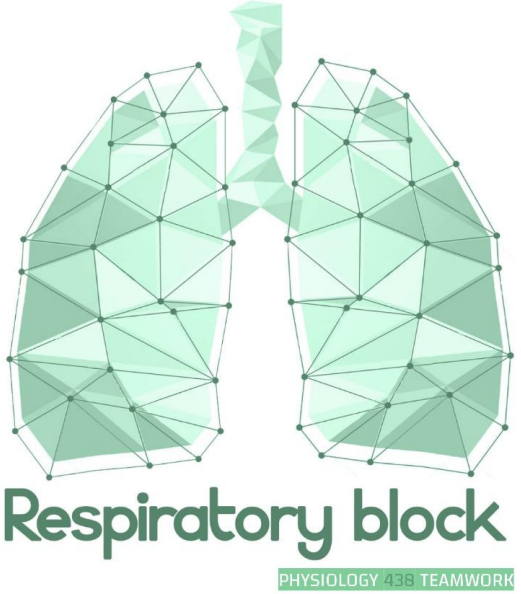
Hypoxia and cyanosis



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

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Objectives

1. Define hypoxia and list its various physiological and pathological causes.
2. Define hypo and hyper-ventilation in terms of arterial PCO_2 and PO_2.
3. Define cyanosis and its clinical presentation
4. Define ventilation/perfusion ($\dot{V}/Q$) ratio and its normal values.

You should understand some concepts before you study the lecture

Extra information

Diffusion-limited gas exchange: the total amount of gas transported across the alveolar/capillary barrier is limited by the **diffusion process**. In these cases, as long as the partial pressure gradient for the gas is **maintained**, diffusion will continue along the length of the capillary.
Perfusion-limited gas exchange: the total amount of gas transported across the alveolar/capillary barrier is limited by **blood flow** (i.e., perfusion) through the pulmonary capillaries. In perfusion-limited exchange, the partial pressure gradient is **not maintained**, and in this case, the only way to increase the amount of gas transported is by increasing blood flow.

Pulmonary blood flow is the cardiac output of the right heart, which is equal to the cardiac output of the left heart. The difference is a result of a small amount of coronary venous blood that drains directly into the left ventricle through the thebesian vein (rather than going to the lungs via the pulmonary artery).
Pulmonary blood flow is directly proportional to the pressure gradient between the pulmonary artery and the left atrium and is inversely proportional to the resistance of the pulmonary vasculature ($Q = \Delta P / R$). When compared with the systemic circulation. However, the pulmonary circulation is characterized by much lower pressures and resistances, although blood flow is the same. The reason that pulmonary blood flow can be equal to systemic blood flow is that pulmonary pressures and resistances are proportionately lower than systemic pressures and resistances

Ventilation – perfusion ratio (V/Q)

It is the ratio of alveolar ventilation to pulmonary blood flow per minute.
The main function of this ratio is to determine the state of oxygenation in the body.

The alveolar ventilation **at rest**	The pulmonary blood flow is **equal to right ventricular** output per minute	V/Q ratio (Normal value)
4.2 L/min	5L/min	4.2/5 = 0.84

Average V/Q ratio across the lung is **0.8**

At the apex V/Q ratio = 3

(moderate degree of physiologic dead space)

At the base V/Q ratio= 0.6

(represent a physiologic shunt).

Increased V/Q Ratio	Decreased V/Q Ratio
Hyperventilation	Hypoventilation
Increased PO2	Decreased PO2
Decreased PCO2	Increased PCO2
PCO2 < 40	PCO2 > 40

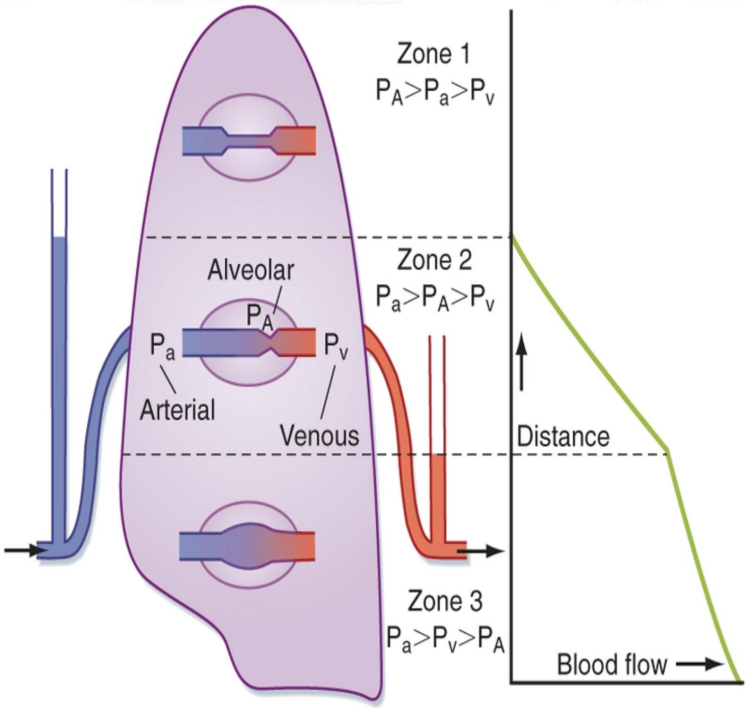
So the **apex is more ventilated** than **perfused** and the **base is more perfused** than **ventilated** due to gravity force.

•During exercise the V/Q ratio becomes more homogenous among different parts of the lung.

Male's slides only

Regional Blood Flow and Distribution

Zone 1: Apex	Ventilation is *higher* than Perfusion. There is more *Alveolar* Oxygen. because Alveolar pressure is higher than arterial pressure so it compresses the vessels.
Zone 2	Ventilation and Perfusion are similar
Zone 3: Base	Ventilation is *lower* than Perfusion. There is less *Alveolar* Oxygen. Because Alveolar pressure is less than arterial pressure, so it can't collapse the vessels



Prone or supine Posture (lying down): In the prone posture, all lung regions are near heart level, so the effect of gravity is much less and the pulmonary flow is more uniform

Female's slides only

Ventilation/perfusion abnormalities

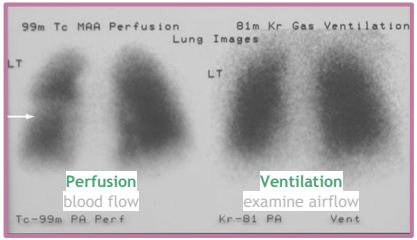
- Any mismatch in the ratio can result in **hypoxia.**

less than normal *physiologic shunt*

- a certain fraction of the venous blood is passing through the pulmonary capillaries without being oxygenated
- i.e shunted blood

more than normal *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



Ventilation- Perfusion Lung Scan

A ventilation-perfusion (VQ) scan is a nuclear medicine scan that uses radioactive material (radiopharmaceutical)

Male's slides only

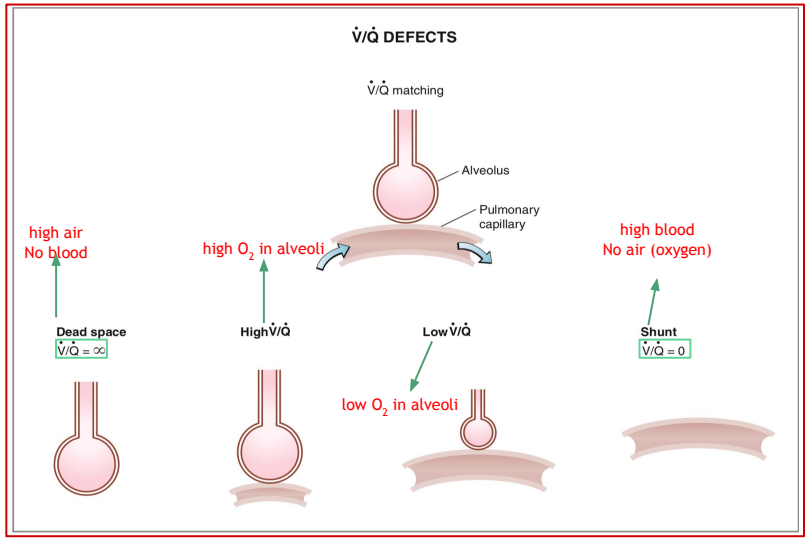
Causes of V/Q Mismatching

Causes of non violence uniform ventilation

- Uneven resistance to airflow
- Collapsed airways (Emphysema)
- Bronchoconstriction (Asthma)
- Inflammation (Bronchitis)

Non-uniform compliance throughout the lung

- Fibrosis
- Pulmonary vascular congestion
- Atelectasis



Dead space	High V/Q	Shunt	Low V/Q
No gas exchange is possible in dead space, because there is **no blood flow** to receive O_2 from alveolar gas or add CO_2 to alveolar gas.	Usually because **blood flow is decreased**. high V/Q regions have some blood flow. Because ventilation is high relative to perfusion, pulmonary capillary blood from these regions has a high PO_2 and a low PCO_2.	Right-to-left shunt is perfusion of lung regions that are **not ventilated**. No gas exchange is possible in regions of shunt, because there is no ventilation to deliver O_2 to the blood or carry away CO_2 from the blood.	Usually because **ventilation is decreased**. which has no ventilation, low V/Q regions have some ventilation. Because ventilation is low relative to perfusion, pulmonary capillary blood from these regions has a low PO_2 and high PCO_2.

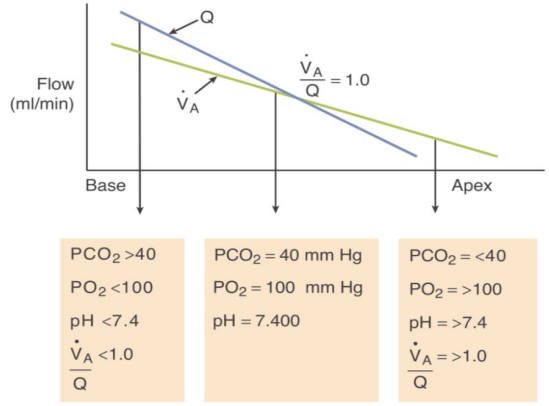
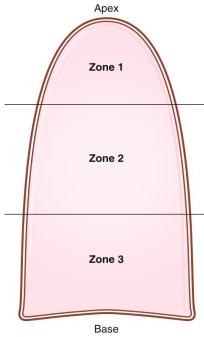


Figure V-4-3. Ventilation–Perfusion Relationships

V̇/Q̇ DISTRIBUTION IN THE LUNG



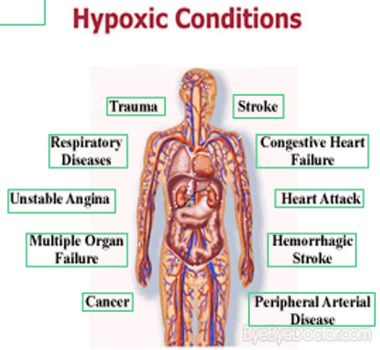
	Blood Flow ($\dot{Q}$)	Alveolar Ventilation ($\dot{V}$)	$\frac{\dot{V}}{\dot{Q}}$	Pa_{O_2}	Pa_{CO_2}
Zone 1	Lowest	Lower	Highest (3.0)	Highest (130 mm Hg)	Lower (28 mm Hg)
Zone 2	–	–	–	–	–
Zone 3	Highest	Higher	Lowest (0.6)	Lowest (89 mm Hg)	Higher (42 mm Hg)

Hypoxia

Is defined as deficiency of oxygen in the tissue cells.

Types of Hypoxia

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



* more details in next slides

Female's slides only

Hypercapnia

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

→ recall from the 1st lecture: CO_2 always make the medium acidic

Features of hypercapnia :

- Peripheral vasodilatation
- Sweating
- Warm extremities and bounding pulse
- Muscle twitching
- Headache, drowsiness and coma
- Papilledema (swelling of optic disc)

Helpful video

Types of Hypoxia

Hypoxic or arterial hypoxia

Reduced **arterial PO_2.**

Causes:

- Alveolar hypoventilation due to central , muscular or neuromuscular causes
  - High altitude, reduced compliance, airway resistance, paralysis of respiratory muscles, depressed respiratory center
- Diffusion abnormalities ex: pneumonia ,edema and inflammation
  - Seen in conditions like alveolar-capillary block
- Right to left shunt 1*
- Ventilation-perfusion imbalance
- Pulmonary Edema
- Emphysema
- Obstruction

1*right to left shunt: Shunting of blood from the right heart to the left heart can occur if there is a defect in the wall between the right and left ventricles. In a right-to-left shunt, hypoxemia always occurs because a significant fraction of the cardiac output is not delivered to the lungs for oxygenation and sometimes hypoxia.

Anemic hypoxia

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.** less Hb ⟶ less O_2

- The PO_2 and % Hb-O_2 is normal.

Causes:

1- Anemia

2-Abnormal Hb e.g methemoglobin,carboxyhemoglobin, sulfhemoglobin

Methemoglobin: If the iron component of the heme moieties is in the ferric, or Fe^{3+}, state (rather than the normal Fe2þ state), it is called methemoglobin. Methemoglobin does not bind to O_2.

Types of Hypoxia

Stagnant (hypokinetic/ischemic) hypoxia:

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, shock

2-Local slowing e.g vasoconstriction, cold, arterial wall spasm.

Histotoxic hypoxia

- This is **inability of the tissues to <u>use</u> oxygen** due to inhibition of the oxidative enzyme activity
- This is caused by **inhibition of respiration electron transport chain** in the tissue.
- e.g cyanide poisoning causing blockage of the cytochrome oxidase activity

Hypoxia cont...

Effect of Hypoxia

•**According to the <u>degree</u> of hypoxia:** (how fast and how severely partial pressure of O_2 is decreased)

Fulminant: occurs very rapidly, within seconds.

- Unconsciousness (15-20 seconds)
- Brain tissue death (4-5 minutes)

Acute:

- Slowed body reflexes
- Slurred Speech
- Coma and death may occur

Chronic:

- Fatigue
- Dyspnea
- Cyanosis
- Tachypnea
- Tachycardia

Female's slides only

- Impairment of judgement
- Inability to perform complex calculations
- Headache, nausea, irritability

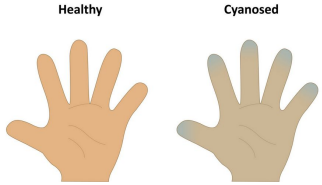
Treatment

Is by giving **oxygen therapy** in a tent or high oxygen tension mask. (Only in hypoxia due to the lack of O_2)

This is useful in **<u>hypoxic</u>** hypoxia, but of less value in other types of hypoxia.

Histotoxic hypoxia will not benefit from O_2 therapy.

Cyanosis

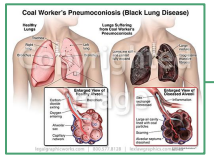


- **Blue** discoloration of the skin and mucous membrane due to more than 5 g/dl of **reduced** (deoxygenated) hemoglobin in blood.
- A person with anemia almost never develop cyanosis due to low amount of Hb for 5 grams to be deoxygenated /100ml blood. but can develop it in polycythemia.

Causes:

Male's slides only

1 Inadequate oxygenation of blood in the lungs



- High altitude
- Obstruction of respiratory passages
- Pneumoconiosis
- Emphysema
- CO poisoning

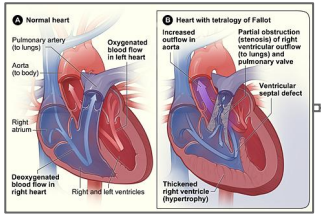
2 presence of aerated shunt between vessels

- Coarctation of aorta (aorta is narrow)
- Fallot's tetralogy (abnormalities in heart)

3 Other

- Moderate cold
- Diminished blood flow to tissues

Male's slides only



- Cyanotic congenital heart-disease
  - Fallot tetralogy
    defects that are present at birth (congenital)
  - Tricuspid atresia

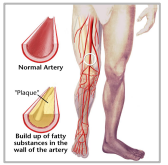
- Reduced cardiac output, as in congestive heart failure
- Mitral stenosis
- Exposure to cold

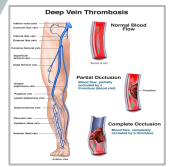
- Pulmonary arteriovenous fistula
- Pulmonary diseases
- Acute pulmonary embolism

Central
Generalized impairment of circulation. can occur in hypoxic hypoxia a part of the body.

Peripheral
decreased blood flow through

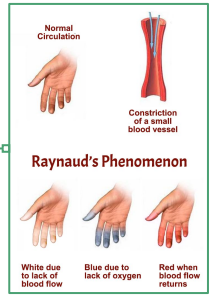
- Arterial obstruction
- Venous obstruction



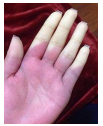


- Pneumonia
- Chronic Obstructive airway disease
- Restrictive lung disease
- Hemoglobin abnormality

- Raynaud's disease
- Polycythemia vera is a stem cell disorder characterized as a pan hyperplastic, malignant, and neoplastic marrow disorder.



→ Recall from Anatomy **MSK** :) Raynaud's disease is a rare disorder of the blood vessels, usually in the fingers and toes. It causes the blood vessels to narrow when you are cold or feeling stressed. When this happens, blood can't get to the surface of the skin and the affected areas turn white and blue. It may require *cervicodorsal preganglionic sympathectomy*



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 have some areas of the lung exhibiting serious physiologic shunt and other areas serious physiologic dead space. (mixed)
- ★ COPD is the most prevalent cause of pulmonary disability today, lung effectiveness as a gas exchange organ may decrease to 10% as in smokers or workers in pollution areas

Summary

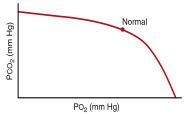
Table 5-6 Causes of Hypoxia

Cause	Mechanism	Pa_{O_2}
↓ Cardiac output	↓ Blood flow	—
Hypoxemia	↓ Pa_{O_2} ↓ O_2 saturation of hemoglobin ↓ O_2 content of blood	↓
Anemia	↓ Hemoglobin concentration ↓ O_2 content of blood	—
Carbon monoxide poisoning	↓ O_2 content of blood Left shift of O_2-hemoglobin curve	—
Cyanide poisoning	↓ O_2 utilization by tissues	—

Quiz

You don't understand why we choose this answer? Click here to read the explanations

1-The O_2-CO_2 diagram shows a ventilation-perfusion (V/Q) ratio line for the normal lung. Which of the following best describes the effect of decreasing V/Q ratio on the alveolar Po_2 and Pco_2?



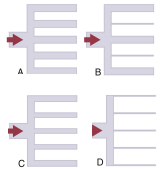
	CO_2 tension	O_2 tension
A.	Increased	Decreased
B.	Increased	Increased
C.	Decreased	Decreased
D.	No change	Decreased

2- Which cause of hypoxia is corrected best with supplemental O_2:

A. anemia
B. decreased cardiac output
C. high altitude
D. right-to-left shunt

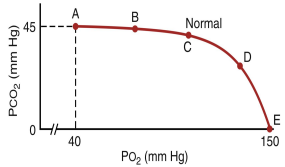
3- Which diagram in the figure below best illustrates the pulmonary vasculature when the cardiac output has increased to a maximum extent?

A. A
B. B
C. C
D. D



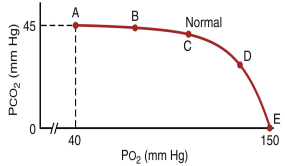
4- A 67-year-old man has a solid tumor that pushes against an airway, partially obstructing airflow to the distal alveoli. Which point on the V/Q line of the O_2- CO_2 diagram above corresponds to the alveolar gas of these distal alveoli?

A. A
B. B
C. C
D. D
E. E



5- 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 O_2-CO_2 diagram above corresponds to the alveolar gas of his right lung?

A. A
B. B
C. C
D. D
E. E



SAQ

1- The following ratios represent 2 lungs at rest. VA/Q
Patient A = 0.62
Patient B = 0.73
Which lung has the greatest (in the end capillaries) :
PCO_2, PO_2, pH?

2- Abdulsamad Jafar comes into the ER suffering with Hypoxia. His Alveolar PO_2 and Arterial PO_2 are normal. You can observe a bluish color on his extremities. Which type of Hypoxia is he most likely suffering from?

Answers
1-
PCO_2: Patient A
PO_2: Patient B
pH: Patient B

2- Stagnant Hypoxia

Key answers:
1-A 2-C 3-A 4-B 5-E

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