KPCOM Respiratory System Lecture
03/28/2025 1010-1100
Ventilation – Perfusion Matching

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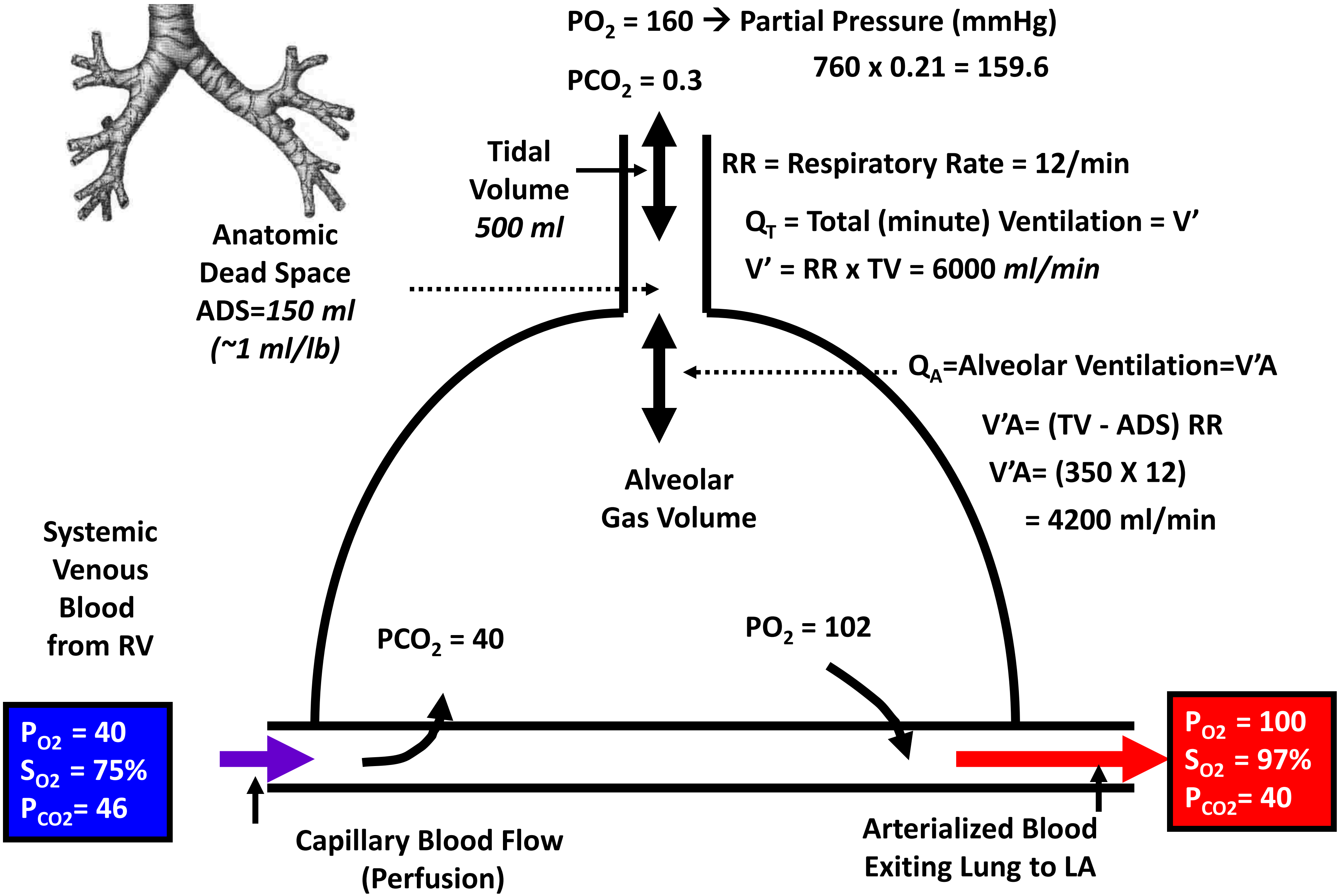
Ventilation Related Processes: REVIEW



Review of Complete Alveolar Gas Equation

$$PA_{O2} = \underbrace{(P_{ATM} - 47) \times F_{IO2}}_{PO_2 \text{ (trachea)}} - \underbrace{PA_{CO2}}_{\text{Alveolar } CO_2} \underbrace{[F_{IO2} + (1-F_{IO2})/ R]}_{\text{"Correction" factor}}$$

R = respiratory exchange ratio
= CO_2 produced/O_2 consumed

Calculation at sea level with room air

$$PA_{O2} = (760-47) \times .21 \quad - 40 \quad [.21 + (1-.21)/.8]$$

$$PA_{O2} = \quad (713) \quad \times .21 \quad - 40\ [1.2]$$

$$PA_{O2} \approx \quad 150 \quad - 40\ [1.2] \quad = 102 \text{ torr}$$

$PA_{O2} \approx 150 - 1.2\ PA_{CO2}$ *for room air at sea level*

Approximate Equation B&L 23.13

$$PA_{O2} = \underbrace{(P_{ATM} - 47) \times F_{IO2}}_{PO_2 \text{ (trachea)}} - PA_{CO2}/R$$

$$PA_{O2} \approx \quad 150 \quad - 40/0.8 \quad = 100 \text{ torr}$$

Review of the Alveolar Ventilation Equation

$$P_{A_{CO2}} = K \frac{CO_2 \text{ Production}}{\text{Alveolar Ventilation}} = K \frac{\dot{V}_{CO_2}}{Q_A}$$

K = 0.863 (mmHg) with $V'CO_2$ in ml/min and Q_A in L/minute

K = 863 (mmHg) with $V'CO_2$ in ml/min and Q_A in ml/minute

- **Hypoventilation** if ratio too high: $P_{A_{CO2}}$ rises
- **Hyperventilation** if ratio is too low: $P_{A_{CO2}}$ falls

If as usual, P_{ATM} = 760 mmHg and Q_A measured at 310°K (37°C) and V'_{CO2} measured at 273° STP

Then K = 760 mmHg x (310K/273K) = 760 x 1.1355 = 863 as shown above

Berne and Levy equation 23.16 not quite correct!

Ventilation-Perfusion Matching

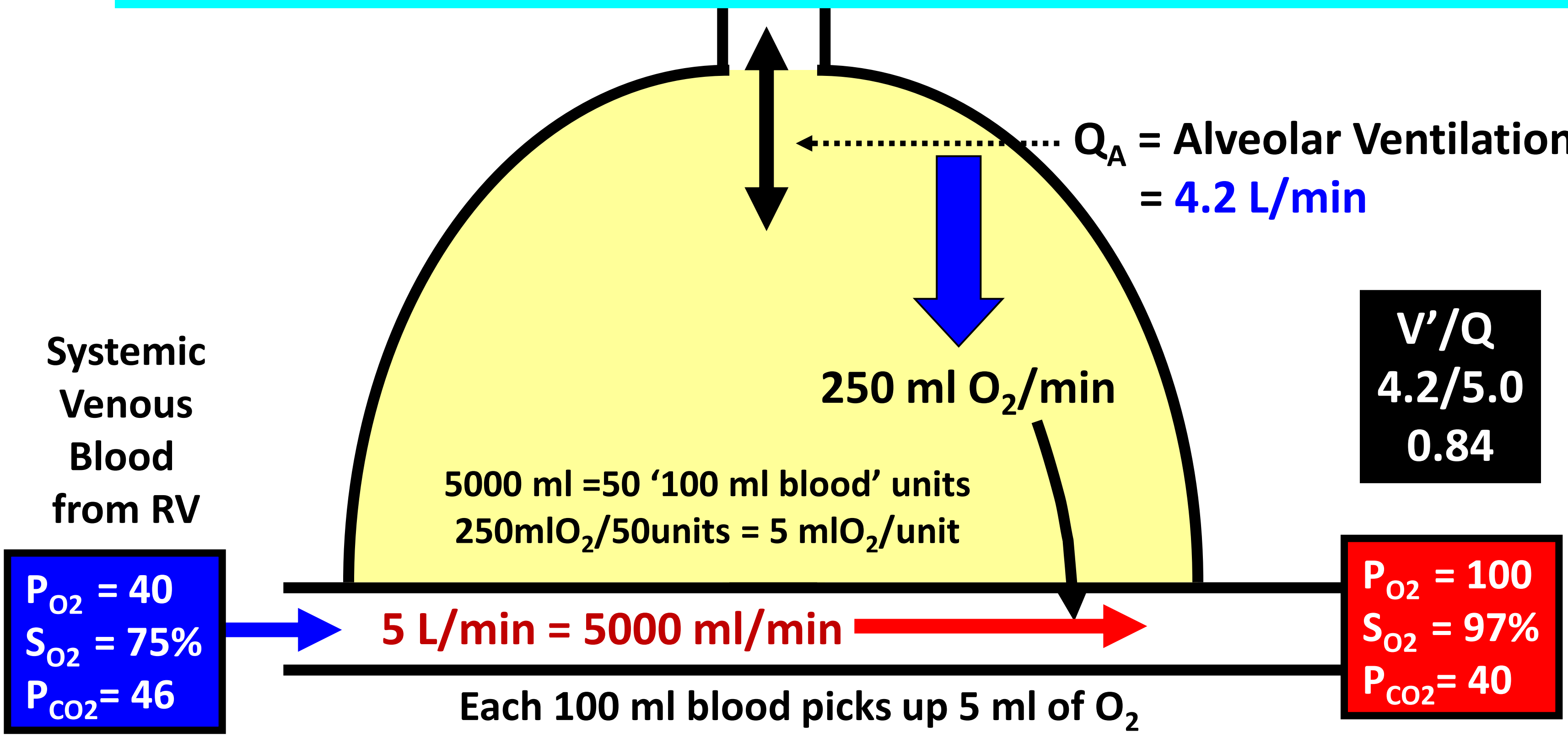
Basic Concept

It is neither ventilation nor perfusion alone that determines arterial blood gases. It is the ratio of ventilation to perfusion that is the determinant!

Ventilation/Perfusion = V'/Q ratio

Case A: Ventilation-Perfusion Concept

- Assume that 5 mlO_2 /100 ml blood are used by the body per minute
- At a CO of 5000 ml/min each of the 50 100 ml “train cars” needs 5 mlO_2
- Assume that an alveolar ventilation of 4.2 L/min just supplies this amt of O_2
- This results in a proper “arterialization” of blood exiting the lung.
- Ventilation is MATCHED to the Perfusion arterialize blood exiting lung

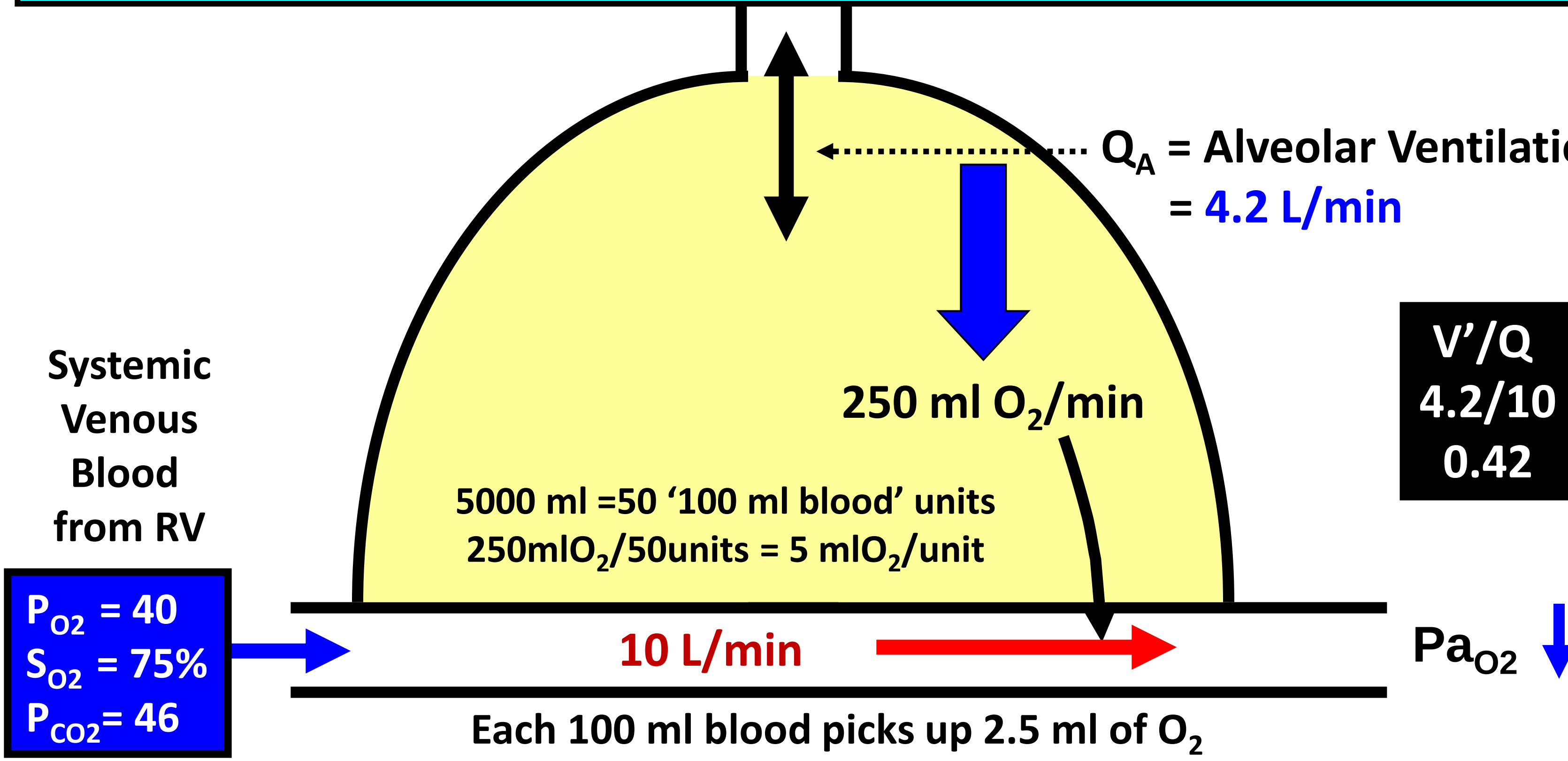


Blood flow is just right for the rate of O_2 delivery!

Case B: Ventilation-Perfusion Concept

Now assume that an alveolar ventilation remains unchanged at 4.2 L/min
BUT that blood flow increases to 10 L/min

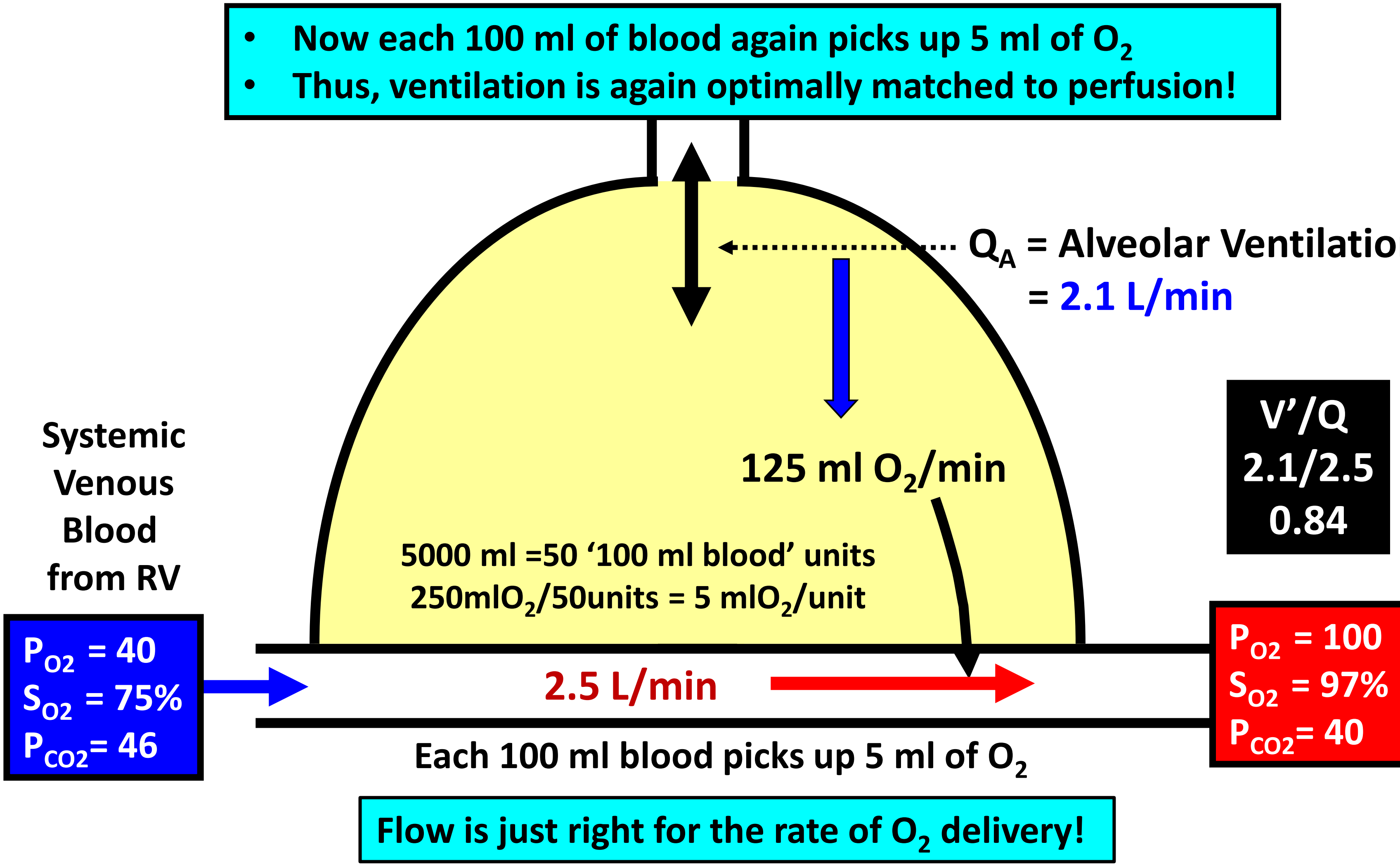
- **Now, 100 "100 ml units" pass by each min - So – each dl picks up only 2.5 ml of O_2**
- **Since this is ½ that needed, blood exiting the lung will have its PO_2 much reduced!**



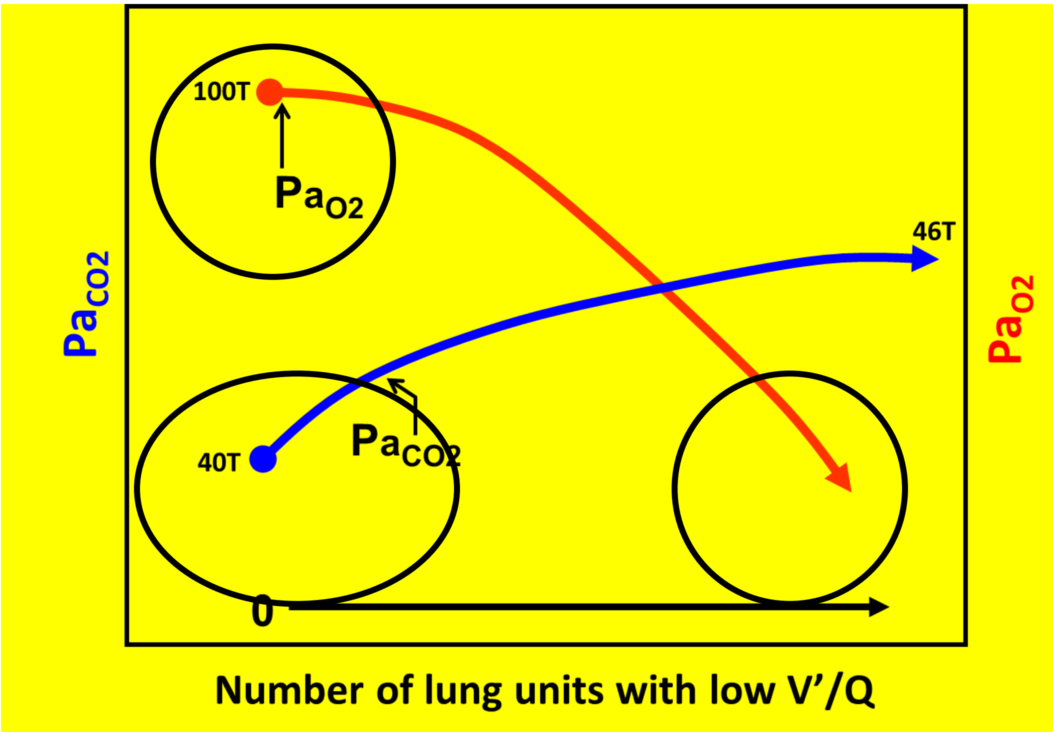
Flow is too great for the rate of O_2 delivery!

Case C: Ventilation-Perfusion Concept

Now suppose ventilation and perfusion become 1/2 of what they originally were

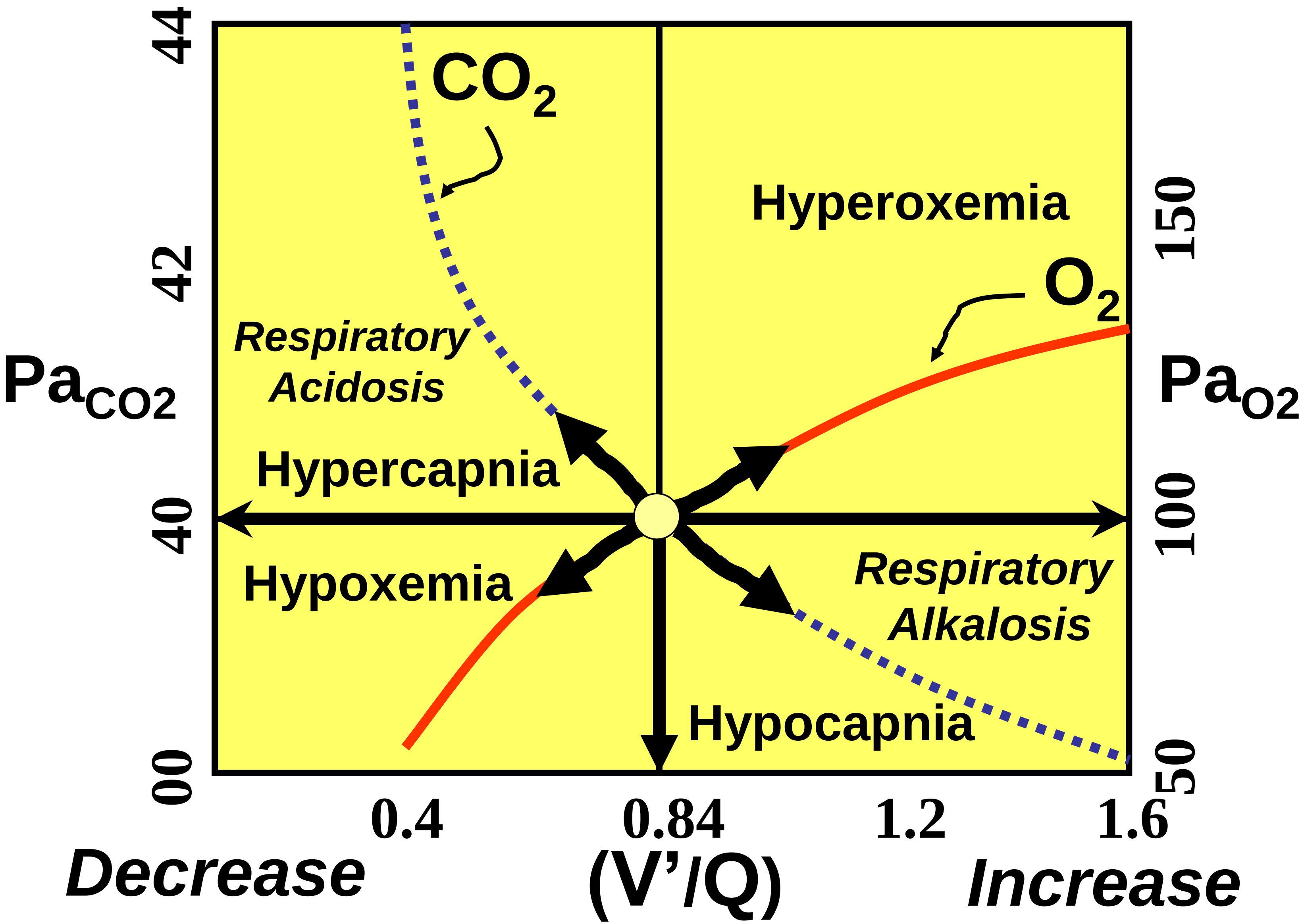


Another View of V'/Q Mismatching

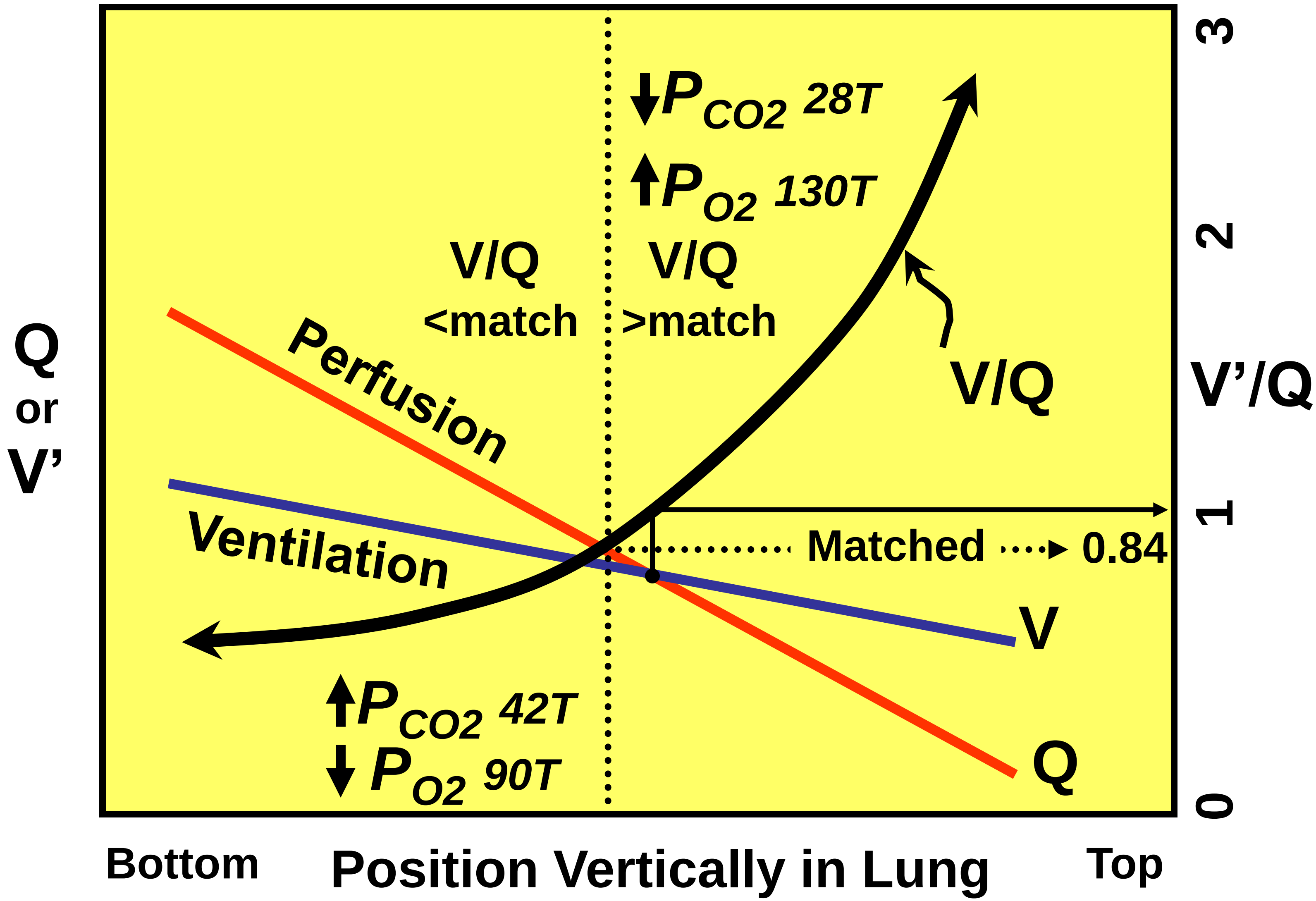


- If all lung units were V'/Q matched, then optimum lung function; but this is not the case
- Some units have V'/Q less than a match and other have V'/Q greater than a match
- The combined blood coming from all units determines the arterial values of O_2 and CO_2
- As the number of low V'/Q lung units increases the blood exiting the lung will have increasing values of CO_2 and decreasing values of O_2

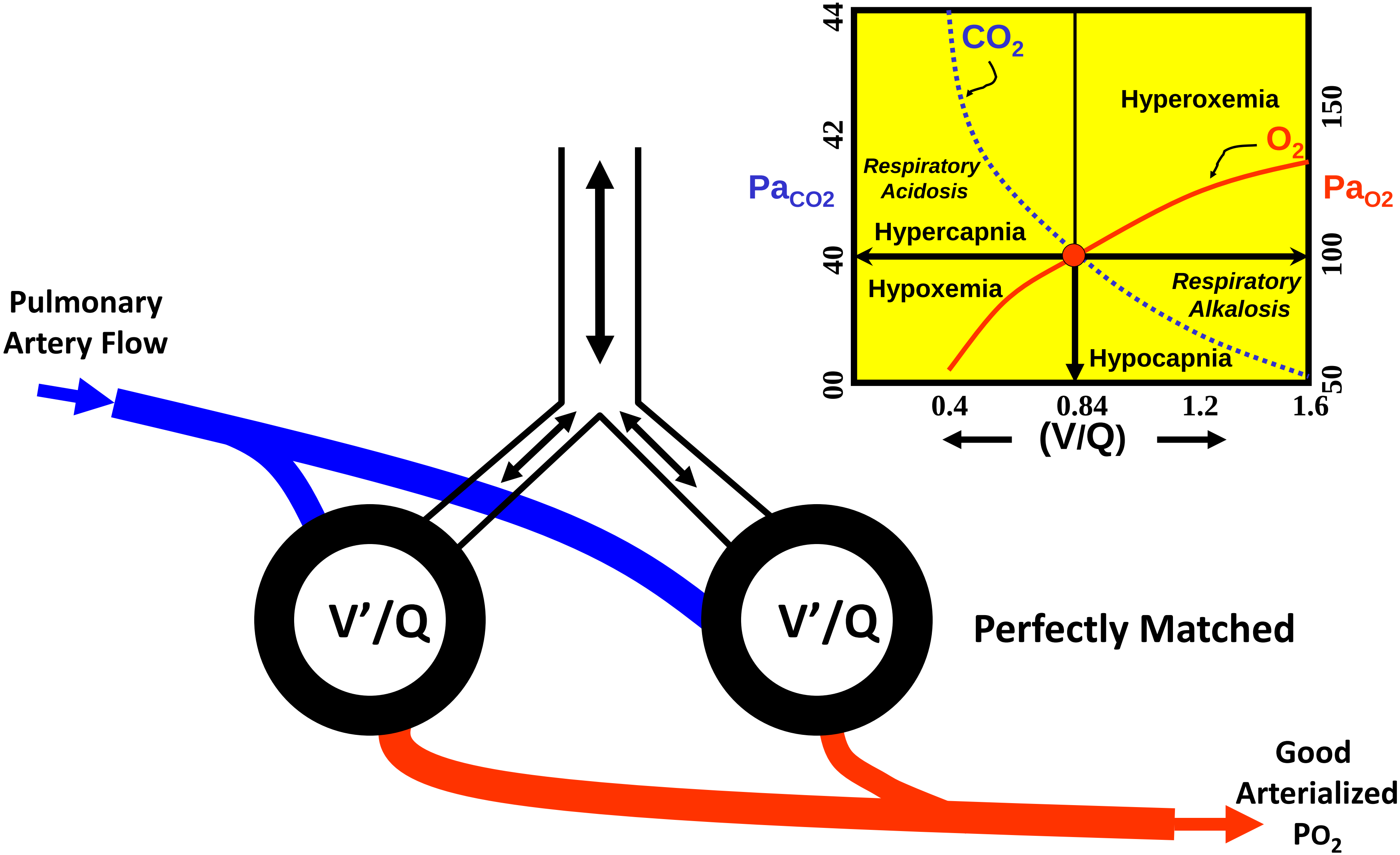
Effects of Changes in V'/Q



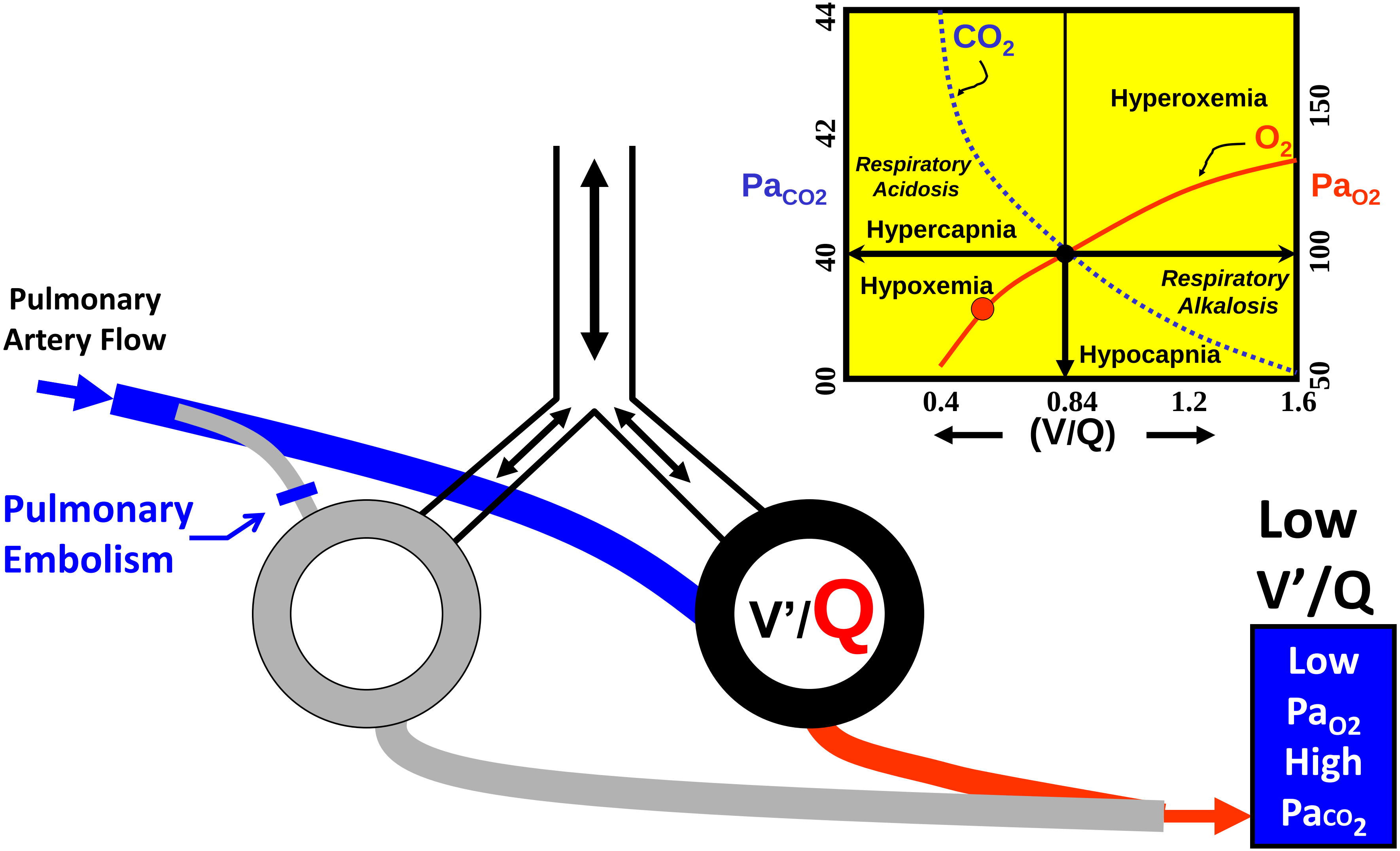
Regional V'/Q Variations



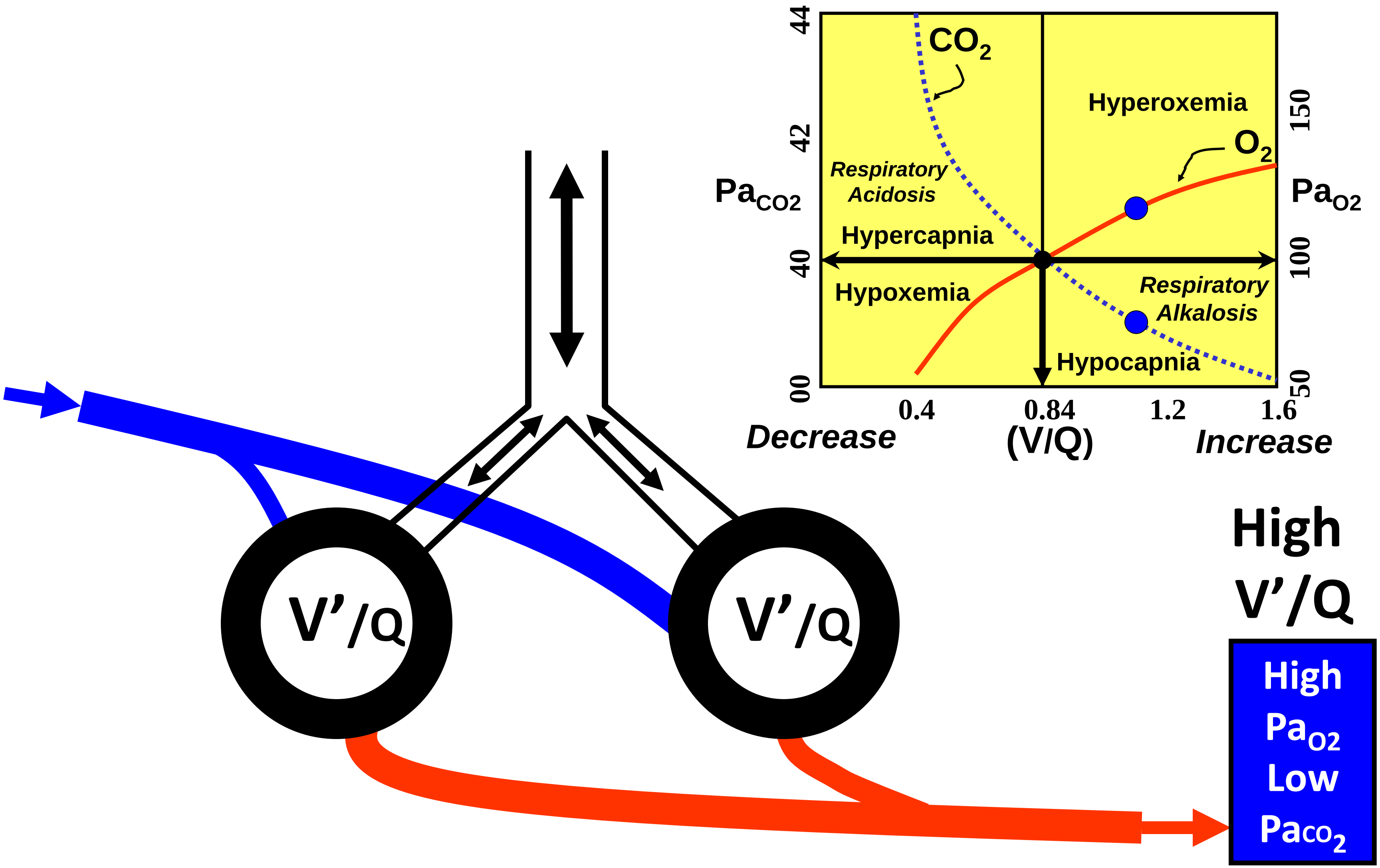
Clinical Correlation: Ventilation matched to Perfusion



Clinical Correlation: Pulmonary Embolism



Clinical Correlation: Hyperventilation



Review of Dead Space Definitions and Calculations

- Anatomic (Airway) Dead Space = No gas exchange → Dead Space
- Alveolar Dead Space = Sum of alveolar volumes that receive little or no blood flow
  Ventilated but low or no perfusion (V'/Q → infinity)
  Example is Zone I if low pulmonary artery pressure)
- Physiological Dead Space = Amount of each tidal volume that
  does NOT participate in gas exchange
- Physiological Dead Space = PDS = Anatomic DS + Alveolar DS

Collecting Expired Volume in a Bag

$$PDS = TV \times (1 - P_ECO_2/P_aCO_2)$$

P_aCO_2 = CO_2 tension in arterial blood

P_ECO_2 = CO_2 tension in expired air

- If ratio = 1 → no dead space
- If ratio = 0 → all dead space
- The lower the CO_2 tension in the expired air the greater is the physiological dead space!

Review of Sources of Uneven Ventilation in the Lung

Variable Resistance Distribution Within the Lung

- Uneven Regional obstruction → e.g. **Bronchoconstriction** in Asthma
- Uneven Airway collapse → e.g. as in **Emphysema**
- Uneven Airway narrowing → e.g. as in **Bronchitis**
- Uneven Airway compression → e.g. as in **Tumors or Edema**
- Uneven lung and airway expansion → e.g. due to **Gravity**

Variable Compliance Distribution within the Lung

- Uneven Fibrosis distribution → e.g. as in **interstitial fibrotic disease**
- Uneven loss of elastic recoil → e.g. as in **emphysema**
- Uneven surfactant distribution → e.g. due to **structural issues**
- Uneven pleural thickness
- Uneven areas of edema

Oxygen Deficiency –Terms and Definitions

ANOXIA = No O_2

HYPOXEMIA = Hypoxic Hypoxia

= Low arterial blood PO_2

HYPOXIA = Inadequate O_2 Available for Tissue Needs

Hematological Hypoxia

Low Hb to bind/carry O_2 but normal PO_2

e.g. Anemia or Carbon Monoxide Poisoning

Ischemic Hypoxia

Low tissue O_2 due to low flow (blood PO_2 is normal)

Histotoxic Hypoxia

Normal O_2 supplied but can't be utilized by tissue;

e.g. Cyanide Poisoning

Interactive Questions

1. According to the Alveolar **Ventilation** Equation, if alveolar ventilation decreases in relation to CO_2 removal, what happens to alveolar CO_2 tension?

$$PA_{CO2} = K \frac{\dot{V}_{CO_2}}{Q_A}$$

2. According to the Alveolar **Gas** Equation, if alveolar CO_2 tension increases, what happens to alveolar oxygen tension?

$$PA_{O2} = (P_{ATM} - 47) \times F_{IO2} - PA_{CO2}/R]$$

3) If alveolar ventilation increases above normal the
a) alveolar PO2 decreases
b) alveolar PCO2 decreases ←
c) arterial PO2 decreases
d) arterial PCO2 increases

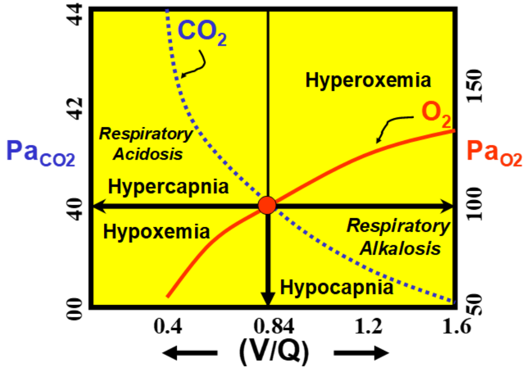
4) If barometric pressure is 1000 torr, PO2 in your trachea is closest to which of the following?
a) 40 torr
b) 100 torr
c) 150 torr ←
d) 200 torr

=(1000 - 47)x 0.21
= 953 x 0.21 = 200 torr

Interactive Questions

5) Reduced alveolar ventilation will tend to
a) increase arterial PCO2 ←
b) decrease alveolar PCO2
c) increase arteriolar PO2
d) increase alveolar PO2

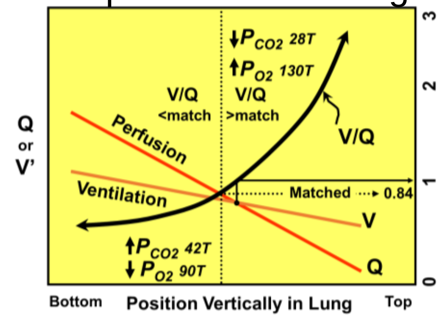
6) If alveolar ventilation is constant, a large increase in pulmonary blood flow will tend to
a) increase the oxygen saturation of arterial blood
b) increase the oxygen tension in arterial blood
c) increase the arterial CO2 tension ←
d) have no effect on arterial CO2 tension



7) With no change in blood flow, a large decrease in alveolar ventilation will tend to
a) cause alveolar oxygen to rise
b) cause alveolar carbon dioxide to fall
c) produce respiratory acidosis ←
d) produce respiratory alkalosis

8) Which tends to cause arterial hypoxemia?
a) increased ventilation/perfusion ratio
b) decreased barometric pressure ←
c) decreased arterial PCO2
d) increased lung diffusion capacity

9. Which one of the following is higher at the apex of the lung than at the base when a person is standing?
A) V/Q ratio ←
B) Blood flow
C) Ventilation
D) PACO2
E) Lung compliance



End Respiration Physiology
Lecture 3