TRANSPORT OF BLOOD GASES

From The Lungs To The Tissues & Back

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Objectives

1. Specify in what forms O_2 & CO_2 are carried in the blood.
2. Describe the physiological significance of the oxy-hemoglobin dissociation curve.
3. Relates shifts in the position of this curve to affinity of Hb & oxygen loading / unloading in the blood.
4. Describe the effect of anemia & carbon monoxide poisoning on tissue oxygenation.
5. Identify the color of hemoglobin in the following forms: 1) oxyhemoglobin, 2) deoxyhemoglobin 3) caboxyhemoglobin.
6. Specify the significance of carbonic anhydrase in transport of CO2
7. Describe the "Bohr & Haldane Effects" illustrating the effect O_2 & CO_2 on the transport of each other.

TRANSPORT OF OXYGEN BY BLOOD

Oxygen Is Transported In Two Forms In The Blood—

1. physically dissolved [2 %]
2. chemically bound to the Hemoglobin, Hb, molecule [98 %]

OXYGEN PHYSICALLY DISSOLVED IN BLOOD

Compared to carbon dioxide, oxygen is relatively insoluble in the blood--

at PO2 = 100 mmHg,
100 ml blood contains 0.3 ml of O2

TRANSPORT OF OXYGEN BY BLOOD

Chemically Bound to the Hemoglobin Molecule

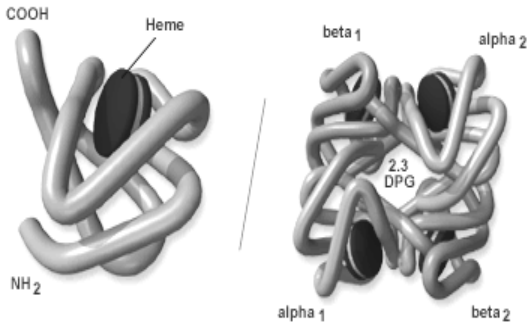
- Hb can combine rapidly & reversibly with O_2.
- The reversibility of this chemical reaction allows O_2 to be released to the tissues.

Hb + **O_2** ⇔ **O_2Hb**
deoxyhemoglobin oxygen oxyhemoglobin
a.k.a
reduced hemoglobin

THE STRUCTURE OF THE HEMOGLOBIN MOLECULE

4 SUBUNITS EACH MADE OF –

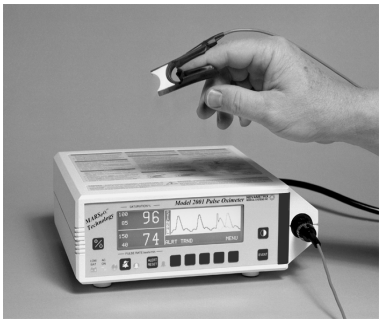
- a globular protein (soluble in aqueous solution) with an embedded heme group
- Heme group contains an iron atom responsible for the binding of oxygen



PULSE OXIMETER

A Non-invasive Device Measuring Percentage of Oxyhemoglobin in the arterial blood [Hb Saturation/SaO_2/SpO_2]

- colour of blood varies depending on how much oxygen it contains.
- pulse oximeter shines 2 beams of light through a finger/earlobe, one red (λ of 660 nm which you can see), one infrared light (λ of 940 nm which you don't see).
- absorption at these wavelengths differs between oxy & deoxy Hb form & their ratios allows calculation of % oxyHb in arterial blood, SaO_2. normal range = 95-100%



Other components of tissue absorb light as well. Pulse oximeter measures the max & min absorptions of a pulse, eliminating contribution of components other than Hb.

The Colors Of Hemoglobin

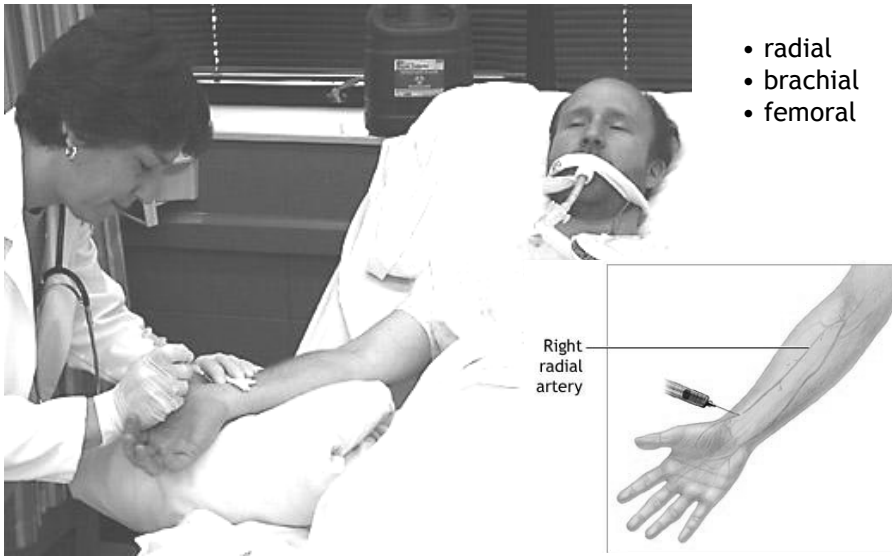
- Oxygenated Hb, HbO2 - bright red [e.g. normal arterial blood]
- Deoxygenated Hb, Hb- blue [same as the color of systemic veins carrying venous blood]
- Carboxyhemoglobin, COHb – cherry red [e.g. patient with CO poisoning]

Cyanosis = arterial blood with > 5g Hb/100ml in deoxygenated state
bluish / purple discoloration of nail beds and mucous membranes

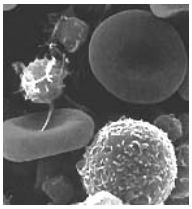
- Presence-- is a sign of poor transport of oxygen
- whereas absence-- does not indicate normal oxygen transport

  e.g. an anemic patient with low oxygen in the blood may not appear cyanotic because he may not have sufficient deoxygenated Hb to appear cyanotic. Also patients with abnormally high levels of Hb, such as those with polycythemia may appear cyanotic.

Sampling of Arterial Blood Gases



- radial
- brachial
- femoral



OXYGEN CONTENT OF BLOOD

TOTAL AMOUNT OF O_2 IN THE BLOOD
PHYSICALLY DISSOLVED & CHEMICALLY BOUND TO HB

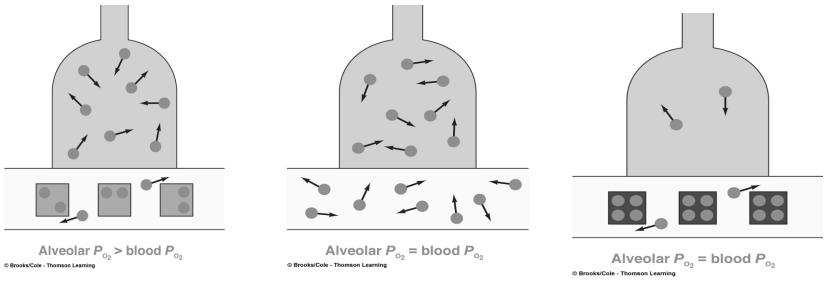
units = ml O_2 per 100 ml blood (volume %)

CaO_2 = 20 vol% CvO_2 = 15 vol%

Each time blood circulates through the systemic circulation
5 vol% O_2 diffuses to the tissues

DIFFUSION OF OXYGEN CONTINUES AS LONG AS THERE IS A PARTIAL PRESSURE GRADIENT FOR OXYGEN BETWEEN THE ALVEOLI & PLASMA

oxygen bound to Hb does not participate in diffusion



= O_2 molecule

= Partially saturated hemoglobin molecules

= Fully saturated hemoglobin molecules

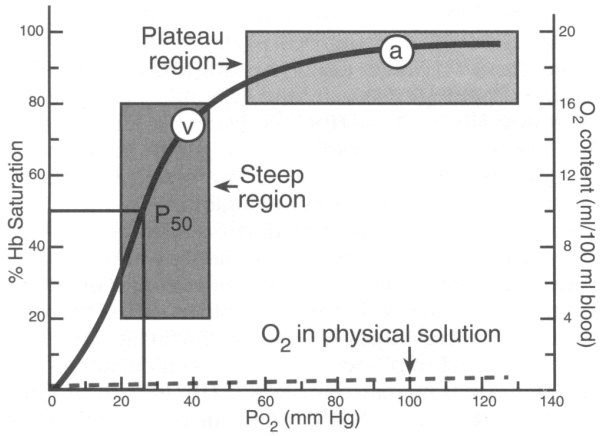
THE OXYHEMOGLOBIN DISSOCIATION CURVE

Loading Oxygen in the Lungs

•mixed venous blood enters the capillary at PO2=40; sat =75%. It equilibrates with alveolar gas PO2=100; sat=100%

• the plateau region, PO2 = 60-100, provides a safety margin for gas exchange in the lungs [disease/altitude]

•PO2 > 100 does not improve gas exchange

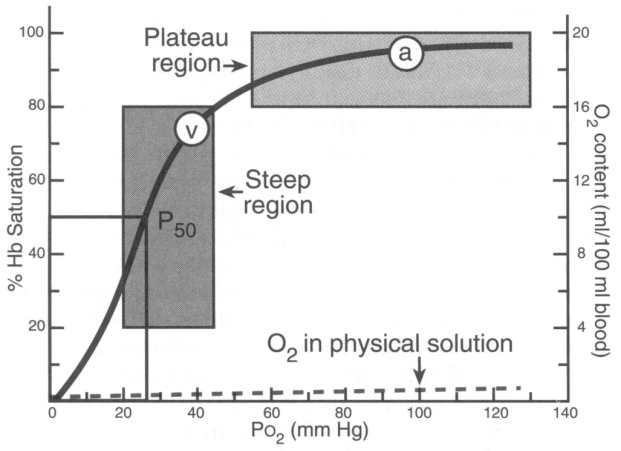


THE OXYHEMOGLOBIN DISSOCIATION CURVE

Unloading of Oxygen at the Tissues

•as blood courses through systemic capillaries O2 unbinds from the Hb; PO2 falls from 100 to 40

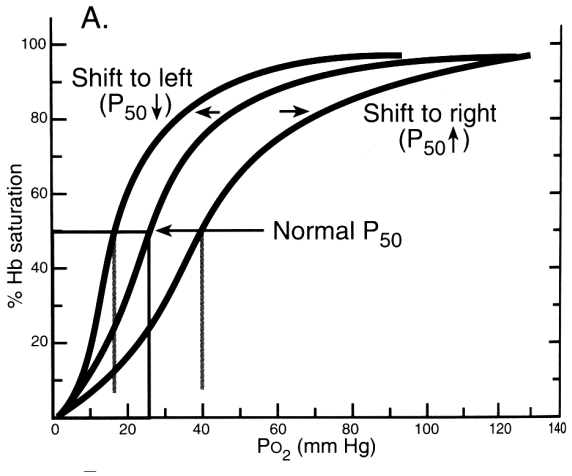
• in the steep region, PO2 = 40-10, a small decrease in tissue PO2 results in substantial unbinding of O2 from Hb i.e. O2 unloading from the blood. Tissue PO2 depends on tissue metabolic activity- on average= 40.



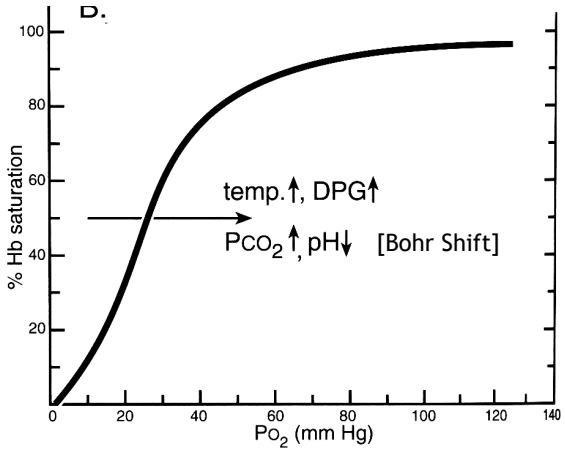
THE POSITION OF THE CURVE IS NOT FIXED

It is described by changes in affinity of Hb for Oxygen

- P50 = PO2 at which 50% Hb is bound to O2.
- at pH=7.4, Tb=37ºC PaCO2=40 mmHg P50=26.6mmHg
- ↑ affinity of Hb for O2 shifts the curve to the left
- ↓ affinity of Hb for O2 shifts the curve to the right



Increased temperature, PCO_2, H^+ & 2,3 BPG shift the curve to the right, opposite changes result in a left shift.



Niel Bohr Nobel Prize in Physics 1922-Did pioneering work on the atom & discovery of nuclear fission-Fled the Nazis for Sweden, U.K and then U.S.A.

His son- Aage Bohr won Nobel Prize in Physics in 1975.

His Father-Christian Bohr (1855-1911) Danish Physiologist" Bohr Effect".

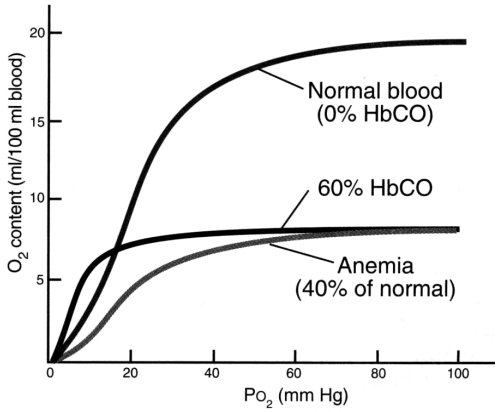
His brother- Harald Bohr, a great mathematician (famous for his skill in soccer)- no Nobel Prize for mathematics (see Field's Prize Why?

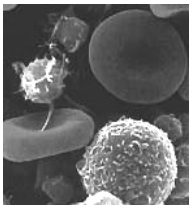
EFFECTS OF ANEMIA & CARBON MONOXIDE ON
The Oxyhemoglobin Dissociation Curve

Anemia
↓ Hb → ↓ O_2 carrying capacity of blood & ↓ O_2 content; SaO_2 remains normal

Carbon Monoxide [CO]
- affinity of Hb for CO is 250 fold↑ relative to O_2 competes with O2binding
- odorless/tasteless/ colorless gas
- L shift- interfere with O2 unloading at tissues
- severe tissue hypoxia

COHb=carboxyhemoglobin





CARBON DIOXIDE TRANSPORT BY BLOOD

Carbon dioxide is transported in three forms by blood--

1. Physically dissolved in blood (7%)
2. Physically dissolved as bicarbonate ion [HCO^-_3] (70%)
3. Chemically combined to the Hb molecule (23%)

BLOOD TRANSPORTS MORE CO2 THAN O2

CO2 is twenty fold more soluble than O2 in plasma

The total amount of CO_2 in the blood, [CO_2 content] reflects the sum of CO_2 in the blood in all three forms.

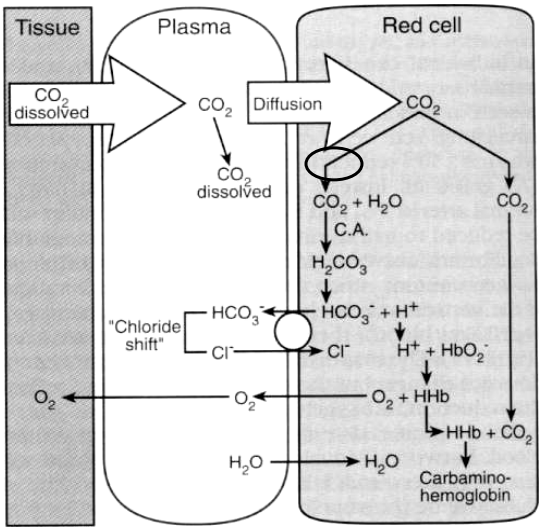
$CaCO_2$= 48 vol % $CvCO_2$=52 vol%

Each time blood circulates through the body, 4 vol% of CO_2 is removed from the tissues and delivered to the lungs to be exhaled.

THE KEY ENZYME IN TRANSPORT OF CARBON DIOXIDE IN BLOOD

CARBONIC ANHYDRASE

- an enzyme in the red blood cells--not in plasma
- accelerates formation of carbonic acid [H_2CO_3] from CO_2 + water over 1000 fold

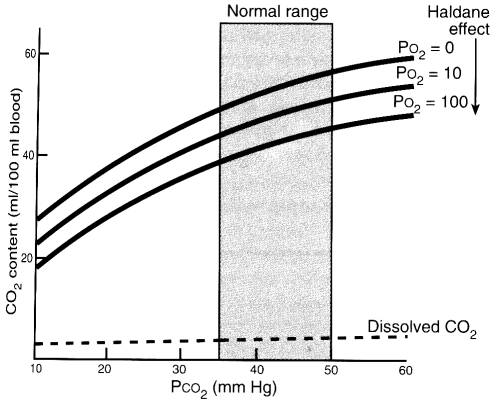


JBS Haldane [1892-1964]
son of John Scott Haldane

THE CARBON DIOXIDE DISSOCIATION CURVE

The Haldane Effect

- the CO_2 dissociation curve is influenced by the oxygenation state of Hb
- transport of CO_2 is dependent on O_2 release



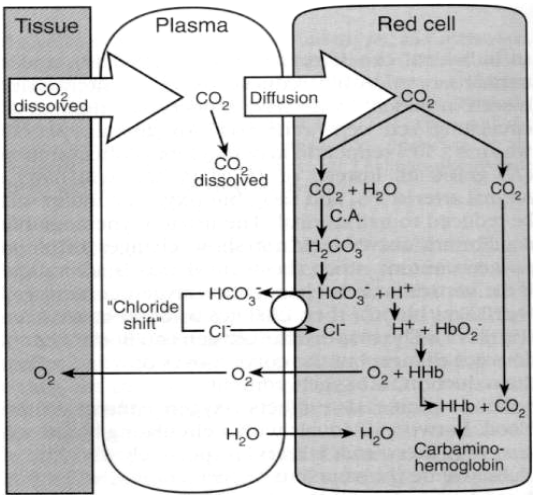
THE MOLECULAR BASIS FOR THE HALDANE EFFECT

Reduced Hb is better than oxygenated Hb in combining with--

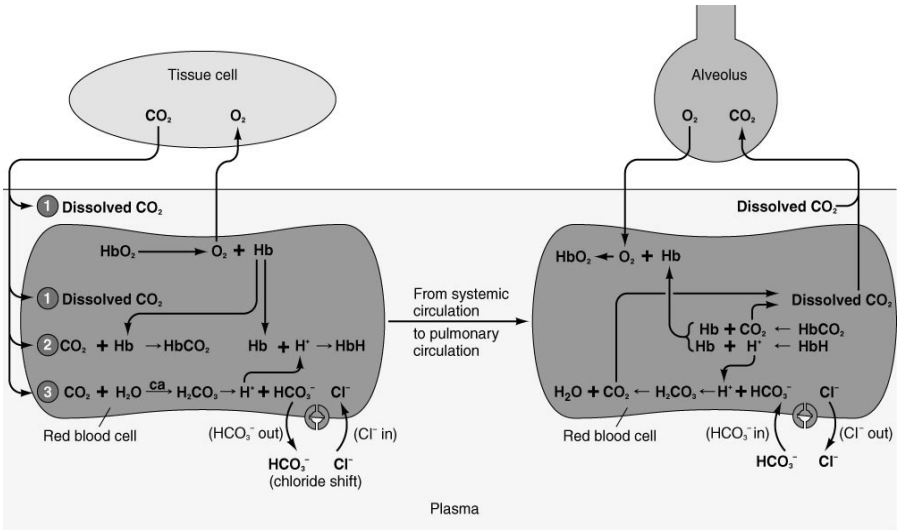
1. H^+ ions

2. CO_2 to form carbamino compounds

in turn assisting blood to load more CO_2 from the tissues



COMPARE BLOOD GAS TRANSPORT AT THE TISSUES RELATIVE TO THE LUNGS



ca = Carbonic anhydrase

Fig. 13-30, p. 485