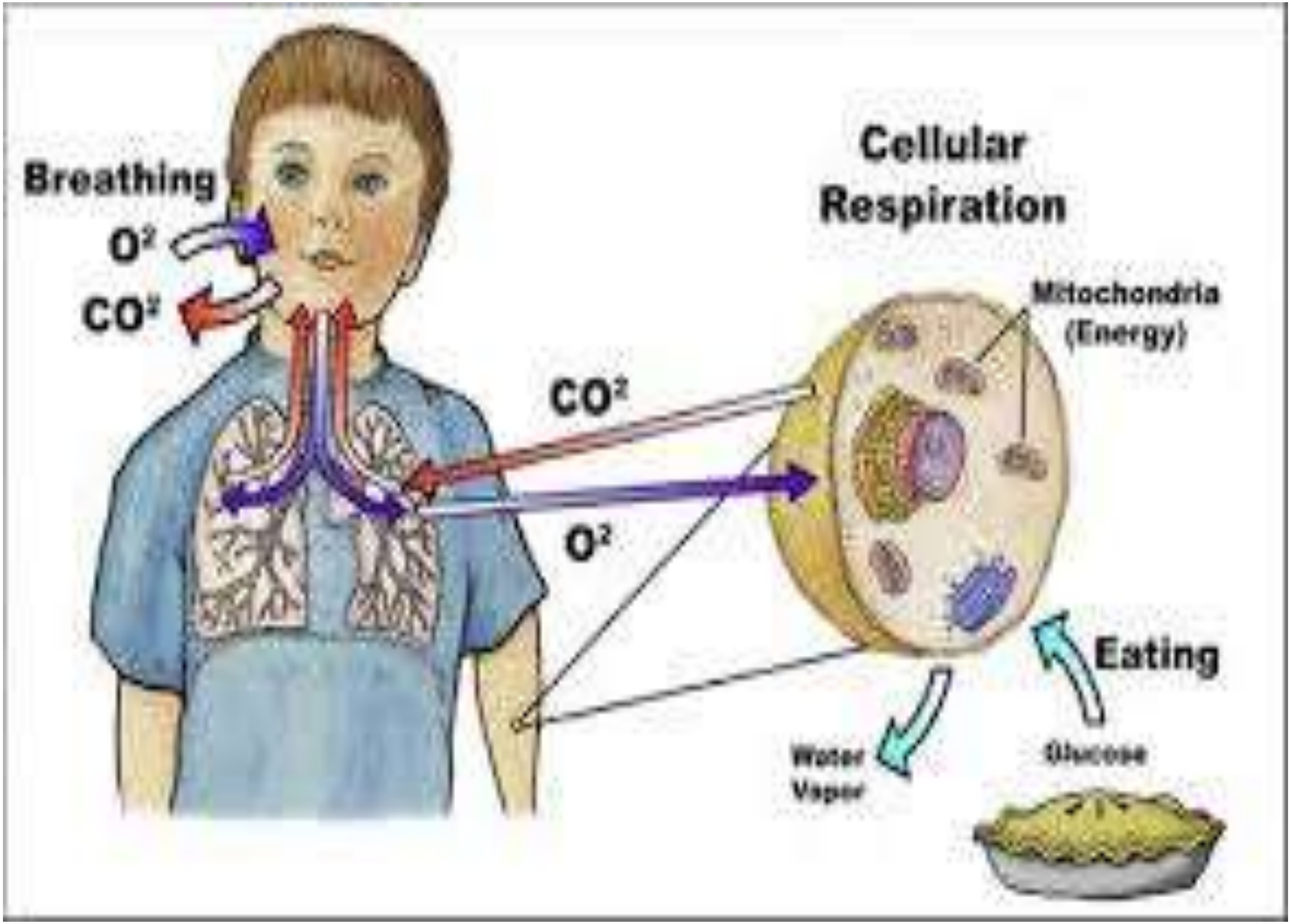
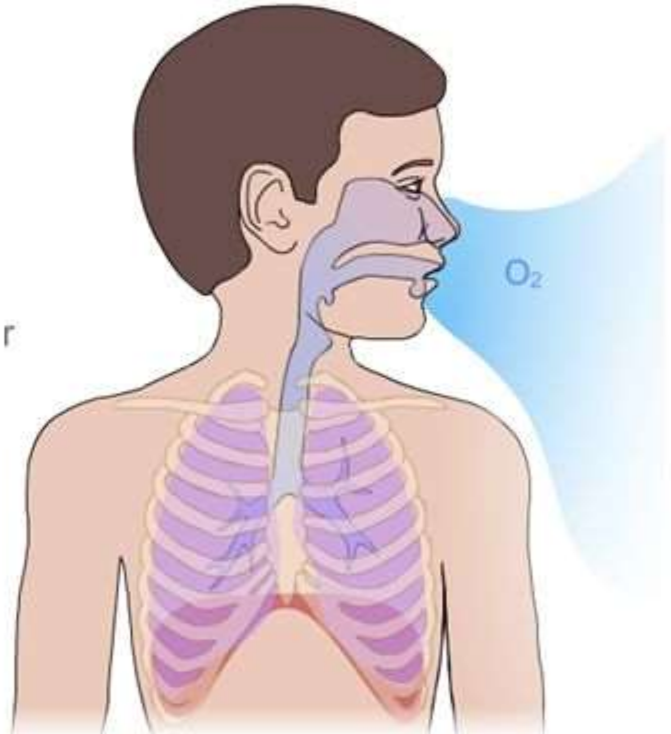
EXTERNAL RESPIRATION



Breathing
O2
CO2
Cellular
Respiration
Mitochondria
(Energy)
CO2
O2
Eating
Water
Vapor
Glucose

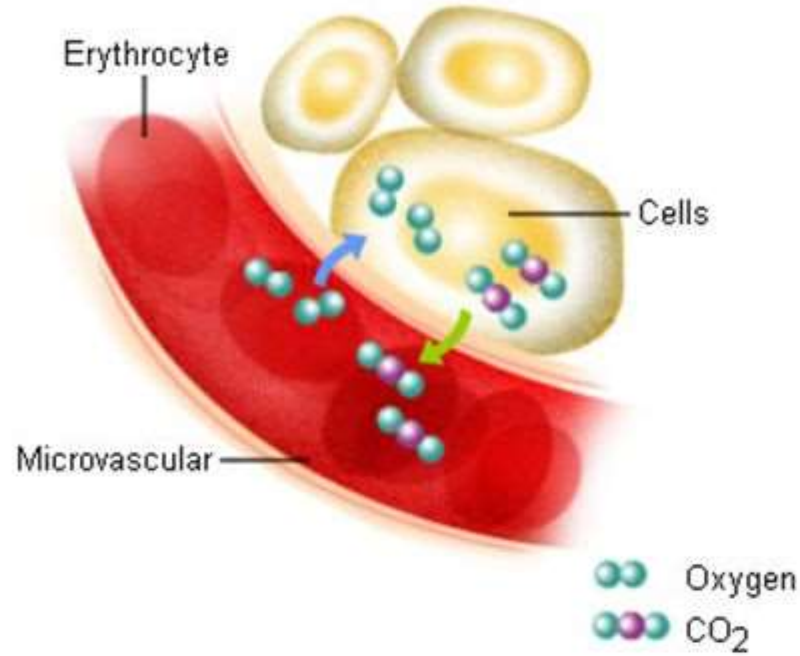
RESPIRATION

External



Between environment and lungs

Internal



Between blood and cell

http://activity.ntsec.gov.tw/lifeworld/english/content/body_cc4.html

Why do we need a ventilation system?

We are **large organisms**. Oxygen cannot diffuse into all our cells directly from the air, nor can waste products be directly ejected from the body. We have specialised organ systems, which are efficient, but need delivery of nutrients and removal of waste. The ventilation system ensures the blood can be the medium for this.

We are **land-borne**. Gases need moist surfaces (membranes) in order to diffuse. Our lungs are moist membranes, allowing oxygen to diffuse into the blood and carbon dioxide to diffuse out.

The ventilation system **maintains a large concentration gradient** between the alveoli and the blood. The constant flow of past the alveoli brings blood with a high CO_2 concentration and low O_2 concentration. Breathing out keeps the CO_2 concentration in the alveoli low, so it diffuses out of the blood. Breathing in keeps O_2 concentration in the alveoli high, so it diffuses into the blood.

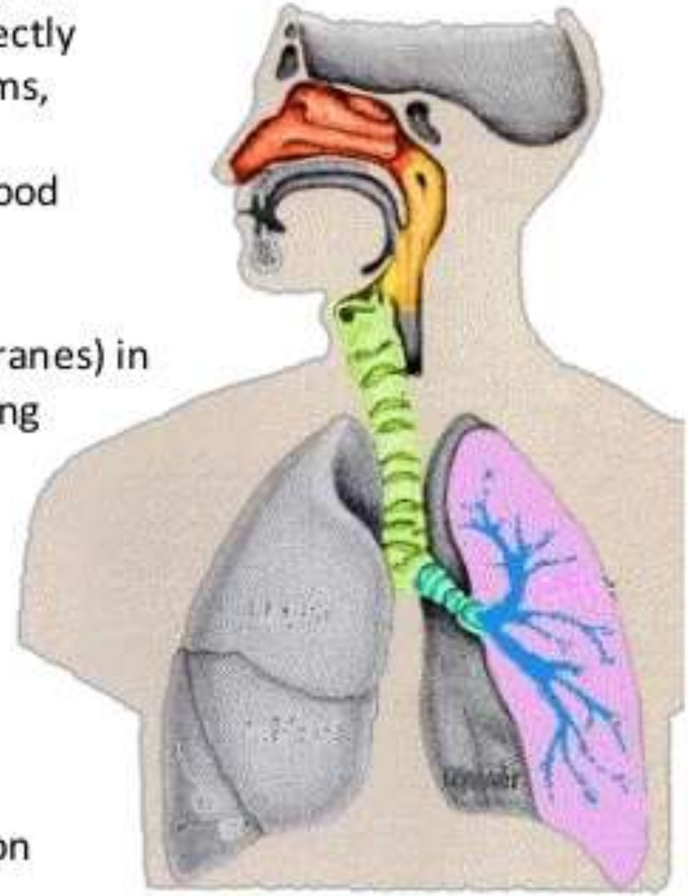
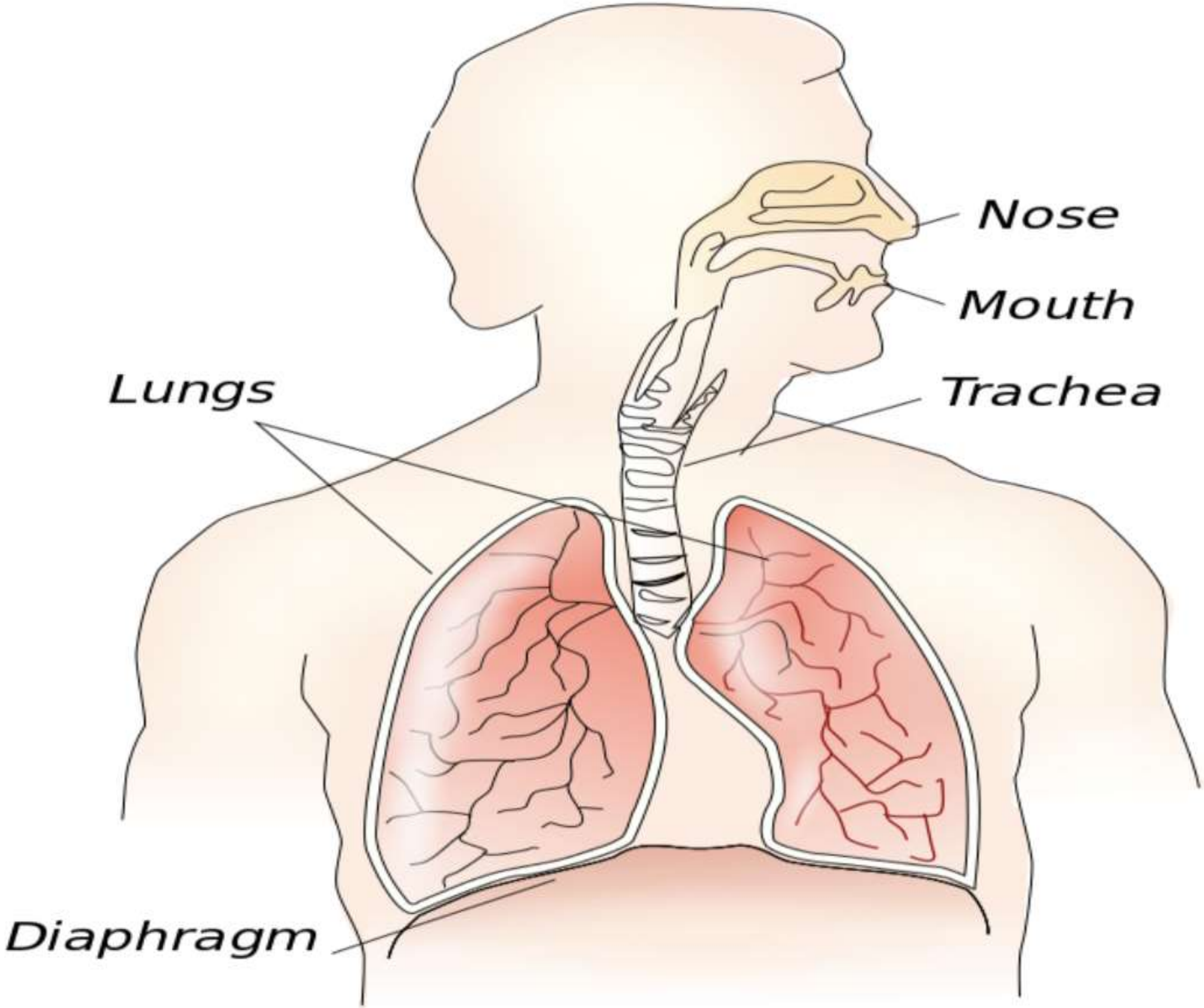
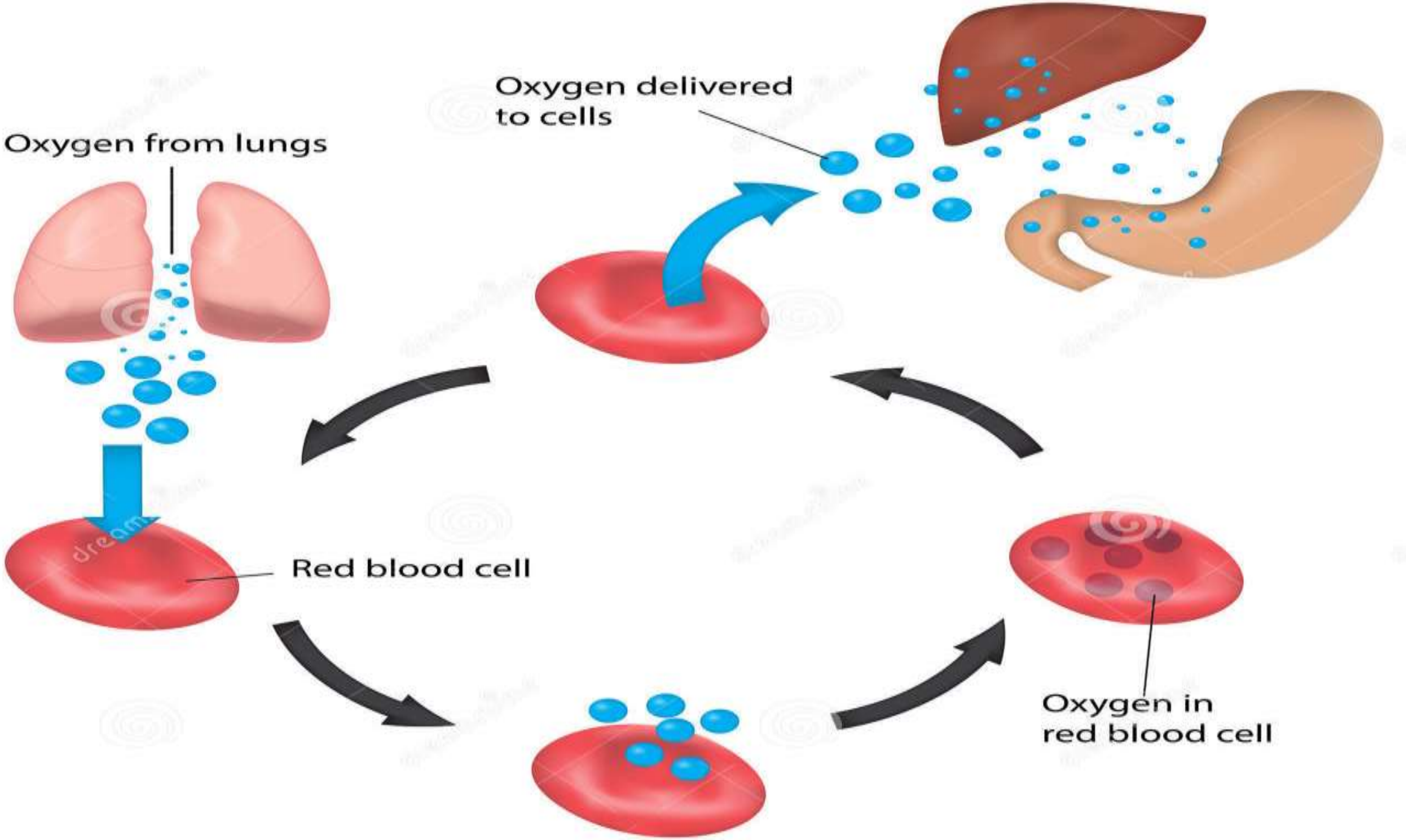
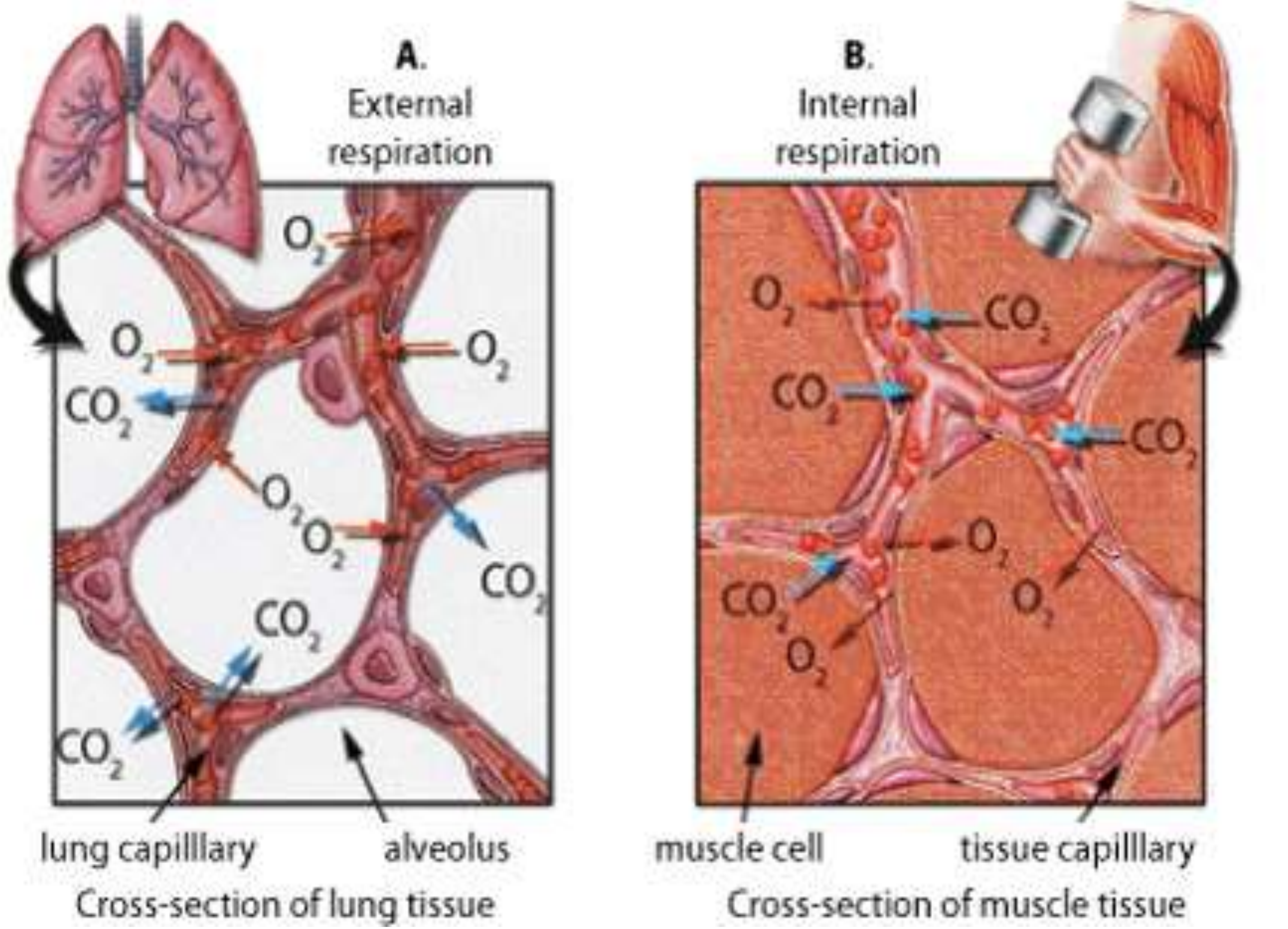


Diagram from: http://www.sciencequiz.net/jcscience/jcbiology/gapfilling/breathingsystem.htm

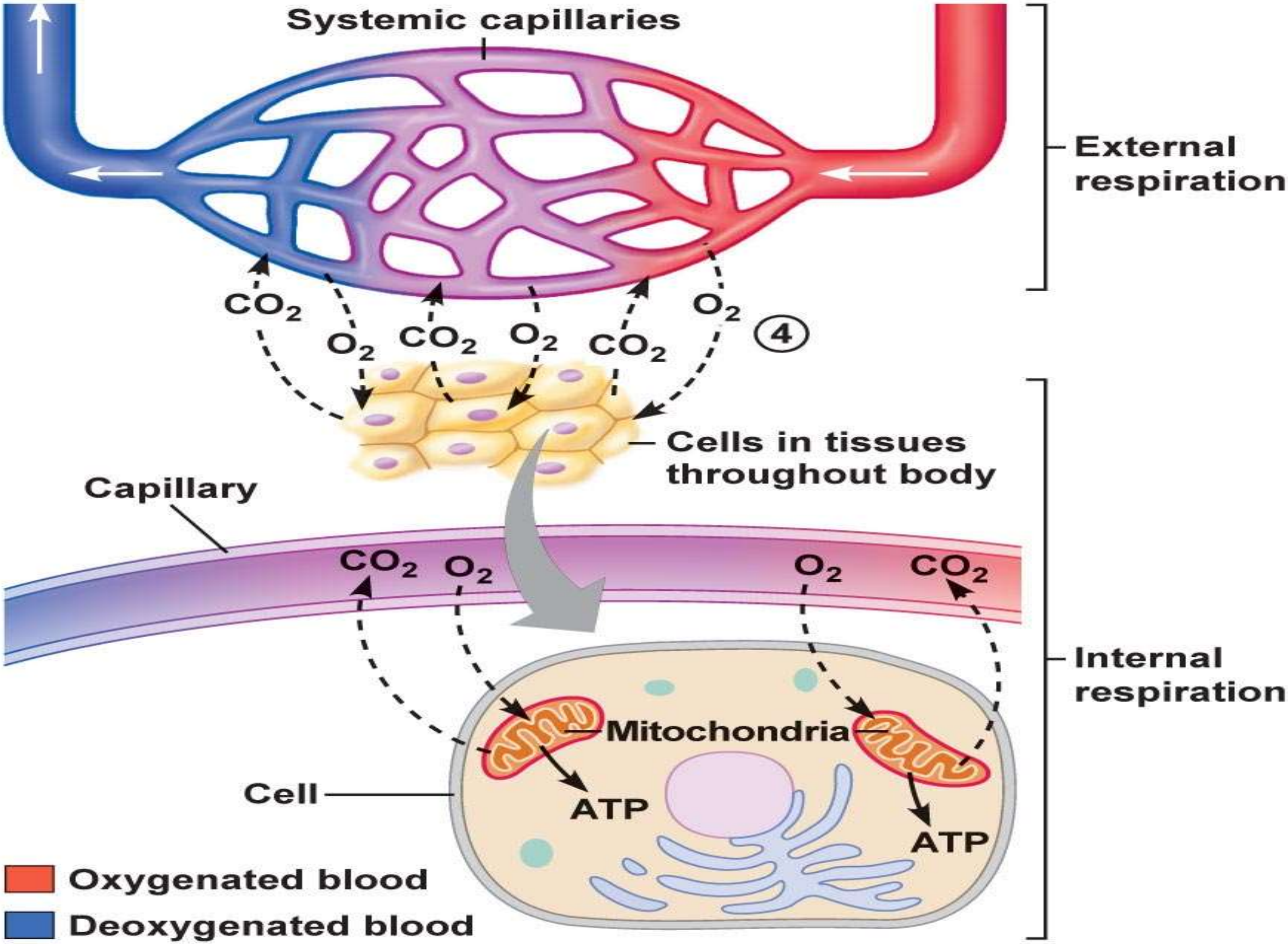


Nose
Mouth
Lungs
Trachea
Diaphragm

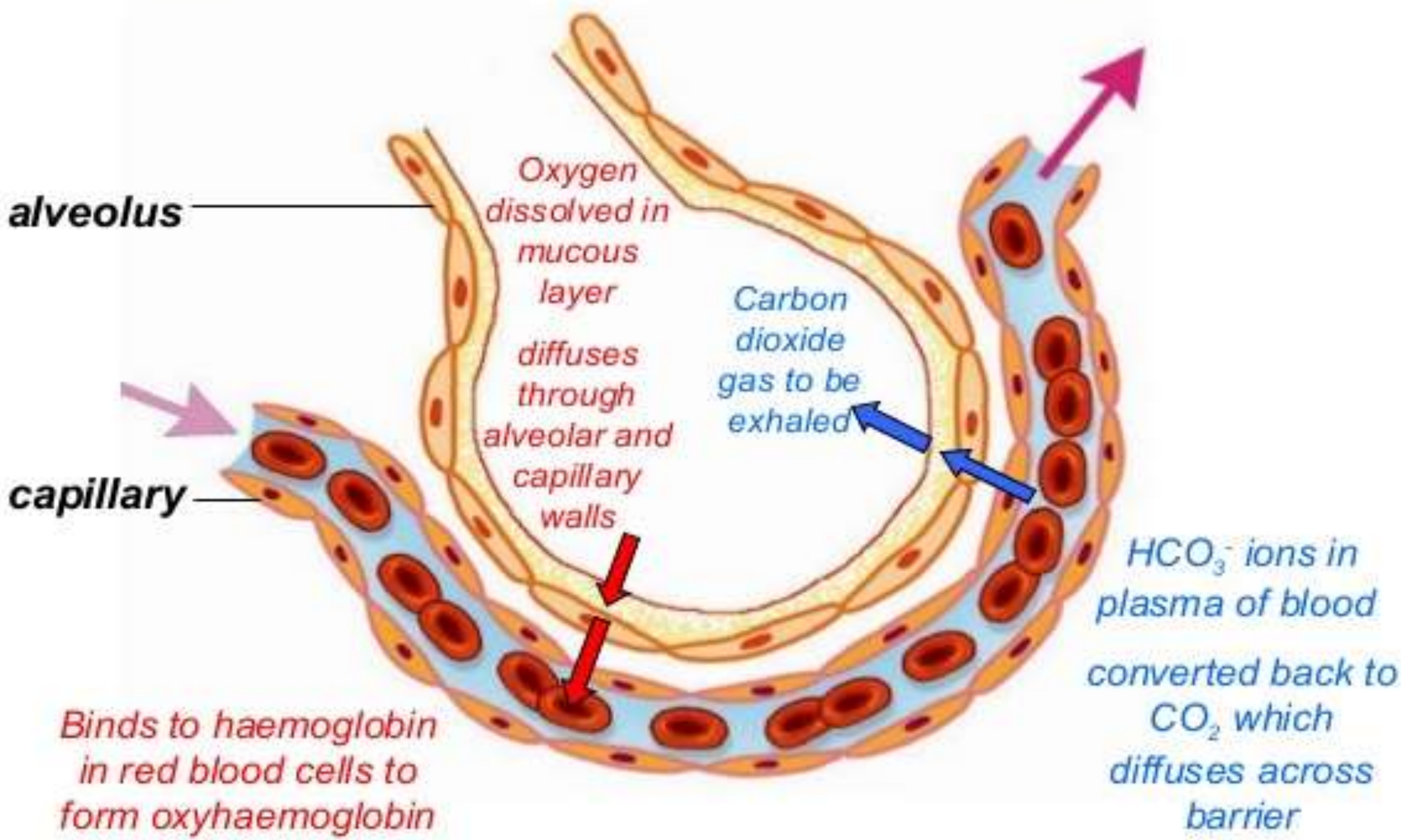

Oxygen delivered
to cells
Oxygen from lungs
Red blood cell
Oxygen in
red blood cell

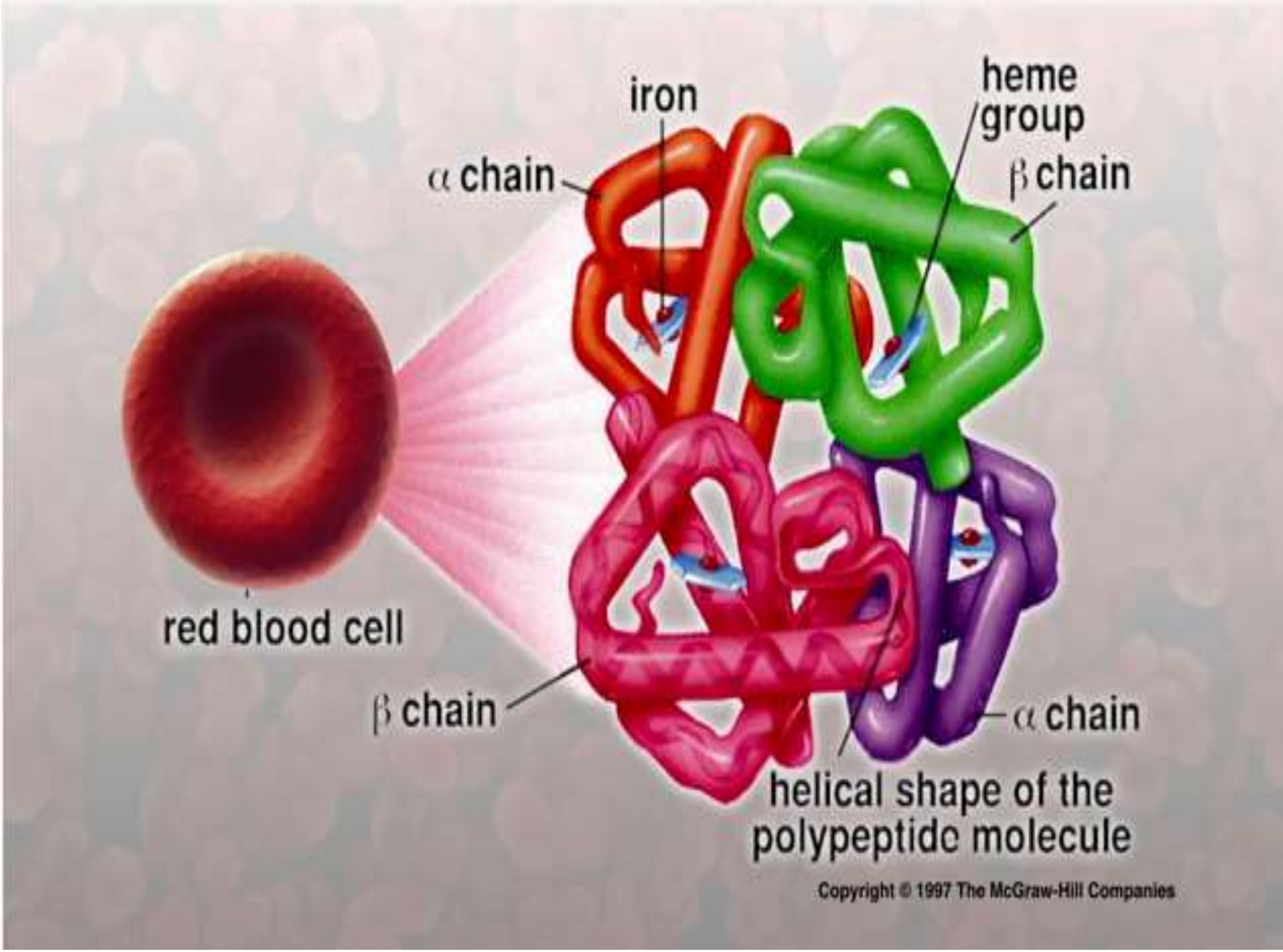


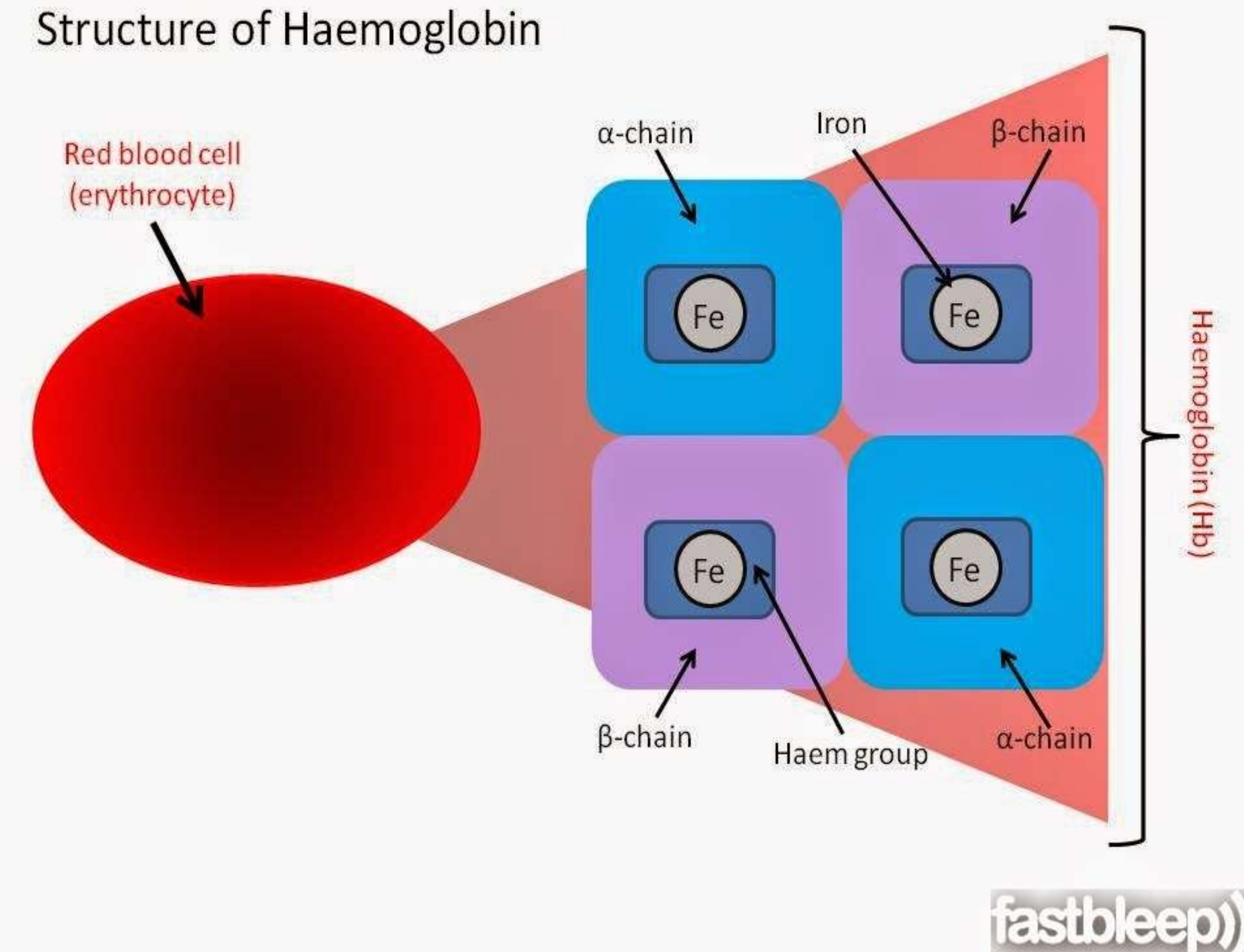
A.
External respiration
O2
O2
O2
CO2
O2
O2
CO2
CO2
CO2
lung capilllary
alveolus
Cross-section of lung tissue
B.
Internal respiration
O2
CO2
CO2
CO2
O2
CO2
O2
O2
muscle cell
tissue capilllary
Cross-section of muscle tissue

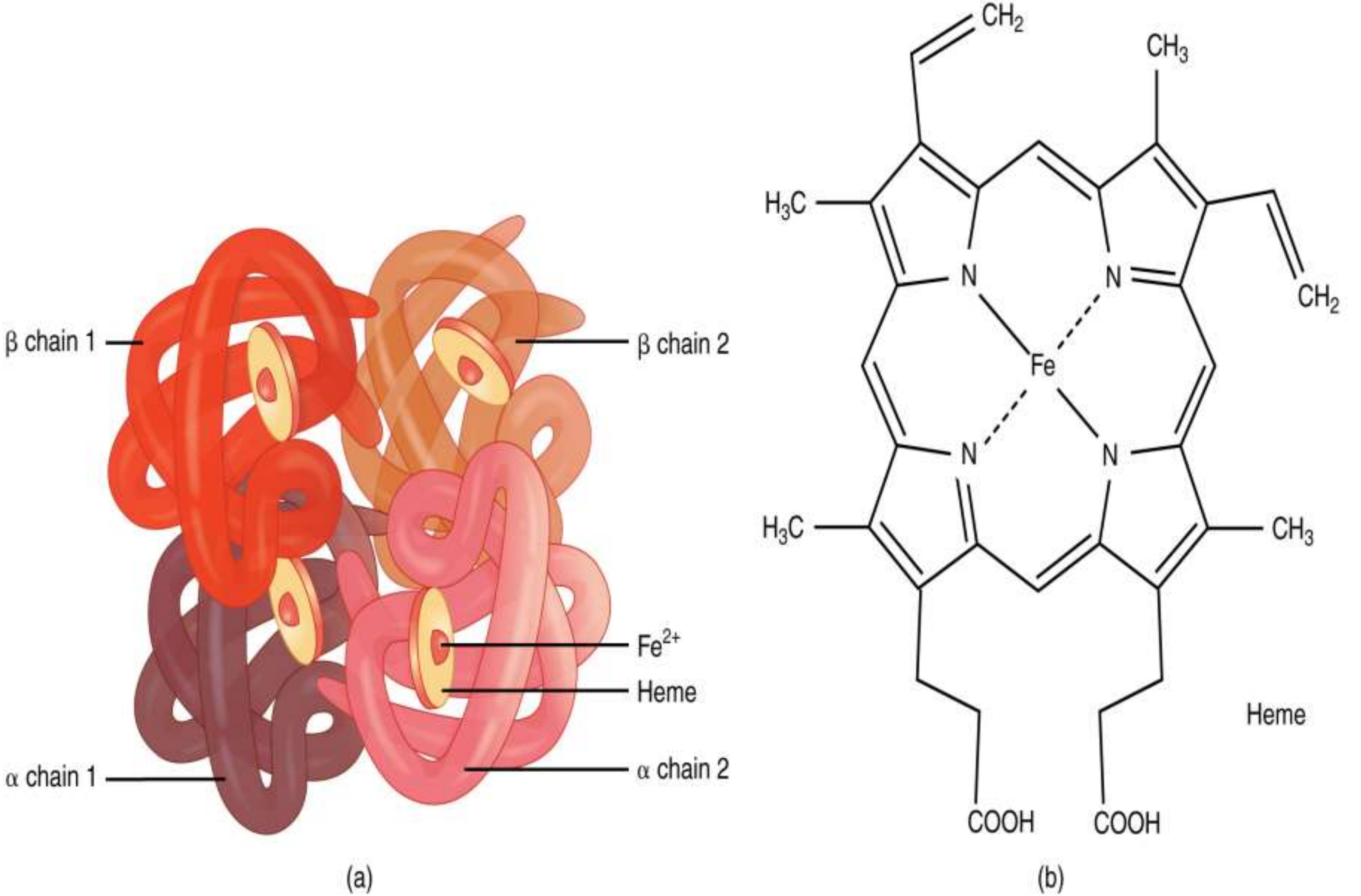

Systemic capillaries
External respiration
CO_2
O_2
CO_2
O_2
CO_2
O_2
4
Cells in tissues throughout body
Capillary
CO_2
O_2
O_2
CO_2
Internal respiration
Mitochondria
Cell
ATP
ATP
Oxygenated blood
Deoxygenated blood

Gaseous Exchange in the Alveolus

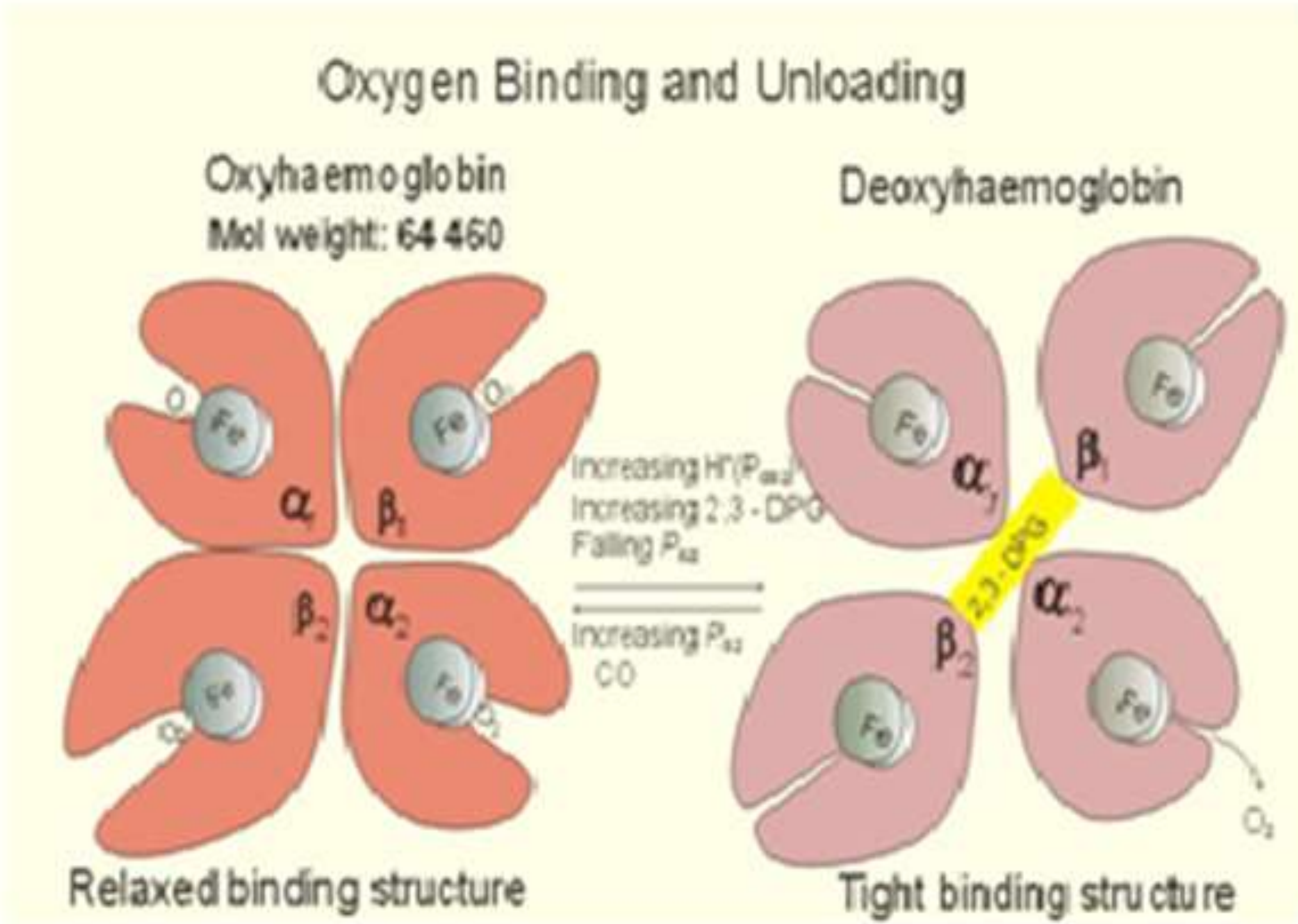



iron
heme
group
α chain
β chain
red blood cell
β chain
α chain
helical shape of the
polypeptide molecule
Copyright © 1997 The McGraw-Hill Companies


Structure of Haemoglobin
Red blood cell
(erythrocyte)
α-chain
Iron
β-chain
Fe
Fe
Fe
Fe
β-chain
Haem group
α-chain
Haemoglobin (Hb)
fastbleep))

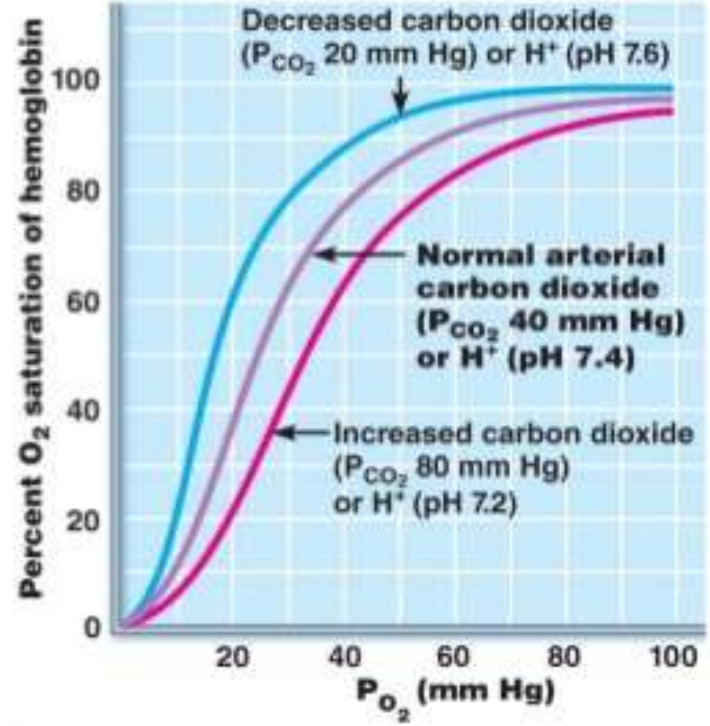


β chain 1
β chain 2
Fe2+
Heme
α chain 1
α chain 2
(a)
CH2
CH3
H3C
N
Fe
CH2
N
N
N
H3C
CH3
COOH
COOH
Heme
(b)


Oxygen Binding and Unloading
Oxyhaemoglobin
Mol weight: 64 460
Deoxyhaemoglobin
Increasing H^+(P_{CO_2})
Increasing 2,3 - DPG
Falling P_{O_2}
Increasing P_{O_2}
CO
2,3 - DPG
α_1
β_1
β_2
α_2
Fe
O_2
Relaxed binding structure
Tight binding structure

Haldane Effect

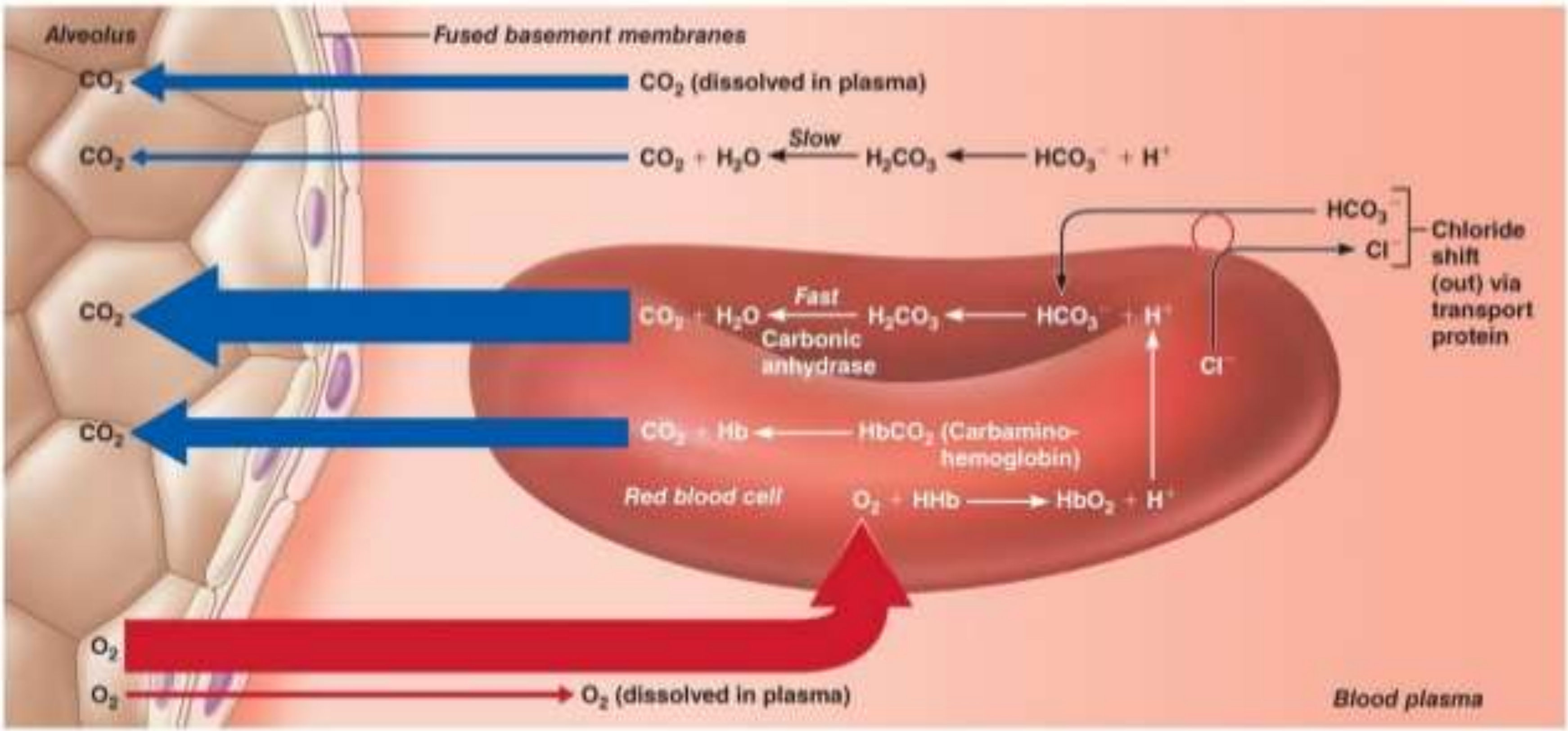
- Amount of CO_2 transported affected by Po_2
  - HHb forms carbaminohemoglobin and buffers H^+ more easily →
  - Po_2 and hemoglobin saturation ↓; CO_2 in blood ↑
- ↑ CO_2 exchange in tissues and lungs
- At tissues, as more CO_2 enters blood
  - O_2 unloading ↑ (**Bohr effect**)
  - HbO_2 releases O_2 and readily forms carbaminohemoglobin



(b)

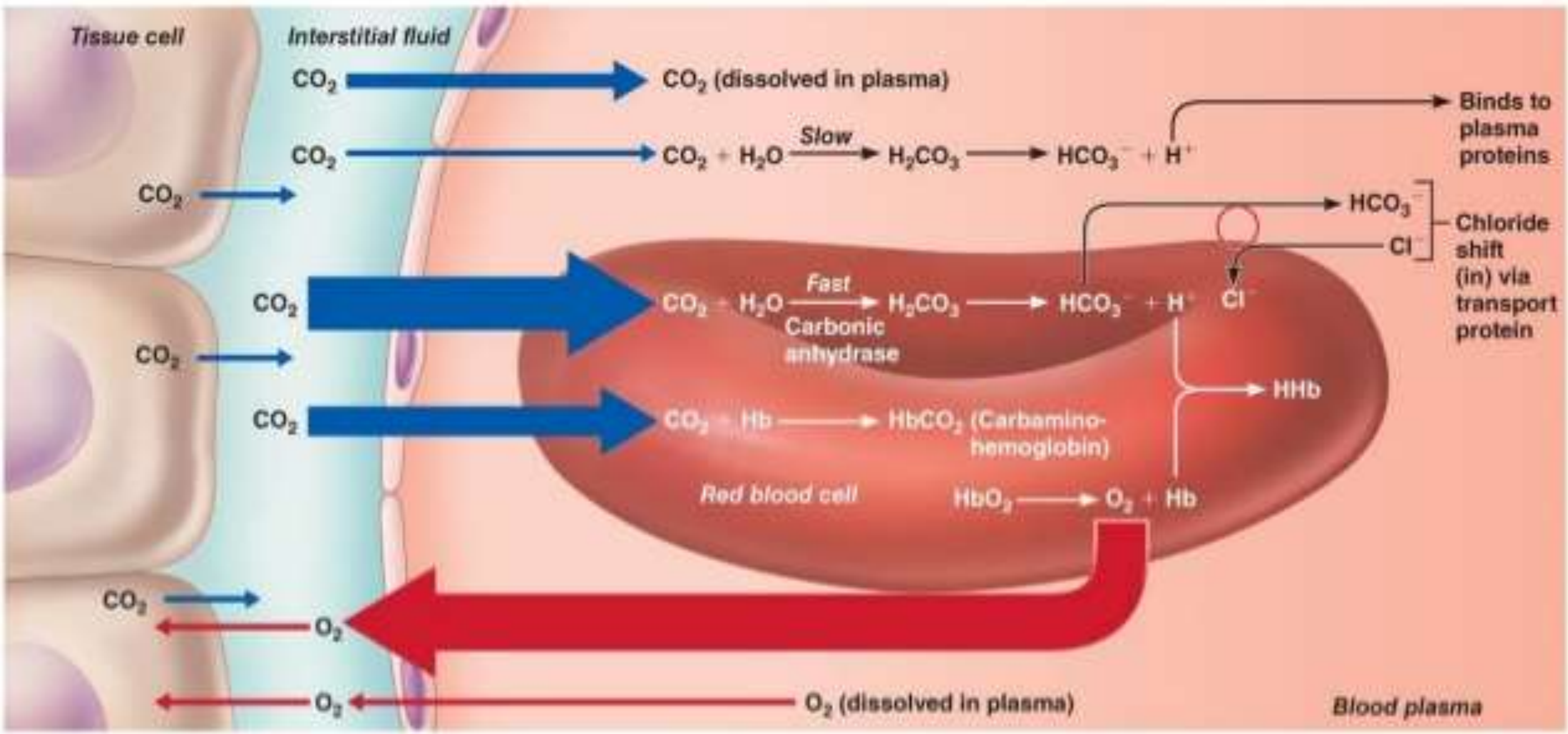
- **Carbonic acid–bicarbonate buffer system**–resists changes in blood pH
  - If H^+ concentration in blood rises, excess H^+ is removed by combining with HCO_3^- → H_2CO_3
  - If H^+ concentration begins to drop, H_2CO_3 dissociates, releasing H^+
  - HCO_3^- is **alkaline reserve** of carbonic acid-bicarbonate buffer system
- Changes in respiratory rate and depth affect blood pH
  - Slow, shallow breathing → increased CO_2 in blood → drop in pH
  - Rapid, deep breathing → decreased CO_2 in blood → rise in pH
- Changes in ventilation can adjust pH when disturbed by metabolic factors

- **In pulmonary capillaries**
  - HCO_3^- moves into RBCs (while Cl^- move out); binds with H^+ to form H_2CO_3
  - H_2CO_3 split by carbonic anhydrase into CO_2 and water
  - CO_2 diffuses into alveoli

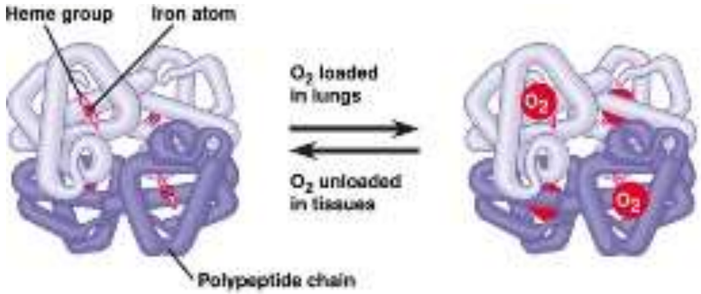


(b) Oxygen pickup and carbon dioxide release in the lungs

- **In systemic capillaries**
  - HCO_3^- quickly diffuses from RBCs into plasma
    - **Chloride shift** occurs
      - Outrush of HCO_3^- from RBCs balanced as Cl^- moves into RBCs from plasma

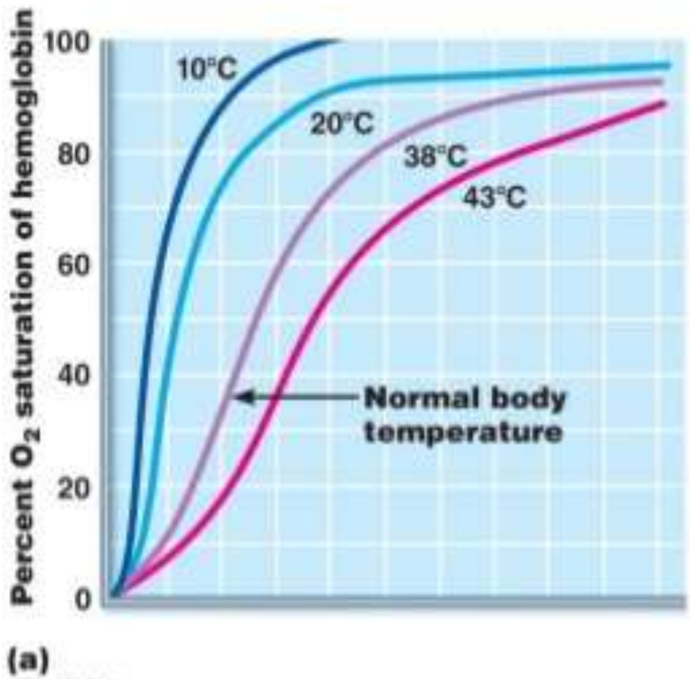


(a) Oxygen release and carbon dioxide pickup at the tissues

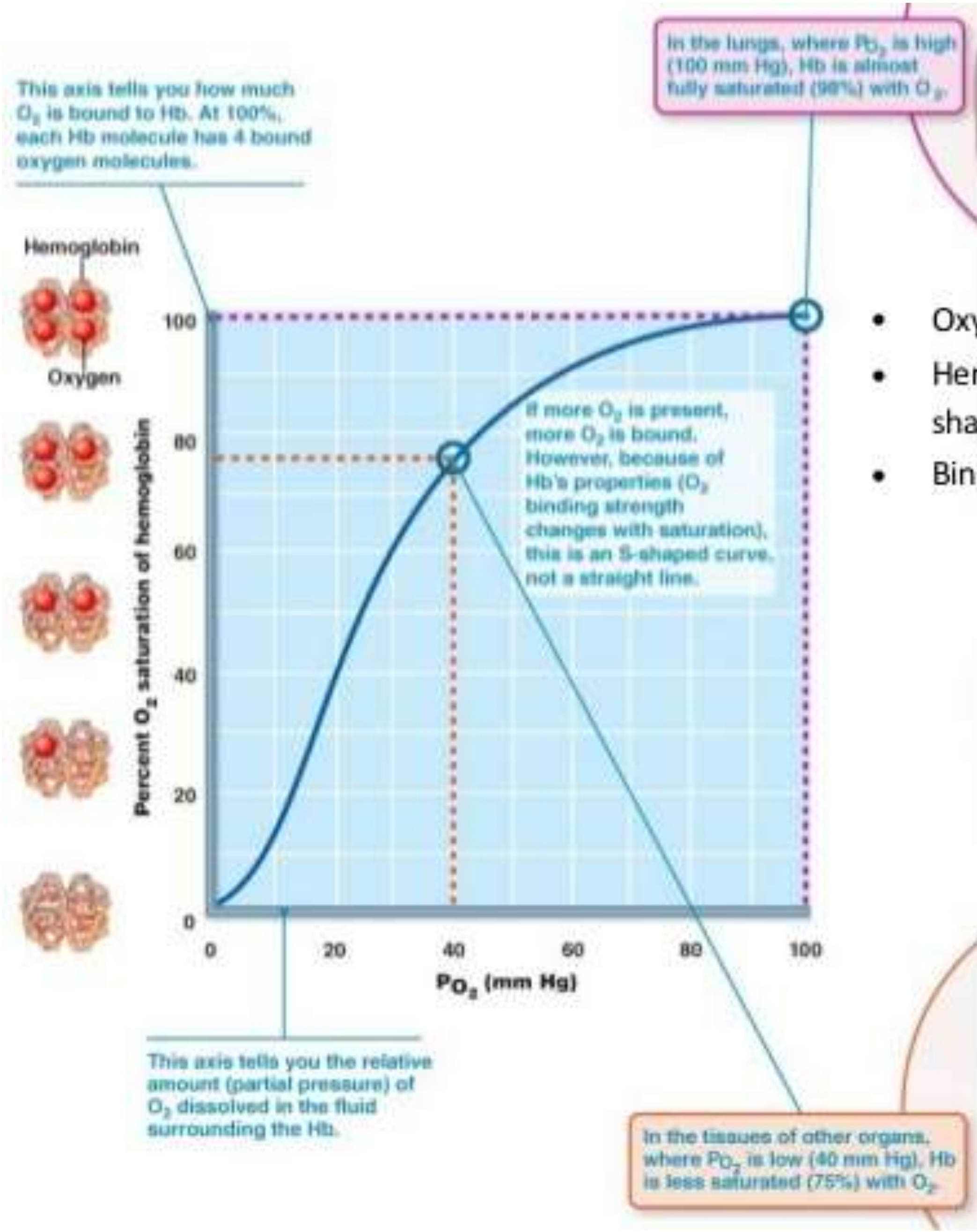


O_2 Transport

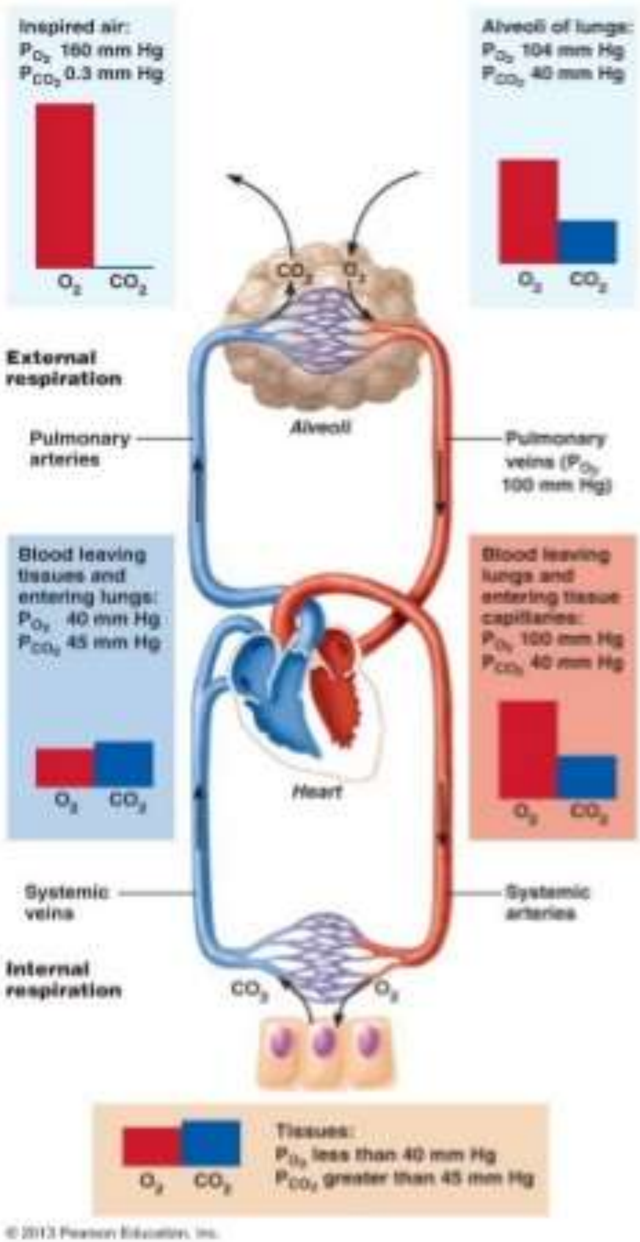
- Molecular O_2 carried in blood
  - 1.5% dissolved in plasma
  - 98.5% loosely bound to each Fe of hemoglobin (Hb) in RBCs
    - 4 O_2 per Hb
- **Oxyhemoglobin** (HbO_2)
- **Deoxyhemoglobin** (HHb – no O_2)
- Loading and unloading of O_2 → change in shape of Hb
  - As O_2 binds, Hb affinity for O_2 increases and vice versa
  - Cooperative binding
- All four heme groups carry O_2 – full saturation
- Rate of loading and unloading of O_2 regulated to ensure adequate oxygen delivery to cells
  - Po_2
  - Temperature
  - Blood pH
  - Pco_2
  - Concentration of BPG–produced by RBCs during glycolysis; levels rise when oxygen levels chronically low



Hemoglobin Dissociation Curve

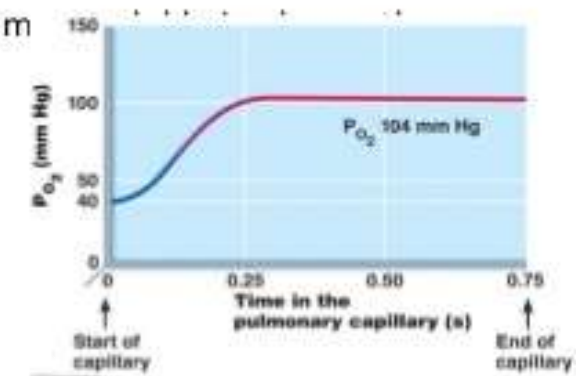


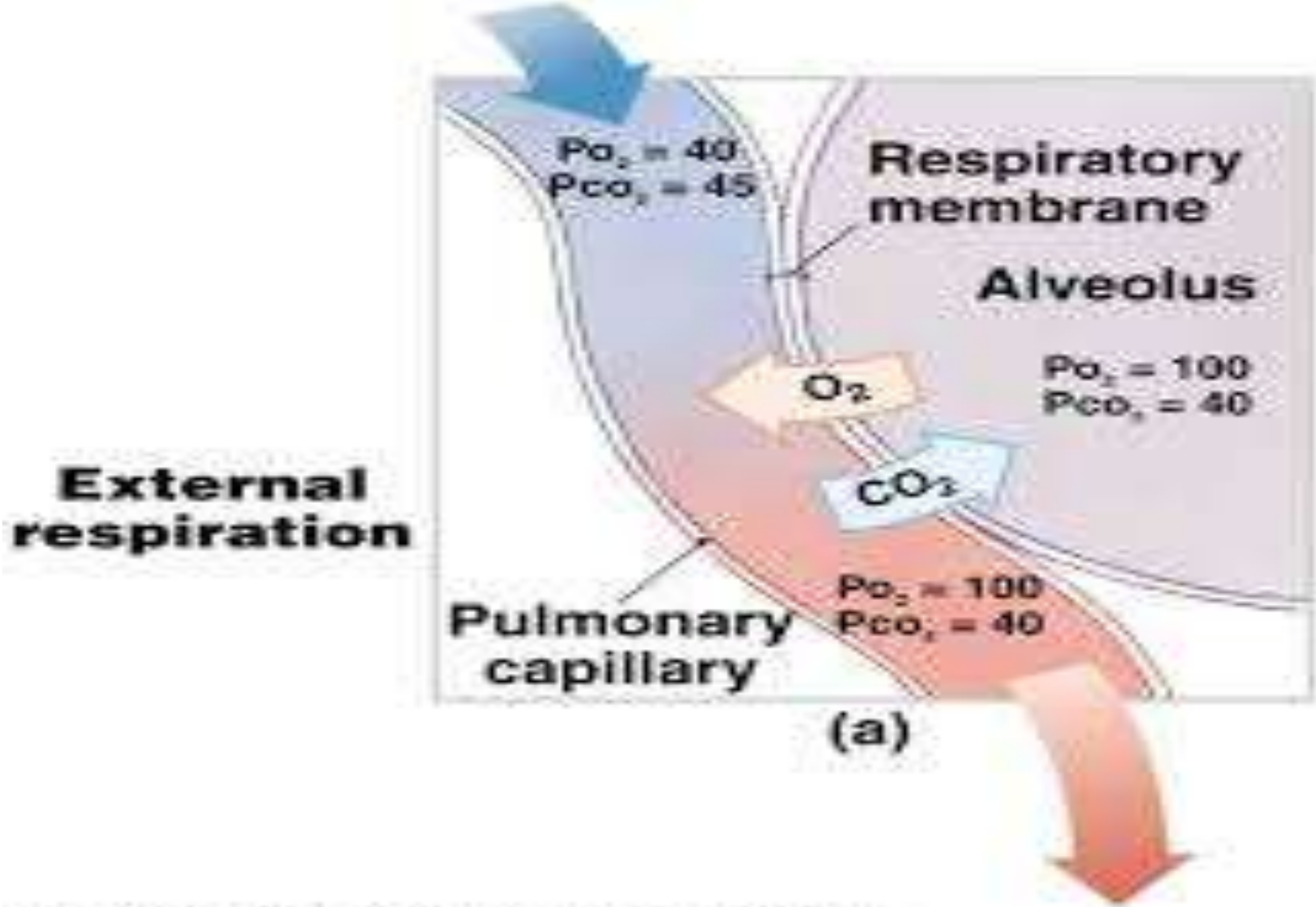
- Oxygen-hemoglobin dissociation curve
- Hemoglobin saturation plotted against Po_2 is S-shaped curve
- Binding and release of O_2 influenced by Po_2

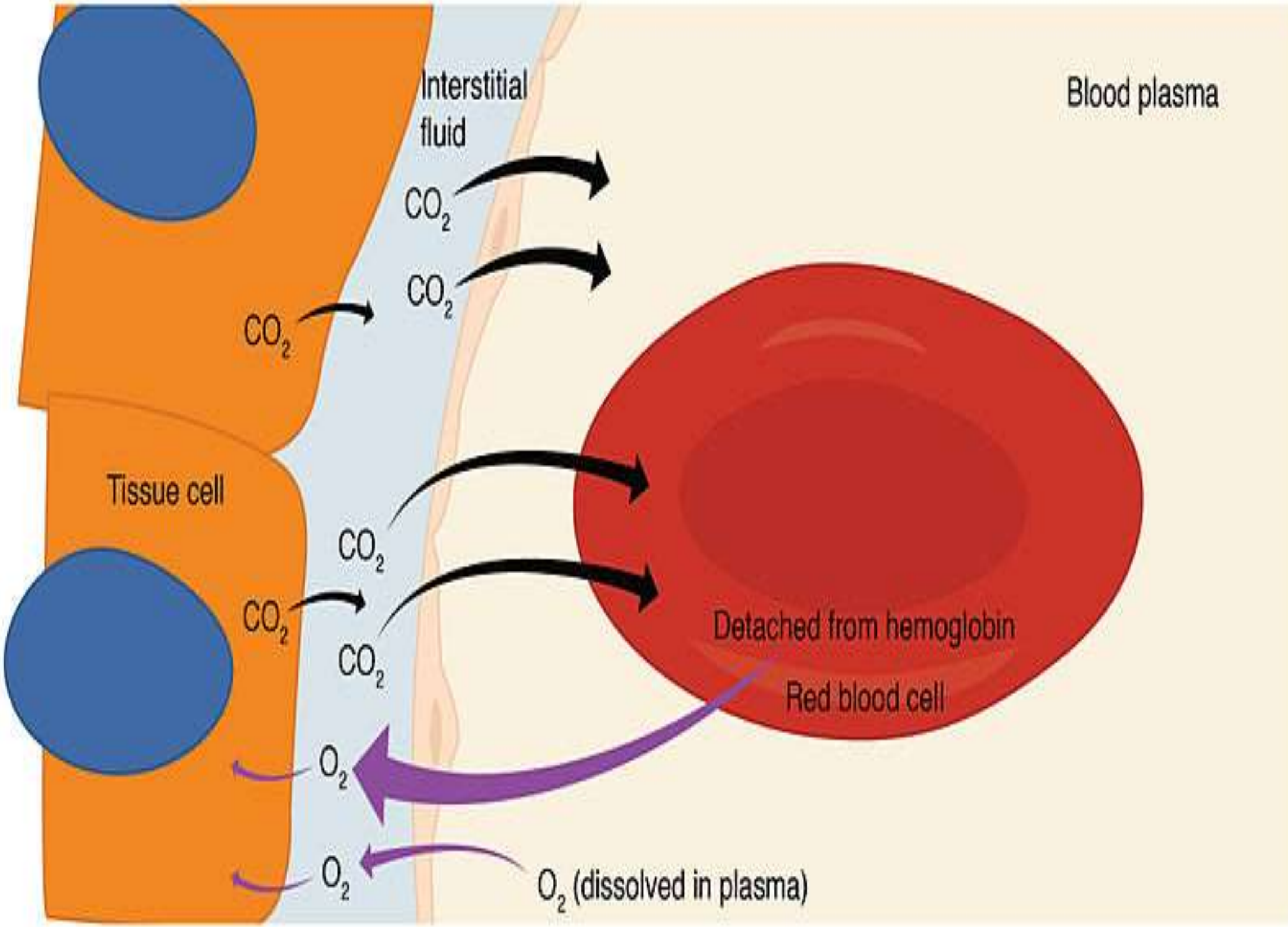


External Respiration

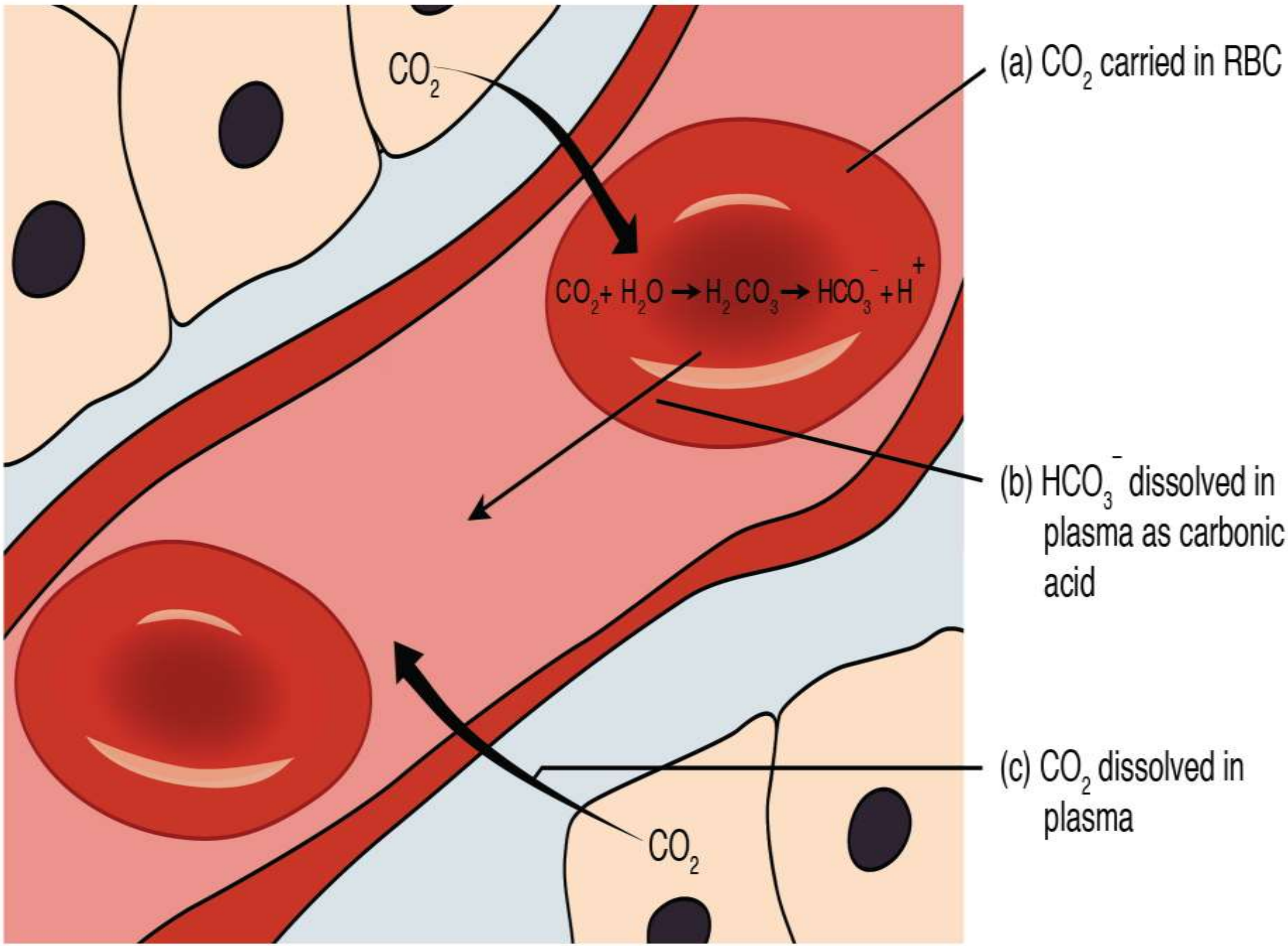
- Exchange of O_2 and CO_2 across respiratory membrane Influenced by
  - **Partial pressure gradients and gas solubilities**
    - O_2 gradient in lungs
      - Venous blood Po_2 = 40 mm Hg
      - Alveolar Po_2 = 104 mm Hg
      - Oxygen to blood
    - CO_2 gradient in lungs
      - Venous blood Pco_2 = 45 mm Hg
      - Alveolar Pco_2 = 40 mm Hg
      - CO_2 to lungs
    - Though gradient not as steep, CO_2 diffuses in equal amounts with oxygen
      - CO_2 20 times m oxygen




P_{O_2} = 40
P_{CO_2} = 45
Respiratory membrane
Alveolus
O_2
P_{O_2} = 100
P_{CO_2} = 40
External respiration
CO_2
P_{O_2} = 100
P_{CO_2} = 40
Pulmonary capillary
(a)

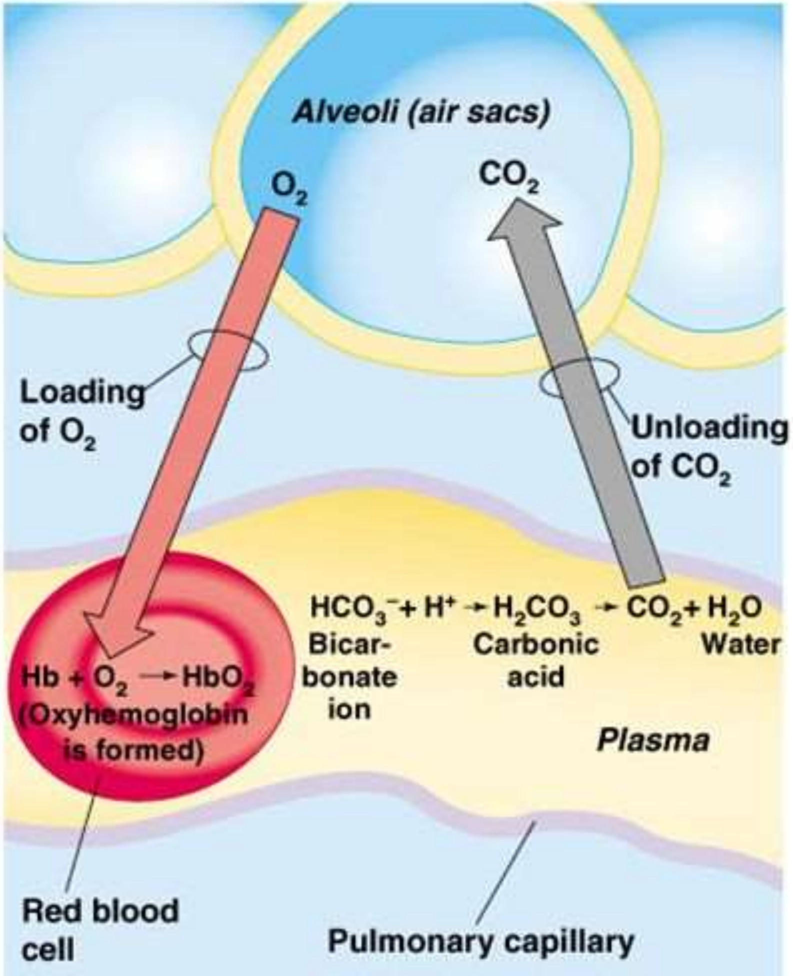


Interstitial fluid
Blood plasma
CO_2
CO_2
CO_2
Tissue cell
CO_2
CO_2
CO_2
Detached from hemoglobin
Red blood cell
O_2
O_2
O_2 (dissolved in plasma)

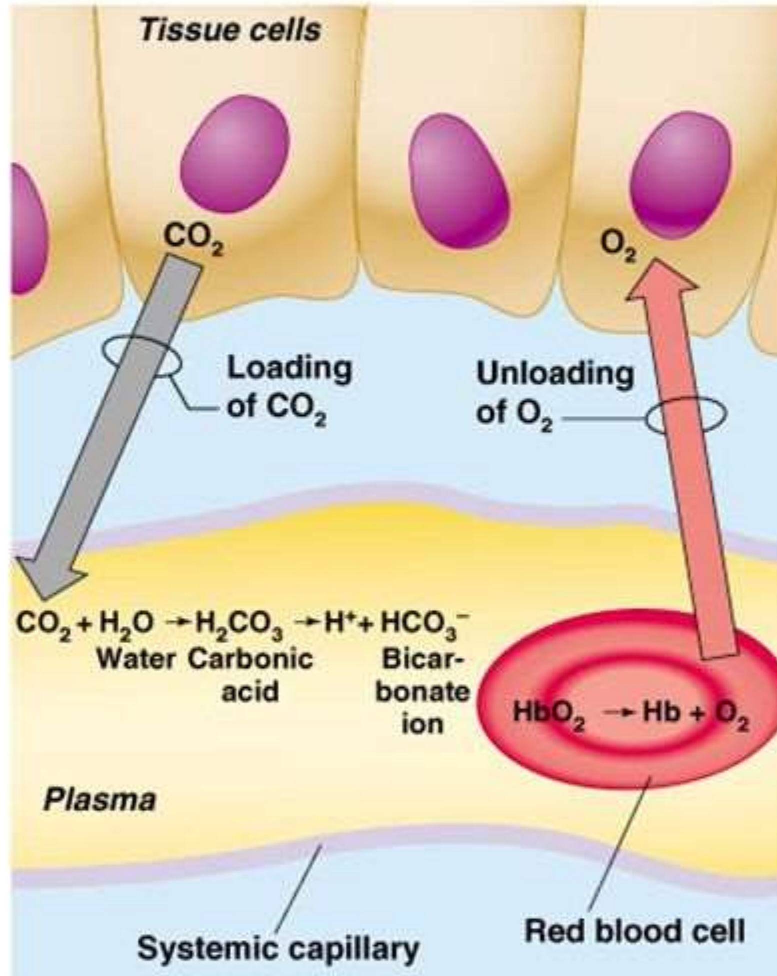


CO_2
$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$
CO_2
(a) CO_2 carried in RBC
(b) HCO_3^- dissolved in plasma as carbonic acid
(c) CO_2 dissolved in plasma

External and Internal Respiration

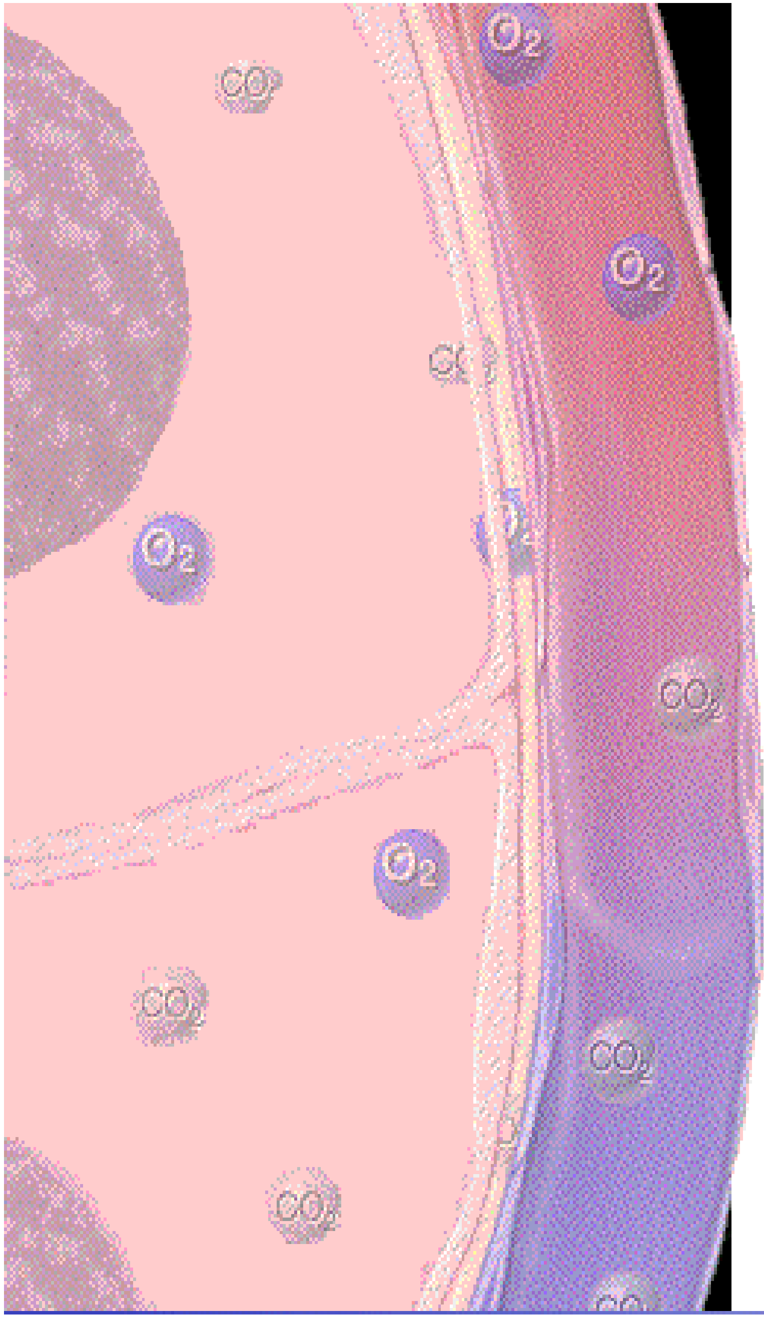


(a)



(b)

Figure 13.1
Slide 13.34



Summary

- Gas laws show the relationship between **partial pressure**, **solubility**, and concentration of gases.
- Gases diffuse along their partial pressure gradients, from regions of high partial pressure to regions of low partial pressure.
- External respiration: O_2 loads from alveoli into pulmonary capillaries, and CO_2 unloads from pulmonary capillaries into alveoli.
- Internal respiration: O_2 unloads from systemic capillaries into cells, and CO_2 loads from cells into systemic capillaries.
- Efficient gas exchange depends on several factors including surface area, partial pressure gradients, blood flow and airflow.
- During external respiration, **ventilation-perfusion coupling** maintains airflow and blood flow in proper proportions for efficient gas exchange.

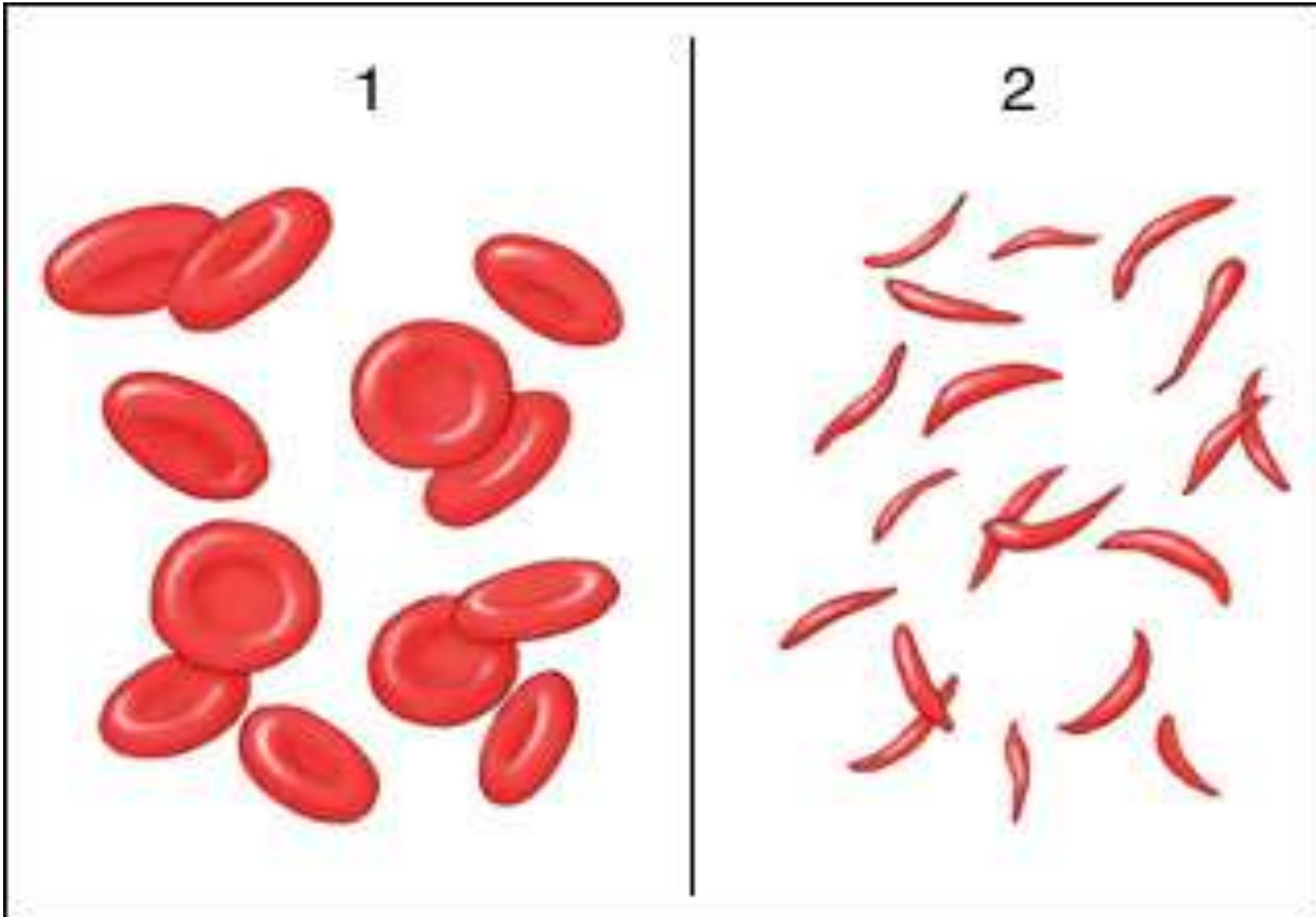
External and Internal Respiration Chemical Equation Summary

External

- $Hb + O_2 \rightarrow HbO_2$
- $HbCO_2 \rightarrow Hb + CO_2$
- $H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$

Internal

- $HbO_2 \rightarrow Hb + O_2$
- $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$
- $Hb + CO_2 \rightarrow HbCO_2$
- $H^+ + Hb \rightarrow HHb$
- HCO_3^- dissolves in plasma


1
2