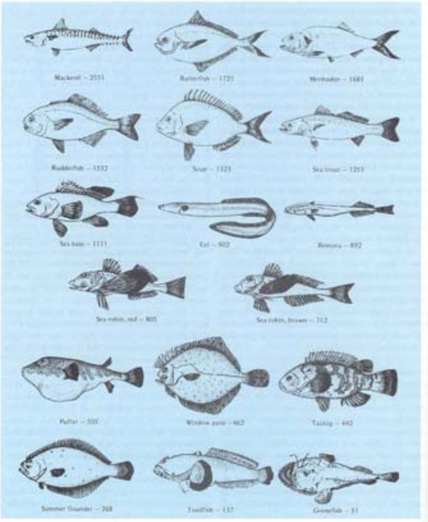
Lecture 22
07 March 2008

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

Kevin Bonine & Kevin Oh

1. Respiration (Ch 20-21)



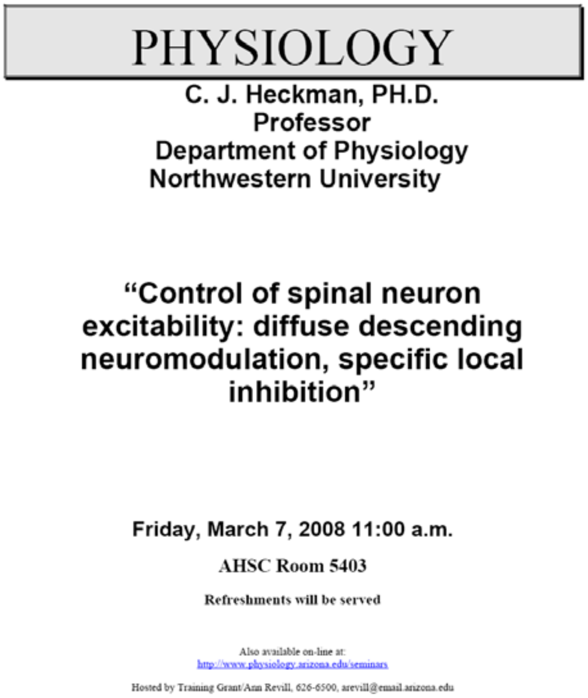
http://eebweb.arizona.edu/eeb_course_websites.htm

Housekeeping, 07 March 2008

Upcoming Readings
Fri 07 Mar: Ch 21 (respiration)

Mon 10 Mar: Ch 21, 22
Wed 12 Mar: Ch 23 (circulation)
LAB Wed 12 Mar: no reading
Fri 14 Mar: EXAM TWO (through respiration)
SPRING BREAK

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



PHYSIOLOGY

C. J. Heckman, PH.D.
Professor
Department of Physiology
Northwestern University

“Control of spinal neuron excitability: diffuse descending neuromodulation, specific local inhibition”

Friday, March 7, 2008 11:00 a.m.

AHSC Room 5403

Refreshments will be served

Also available on-line at:
http://www.physiology.arizona.edu/seminars

Hosted by Training Grant/Ann Revill, 626-6500, arevill@email.arizona.edu

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The Edges of Life Lecture Series

The Edges of Life – 7pm at Centennial Hall

Wednesday, March 5
Life's Technological Edge: The Singularity is Near: When Humans Transcend Biology
Ray Kurzweil, *via Teleportec Teleporter*
Founder, Chairman and Chief Executive Officer, Kurzweil Technologies

Humanity is on the edge of a vast transformation, when what it means to be human will be both enriched and challenged. Inventor and futurist Ray Kurzweil will introduce this radically optimistic singularity, an era when we break our genetic shackles to create a nonbiological intelligence trillions of times more powerful than today. In this new world, humans will transcend biological limitations to achieve entirely new levels of progress and longevity.

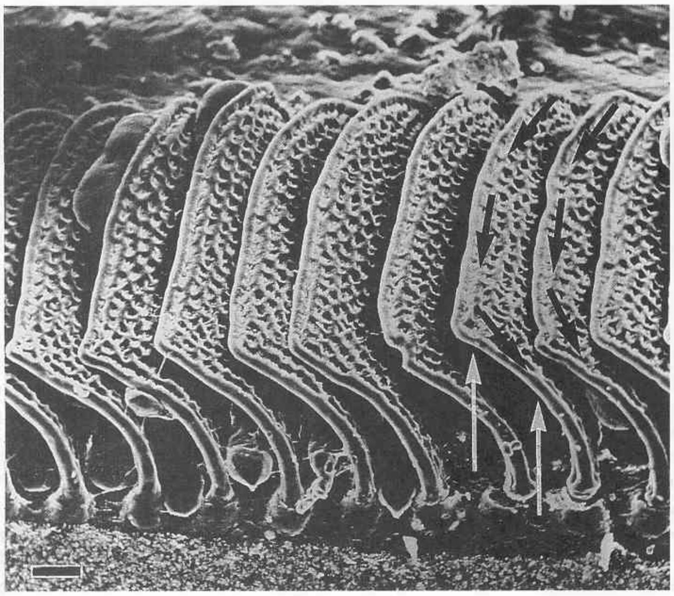
This lecture co-sponsored by: UA College of Engineering and UA College of Science

These do not count as physiology lectures.

Vertebrate

Respiration

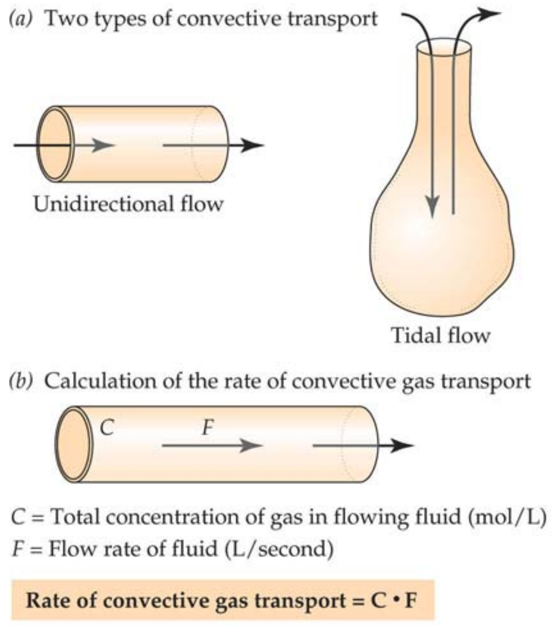
Con't



FISH GILL Scanning electron micrograph of gill filaments of a sturgeon (*Acipenser transmontanus*). White arrows show the direction of water flow and black arrows the direction of blood flow. The bar in the lower left corner represents 0.05 mm. [Burggren et al. 1979; courtesy of Warren W. Burggren, University of Massachusetts]

Fish Gill

Knut Schmidt_Nielsen 1997

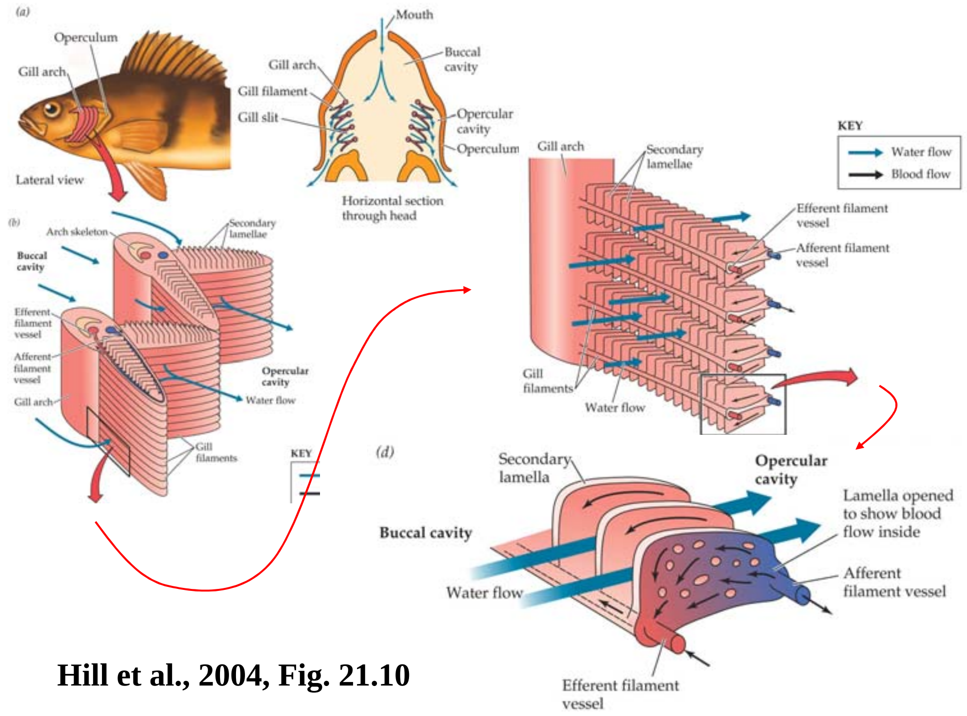


C = Total concentration of gas in flowing fluid (mol/L)
F = Flow rate of fluid (L/second)

Rate of convective gas transport = C • F

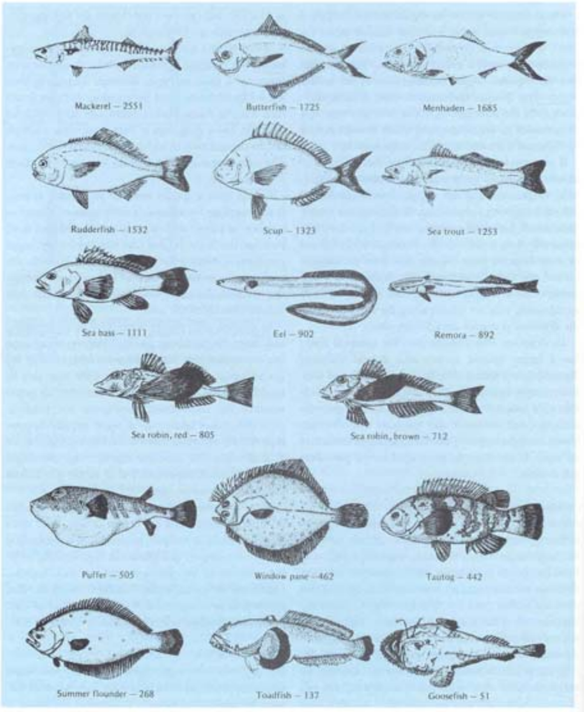
Hill et al., 2004, Fig. 20.3

ANIMAL PHYSIOLOGY, Figure 20.3 © 2004 Sinauer Associates, Inc.



Hill et al., 2004, Fig. 21.10

Relative Gill Surface Area in Fishes



Knut Schmidt_Nielsen 1997

Fish Gill

-breathing in water

-need much higher ventilation rate

-unidirectional

-pump water across gills (or ram ventilation)

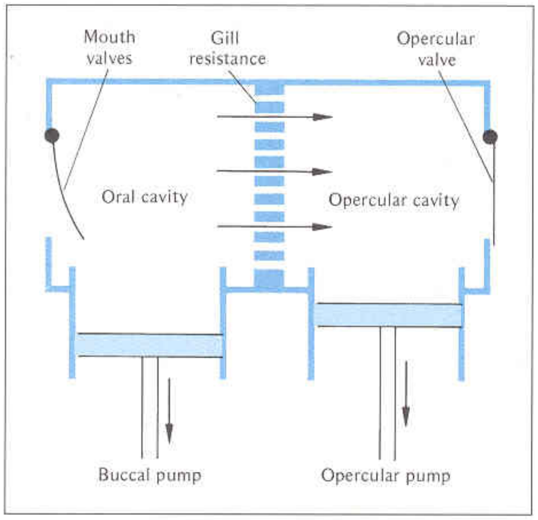


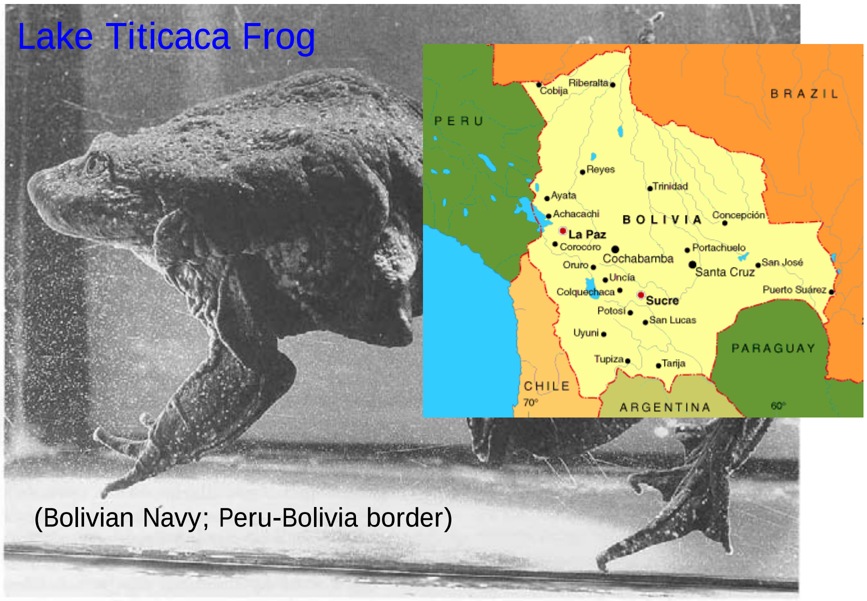
Figure 1.9 Water is pumped over the gills of a fish by a dual pumping system. With the aid of suitable valves, the pumps provide a unidirectional flow of water over the gill surface. [Hughes 1960]

Knut Schmidt_Nielsen 1997

Rate of diffusion depends on molecular weight (Graham's Law)

	Air		Water
O_2 solubility		>	
O_2 rate of diffusion		>	
Weight of medium (amt. needed to get O_2)		<	
Movement of medium	tidal (take in, expel)		unidirectional (less energy required)

Lake Titicaca Frog



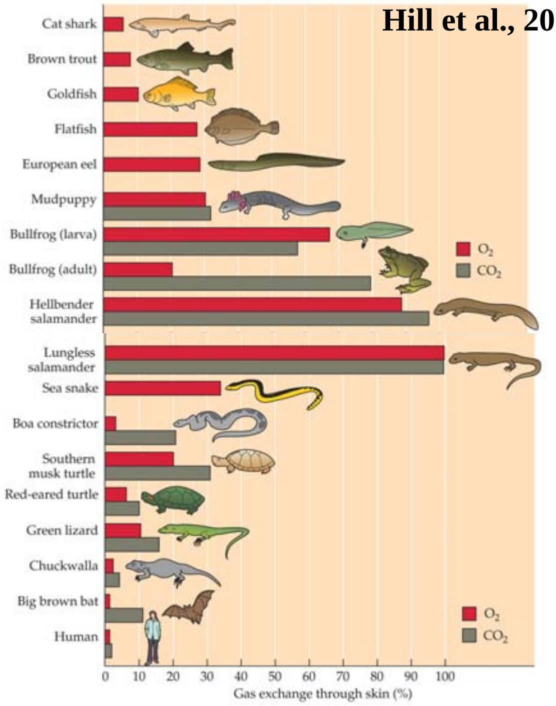
(Bolivian Navy; Peru-Bolivia border)

A FROG THAT BREATHES THROUGH ITS SKIN The Titicaca frog (*Telmatobius culeus*) lives in the depths of Lake Titicaca at 3812 m altitude. This animal does not surface to breathe and obtains oxygen entirely by diffusion through the skin surface, which is highly vascularized and enlarged by loose folds. [Courtesy of Victor H. Hutchison, University of Oklahoma]

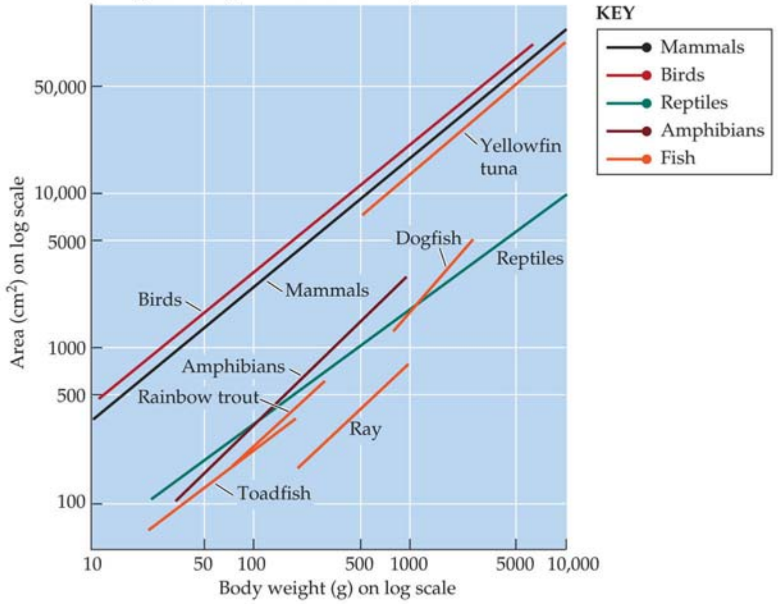
Knut Schmidt_Nielsen 1997

Gas Exchange Across Skin

Hill et al., 2004, Fig. 21.8



(a) Area of the gas-exchange membrane vs. body size



Hill et al., 2004, Fig. 21.7

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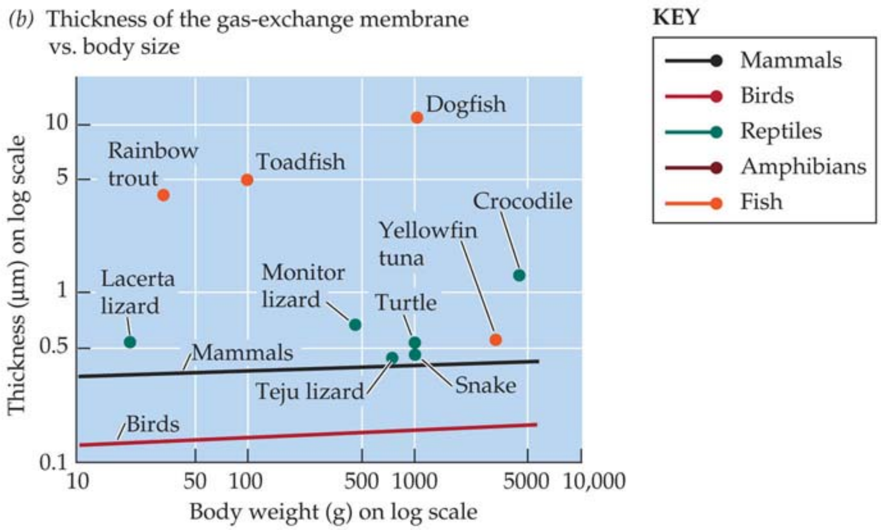

Hill et al., 2004, Fig. 21.7

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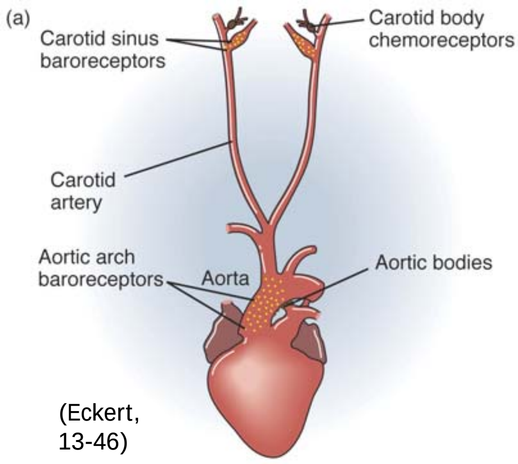
Rate and Depth Regulation



(Eckert, 13-46)

-Primarily via CO_2 changes (central)

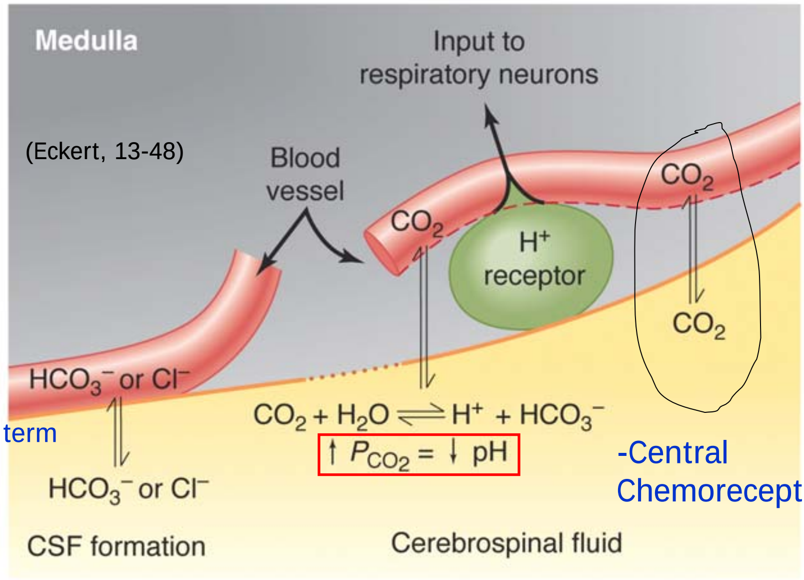
-Peripheral Chemoreceptors
PO_2, PCO_2, pH
(Vagus nerve to medulla oblongata)

-Innervate Medullary Respiratory Center
(phrenic nerve to diaphragm and intercostals)

-Emotions, sleep, light, temperature, speech, volition, etc.

-O_2 ~controls respiration in aquatic vertebrates

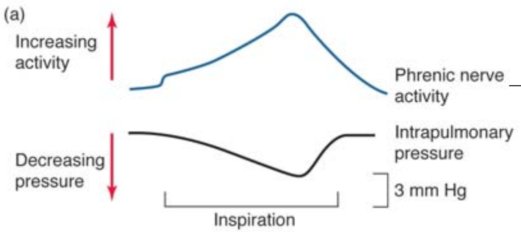
Rate and Depth Regulation



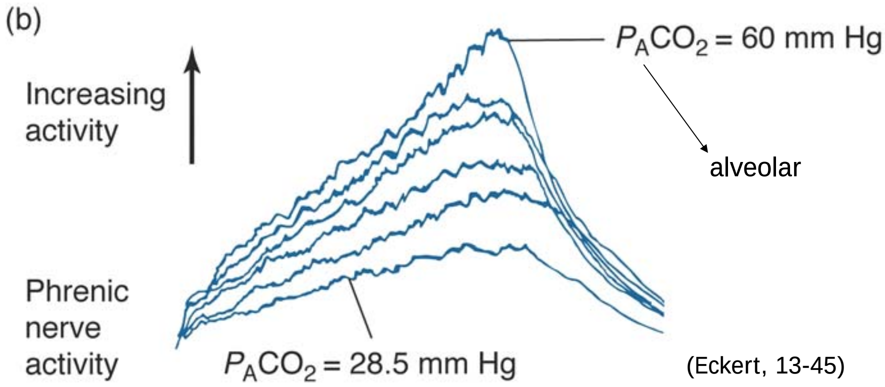
(Eckert, 13-48)

Long term

-Central Chemoreceptors



→ To Diaphragm



alveolar

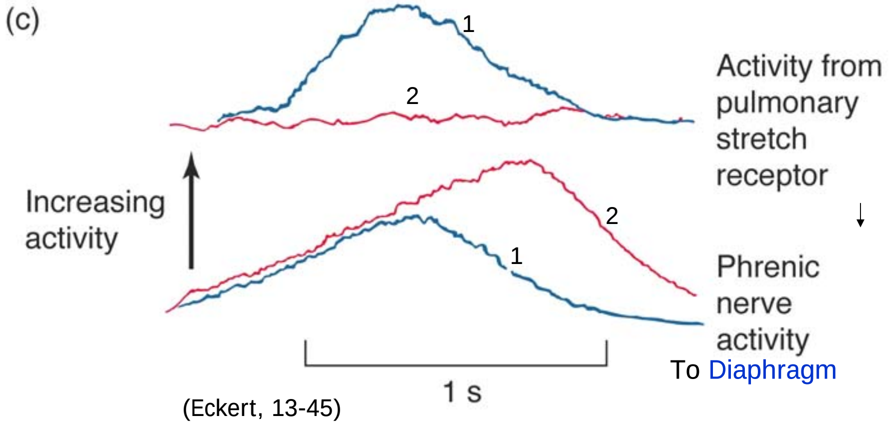
(Eckert, 13-45)

Hering-Breuer reflex

-Stimulation of stretch receptors inhibits medullary inspiratory center

-Prevent overinflation

-Ectotherms often breathe intermittently



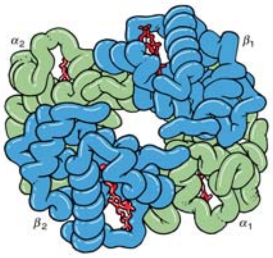
(Eckert, 13-45)

Blood-Gas Chemistry

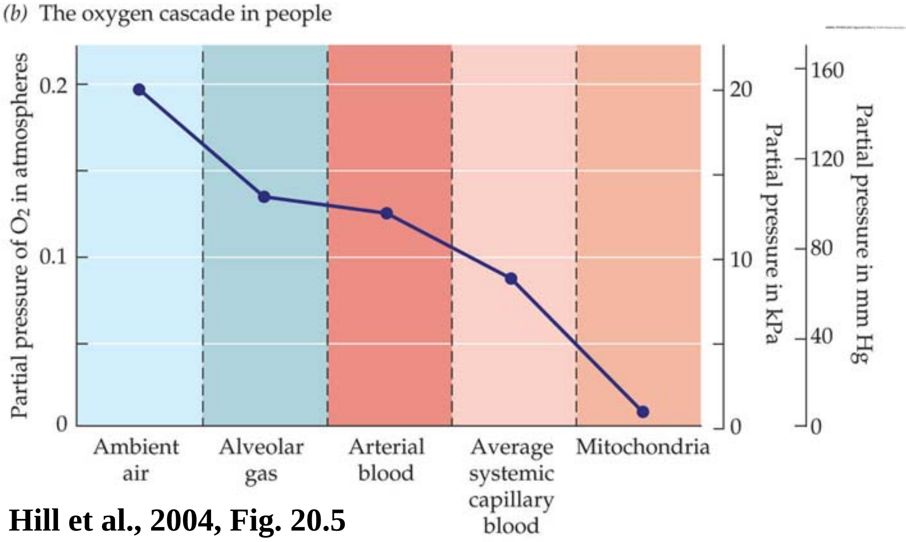
Oxygen and Carbon Dioxide
- Air vs. Water
- Epithelial Transfer
- Transport and Regulation

pH regulation
Chloride shift
Carbonic Anhydrase

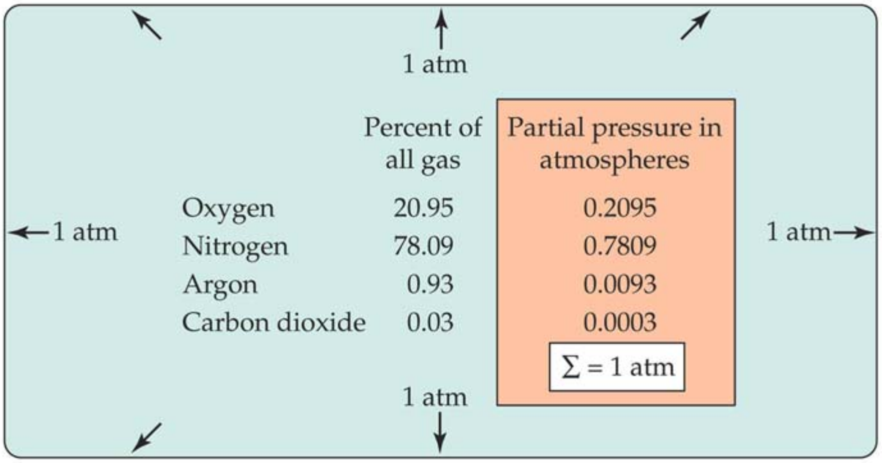
Elevation



Oxygen Partial Pressure



Hill et al., 2004, Fig. 20.5



	Percent of all gas	Partial pressure in atmospheres
Oxygen	20.95	0.2095
Nitrogen	78.09	0.7809
Argon	0.93	0.0093
Carbon dioxide	0.03	0.0003

Hill et al., 2004, Fig. 20.1

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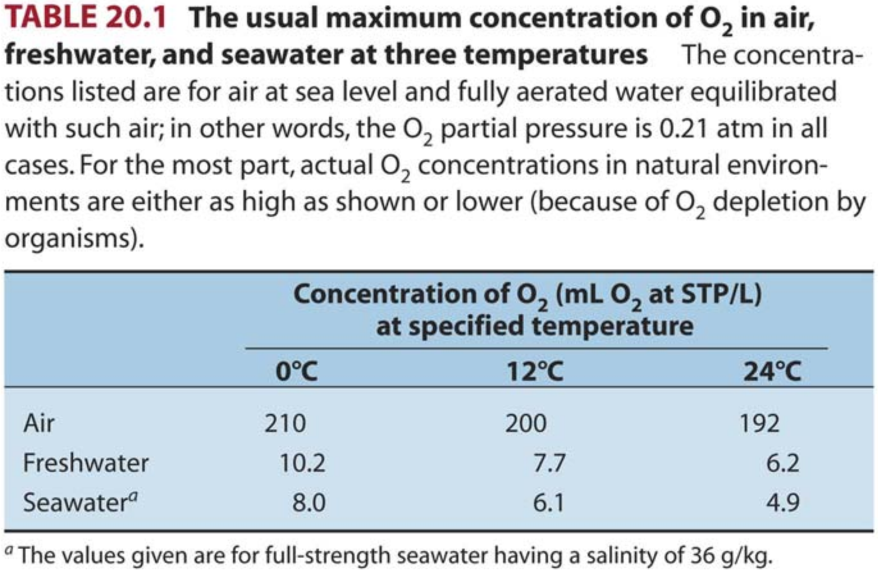


TABLE 20.1 The usual maximum concentration of O_2 in air, freshwater, and seawater at three temperatures The concentrations listed are for air at sea level and fully aerated water equilibrated with such air; in other words, the O_2 partial pressure is 0.21 atm in all cases. For the most part, actual O_2 concentrations in natural environments are either as high as shown or lower (because of O_2 depletion by organisms).

	Concentration of O_2 (mL O_2 at STP/L) at specified temperature		
	0°C	12°C	24°C
Air	210	200	192
Freshwater	10.2	7.7	6.2
Seawater[a]	8.0	6.1	4.9

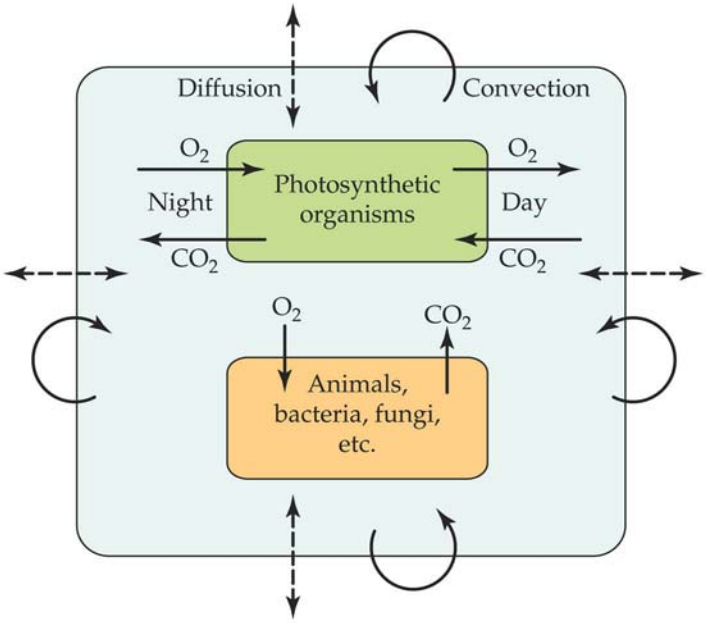
[a] The values given are for full-strength seawater having a salinity of 36 g/kg.

Hill et al., 2004

ANIMAL PHYSIOLOGY, Table 20.1 © Sinauer Associates, Inc.

Gas composition in air	O_2	CO_2	N_2
% of dry air	21	0.03	78
pp at 760 mm Hg	159	0.23	594
380mmHg (at 6000m)	79.6	0.11	297
Solubility in water (ml/L)	34	1,019	17

Why is pO_2 in lungs less than ‘expected’?



Hill et al., 2004, Fig. 20.6

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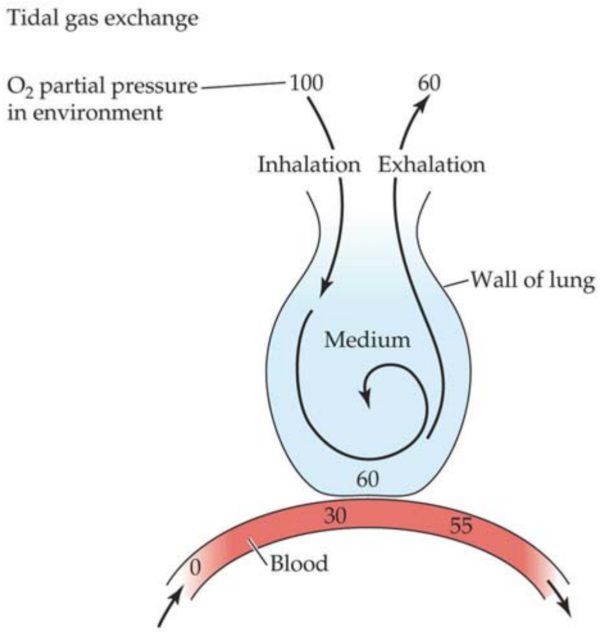

Hill et al., 2004, Fig. 21.3

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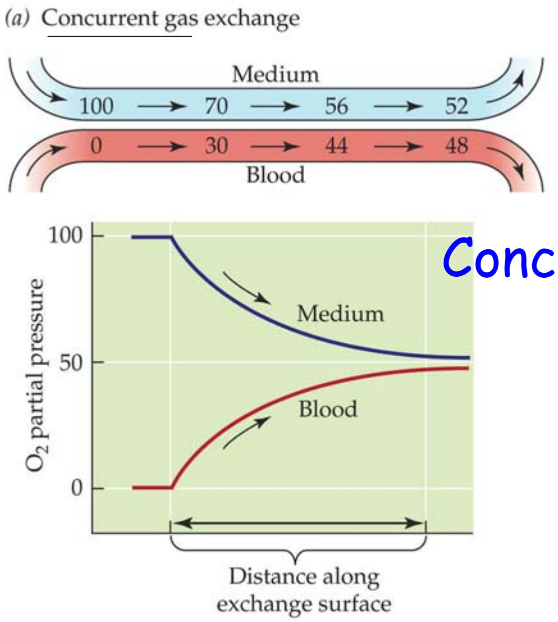

Concurrent

Hill et al., 2004, Fig. 21.4

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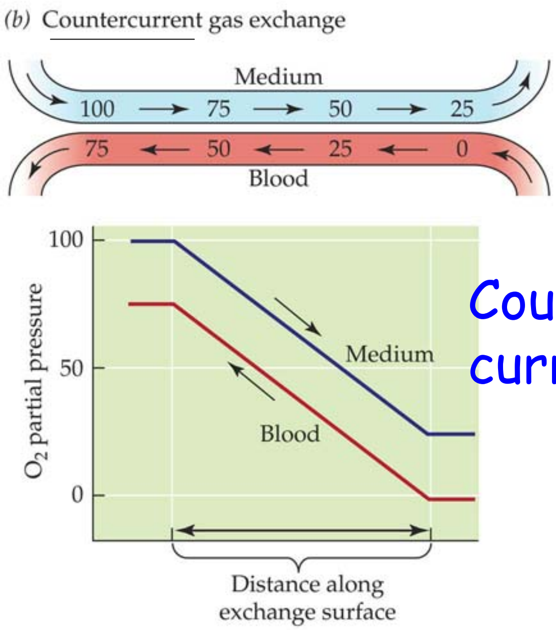

Counter-current

Hill et al., 2004, Fig. 21.4

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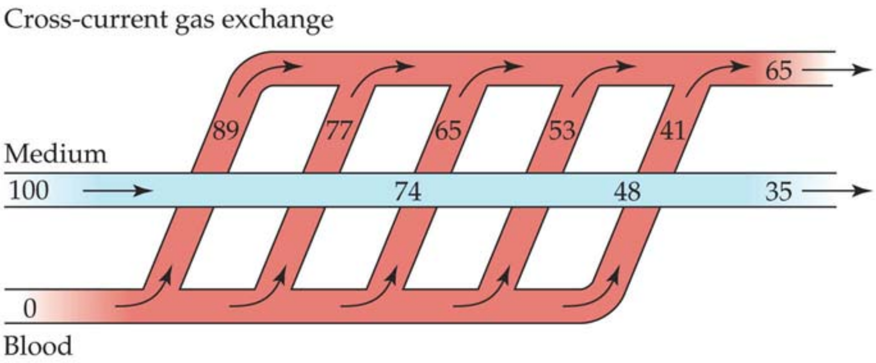
Cross-current



Hill et al., 2004, Fig. 21.5

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Gas transport in blood

Respiratory pigments

- all have either Fe^{2+} or Cu^{2+} ions that O_2 binds
- pigment increases O_2 content of blood
- complex of proteins and metallic ions
- each has characteristic color that changes w/ O_2 content
- ability to bind to O_2 (affinity) affects carrying capacity of blood for O_2

98% of O_2 transported via carrier molecules

	hemoglobin	hemocyanin	hemerythrin
Metal	Fe^{2+}	Cu^{2+}	Fe^{2+}
Distribution	over 10 phyla (all verts, many inverts)	2 phyla (arthropods, mollusks)	4 phyla
Location	RBCs (verts)	dissolved in plasma	intracellular
Color	deox – maroon ox – red	colorless blue	colorless reddish violet

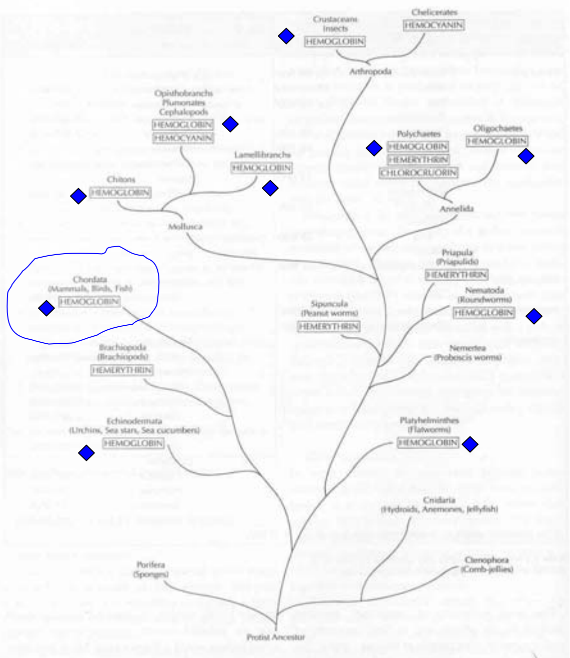


Figure 2.1 Distribution of respiratory pigments across several animal groups. Notice the widespread occurrence of hemoglobin and hemerythrin as compared to hemocyanin and chlorocruorin. Also notice the general lack of pattern in any one pigment's distribution. [Phylogeny from Brusca and Brusca 1990]

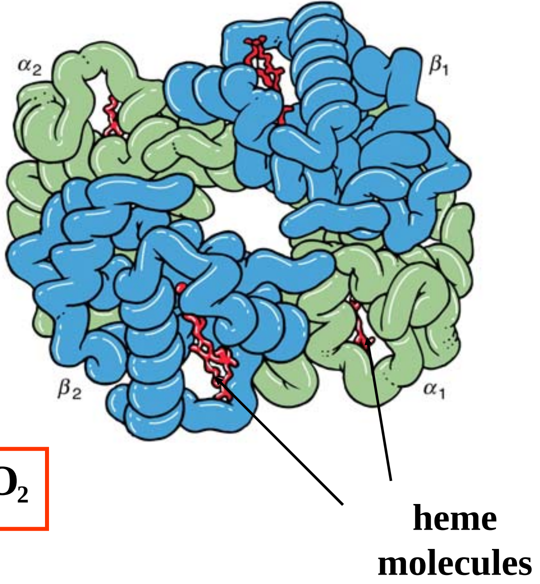
how good is this?

Hemoglobin ◆ and other Respiratory Pigments

Knut Schmidt_Nielsen 1997

hemoglobin

4 heme + 4 protein chains



can carry 4 O_2