Gas Exchange and Transport

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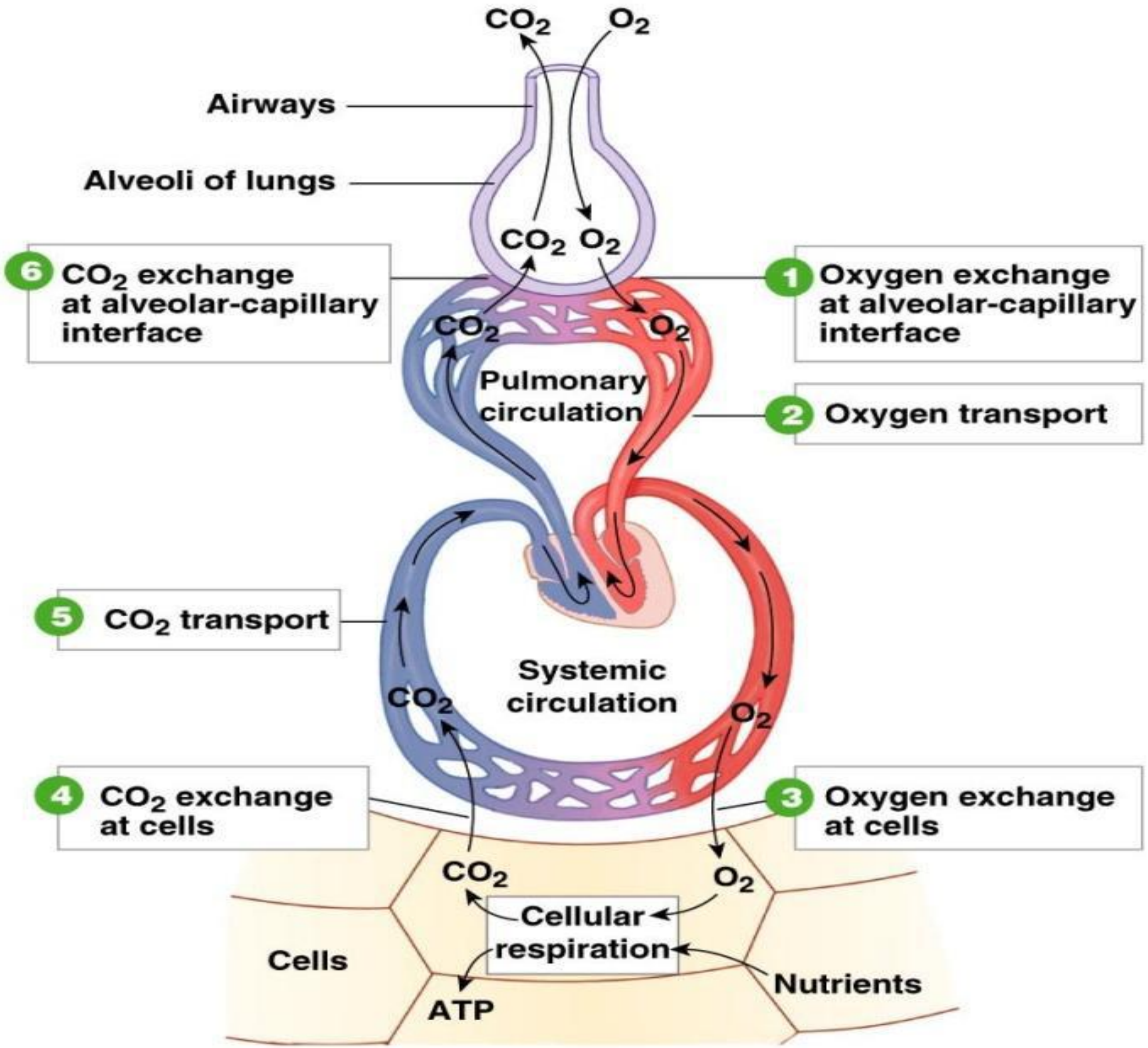
Diffusion and Solubility of Gases

- *Fick's law furthers the principles of diffusion:*

$$\textbf{Diffusion rate} = \frac{\text{Surface area} \times \textbf{conc. gradient} \times \text{membrane permeability}}{\text{Membrane thickness}}$$

- Diffusion most rapid over short distances
  - –At alveolar and systemic capillaries
- Concentration Gradient expressed as Partial Pressure

General principal of gaseous transport



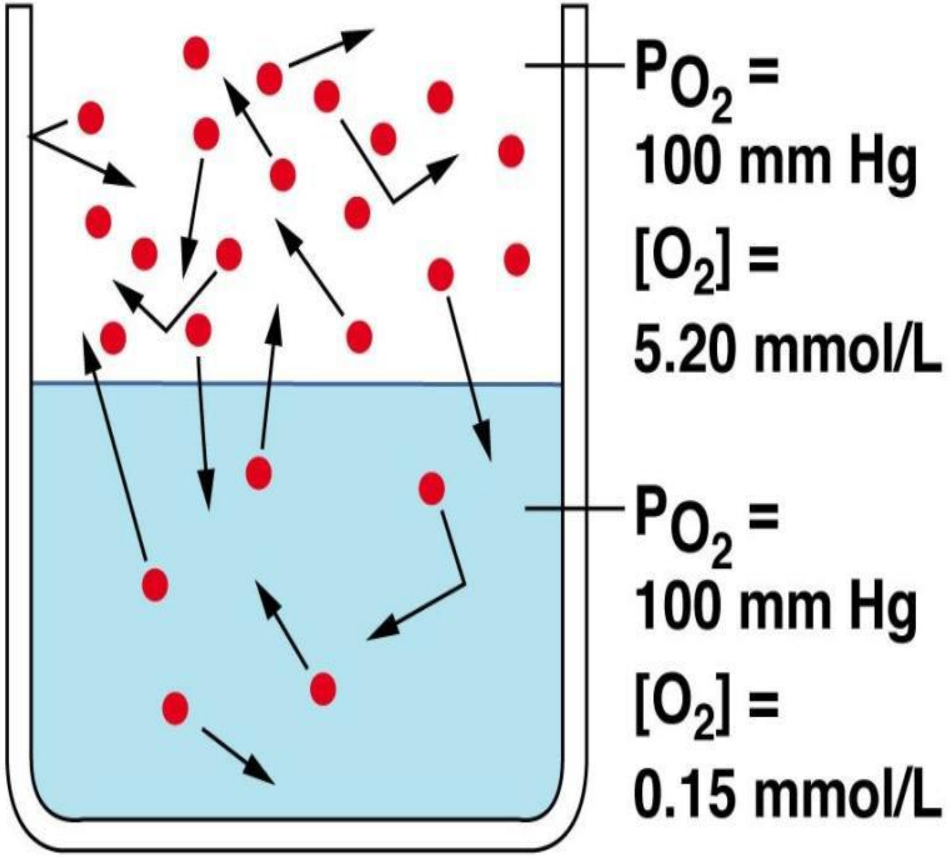
Partial Pressure

1.= P O2 = 100 mmHg at sea level

2.Since gases can diffuse/dissolve into liquids, partial pressure allows comparison between the two media.

- 1.Determines concentration gradient
- **3.Solubility** of gas depends on
  - solubility of molecule in particular liquid
  - pressure gradient
  - temperature
  - Equilibrium not necessarily the same concentration
- CO2 is 20x more soluble than O2, explains the need for Hb

(c) At equilibrium, P_{O_2} in air and water is equal. Low O_2 solubility means concentrations are not equal.

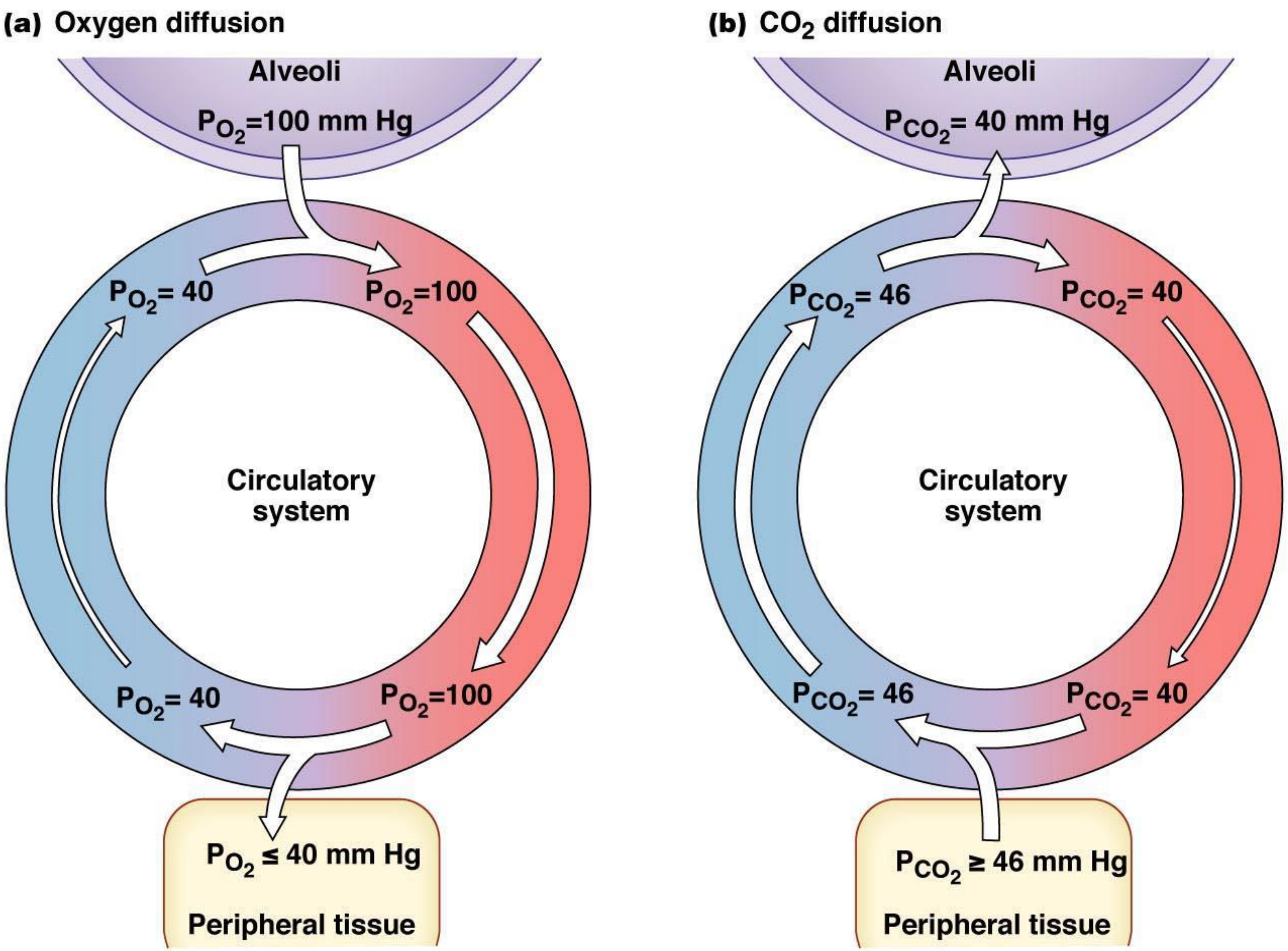


Gas Exchange in Lungs

Partial Pressure Gradient

- Alveolar PO_2 = 100mm Hg
- Venous PO_2 = 40 mm Hg

- Simple diffusion drives the transfer
- PCO_2 has the opposite diffusion from capillary to alveoli



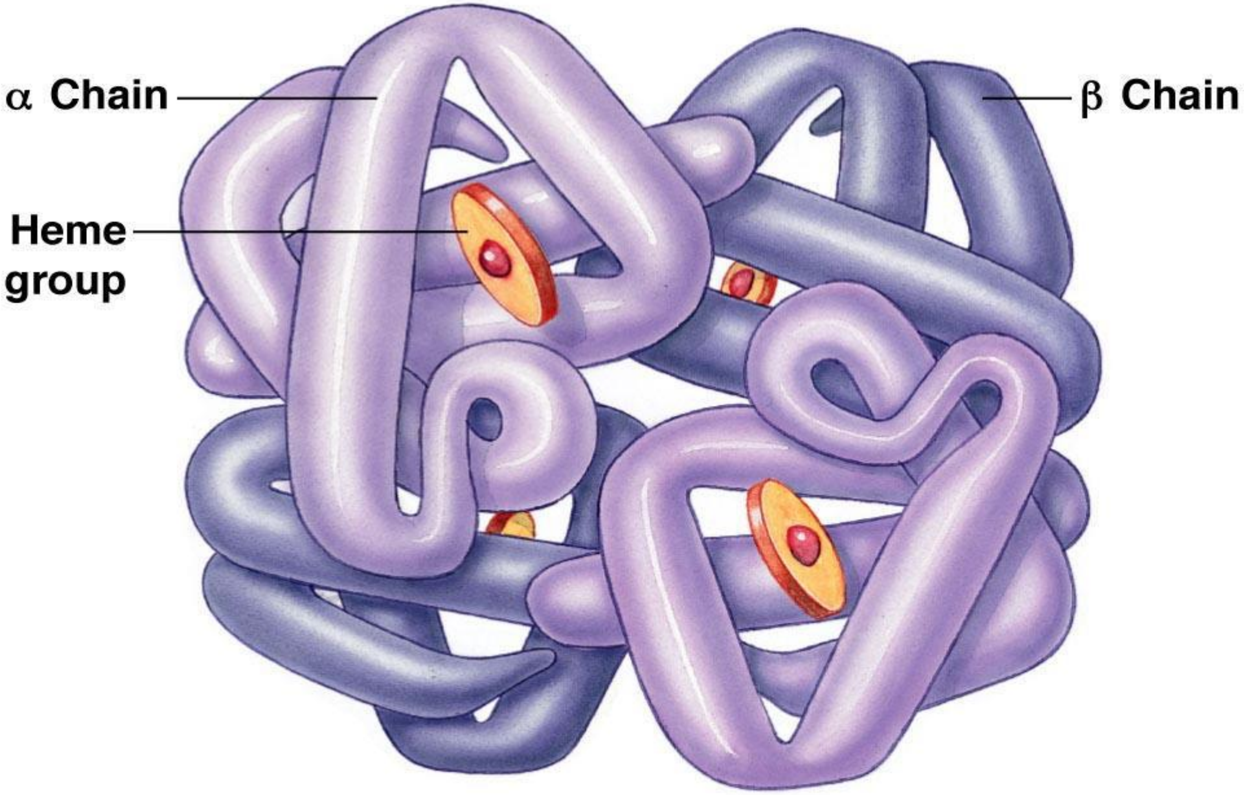
Oxygen Transport in Blood

- > 98% carried by Hb
- Rest dissolved in plasma
- O_2 poorly soluble in plasma
- O_2-Hb dissociation curve demonstrates relationship between PO_2 and Hb binding of O_2
- Other factors affecting O_2-Hb dissociation curve

Hemoglobin (Hb)

- Four protein fractions
- •Four heme groups with Fe
  - 70% of Fe in the body is in heme
- Binds reversibly to O2
  - HbO2 or oxyhemoglobin
  - 100% binding = saturation
  - Pulse Oximeter
- Binding increased by many different conditions:
  - ↑ Plasma PO2
    - Alveolar PO2 determines plasma PO2
  - ↑ pH
  - ↓Temperature
  - ↑ CO2
  - ↓ 2,3-DPG
    - ↑ by hypoxia, e.g., high altitude
    - ↓ in stored blood
- HbF (Foetal Hb)

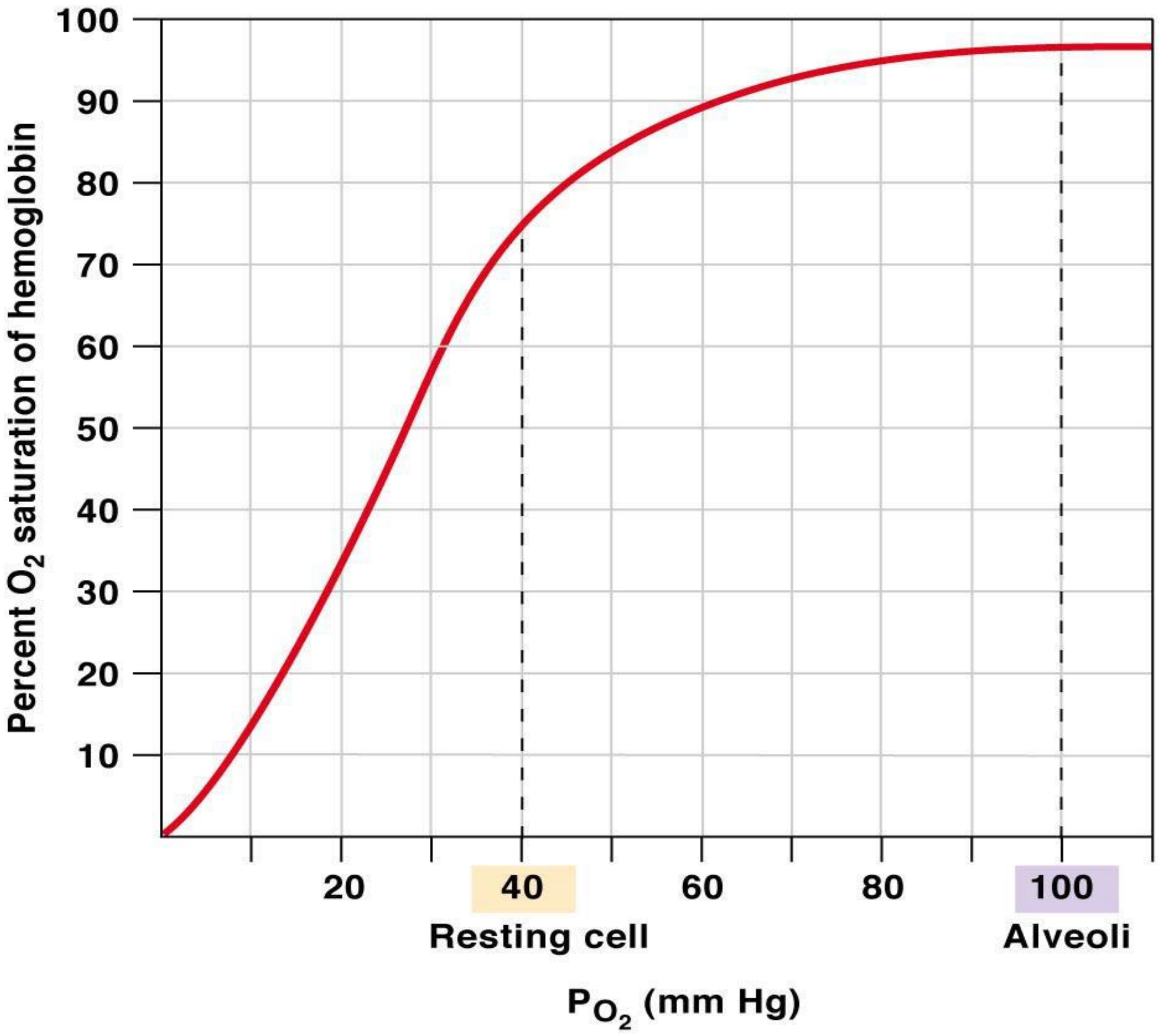
(a) A hemoglobin molecule is composed of four protein globin chains, each surrounding a central heme group.



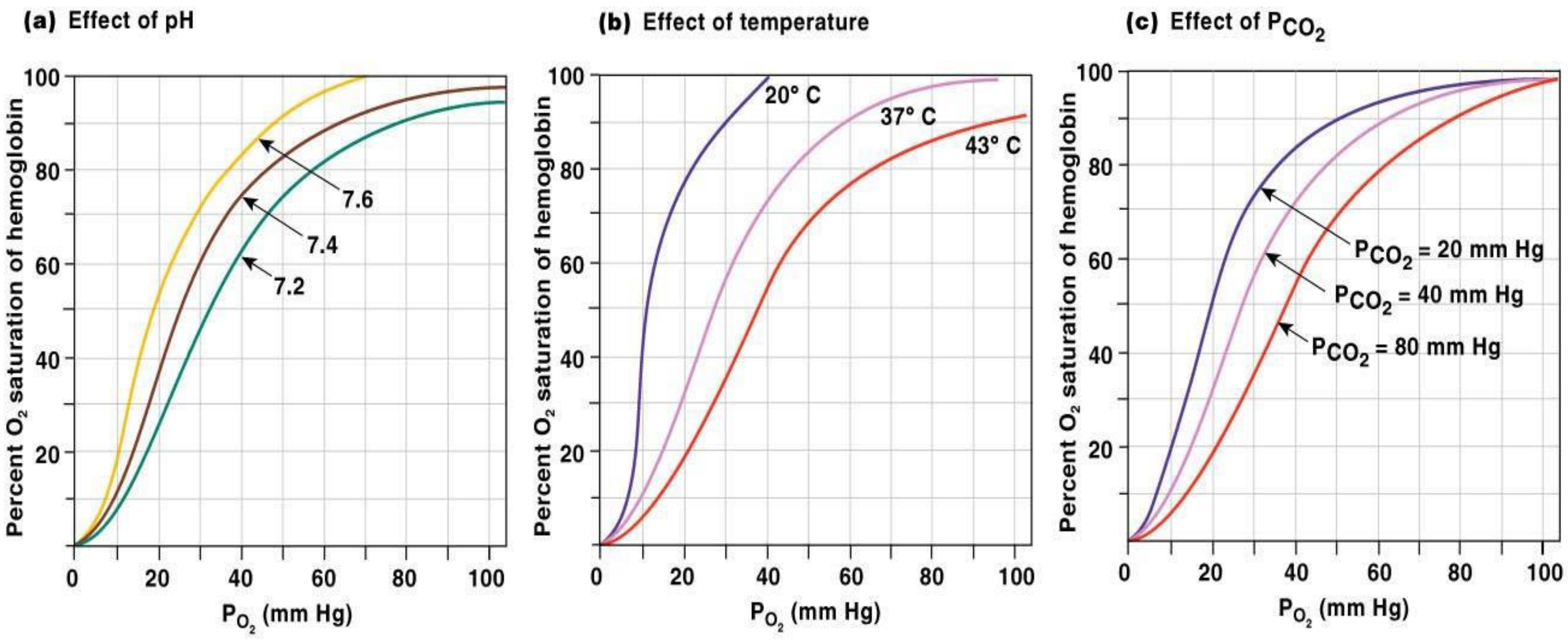
In most adult hemoglobin, there are two alpha chains and two beta chains as shown.

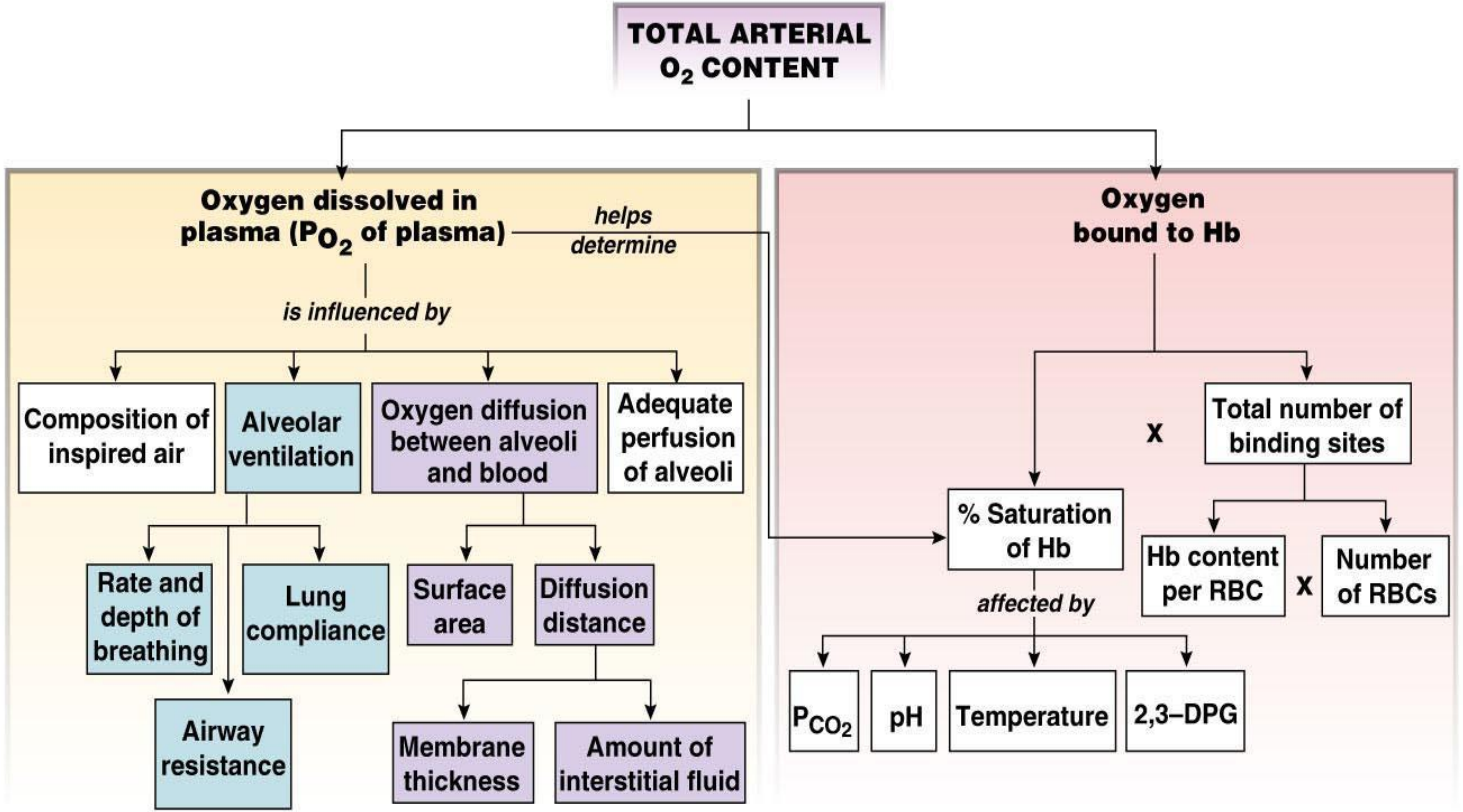
O_2 - Hb Dissociation Curve

- Binding is expressed as a %
  - Amount of O2 that is delivered is dependent on available Hb
  - Range 70-98%
  - Easily measured with pulse oximeter



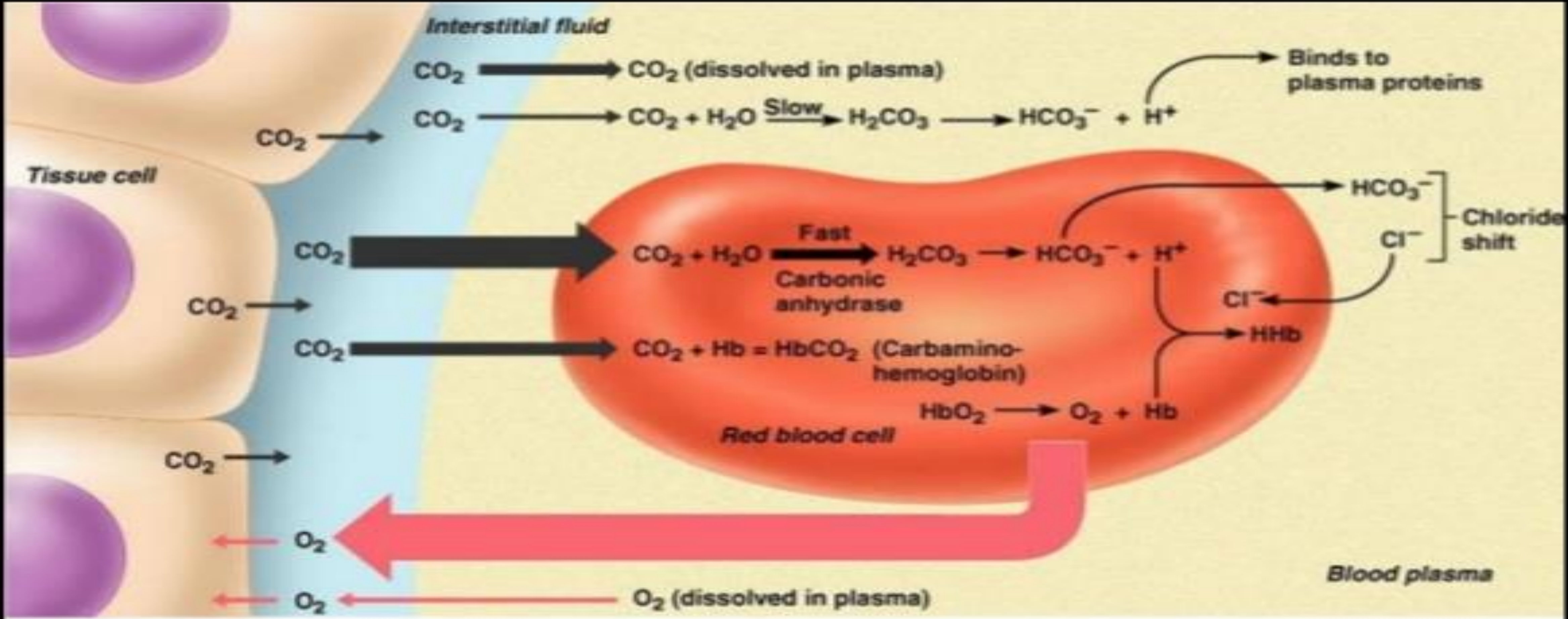
Effect of pH, Temp. and PCO_2




TOTAL ARTERIAL O_2 CONTENT
Oxygen dissolved in plasma (P_{O_2} of plasma)
helps determine
is influenced by
Composition of inspired air
Alveolar ventilation
Oxygen diffusion between alveoli and blood
Adequate perfusion of alveoli
Rate and depth of breathing
Lung compliance
Airway resistance
Surface area
Diffusion distance
Membrane thickness
Amount of interstitial fluid
Oxygen bound to Hb
% Saturation of Hb
X
Total number of binding sites
affected by
P_{CO_2}
pH
Temperature
2,3–DPG
Hb content per RBC
X
Number of RBCs

CO2 Transport in Blood

- **7% directly dissolved in plasma**
- **70% transported as HCO- dissolved in plasma (acts as a buffer)**
  - $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
  - Carbonic Anhydrase in RBC
- **23% bound to Hb** ⟶ **Carbaminohemoglobin**
- **Excess CO_2 in blood = Hypercapnia** that **Leads to acidosis, CNS depression & coma**
- **At the alveoli, CO_2 removed via PP gradients**



(a) Oxygen release and carbon dioxide pickup at the tissues

Regulation of Ventilation

- Respiratory centers in brain stem integrate input from cortex, limbic & both central and peripheral chemoreceptors
  - Carotid & aortic chemoreceptors for O2, CO2 & H+
  - Medullary chemoreceptor for CO2
- Phrenic and intercostal nerves → inspiratory muscles
- When neurons cease firing → muscles relax → expiration
- Low $[O_2]$, high $[CO_2]$ & high $[H^+]$ → ↑ ventilation
- $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

COMPARISON OF DIFFERENT VEHICLES FOR CO_2 TRANSPORT.

- **Plasma** – not good transporter (**0.2ml/100 ml**)
- **Bicarbonate** also not a good transporter – beyond PO_2 40 mmHg no further transport of CO_2
- **Whole Blood** ideal vehicle

Further studies

- https://www.slideshare.net/nileshkate79/transport-of-carbon-dioxide-69934735
- https://teachmephysiology.com/respiratory-system/transport-in-the-blood/transport-carbon-dioxide-blood/
- https://study.com/academy/lesson/carbon-dioxide-transport-in-the-blood.html
- Any Physiology Book available to you