MEDICINE
KING SAUD UNIVERSITY

Physiology Team 436

Revised by
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Oxygen and Carbon Dioxide Transport

RESPIRATORY BLOCK

Red: very important.
Green: Doctor's notes.
Pink: formulas.
Yellow: numbers.
Gray: notes and explanation.

Physiology Team 436 – Respiratory Block Lecture 7

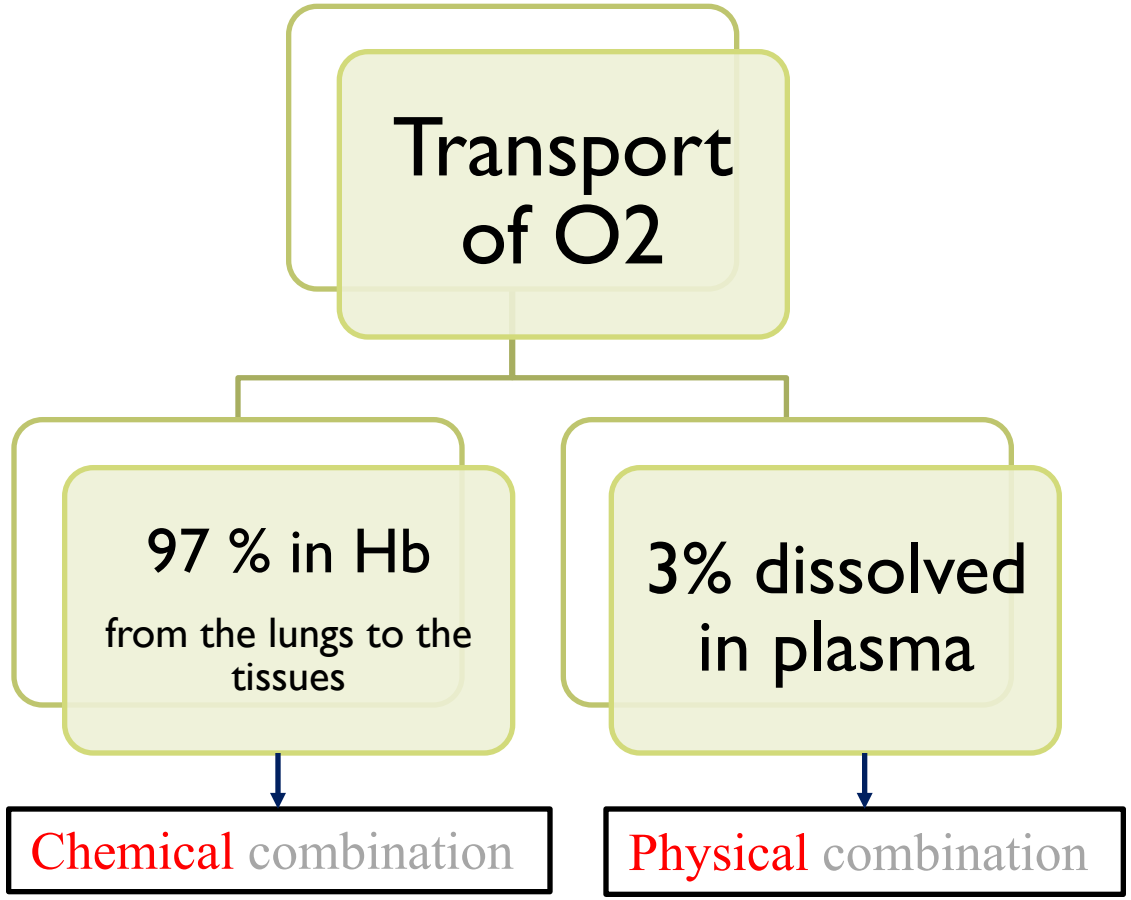
Lecture: If work is intended for initial studying.
Review: If work is intended for revision.

Objectives

- Understand the forms of oxygen transport in the blood, the importance of each.
- Differentiate between O2 capacity, O2 content and O2 saturation.
- Describe (Oxygen- hemoglobin dissociation curve)
- Define the P50 and its significance.
- How DPG, temperature, H+ ions and PCO2 affect affinity of O 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.

Transport of O2

The main function of blood: Transporting respiratory gases between the lungs and body (tissues).



Hb + Oxygen = Oxyhaemoglobin

Binding:

- O2 binds loosely and reversibly to Haem portion on hemoglobin.

Haem part:

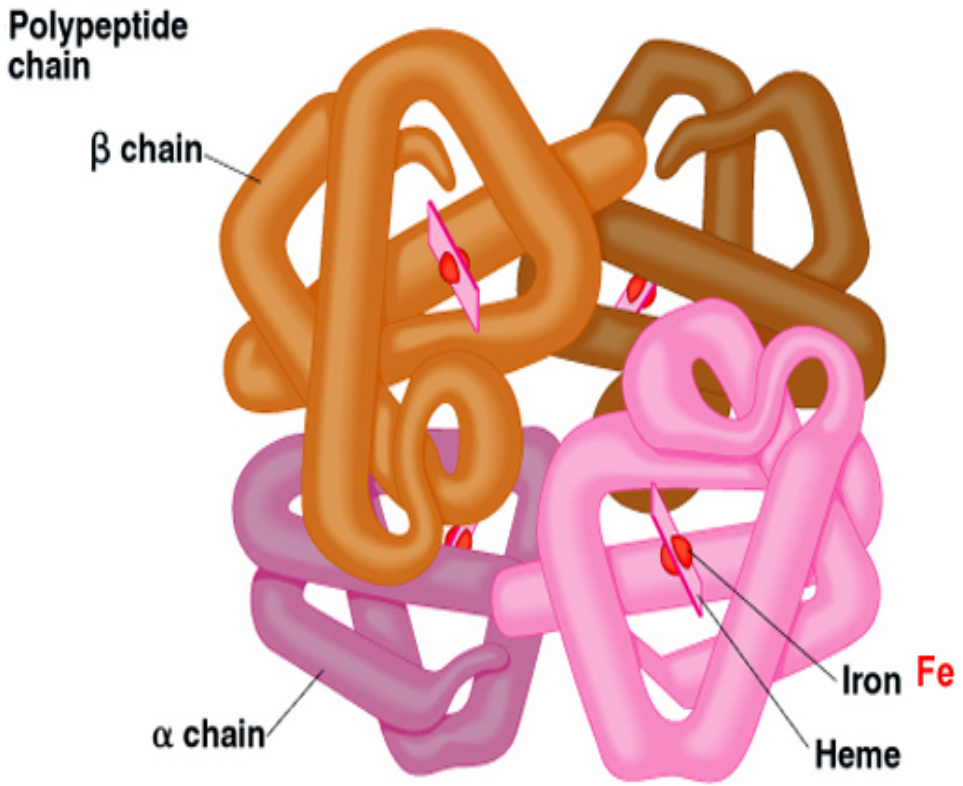
- The haem part of the Hb contains 4 atoms of iron → able to combine with a molecule of oxygen.

Result:

- Hemoglobin can carry 4 molecules of O2 or 8 atoms of O2: $Hb + 4O_2 \rightarrow Hb(O_2)_4$

Binding to Hemoglobin

- The amount of O_2 carried in the blood in oxyhaemoglobin depends on the amount of Hb present in the blood.
- The normal amount of Hb in young adults: 14-16 gm/dl of the blood.
- Each gram of Hb can bind with: 1.34 ml of O_2.
- Thus, if a person's Hb is 16 gm/dl of blood his blood can carry: 16 x 1.34 = 21.44 ml of O_2/dl



(b) Hemoglobin

هذا يفسر ليش يصير الاختناق وقت الحرايق , أول اكسيد الكربون (CO) يرتبط بال Hb بكمية عالية فبالتالي يمنع o2 من الأرتباط بال Hb .

Transport of O2 in the Dissolved State

- Oxygen combines with Hb is determined by: PO_2

- **If the PO2 is high:** oxygen binds with Hb
- Result: greater Hb saturation
- Example: pulmonary capillaries

At normal arterial PO2 of 95 mmHg, about 0.29 ml of oxygen is dissolved in each 100ml of blood.

If the PO2 is low: oxygen is released from Hb

- Result: lesser Hb saturation
- Example: tissue capillaries

When the PO2 of the blood falls to 40 mmHg in tissue capillaries, only 0.12 of oxygen remains dissolved. Therefore 0.17 ml of oxygen is normally transported in the dissolved state to the tissues per each 100 ml of blood

Anemia is reduction of hemoglobin; with anemia, there is shortness of breath.

O2 Capacity, Content and Saturation

- **O2 Content:** amount of O2 in blood (ml O2/100 ml blood)
- **O2-binding capacity:** maximum amount of O2 bound to hemoglobin (ml O2/100 ml blood) measured at 100% saturation.
- **Percent saturation:** percentage (%) of heme groups bound to O2
- **Percentage of Saturation of Hb** $= \frac{\text{oxygen content}}{\text{oxygen capacity}} \times 100$
- **Dissolved O2:** unbound O2 in blood (ml O2/100 ml blood)

The definitions are important to understand the curve.

Transport of Oxygen in Arterial Blood

- Blood is 100% saturated with O2: each gram of Hb carry 1.34 ml O2.
  So →O2 content = 15g Hb x 1.34 O2 = 20 ml.

- Blood is only 97% saturated with O2: contain 19.4 ml O2/100 ml blood

- Amount of oxygen released from the hemoglobin to the tissues is: 5ml O2/100ml blood
  So →O2 content in venous blood =19.4 - 5= 14.4 ml

- During strenuous (hard) exercise: the oxygen uptake by the tissue increases 3 folds

So 5x3 = 15 ml O2 /100 ml blood
So→ O2 content in venous blood =19.4 -15 = 4.4 ml O2/100ml blood.

- At rest: tissues (our bodies) consume 250 ml O2/min and produce 200 ml CO2

Both arterial blood and venous blood contain oxygen, but arterial blood is more oxygenated than venous blood.

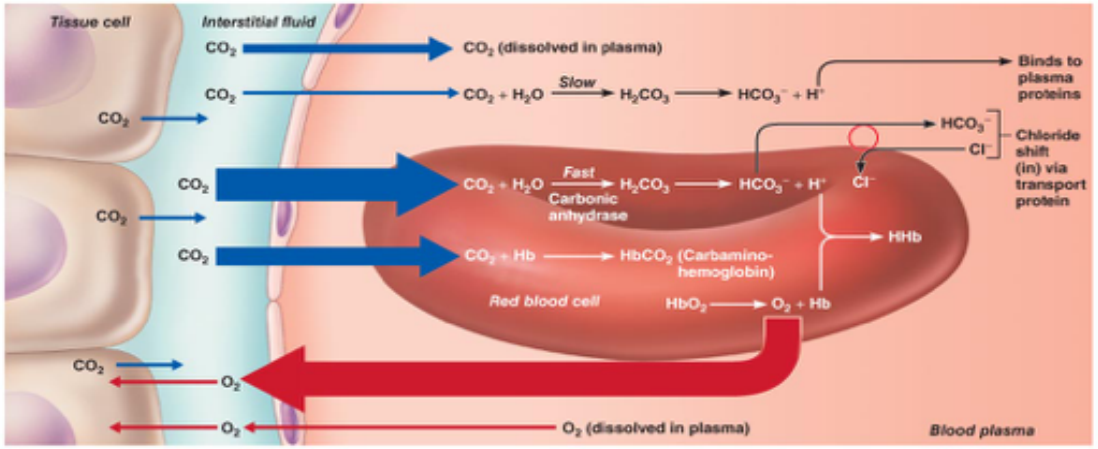
Transport of Carbon Dioxide in the Blood

- CO_2 is produced in large amounts in the body
- CO2 + globin part = carbaminohemoglobin
- Remember: O2 + Haem part = Oxyhaemoglobin
- CO_2 in normal resting conditions:

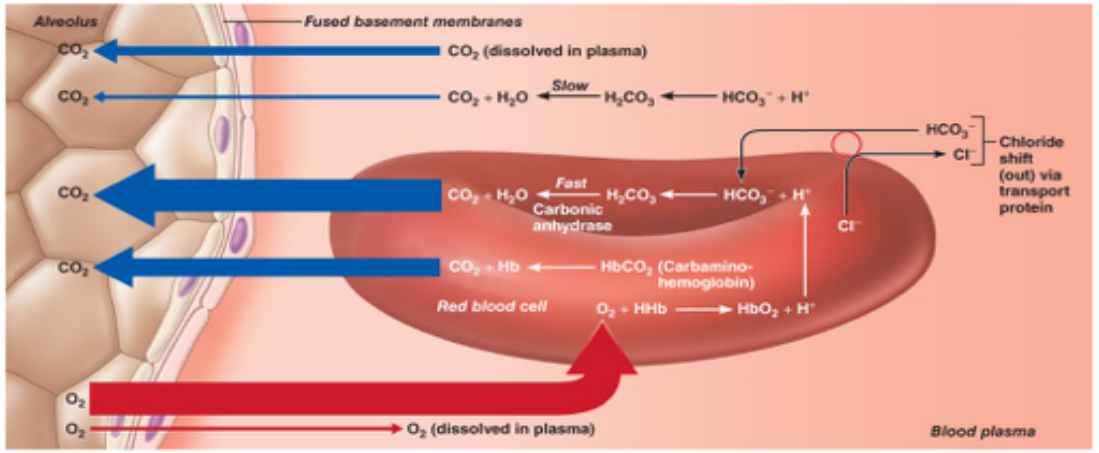
  4ml of CO_2/100 ml of deoxygenated blood

- CO_2 is carried in the blood in three forms:

1. 70% of CO_2 is transported in bicarbonate form.
2. 23% combines with the globin part of Hb to form carbamino-haemoglobin.
3. 7% is dissolved in plasma



(a) Oxygen release and carbon dioxide pickup at the tissues



(b) Oxygen pickup and carbon dioxide release in the lungs

Venous blood is not literally deoxygenated it only carries less oxygen than arterial blood and that is why we refer to is as deoxygenated blood

1- CO2 Transport (Bicarbonate) and Chloride Shift

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Tissue Capillaries

1. Co2 + water (in RBC) —Carbonic Anhydrase→ H2CO3 (carbonic acid)
2. H2CO3 —Dissociates→ HCO3 (bicarbonate)+ H+
3. H ion + hemoglobin → hydrogenhemoglobin

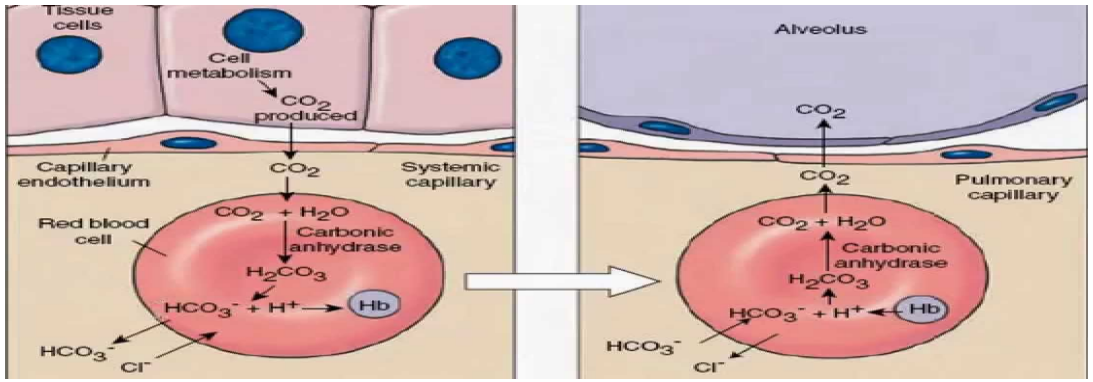
Bicarbonate Shift Phenomena:
Bicarbonate gets out of RBCs, and Cl enters to maintain negative charge of cell.

<u>If chloride does not enter the cell will shrink</u>

Pulmonary Capillaries

1. HCO3 (bicarbonate)+ H+ → H2CO3
2. H2CO3 —Carbonic Anhydrase→ Co2 + water

Bicarbonate enters RBC, Cl gets out to maintain negative charge of cell.



2- Transport of CO_2 Combined with Hb (Displacement of O2)

CO (Carbon Monoxide) binding:

- Co2 combines with Hb at the same point on the Hb molecule as does oxygen.
- It binds with Hb about 250 times as much as O2 (affinity of Hb to CO is 250 times of that to O2).
- It causes left shift of the O2-Hb curve (discussed later)

3- Transport of CO2 Dissolved in Plasma (7%)

- PCO_2 of venous blood is: 45 mm Hg (Higher because it is carrying it back to the lungs be exhaled out)
- PCO_2 of arterial blood is: 40 mmHg

- The amount of CO_2 dissolved in the blood at 45 mmHg is 2.7 ml/dl (2.7%)
- The amount of CO_2 dissolved at 40 mmHg is about 2.4 ml

- The difference between 2.7 and 2.4 is only 0.3 ml

- About 0.3 ml CO_2 / 100 ml of blood in the form of dissolved CO_2

dl = 100 ml

The Haldane Effect

- When oxygen binds with hemoglobin, carbon dioxide is released to increase CO2 transport.
- Binding of Hb with O2 at the lung causes the Hb to become a stronger acid, and this in turn displaces CO2 from the blood and into the alveoli.
- Change in blood acidity during CO2 transport:

  Arterial blood has a pH of 7.41, and the pH of venous blood (which has higher PCO2) falls to 7.37 (i.e. change of 0.04 units takes place).

  The pH decreases because of the carbonic acid formed when CO2 enters the blood.

Respiratory Exchange Ratio (Respiratory Quotient)

- $R = \frac{\text{Rate of CO2 output}}{\text{Rate of O2 uptake}}$
- Normally (person with normal diet) it is 4/5 (200\250) = 82% =0.825
- When Carbohydrate diet is used , R = 1 (every 1O2 consumed 1CO2 produced)
- When only fats are used, R=0.7

Very Important

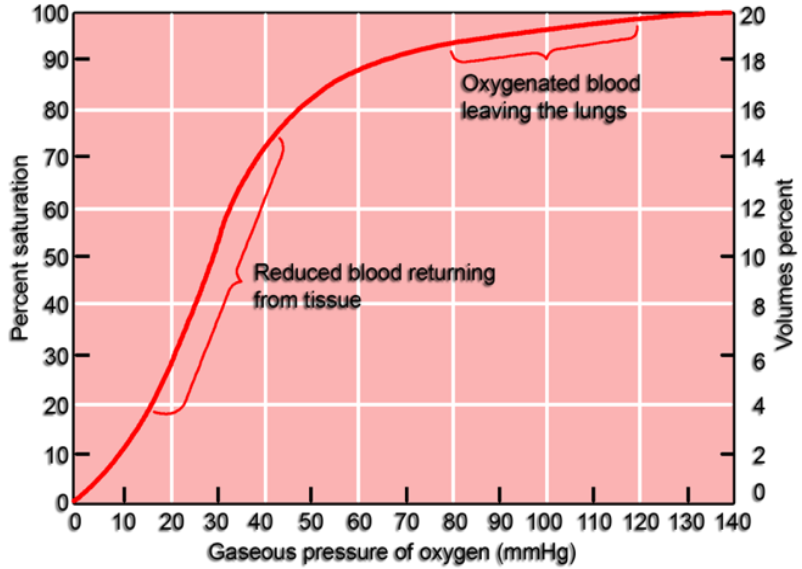
Oxygen-hemoglobin Dissociation Curve

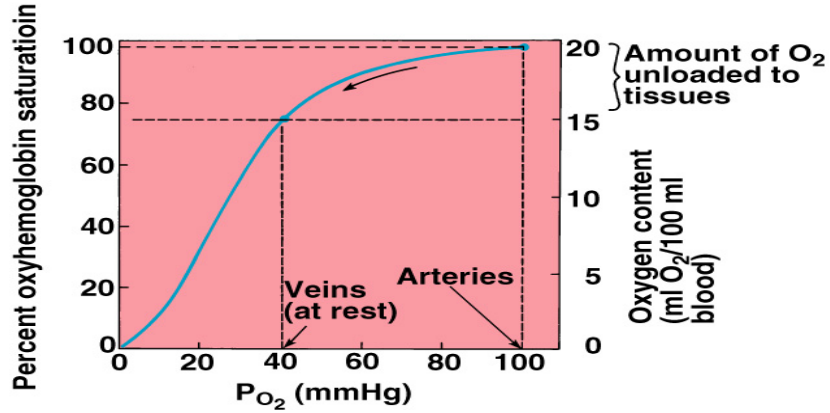
- **Curve Shape:** is S - shaped or sigmoid (not linear)

- **Represent:** relationship between the percent O_2 saturation of Hb and the partial pressure of O_2 (PO2)
- This curve is called the oxyhemoglobin saturation curve.

- **Relation:** shows progressive increase in the percentage saturation of the Hb with the increase in the PO2 in the blood.
- Higher PO2 results in greater Hb saturation.

	Arterial Blood	Venous Blood (returning from the tissues)
PO2	95 mmHg	40 mmHg
Saturation of Hb with O2	97%.	75%.





Shift of Oxygen-Hemoglobin Dissociation Curve

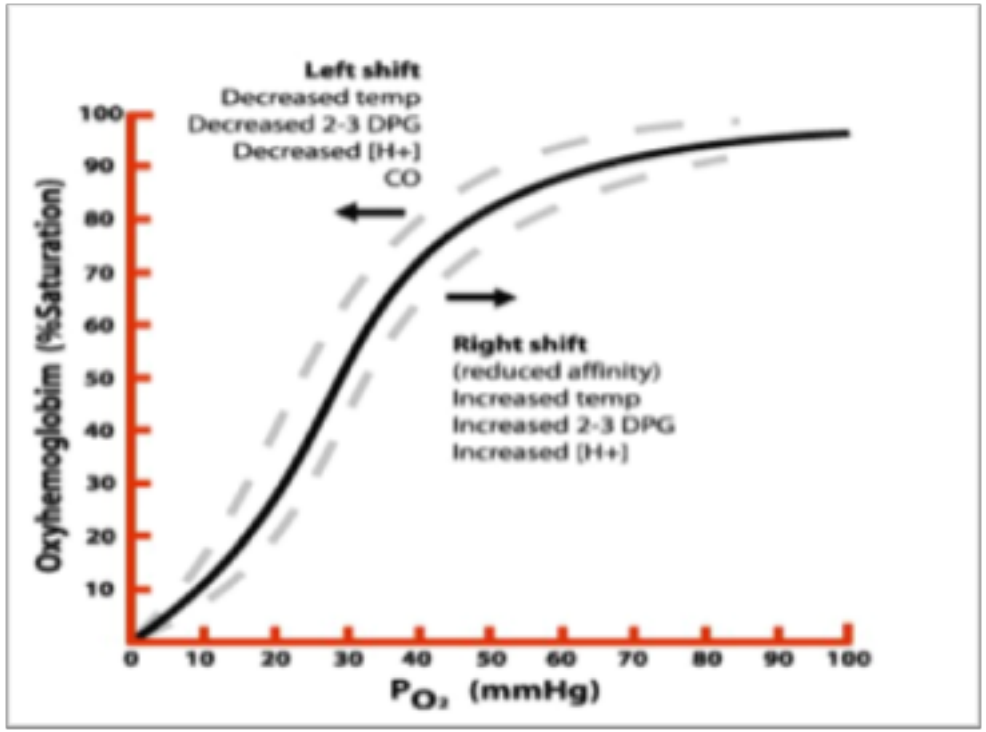
Shifted to the Left

Means:

- Hb affinity for oxygen is increased.

or

- Loading or attachment of oxygen to Hb increased.



Shifted to the Right

Means:

- O2 is dissociated or released (unloaded) to the tissues from Hb.

Definitions/Other Explanations:

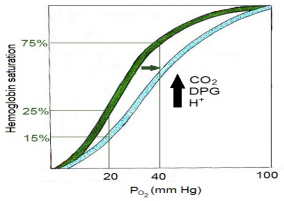
- Rt shift means the oxygen is unloaded to the tissues from Hb
- Lt shift means loading or attachment of oxygen to Hb.

Factors Shifting Oxygen-hemoglobin Dissociation Curve to the Right/Left (Affecting Affinity of HB for O2)

Factors shifting to the Right

Decreasing affinity

1. Increased PCO2 (Bohr effect)
2. Increased hydrogen ions (PH)
3. Increased temperature
4. Increased 2, 3 DPG 2,3 diphosphoglycerate:
   - Synthesized in RBCs from the glycolytic pathway
   - Facilitate the oxygen release
   - Binds tightly to reduced Hb



Exercise increases all of them

Factors shifting to the Left

Increasing affinity

1. Decreased CO2 (Bohr effect)
2. Decreased hydrogen ions (PH)
3. Decreased temperature
4. Decreased 2,3 DPG
5. Fetal haemoglobin (coming next)

Anemia and hypoxemia :

2,3 DPG increases the RBCs in case of these diseases (anemia and hypoxia) → thus serves as an important adaptive response in maintaining tissue oxygenation.

Right and Left Shifts (Bohr Effect)

- Effect of CO2 and H ions on the curve (Bohr effect):

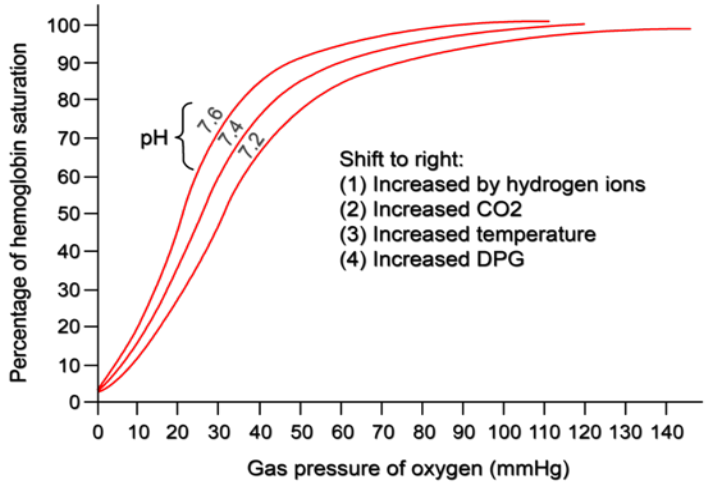
(Increased delivery of O2 to the tissues when CO2 and H ions shift the oxygen-hemoglobin dissociation curve)

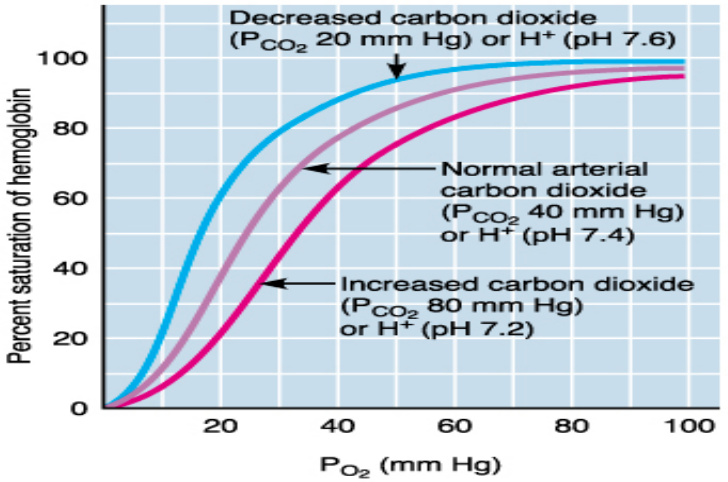
At Lungs:

- Movement of CO2 from blood to alveoli (where it will be exhaled out of the body) will **decrease** blood CO2 & H+ → shifting the curve to **left.**
- **Increased O2 affinity** of Hb allowing more O2 transportation into the **tissues.**

At Tissues:

- **Increase** CO2 & H+ in blood leads to → shifting the curve to **Right.**
- **Decreased** O2 affinity of Hb allowing more O2 transportation to the **tissues.**





الكلام في هذا السلايد ما يشرح الصور

Shift of Dissociation Curve During Exercise

- Fetal Hb: has a P50 of 20 mmHg in comparison to 27 mmHg of adult Hb.

P50: is the partial pressure of O2 at which 50% of Hb is saturated with O2.
↑ P50 means right shift (lower affinity for O2)
↓ P50 means left shift (higher affinity for O2)

- **Utilization Coefficient**: the percentage of the blood that gives up its oxygen as it passes through the tissue capillaries.
- **Utilization Coefficient** = $\frac{\text{O2 delivered to the tissues}}{\text{O2 content of arterial blood}}$

- Normally at rest = 5 ml/20 m, which = 25% .
- During exercise = 15 ml/20 ml, which = 75 % - 85%

Quiz

- https://www.onlineexambuilder.com/lecture-7/exam-129877

Link to Editing File

(Please be sure to check this file frequently for any edits or updates on all of our lectures.)

References:

- Girls' and boys' slides.
- Guyton and Hall Textbook of Medical Physiology (Thirteenth Edition.)

Thank you!

اعمل لترسم بسمة، اعمل لتمسح دمعة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

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