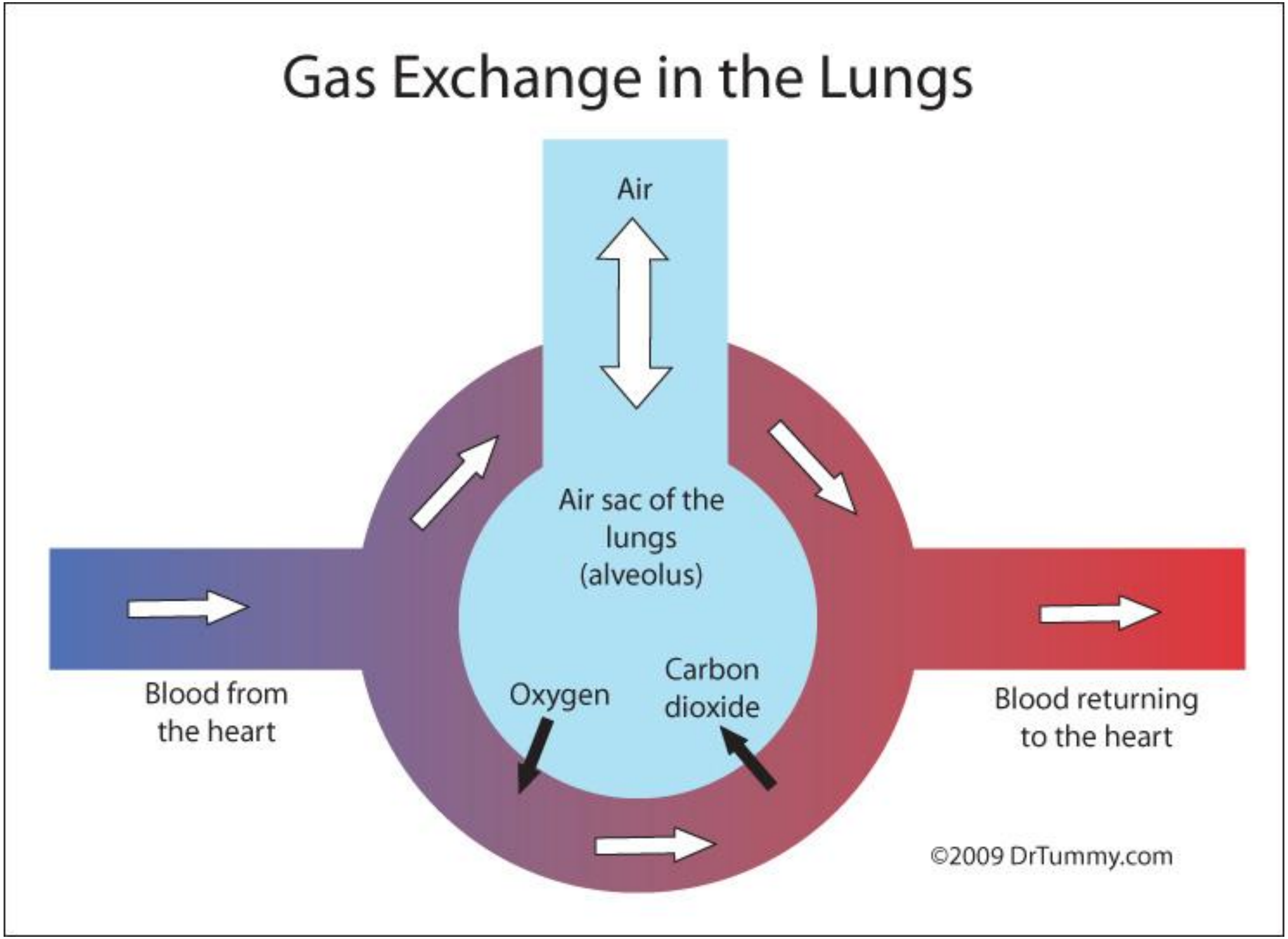
TRANSPORT OF OXYGEN & CARBON DIOXIDE

DR SARAH SHAHID
Assistant Professor
Department of Physiology
KGMC


Gas Exchange in the Lungs
Air
Air sac of the
lungs
(alveolus)
Blood from
the heart
Oxygen
Carbon
dioxide
Blood returning
to the heart
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ATMOSPHERIC AIR:COMPOSITION

TOTAL PRESSURE (AT SEA LEVEL)=760MM HG

N_2 = 78.6% P_{N2} = 596mm Hg

O_2 = 20.8% Po_2 = 160 mm Hg

CO_2=0.04% P_{Co2}=0.3mm Hg

$H_2$0=0.5% P_{H2O}=3.7mm Hg

DIFFUSION OF GASES

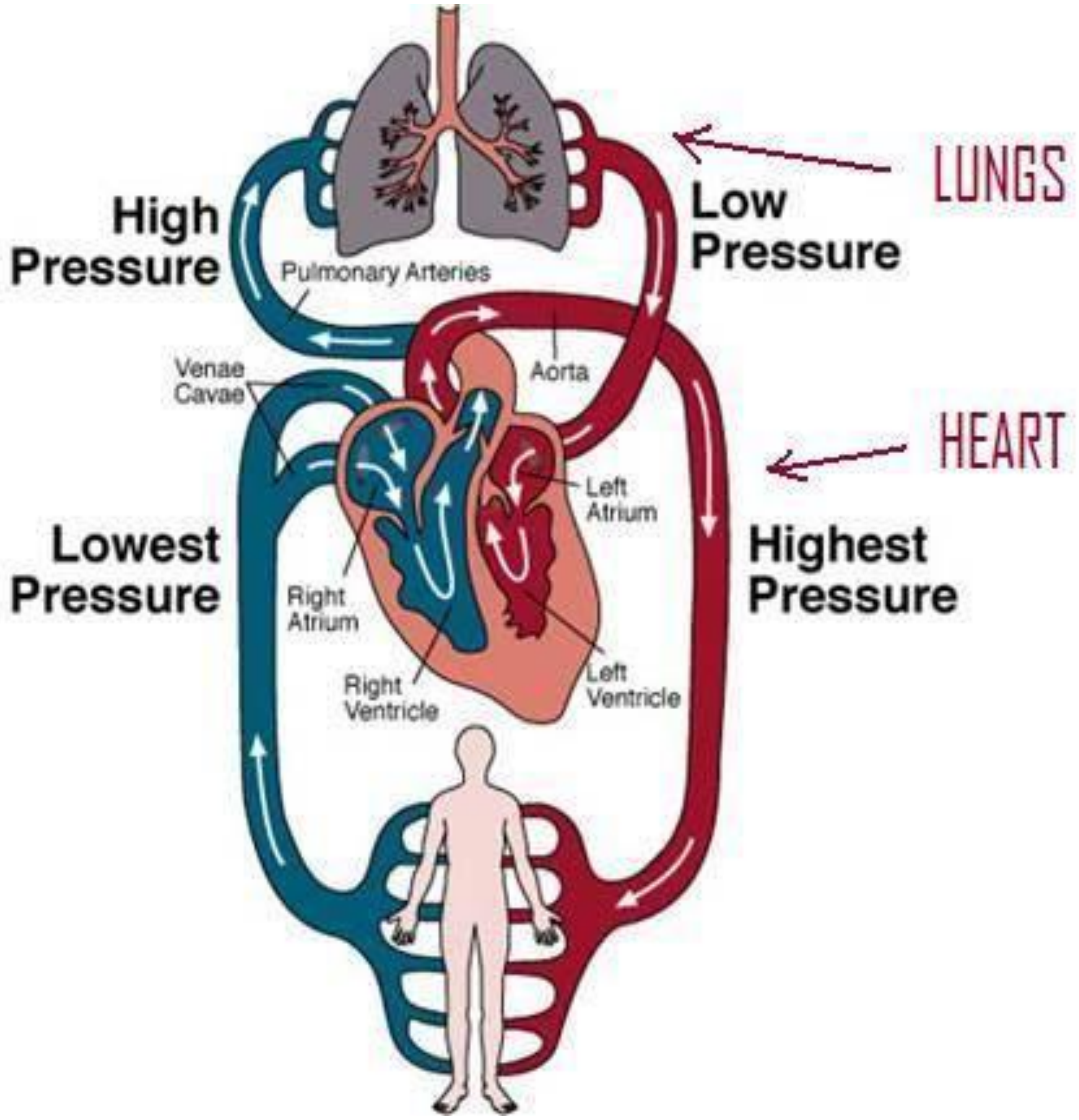
Alveolo capillary Membrane

Along partial pressure gradient,

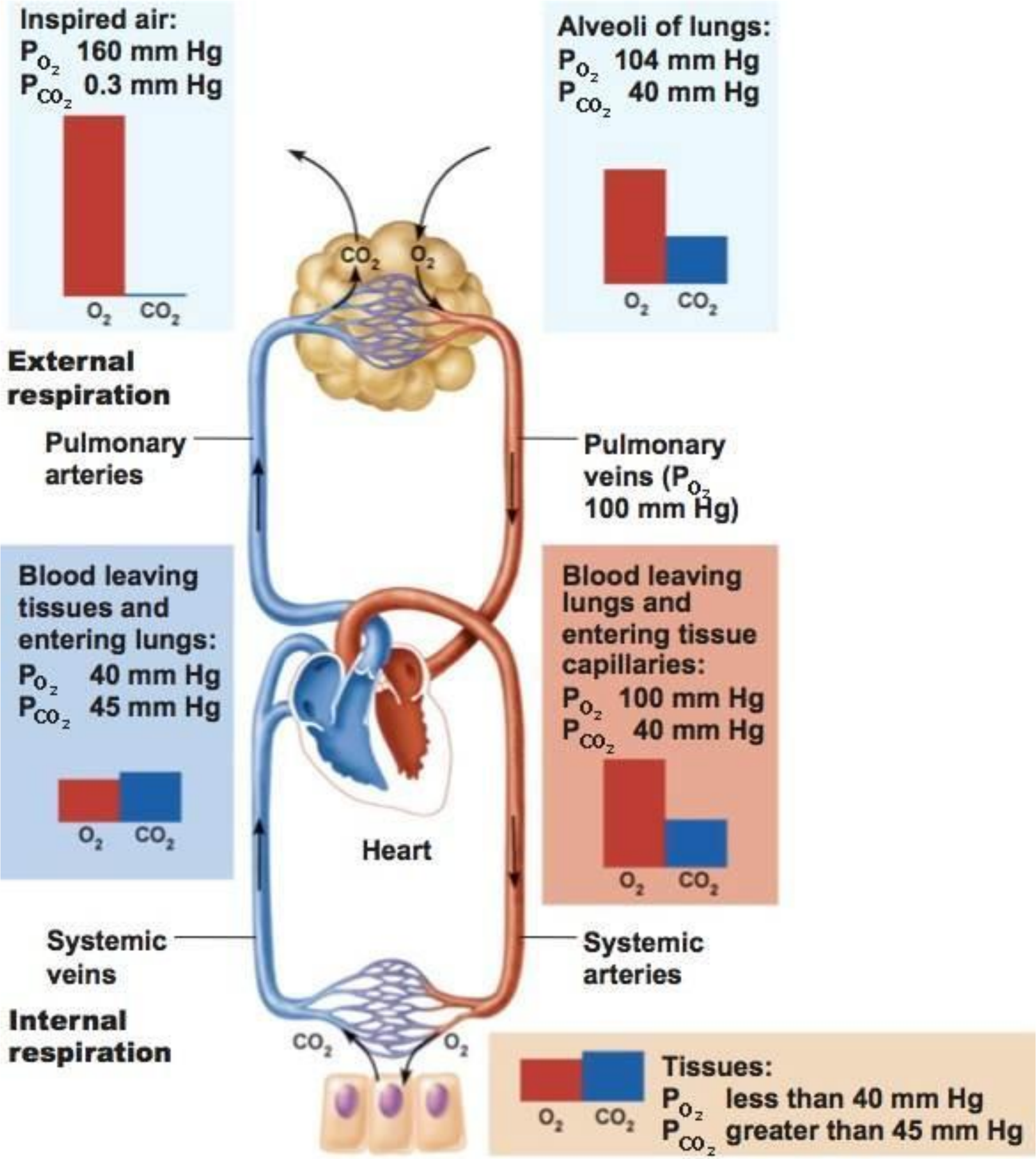
Until equilibrium is reached

Oxygen diffuses from the alveolus into the blood

Carbon dioxide from the blood into the alveolus



High
Pressure
Low
Pressure
LUNGS
Pulmonary Arteries
Venae
Cavae
Aorta
HEART
Left
Atrium
Lowest
Pressure
Highest
Pressure
Right
Atrium
Right
Ventricle
Left
Ventricle



Inspired air:
P_{O_2} 160 mm Hg
P_{CO_2} 0.3 mm Hg
O_2 CO_2
Alveoli of lungs:
P_{O_2} 104 mm Hg
P_{CO_2} 40 mm Hg
O_2 CO_2
CO_2 O_2
External respiration
Pulmonary arteries
Pulmonary veins (P_{O_2} 100 mm Hg)
Blood leaving tissues and entering lungs:
P_{O_2} 40 mm Hg
P_{CO_2} 45 mm Hg
O_2 CO_2
Blood leaving lungs and entering tissue capillaries:
P_{O_2} 100 mm Hg
P_{CO_2} 40 mm Hg
O_2 CO_2
Heart
Systemic veins
Systemic arteries
Internal respiration
CO_2 O_2
O_2 CO_2
Tissues:
P_{O_2} less than 40 mm Hg
P_{CO_2} greater than 45 mm Hg

CONTD…

Carbon dioxide : very soluble in blood, allowing many molecules to diffuse along small pressure gradient

Oxygen : less soluble, requires a larger concentration gradient

EFFECT OF WATER VAPOR

Fresh air enters respiratory passage

Immediately mixes with water vapor (Humidification)

Water vapor lowers the partial pressure of gases (total pressure remains constant)

P_{O2} is lowered to about 149 mmHg

Constant P_{H2O}=47mmHg

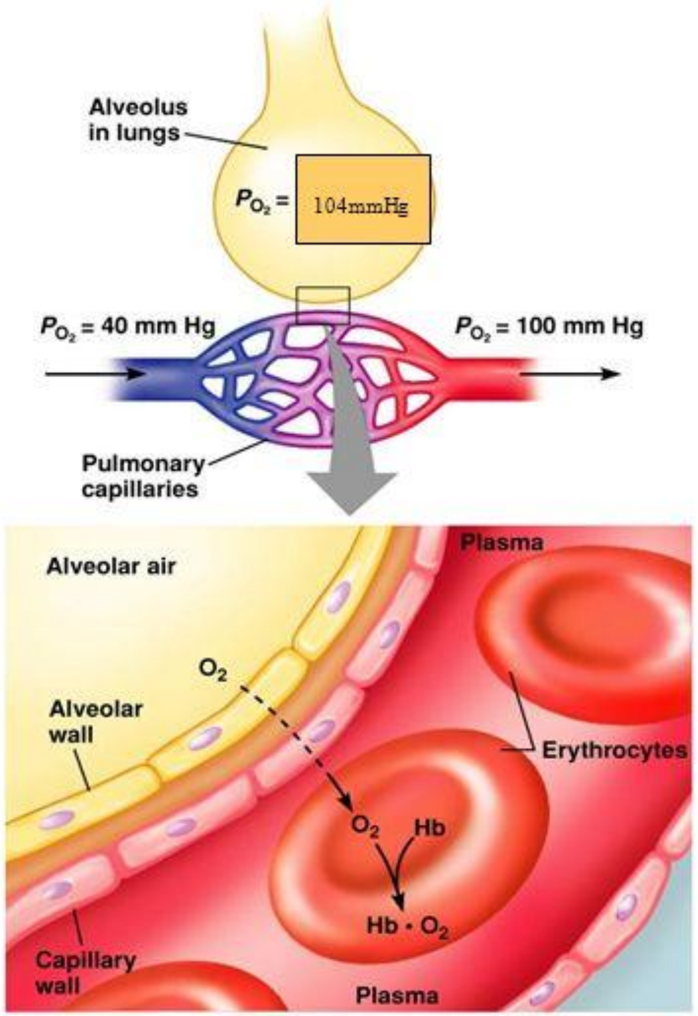
Oxygen transport in the blood

O_2 from the alveoli diffuse into the blood

Then O_2 enters the RBC and binds to hemoglobin

3% of O_2 is dissolved in plasma while 97% is bound to Hb → oxyHb

The binding is reversible
$Hb + O_2 \Leftrightarrow HbO_2$



OXYGEN TRANSPORT

Method	Percentage
• Dissolved in Plasma	3 %
• Combined with Hemoglobin	97 %

O_2 DISSOLVED IN PLASMA

0.3 ml O_2 per 100 ml of blood(arterial P_{O2} Of 100 mm Hg)

Normal P_{O2} of 95mmHg :0.29 ml of O_2 is dissolved per 100 ml of water in blood

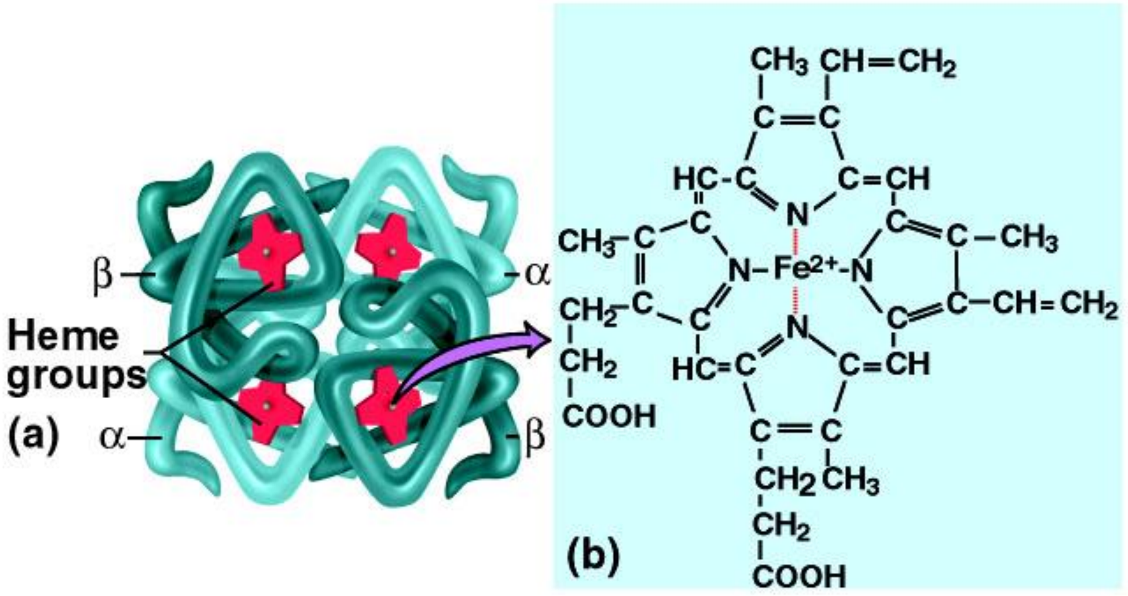
P_{O2} 40 mmHg in tissue capillaries-0nly 0.12 ml of O_2 remains dissolved

0.17 ml of O_2 is normally transported in dissolved state to the tissues by each 100 ml of arterial blood flow

HEMOGLOBIN STRUCTURE

Protein made up of 4 subunits

Every subunit contains a heme moiety attached to a polypeptide chain.



HAEMOGLOBIN

Haemoglobin molecules can transport up to four O_2's

When 4 O_2's are bound to haemoglobin, it is 100% saturated, with fewer O_2's it is partially saturated

Haemoglobin's affinity for O_2 increases as its saturation increases

Oxygen binding occurs in response to the high P_{O2} in the lungs

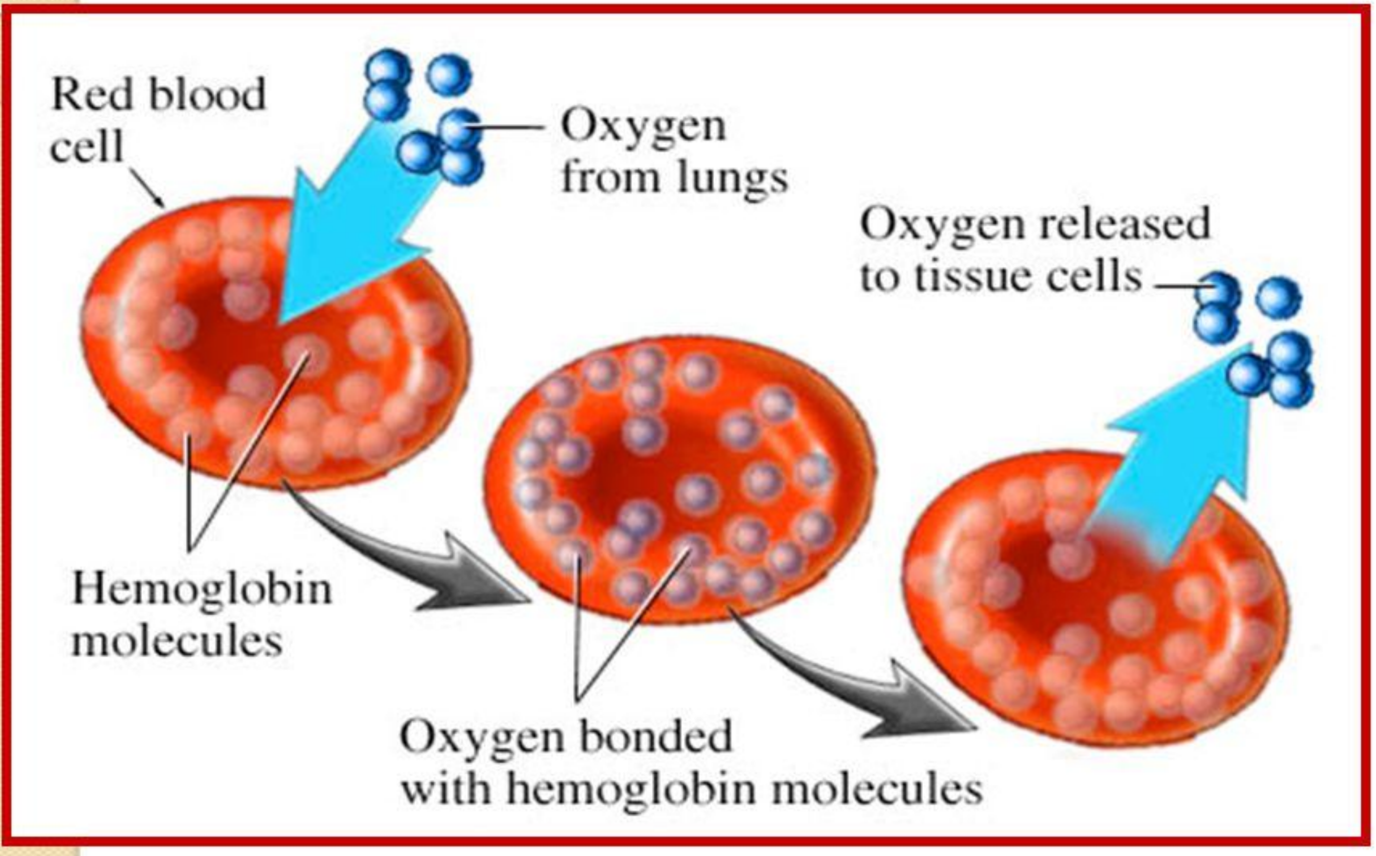
OXYHEMOGLOBIN FORMATION

- Oxygen molecule reversibly attaches to the heme portion of hemoglobin

- Heme unit contains iron (Fe^{+2}) which provides the attractive force

$$0_2 + Hb \rightleftharpoons HbO_2$$

Oxyhemoglobin



TERMS

Oxygen Capacity : Maximum quantity of oxygen that will combine chemically with the hemoglobin in a unit volume of blood

Oxygen Content: *how much* oxygen is in the blood

CONTD…

Oxygen Saturation : Percentage of all the available heme binding sites saturated with oxygen

Volume percent (vol%) refers to the milliliters of oxygen extracted from a 100 ml sample of whole blood

MAXIMUM AMOUNT OF O2 THAT CAN COMBINE WITH HB OF BLOOD

Normal Hb -15 gms/100 ml of blood

Each gm of Hb can bind 1.34 ml of O_2

(In chemically pure Hb-1.39 ml O_2)

Total O_2 bound with Hb :

15x1.34=20 ml (if Hb 100% saturated)

O_2 RELEASED FROM HB IN TISSUES

In normal systemic arterial blood -Total O_2 bound with Hb **19.4ml**/100 ml of blood(97% saturated)

Tissue capillaries: O_2- 14.4ml/100 ml of blood(P_{O2} 40mmHg,75% saturated Hb)

Under normal conditions about 5ml of O_2 is transported from the lungs to the tissues by each 100 ml of blood flow

THE PO2 IS PRIMARY FACTOR IN DETERMINING THE PERCENT HB SATURATION

Acc to law of mass action when concentration of one substance in a reversible reaction increases, the reaction is driven towards the opppsite side

In Pulmonary Capillaries

PO2 increases so Hb +O2 = HbO2

Loading of O2 on HB

In systemic capillaries

PO2 decreases so HbO2= Hb + O2

oxygen is released (unloading)

O_2-HB DISSOCIATION CURVE

Illustrates the %saturation of Hb with oxygen at various P_{O2} values

Sigmoid shaped curve

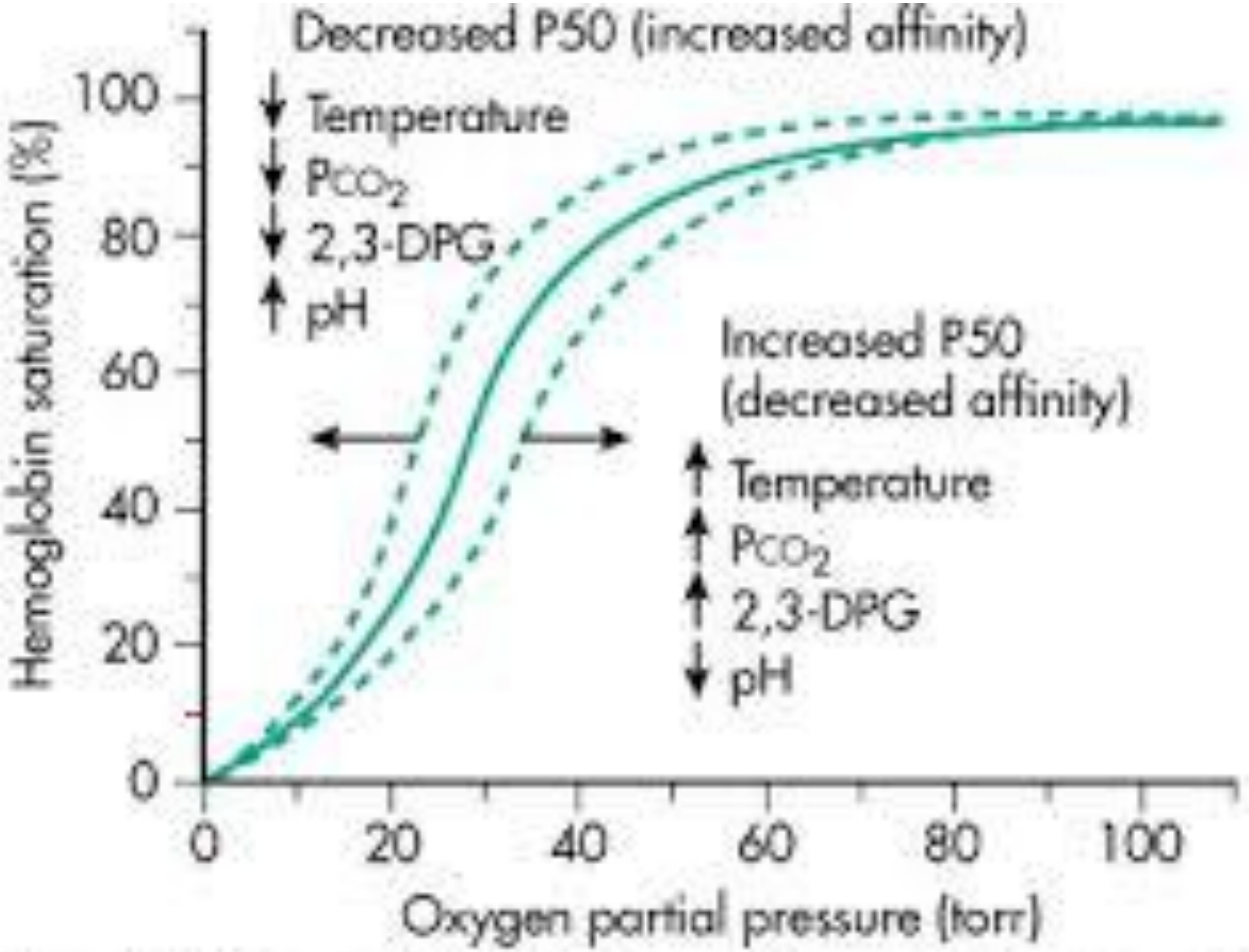
Progressive increase in the % of Hb bound with O_2 as blood P_{O2} increases

P_{50} :point at which Hb is 50% saturated

CONTD…

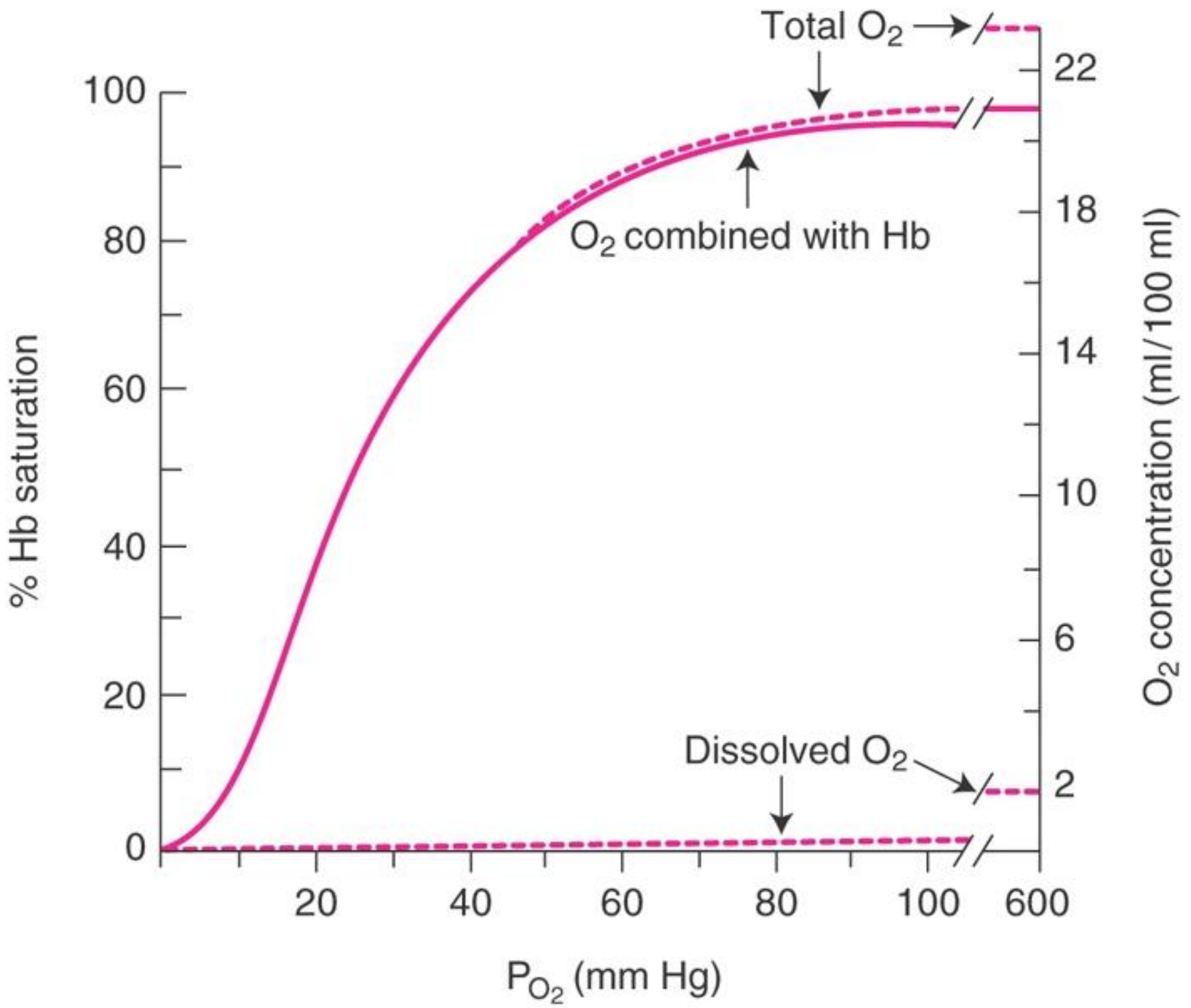
Plateau: Provides a margin of safety in the oxygen carrying capacity of the blood

Steep portion: Small changes in Oxygen levels can cause significant changes in binding. This promotes release of O_2 to the tissues



Decreased P50 (increased affinity)
↓ Temperature
↓ P_{CO_2}
↓ 2,3-DPG
↑ pH
Increased P50
(decreased affinity)
↑ Temperature
↑ P_{CO_2}
↑ 2,3-DPG
↓ pH
Hemoglobin saturation (%)
100
80
60
40
20
0
0
20
40
60
80
100
Oxygen partial pressure (torr)

OXYGEN-HB DISSOCIATION CURVE



ROLE OF HB IN MAINTAINING NEARLY CONSTANT PO_2 IN TISSUES

Function as Tissue O_2 buffer system

Stabilize the O_2 pressure in the tissues

Tissue P_{O2} can not rise above 40 mmHg

FACTORS THAT SHIFT THE OXYGEN-HEMOGLOBIN DISSOCIATION CURVE

pH and P_{CO2}

Temperature

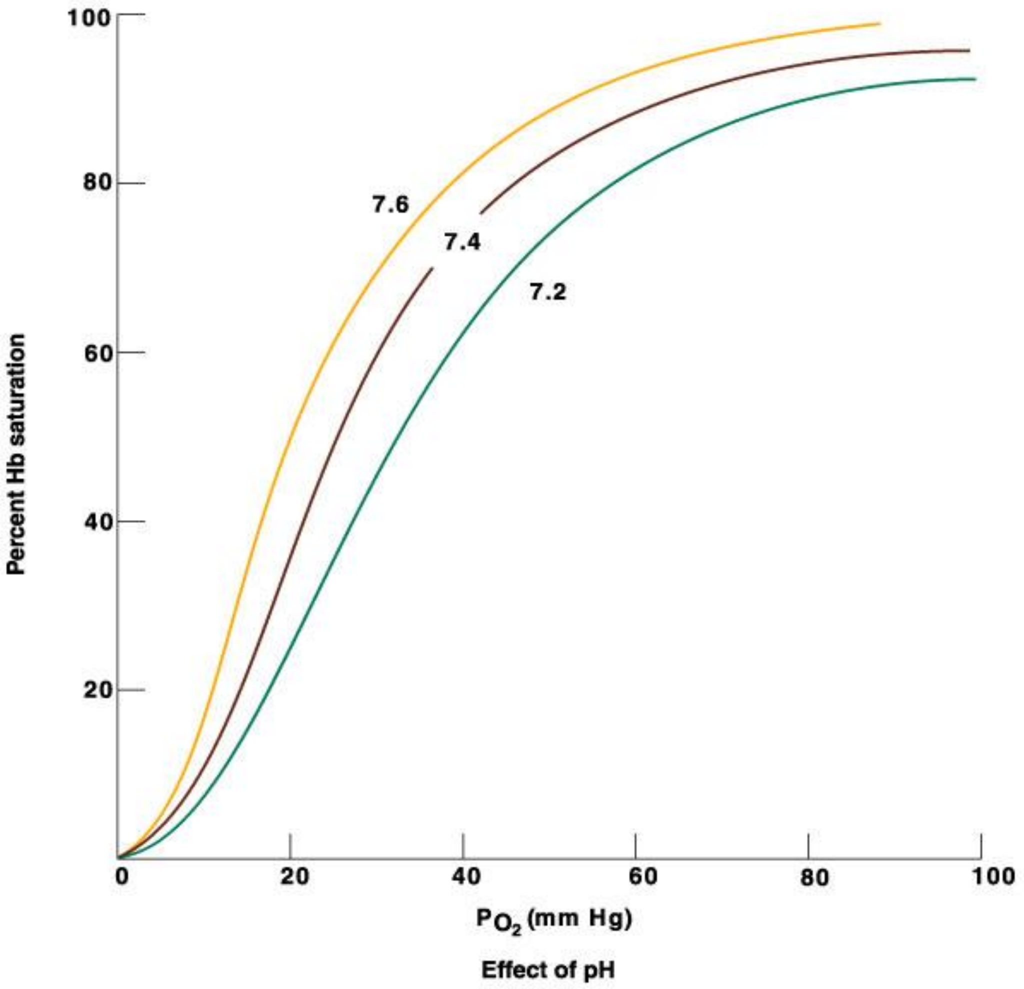
2,3-diphosphoglycerate(2,3-DPG)

PH AND P_{CO2}: BOHR EFFECT

Increase CO2 and acidity will decrease affinity of HB for O2

CO_2 & H+ ions shift the O_2-Hb Dissociation curve to the right

Increased delivery of O_2 to the tissues

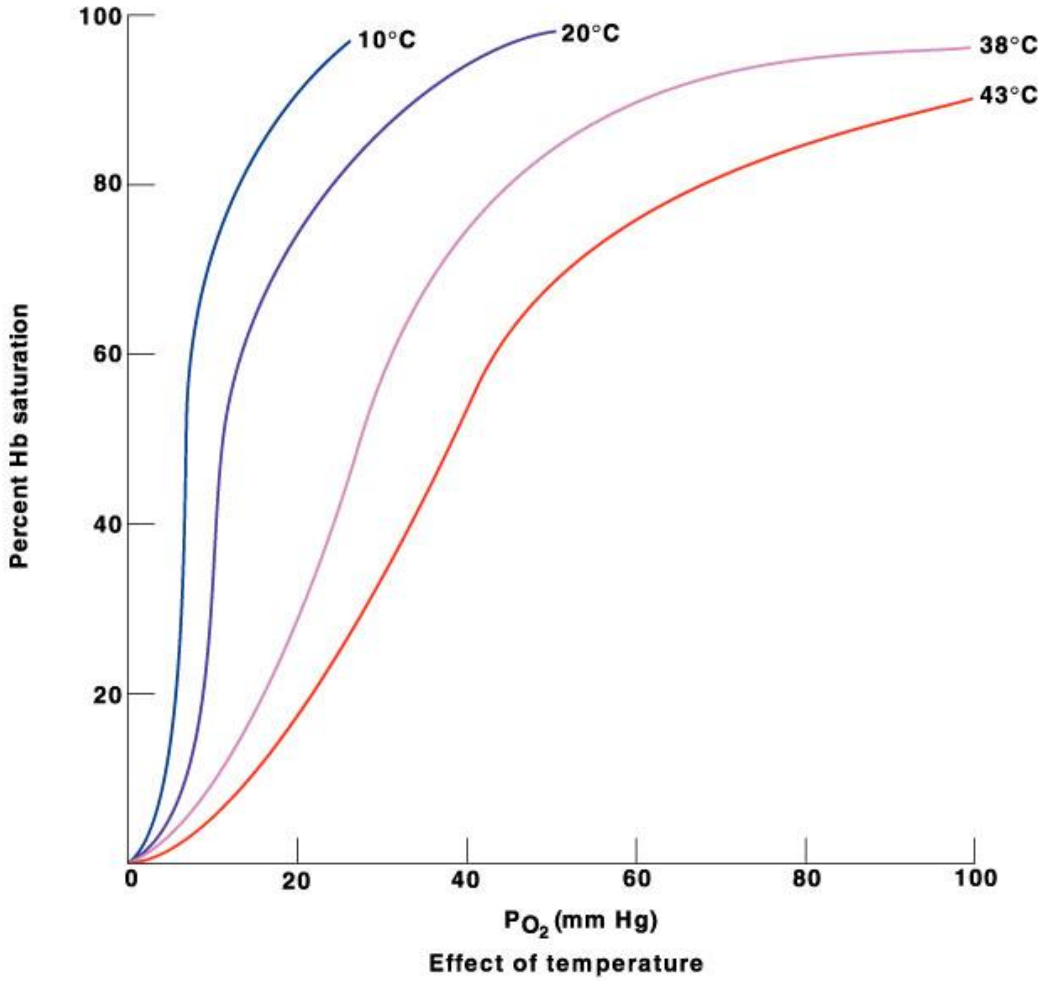


TEMPERATURE

A rise in Temperature shifts O2-HB curve to the Right

Increase unloading of O2 to tissues

During exercise the local rise in temp enhances release of O2 from HB for use by the active tissues



2,3-DIPHOSPHOGLYCERATE

Byproduct of anaerobic glycolysis

Present in high concentration in red blood cells

Diminishes the affinity of hemoglobin for O_2 (Right Shift) by binding reversibly with HB

CONTD…

Importance:

Normal DPG in blood keeps the curve slightly to the right all the time

In Hypoxic condition, DPG increases

Disadvantage:

Excess DPG : Difficulty for the hemoglobin to combines with O_2 in the lungs

TRANSPORT OF OXYGEN IN THE ARTERIAL BLOOD

About 98 percent of the blood that enters the left atrium from the lungs has just passed through the alveolar capillaries and has become oxygenated up to a PO_2 of about 104 mm Hg.

Another 2 percent of the blood has passed from the aorta through the bronchial circulation, which supplies mainly the deep tissues of the lungs and is not exposed to lung air.

This blood flow is called “shunt flow,” meaning that blood is shunted past the gas exchange areas.

On leaving the lungs, the PO_2 of the shunt blood is about that of normal systemic venous blood, about 40 mm Hg.

When this blood combines in the pulmonary veins with the oxygenated blood from the alveolar capillaries, this so-called *venous admixture of blood* causes the PO_2 of the blood entering the left heart and pumped into the aorta to fall to about 95 mm Hg.

- **Diffusion of Oxygen from the Peripheral Capillaries into the Tissue Fluid**

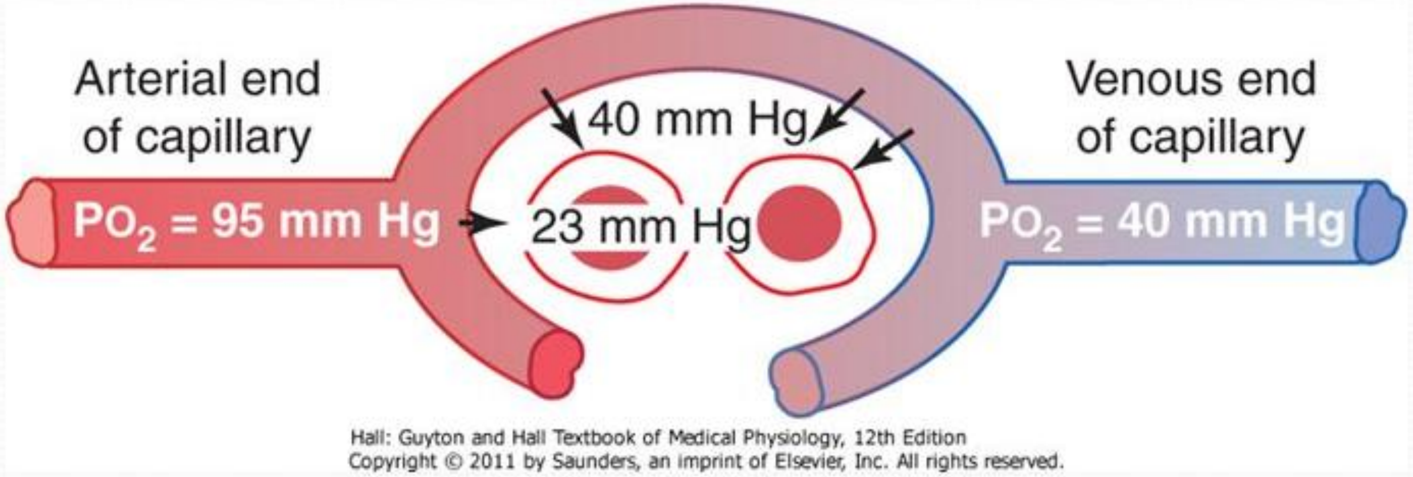
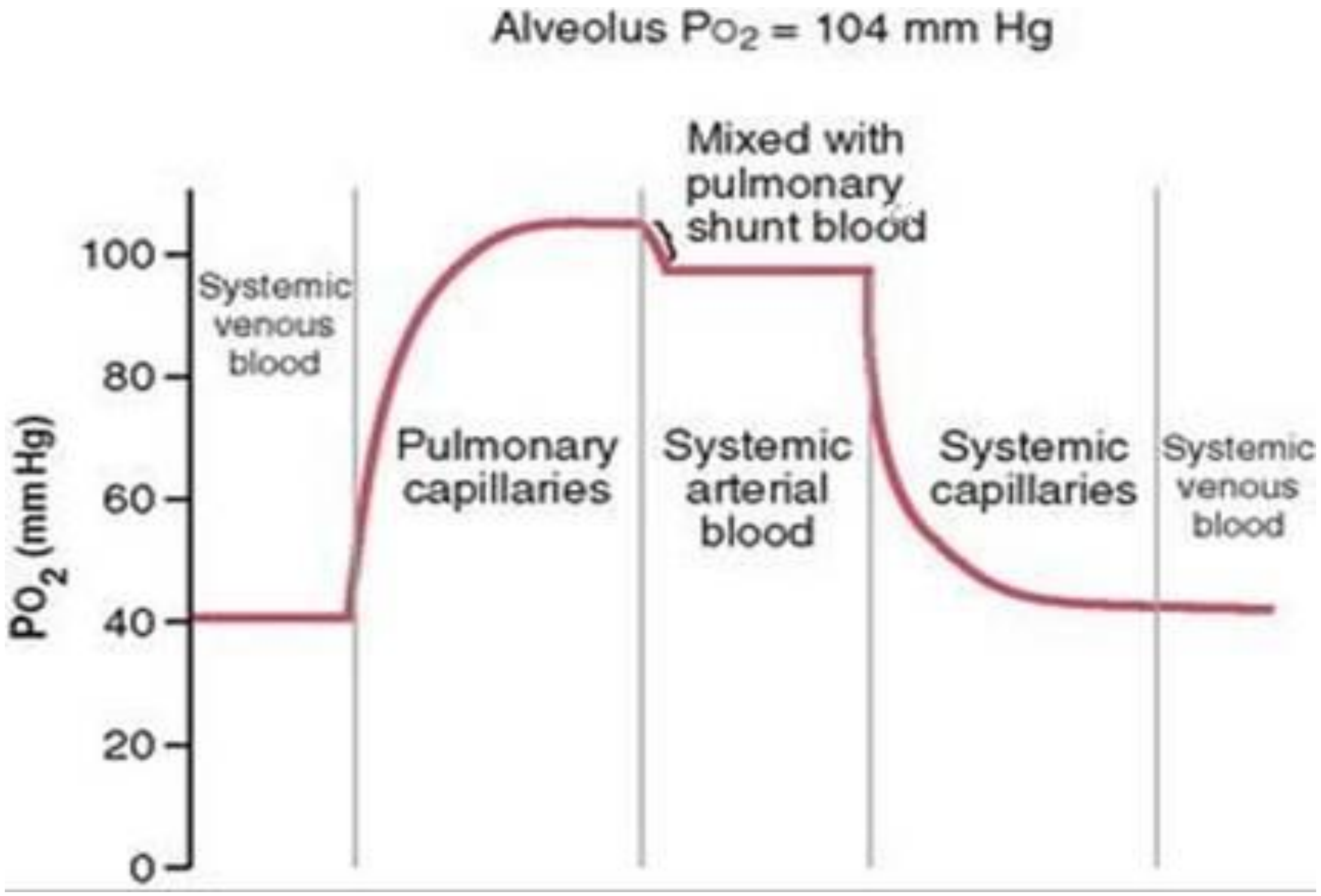


Fig. 40.3 Diffusion of oxygen from a peripheral tissue capillary to the cells



Changes in PO_2 in the pulmonary capillary blood, systemic arterial blood, and systemic capillary blood, demonstrating the effect of “venous admixture.”

DIFFUSION OF OXYGEN FROM THE PERIPHERAL CAPILLARIES INTO THE TISSUE FLUID

When the arterial blood reaches the peripheral tissues, its PO_2 in the capillaries is 95 mm Hg.

the PO_2 in the interstitial fluid that surrounds the tissue cells averages only 40 mm Hg.

there is a tremendous initial pressure difference that causes oxygen to diffuse rapidly from the capillary blood into the tissues—

so rapidly that the capillary PO_2 falls almost to equal the 40 mm Hg pressure in the interstitium.

the PO_2 of the blood leaving the tissue capillaries and entering the systemic veins is also about 40 mm Hg.

DIFFUSION OF OXYGEN FROM THE PERIPHERAL CAPILLARIES TO THE TISSUE CELLS

Oxygen is always being used by the cells. Therefore, the intracellular PO_2 in the peripheral tissue cells remains lower than the PO_2 in the peripheral capillaries.

Therefore, the normal intracellular PO_2 ranges from as low as 5 mm Hg to as high as 40 mm Hg, averaging (by direct measurement in lower animals) 23 mm Hg.

only 1 to 3 mm Hg of oxygen pressure is normally required for full support of the chemical processes that use oxygen in the cell

this low intracellular PO_2 of 23 mm Hg is more than adequate and provides a large safety factor.

- **Diffusion of Oxygen from the Peripheral Capillaries into the Tissue Fluid**

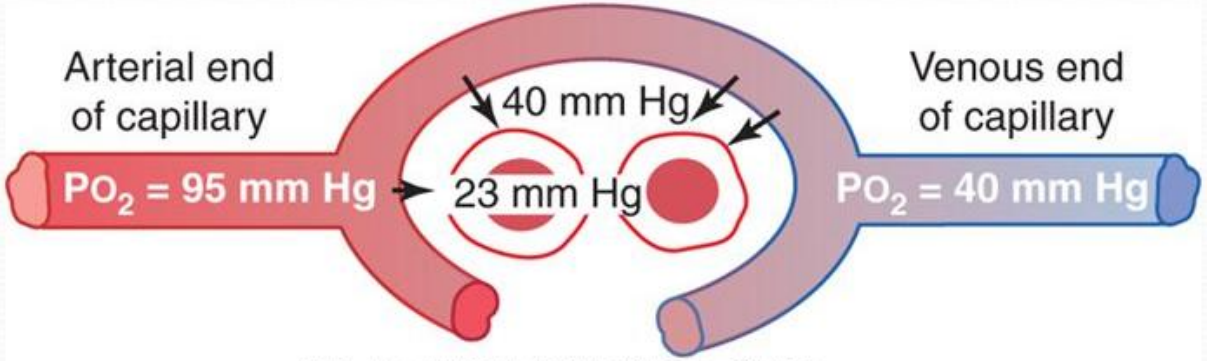


Fig. 40.3 Diffusion of oxygen from a peripheral tissue capillary to the cells

QUESTION:1

At which of the following sites is the partial pressure of oxygen (P_{O2}) highest?

A. Exhaled gas
B. Anatomical dead space at the end of expiration
C. Anatomical dead space at the end of inspiration
D. Alveolar gas

QUESTION:2

The exchange of gases between inhaled air and Pulmonary blood is referred as:

A) Cellular respiration

B) External respiration

C) Internal respiration

D) Circulatory respiration

QUESTION:3

Most Oxygen in the blood is transported as:

A)De-oxyhemoglobin

B)Dissolved in plasma

C)Oxy-hemoglobin

D)Reduced hemoglobin

QUESTION:4

Shift of O_2-Haemoglobin dissociation curve to the right is caused by…. (in blood):

A) Decreased hydrogen ions

B) Increased CO_2

C) Decreased temperature

D) Decreased BPG

QUESTION:5

Oxyhaemoglobin dissociation curve is shifted to the left by:

A) increase in arterial PCO_2

B) acidosis

C) increase in 2,3 DPG

D) fall in temperature

ANSWERS

1- C

2- B

3- C

4- B

5- D

REFERENCES

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Thank
You!!!

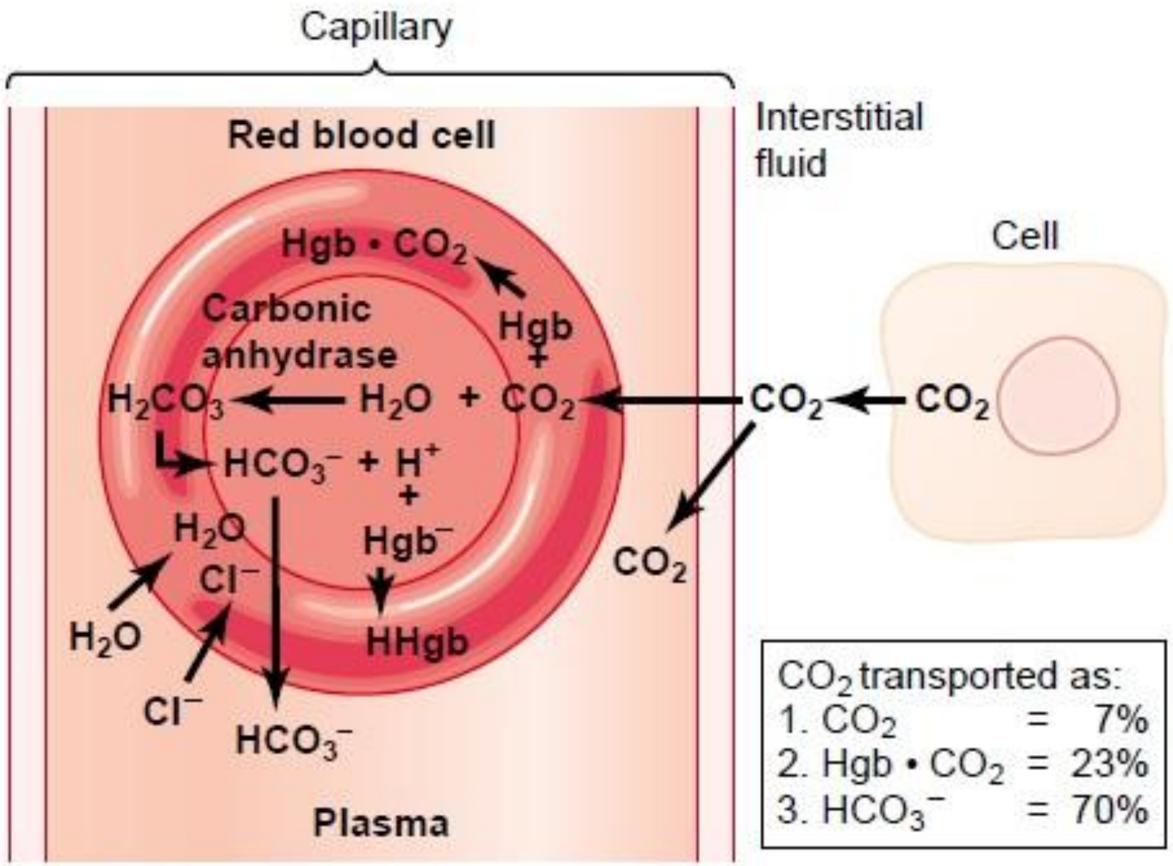

Figure 40–13

Transport of carbon dioxide in the blood.