6th lecture

Oxygen & Carbon dioxide Transport

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OBJECTIVES :

- Understand the forms of oxygen transport in the blood, the importance of each.
- Differentiate between O_2 capacity, O_2 content and O_2 saturation.
- Describe (Oxygen- hemoglobin dissociation curve).
- Define the P50 and its significance.
- How DPG, temperature, H+ ions and PCO_2 affect affinity of O_2 for hemoglobin and the physiological importance of these effects.
- Describe the three forms of carbon dioxide that are transported in the blood, and the chloride shift.

CONTENTS :

COLOR INDEX :

- Red = important
- Grey = additional notes

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1- OXYGEN TRANSPORT :

When blood is **100% saturated with O_2**
||
Each gram of **Hb carry : 1.34** ml O_2
||
O_2 content = 15g Hb x 1.34 O_2= **20 ml**

N.B ideal concept by calculations **HOWEVER** not found in reality .

Terminology

O_2 Content: actual Amount of O_2 in blood (mL O2 /100 mL blood)

O_2 binding capacity: Maximum amount of O_2 bound to hemoglobin (mL O2 /100 mL blood) measured at 100% saturation.

Percent saturation (%) : Percentage (%) of heme groups bound to O_2 of Hb = $\frac{\text{oxygen content}}{\text{oxygen capacity}} \times 100$

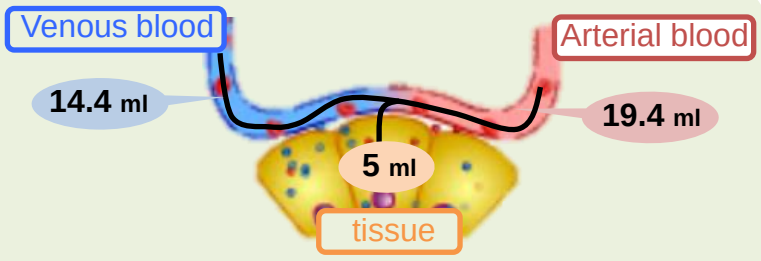
Dissolved O_2: Unbound O_2 in blood (mL O2 /100 mL blood)

✓ The blood is only **97% saturated with O_2** (Each **100** ml blood contain 19.4 ml O_2)

✓ At rest tissues Consume **250ml O_2** and Produce **200ml CO_2**

✧ The amount of O_2 released from hemoglobin → tissues is **5** (mL O_2 /100 mL blood)

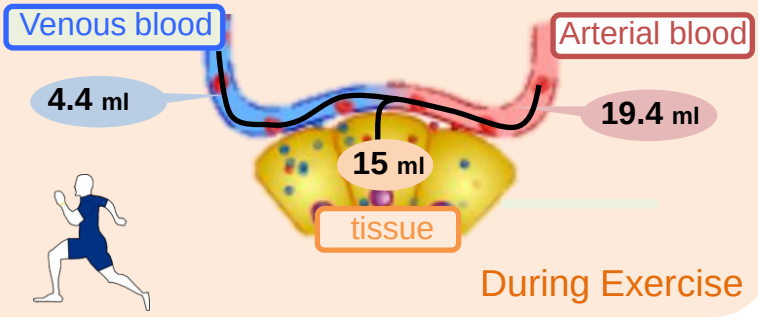
We use this to calculate the venous O_2 content =
19.4 - 5 = 14.4 ml



Normally

✧**During strenuous exercise**
The oxygen uptake by the tissue **increases** 3 folds. ➔**15** ml O_2 is given.

O_2 content in venous blood =
19.4 – 15 = 4.4 ml



During Exercise

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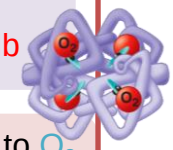
2- FORMS OF OXYGEN TRANSPORT :

Bounded to Hemoglobin — 20 ml, 97% — Oxyhemoglobin

Dissolved in plasma — 0.3 ml, 3%

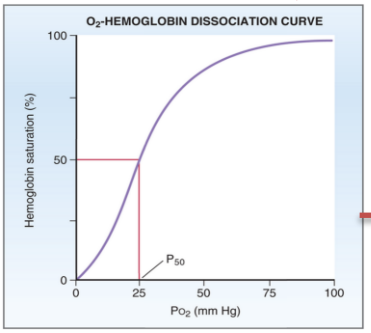
O_2 binds to the heme group in the **center** of each chain = 4 O_2 per 1 Hb



- ✧ If the PO_2 **increases** ➔Hb **binds** to O_2
- ✧ If the PO_2 **decreases** ➔Hb **releases** O_2

Higher PO_2 ,,, greater Hb saturation

The relation between PO_2 and O_2-Hb is described in the curve below..



At normal arterial **PO_2 = 95** mmHg
||
0.29 (~0.3) ml of O_2 is dissolved in each **100 ml** of blood

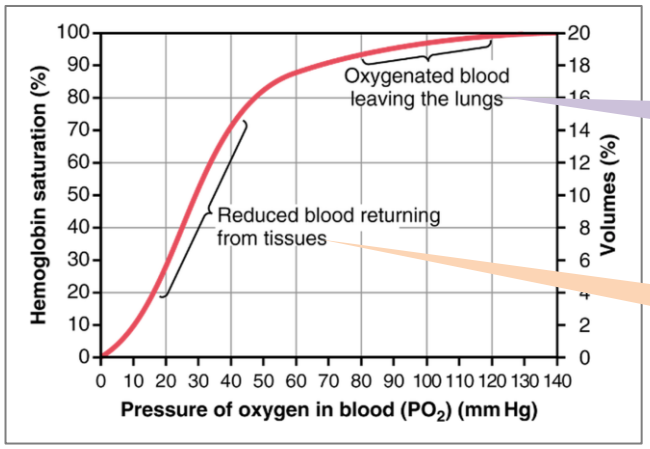
PO_2 of the blood **falls** to **40** mmHg in tissues
||
Only **0.12** ml of O_2 remains dissolved

i.e **0.17 ml** of oxygen is normally transported in the dissolved state to the tissues. per 100 ml of blood

General info ..

- The curve is called **Oxyhemoglobin saturation curve** OR Hb-O_2 dissociation curve
- The relation between PO_2 and Hb-O_2 is not linear rather S- shaped or sigmoid

3- OXYHEMOGLOBIN DISSOCIATION CURVE :



**During rest

PO_2 = 100 mmHg
Hemoglobin is **saturated** with oxygen **98%**

↓ **23%** will be released

PO_2 = 40 mmHg
Hemoglobin is **saturated** with oxygen **75%**

✓ The position of the dissociation curve can be determined by measuring the **P50**

What is the P50?

The arterial PO_2 at which **50%** of the Hb is saturated with O_2

Normal value= **26.5**

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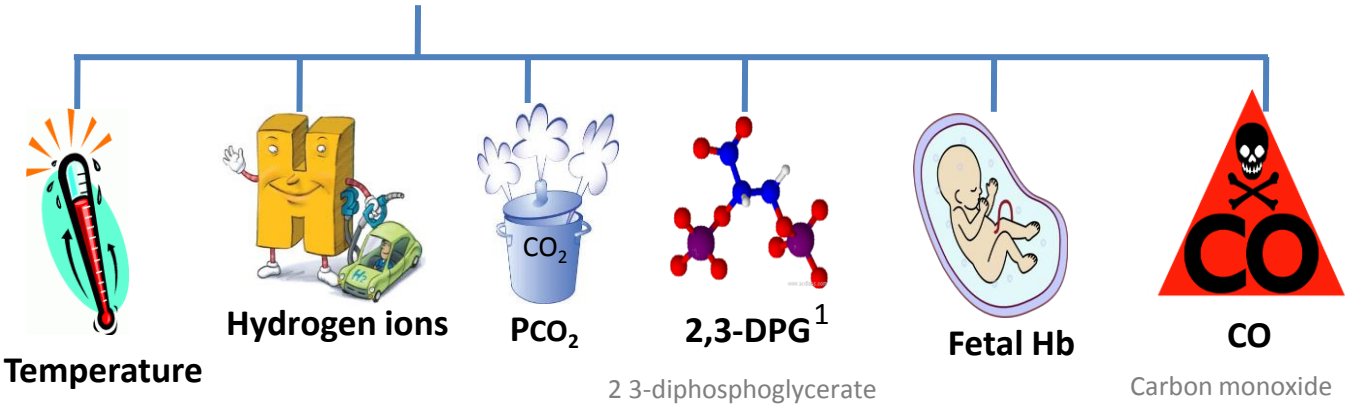
4- CHANGES IN THE DISSOCIATION CURVE :

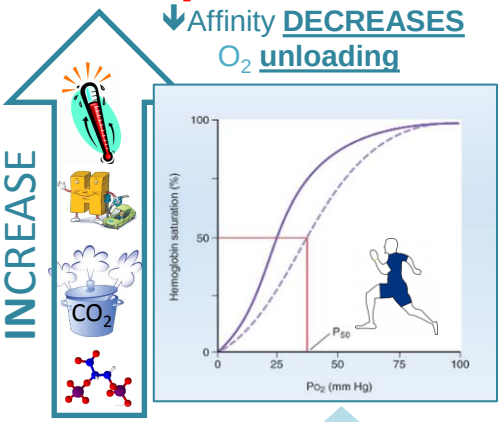
The curve can shift to the right or shift to the left. Without change in shape , such shifts reflect the changes in the **affinity of Hb for O_2** , and produces **changes in p50 (increase or decrease)…**

FACTORS AFFECT THE SHIFTS:



Right shifted

↑P50 INCREASES
↓Affinity **DECREASES**
O_2 **unloading**

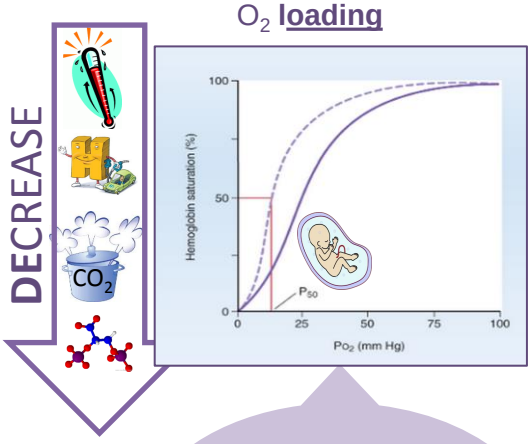


Increase temperature
Increase 2,3-DPG
Increase H^+ (**Decrease** pH)
Increase PCO_2

Exercise

Left shifted

↓P50 DECREASES
↑Affinity **INCREASES**
O_2 **loading**



Decrease temperature
Decrease 2,3-DPG
Decrease H^+ (**Increase** pH)
Decrease PCO_2

Fetal Hb
CO

1- Is synthesized in RBCs from the glycolytic pathway, it binds tightly to reduced Hb (Binds to oxyhemoglobin and act to stablize low O_2 affinity state “T-state” of the O_2 carier “Hb”)

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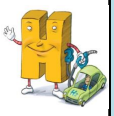
	Right shifted	Left shifted
Temperature 	**Increases** During exercise as muscles are working they produce heat, which facilitates unloading of O_2.	**Decreases** facilitates loading of O_2
H^{+2} ions 	**Increases** When tissue metabolic activity increases -> production of CO_2 increases -> increases PCO_2 -> increase in H^+ concentration -> decrease in pH => which facilitates unloading of O_2. (Bohr's effect)	**Decreases** When tissue metabolic activity decreases -> production of CO_2 decreases -> decreases PCO_2 -> decreases H^+ concentration -> increase in pH => which facilitates loading of O_2 (Bohr's effect)
PCO_2 		
2 3-diphosphoglycerate 	**Increases** when it increases it facilitates unloading of O2 **increases within RBCs in anemia and hypoxemia , and thus serves as an important adaptive response in maintaining tissue oxygenation**	**Decreases** It reflects decreased tissue metabolism and less O_2 is unloaded to tissue.
Fetal Hb 		Fetal Hb-type F has more affinity to O_2. Has a P50 of 20 mmHg in comparison to 27 mmHg of adult Hb.
Carbon monoxide 		CO combines with Hb at the same point on the Hb molecule as does oxygen. But with much higher affinity (around 250 times) Called carboxy

IN MORE DETAILS

For easy recalling we advise you memorize only one of the shifts and know that the other one is exactly the opposite..

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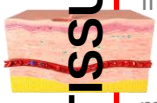
5- BOHR'S EFFECT:

Which is Effect of carbon dioxide and hydrogen ions on the curve.

IN LUNG

Movement of CO_2 from blood to alveoli -> decrease blood CO_2 & H^+ -> shift the curve to left and increase O_2 affinity to Hb allowing more O_2 transport to tissues.

And the reverse occur in tissues →



IN TISSUES

Movement of CO_2 from tissue to blood -> increase blood CO_2 &H^+ -> shift the curve to right and decrease O_2 affinity to Hb allowing more O_2 to be released and more CO_2 to be transported back to lung.

6- UTILIZATION COEFFICIENT :

The percentage of the blood that gives up its oxygen as it passes through the tissues capillaries.

$$\frac{5\ ml}{20\ ml} = 25\%$$

$$\frac{O_2 \text{ delivered to the tissues}}{O_2 \text{ content of arterial blood}}$$

$$75\% = \frac{15\ ml}{20\ ml}$$

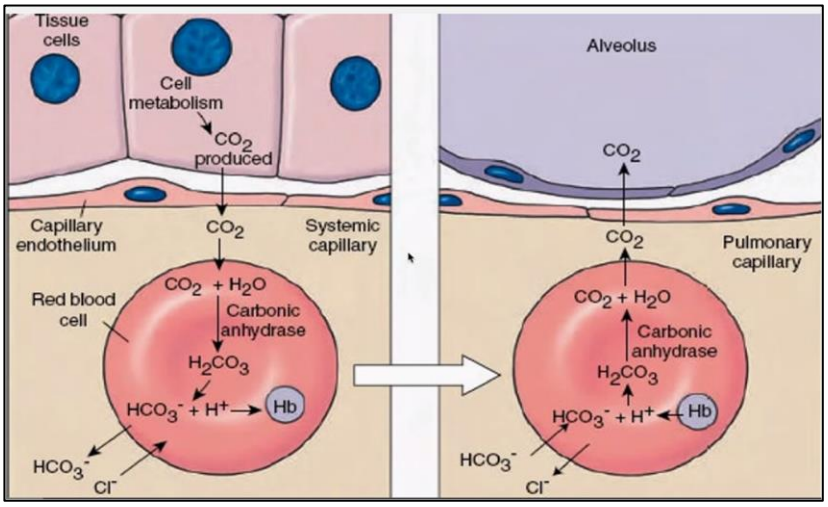
7- CARBON DIOXIDE TRANSPORT :

Forms of carbon dioxide transport

- **Bounded to Hemoglobin** — 23% — Carbaminohemoglobin
- **Bicarbonate Ions** — 70%
- **Dissolved CO_2** — 7%

Each 100 ml of blood carry 4 ml of CO_2 from the tissues/min.

* FORMATION OF HCO_3^- AND CHLORIDE SHIFT:



IN TISSUE

IN PULMONARY CAPILARIES

https://www.youtube.com/watch?v=VINQnL_oVFY

8- HALDANE EFFECT :

When the O_2 binds to the Hb at the Lung ➔ Hb to become **stronger acid.**
This change in acidity make the CO_2 transport from blood to the alveoli

Note: Halden effect is the effect of O_2 on CO_2 transport while Bohrs effect is the effect of CO_2 on O_2 transport .

9- CHANGE IN BLOOD ACIDITY DURING CO_2 TRANSPORT :

Arterial blood has a **pH of 7.41**
venous blood has a **pH of 7.37** (i.e change of **0.04** unit takes place)

As we can see above, the difference in acidity between the arterial and venous play an important role in **transport**

10- RESPIRATORY QUOTIENT Respiratory Exchange ratio :

$$R = \frac{\text{Rate of carbon dioxide output}}{\text{Rate of oxygen uptake}}$$

Normally → 0.825, 82%

Fat diet → 0.7, 70%

Carbs diet → 1, 100%

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GOOD LUCK ☺

https://www.examtime.com/en-US/p/1988760-Untitled-quizzes

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