VENTILATION/PERFUSION RATIO

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Objectives

- By the end of this lecture you will be able to:
- Recognize the high pressure and low pressure circulations supplying the lung.
- 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 abnormal patterns of the V/Q ratio, shunt and dead space patterns.

Pulmonary Circulation

(1) 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.

(2) 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.

Cont.

- Blood flows to the lungs through small bronchial arteries that originate from the systemic circulation, amounting to 1-2 % 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 and arterial 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.
- 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.

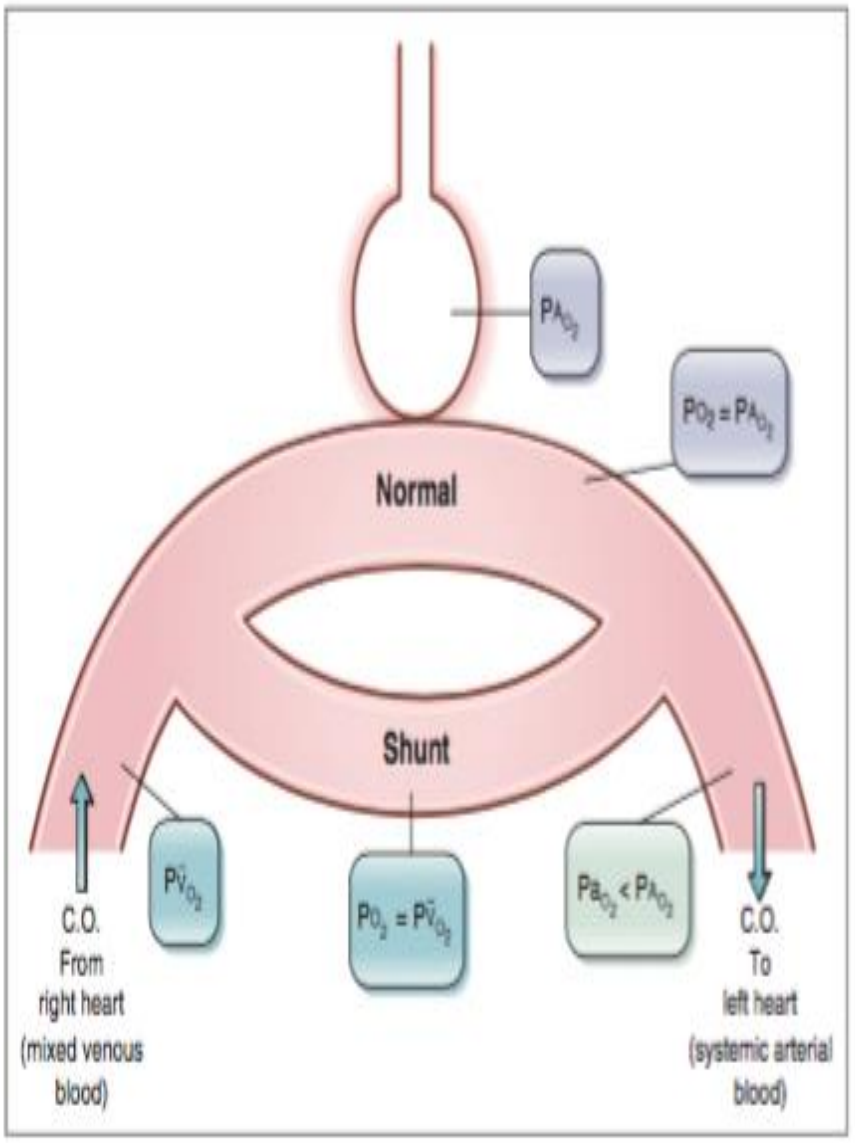
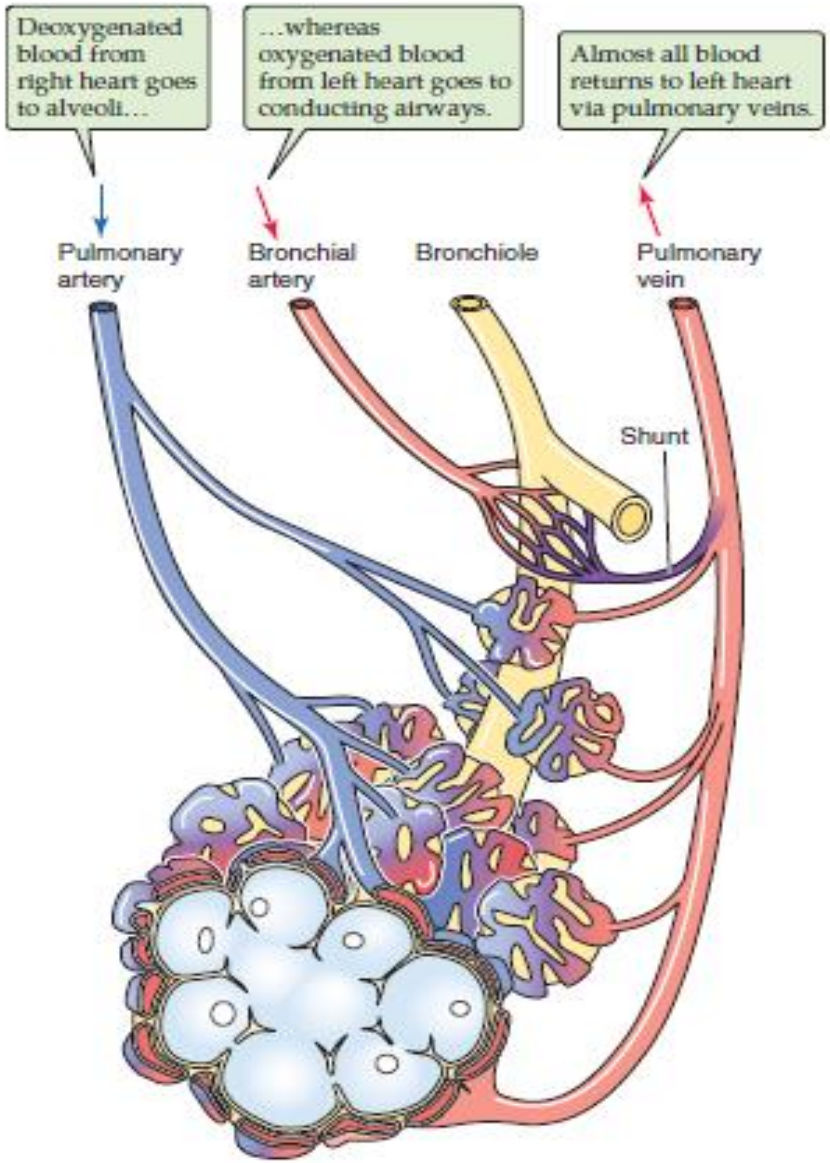


Fig. 5.27 Right-to-left shunt. C.O., Cardiac output.

Regulation of pulmonary blood flow

- The major factor regulating pulmonary blood flow is the partial pressure of O2 in alveolar gas,PAo2.
- Decreases in PAo2 produce pulmonary vasoconstriction (adaptive mechanism: Blood flow is directed away from poorly ventilated region.
- If PAo2 is reduced below 70 mmHg, vasoconstriction occurs.
- High altitude,PAo2 is reduced which produced global vasoconstriction.
- Fetal pulmonary blood flow circulation is about 15%of cardiac output due to global vasoconstriction.



Shunts

- A shunt:

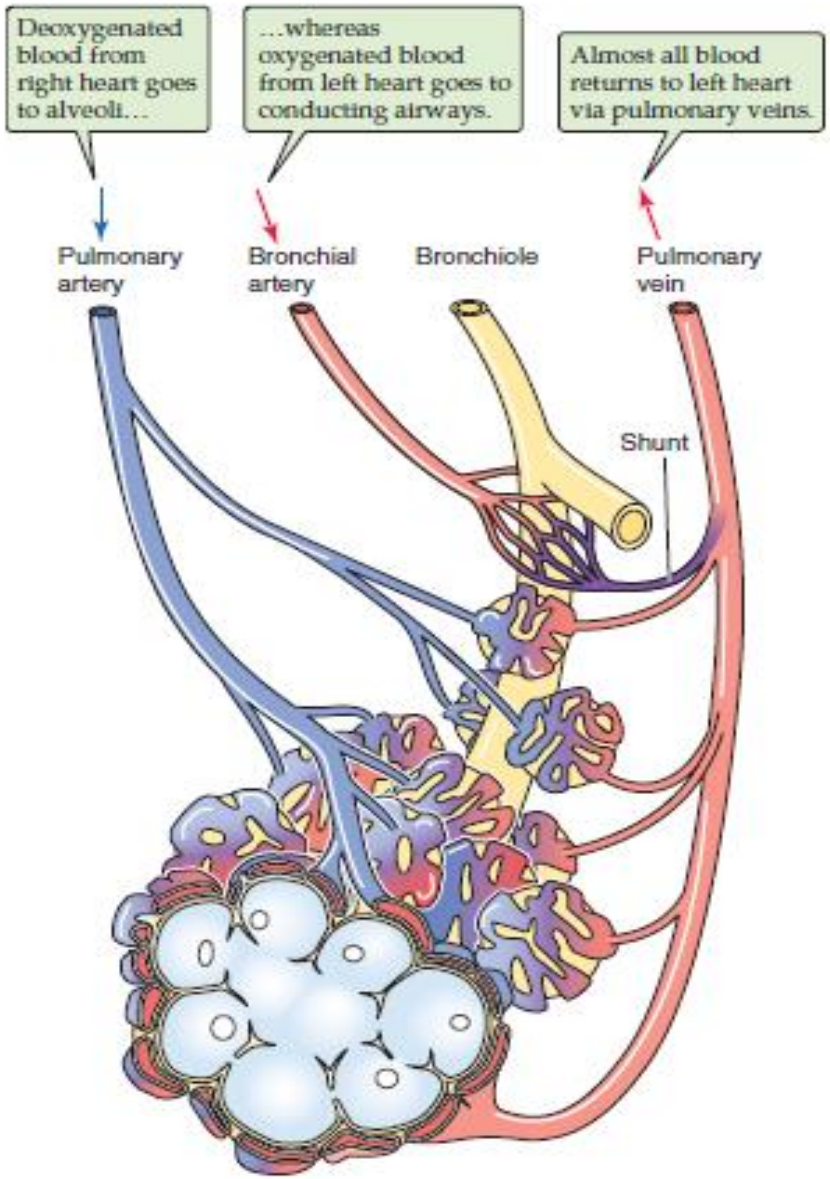
refers to a portion of the pulmonary blood flow that bypasses the alveoli(no gas exchange).

- Physiologic shunt:

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

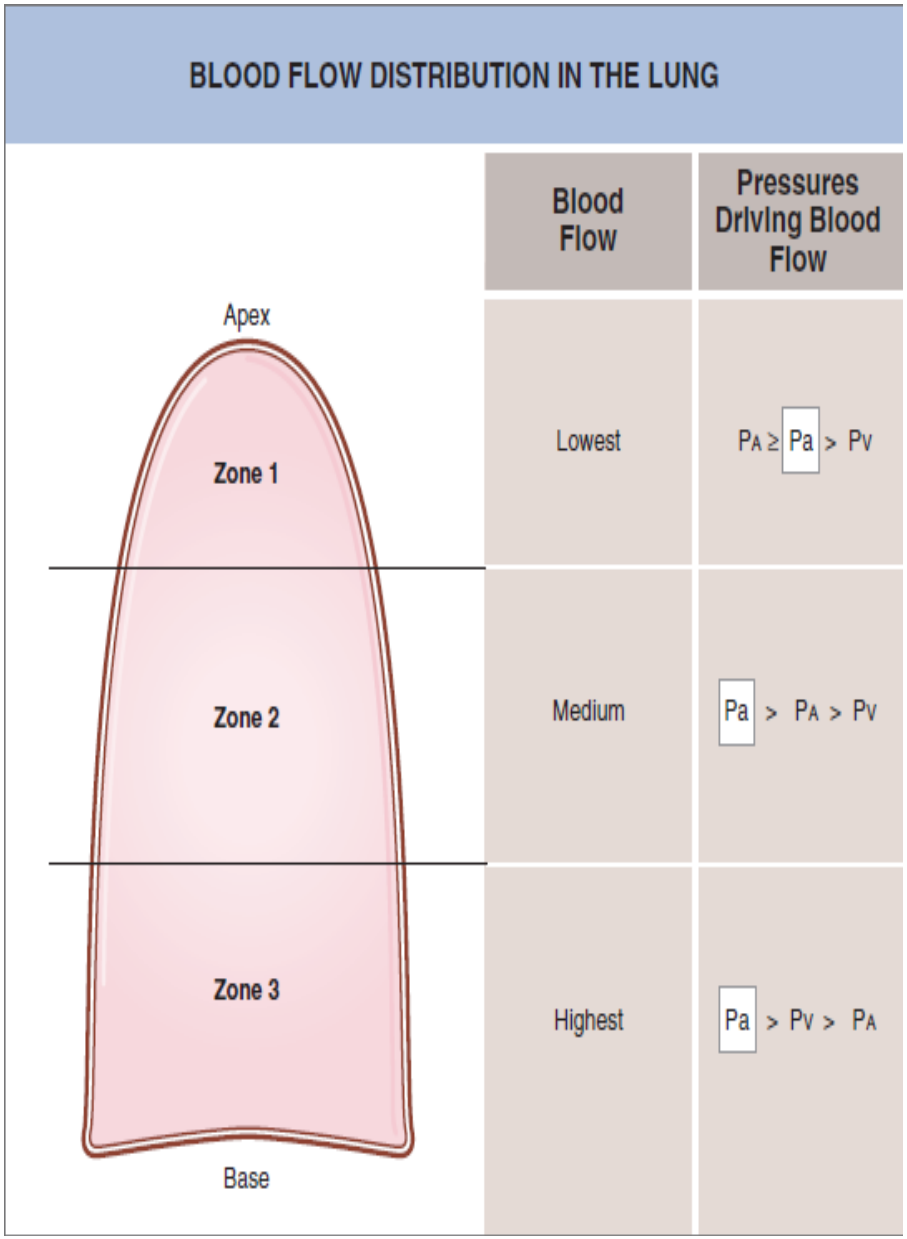
- Example of abnormal shunt:

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



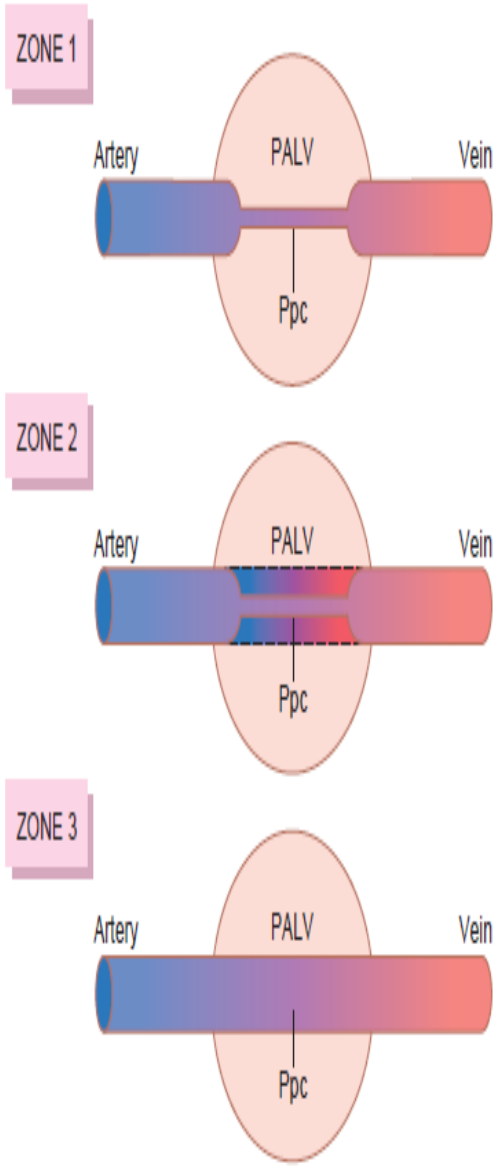
Effect of hydrostatic pressure on blood flow

- 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.
- In supine position, blood flow is nearly uniform.

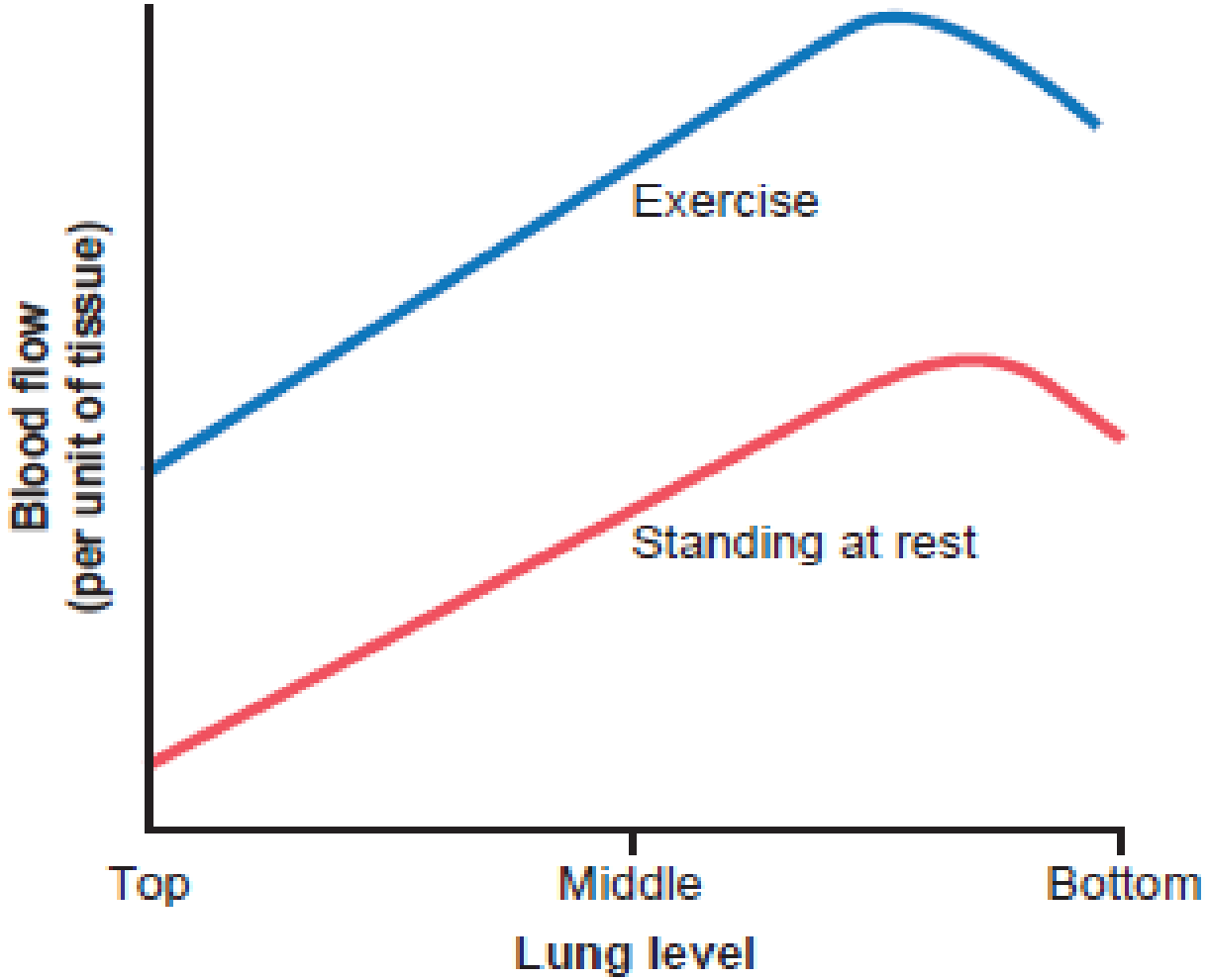


Zones 1, 2, and 3 of pulmonary blood flow

- Zone 1: No blood flow during all portions of the cardiac cycle because the local alveolar capillary pressure in that area of the lung never rises higher than the alveolar air pressure during any part of the cardiac cycle (almost closure of the capillaries).
- 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.
- Normally, the lungs have only zones 2 and 3 blood flow—zone 2 (intermittent flow) in the apices and zone 3 (continuous flow) in all the lower areas.



Blood flow at different levels in the lung



Ventilation/perfusion ratio (V/Q)

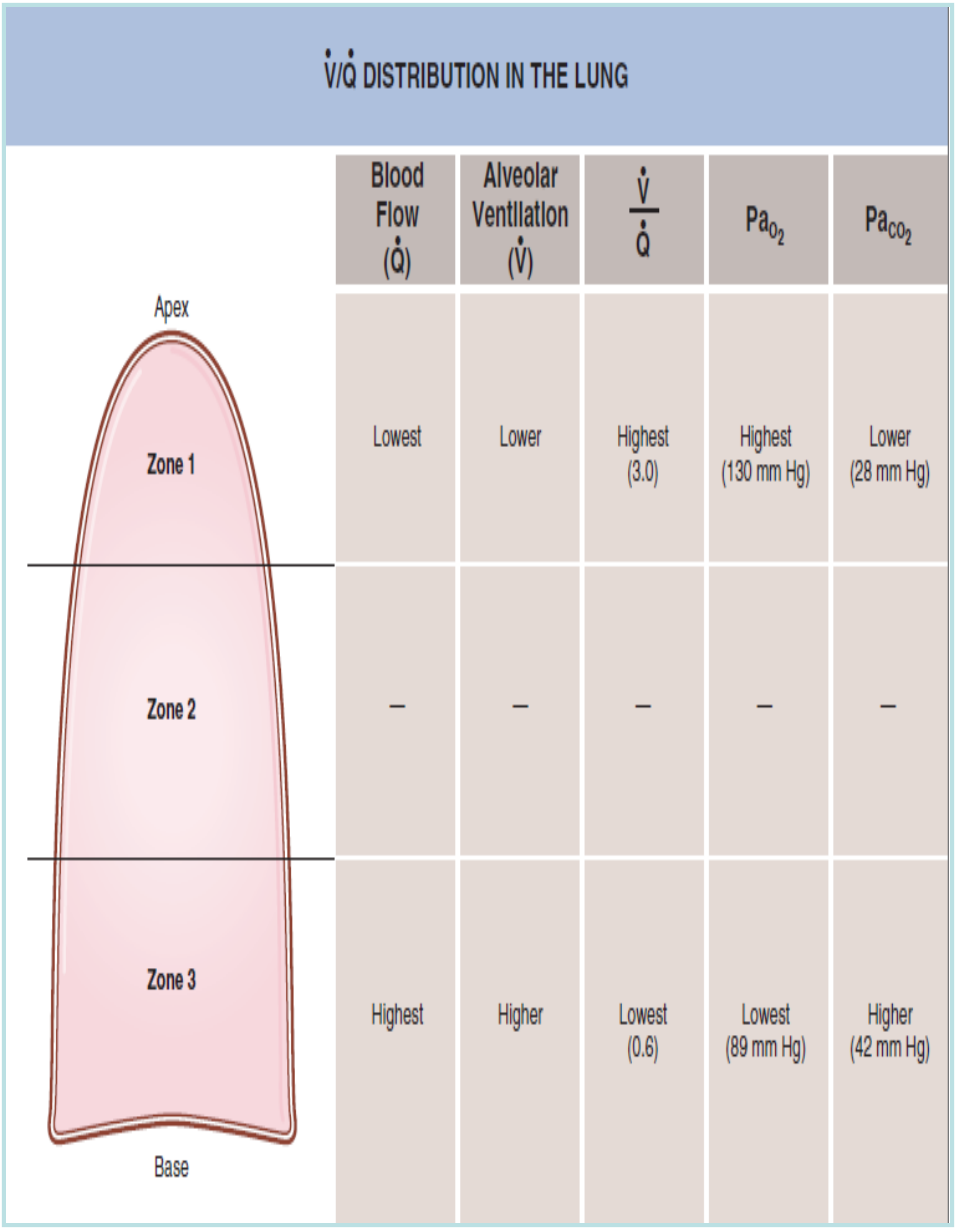
- It is the ratio of alveolar ventilation to pulmonary blood flow per minute.
- The alveolar ventilation at rest (4.2 L/min)
- The pulmonary blood flow is equal to right ventricular output per minute (5L/min)

$$\text{V/Q ratio} = \frac{4.2}{} = 0.84$$

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

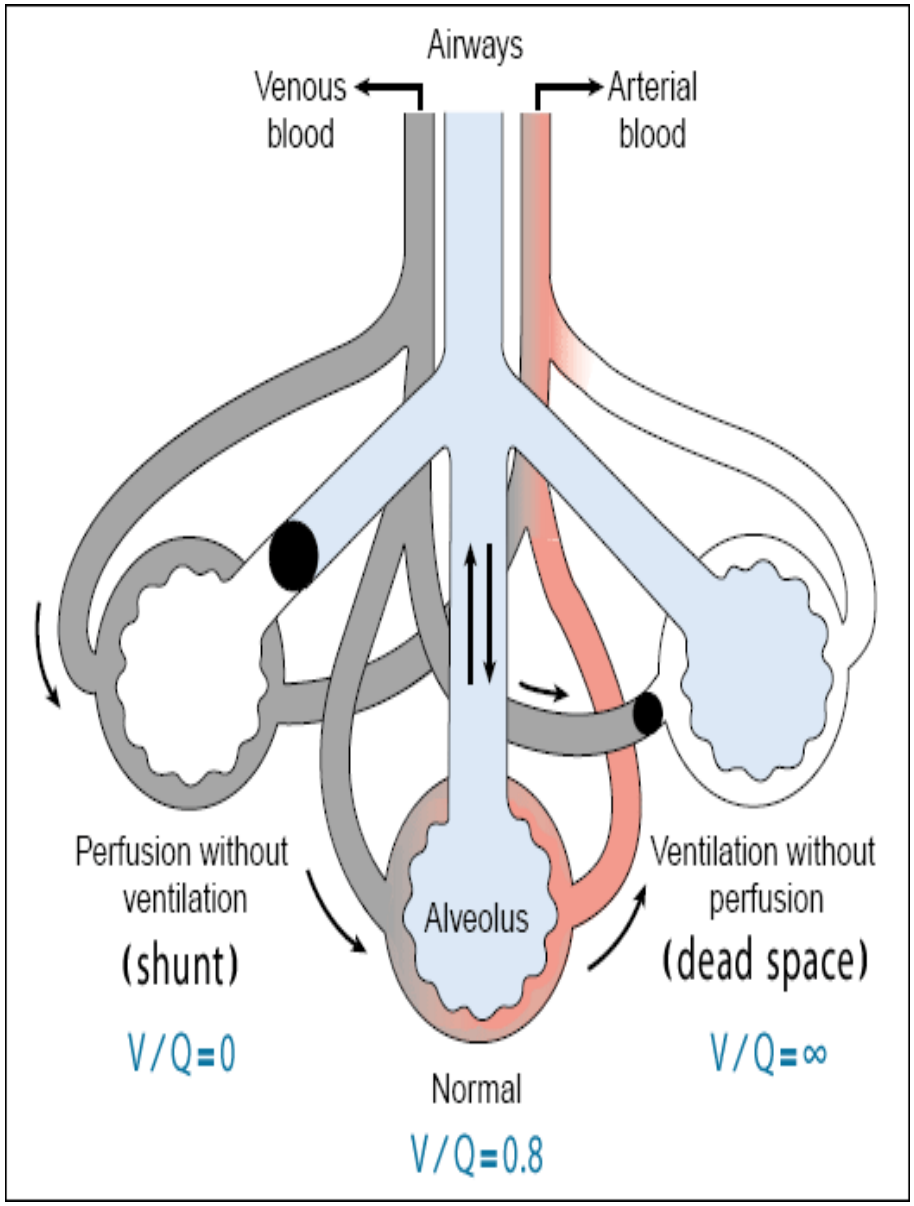
Variation in V/Q in the zones of the lung

- V/Q is uneven in the three zones.
- At the apex V/Q ratio = 3
- At the base V/Q ratio=0.6
- The apex is more ventilated than perfused and the base is more perfused than ventilated.
- During exercise the V/Q ratio becomes more homogenous among different parts of the lung.



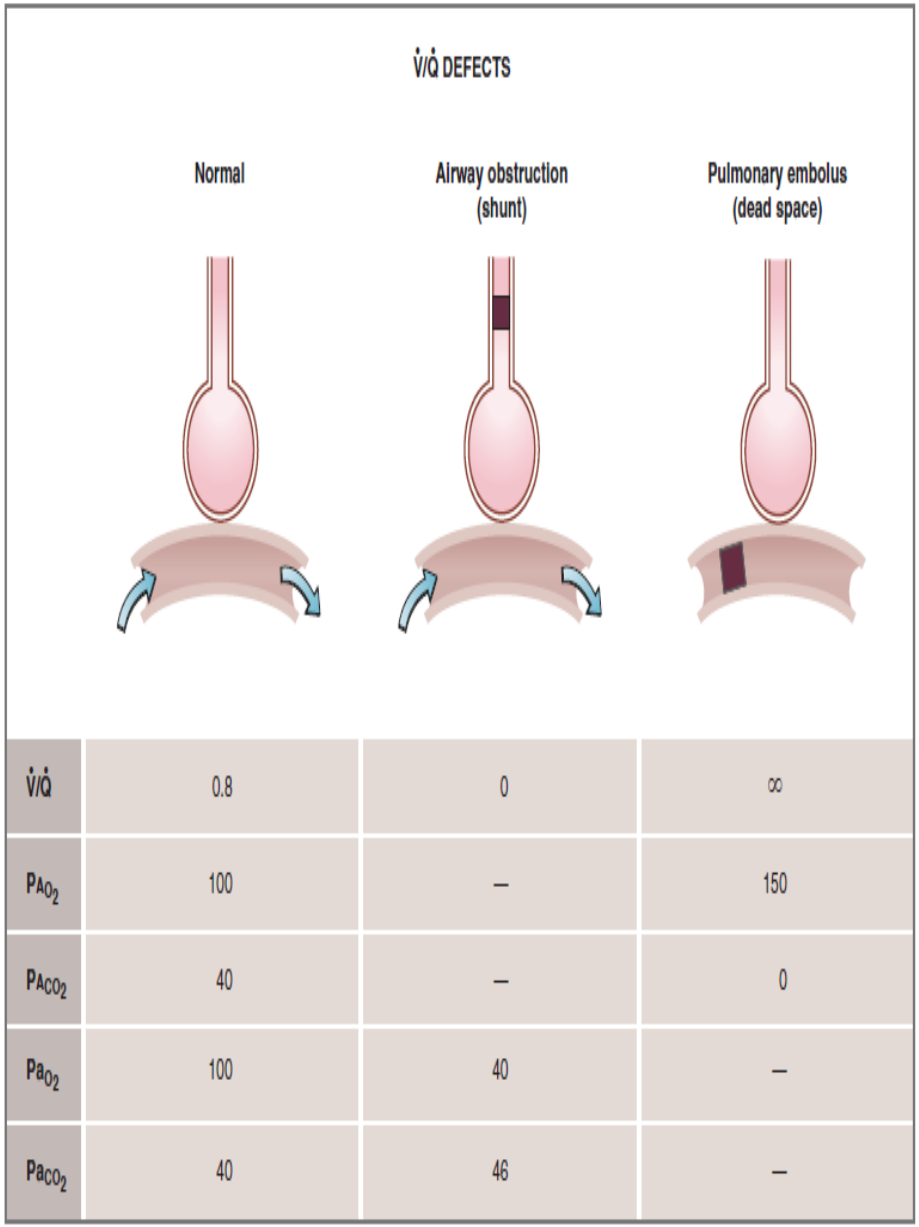
Cont. V/Q ratio

- The main function of this ratio is to determine the state of oxygenation in the body.
- Apex V/Q ratio = 3 (moderate degree of physiologic or normal dead space).
- Base V/Q ratio= 0.6 (represent a physiologic or normal shunt).
- Any mismatch in the ratio can result in hypoxia.



Abnormalities of the V/Q ratio

- 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).



$\dot{V}/\dot{Q}$	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	–