vessel, such as a blood clot in your lung.
- It can also happen when a medical condition causes you to bring in air but not extract oxygen, or bring in blood but not pick up oxygen.



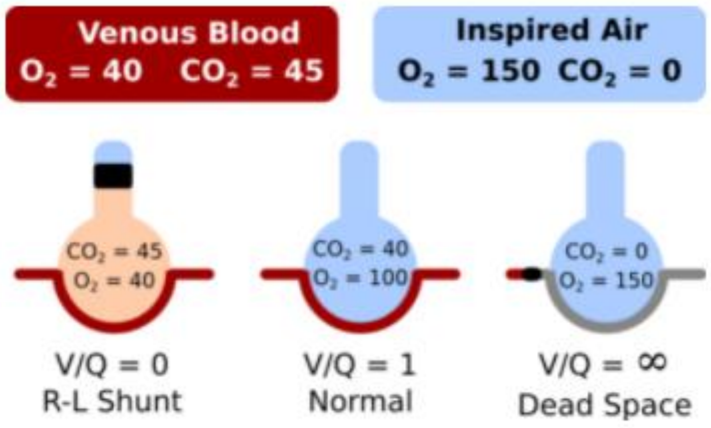
Alveolar PO2 and PCO2 When V/Q̇̇ Equal 0

- When (V̇) is zero (e.g in case of bronchial obstruction), yet there is still perfusion(Q̇) of the alveolus, the V/Q= is zero
- Without any alveolar ventilation—the air in the alveolus comes to equilibrium with the venous blood returning to the lungs from the systemic circulation.
- The normal venous blood (V) has a PO2 of 40mmHg and PCO2 of 45mmHg. (shunt blood)
- Therefore, these are also the normal partial pressures of these two gases in alveoli that have blood flow but no ventilation.



Alveolar PO2 and PCO2 When V/Q ratio equals Infinity

- when there is adequate ventilation (V̇) but zero perfusion (Q̇) e.g in case of pulmonary artery occlusion by thrombus or embolism, the ratio V̇/Q̇ is infinity.
- There is no capillary blood flow to carry O2 away or to bring CO2 to the alveoli.
- The air that is inspired loses no O2 to the blood and gains no CO2 from the blood (dead space).
- Furthermore, because normal inspired and humidified air has a PO2 of 149 mm Hg and a PCO2 of 0 mm Hg, these will be the partial pressures of these two gases in alveoli.

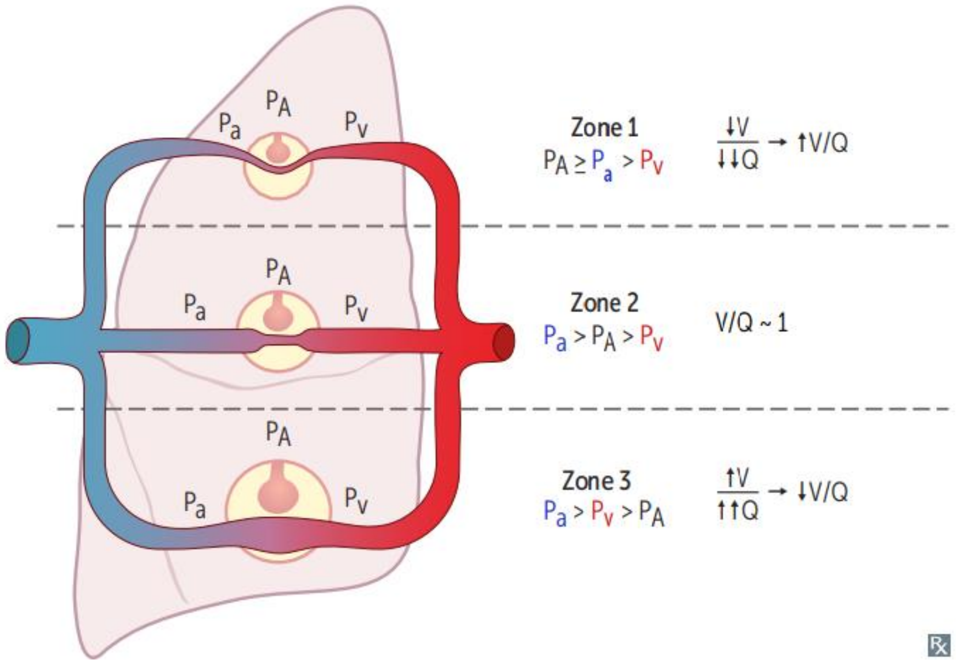


What is the importance of V/Q ratio?

- The main function of this ratio is to **determine the state of oxygenation in the body**. Any mismatch in the ratio can result in hypoxia.
- At a ratio of either zero or infinity, there is no exchange of gases through the respiratory membrane of the affected alveoli.
- When the V/Q ratio is less than normal a fraction of the venous blood is passing through the pulmonary veins without being oxygenated i.e (shunted blood). Also, the blood flows from the bronchial veins into the pulmonary vein is unoxygenated. The total quantitative amount of shunted blood per minute is called the Physiological 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).

(V̇/Q̇) in the zones of the lung

- Average V/Q ratio across the lung is = 0.8
- At the apex V/Q ratio = 3 (physiological dead space).
- At the base V/Q ratio=0.6 (physiological shunt).
- So the apex is more ventilated than perfused and the base is more perfused than ventilated.
- During exercise and lying flat in bed the V/Q ratio becomes more homogenous among different parts of the lung.

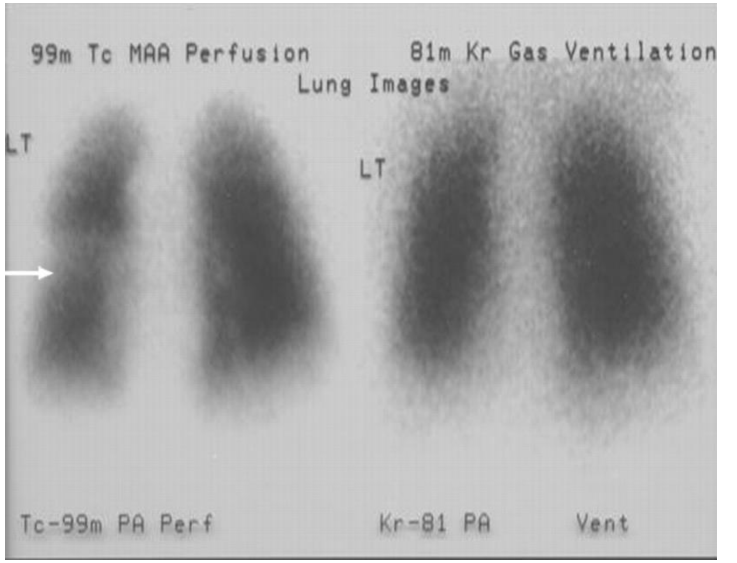


Causes of V/Q mismatch

- COPD
- Pneumonia
- Asthma
- Pulmonary edema
- Chronic bronchitis
- Airway obstruction

Abnormal (V /Q) ratio in Chronic Obstructive Lung Disease e.g chronic smokers with emphysema

- In COPD: 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.
- Both conditions tremendously decrease the effectiveness of the lungs as gas exchange organs, to as little as 10% of normal.
- In fact, COPD is the most prevalent cause of pulmonary disability today.



Ventilation- Perfusion Lung Scan

Thank you

Reference: Guyton and Hall textbook of Medical Physiology

Stay safe & stay healthy