

وَقُلْ رَبِّ زِدْنِي عِلْمًا



# RESPIRATORY SYSTEM

HAYAT BATCH

SUBJECT : Lecture 7

LEC NO. : \_\_\_\_\_

DONE BY : Hala Al Beshtawe

# **Ventilation-Perfusion Relationship ( $\dot{V}_A/\dot{Q}$ )**

**Dr. Waleed R. Ezzat**

# Objectives:

1. Describe how the ventilation/perfusion (V/Q) ratio of an alveolar-capillary lung unit determines the  $PO_2$  and  $PCO_2$  of the blood emerging from that lung unit.
2. Identify the average V/Q ratio in a normal lung and explain how V/Q is affected by the vertical distribution of ventilation and perfusion in the healthy lung.
3. Describe the normal relative differences from the apex to the base of the lung in alveolar and arterial  $PO_2$ ,  $PCO_2$ , pH, and oxygen and carbon dioxide exchange.
4. Predict how the presence of abnormally low and high V/Q ratios in a person's lungs will affect arterial  $PO_2$  and  $CO_2$ .
5. Define right-to-left shunts, anatomic and physiological shunts, and physiologic dead space (wasted ventilation).
6. Describe the airway and vascular control mechanisms that help maintain a normal ventilation/perfusion ratio.
7. Characterize the pathophysiology of abnormal ventilation perfusion inequality.

**Definition:** Is the ratio of the alveolar ventilation to the pulmonary blood flow. The  $V_A/Q$  for the whole lung at rest is about 0.8-0.9. → هذا يعني ان الدم الداخل للرئة كمية اكبر من ال ventilation Perfusion

نسبة الدم الداخل لك (perfusion) alveoli نسبة الهواء الذي يدخل الرئة

$$V_A/Q = \text{alveolar ventilation} / \text{cardiac output}$$

بمعنى غير متساوية حيث ان ال ventilation ان ياتى ال perfusion ال alveoli غير متساوية

$$V_A/Q = (4.5-5 \text{ L/min}) / (5-5.5 \text{ L/min})$$

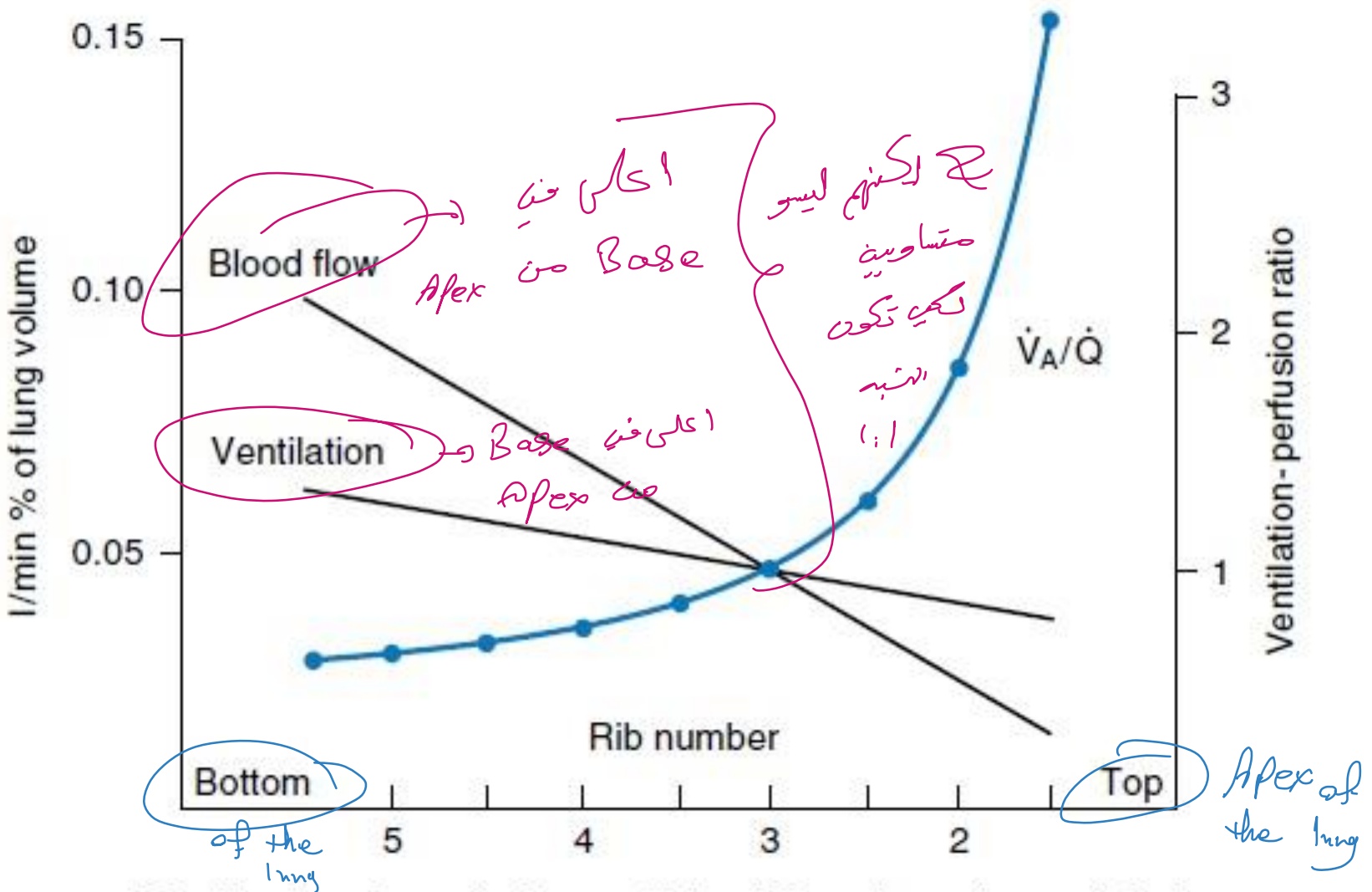
♀ tidal volume / min

\* النسبة في Base و Apex غير متساوية of the lung ← في اسفل الرئة الدم اكبر من ventilation فيصل جدران الدم و الـ  $O_2$  من Base

In upright position the ratio is less than 1 (about 0.6) at the base of the lungs, and greater than 1 (about 2.5) at the apex. The most efficient gas exchange occurs when the  $V_A/Q$  is approximately 1.

في Apex of the lung تكون الدم اقل من الهواء صينية ان الهواء اكثر بكثير

The ventilation perfusion ratio in the base of the lung is lower than the apex of the lung وذلك بسبب اختلاف قيم blood flow and ventilation

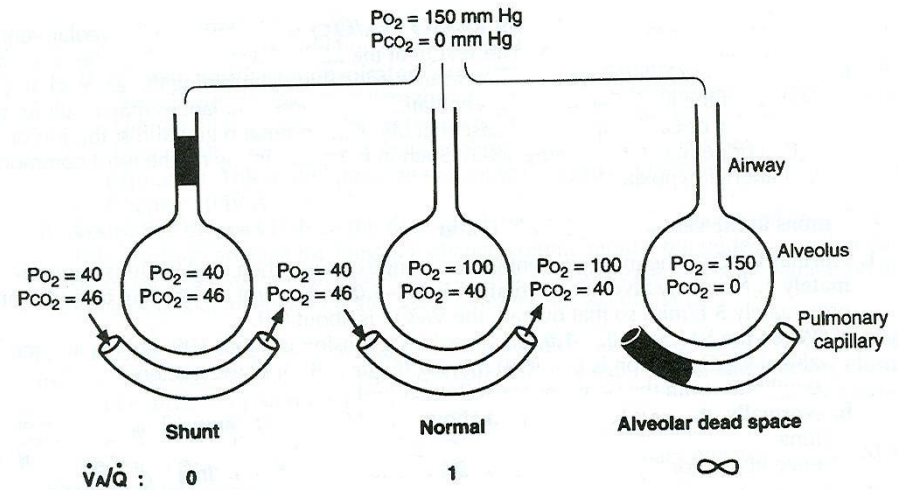


Distribution of ventilation and blood flow down the upright lung  
 Note that the ventilation-perfusion ratio decreases down the lung

# Effect of $V_A/Q$ on alveolar gas concentration:

1. When  $V_A/Q$  equals zero, this means that there is no alveolar ventilation (=shunt). The air in the alveolus equilibrates with blood oxygen and  $CO_2$ . Since the perfusing blood is the venous blood returning to the lungs from the systemic circulation, the alveolar  $PO_2$  sets at 40 mmHg and  $PCO_2$  at 45 mmHg.

يتم نقل الأكسجين بكفاءة يجب أن يكون ال ventilation  
perfusion ratio is equal one ولأن هذا ليس موجود  
في الرئة ستتأثر عملية تبادل الغازات oxygen &  $CO_2$

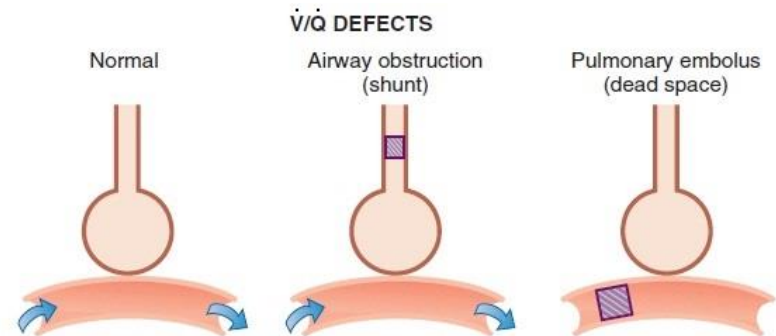


Ventilation equals zero due to obstruction of the airway and occurs what we call ventilation, shunt, and vasoconstriction

Creation of dead space

# Effect of $V_A/Q$ on alveolar gas concentration:

- When  $V_A/Q$  equals infinity, this means that there is no capillary blood flow (= alveolar dead space). The alveolar air becomes equal to humidified inspired air ( $PO_2$  of 149 mmHg and a  $PCO_2$  of 0 mmHg).
- When  $V_A/Q$  is normal; alveolar  $PO_2$  is normal (104 mmHg) and  $PCO_2$  is 40 mmHg.



$V/Q$	0.8	0	$\infty$
$PA_{O_2}$	100 mm Hg	–	150 mm Hg
$PA_{CO_2}$	40 mm Hg	–	0 mm Hg
$Pa_{O_2}$	100 mm Hg	40 mm Hg	–
$Pa_{CO_2}$	40 mm Hg	46 mm Hg	–

**FIGURE** Effect of ventilation/perfusion ( $\dot{V}/\dot{Q}$ ) defects on gas exchange. With airway obstruction, the composition of systemic arterial blood approaches that of mixed venous blood. With pulmonary embolus, the composition of alveolar gas approaches that of inspired air.  $PA_{O_2}$  = alveolar  $PO_2$ ;  $PA_{CO_2}$  = alveolar  $PCO_2$ ;  $Pa_{O_2}$  = arterial  $PO_2$ ;  $Pa_{CO_2}$  = arterial  $PCO_2$ .

## Note:

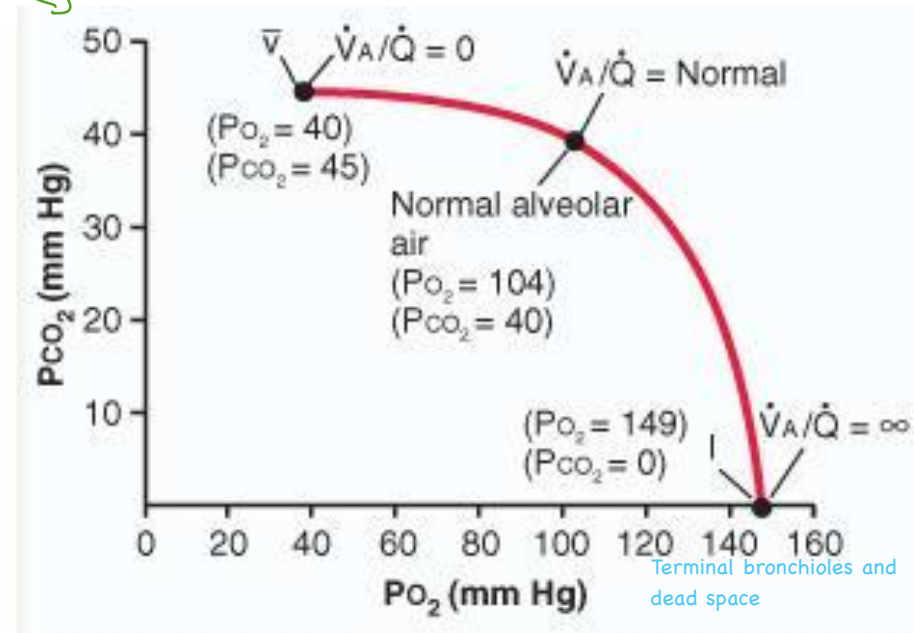
The term **V/Q mismatch** is more appropriate to be used to describe conditions fall in between these two extremes.

# Effect of $V_A/Q$ on alveolar gas concentration:

## Note:

الارتجاع القليل عند  $P_{CO_2}$  يعاقبه انخفاضه  
كبير  $O_2$

1. There can be marked decrease in oxygen tension with only a minimal rise in the  $CO_2$  tension. (See the graph)
2. Many of the conditions that cause mismatching of ventilation and perfusion involve both dead air space and shunt. In chronic obstructive lung disease, for example, there may be impaired ventilation in one area of the lung and impaired perfusion in another area





# Physiologic shunt and physiologic dead space:

Oxygen content  $\neq$  oxygen  $[P_{O_2}]$   
معدل الأوكسجين ذاته منكم معدل الأوكسجين

- When  $V_A/Q$  is **below normal** this means that there is **inadequate ventilation** needed for full oxygenation, or **excessive blood flow** → some of the venous blood remains unchanged (= shunted blood).  
ما تغيره لم يتغير

- The total amount of shunted blood/minute is called **Physiologic shunt**. Physiologic shunt → decrease in the overall arterial  $PO_2$  and oxygen content.  
يقل عنه ما يتدحج مع الدم الكامل

- When  $V_A/Q$  is *greater* than normal this means that some of the ventilated air is wasted (alveolar dead space) → ↑ **physiologic dead space** →  $CO_2$  retention and hypoxia → **compensated hyperventilation** → correction of hypercapnea only.

hypoxymia \* كيرت

collection of  $PO_2$   
↓  
 $PO_2$

ك كيرت

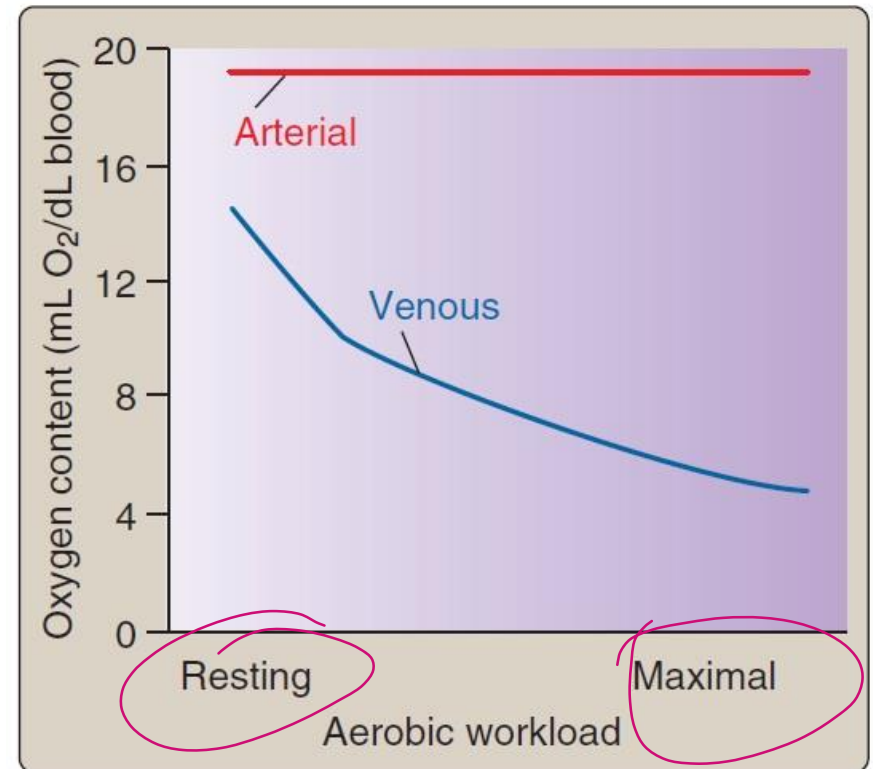
# Respiratory responses to exercise:

- Cardiac output increases approximately linearly with work level.
- The change in cardiac output (in liter/min) is only about a quarter of the increase in ventilation. 4 ↑  $V_A$ /Cardiac out ↑
- Ventilation increases linearly with  $O_2$  uptake until the ventilatory (or anaerobic) threshold is reached after which ventilation increases more rapidly.
- Despite the increase in ventilation, the difference between inspired and expired  $O_2$  concentrations does not change. →  $V_A/P$  ratio يتغير
- In normal subjects, the amount of ventilation-perfusion inequality decreases during moderate exercise because of the more uniform topographical distribution of blood flow. → mismatch

# $PaO_2$ remains stable during exercise because of:

\* نسبة ال  $O_2$  تبقى ثابتة في Arterial blood حتى في exercise  
\* نسبة ال  $O_2$  في Venous blood تقل نظراً لـ استهلاك ال  $O_2$  العالي من قبل الخلايا .

- $\uparrow$  Ventilation : maintains a steep  $PO_2$  gradient across the blood-gas barrier  
*معدل تنفس ال  $O_2$  في exercise*
- $\uparrow$  Tidal volume : improves  $V_A/Q$  ratio at the lung base
- $\uparrow$  Pulmonary flow : recruits pulmonary capillaries and increases blood-gas interface surface area



## Summary of Respiratory Responses to Exercise

Parameter	Response
O <sub>2</sub> consumption	↑
CO <sub>2</sub> production	↑
Ventilation rate	↑ (Matches O <sub>2</sub> consumption/CO <sub>2</sub> production)
Arterial P <sub>O<sub>2</sub></sub> and P <sub>CO<sub>2</sub></sub>	No change
Arterial pH	No change in moderate exercise ↓ In strenuous exercise (lactic acidosis)
Venous P <sub>CO<sub>2</sub></sub>	↑
Pulmonary blood flow (cardiac output)	↑
$\dot{V}/\dot{Q}$ ratios	More evenly distributed in lung

$\dot{V}/\dot{Q}$  = ventilation/perfusion ratio.

# Test Question 1:

لم أتأكد من الحل يحتمل الصواب والخطا

Q. The apex of the upright human lung compared with the base has?

- A. A higher alveolar  $PO_2$ . ✓
- B. A higher ventilation. ✗
- C. A lower pH in end-capillary blood. ✗
- D. A higher blood flow. ✗
- E. Smaller alveoli. ✗

# Pathophysiology:

A mismatch in ventilation and perfusion can arise due to either reduced ventilation of part of the lung or reduced perfusion.

## Reduced Perfusion of the Lungs

- This finding is typically associated with pulmonary embolism. Ventilation is wasted, as it fails to oxygenate any blood.
- The  $V_A/Q$  ratio is high with decreased  $PACO_2$  and increased  $PAO_2$ , because of the increased dead space ventilation. *in alveoli*
- The  $PaO_2$  is reduced and thus also the peripheral oxygen saturation is lower than normal, leading to tachypnea and dyspnea. *arterial*

# Pathophysiology:

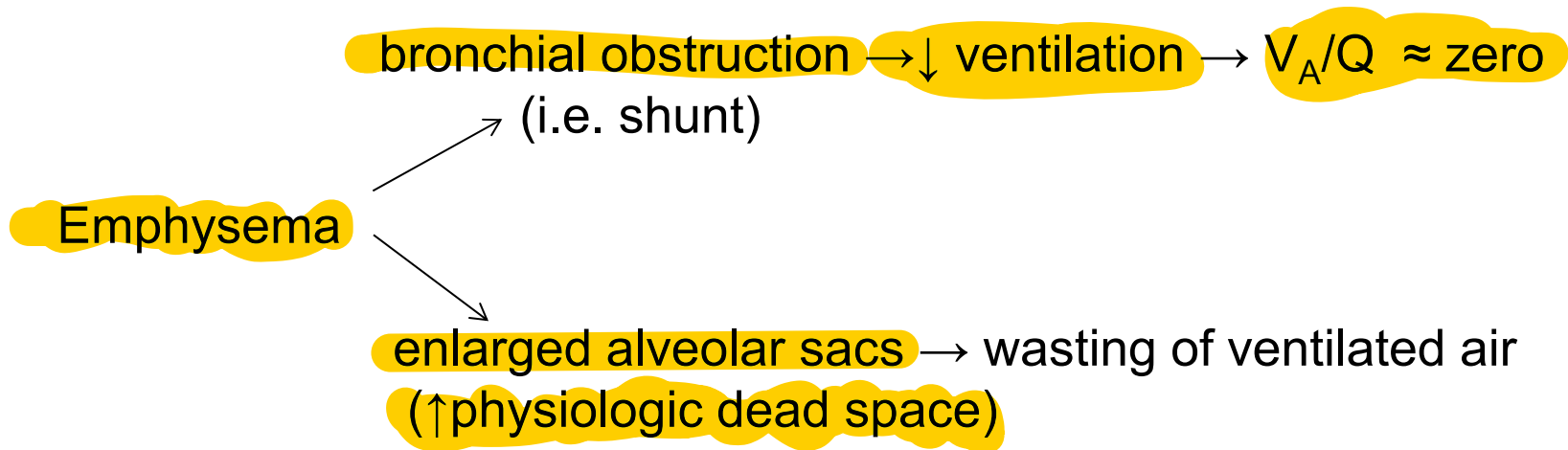
## Reduced Ventilation of the Lungs

- Reduced ventilation can occur for a number of reasons.
- This includes **pneumonia**, whereby the alveoli are filled with exudate, limiting the ability to maintain ventilation.
- **Asthma** and **COPD** may also result in a reduction in ventilation, as well as **respiratory distress syndrome** of the newborn, whereby **reduced surfactant** production results in multiple collapsed alveoli, limiting its ventilating capability.
- The effect of reduced ventilation is **hypoxemia**. However, as the rest of the lung can still remove CO<sub>2</sub>, **hypercapnia does not occur**.
- In severe asthmatics, **aerosolized bronchodilator therapy**, by increasing blood flow to potentially underventilated lung units, increases shunt and arterial desaturation. This may lead to worsening hypoxemia following bronchodilator therapy.
- Drugs, such as anesthetics can **lower V<sub>A</sub>/Q ratios**, as there is impaired matching of ventilation and perfusion during **anesthesia**.

# Pathophysiology:

perfusion & ventilation disequilibrium

- The pathophysiology in some pulmonary diseases is complex, and can be associated with multiple pathologies.
- Prolonged smoking can end in **chronic obstructive lung diseases** (e.g. **emphysema**)



- The effectiveness of gas exchange can be reduced in emphysema to one-tenth the normal value.



## Test Question 2:

Q. If the ventilation-perfusion ratio of a lung unit is decreased by partial bronchial obstruction while the rest of the lung is unaltered, the affected lung unit will show?

A. Increased alveolar  $PO_2$ .

B. Decreased alveolar  $PCO_2$ .

C. No change in alveolar  $PN_2$ .

D. A rise in pH of end-capillary blood.

E. A fall in oxygen uptake.