Respiration

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Respiratory function of the blood

O2 transport by blood

- Once oxygen **has diffused from the alveoli** into the pulmonary blood it is transported to the peripheral tissues.
- **Each 100 ml arterial blood** contains **19.5** ml O2 when PO2 = 100 mm Hg , present in **two forms**:

1- Physical solution	2- Chemical combination
- it's the volume dissolved physically in plasma.	- it's the part of O2 carried by haemoglobin (HB).
- In **arterial blood** **it equals 0.3 ml /100 ml blood.** **i.e 2% of O2.**	**- it equals 19.2 ml /100 ml blood** **i.e 98 % of O2.**
Significance: – **It reflects O2 tension (P O2) in the bloo**it equals **0.3 ml / 100 ml when O2 tension equals 100 mm Hg (arterial blood).** – **while it equals 0.13 ml / 100 ml when O2 tension equals 40 mm Hg (venous blood).** **2) It acts as a pathway** for the supply of O2 to HB at lung and from HB to tissues at tissues. -***When blood reaches tissues***, *it is this small amount that is first transported to the cells and then it is replaced rapidly by more O2 from HB.*	

Haemoglobin (HB)

- is O2 carrying pigment present in the blood.

Structure of HB: it's formed of:

1- Globin: a protein composed of **4** polypeptide chains:

α, β, γ & δ.

- **according to the type of polypeptide chains**, HB may be **classified into**:

HB A(adult)	**- 2 α (141 aa) + 2 β (146 aa) chains. - represents 98 % of normal adult HB.**
ii) HB A2	**-2 α & 2 δ** chains,represents 2% of adult HB
ii) HB F(fetal)	-2 α & **2 γ.** **- present in fetal life and totally replaced by adult haemoglobin 6 months after birth.**

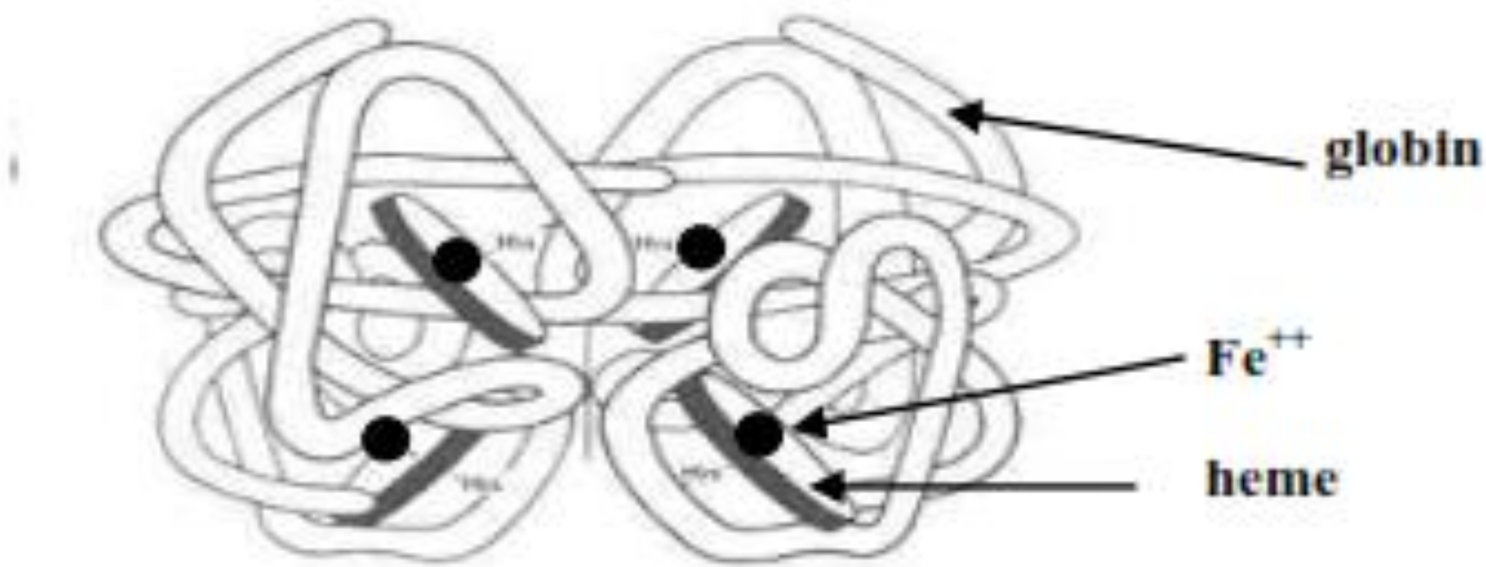
Haemoglobin (HB)

2- 4 heme groups:

- each **heme group** **contains a single ferrous iron, Fe^{++} in its centre.**
- each Fe^{++} can combine with one molecules of O2 so **that each HB molecule can combine with 4 molecules of O2, this binding is Characterized by:**

i) **the reaction is rapid and reversible & no enzymes..**

ii) the reaction is **oxygenation not oxidation** as iron remains in the ferrous state.



HB

Oxygen dissociation curve = O2 - HB dissociation curve

def: it is a curve showing the relation between O2 pressure (or tension = P O2) and % saturation of HB with O2 .

Significance:

- from the curve we can **study the factors that affect % saturation o**f HB with **O2 in relation to O2 tension of the blood.**
- ***it is an important tool for understanding how our blood carries and releases oxygen.***

How to obtain the curve

- blood samples **are placed in special vessels known as tonometers** **(special containers).**
- each tonometer is exposed **to certain O2 tension (P O2) at 37 C. - O2 content(Is the vol. of O2 <u>chemically combined</u>** to HB in 100 ml blood.) is determined & **divided by the O2 capacity(is the vol. of O2 <u>chemically combined</u>** with HB in 100 ml blood when HB is **<u>fully saturated</u>** with O2**). to get % saturation ,which then is put against O2 tension to get the curve.**

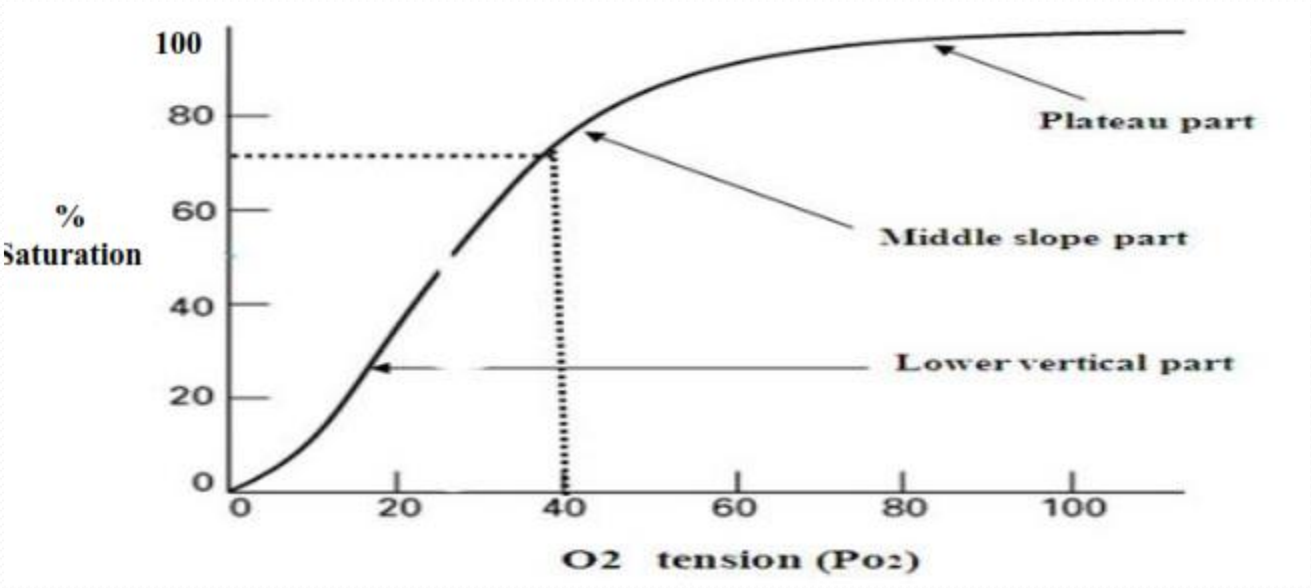
How to obtain the curve

% saturation (= $\frac{\textbf{O2 content}}{\textbf{O2 capacity}}$ **x 100)**

is used so that the curve is universal. *if O2 content is used, **the curve will not be universal because O2 content differs from a person to another**.*

Shape of the curve

- The curve **has a characteristic <u>sigmoid</u> shape** (**<u>not linear</u>**) **because the combination O2 with the HB molecules occurs** in steps, where **<u>each combination facilitates the next</u> i.e affinity of heme gp. To oxygen is increased gradually after first oxygenation**.



Physiological significance of the curve

- **The curve has the following characteristics:**

1) **Upper flat part (plateau).**

2) **Middle curved part (slope).**

3) **Lower vertical (steep).**

1) Upper flat part (plateau)

- **From the curve we note that:**

a- The arterial O_2 % **saturation** **doesn't change significantly until PO_2 has decreased to 60 mm Hg:**

at O_2 pressure **100** mm Hg → **saturation % not 100 % (in the body it's only 97.5 %** due to the physiological shunt(% saturation at the **venous end of the pulmonary capillary blood =100%** however in the arterial blood it **drops to 97.5 %)**

Cause:

- due to **addition of venous blood** from the **bronchial and coronary veins.**

- shunt).
- at O_2 pressure **60** mm Hg → % sat. = **90 %**

So** marked ↓O_2 pressure **from 100 mmHg to 60 → only little ↓ in % sat.: about 7.5 % (in the body) .

b- this indicates that alveolar or arterial PO_2 can be lowered by about 1/3 without much ↓ in % saturation i.e blood gets a good saturation **with O_2 even if alveolar PO_2 fall to 60 mm Hg.**

Significance:

- ***This enables persons living in high altitude, and those complaining of lung disease*** *to get enough O_2 in spite* ***of ↓ PO_2 in atmosphere or in the alveolar air.***

2) Middle curved (slope part):

- **<u>At PO$_2$ 40 mm Hg</u>** <u>(that of the venous blood during</u> rest), the % saturation is **70 %** i.e during rest **30 % of O_2 are given to the** tissues .

<u>Significance:</u>

- *his satisfies their needs, the remaining* ***<u>70 %</u>*** *act as* ***<u>venous O_2 reserve</u>*** *in blood for* ***<u>emergency conditions</u>*** *e.g muscular exercise.*

3) Lower vertical (steep) part of the curve, we note that:

- **Little ↓of PO_2 below 40 mmHg → <u>marked</u> ↓<u>% sat.</u> i.e more O_2 is unloaded from HB so supplies more O_2 to tissues.**

<u>Significance:</u>

- ***This enables peripheral tissues to <u>withdraw large amount of O_2</u> for only a small drop in capillary PO_2 <u>as occurring in ms. excercise.</u>***

Percentage (%) unloading

-**Percentage (%) unloading = % sat. in arterial blood - % sat. in venous blood.**

-equals 30 % during rest **but ↑ in ms. exercise &** may be **70 % or even more.**

Venous O2 reserve

-**def:** it's the volume of O_2 that **remains in venous blood** after supplying tissues.

- **this amount equals 14 ml O_2 i.e 70 % saturation during rest.**

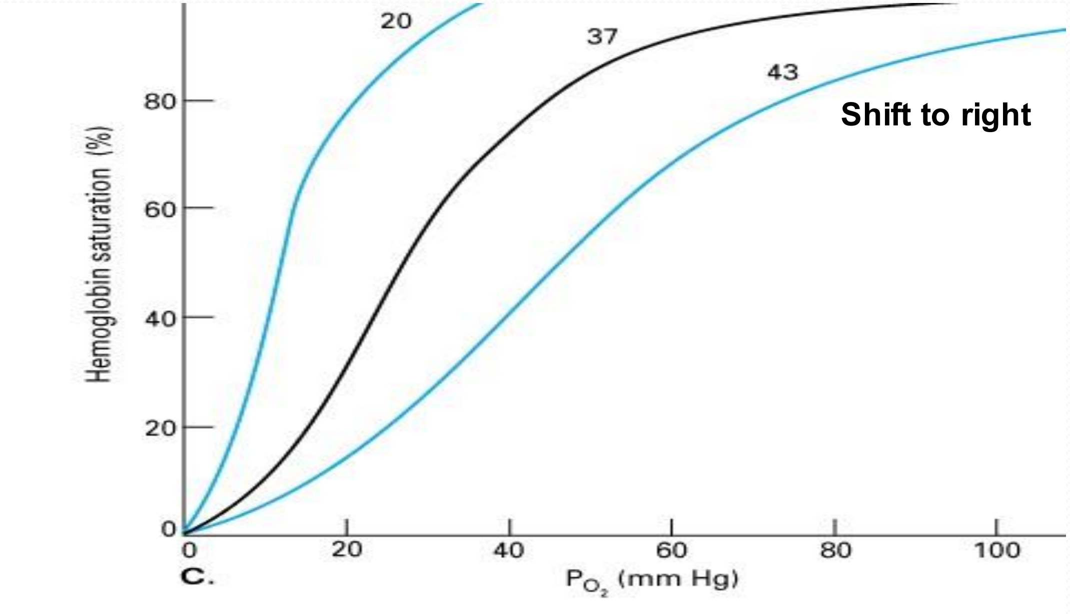
- **this value ↓ markedly during exercise.**

Factors affecting O_2 dissociation curve

- a number of factors can influence the affinity of HB to O_2 & can shift the curve either to the Rt. or to the left .

A. **Shift to the Right :** means **more** **O2 release from HB to tissues.**

B. **Shift to the left :** means **less** **O2 release from HB to tissues.**



A- Factors that shift the curve to the right

1- ↑ H+ Concentration

- **under acidic conditions** , **the amount of O_2 bound to HB at any given PO_2 is diminished,** so **the higher** the H^+ conc. → **the less** O_2 is bound to HB at any given PO_2 .
- **this is because when H^+ ions bind with HB molecules it changes their molecular structure** → ↓ affinity to O_2 → ↑ O_2 release.

$$H^+ + HBO2 \rightarrow H.HB + O2$$

2)↑ PCO_2

- has the **same effects as H^+ conc.**, **so the high the PCO_2 → the less O_2 bound to HB i.e more O_2 released to tissues** .
- this effect because PCO_2 can influence Ph in the **following manner:**

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

3) ↑ temperature

- the higher the temperature → the less O_2 bound to HB.

$$HBO_2 \xrightarrow{\uparrow \text{temerature}} HB + O_2$$

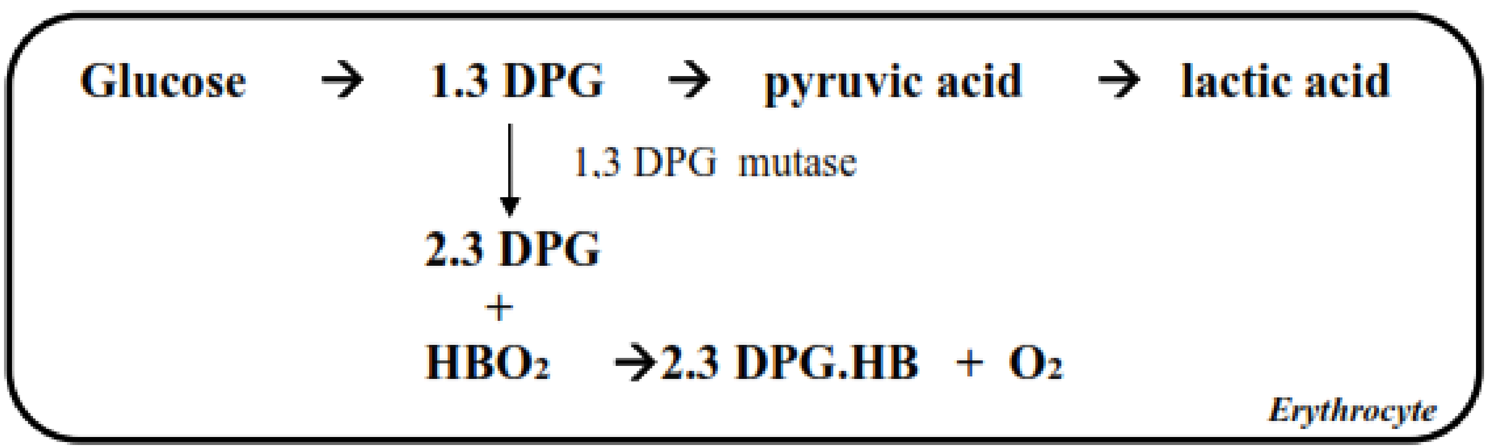
N.B: **exercised ms**. **are acidic , hot and contain high PCO_2 → less O_2 bound to HB i.e more O_2 released to tissues.**

4) ↑ 2,3 DPG (di-phospho-glycerate)

- **2,3 DPG is a substance formed inside RBCS to ↑ release the oxygen from HB.**

a-Formation:

➢ by side reaction **in the glycolytic process (N.B: RBCs depend on anaerobic glycolysis because they have no mitochondria).**



- the activity of 1,3 DPG mutase is stimulated by hypoxia and inhibited by oxy HB.

Functions of 2.3 DPG:

- it combines with β chain of HB → release of O_2 to the tissues.

Factors that ↑ concentration of 2,3 DPG in RBCs include:

i- all conditions of hypoxia as: - anaemia. - high altitude.

ii- muscular exercise.

iii- some hormones as testosterone, growth hor., thyroxine & catecholamines.

iv-during pregnancy.

Function of 2,3 DPG is ↓ed in:

i) Fetal HB:

- **fetal HB can't bind to 2,3 DPG as it doesn't contain β chain so its affinity to O2 is higher than adult HB.**

ii) Stored blood: as the preservative used destroy 2,3 DPG.

B- Factors that shift the curve to the left

1) **↓ H^+ conc.**

2) **↓ Pco_2 .**

3) **↓Temp. : so in cold weather although cheeks & ears are red little O_2 is released to the tissues .**

4) ↓ 2.3 DPG:

this occurs in stored blood because of the preservative used .

accordingly the HB affinity to O_2 is increased & less O_2 delivered to the tissues .

5) Carbon monoxide poisoning:

- **causes maximum shift to left as the affinity of HB for CO is 210 times that for O2.**

-CO **prevents release of the remaining oxygen** from HB.

CO_2 transport by blood

- When oxygen is used by the cells, **all of it is converted into CO2 which diffuses from the cells to the blood.**
- each 100 ml arterial blood that enters the tissues already carries **50** ml Co_2 , **this large amount is carried in two forms:**

<table>
<tr><td colspan="2">1-Physically dissolved = 5%:</td></tr>
<tr><td colspan="2">– dissolved in plasma & RBCS.
– responsible for P CO (CO_2 tension).</td></tr>
<tr><td colspan="2">2-Chemically combined = 95 %:</td></tr>
<tr><td>a) Carbamino compounds, 6 %</td><td>b) as bicarbonate, 89 %</td></tr>
<tr><td>- It is the combination with the terminal amino group of PP chains of blood proteins as HB & plasma proteins. R-NH_2 + CO_2 → R-NH-COOH -The combination is <u>very rapid</u> <u>without enzymes</u>.
-Since HB is <u>15 gm%</u> while PP is <u>7 gm%,</u> CO_2 bound with HB is <u>4</u> % and that bound with PP is only <u>2</u> %.</td><td>– CO_2 combines with water to form carbonic acid .
– Carbonic acid being a weak acid it dissociates into bicarbonate ion (HCO_3^-) and H^+ .
$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

Na HCO_3^- (mainly in plasma): K HCO_3^- (mainly in RBCs)= 3/1.</td></tr>
</table>

Importance of arterial Co2

- it represent **a storage for a strong base** ($NaHCO_3$), this base that **neutralizes acids formed inside the body by normal or abnormal metabolism it's** called **alkali reserve.**

Lactic acid (strong acid) + Na HCO3→ Na lactate + H2CO3(weak acid).

Tidal Co_2

Def: **it's the volume of Co_2 that's added to each 100 ml of arterial blood during its flow through the tissues = 5 ml.**

Fate of tidal CO_2:

- It's carried by blood to the pulmonary capillaries where it **diffuses** into alveoli **and expelled outside the body** .
- **P Co_2 in pulmonary capillaries = 46 mmHg & P CO_2 in alveoli = 40 mmHg so there's pressure gradient of 6 mmHg which allows Co_2 to cross the respiratory membrane.**

- Tidal CO_2 is transported **in the same way as arterial CO_2 (i.e.** in 2 forms):

1) **Physically dissolved (10%): in plasma and RBCs.**

2) **Chemically combined (90%): in two forms.**

a) Carbamino compounds (20%):

- **Reduced Hb can bind much more CO_2 than oxy HB.**

So,% of cabamino compounds is more in venous blood than the arterial.

b) Bicarbonate ions (70%).

Questions

- 1-Which of these ratios is the% of O_2 present in chemical combination with haemoglobin?

60% (a

80% (b

90% (c

<u>98%</u> (d

2% (e

2-Describe O_2 dissociation curve as regard its definition, significance, how to be obtained , shape and physiological significance

- 3-From O_2 dissociation curve at arterial O_2 pressure of 100 mmHg the %saturation of haemoglobin in arterial blood will equal which of these values?

97.5% (a

100% (b

40% (c

60% (d

80% (e

3- mention factors that shift o2 dissociation curve to right

- 4- In which of these conditions the function of 2-3 DPG increases ?

Storage of blood (a

In Fetal haemoglobin during pregnancy (b

Increased oxyhaemoglobin (c

Muscular exercise (d

Absence of 1-3 DPG mutase (e