

TRANSPORT OF BLOOD GASES

From The Lungs To The Tissues And Back

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. Describe the significance of carbonic anhydrase in transport of CO_2 .
6. 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

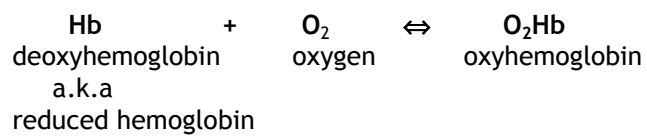
Compared to carbon dioxide, oxygen is relatively insoluble in the blood--

at $PO_2 = 100$ mmHg,
100 ml blood contains 0.3 ml of O_2

TRANSPORT OF OXYGEN BY BLOOD

Chemically Bound to the Hemoglobin Molecule

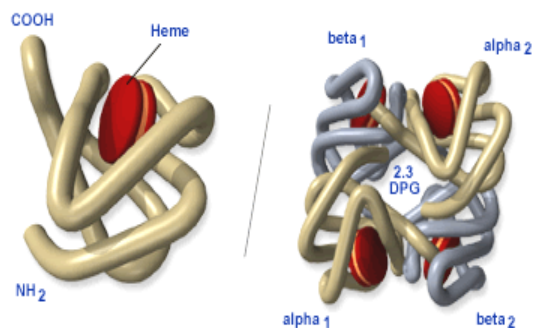
- Hb can combine rapidly & reversibly with O₂.
- The reversibility of this chemical reaction allows O₂ to be released to the tissues.



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



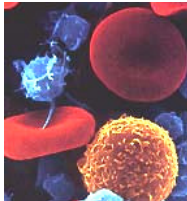
PULSE OXIMETER

A Non-invasive Device Measuring Percentage of Oxyhemoglobin in the arterial blood [Hb Saturation/SaO₂/SpO₂]

- 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 % oxyhemoglobin in arterial blood, SaO₂. Normal range = 95-100%



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



OXYGEN CONTENT OF BLOOD

TOTAL AMOUNT OF O₂ IN THE BLOOD

PHYSICALLY DISSOLVED & CHEMICALLY BOUND TO HB

units = ml O₂ per 100 ml blood (volume %)

CaO₂ = 20 vol%

CvO₂ = 15 vol%

Each time blood circulates through the systemic circulation
5 vol% O₂ 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

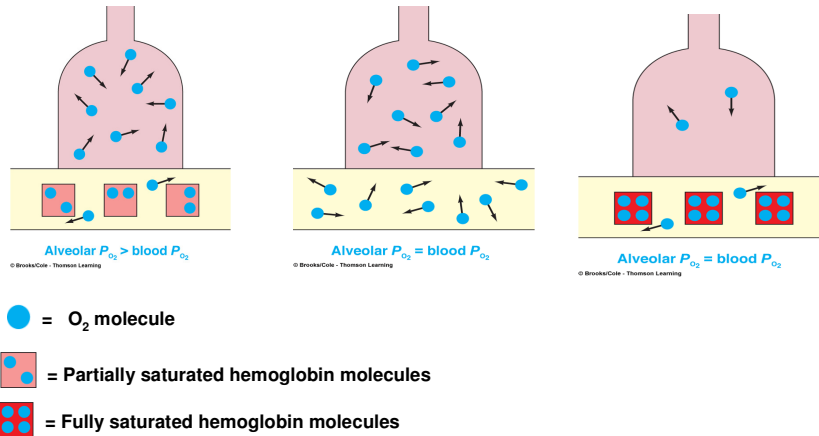


Fig. 13-28, p. 482

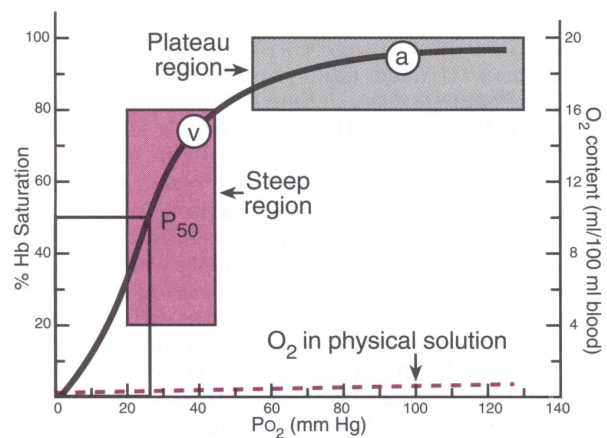
THE OXYHEMOGLOBIN DISSOCIATION CURVE

Loading Oxygen in the Lungs

- mixed venous blood enters the capillary at $PO_2=40$; sat = 75%. It equilibrates with alveolar gas $PO_2=100$; sat=100%

- the plateau region, $PO_2 = 60-100$, provides a safety margin for gas exchange in the lungs [disease/altitude]

- $PO_2 > 100$ does not improve gas exchange

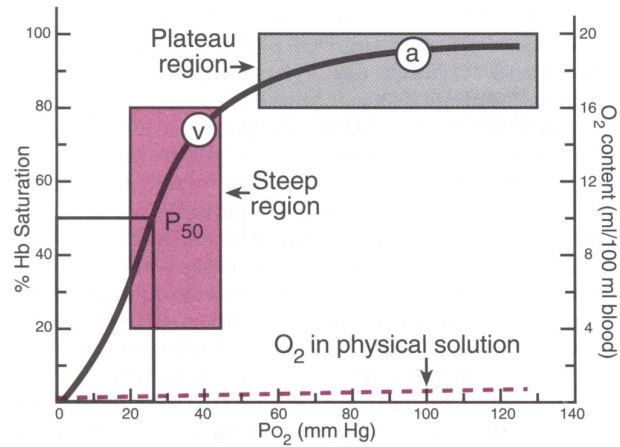


THE OXYHEMOGLOBIN DISSOCIATION CURVE

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

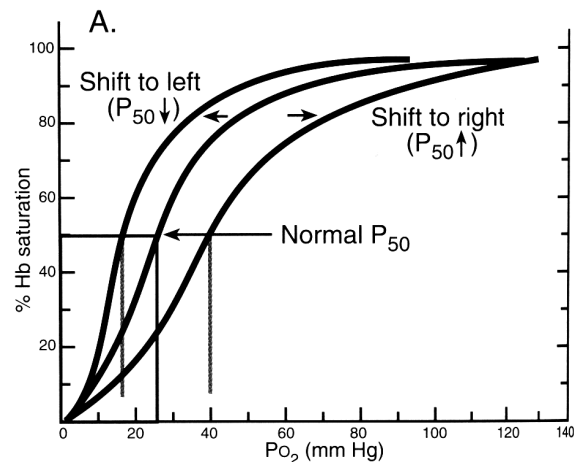
It is described by changes in affinity of Hb for Oxygen

- P₅₀ = PO₂ at which 50% Hb is bound to O₂.

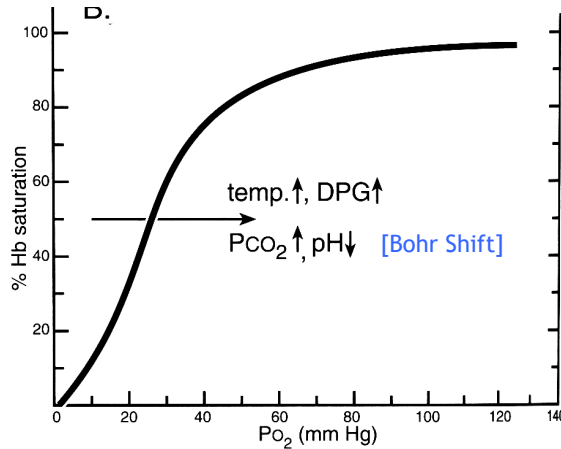
- at pH=7.4, T_b=37°C
PaCO₂=40 mmHg
P₅₀=26.6mmHg

- ↑ affinity of Hb for O₂ shifts the curve to the left

- ↓ affinity of Hb for O₂ shifts the curve to the right



Increased temperature, PCO₂, hydrogen ion & 2,3 BPG shift the curve to the right
Opposite changes result in a left shift.



Niel Bohr Nobel Prize in Physics 1922- pioneering work on the atom & discovery of nuclear fission- fled the Nazis for 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?

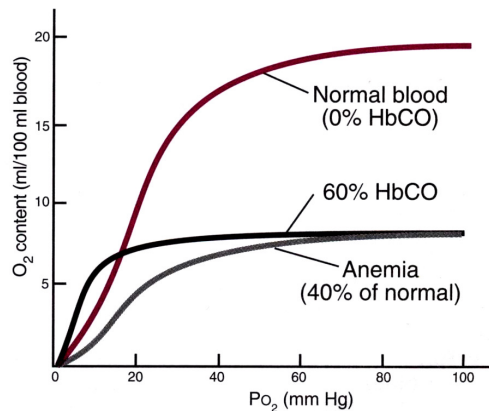
EFFECTS OF ANEMIA & CARBON MONOXIDE ON The Oxyhemoglobin Dissociation Curve

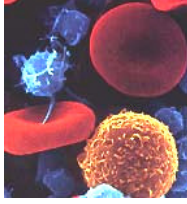
Anemia

↓ Hb → ↓ O₂ carrying capacity of blood &
 ↓ O₂ content; SaO₂ remains normal

Carbon Monoxide [CO]

- affinity of Hb for CO is 250 fold↑ relative to O₂ competes with O₂ binding
 - odorless / tasteless / colorless gas
 - L shift- interfere with O₂ unloading at tissues
 - severe tissue hypoxia
- HbCO=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 CO₂ in the blood, [CO₂ content] reflects the sum of CO₂ in the blood in all three forms.

CaCO₂= 48 vol %

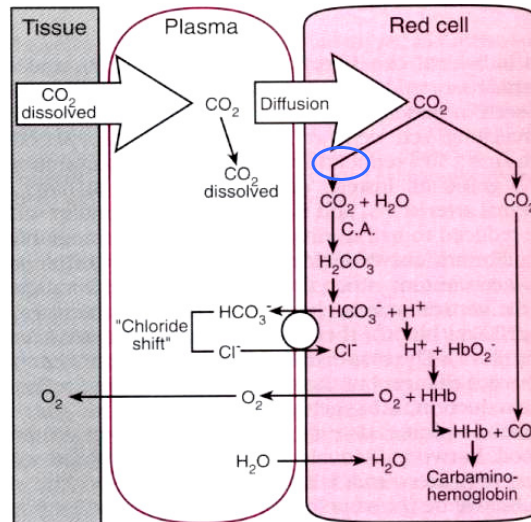
CvCO₂=52 vol%

Each time blood circulates through the body, 4 vol% of CO₂ 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

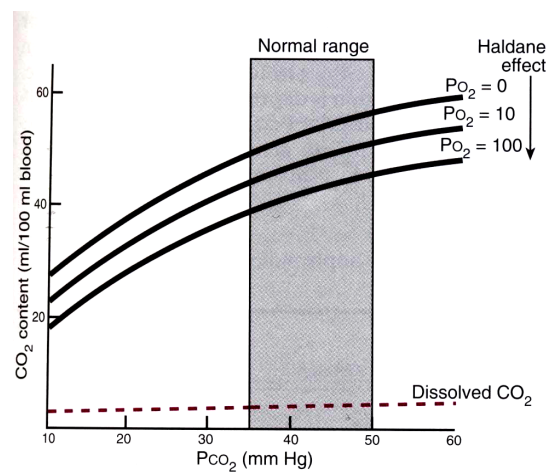
- accelerates formation of carbonic acid [H_2CO_3] from CO_2 + water over 1000 fold



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

THE CARBON DIOXIDE DISSOCIATION CURVE The Haldane Effect

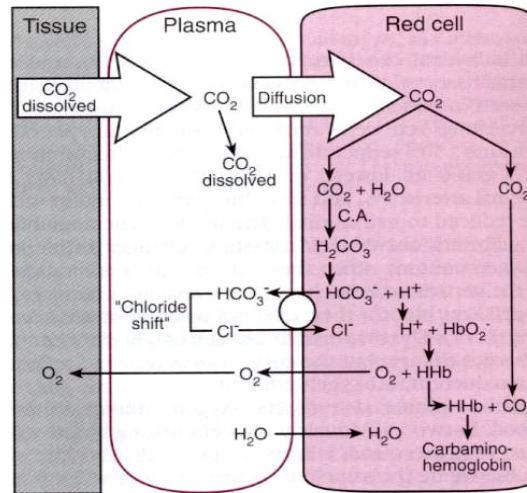
- the CO_2 dissociation curve is influenced by the oxygenation state of Hb
- transport of CO_2 is dependent on O_2 release



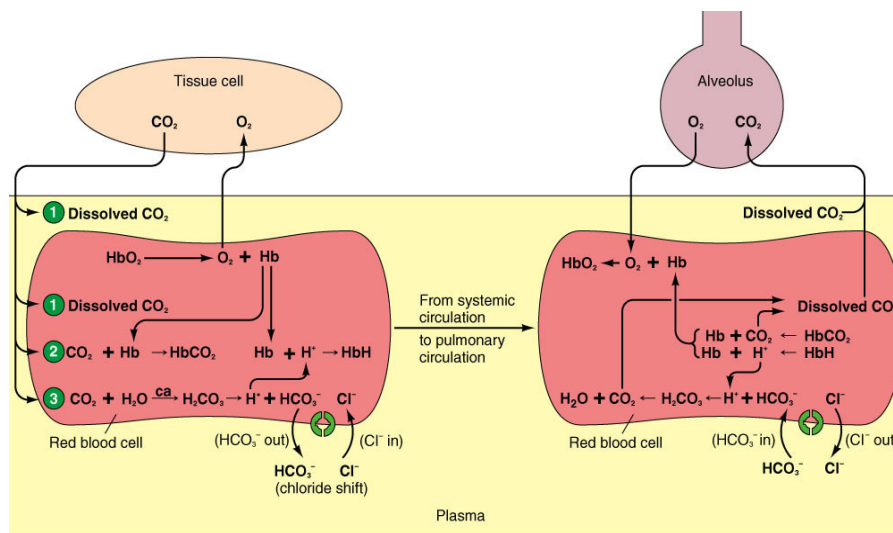
THE MOLECULAR BASIS FOR THE HALDANE EFFECT

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

1. H⁺ ions
 2. CO₂ to form carbamino compounds
- in turn assisting blood to load more CO₂ from the tissues



COMPARE BLOOD GAS TRANSPORT AT THE TISSUES RELATIVE TO THE LUNGS



ca = Carbonic anhydrase
© 2007 Thomson Higher Education

Fig. 13-30, p. 485