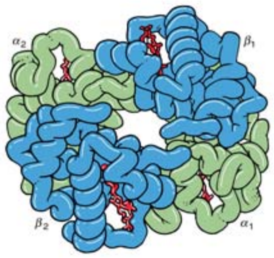
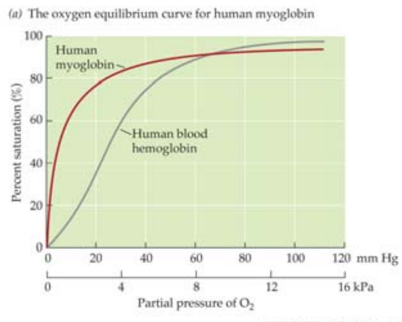
Lecture 23
10 March 2008

Vertebrate Physiology
ECOL 437 (MCB/VetSci 437)
Univ. of Arizona, spring 2008

Kevin Bonine & Kevin Oh



1. Gas Transport (Ch 20-22)



http://eebweb.arizona.edu/eeb_course_websites.htm

Housekeeping, 10 March 2008

Upcoming Readings
Fri 07 Mar: Ch 21 (respiration)

Mon 10 Mar: Ch 21, 22
Wed 12 Mar: Ch 21 (respiration, Jason Pilarski)
LAB Wed 12 Mar: no reading
Fri 14 Mar: EXAM TWO (through respiration)
SPRING BREAK

Lab discussion leaders: 02 April
1pm – none
3pm – Nina

Lab discussion leaders: 26 Mar
1pm – Vangie & Christina
3pm – Prasun & Ajay

Vertebrate
Gas Transport

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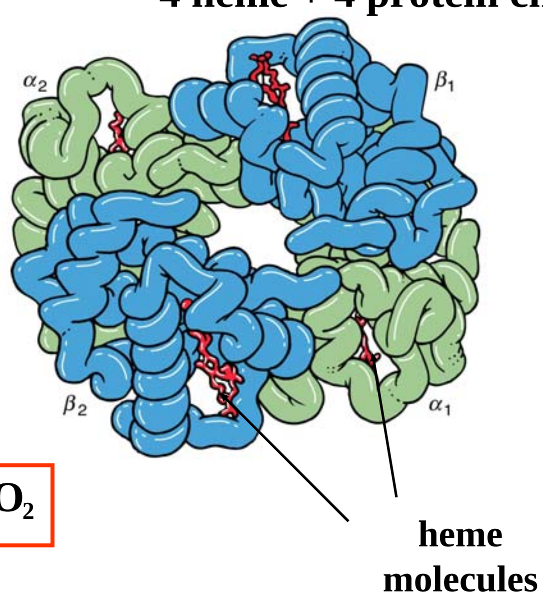
hemoglobin

4 heme + 4 protein chains



can carry 4 O_2

4

hemoglobin

Fetal hemoglobin:

gamma chains (not β) w/ higher affinity for O_2

(enhance O_2 transfer from mother to fetus)

Affinity for CO = 200 x's greater than for O_2

CO poisoning even at low partial pressures

Antarctic icefish lack pigment

low metabolic needs = low metabolism

high cardiac output, blood volume

large heart

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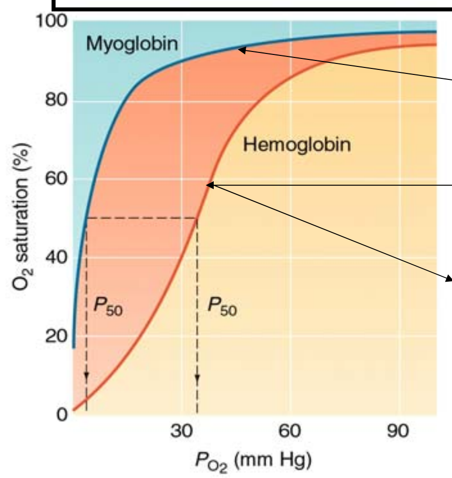
O_2 dissociation curve



hyperbolic

sigmoidal

- not need lots of O_2 to get near 100%

Cooperativity

-binding of 1st O_2 facilitates more binding

-oxygenation of 1st heme group increases affinity of remaining 3 for O_2

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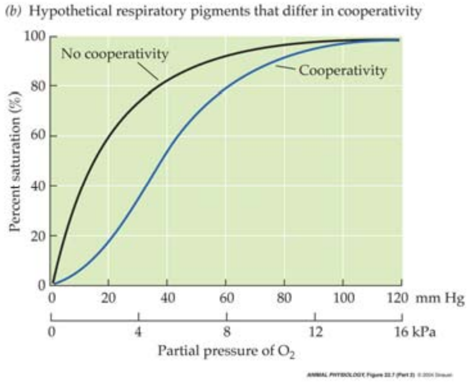
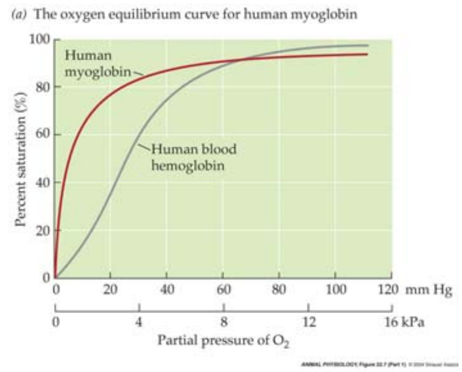


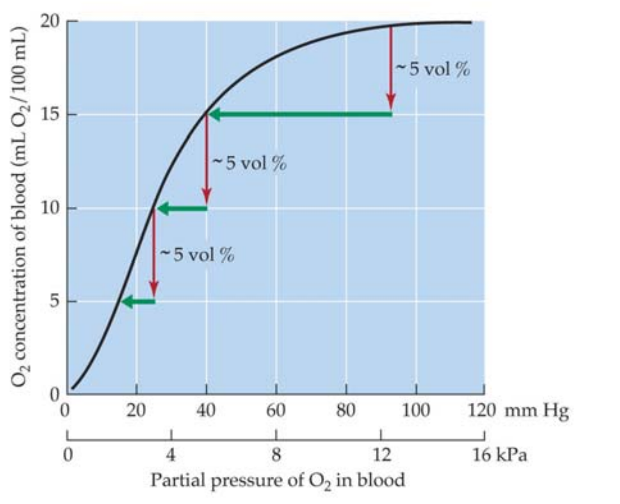
Hill et al., 2004, Fig. 22.7

Sigmoidal vs. Hyperbolic



Hill et al., 2004, Fig. 22.6

Steep Part of Oxygen Dissociation Curve:



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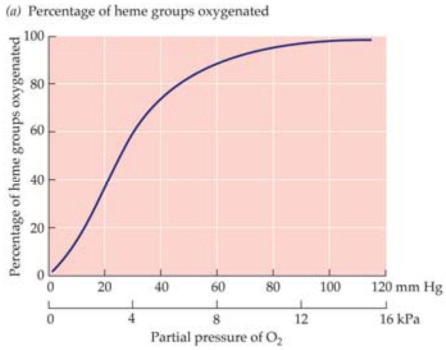
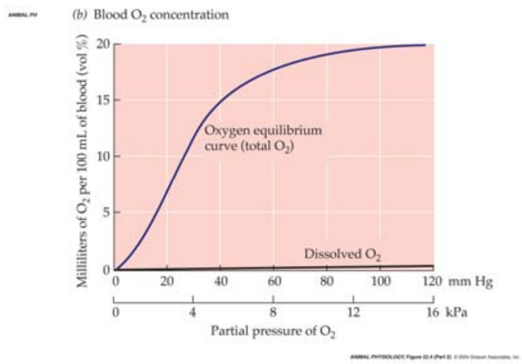


Hill et al., 2004, Fig. 22.4



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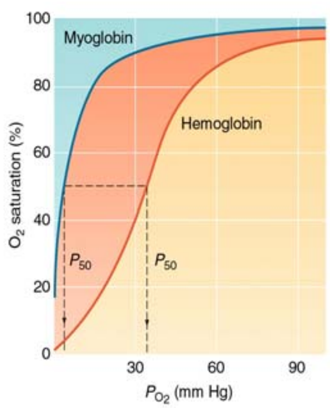
P_{50}- pp of O_2 at which pigment is 50% saturated



Pigment w/ High P_{50}:

- low affinity
- high rate of O_2 transfer to tissues

Pigment w/ Low P_{50}:

- high affinity
- high rate of O_2 uptake

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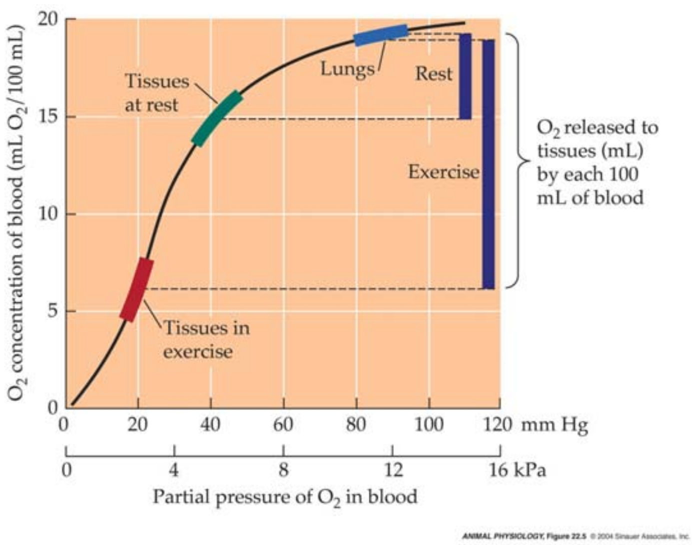
Hill et al., 2004, Fig. 22.5

Venous Reserve:



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Factors that reduce affinity

1. **low pH (increase [H+])**
2. **increase in CO_2**
3. **elevated Temp**
4. **organic compounds**

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Factors that reduce affinity

1. and 2. Increase in [CO_2] or [H+]

- Bohr effect

  CO_2 and H^+ bind to hemoglobin (allosteric site), which changes conformation of molecule and changes binding site for O_2

  at tissues:

  CO_2 binds to hemoglobin, decreasing affinity for O_2, allowing better delivery of O_2

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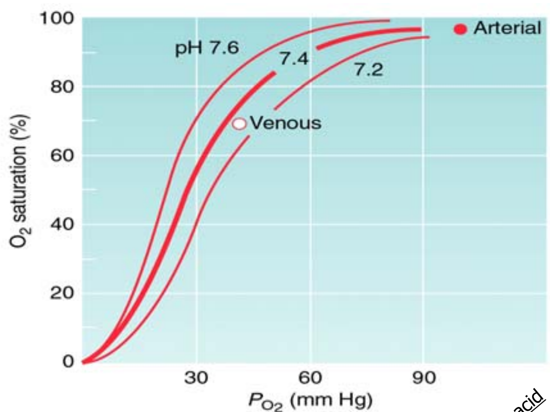

Bohr Effect

CO_2 enters blood at tissues
hemoglobin unloads O_2

CO_2 leaves blood at resp. surface
hemoglobin uptake O_2

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

(Carbonic acid: H_2CO_3; Bicarbonate: HCO_3^-)

Inc in Pco_2 ➡ inc [H+] ➡ dec pH ➡ reduces affinity

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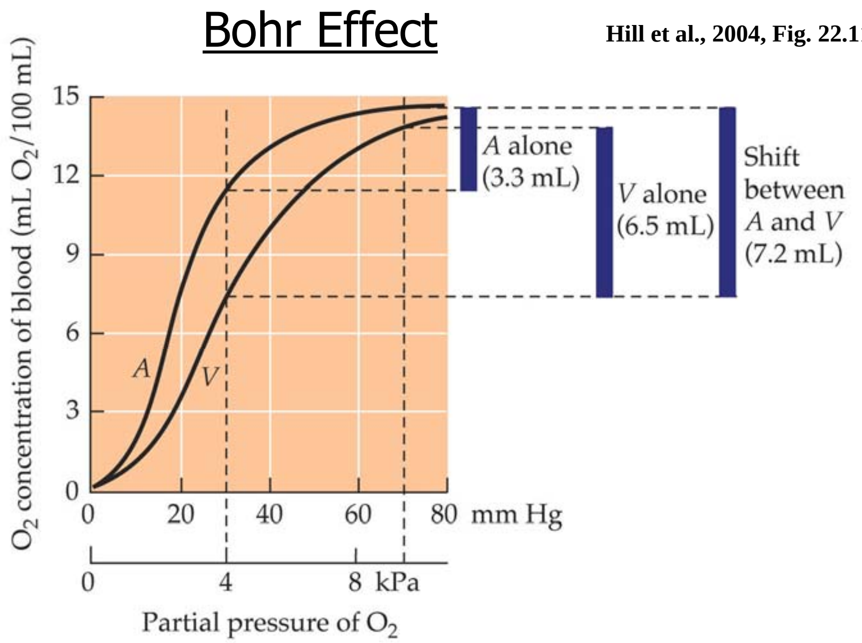
Bohr Effect

Hill et al., 2004, Fig. 22.11



ANIMAL PHYSIOLOGY, Figure 22.11 © 2004 Sinauer Associates, Inc.

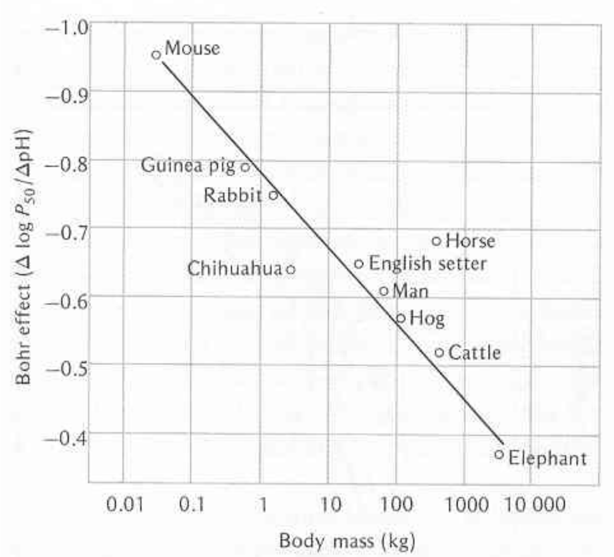


Figure 2.3 The Bohr shift of hemoglobin in relation to body size. The hemoglobin of small mammals has a greater Bohr shift (i.e., is more acid-sensitive) than the hemoglobin of large mammals and, therefore, can release more oxygen at a given P_{O_2}. [Riggs 1960]

Bohr shift as a function of body size

(small animals with greater Bohr shift [more acid sensitive] so can more readily leave oxygen at tissues at given PO)

Knut Schmidt_Nielsen 1997

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Factors that reduce affinity

4. organic compounds

- organophosphates in erythrocytes differ among spp.

  mammals: 2,3 DPG

  birds: IP_3

  fish: ATP, GTP

- bind to hemoglobin as allosteric effectors
- used to maintain O_2 affinity under hypoxic conditions

  at high altitude (low blood [O_2]) → increase 2,3 DPG to increase delivery of O_2 to tissues?

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Carbon Dioxide Transport

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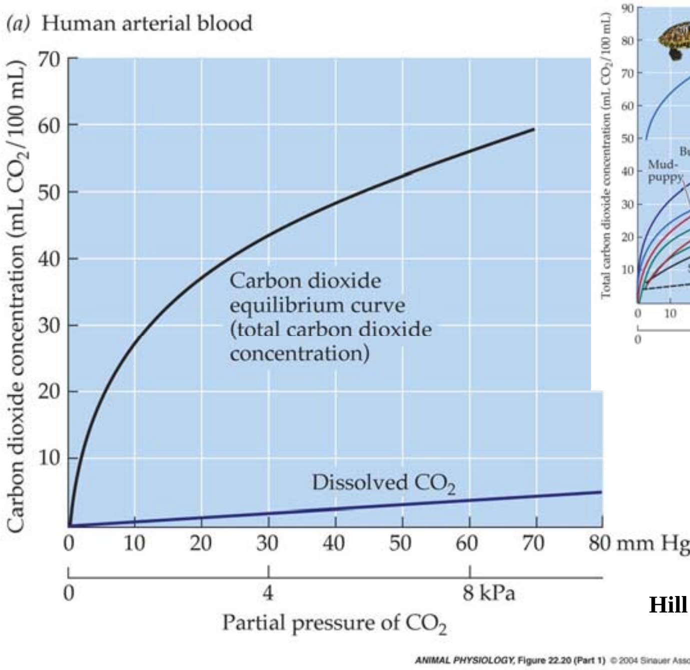

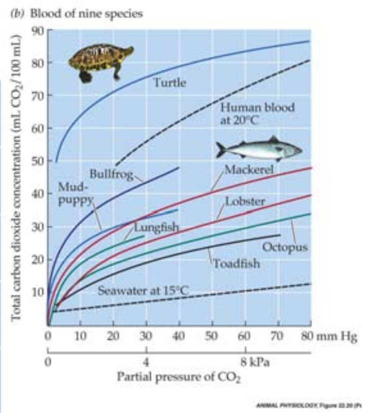

Hill et al., 2004, Fig. 22.20

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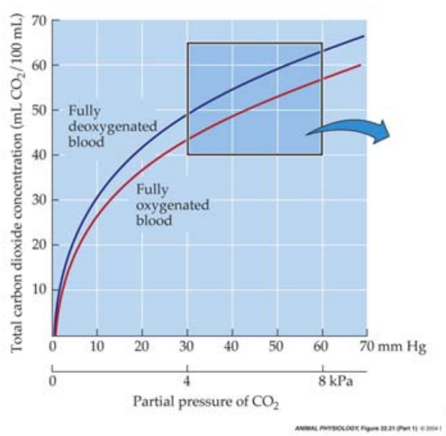
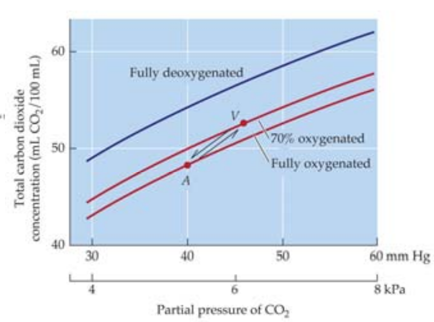


Hill et al., 2004, Fig. 22.21



CO_2 transport in blood

carbonic acid: H_2CO_3; bicarbonate: HCO^-_3

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO^-_3$$

$$HCO^-_3 \leftrightarrow H^+ + CO^{2-}_3$$

carbonate: CO^{2-}_3

$$CO_2 + OH^- \leftrightarrow HCO^-_3$$

Proportions of CO_2 , HCO^-_3 depend on pH, T, ionic strength of blood

<u>At normal pH, Temp</u>:

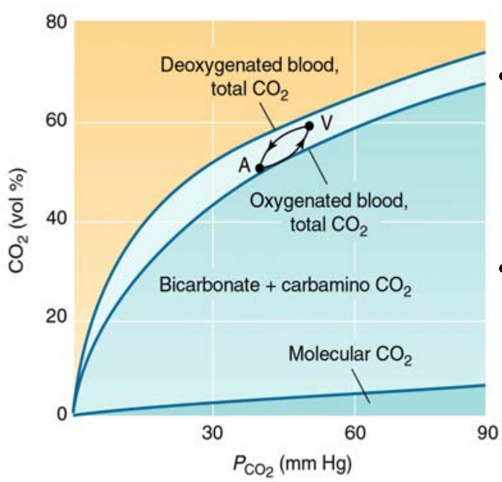
80% of CO_2 in form of bicarbonate ion HCO^-_3

5-10% dissolved in blood

10% in form of carbamino groups

(bound to amino groups of hemoglobin)

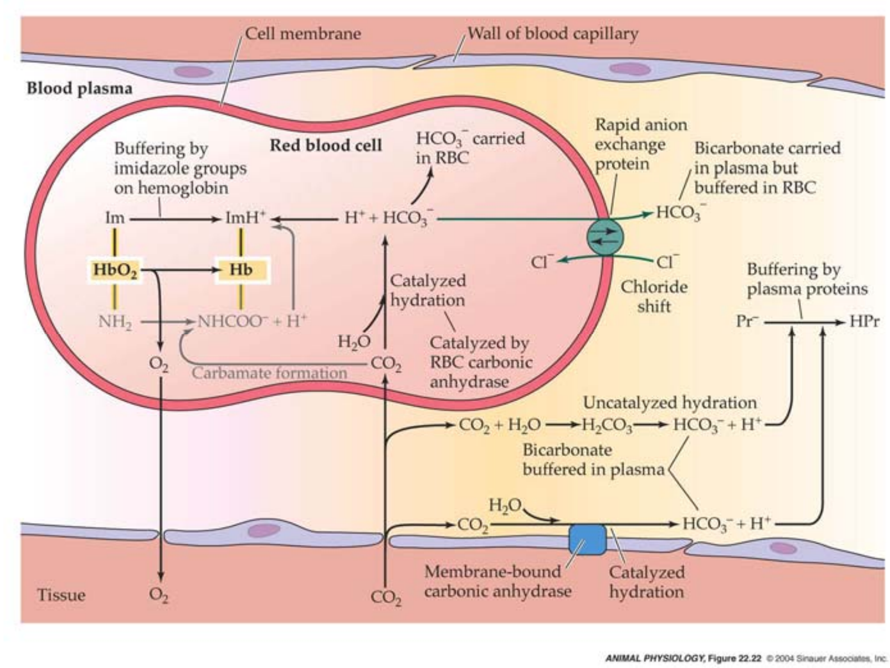
<u>Haldane effect</u>



- deox hemo has high affinity for H^+ creating inc. $[HCO_3^-]$ in blood (more CO_2)
- recall equations on previous slide

Carbon Dioxide Transport:

Hill et al., 2004, Fig. 22.22



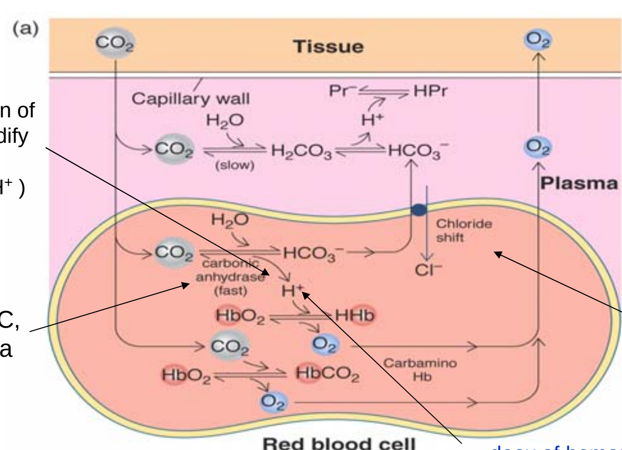
CO_2 transfer at tissue

- enters/leaves blood as CO_2 (more rapid diffusion)
- passes thru RBCs
- CO_2 produced = O_2 released → no change in pH

-Chloride Shift
-Carbonic Anhydrase

oxygenation of hemo: acidify interior (release H^+)

only in RBC, not plasma



Band III protein

maintain charge balance

deox of hemo: increase pH (bind H^+)

(13-10)

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