# 4- O2-Hb dissociation curve, shift & significance

By


Prof. Sherif W. Mansour

Physiology dpt., Mutah school of Medicine .


2023/2024

# Oxygen Transport by Blood

* **$O_2$ is carried by blood in two forms**:

***1) $O_2$ in physical solution*:** Nature: $O_2$ molecules dissolved in blood.

- Volume: it depends on $O_2$ tension according to *Henery's law*: (dissolved $O_2 = PO_2 \times 0.003$). So,

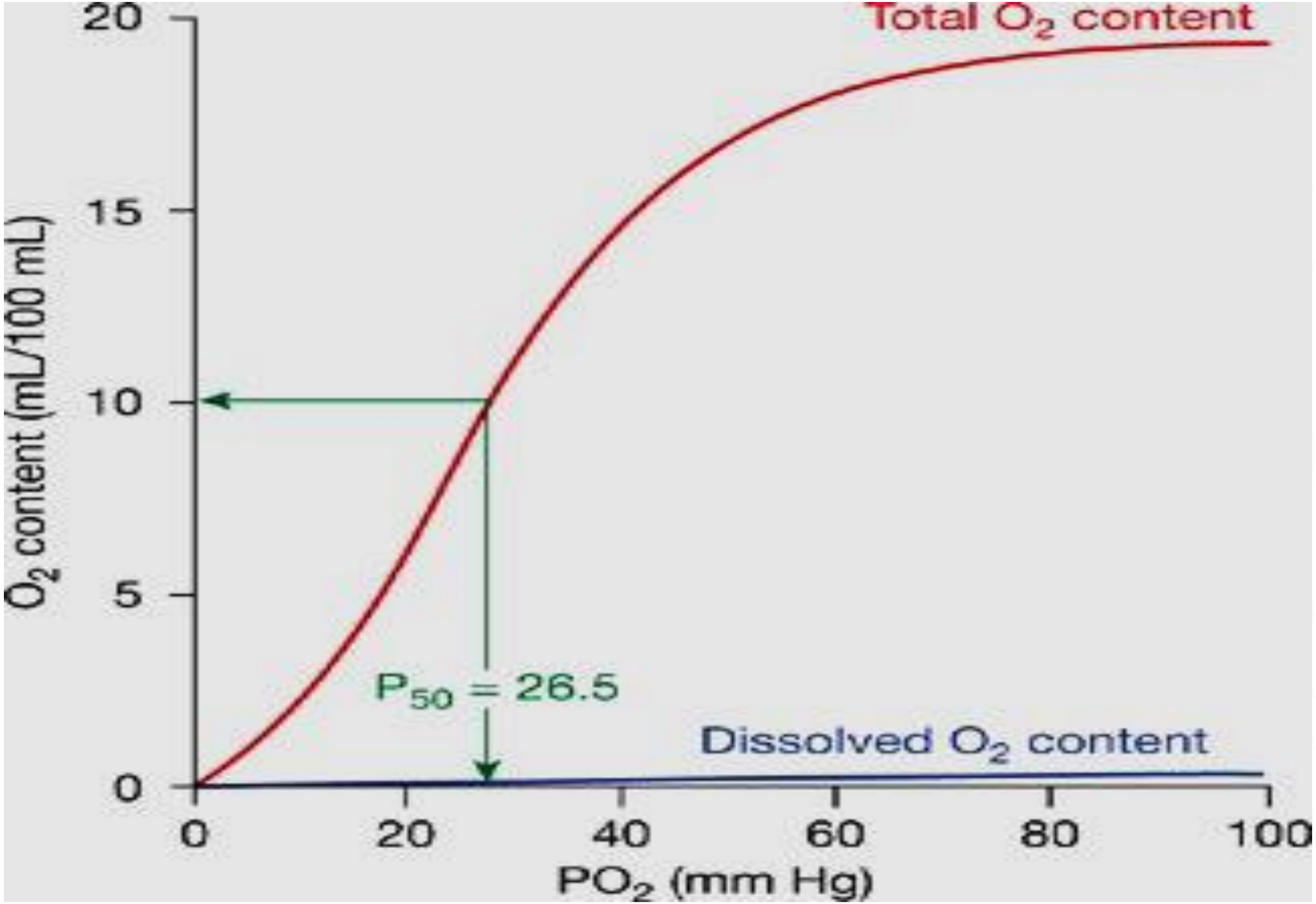
In arterial blood (with tension of **100** mmHg) = **0.3 ml/100** ml. and in venous blood (with tension **40** mmHg) = **0.13** ml/100 ml

- **Importance:** 1) It determines $O_2$ tension in the blood. 2) It is easy to be used by the tissue.

3) It determines the rate and direction of $O_2$ diffusion. 4)It determines the percentage saturation of haemoglobin with $O_2$.

**2) *$O_2$ chemical form:***

- Nature: $O_2$ combines with the iron of haemoglobin while still in the ferrous state (It is called oxygenation not oxidation of Hb). - Hb combines with $O_2$ in steps $HbO_2$, $HbO_4$, $HbO_6$, and $HbO_8$
- Volume: **19** ml $O_2$/100 ml **arterial blood**. **14 ml** $O_2$/100 ml **venous blood** (at rest)
- Importance: it is the main $O_2$ supply to tissues (however, the tissue utilize physical $O_2$ at first then chemical form)



Total O2 content
Dissolved O2 content
P50 = 26.5
O2 content (mL/100 mL)
PO2 (mm Hg)
0
5
10
15
20
0
20
40
60
80
100

# <u>$O_2$ -Dissociation Curve of Hemoglobin</u>

- **<u>Definition</u>:** $O_2$ dissociation curve shows relationship between **$O_2$ tension** and **percentage saturation of Hb** at different $O_2$ tensions (Because the percentage saturation is not varied according to Hb. content in different persons).

- **<u>Method</u>:** 3 ml of blood in **Tonometer** are allowed to form thin layer on the wall and then exposed to different $O_2$ tensions and % saturation is calculated and plotted against the $O_2$ tensions in a cu

**<u>Physiological significance of the curve</u>:**

***<u>(a) At the lung and arterial blood:</u>*** *If the blood is exposed to:*

- $O_2$ tension of **<u>100</u>** <u>mmHg</u> (normal alveolar $O_2$ tension) → **95%** saturation .

- $O_2$ tension of **<u>70</u>** <u>mmHg</u> (alveolar tension at high altitude or diseased lung ) → **90**% saturation.

- So change of $O_2$ tension from 100 to 70 mmHg → mild change of % saturation. So the curve <u>is nearly horizontal</u> and saturation is easy and complete even with low $O_2$ tension at the lung to bind with more oxygen and carry it to tissue indicating that Hb has high affinity to $O_2$ at lungs.

***(b) At the tissue and venous blood:*** *If the blood is exposed to:*

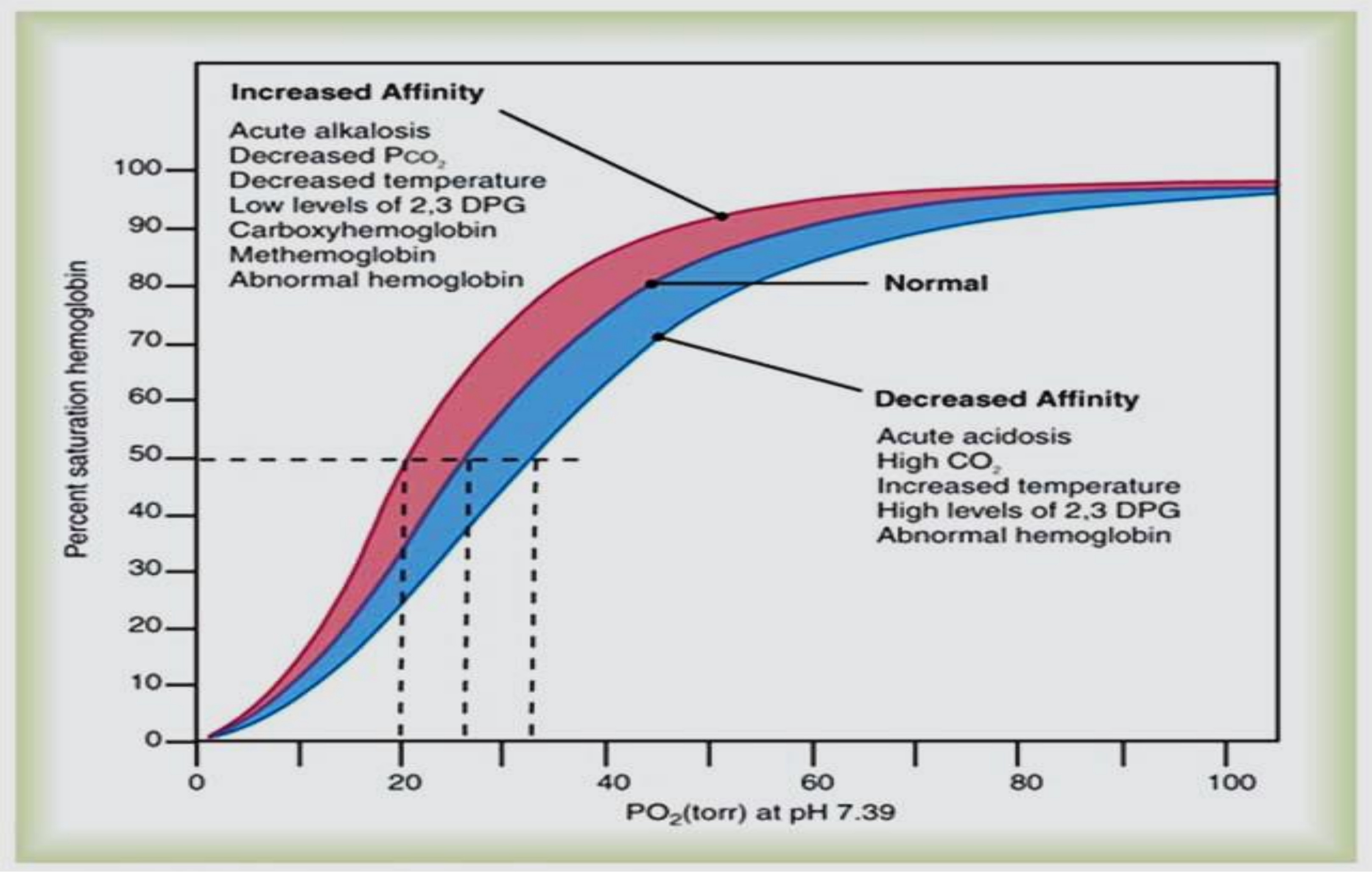
- $O_2$ tension of **40** mmHg (resting muscle& venous blood tension) → **70%** saturation.
- $O_2$ tension of 25 mmHg (during exercise) → **40%** saturation.
  - So, mild change in $O_2$ tension from 40 to 25 mmHg → large decrease in saturation from 70 to 40% to give oxygen to tissue, so the curve is nearly vertical (steep) at tissue & venous side due to low affinity of Hb to $O_2$ at lower $O_2$ tension.
- Also pressure difference between **arterial and tissue $O_2$ is high** (100-40 = 60 mmHg) → loss of 25% (95-70 = 25%) of $O_2$ carried by Hb at rest.

***(c) The curve is sigmoid or "S" shaped*:** because Hb contains **4 ferrous atoms** and each one is saturated at certain $O_2$ tension & saturation of each one facilitates of the following one and so on .As there are 2 states of Hb: (1) **Tense or "T"** state when Hb gives $O_2$, the "**β**" chains moves a **part** with decrease $O_2$ binding. (2) **Relaxed or "R"** state when Hb take $O_2$ the **β** chains move **closer** and favors more $O_2$ binding.

- ***Bohr Effect*:** *it is the decrease in $O_2$ affinity to hemoglobin when pH of the blood falls(Acidic) . It can be attributed to the fact that reduced HB binds $H^+$ more actively than does oxyhemoglobin which causes unloading of O2 more easily.*

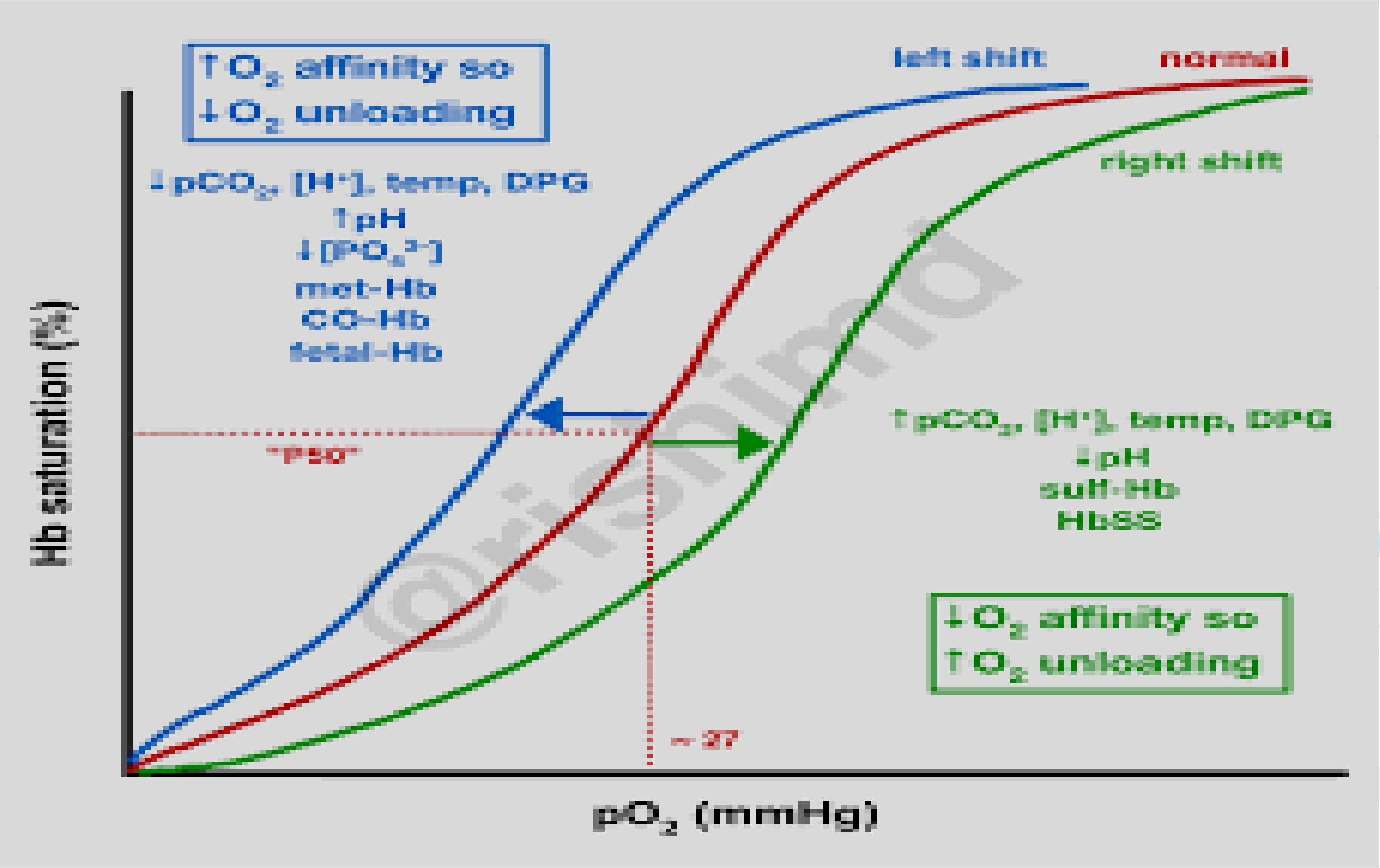
*i.e at lung level (↓ $Co_2$ & $H^+$) →↑Hb affinity to $O_2$, and at tissue level (↑$Co_2$ & H) →↓Hb $O_2$ affinity to give it to tissue.*

***$O_2$-Hb curve* isn't** *between $O_2$ tension and $O_2$ content as this content is variable from person to other according to amount of hemoglobin. However, the percentage saturation isn't varied from one to another.*


Increased Affinity
Acute alkalosis
Decreased $P_{CO_2}$
Decreased temperature
Low levels of 2,3 DPG
Carboxyhemoglobin
Methemoglobin
Abnormal hemoglobin
Normal
Decreased Affinity
Acute acidosis
High $CO_2$
Increased temperature
High levels of 2,3 DPG
Abnormal hemoglobin
Percent saturation hemoglobin
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
$PO_2$(torr) at pH 7.39

# Shift of the $O_2$ dissociation curve

| Shift to right | Shift to left |
| --- | --- |
| **Meanings:**<br>It means that at any $O_2$ tension the Hb is less saturated with $O_2$ and give $O_2$ to tissue (↓ affinity or unloading) | It means that at any $O_2$ tension the Hb is more saturated with $O_2$ so give less $O_2$ to tissue (↑ affinity or loading) |
| **Causes:**<br>(1) decrease $O_2$<br>(2) increase $Co_2$ (Bohr's effect)<br>(3) increase $H^+$ (acidosis or ↓pH)<br>(4) increase temperature (fever)<br>(5) increase 2,3 DPG .<br>(6) Pregnancy<br>(7) Exercise<br>(8) Anemia. | (1) increase $O_2$<br>(2) decrease $Co_2$<br>(3) decrease $H^+$ (alkalosis )<br>(4) decrease temperature<br>(5) decrease 2,3 DPG<br>(6) Fetal Hemoglobin<br>(7) CO poisoning.<br>(8) Polycythemia. |
| **Significance:**<br>This increase $O_2$ supply to active muscle during exercise. | This increases $O_2$ loading on Hb at the lung . |



↑ $O_2$ affinity so
↓ $O_2$ unloading
left shift
normal
right shift
↓ $pCO_2$, [$H^+$], temp, DPG
↑ pH
↓ [$PO_4^{3-}$]
met-Hb
CO-Hb
fetal-Hb
"P50"
↑ $pCO_2$, [$H^+$], temp, DPG
↓ pH
sulf-Hb
HbSS
↓ $O_2$ affinity so
↑ $O_2$ unloading
~ 27
Hb saturation (%)
$pO_2$ (mmHg)

**(1) *Effect of 2,3 DPG:***

- *2,3 Diphosphoglycerate is formed in RBCs by **anaerobic glycolysis**, and combines to the reduced Hb leading to ↓ Hb affinity to $O_2$. 2,3 DPG increased in anemia, muscular exercise, high altitude, increase in thyroid hormone(hyperthyroidism), growth hormones and androgens and in chronic hypoxia → ↑$O_2$ supply to tissue*

*- but in a **stored blood** →↓ 2,3 DPG →↓ $O_2$ supply to tissue of recipient. Also acidosis depress glycolysis and decrease 2,3DPG.*

**(2) *Effect of fetal Hb in newly born:***

*-Adult Hb **contains pair of (α)** and **pair of beta (B)** polypeptides which combine with 2,3 DPG → ↓ Hb affinity to $O_2$.*

*-Fetal Hb contains pair of alpha (α) and pair of gamma (γ) which can't combine with 2,3 DPG so → ↑ Hb affinity to $O_2$. This facilitates movement of $O_2$ from mother to fetus and keeps high $O_2$ in fetal Hb to be used under need.*

**(3) *Effect of muscular exercise:***

- *Muscular exercise increases $O_2$ supply to tissue (muscles) by **50 times** by the followings:*

*1- ↑ cardiac output by 6 times (from 5 to 30 L/min).*

*2- VD of blood vessels of skeletal muscles (sympathetic and metabolic) →↑$O_2$ supply by 3 times.*

*3- ↑ coefficient of $O_2$ utilization by muscles, the muscle take 15 ml $O_2$ from total 19 ml $O_2$/100 ml of arterial blood due to (↓ $O_2$ in tissue & shift of $O_2$ dissociation curve to Rt. as before) →↑$O_2$ supply by 3 times.*

** In **untreated diabetes** and **renal failure** there are shift to **right** due to associated **acidosis**.*

# P50 of Hemoglobin & factors influencing

**The P50 is** the **oxygen tension** at which **hemoglobin** is **50% saturated**. **The normal P50 is 26.7 mm Hg**.

Shifting the curve to the left or right has little effect on the SO2 in the normal range where the curve is fairly horizontal; a much greater effect is seen for values on the steeper part of the curve.

## Shifting of the Oxy-hemoglobin dissociation curve:

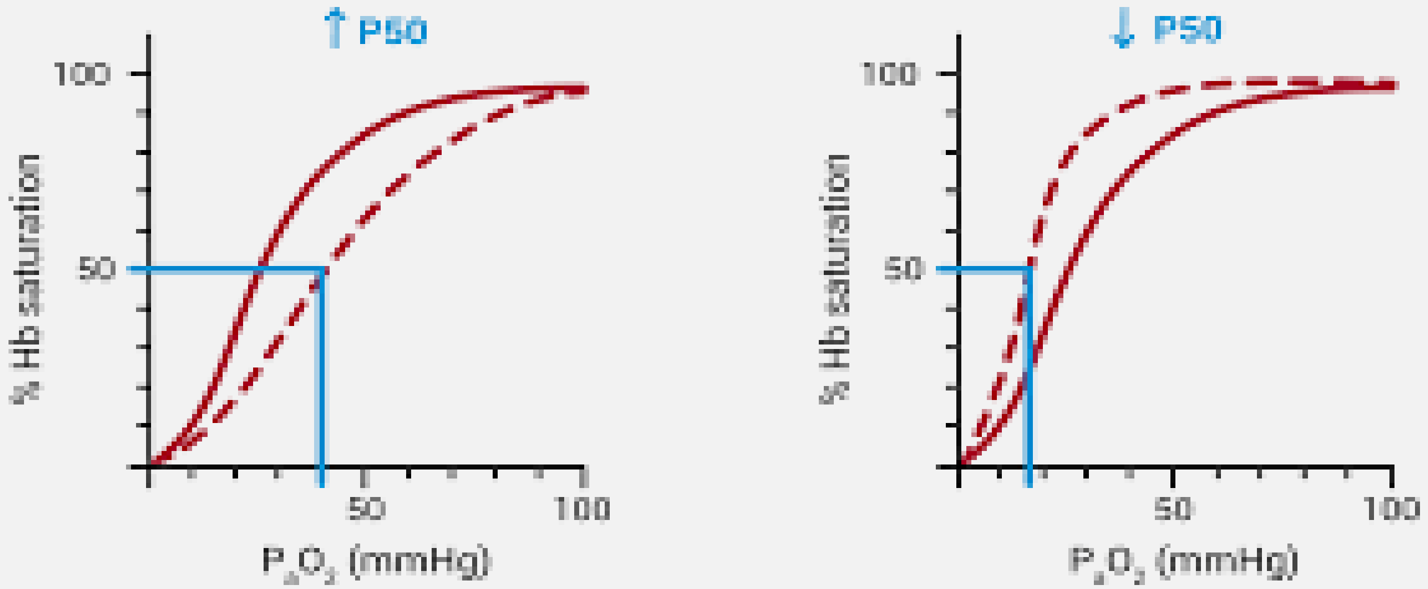
**A right-ward shift increases P50 and lowers hemoglobin's affinity** for oxygen, thus displacing oxygen from hemoglobin and releasing it to the tissues.

**A left-ward shift decreases P50 and increases hemoglobin's affinity** for oxygen, thus reducing its availability to the tissues.

N.B: Met-hemoglobinemia causes a **left-ward shift** in the curve.

Shift to **right**

Shift to **Left**



# Thank You