

# Hypoxia and Cyanosis

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**Red: very important.**

**Green: Doctor's notes.**

**Pink: formulas.**

**Yellow: numbers.**

**Gray: notes and explanation.**

## Physiology Team 436 – Respiratory Block Lecture 9

Lecture: If work is intended for initial studying.  
Review: If work is intended for revision.

# Objectives

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- Define hypoxia and list its various physiological and pathological causes.
- Define hypo and hyper-ventilation in terms of arterial PCO<sub>2</sub> and PO<sub>2</sub>.
- Define cyanosis and its clinical presentation
- Define ventilation/perfusion ( $V/Q$ ) ratio and its normal values.

# Hypoxia

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- ▶ Hypoxia is defined as an inadequate supply (deficiency) of oxygen to the body tissues. It can be classified in the following types:

Type	Definition
Hypoxic hypoxia (arterial hypoxia)	Lack of oxygenation of blood in the lungs
Anemic hypoxia	Decreased oxygen carrying capacity of the blood due to decreased hemoglobin level
Stagnant hypoxia (Hypokinetic or Ischemic hypoxia)	Decreased rate of blood flow throughout the body or a part of the body
Histotoxic hypoxia	The tissue are unable to use oxygen even though plenty of oxygen is available

# Hypoxic Hypoxia (Arterial Hypoxia)

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- ▶ It is defined as a lack of oxygenation of blood in the lungs which leads to a low PO<sub>2</sub> in arterial blood (reduced arterial PO<sub>2</sub>). Since less amounts of Hb are converted into oxy-Hb. The tissues are supplied with blood deficient in oxygen. Hypoxic hypoxia can occur in the following conditions:

High altitude

Emphysema

Fluid in the lungs  
(pulmonary edema)

Obstruction in the  
respiratory passages

## Other Causes: (explained in next slides)

- Alveolar hypoventilation
- Diffusion abnormalities
- Right to left shunt
- V/Q mismatch

# Cont.

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## 1- Alveolar hypoventilation

- E.g.
  - Reduced PO<sub>2</sub> in inspired air (high altitude)
  - Increased airway resistance
  - Reduced lung compliance
  - Paralysis of respiratory muscles (like in M.G)
  - Depressed respiratory center

## 2- Ventilation-perfusion imbalance (including increased physiological dead space and physiological shunt)

- If ventilation and blood flow are mismatched in various parts of the lung, impairment of both oxygen and carbon dioxide diffusion results. Ventilation perfusion imbalance may be caused by uneven ventilation (e.g. obstructive lung conditions), or uneven perfusion (e.g. consolidation of the lung).

## 3- Diffusion abnormalities

- Impaired diffusion from alveolar to pulmonary capillary blood can lead to arterial hypoxia. It is seen in conditions like alveolar-capillary block.

## Cont.

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- ▶ Physiological shunt: Also called venous admixture, blood entering the arterial system without passing through ventilated areas of lung causing PO<sub>2</sub> to be less than alveolar.

### 4- Right to left shunt

- Blood passes from the systemic venous system without going through the gas exchanging part of the lungs. This type of hypoxia can be differentiated clinically from other types by giving the subject 100% oxygen to breathe. Hypoxia because of the shunt will not be abolished while in other types PO<sub>2</sub> in the arterial system will improve considerably.

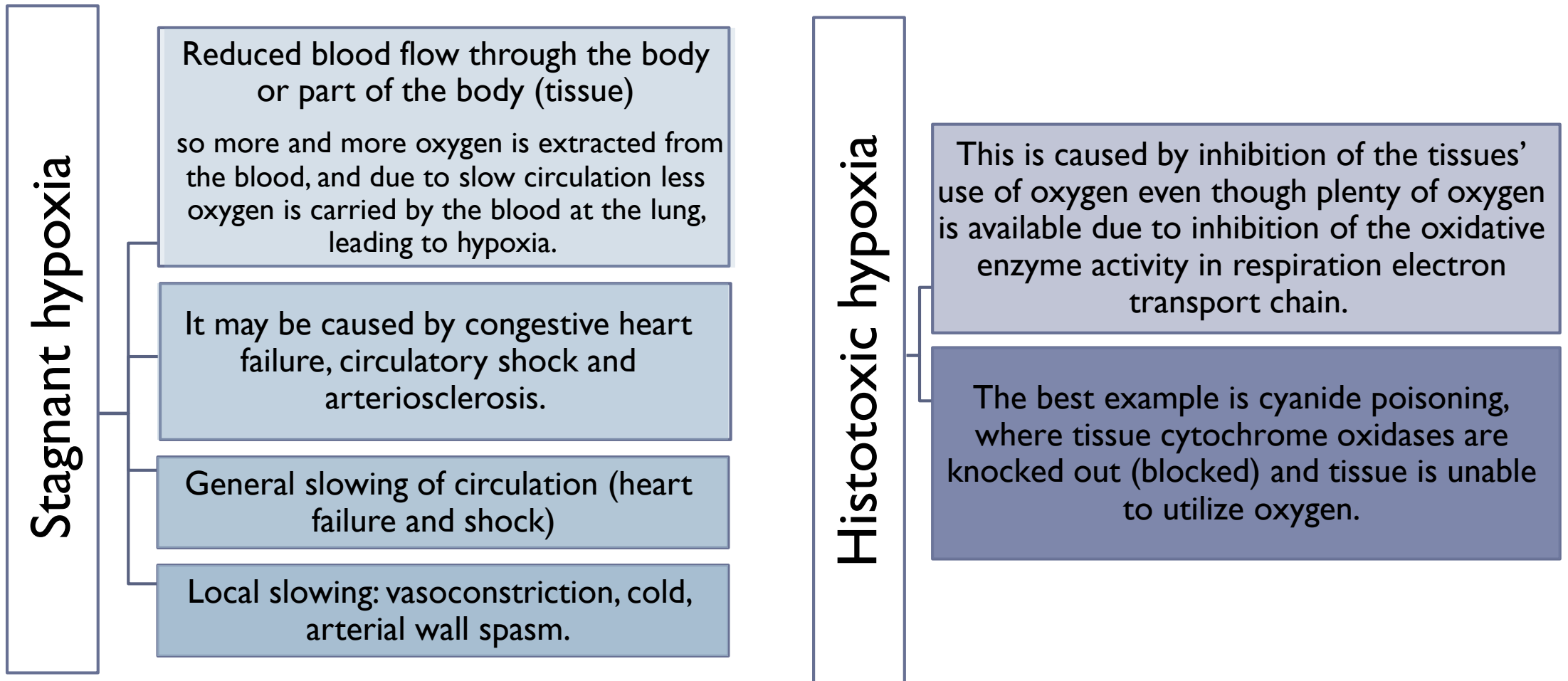
# Anemic Hypoxia

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- ▶ In this condition the PO<sub>2</sub> and %Hb-O<sub>2</sub> are normal.
- ▶ This condition is characterized by **decreased oxygen carrying capacity** of the blood due to decreased hemoglobin level or abnormal type of Hb which is unable to carry oxygen.
  
- ▶ Causes:
  1. Anemia
  2. Abnormal Hb (e.g met hemoglobin, carboxyhemoglobin)
  
- ▶ Anemic hypoxia is seen in hemorrhagic anemia (decreased RBC -quantity or quality-):
  1. Failure of hemoglobin to carry its normal concentration of oxygen, as in carbon monoxide (CO) poisoning.
  2. Altered hemoglobin formation e.g. methaemoglobin, sulphaemoglobin, and carboxyhaemoglobin.

# Stagnant Hypoxia and Histiotoxic Hypoxia

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# Hypoxia and Clinical Features

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## General signs and symptoms of hypoxia:

- ▶ *Cyanosis*, *Tachy-cardia* and *Tachypnea* (abnormally rapid breathing).

## Signs and symptoms of hypoxia:

Hypoxia's clinical features depend on (the degree of hypoxia):

How fast & how severely **partial pressure of O<sub>2</sub>** is decreased.

## Hypoxia can be classified according to its clinical features to 3 types:

### ▶ **Fulminant hypoxia:**

This occurs very rapidly & suddenly. Its symptoms : Unconsciousness occurs in 15-20 seconds and brain tissue death occurs in 4-5 minutes.

### ▶ **Acute hypoxia:**

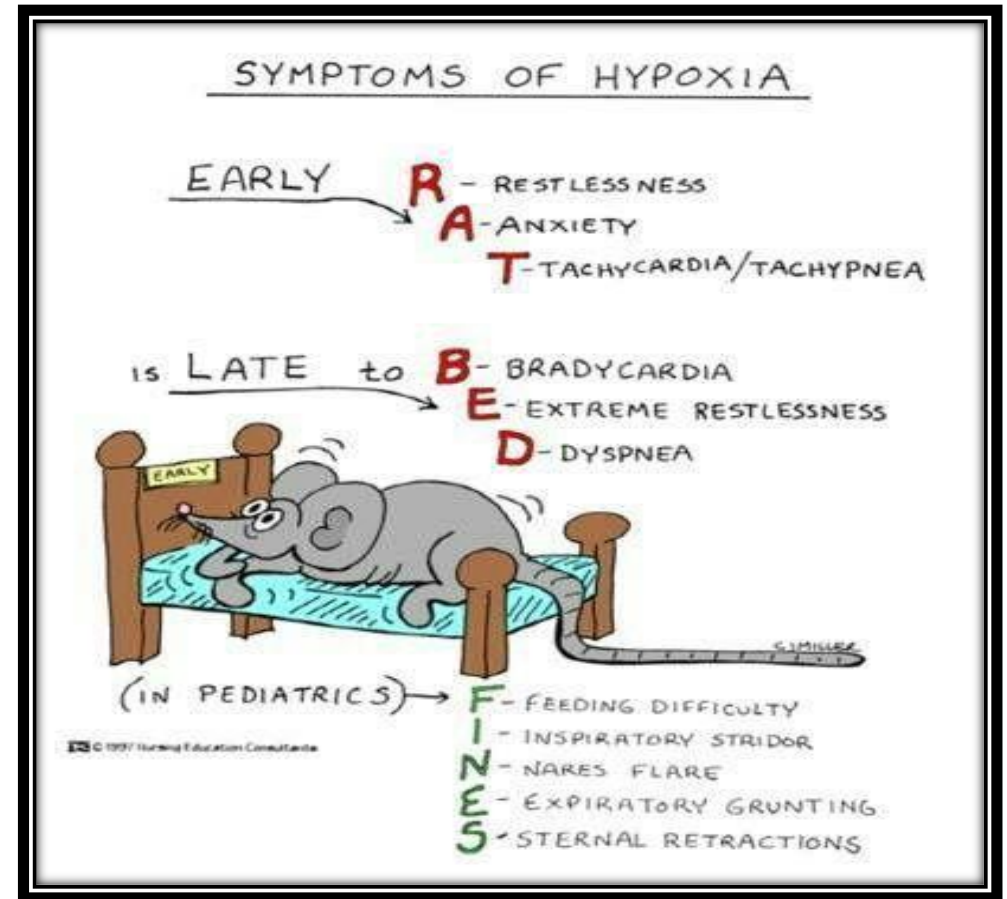
In acute hypoxia body reflexes are slowed, symptoms : there may be slurred (unclear) speech, unconsciousness, coma and death may occur.

### ▶ **Chronic hypoxia:**

The symptoms : fatigue, difficulty in breathing, and shortness of breath can occur.

# Effects of Hypoxia on the Body

- ▶ Impairment of judgment (principally **depressed mental activity**).
- ▶ Inability to perform complex calculations.
- ▶ Headache, nausea, irritability, dyspnea, increased heart rate.
- ▶ Reduction in muscle **working capacity**.
- ▶ **Coma and death** may result (if severe enough).



# Treatment of Hypoxia (Treatment of hypoxia depends on the cause.)

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- Hypoxia is treated by giving oxygen therapy in a tent or high oxygen tension mask.
- This is useful in **hypoxic hypoxia**, but of less value in other types of hypoxia.
- **Histiotoxic hypoxia will not** benefit from O<sub>2</sub> therapy.



# Hypercapnea

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- ▶ Excess of CO<sub>2</sub> in body fluids.
- ▶ It usually occurs with hypoxia\*.
- ▶ PCO<sub>2</sub> increases above 52 mmHg and therefore it decreases the pH.
  
- ▶ Features of hypercapnea:
  1. Peripheral vasodilatation (you feel the pulse easily).
  2. Sweating.
  3. Warm extremities and bounding pulse (strong pounding or racing of the heart).
  4. Muscle twitching.
  5. Headache, drowsiness and coma
  6. Papilledema ( swelling of optic disc) (in chronic hypoxia cases)

# Cyanosis

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Definition: The term cyanosis means blueness of the skin and mucus membrane due to excessive amount for more than 5 g/dl of reduced (deoxygenated) hemoglobin in blood (skin blood vessels especially in the capillaries).

This deoxygenated hemoglobin has an intense dark blue-purple color that is transmitted through the skin. (This is the cause of the blue skin color for people with cyanosis).

**ONLY IN MALES' SLIDES**

Cyanosis appears whenever the arterial blood contains more than 5 grams of deoxygenated hemoglobin in each 100 milliliters of blood.

# Cyanosis

- ▶ A person with anemia never becomes cyanotic because there is not enough hemoglobin for 5 grams to be deoxygenated in 100 milliliters of arterial blood.

(Anemia → **Less** blood cells → **Less** hemoglobin to be deoxygenated → Cyanosis cannot be achieved due to the **lack of hemoglobin** and red blood cells).

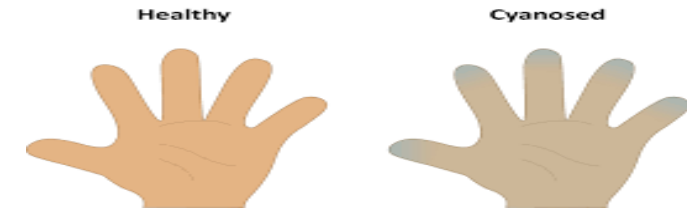
- ▶ While In a person with excess red blood cells in the case of polycythemia, has a great excess of available hemoglobin that can become deoxygenated leads frequently to cyanosis.

(Polycythemia → **More** blood cells → **More** hemoglobin to be deoxygenated → Cyanosis can be achieved due to the **excess hemoglobin** and red blood cells.)



# Causes of Cyanosis

- Inadequate oxygenation of blood in the lungs:
  - High altitude.
  - Obstruction of respiratory passages.
  - Pneumoconiosis\*.
  - Emphysema.
  - CO-poisoning.
- Presence of an aerated shunt between vessels:
  - Coarctation\*\* of aorta.
  - Fallot's tetralogy\*\*\*.
- Other Causes:
  - Moderate cold.
  - Diminished blood flow to tissues.



\*a disease of the lungs due to inhalation of dust, characterized by inflammation, coughing, and fibrosis.

\*\*Coarctation of the Aorta (CoA) A narrowing of the major artery (the aorta) that carries blood to the body. This narrowing affects blood flow where the arteries branch out to carry blood along separate vessels to the upper and lower parts of the body. CoA can cause high blood pressure or heart damage.

\*\*\*Tetralogy of Fallot (TOF) is a congenital heart defect that is present at birth causing a number of heart-related abnormalities that disrupt blood flow.

# Types of Cyanosis

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## Cyanosis

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graph TD; Cyanosis --> LocalCyanosis[Local cyanosis:]; Cyanosis --> GeneralizedCyanosis[Generalized cyanosis:];
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### Local cyanosis:

This is seen during decreased blood flow through a part of the body as in Raynaud's disease. In this disease, circulation through the upper limb is impaired, it causes local cyanosis.

### Generalized cyanosis:

Generalized impairment of circulation as in the case of heart failure leads to generalized cyanosis. It also occurs in hypoxic hypoxia.



# Ventilation-Perfusion Ratio (V/Q)

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- ▶ Ventilation-Perfusion Ratio ( $V_A/Q$ ): This is the ratio of alveolar ventilation to the pulmonary blood flow per minute.
- ▶ Ventilation-perfusion ratio is expressed as  $V_A/Q$
- ▶ When  $V_A$  (alveolar ventilation) is normal for a given alveolus and  $Q$  (blood flow) is also normal for the alveolus, the ventilation-perfusion ratio ( $V_A/Q$ ) is also said to be normal.
  
- ▶ Ventilation - Perfusion Ratio ( $V/Q$ ): The alveolar ventilation at rest is about (4.2 L/minute)
- ▶ Calculated as: Alveolar ventilation = respiration rate x (tidal volume – dead space air)
- ▶ The pulmonary blood flow is equal to right ventricular output per minute (5 L/min). Hence ventilation perfusion ratio is  $(V/Q) = 4.2/ 5 = 0.84$

# Ventilation-Perfusion Ratio (V/Q)

## Ventilation-perfusion ratio (V/Q)

<p>Ventilation (V) Alveolar Minute ventilation = 4 to 6 L</p>	<p>Perfusion (Q) Normal cardiac output = 5 L</p>	<p>Normal ventilation / perfusion ratio (average)(V/Q ratio) = 0.8 to 1.2 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).</p> <p>*So the apex is more ventilated (gravity pulls it down) than perfused and the base is more perfused than ventilated.</p> <p>*During exercise the V/Q ratio becomes more homogenous among different parts of the lung (because of hyperventilation).</p>
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Ventilation and perfusion must be matched at the alveolar capillary level.

# Decrease in Ventilation-Perfusion Ratio ( $V/Q$ )

- ▶ A decrease in  $V/Q$  ratio is produced by either decreasing ventilation or increasing blood flow.

## DECREASED VENTILATION

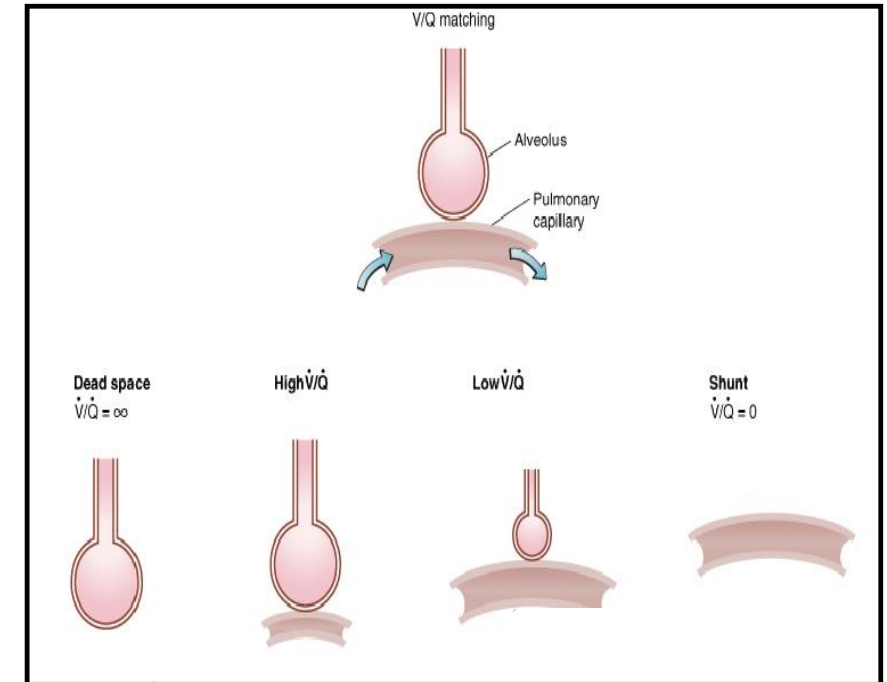
Bringing in less oxygen to meet metabolic need

Blowing out less  $CO_2$  from the lungs

## INCREASED PERFUSION

More blood cells are coming to remove  $O_2$  from alveolus

They deliver more  $CO_2$  than exhaled



# Increase in Ventilation-Perfusion Ratio (V/Q)

Either caused by increased ventilation or decreased perfusion.

## INCREASED VENTILATION

Bringing in more oxygen to the alveoli

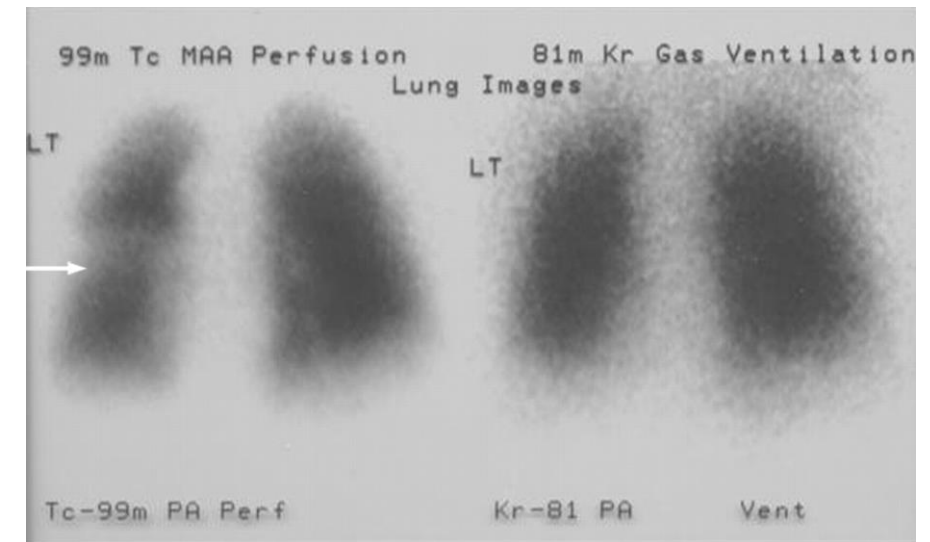
Blowing out more CO<sub>2</sub> from the lungs

## DECREASED PERFUSION

Blood takes away less oxygen

Delivers less CO<sub>2</sub>

## Ventilation- Perfusion Lung Scan



# Ventilation-Perfusion Ratio (V/Q)

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- ▶ The normal value means on average lungs are over-perfused but under-ventilated at rest.
- ▶ 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.**
- ▶ During exercise: Less difference in pulmonary blood flow between basal and apical portions of the lungs occurs. This makes ventilation more closely matching perfusion of the lungs.

## **ONLY IN MALES' SLIDES**

- ▶ The ratio is variable from apex to base of the lung
- ▶ As lung is centered vertically around the heart, part of the lung is superior to the heart, and part is inferior

High (V/Q) ratio of the apex leads to an increase in alveolar and arterial oxygen levels while decreasing the carbon dioxide. The blood leaving the apex of each lung in a standing person is estimated to have a PaO<sub>2</sub> of 130 mm Hg and a PaCO<sub>2</sub> of 28 mm Hg.

# Abnormalities of the V/Q Ratio

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- ▶ 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).
- ▶ 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).
- ▶ 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 have some areas of the lung exhibit serious physiologic shunt and in 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%**.

# Pulmonary Blood Flow (Extra Slide From Guyton)

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Important so you could understand the next slide.

- ▶ The capillaries in the alveolar walls are distended by the blood pressure inside them but simultaneously they are compressed by the alveolar air pressure on their outsides.
- ▶ Therefore anytime the lung alveolar air pressure becomes greater than the capillary blood pressure (((the capillaries are closed))).
- ▶ Blood pressure in the apex is decreased but increased in the base due to gravity.

# Regional Blood Flow Distribution

## Zone 1

alveolar air pressure  $>$  arterial and venous pressures

- Vessels are collapsed and flow is close to zero

## Zone 2

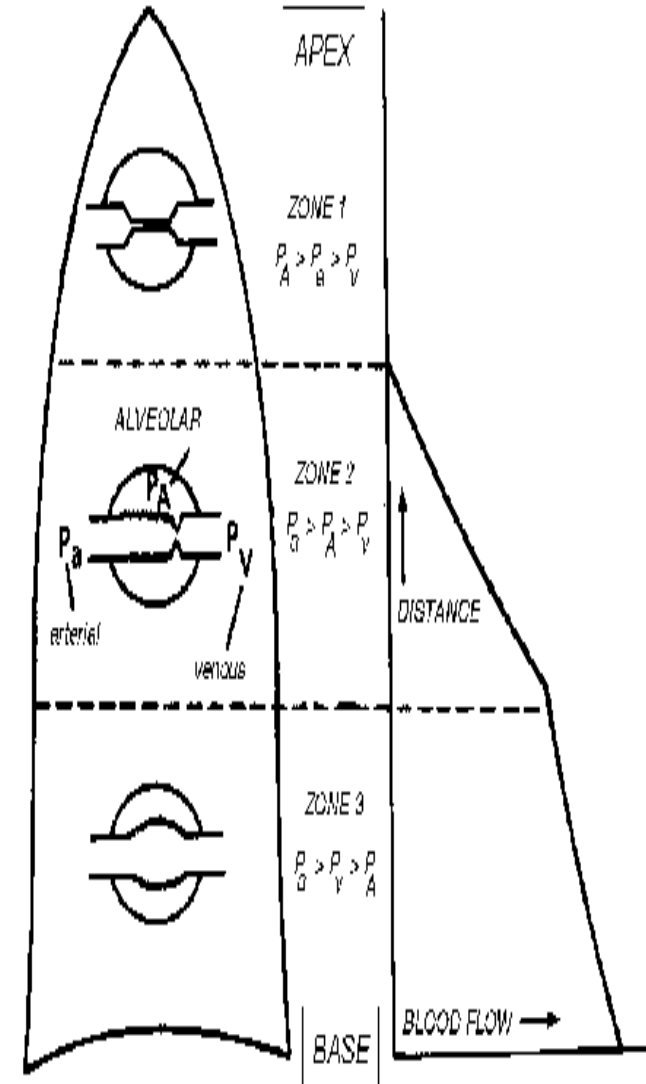
venous pressure  $<$  alveolar air pressure  $<$  arterial pressure

- vessels partially collapsed and flow is low

## Zone 3

alveolar air pressure  $<$  arterial and venous pressure

- vessels open for full length and flow highest





# Composition of Alveolar Air (Extra Slide From Guyton)

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- ▶ In alveoli the partial pressure of CO<sub>2</sub> is increased and O<sub>2</sub> is decreased in relation to atmospheric pressure due to:
  1. Alveolar air is only partially replaced by atmospheric air.
  2. As air moves into the **alveoli**, water **vapor (which dilutes all other gases)** and **carbon dioxide (from pulmonary blood)** are added.
  3. Oxygen is constantly being absorbed into the pulmonary blood from alveolar air.
- ▶ Since the apex is over ventilated it has higher oxygen concentration and lesser carbon dioxide concentration.
  - Partial pressure of O<sub>2</sub> in atmosphere is 159 mmHg
  - Partial pressure of Co<sub>2</sub> in atmosphere is 0.3 mmHg

# Quiz

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- ▶ <https://www.onlineexambuilder.com/lecture-9/exam-129881>

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## [Link to Editing File](#)

(Please be sure to check this file frequently for any edits or updates on all of our lectures.)

### References:

- Girls' and boys' slides.
- Guyton and Hall Textbook of Medical Physiology (Thirteenth Edition.)

# Thank you!

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اعمل لترسم بسمة، اعمل لتمسح دمة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

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