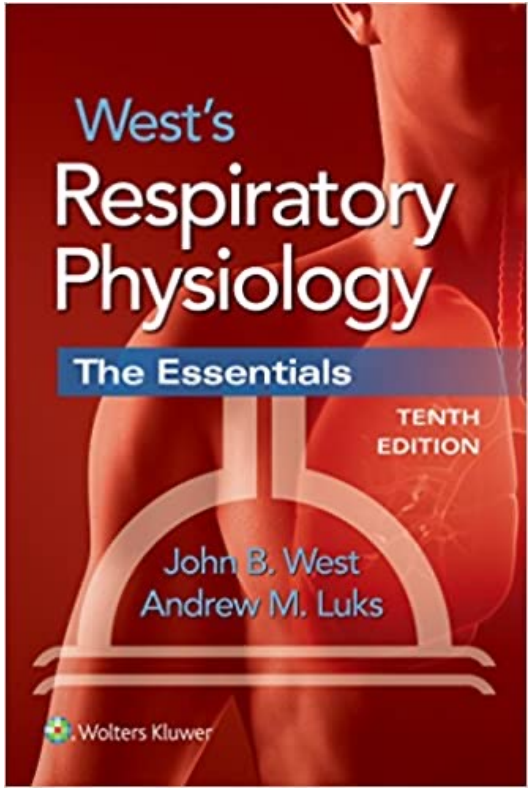
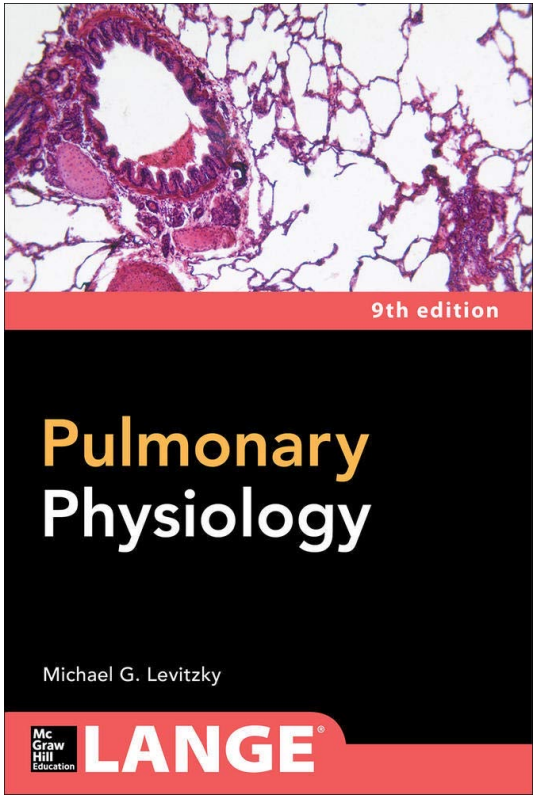
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The Alveolar Gas Equation

Mac Walter, MD
PCCM Fellows Academic Half Day

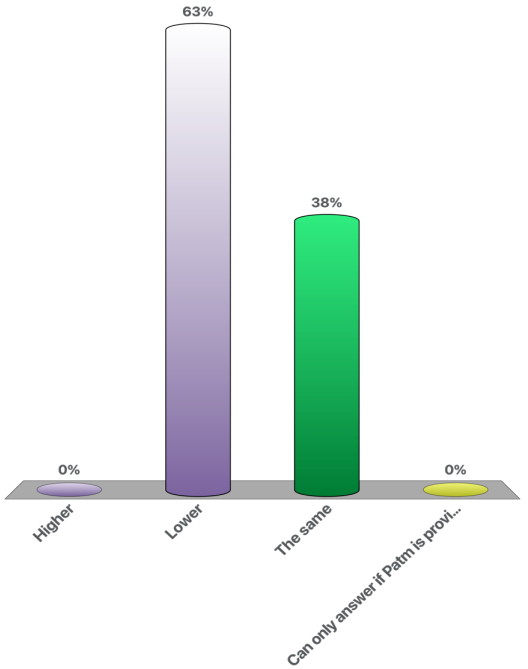
Suggestion: Learn to Love One of These





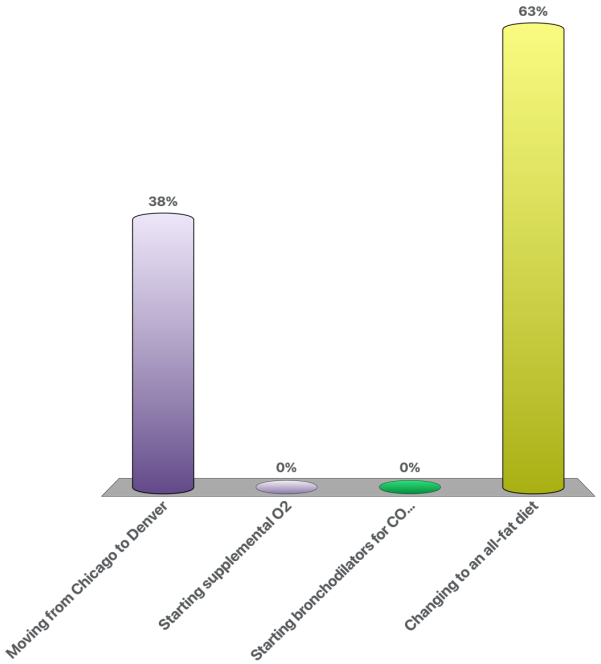
Compared to the partial pressure of oxygen in the atmosphere, the partial pressure of oxygen measured at the carina is which of the following?

A. Higher
B. Lower
C. The same
D. Can only answer if Patm is provided



Which of the following would be most likely to significantly change a patient's respiratory quotient (RQ)?

A. Moving from Chicago to Denver
B. Starting supplemental O2
C. Starting bronchodilators for COPD
D. Changing to an all-fat diet

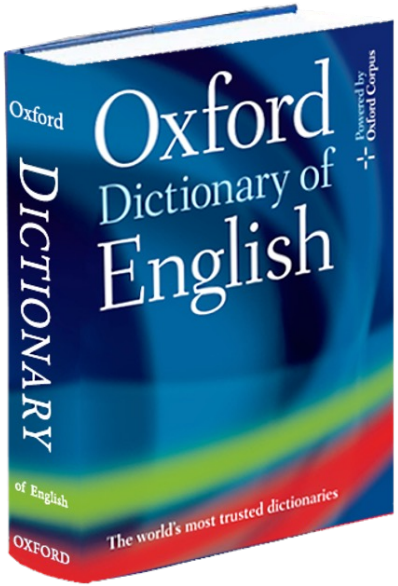


Learning Objectives

- Explain a conceptual derivation of the alveolar gas equation
- Describe a structured approach the mechanisms of hypoxemia

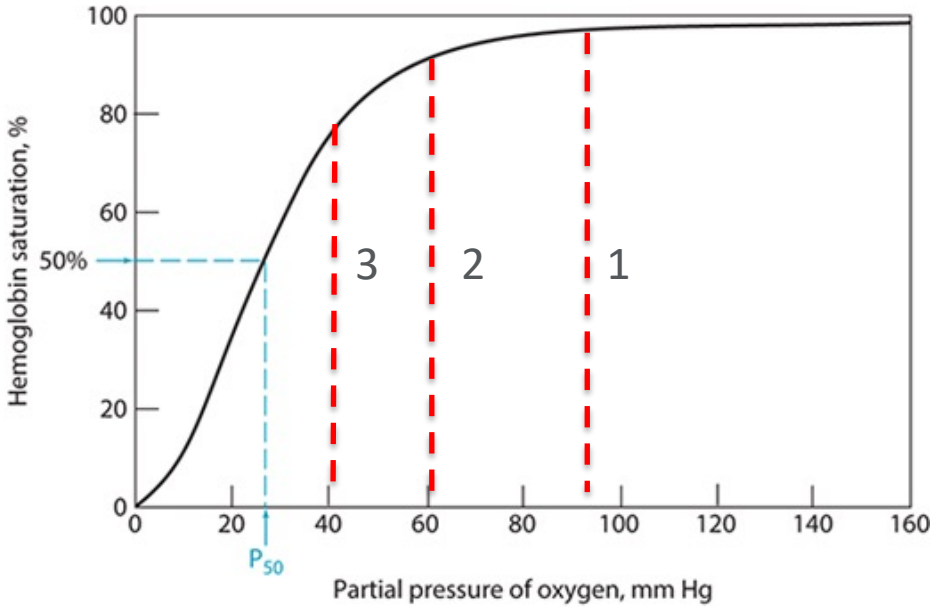
Hypoxemia vs Hypoxia

- Hypoxemia: Decreased PO_2 in blood
- Hypoxia: Decreased PO_2 in tissue
- Most (but not all) hypoxia is driven by hypoxemia



Oxy-hemoglobin Dissociation Curve

3 key points



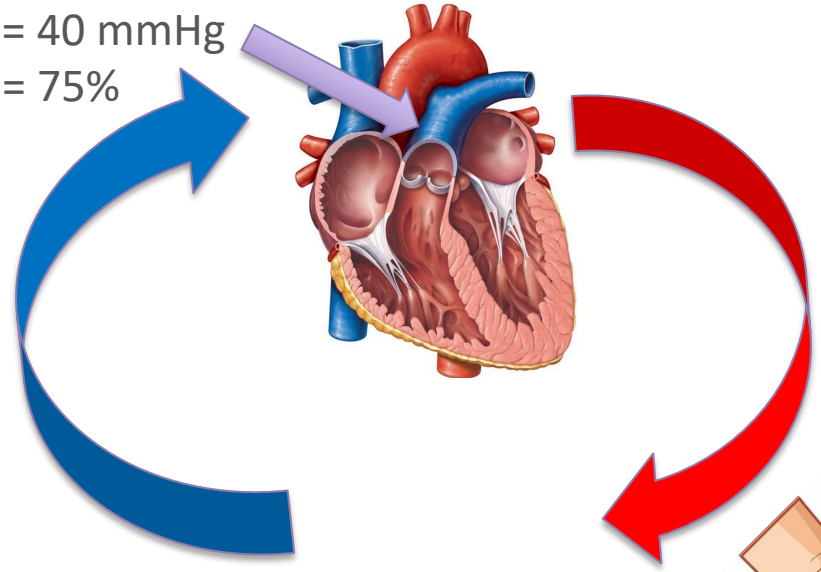
Points	PO2 (mmHg)	Hgb Sat (%)
1. Normal	95	97
2. “Knee”	60	90
3. Mixed venous	40	75

Levitzky Pulmonary Physiology 9e

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Normal Values

PvO_2 = 40 mmHg
SvO_2 = 75%

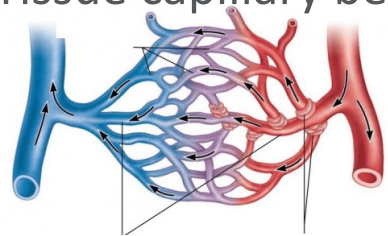


Venous return

PaO_2 = 95 mmHg
SpO_2 = 97%



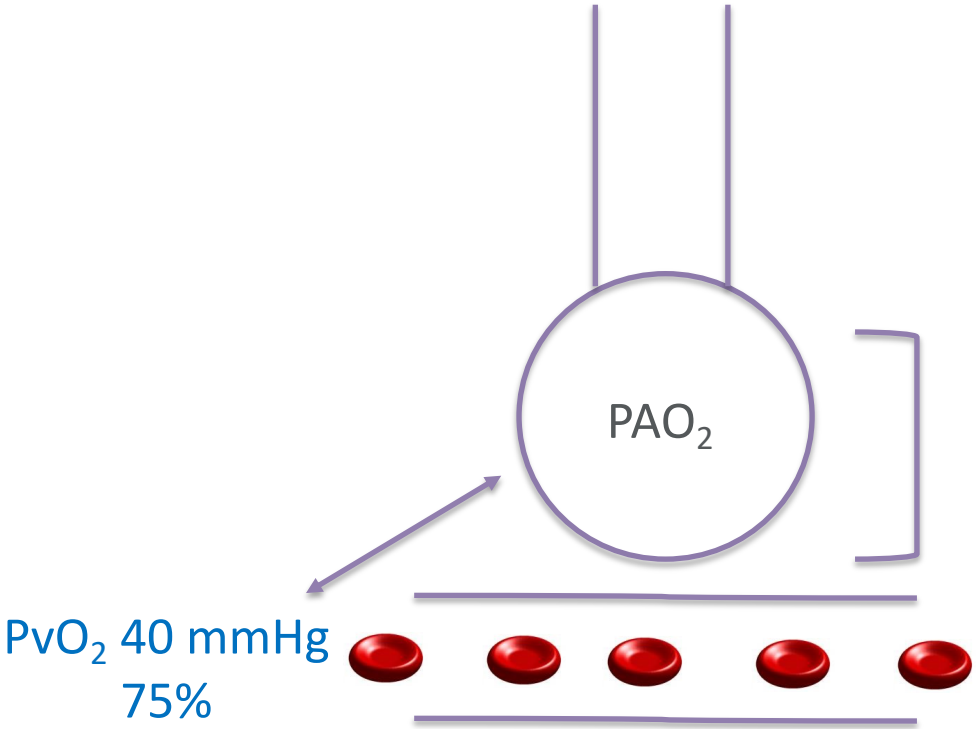
Tissue capillary beds





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What Drives Oxygenation?



PAO2

Delivery = flow x content

- Mass balance equation
- O_2 delivered in = O_2 consumed ($\dot{V}O_2$) + O_2 delivered out of lung
- $$\boldsymbol{PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}}$$

PO_2

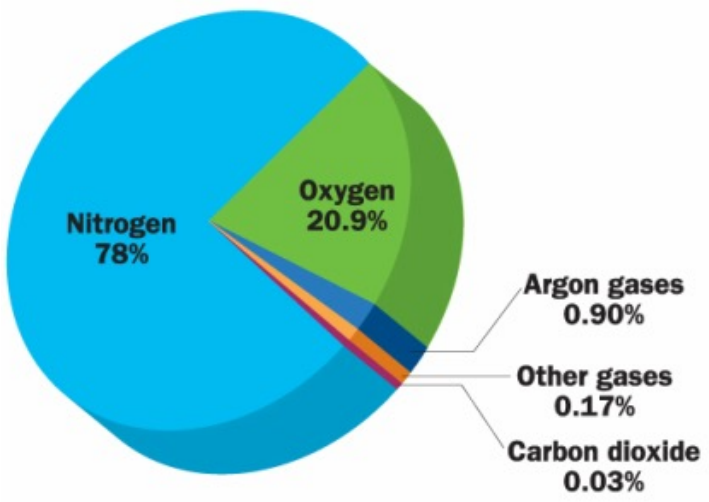


PO_2

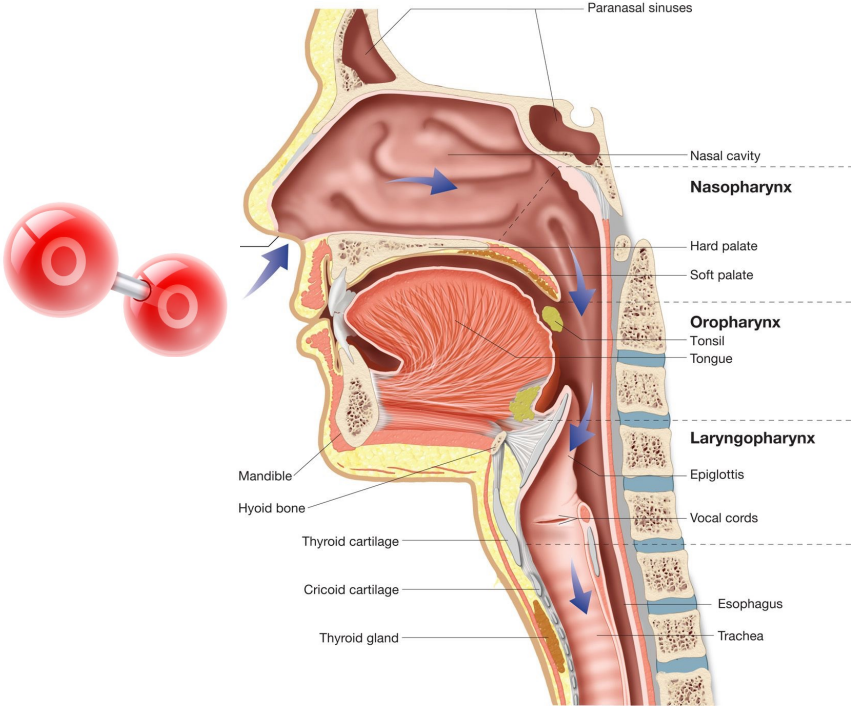
Patm x FiO_2

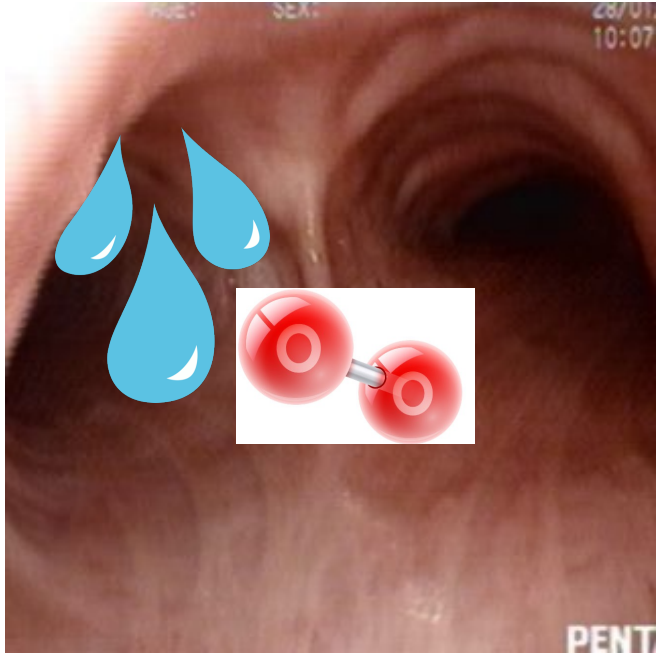
- Barometric pressure (Patm)
- Fractional concentration of oxygen (FiO_2)
- PO_2 = (Patm) x FiO_2
- PO_2 = 760 mmHg x 0.21
- PO_2 = 160 mmHg

Composition of ambient air



Traveling Down the Upper Airway





PiO_2

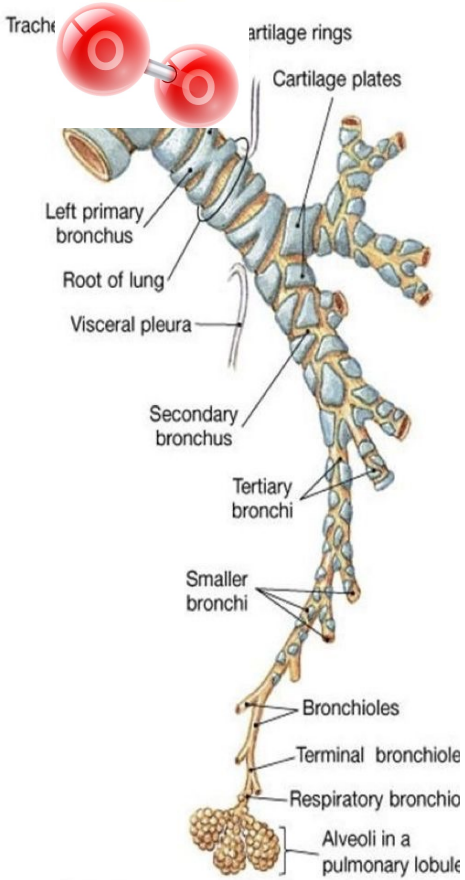
$(Patm - PH_2O) \times FiO_2$

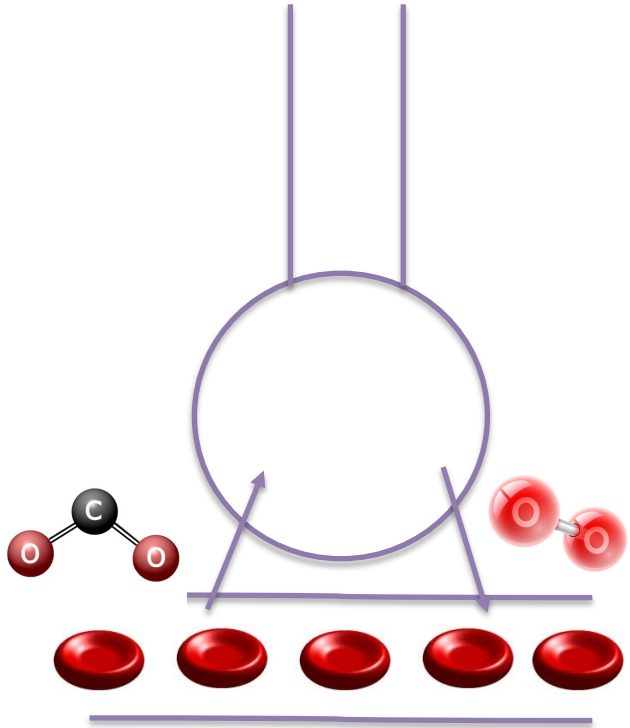
- Inspired air is warmed and humidified in upper airway (adding water vapor)
- $PiO_2 = (Patm - PH_2O) \times 0.21$
- $PiO_2 = (760\ mmHg - 47\ mmHg) \times 0.21 = 150\ mmHg$

Compared to the partial pressure of oxygen in the atmosphere, the partial pressure of oxygen measured at the carina is which of the following?

A. Higher
B. Lower
C. The same
D. Can only answer if Patm is provided

Heading Down to Alveoli





Respiratory quotient (R or RQ)

Respiratory Quotient

$(Patm - PH_2O) \times FiO_2 - PaCO_2 / R$

- Set by diet and metabolism
- $R = \frac{\dot{V}CO_2}{\dot{V}O_2}$
- Typical American diet, R = 0.8
- $\dot{V}CO_2$ = 200 mL/min
- $\dot{V}O_2$ = 250 mL/min

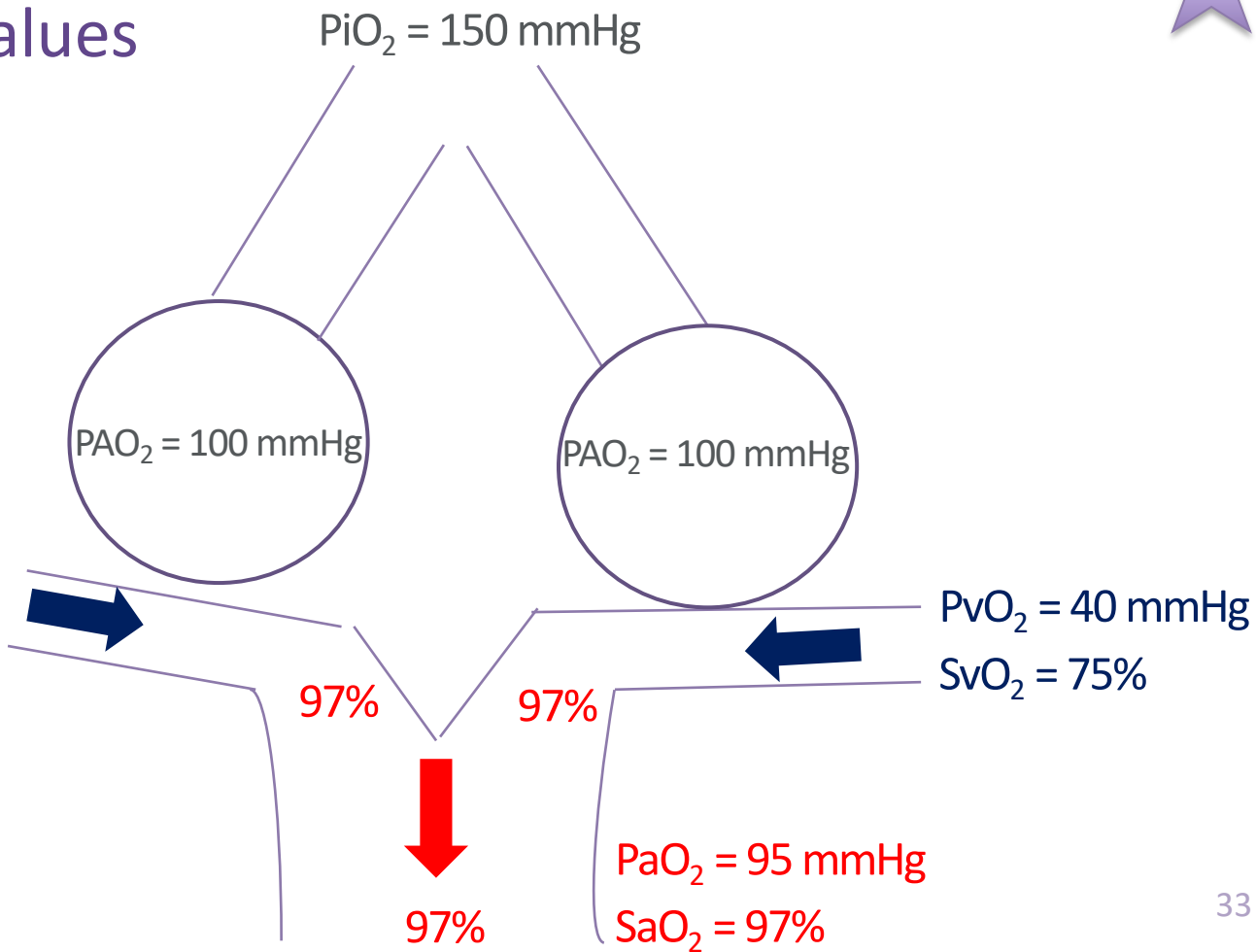
Which of the following would be most likely to significantly change a patient's respiratory quotient (RQ)?

A. Moving from Chicago to Denver
B. Starting supplemental O2
C. Starting bronchodilators for COPD
D. Changing to an all-fat diet

Alveolar Gas Equation

- $\boldsymbol{PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}}$
- $\boldsymbol{PAO_2}$ = (760 mmHg – 47 mmHg) x 0.21 – 40 mmHg / 0.8
- $\boldsymbol{PAO_2}$ = 100 mmHg

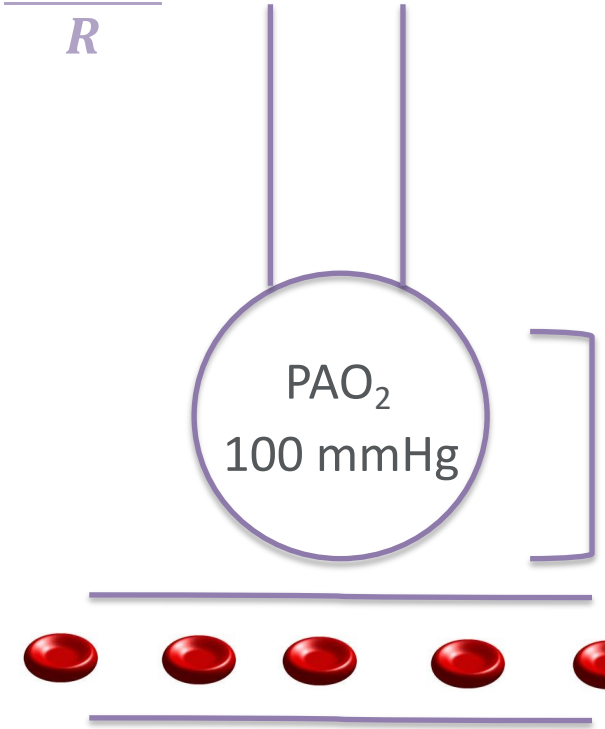
Normal Values



Key Concepts

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$

- PAO_2 sets the partial pressure gradient for oxygenating blood
- $PAO_2 \neq PiO_2$
- Dropping “Big A” will drop “Little a”



8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$

1.
2.
3.

4.

5.
6.
7.
8. ↓R

↓ PAO_2

8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$

1.
2.
3.
4.
5. ↓Patm
6.
7.
8. ↓R

↓ PAO_2

Commercial Airline Travel

Cabin pressurized to 35,000 feet, ~574 mmHg

- $PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$
- $PAO_2 =$ (574 mmHg – 47 mmHg) x 0.21 – 40 mmHg / 0.8
- $PAO_2 = 60$ mmHg



Everest Summit

Patm = 255 mmHg



- $PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$
- $PAO_2 = (255 - 47)$ x 0.21 – 40 / 0.8
- $PAO_2 =$ - 6 mmHg (!!!)

In 1978 Reinhold Messner and Peter Habeler summitted Everest without supplemental O_2. Considering the math from the last question, how is this possible?



8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$

1.
2.
3.

4.

5. ↓Patm
6. ↓FiO_2
7.
8. ↓R

↓ PAO_2

Low FiO_2





8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$

1.
2.
3.

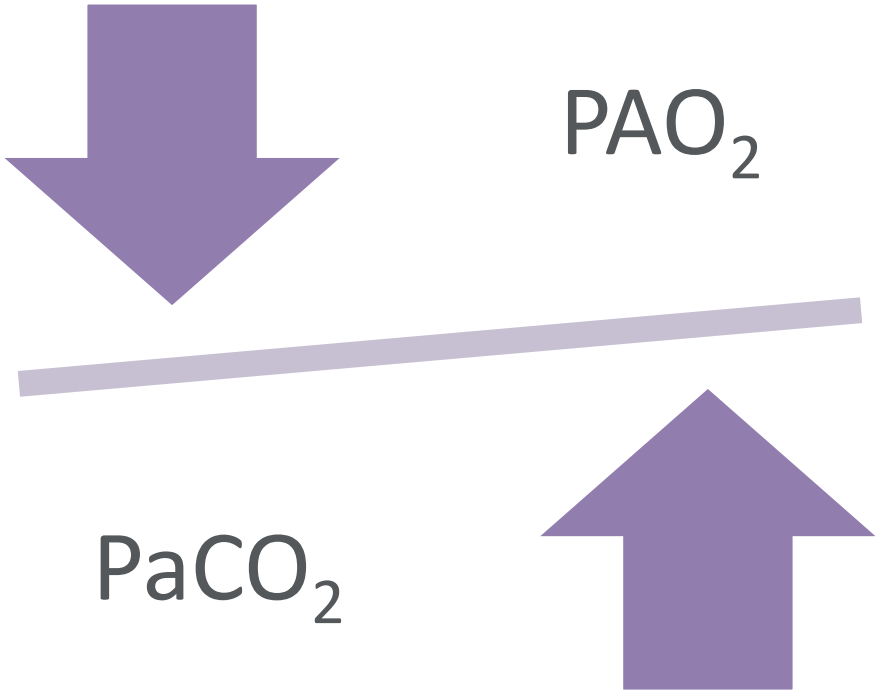
4.

5. ↓Patm
6. ↓FiO_2
7. ↑$PaCO_2$
8. ↓R

↓ PAO_2

Key Relationship

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$



8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$

1.
2.
3.

↑ A – a difference

4.

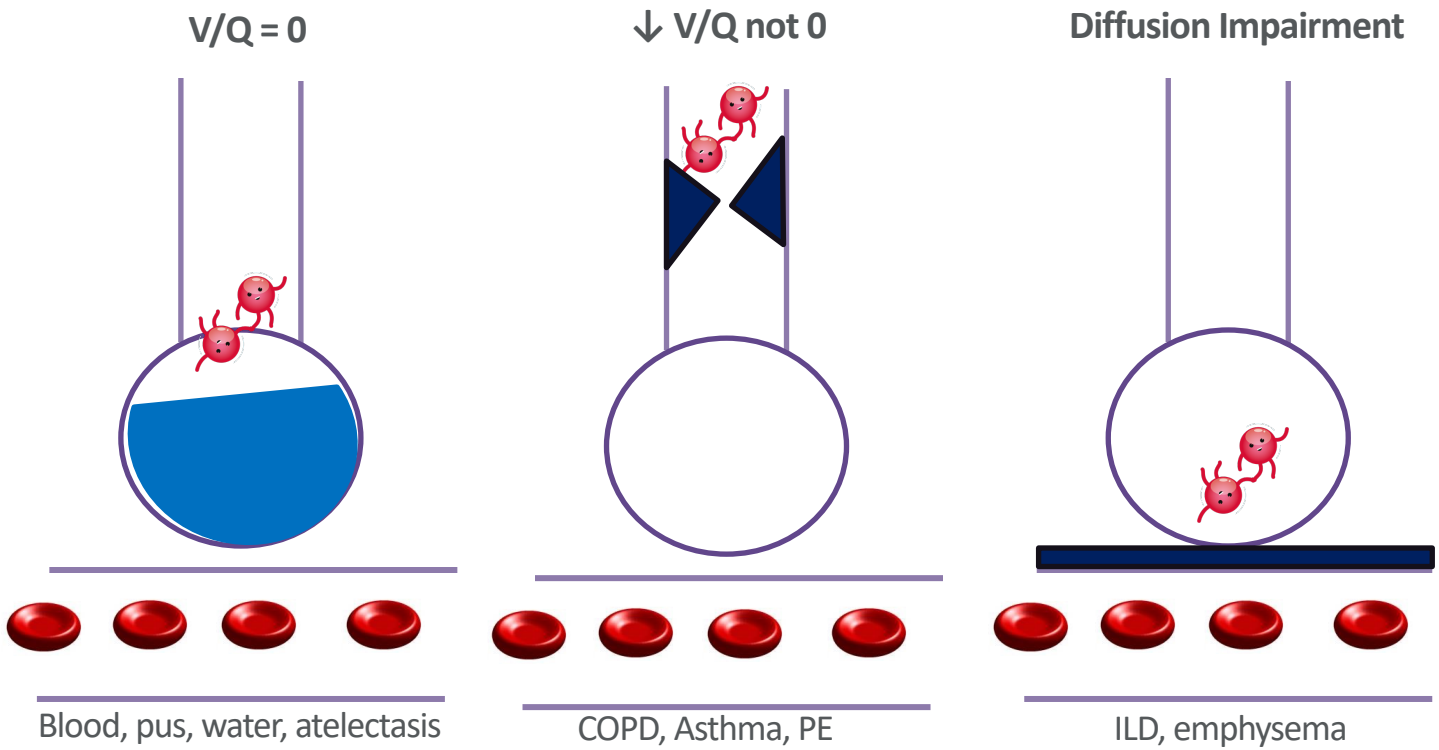
5. ↓Patm
6. ↓FiO_2
7. ↑$PaCO_2$
8. ↓R

↓ PAO_2

Small A – a difference

Hypoxemia: Problem with Alveolar Capillary Units

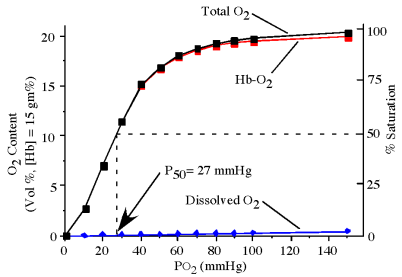
**** High A-a difference, Low PaO_2 / FiO_2 ****



$$\dot{V}gas = \frac{A}{t} \times D \times \Delta P$$

50% Shunt

100% FiO_2



PiO_2 = 713 mmHg

PAO_2 = 663 mmHg

PvO_2 = 40 mmHg

SvO_2 = 75%

PvO_2 = 40 mmHg

SvO_2 = 75%

75%

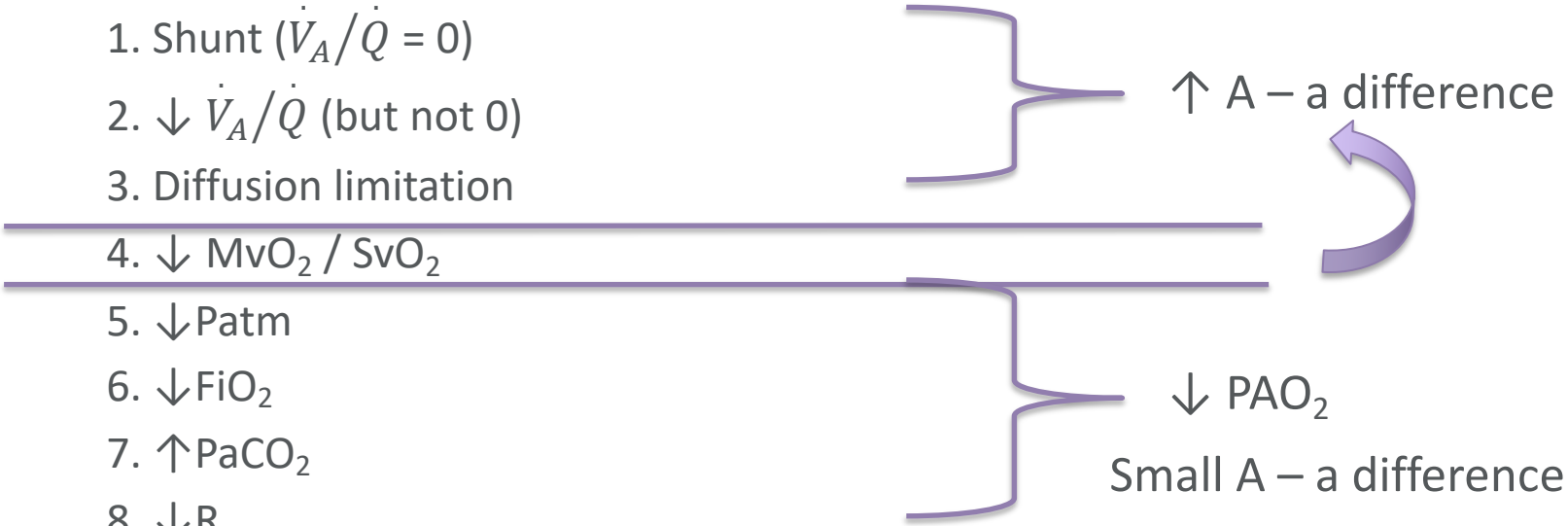
100%

87.5%

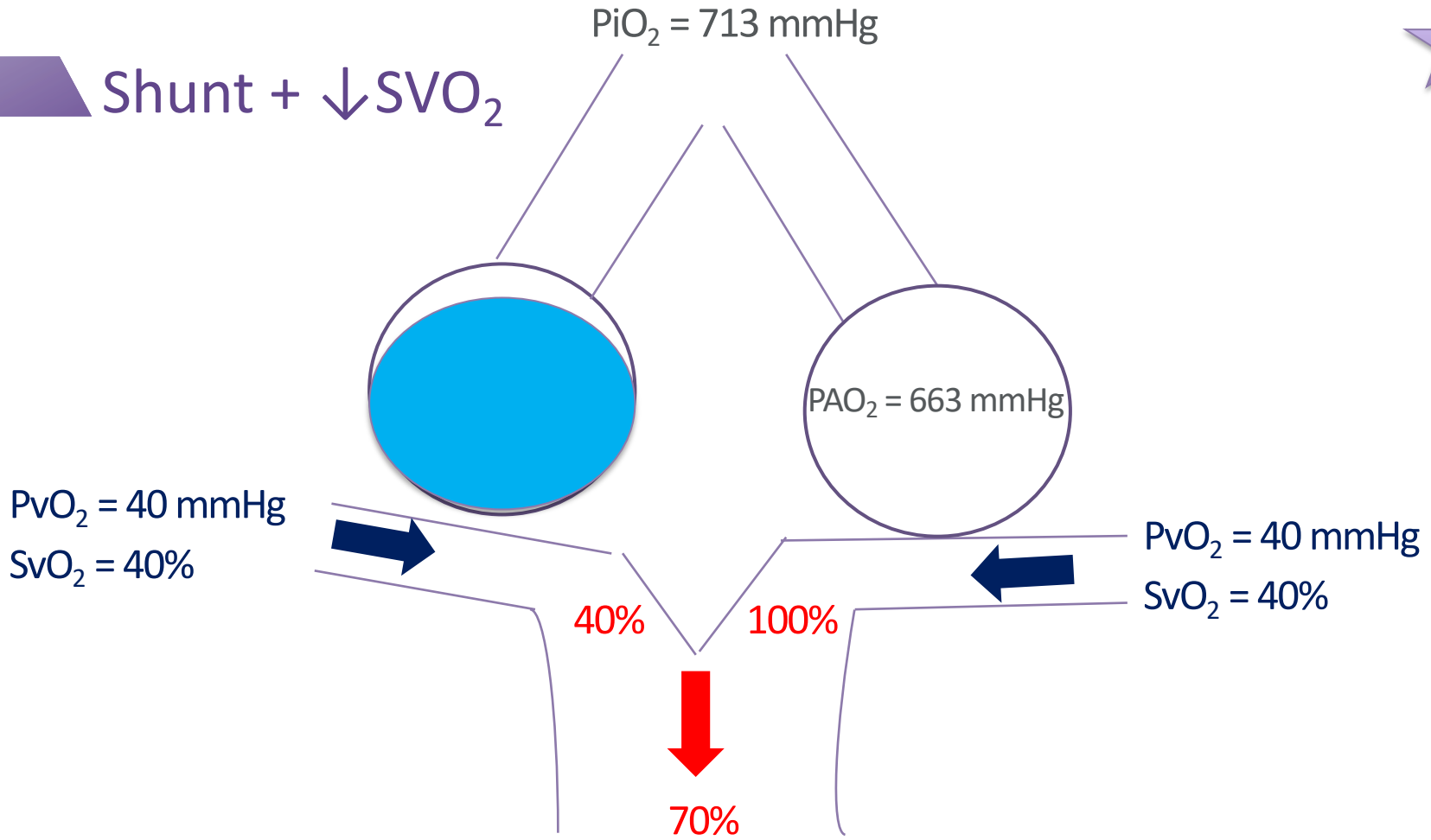
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8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$



Shunt + ↓SVO_2

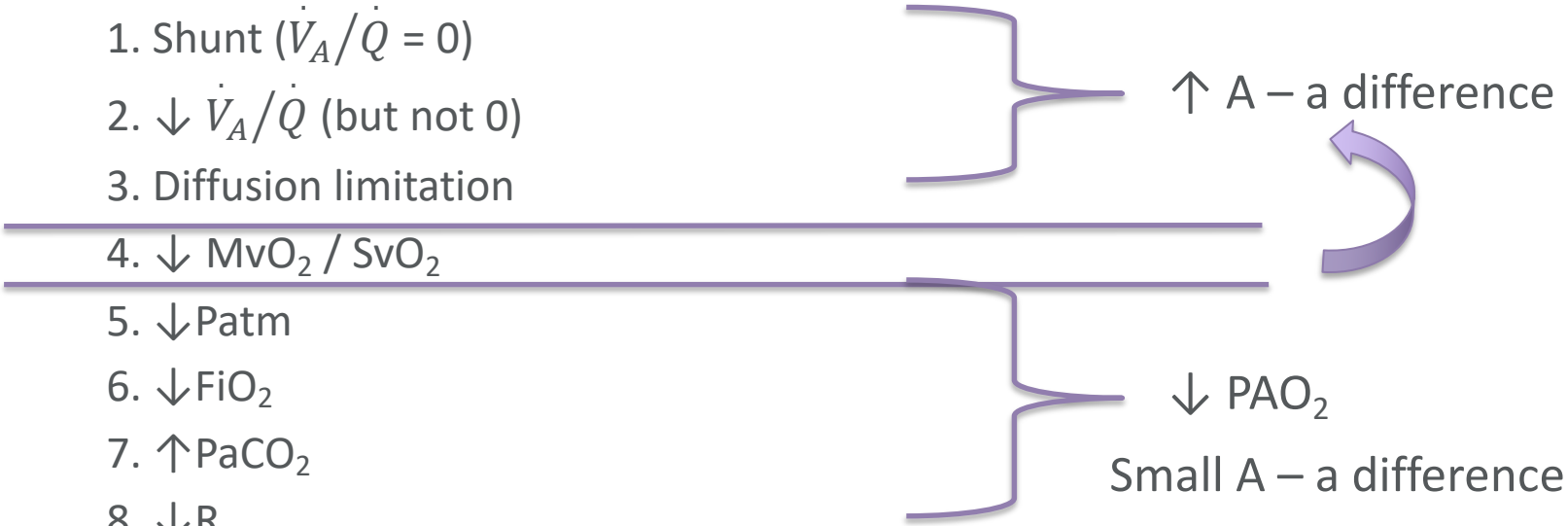

PiO_2 = 713 mmHg
PAO_2 = 663 mmHg
PvO_2 = 40 mmHg
SvO_2 = 40%
PvO_2 = 40 mmHg
SvO_2 = 40%
40%
100%
70%

Learning Objectives

- Explain a conceptual derivation of the alveolar gas equation
- Describe a structured approach the mechanisms of hypoxemia

8 Causes of Hypoxemia

$$PAO_2 = (Patm - PH_2O) \times Fi0_2 - \frac{PaCO_2}{R}$$



Thank you

James.walter@northwestern.edu