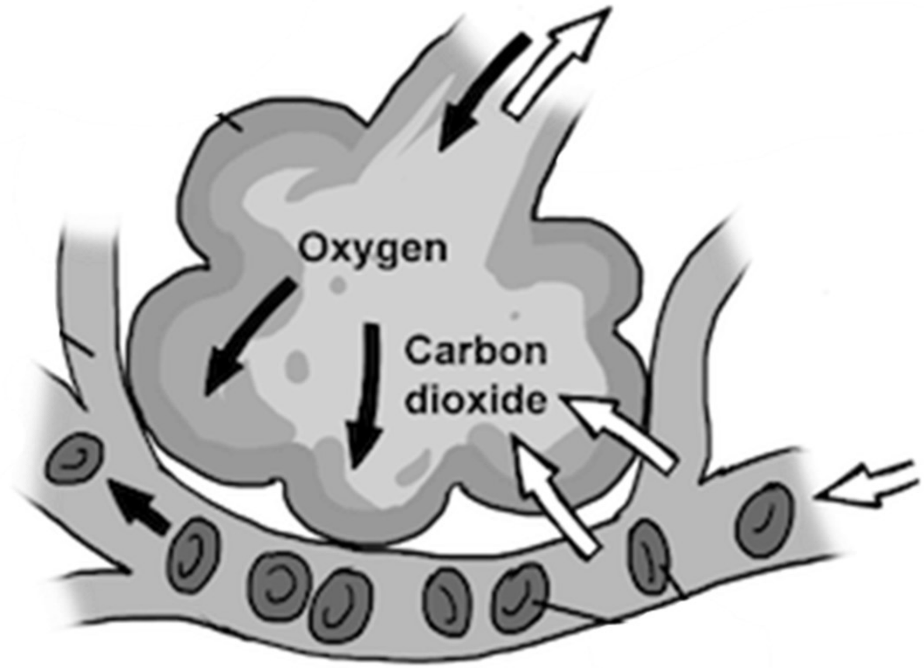
Lecture 41
Gas Diffusion and Transport



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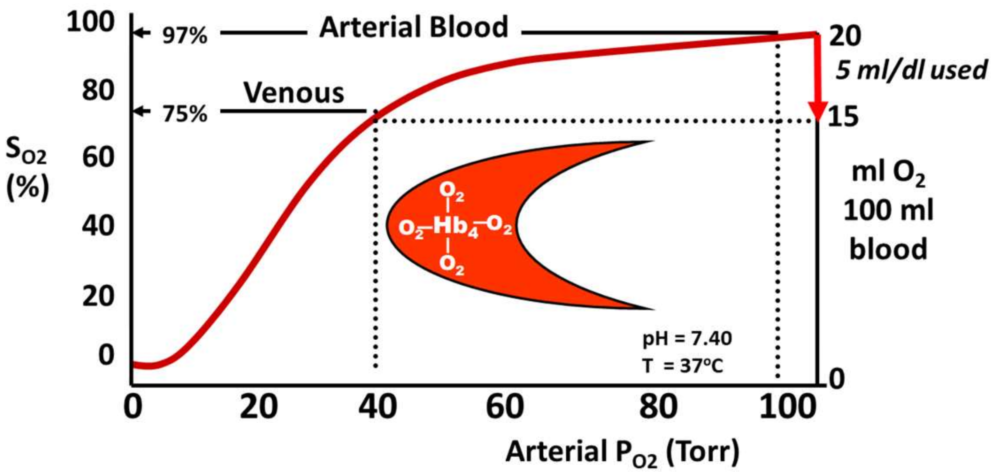
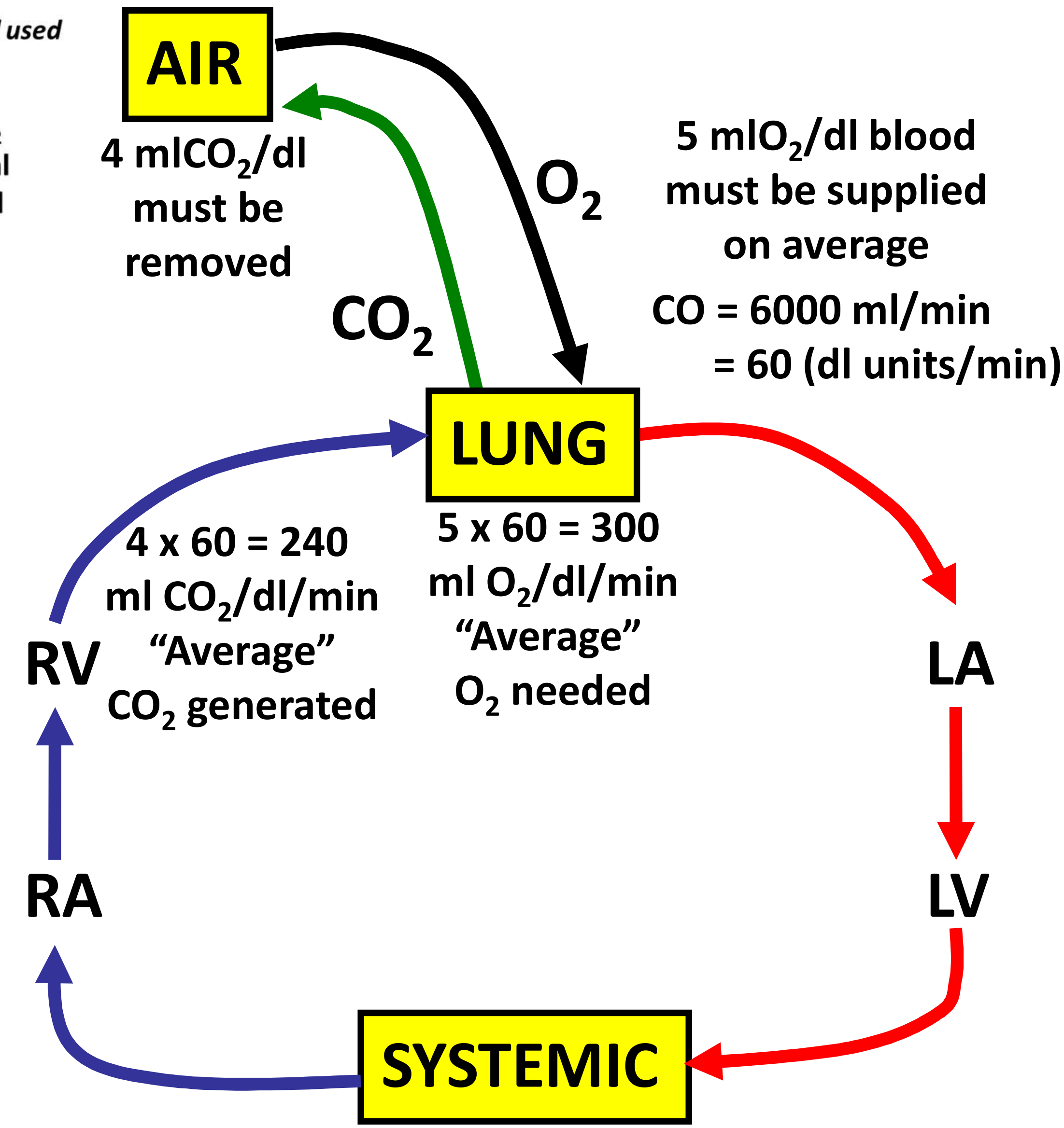
O_2 delivered and CO_2 removed



For every ml of O_2 used ≈ 0.8 ml CO_2 produced



Respiratory Quotient
CO_2 produced/O_2 consumed
R = 240/300 = 0.8

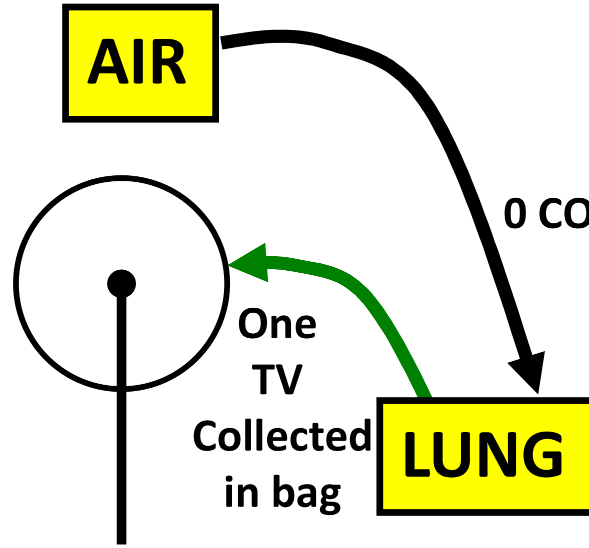
Lipid → 0.70
Protein → 0.80
Carbohydrate → 1.0
Average →0.80 – 0.84

Dead Space

- Anatomic (Airway) Dead Space
  = No gas exchange → ADS

- Alveolar Dead Space (ALDS)
  = Sum of alveolar volumes that are ventilated but receive little or no blood flow

- Physiological Dead Space (PDS)
  = Amount of each TV that does NOT participate in gas exchange
  PDS = ADS + ALDS



If $CO_2 = 0$ → $P_ECO_2 = 0$ then no gas exchange has occurred and all TV = Dead Space

If $CO_2 > 0$ → $P_ECO_2 > 0$ then Some gas exchange has occurred and only some of TV = Dead Space

The more CO_2 there is relative to arterial blood the less is the dead space

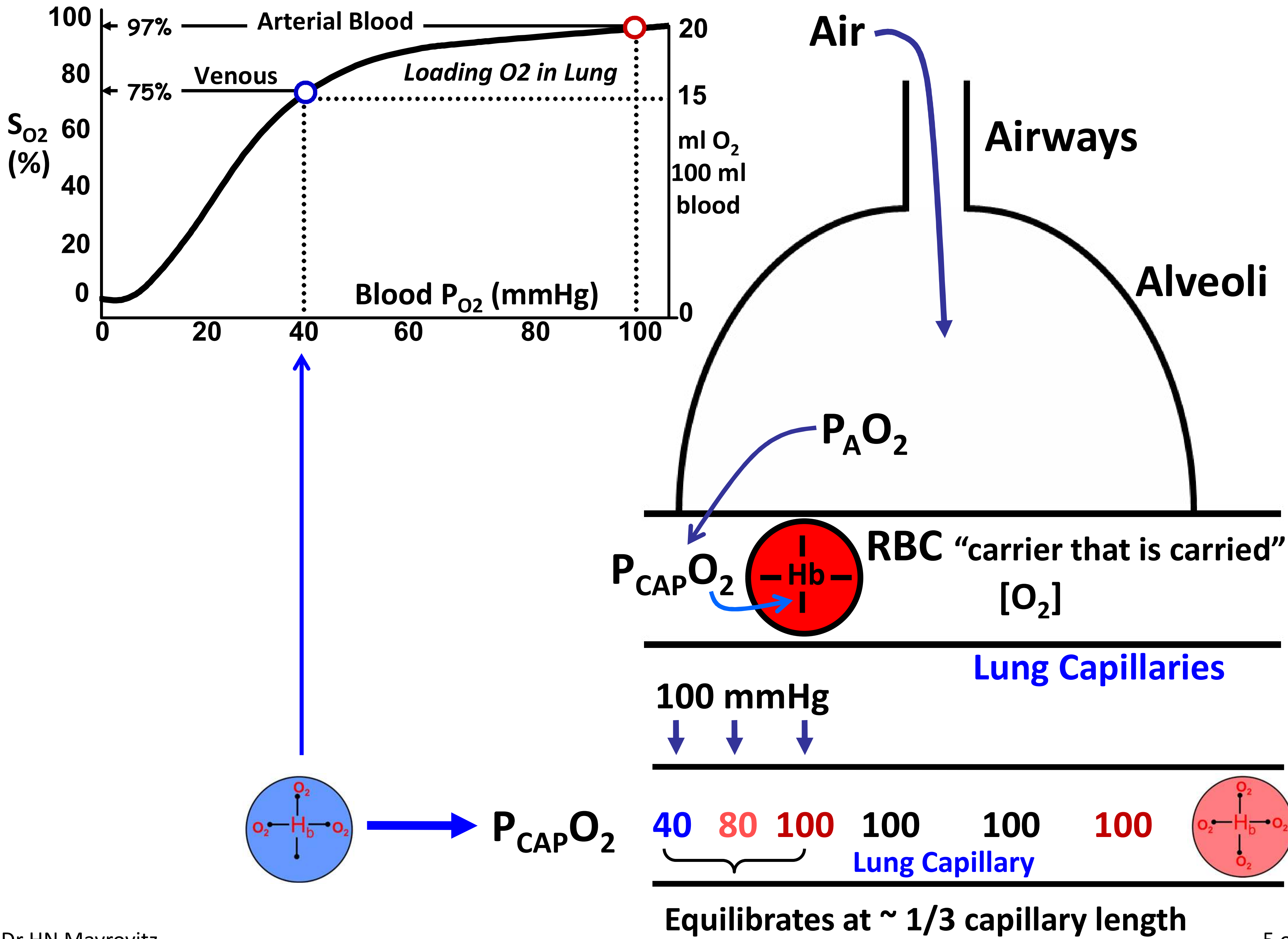
$$PDS = TV \times (1 - [P_ECO_2/P_aCO_2])$$

P_aCO_2 = CO_2 tension in arterial blood

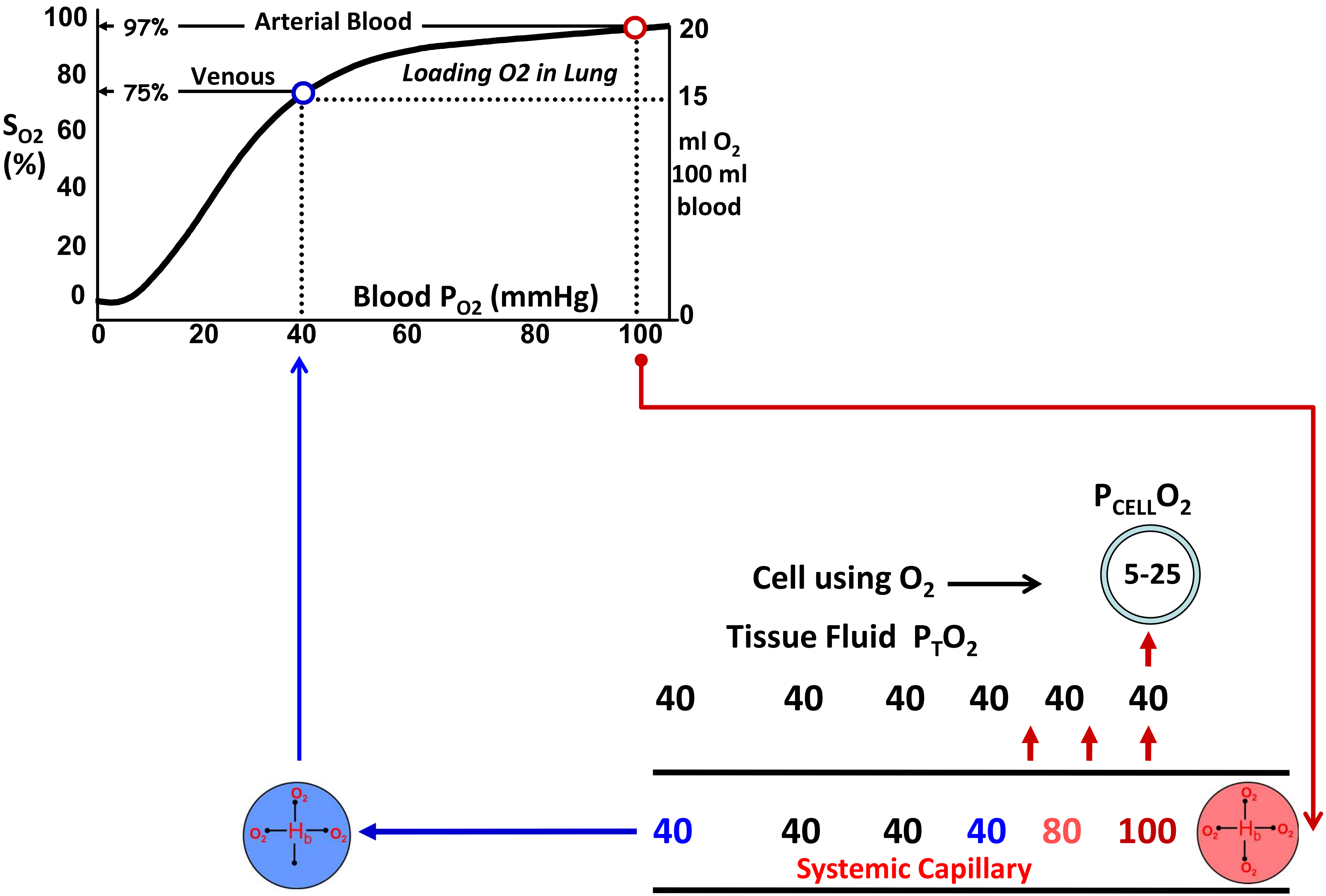
P_ECO_2 = CO_2 tension in expired air

Gas dynamics

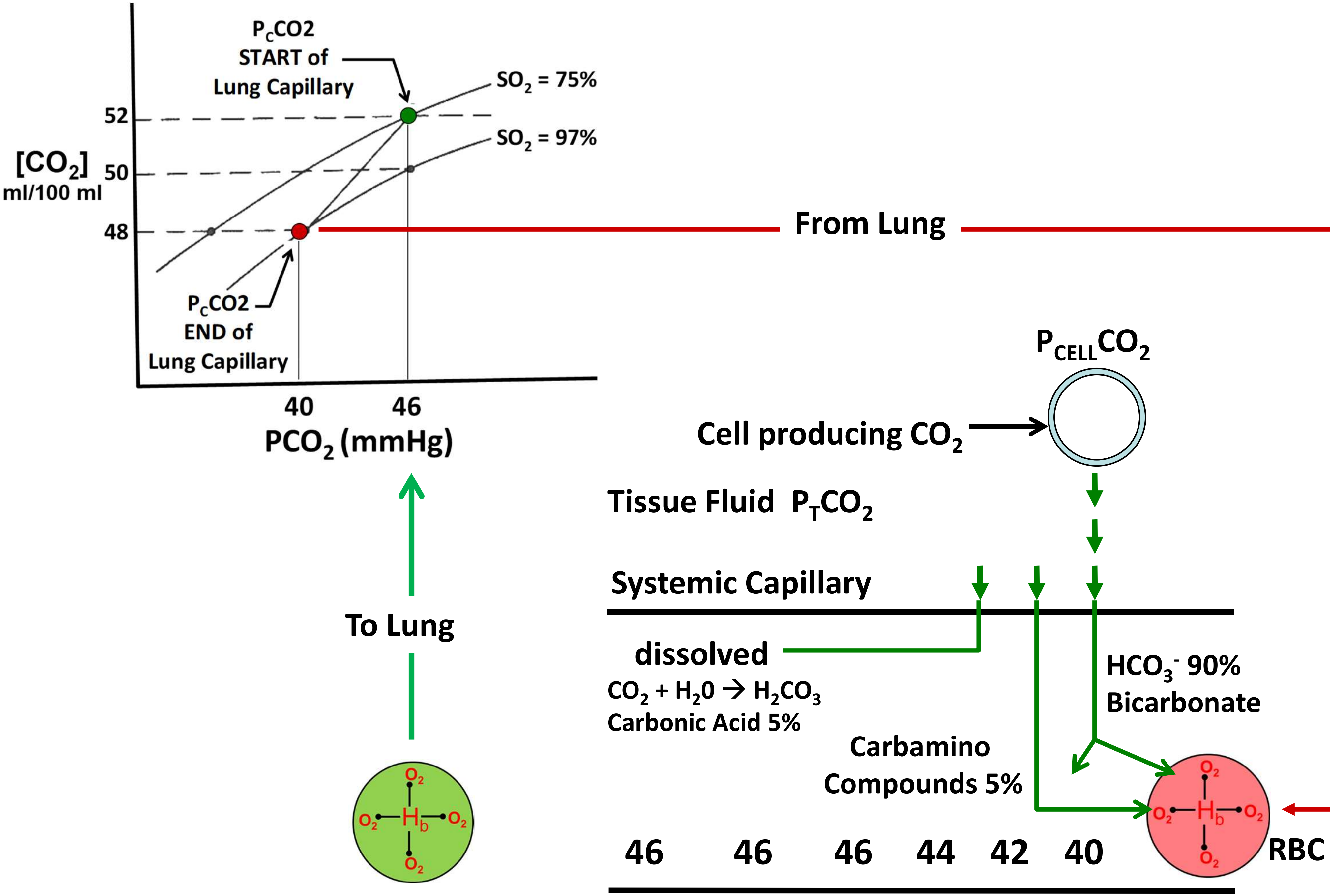
Loading up with O_2 in Lung



Unloading O_2 to Tissues

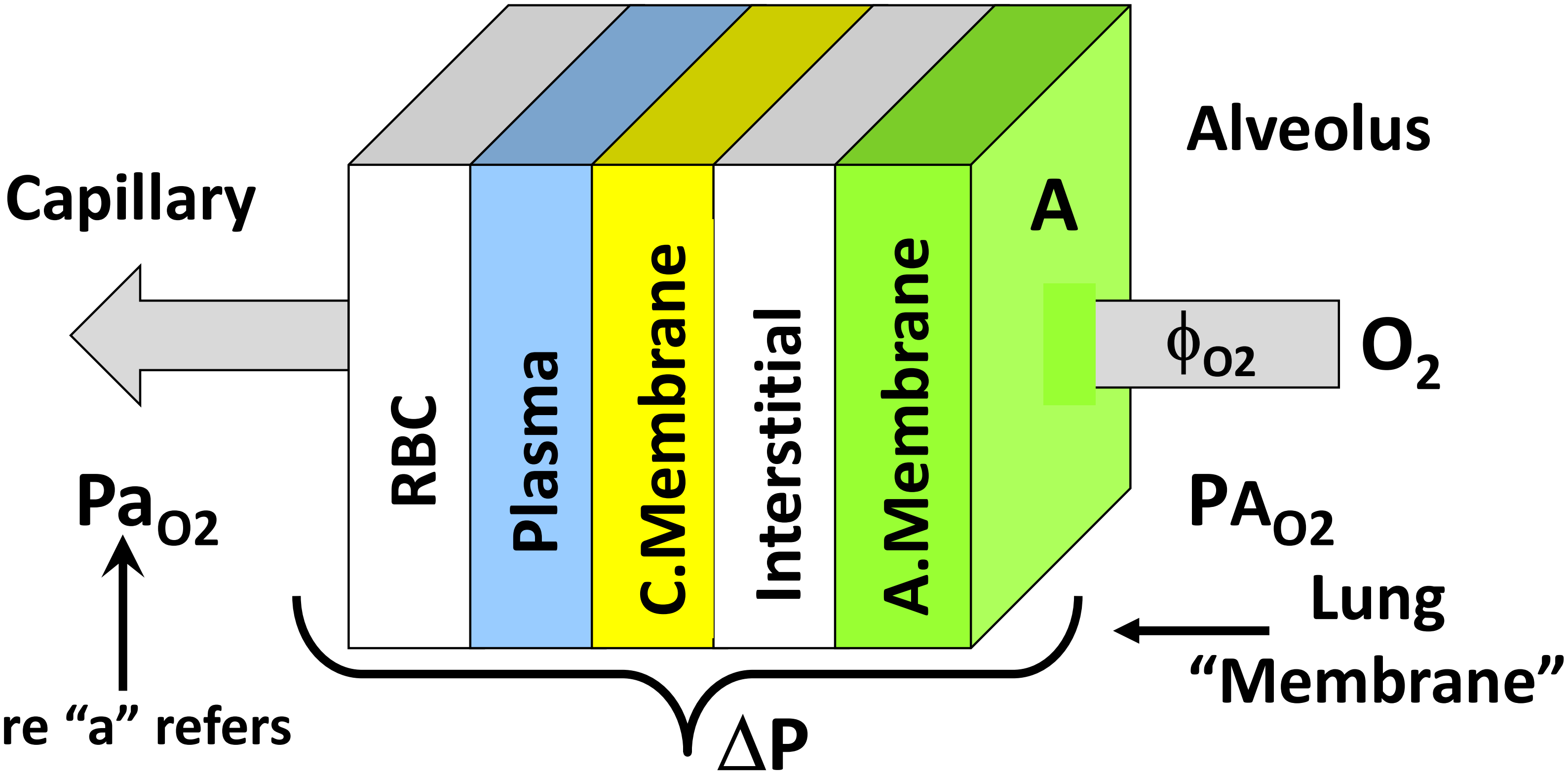


Picking Up CO_2 from Tissues

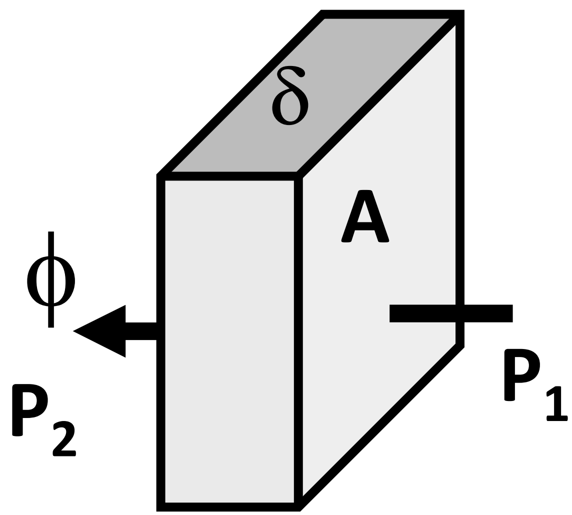


Diffusional Processes

Basic Diffusion Processes



Here "a" refers to blood exiting pulmonary capillaries.



Main Factors

1. Area (A)
2. Thickness (δ)
3. Pressure Difference (ΔP)
4. Diffusion coefficient (D)

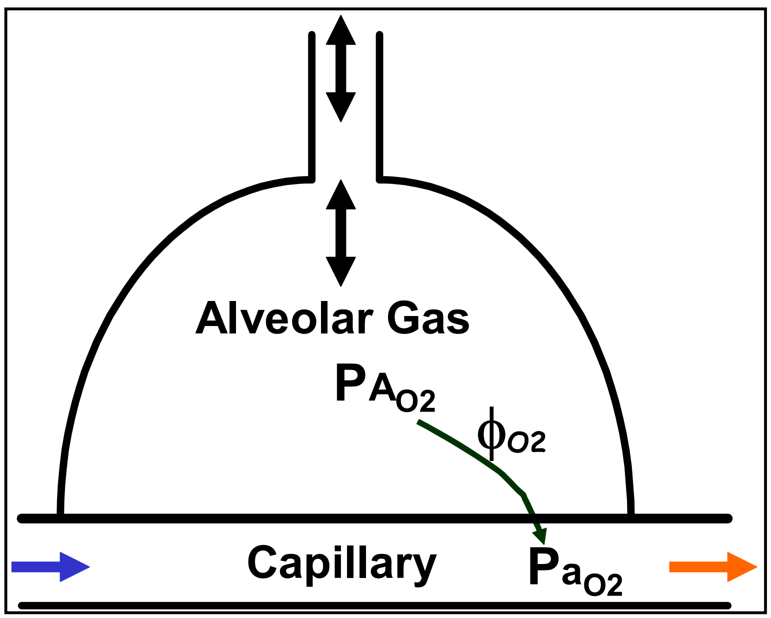
$$\phi = D\,(A/\delta)\,\Delta P$$

Lung Diffusing Capacity

D_L considers all factors that effect

whole lung Alveolar to Blood diffusion

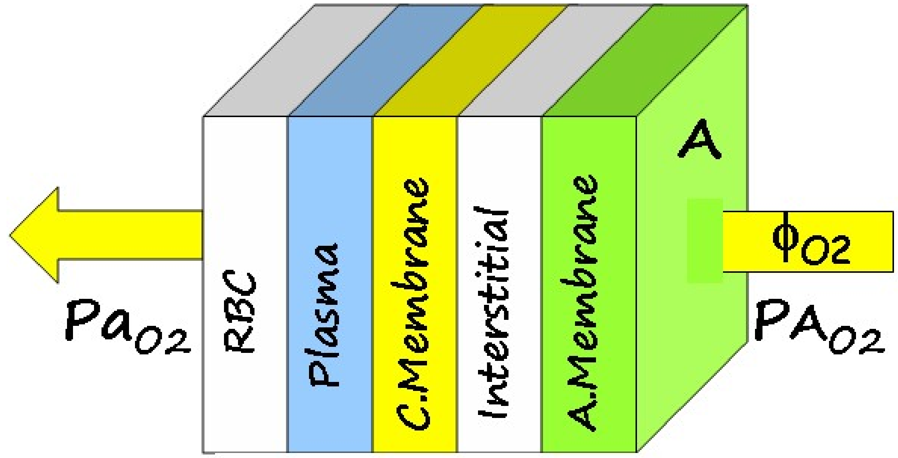
$$D_L = \frac{\text{ml } O_2\text{/min from alveoli to blood}}{\text{(alveolar) } PA_{O2} - Pa_{O2} \text{ (arterial)}}$$



$$D_L = \frac{\phi_{O2}}{PA_{O2} - Pa_{O2}}$$

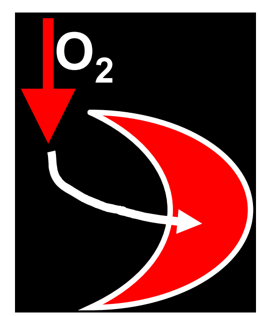
D_L is a form of "conductance" i.e. Flow/ΔP

Factors Decreasing D_L



$$\phi = D\,(A/\delta)\,\Delta P$$

$$D_L = \frac{\phi_{O2}}{PA_{O2} - Pa_{O2}}$$



Diffusion Distance

- **Alveolar Wall Thickening**
- **Alveoli-Capillary separation by:**

 edema, exudate or fibrous tissue

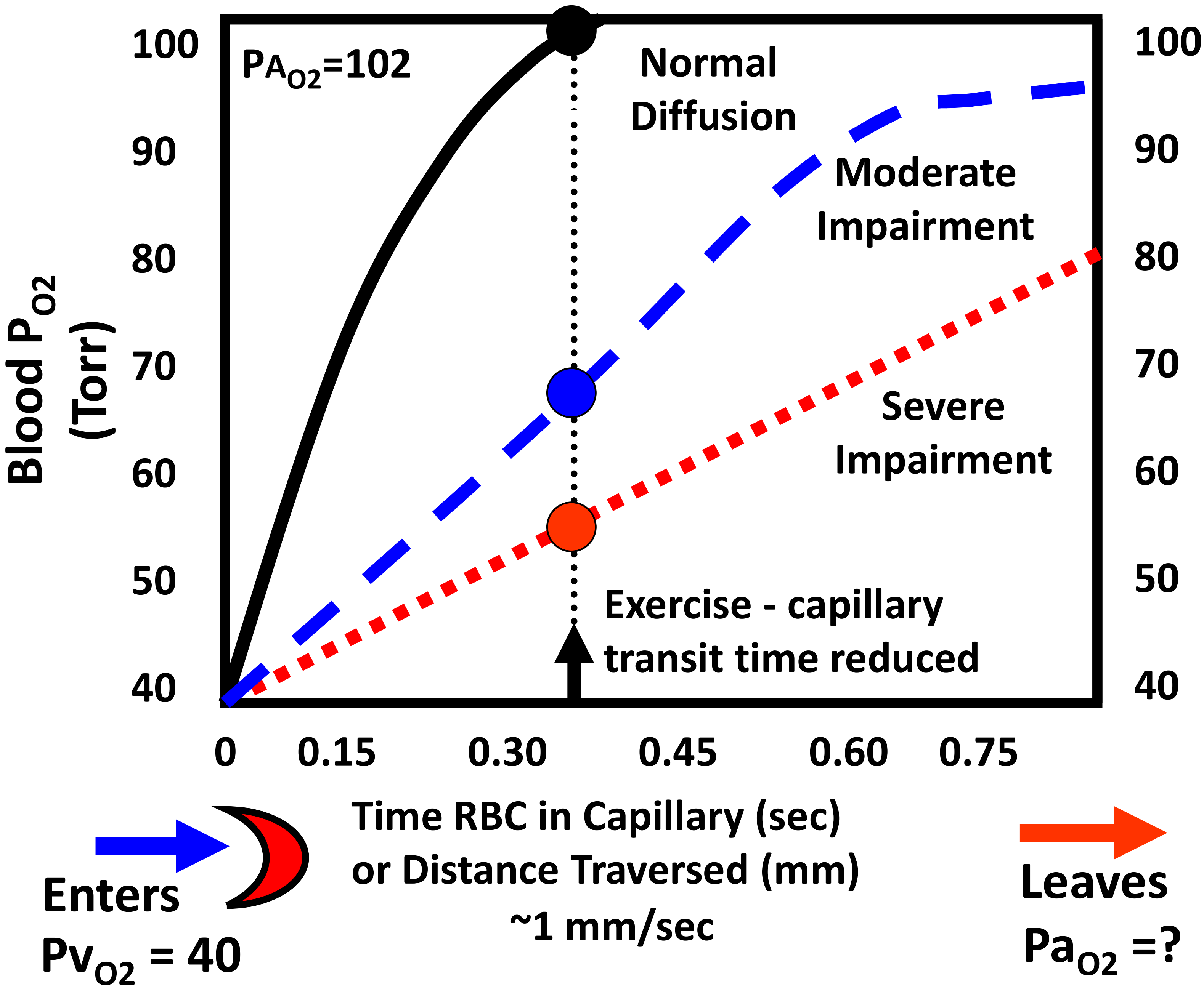
Surface Area

- **Fewer functioning capillaries**
- **Fewer functioning alveoli**
- **Disrupt normal alveolar architecture**

Red Blood Cells and Diffusion Resistance

- **Decreased rbc membrane permeability**
- **Decreased Hb O_2 affinity**
- **Decreased total amount of Hb available**

Diffusion and Capillary Blood Oxygenation

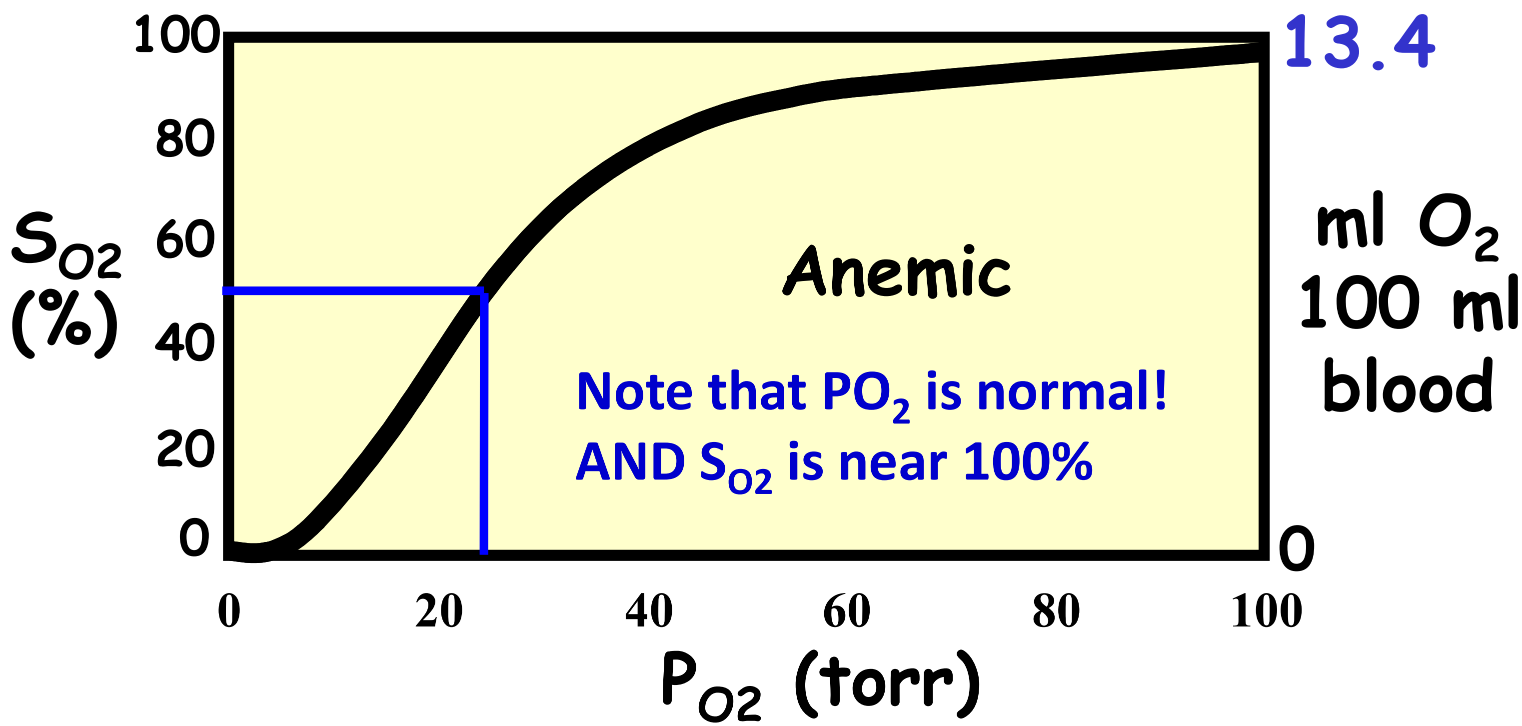


Interactive MCQ

An SO_2 measurement reveals that a patient's blood is near 100% saturated, but that her hemoglobin is only 10 g/100 ml blood.

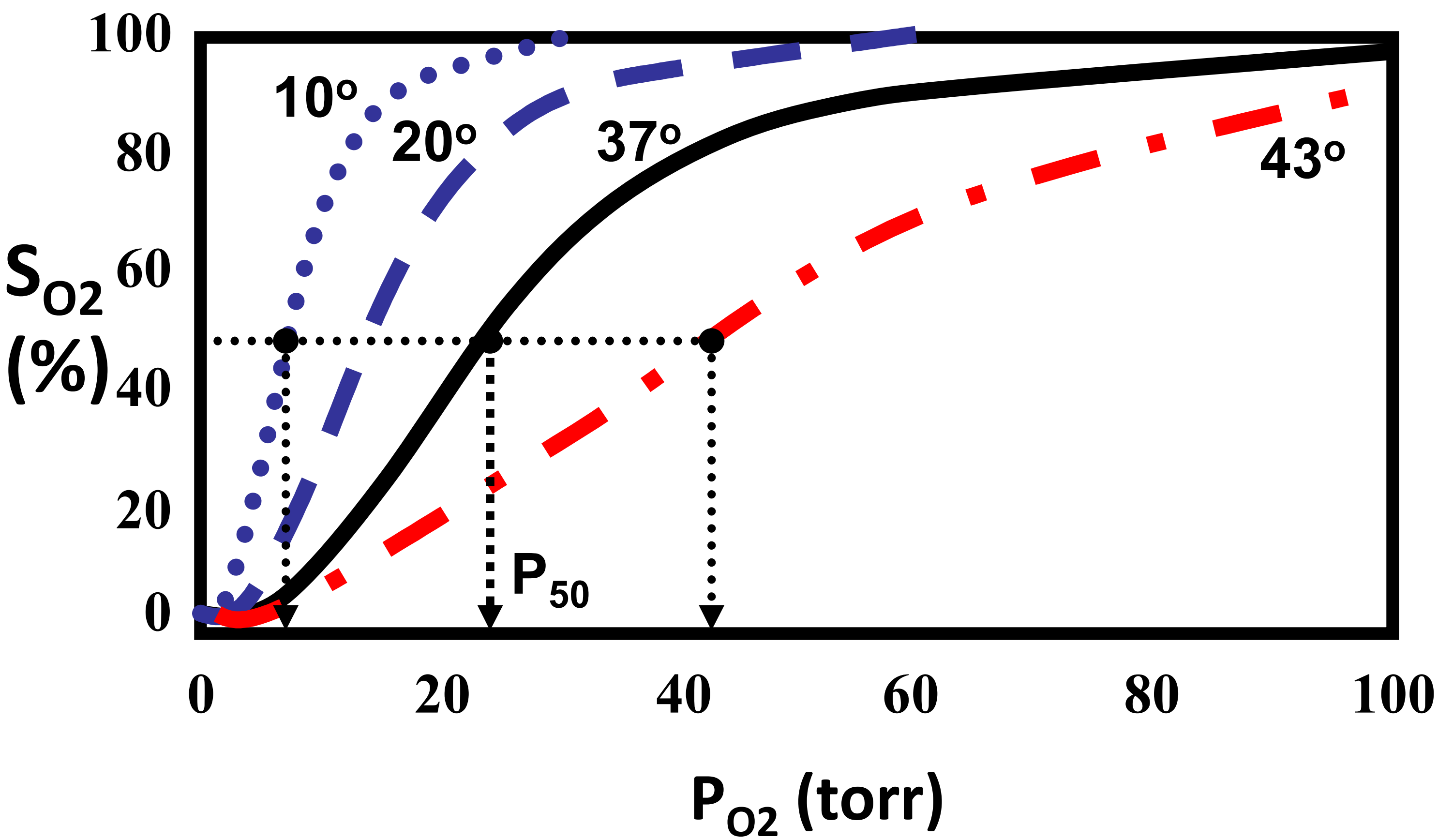
Her blood oxygen *<u>CONTENT</u>* *(mlO_2/dl) is closest to which of the following? (60 sec)*

A. **10.4**
B. **11.4**
C. **13.4**
D. **15.3**
E. **20.4**



O_2 Binding-Release Curve Shifting

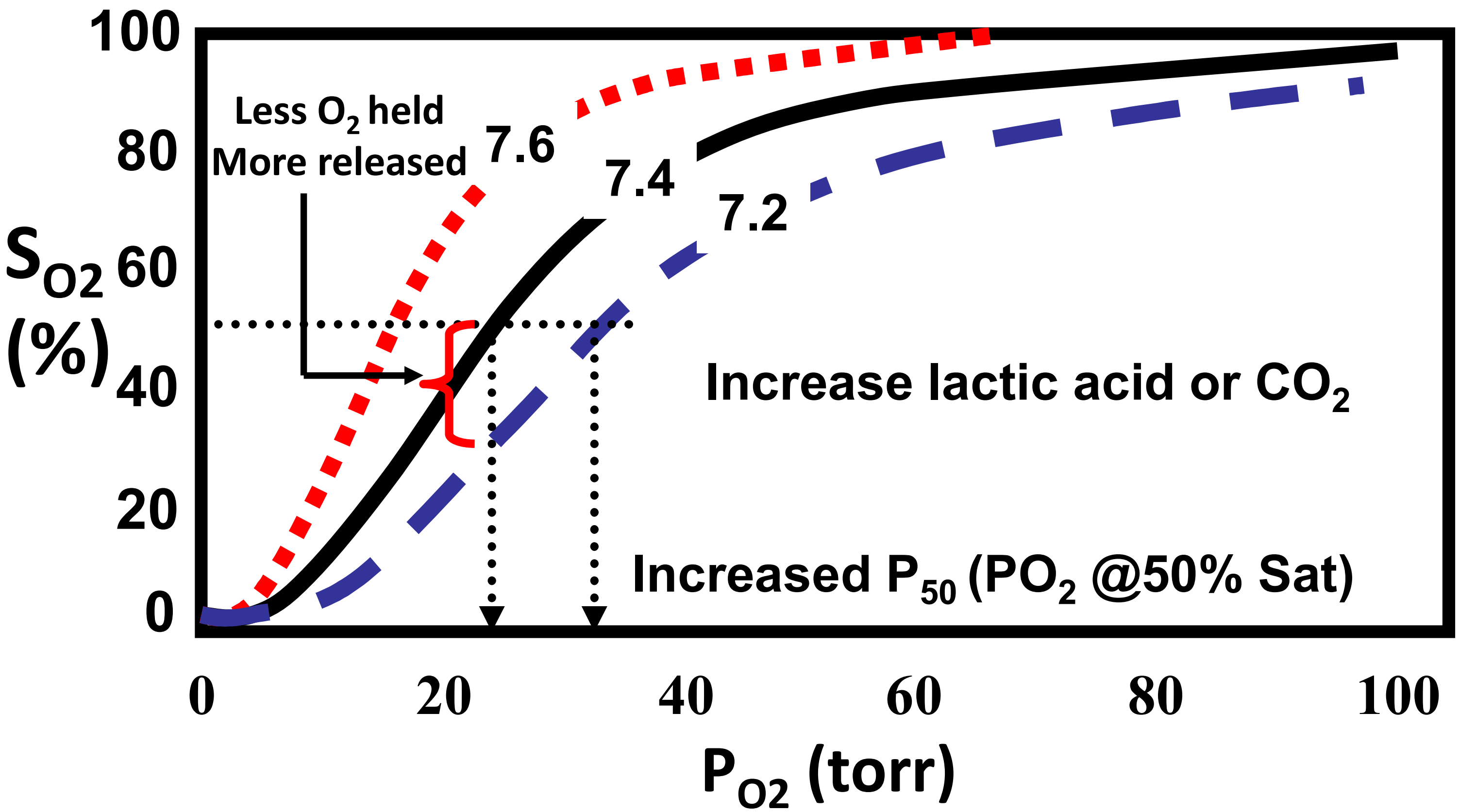
Temperature



Hotter: Facilitates O_2 Release

- **Less Saturation for same P_{O2}**
- **More P_{O2} for same saturation**

pH and CO_2 Effects



- pH or + CO_2
(H^+ or CO_2 binds to Hb)
- Facilitates O_2 Release
- P_{50} is increased

2.3-diphosphoglycerate (DPG)

DPG Regulates RBC's Affinity for O_2

- **Binds to Hb → More DPG → Less affinity**
  More DPG facilitates O_2 release **(P_{50} → right)**
  Easier to deliver O_2 to tissue

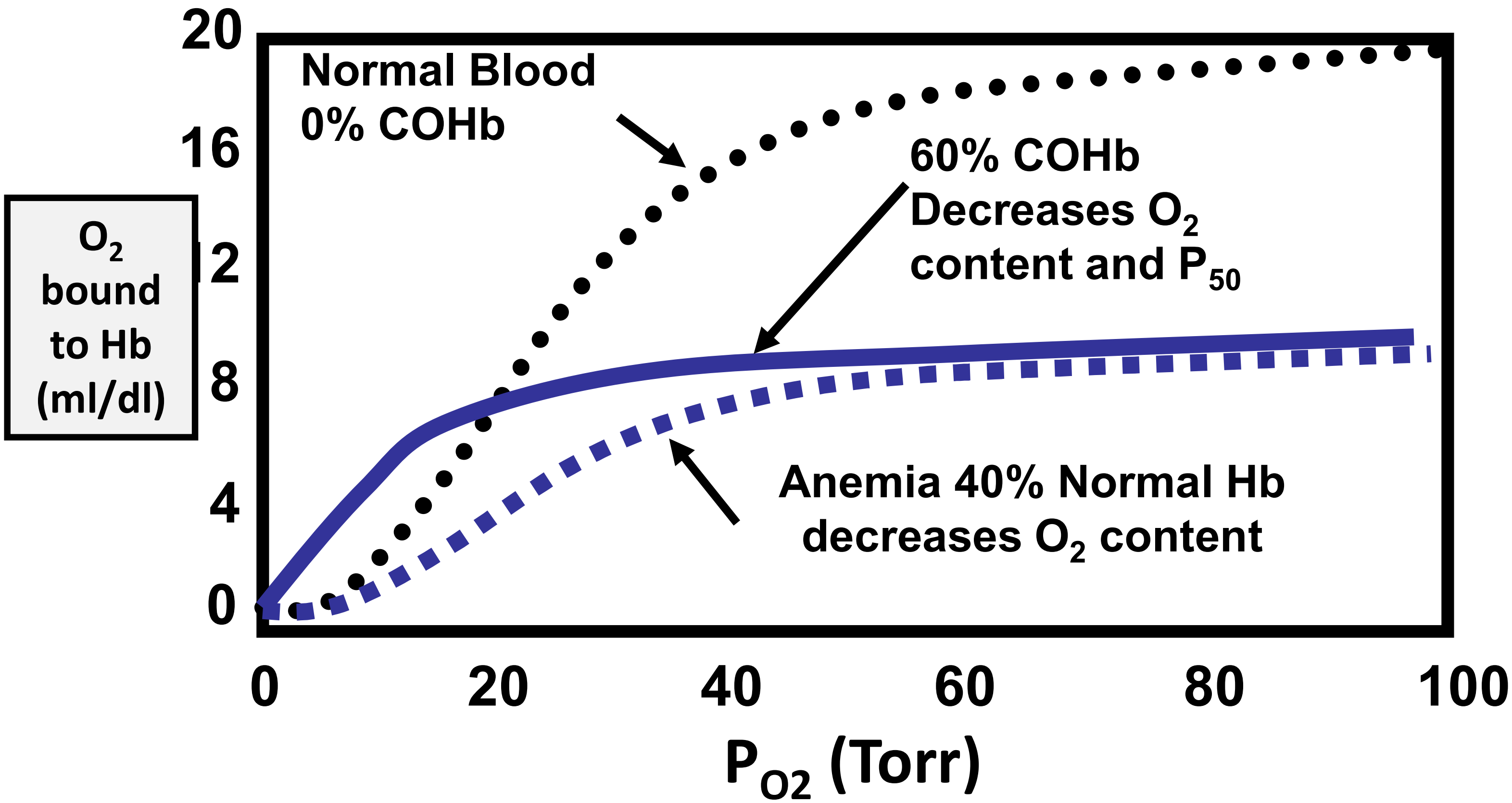
- **Less DPG (P50 → left)**

Increased DPG Concentrations (facilitates O_2 release)

- **Residence at high altitude**
- **Hypoxia: cardiopulmonary disease or anemia**
- **Sickle cell anemia (sickle cells have increased DPG)**
- **Pyruvate kinase deficiency (leads to increased DPG)**
- **Exercise Conditioning**

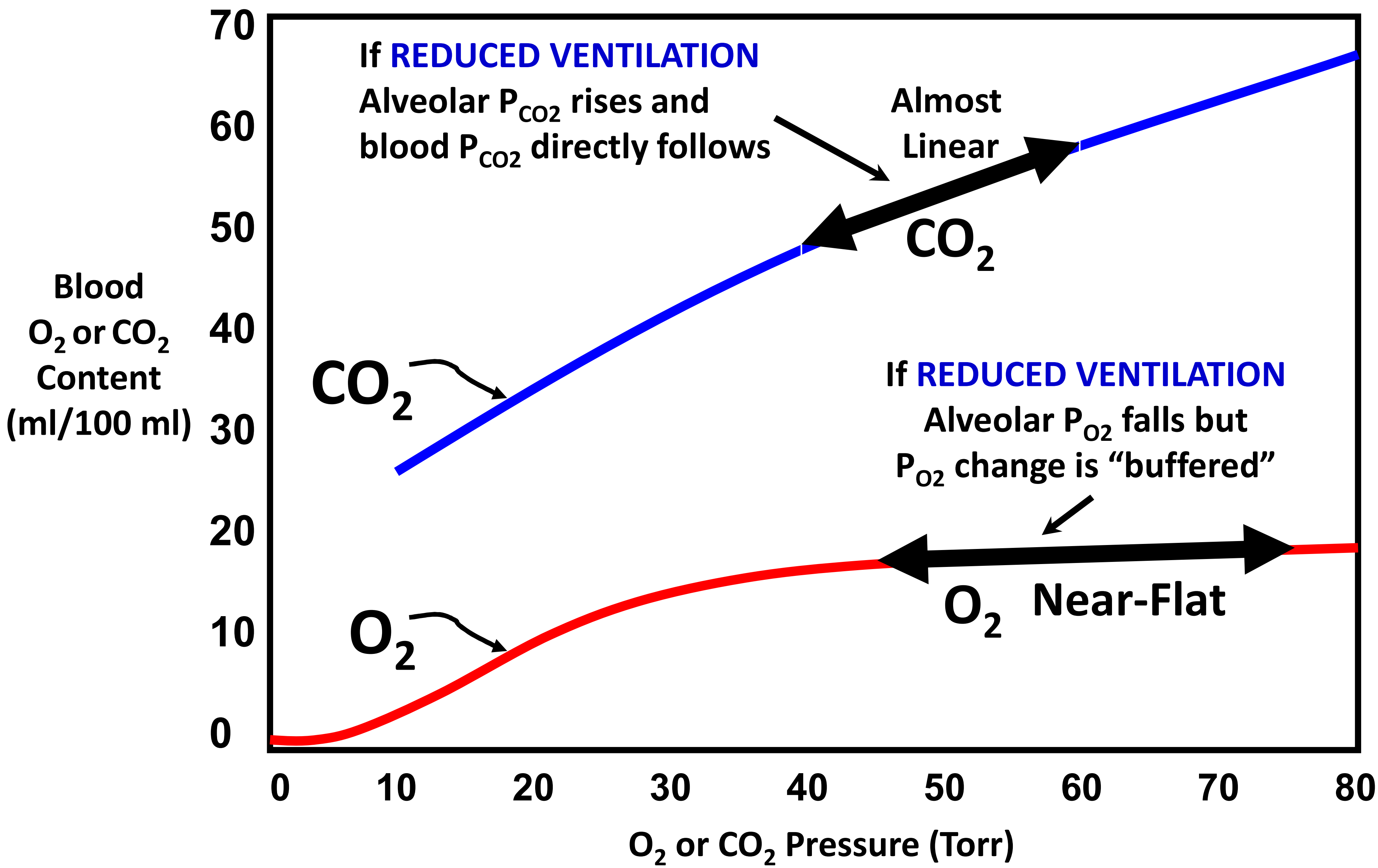
Carbon Monoxide Effects

- Affinity of CO for Hb ~210x O_2; 0.1% CO results in 50% HbCO
- Because of low CO tension may take ~1-2 hours to equilibrate



- Less O_2 is bound (less available for tissue)
- Shift in P_{50} makes removal of O_2 more difficult

CO_2 vs. O_2 Association Curves



Acid-Base Issues in Brief

Acid Base Issues in Brief: Henderson-Hasselbalch

$$pH = pK_A + \log\left[\underbrace{(HCO_3^-)/(0.03P_{CO2})}_{\text{Normal Ratio = 20}} \right] = 7.4$$

pK_A = 6.1

Normal Ratio = 20

Deviations in the ratio from 20 alter blood pH

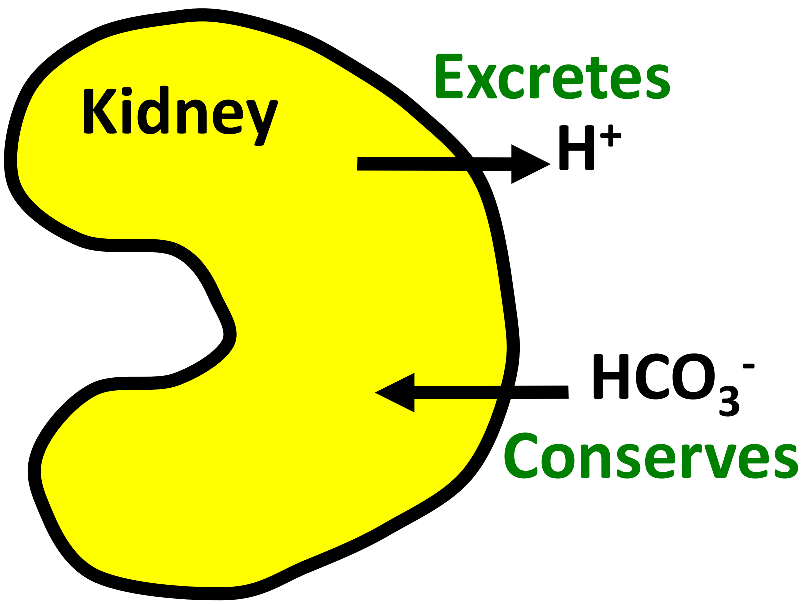
- **Respiratory Acidosis**
- **Respiratory Alkalosis**
- **Metabolic Acidosis**
- **Metabolic Alkalosis**

Respiratory Acidosis → Metabolic Compensation

Low alveolar ventilation → + PCO2 → Reduced ratio → Decreased pH

$$pH \propto \frac{HCO3^-}{PCO_2}$$

Renal Compensation to Respiratory and/or non-Renal Acidosis



$$\uparrow pH \propto \frac{HCO3^-}{PCO_2}$$

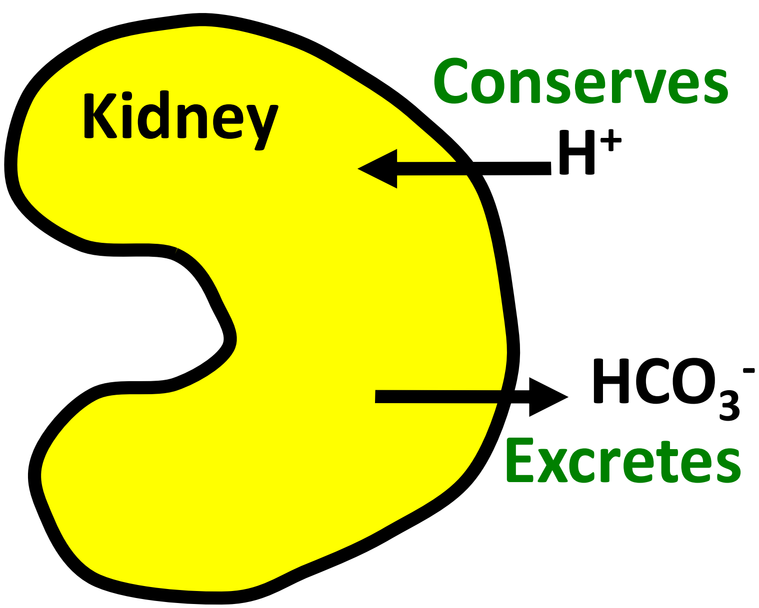
Tends to normalize pH

Respiratory Alkalosis → Metabolic Compensation

Hyperventilation at altitude → - PCO2 → Increased ratio → Increased pH

$$pH \propto \frac{HCO3^-}{PCO_2}$$

Renal Compensation to Respiratory and/or non-Renal Alkalosis



$$\downarrow pH \propto \frac{HCO3^-}{PCO_2}$$

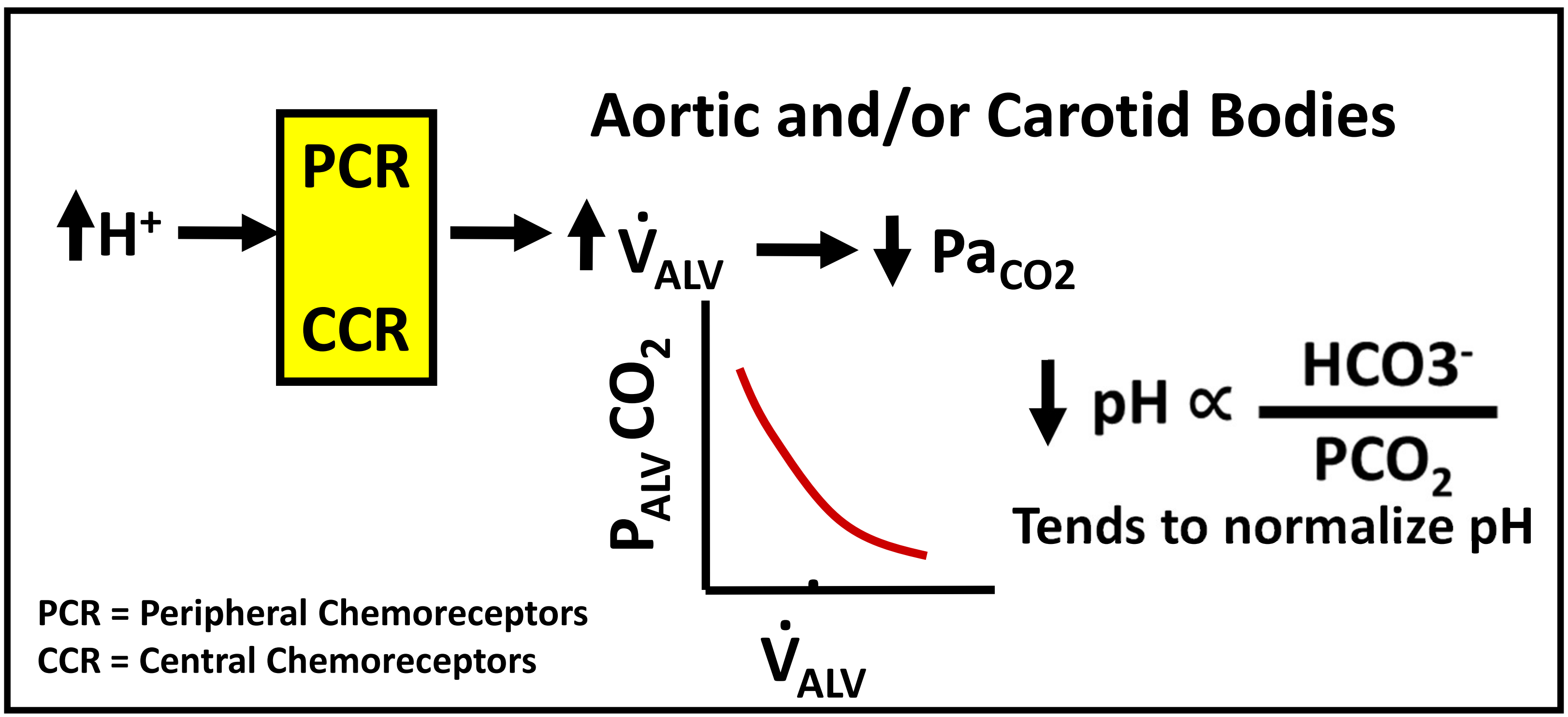
Tends to normalize pH

Metabolic Acidosis → Respiratory Compensation

Severe diarrhea/Kidney disease -$HCO3^-$ → Decreased ratio → Decreased pH

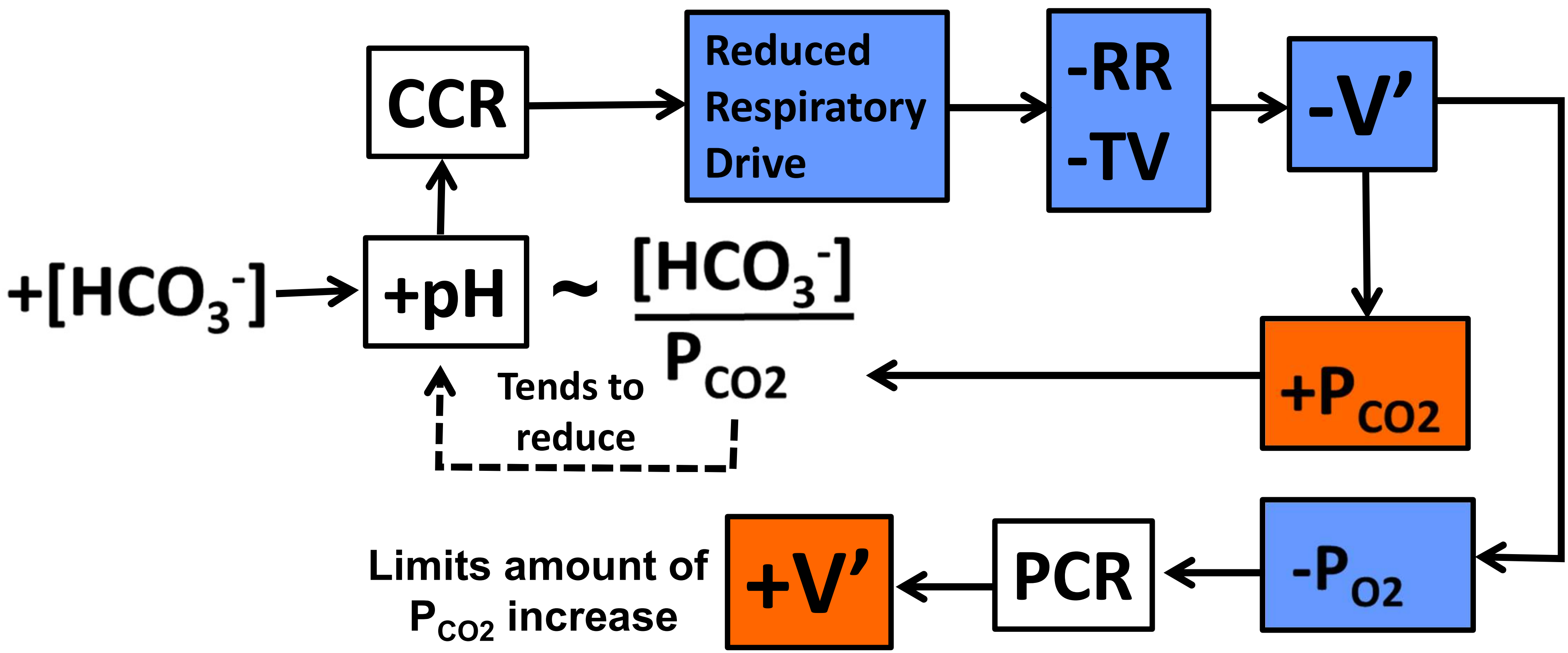
$$pH \propto \frac{HCO3^-}{PCO_2}$$

- **Respiratory Compensation is increased ventilation**
- **Reduces P_{CO2} to normalize ratio**



Metabolic Alkalosis → Respiratory Compensation

Increased extracellular [HCO3$^-$] → *increased* ([HCO_3^-] / P_{CO2}) *ratio*



End Respiratory Physiology
Lecture 41