UNIVERSITY OF BASRAH
AL-ZAHRAA MEDICAL COLLEGE

Ministry of higher Education
and Scientific Research

MODULE: THE RESPIRATORY SYSTEM

SESSION 4: LECTURE: 2

DURATION: 1hr

CARBON DIOXIDE IN BLOOD

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Guyton, A.C., Human Physiology and Mechanisms of Disease, 13th Edition, W.B. Saunders, 2016, ISBN: 978-1-4557-7005-2.

Koeppen, B.M. & Stanton, B.A. Berne & Levy: Principles of Physiology, 7th Edition, Philadelphia, PA, 2018, ISBN: 978-0-323-39394-2.

For more discussion, questions or cases need help
please post to the session group

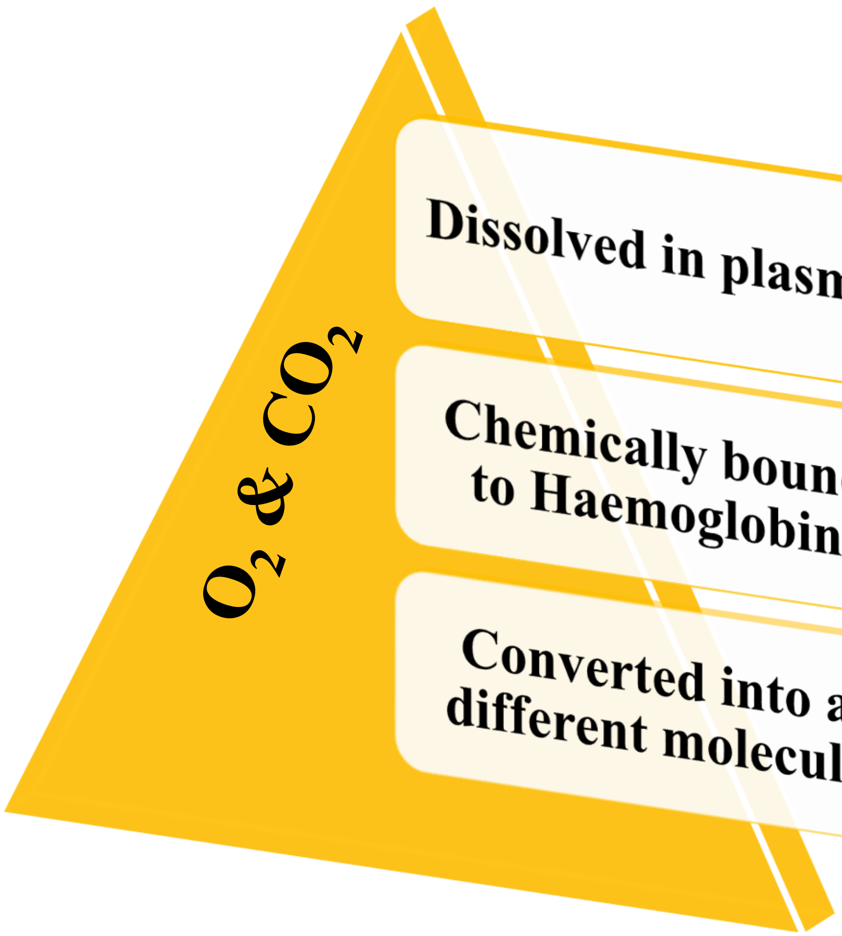
Learning outcomes (LO):

- **List the reactions of CO_2 in blood. (LO1)**
- **Write the Henderson-Hasselbach equation, and be able to calculate the plasma pH, given the pCO_2 and $[HCO_3^-]$. (LO2)**
- **State the factors influencing the hydrogen carbonate concentration of plasma. (LO3)**
- **Describe the buffering action of haemoglobin in red cells. (LO4)**

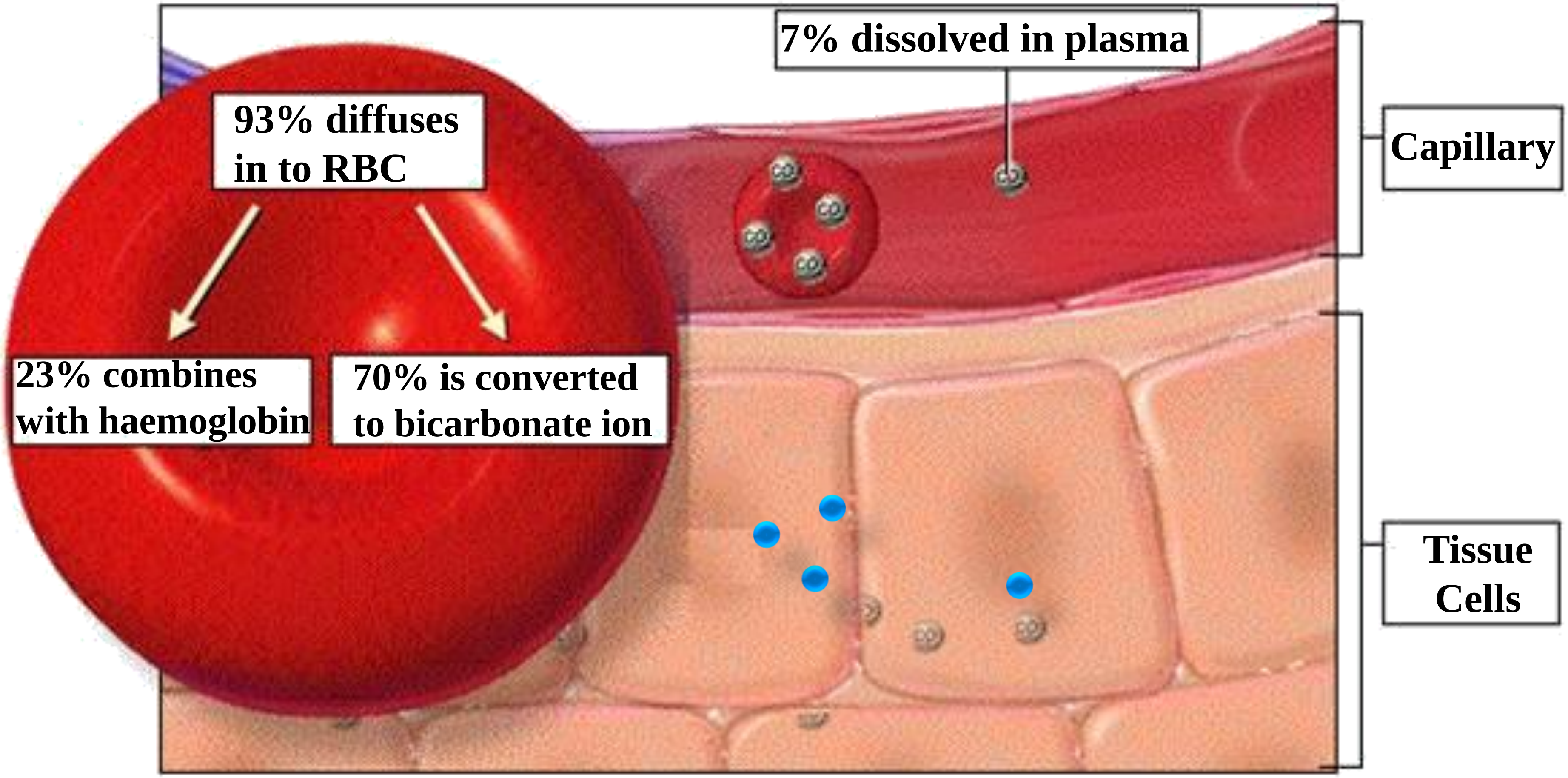
Learning outcomes (LO):

- Describe the function of carbamino compounds. (LO5)
- State the normal content of carbon dioxide in arterial and venous blood. (LO6)
- Describe the process of transport of CO_2 from tissues to lungs, and state the proportion of CO_2 traveling in various forms. (LO7)

- **The blood transports O_2 and CO_2 between the lungs and other tissues throughout the body.**



CO_2 transport



- **CO_2 is an essential part of the buffer systems which controls the pH of ECF.**

- **In spite of CO_2 is transported in venous blood, there is a substantial amount in arterial blood which has an important role in acid base status.**

Reactions of CO_2 in the blood

1- Dissolved form (7%)

- CO_2 dissolves in plasma, and may form H^+ ions and HCO_3^- ions.
- The reaction is slow because there is a little **carbonic anhydrase (CA)** in the plasma.
- The extent of dissociation, however, determines the pH of plasma, and therefore ECF.

LO3

- At a pCO_2 of 5.3 kpa
- H_2O dissolves 1.2 $mmol.l^{-1}$
- Dissolved CO_2 can then react with H_2O in different components of blood depends directly on pCO_2.

pCO_2 ↑ **pH will fall**

pCO_2 ↓ **pH will rise**

- This is represented mathematically by **Henderson-Hasselbach equation**.

Henderson-Hasselbalch equation

$$pH = pK + \log ([HCO_3^-]/(pCO_2 \times 0.23))$$

In **plasma** the ratio of $[HCO_3^-]$ to dissolved CO_2 is **20:1** (25 $mmol.l^{-1}$: 1.2 $mmol.l^{-1}$).

$pK = 6.1$
$pCO_2 = 5.3$ kPa
$[HCO_3^-] = 25mM$

→ $pH = 7.4$

2- As carbamino compounds (23%)

- CO_2 combines reversibly with Hb to form carbamino Hb, contributing to CO_2 transport but not acid base balance.

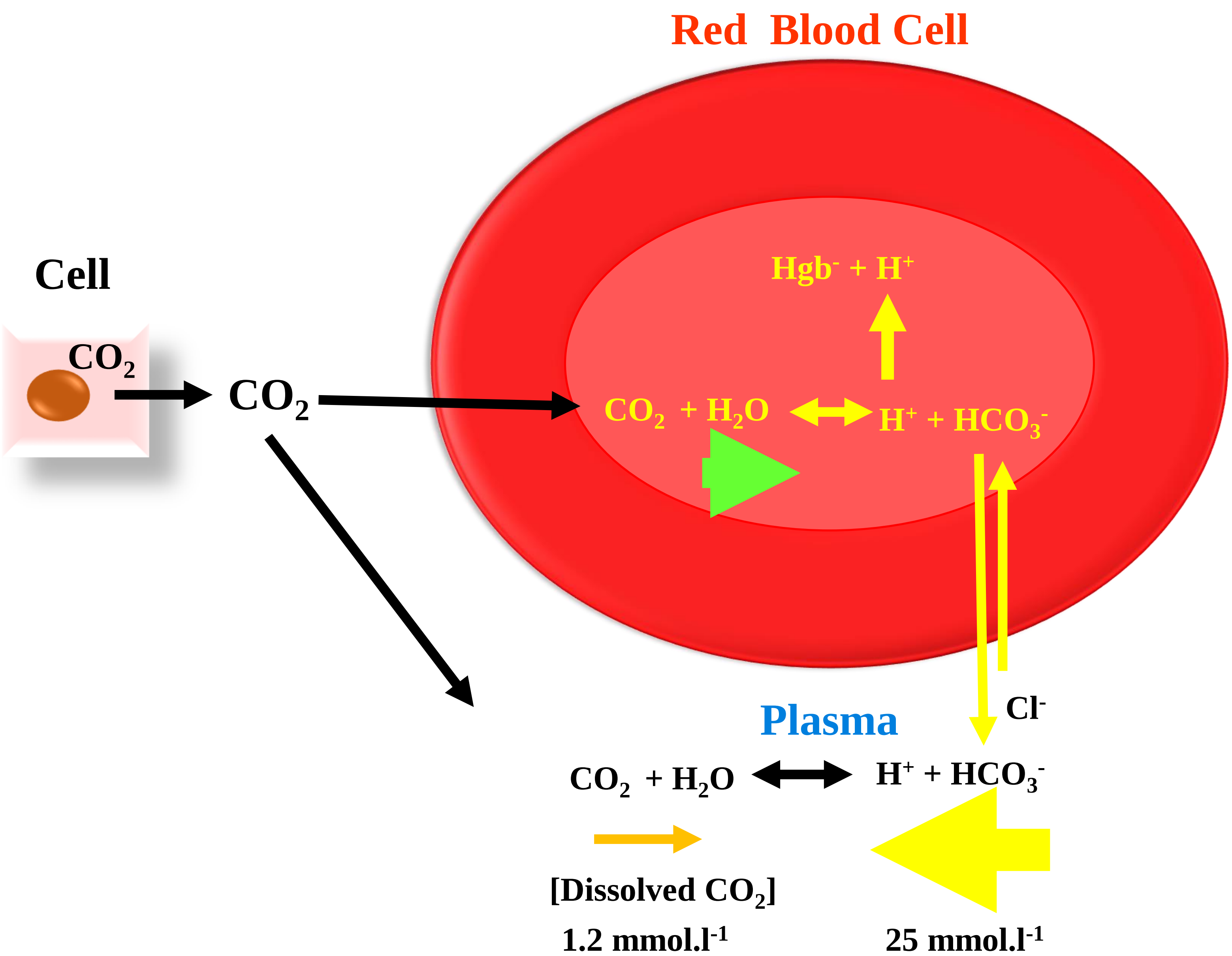
$CO_2 + Hb \leftrightarrows Hb\text{-}CO_2$

- Does not compete with O_2-Hb binding
  - O_2 binds to heme portion of Hb.
  - CO_2 binds to protein (-globin) portion of Hb.

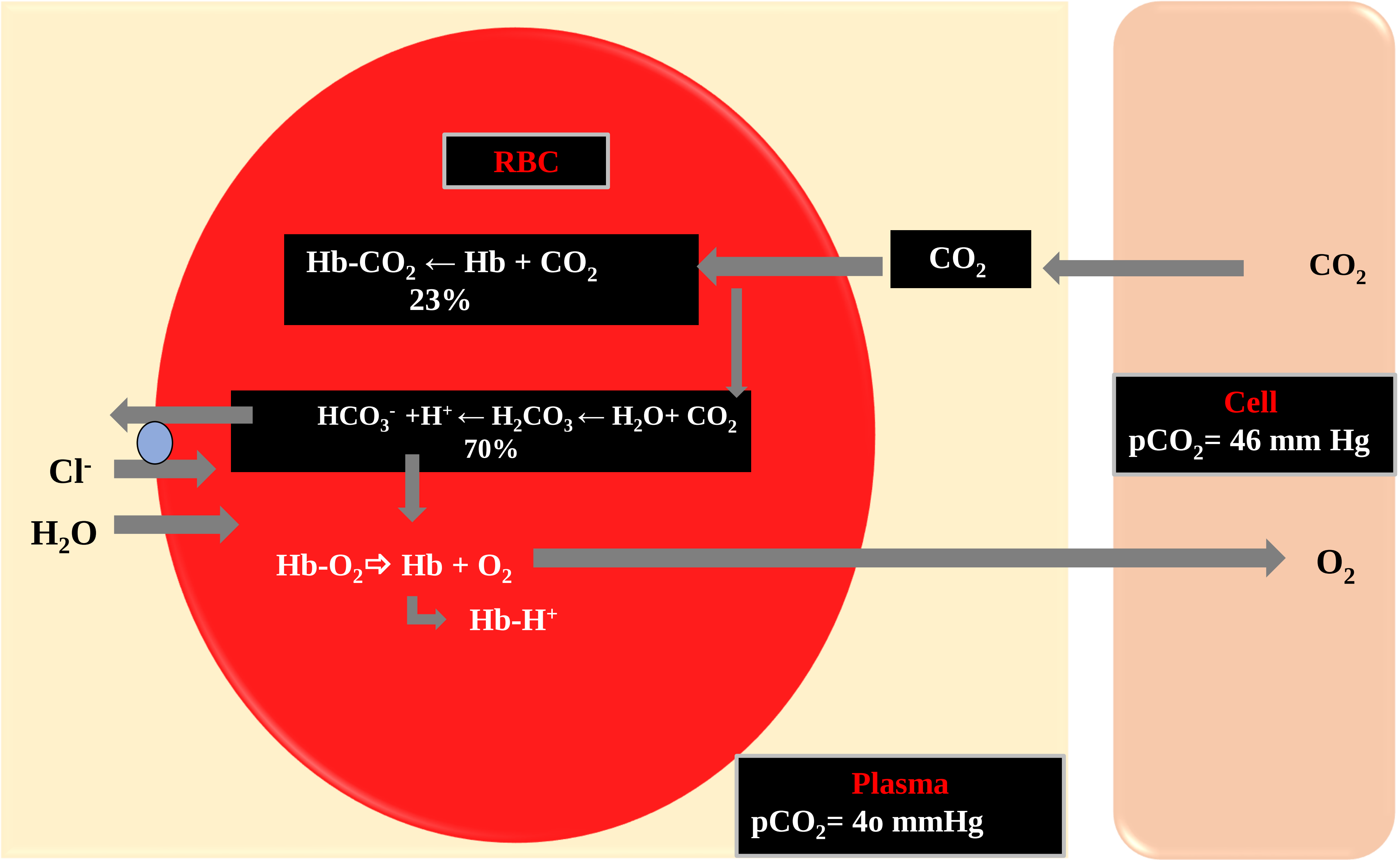
3- As bicarbonate HCO_3^- (70%)

- In the RBC, CO_2 also reacts with H_2O, this time rapidly because of carbonic anhydrase is present in the RBC, to form H^+ and HCO_3^-.

$$CO_2 + H_2O \leftrightarrows H_2CO_3^- \leftrightarrows H^+ + HCO_3^-$$

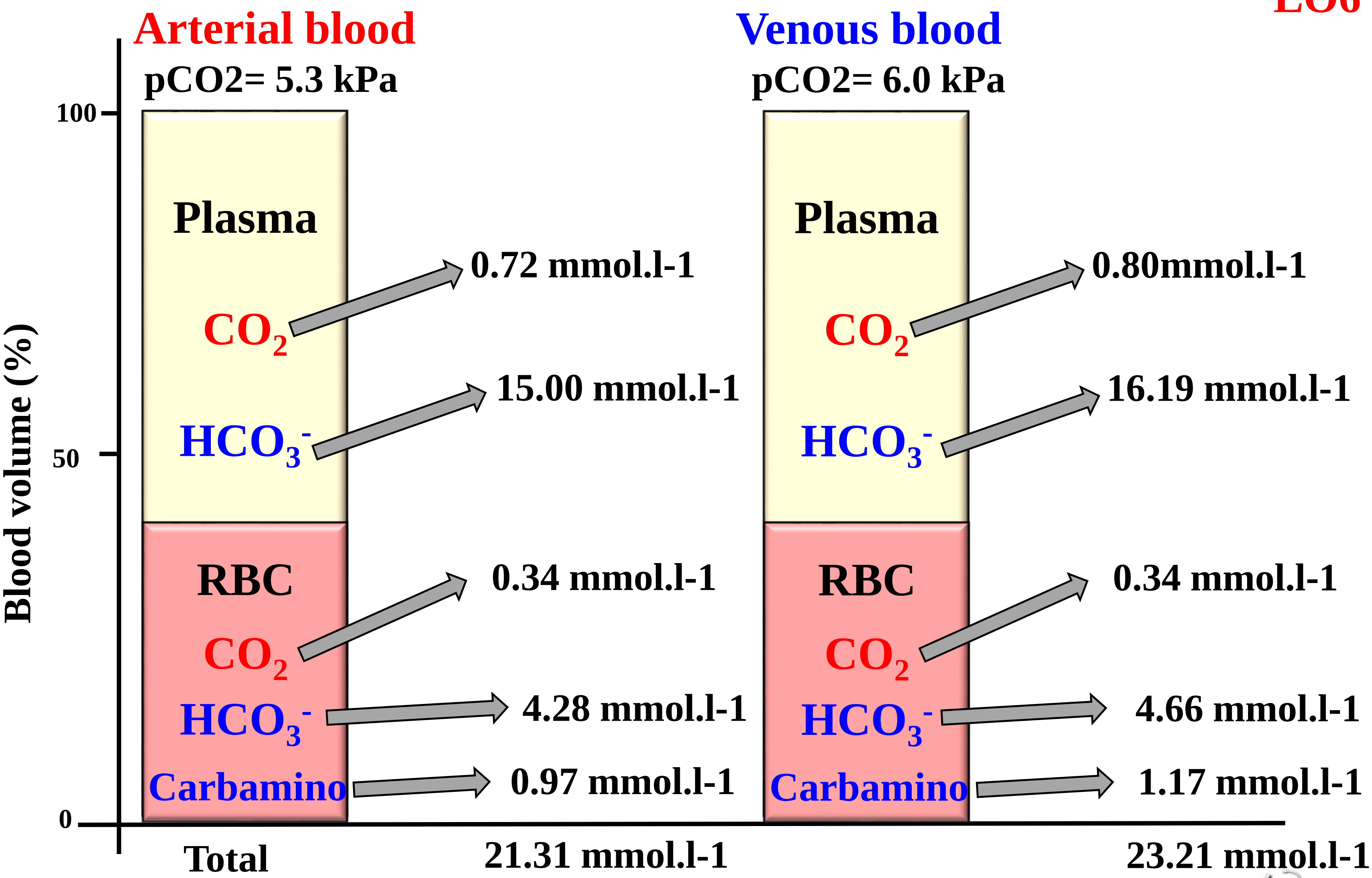

Red Blood Cell
Cell
CO_2
CO_2
$Hgb^- + H^+$
$CO_2 + H_2O$
$H^+ + HCO_3^-$
Plasma
Cl^-
$CO_2 + H_2O$
$H^+ + HCO_3^-$
[Dissolved CO_2]
$1.2\ mmol.l^{-1}$
$25\ mmol.l^{-1}$

- The H^+ ions are bound to Hb. which has a large buffering capacity, enhanced further when it is deoxygenated.
- The HCO_3^- formed in large quantities is exported from the RBC in exchange for inward movement of Cl^-.
- The 25 $mmol.l^{-1}$ of HCO_3^- in the plasma is determined much more by the buffering capacity of Hb. than the pCO_2 (only minor effects of changes in pCO_2).
- Additional control of the plasma conc. of HCO_3^- is provided by the kidneys.


RBC
Hb-CO2 ← Hb + CO2
23%
CO2
CO2
HCO3- +H+ ← H2CO3 ← H2O+ CO2
70%
Cell
pCO2= 46 mm Hg
Cl-
H2O
Hb-O2⇨ Hb + O2
O2
Hb-H+
Plasma
pCO2= 4o mmHg

The buffering action of Hb. in RBCs

- When the blood arrives at the tissues, O_2 is removed from Hb., making it a better buffer. More CO_2 therefore reacts in the RBCs to form HCO_3^- which is mostly exported to the plasma.
- H^+ ions bind to Hb. so it acts as buffer by mopping up H^+ ions. This drives the reaction of CO_2 with H_2O in RBCs, producing more H^+ ions and HCO_3^-.
- If the body produces acid, this reacts with HCO_3^- to form CO_2 which is breathed out and stops pH changing too much.


Arterial blood
pCO2= 5.3 kPa
Venous blood
pCO2= 6.0 kPa
Blood volume (%)
100
50
0
Plasma
CO_2
0.72 mmol.l-1
HCO_3^-
15.00 mmol.l-1
RBC
CO_2
0.34 mmol.l-1
HCO_3^-
4.28 mmol.l-1
Carbamino
0.97 mmol.l-1
Plasma
CO_2
0.80mmol.l-1
HCO_3^-
16.19 mmol.l-1
RBC
CO_2
0.34 mmol.l-1
HCO_3^-
4.66 mmol.l-1
Carbamino
1.17 mmol.l-1
Total
21.31 mmol.l-1
23.21 mmol.l-1

Transported carbon dioxide

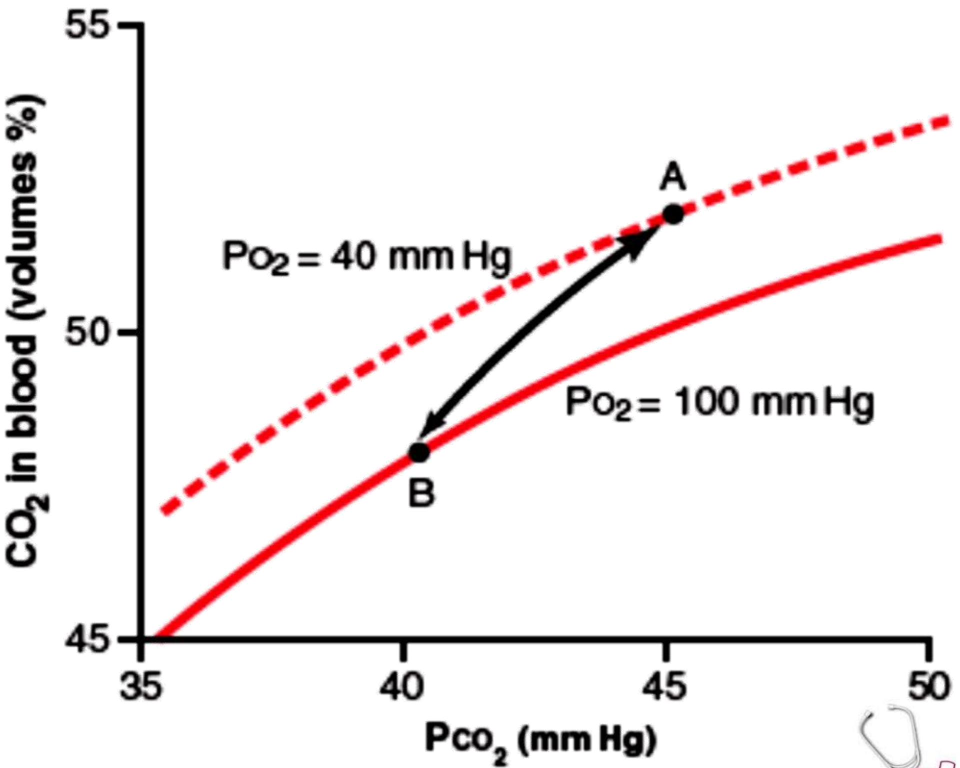
23.21 − 21.31 = 2 mmol/ litre of blood

- **Only about 10% of total**

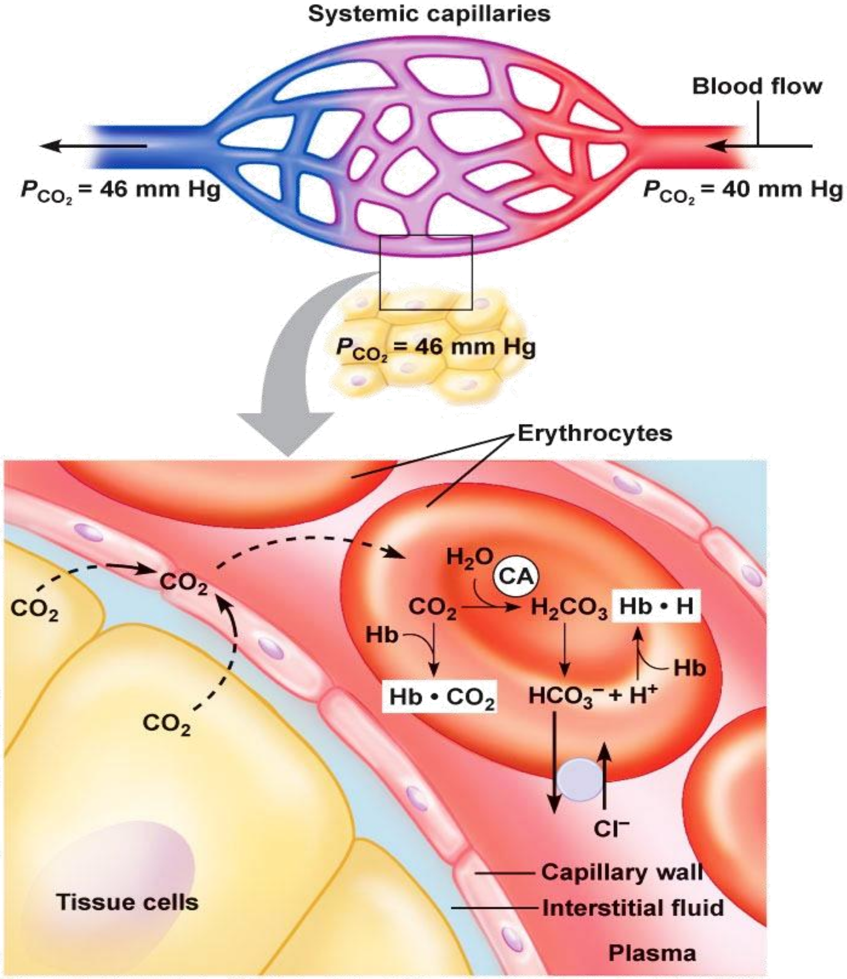
Carbon dioxide dissociation curve

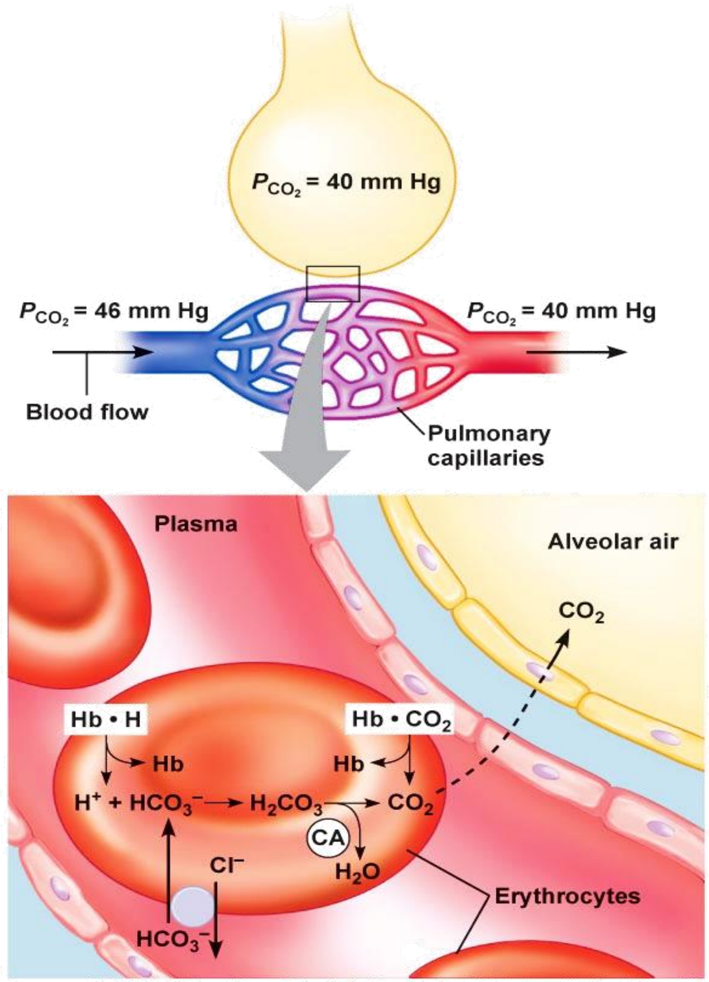
LO6

- Relationship between the pCO_2 and the content of CO_2 in the blood.
- It is linear (physiological range of pCO_2).
- Any change in pCO_2 will produce a great change in CO_2 content.
- **Haldane effect?**



Diffusion of CO_2 from the cells to the tissue capillaries and from the pulmonary capillaries to the alveoli





http://droualb.faculty.mjc.edu/Course%20Materials/Physiology%20101/Chapter%20Notes/Fall%202011/chapter_17%20Fall%202011.htm

Thank you