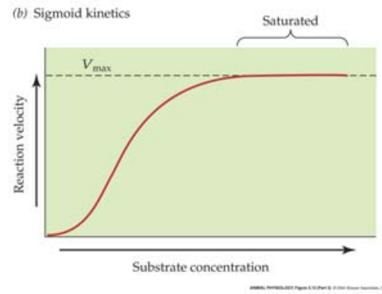
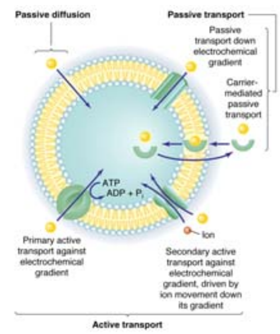
Lecture 4, 25 Jan 2008

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

Kevin Bonine & Kevin Oh



1. Enzymes etc. (Ch 2)
2. Water, Solutes, Osmosis (Ch 3)



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

1

Housekeeping, 25 January 2008

Upcoming Readings

today: Ch 3
LAB Wed 30 Jan: Bisbal & Specker, plus two optional papers
(see website for links to papers, or get via email)
Mon 28 Jan: Ch 3&10
Wed 30 Jan: Ch 10&11

Lab discussion leaders: 30 Jan
1pm – Josh, Seth
3pm – Aaron, Adam

Lab discussion leaders: 06 Feb
1pm – Rittner, Whitney
3pm – Roxanne, Maria

2

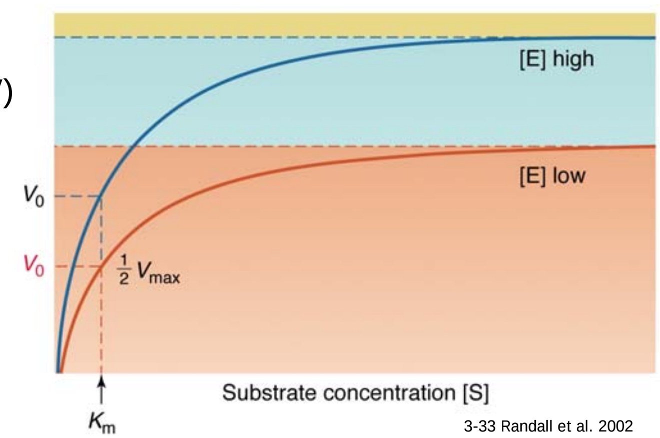
Enzymes, Kinetics, Pathways…
(Hill et al. Ch 2, con’t)

3

Enzymes

- Rates of Rxn (V)

- MM constant
  (Km)



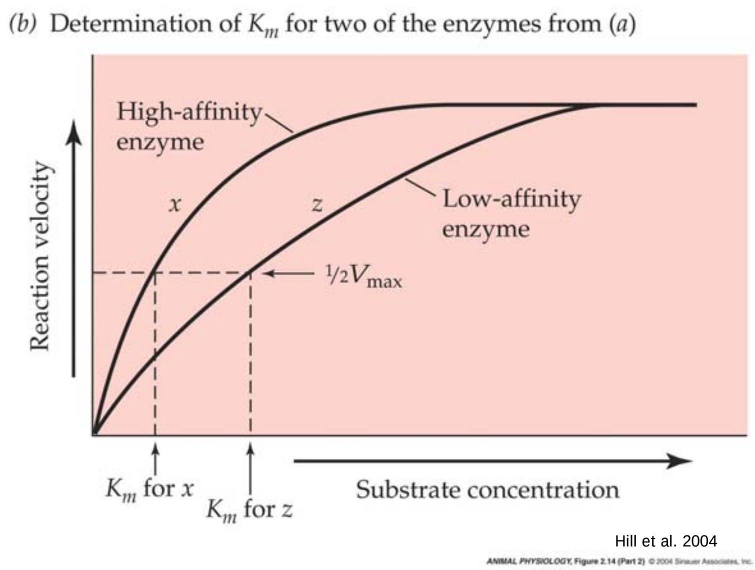
3-33 Randall et al. 2002

- Michaelis-Menten equation

$$Vo = \frac{Vmax[S]}{Km + [S]}$$

4

Figure 2.14 The approach to saturation depends on enzyme–substrate affinity

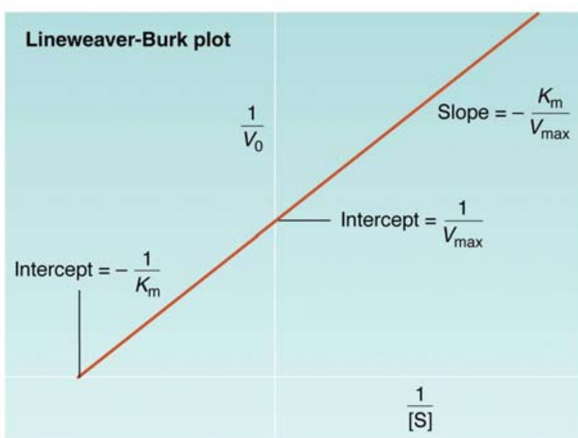


Hill et al. 2004

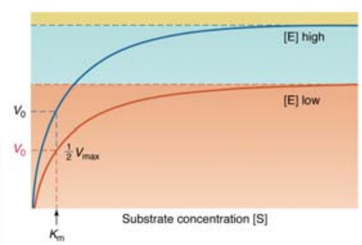
5

Enzymes

- Lineweaver-Burk Plot



3-34 Randall et al. 2002



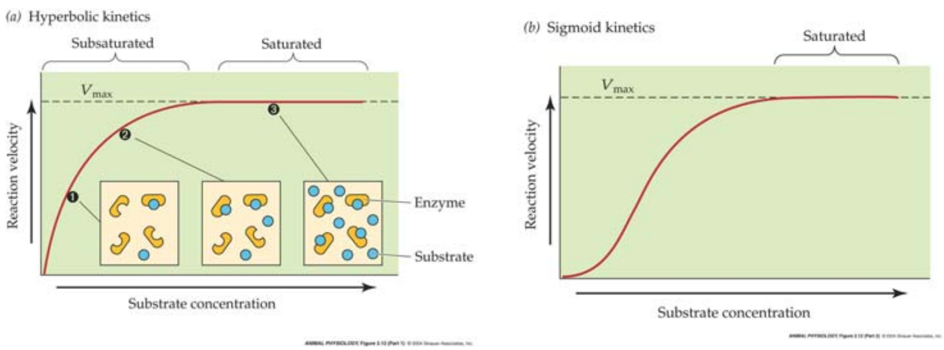
3-33 Randall et al. 2002

Inverse of M-M equation →

$$\frac{1}{Vo} = \frac{Km}{Vmax[S]} + \frac{1}{Vmax}$$

6

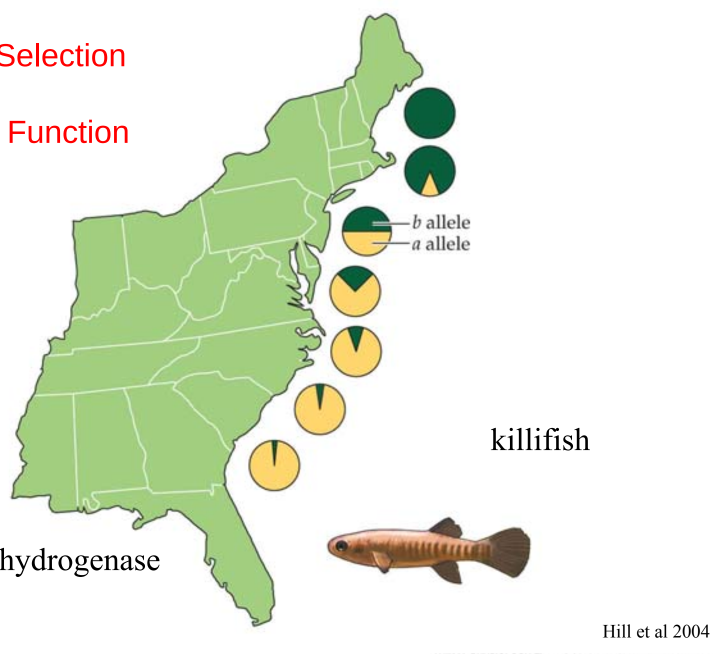
Figure 2.12 Reaction velocity as a function of substrate concentration



Enzyme Kinetics
-hyperbolic
-sigmoidal

Hill et al. 2004 7

Natural Selection
on
Enzyme Function

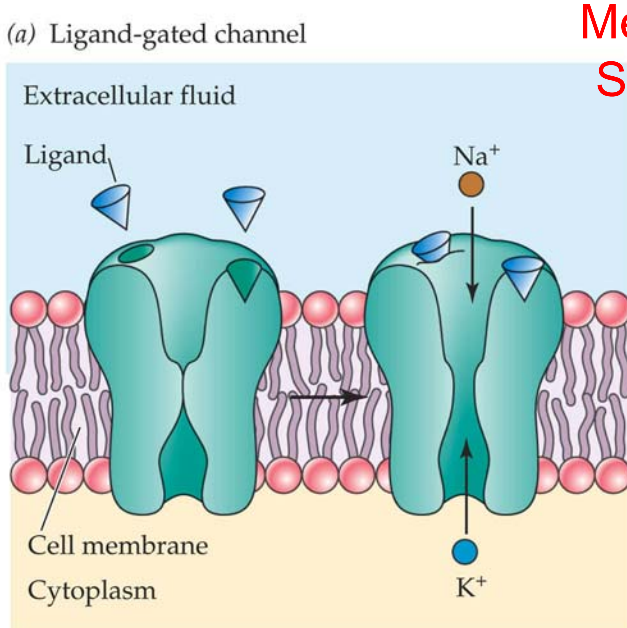


killifish

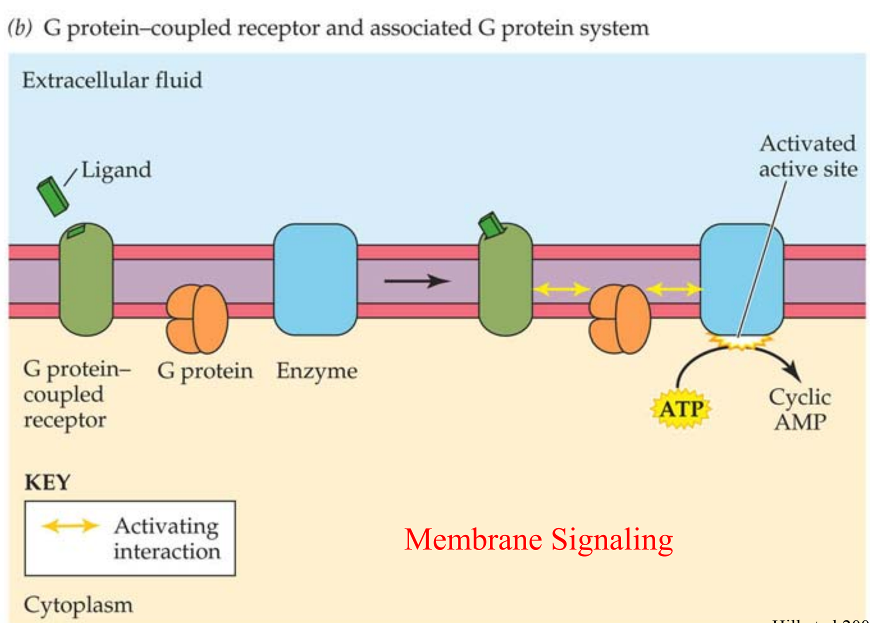
Lactate dehydrogenase
2 alleles

Hill et al 2004

Membrane Signaling



Hill et al 2004
9

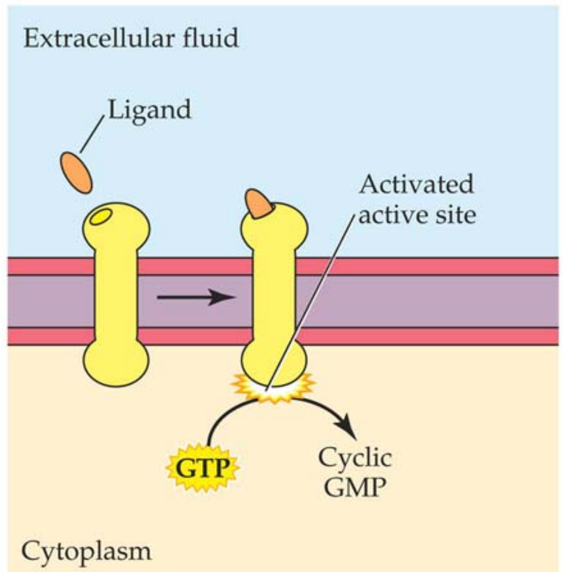


Membrane Signaling

Hill et al 2004

Membrane Signaling

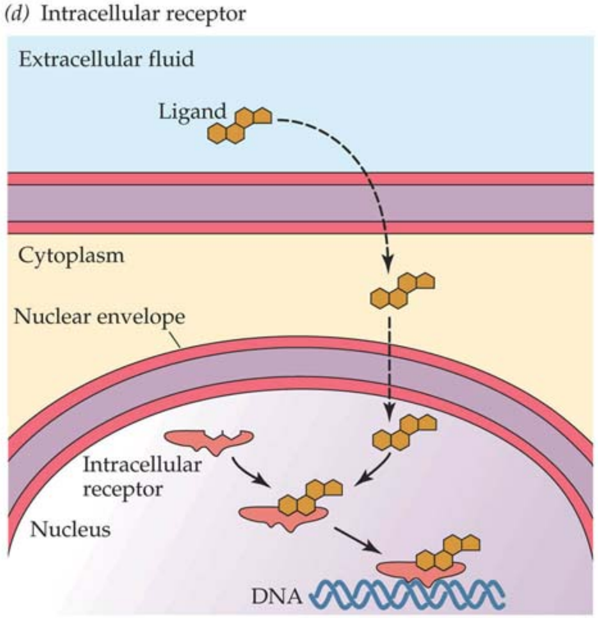
(*c*) Enzyme/enzyme-linked receptor



Hill et al 2004

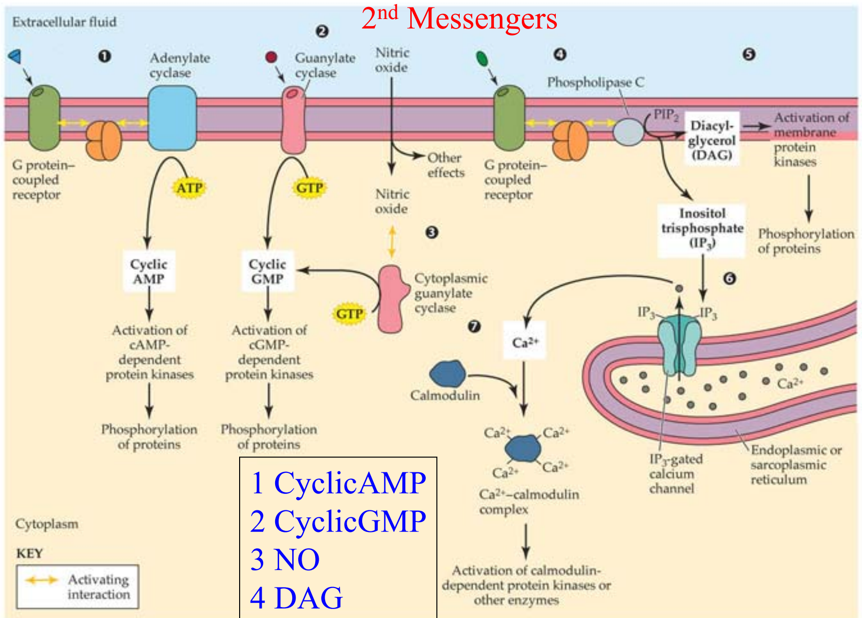
Membrane Signaling

(*d*) Intracellular receptor



Hill et al 2004

2^{nd} Messengers



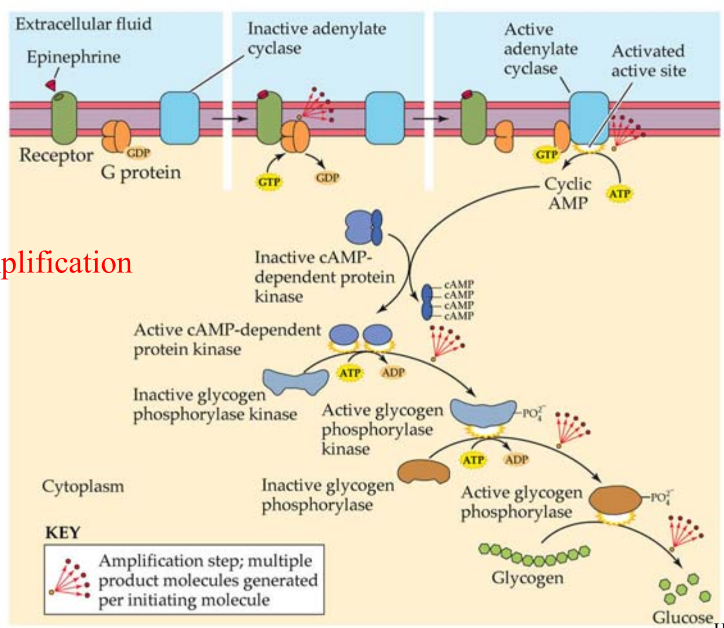
1 CyclicAMP
2 CyclicGMP
3 NO
4 DAG
5 IP_3
6 Calcium

Hill et al 2004

ANIMAL PHYSIOLOGY, Figure 2.26 © 2004 Sinauer Associates, Inc.

13

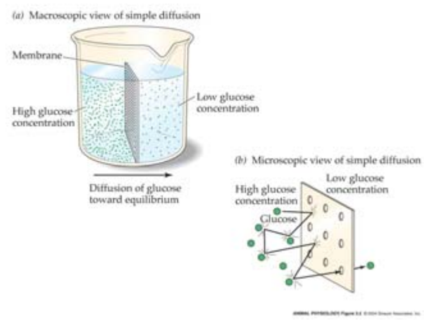
Amplification



Hill et al 2004

ANIMAL PHYSIOLOGY, Figure 2.25 © 2004 Sinauer Associates, Inc.

Vertebrate Physiology 437



Chapter 3

Movement of Solutes and Water

15

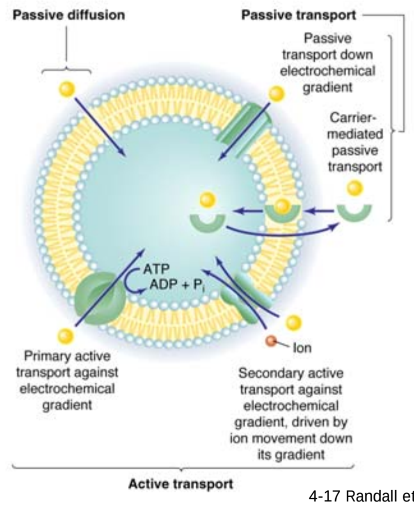
What are the different ways to get substances across membranes?

16

Movement Across Membranes

1. Passive Diffusion (= simple diffusion)
2. Passive Transport (= facilitated diffusion)
3. Active Transport

Transport (pore or carrier) may be highly selective



17

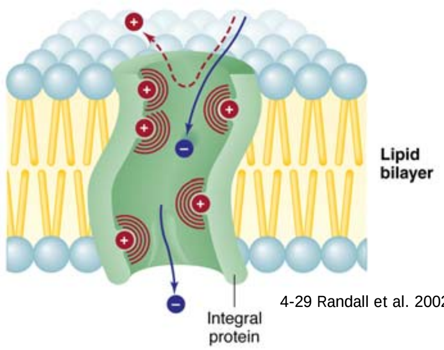
4-17 Randall et al. 2002

How does a channel act selectively?

18

Ion Channels

- Ion selectivity
- Leaky channels (e.g., K+)
- Voltage-gated channels (e.g., Na+, K+, Ca+)
- Ligand-gated channels etc.



4-29 Randall et al. 2002

-charge
-ease of dehydration
-size

19

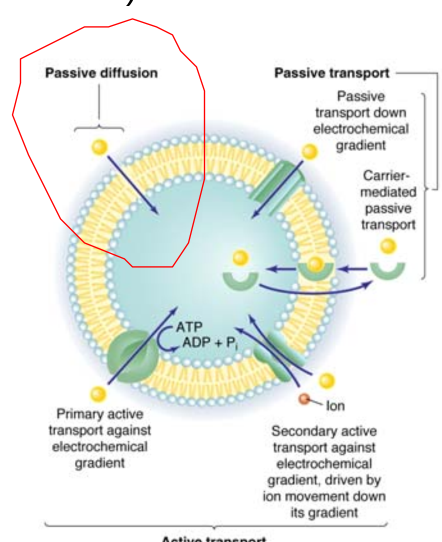
Movement Across Membranes

1. Passive Diffusion (= simple diffusion)

- nonpolar/nonelectrolyte
- lipid soluble (steroid hormones)
- few H bonds
- ~smaller size

-rate depends on
  [ ] gradient

-No saturation



4-17 Randall et al. 2002

Diffusion

Fick Equation:

$$J = D\frac{C_1\text{-}C_2}{X}$$

J = net rate of diffusion
D = diffusion coefficient (depends on permeability and Temp)
C_1-C_2 = [gradient]
X = distance separating C1 from C2

TABLE 3.1 The time required for diffusion through water to halve a concentration difference Values are calculated for small solutes such as O_2 or Na^+. For each distance between solutions, the time listed is the time that will be required for diffusion to transport half the solute molecules that must move to reach concentration equilibrium. It is assumed that no electrical effects exist, and thus only diffusion based on concentration effects is occurring.

Time required to halve a concentration difference by diffusion	Distance between solutions	A biological dimension that exemplifies the distance specified
100 nanoseconds	10 nanometers	Thickness of a cell membrane
100 milliseconds	10 micrometers	Radius of a small mammalian cell
17 minutes	1 millimeter	Half-thickness of a frog sartorius muscle
1.1 hours	2 millimeters	Half-thickness of a human eye lens
4.6 days	2 centimeters	Thickness of the human heart muscle
32 years	1 meter	Length of a long human nerve cell

Source: After Weiss 1996.

Hill et al 2004

Movement Across Membranes

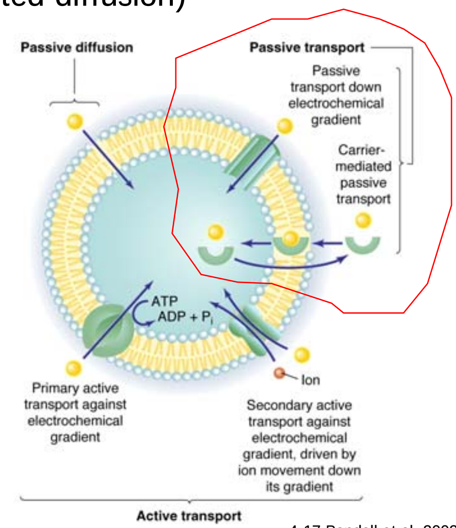
1. Passive Diffusion (= simple diffusion)
2. Passive Transport (= facilitated diffusion)

Down Electrochemical gradient

A. pore

B. carrier mediated

- pores show some saturation, but not as much as carriers

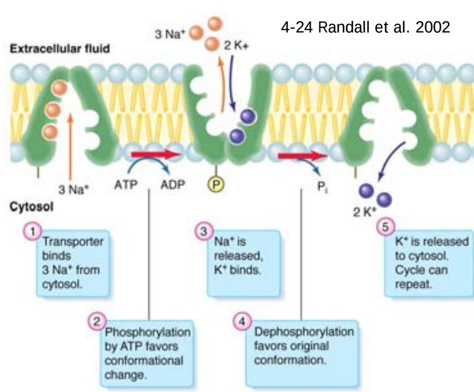


4-17 Randall et al. 2002

Movement Across Membranes

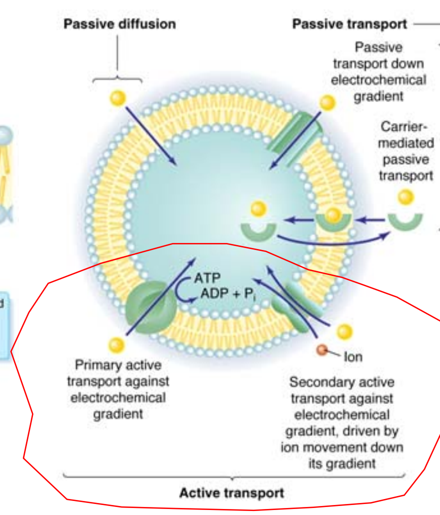
1. Passive Diffusion (= simple diffusion)
2. Passive Transport (= facilitated diffusion)
3. Active Transport (1°, 2°)

4-24 Randall et al. 2002



Na+/K+ ATPase Pump

4-17 Randall et al. 2002



Fernandina

Galapagos Marine Iguana (Iguanidae)

El Nino → lack of food

Starvation

high cost of salt excretion

Animals may lose 15% body length
-bone absorption

Only adult vertebrate known to regularly shrink
(astronauts?)

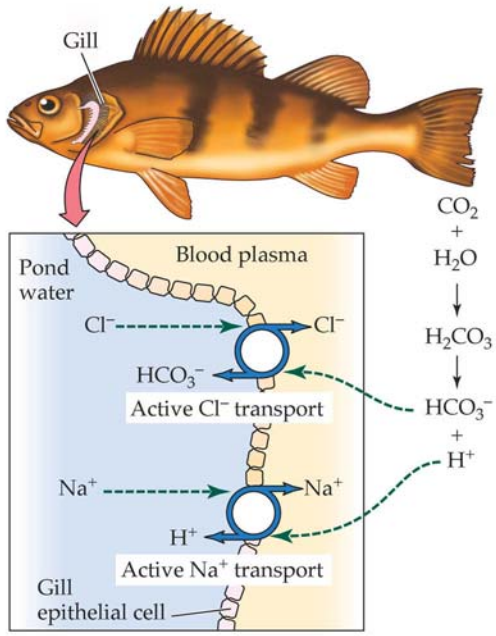
Largest animals die
- natural selection vs.
- sexual selection

(Most efficient
salt glands
known in reptiles)

Amblyrhynchus cristatus

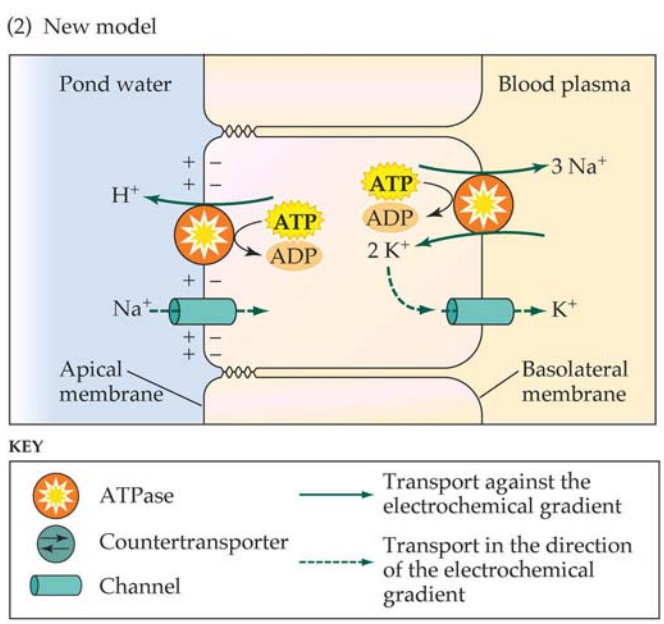
28

In Freshwater



Hill et al 2004

ANIMAL PHYSIOLOGY, Figure 3.14 © 2004 Sinauer Associates, Inc.



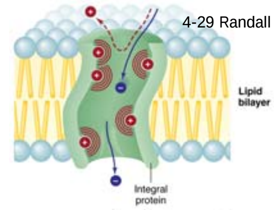
Hill et al 2004

ANIMAL PHYSIOLOGY, Box 3.1, Figure A (Part 2) © 2004 Sinauer Associates, Inc.

(See Tipsmark et al 2002)

Membrane Selectivity (Channels)

Charge, ease of dehydration, size



4-29 Randall et al. 2002

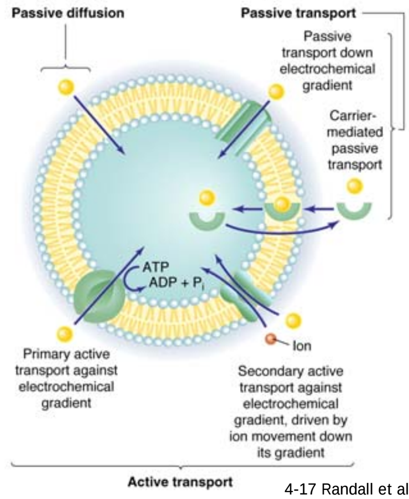
Diffusion

- nonpolar/nonelectrolyte
- lipophilic
- few H bonds
- smaller size

Transport

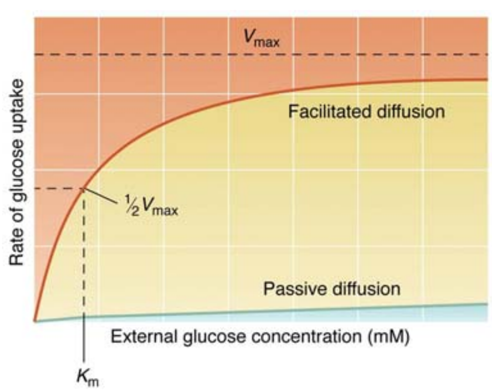
-rates depend on

1. electrochemical gradient
2. # carriers/pores



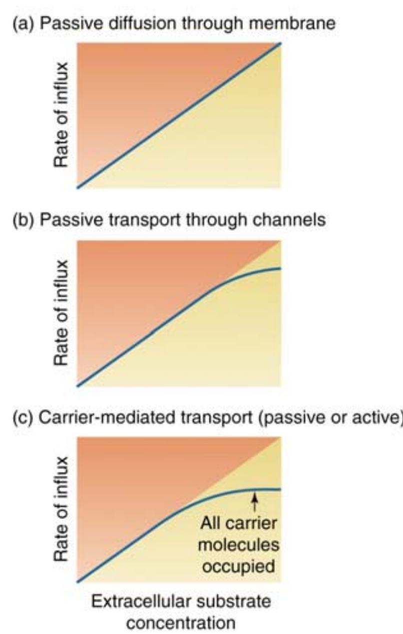
4-17 Randall et al. 2002

Movement Across Membranes



4-23 Randall et al. 2002

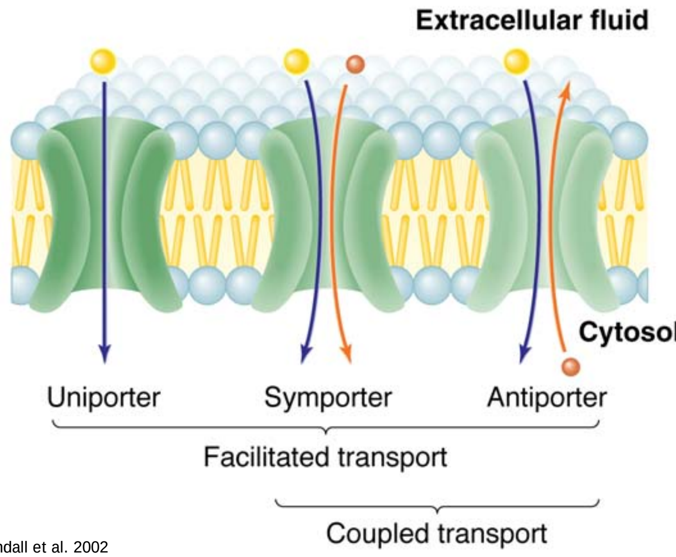
4-20 Randall et al. 2002



How is this related to the early test for diabetes??

32

Movement Across Membranes

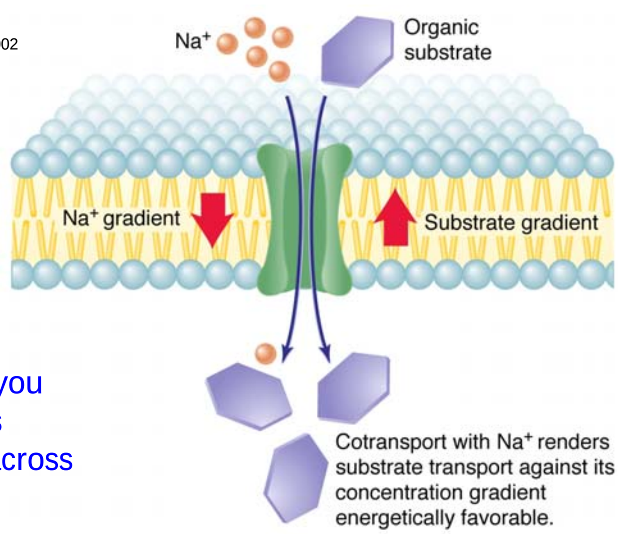


4-22 Randall et al. 2002

33

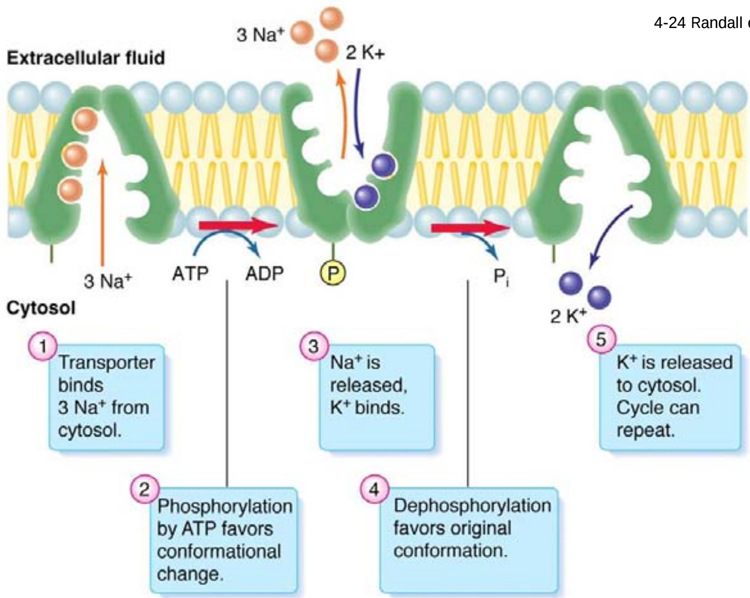
Movement Across Membranes

4-26 Randall et al. 2002



How would you describe this movement across membrane?

34



Na+/K+ ATPase Pump

35

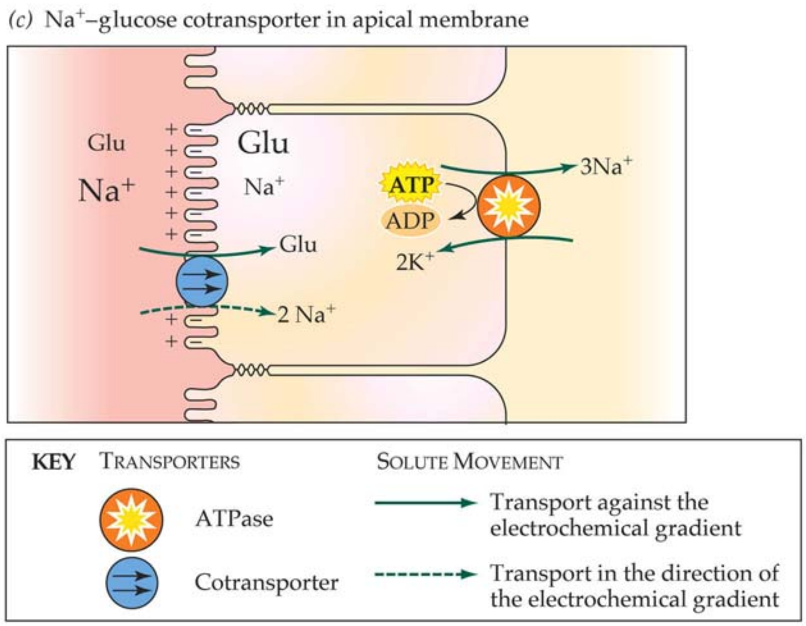
Movement Across Membranes

How does glucose cross membranes?

Most tissues:
-Passive transport down [ ] gradient via carrier proteins

In gut:
-2º active to move Glu against [ ] gradient into blood from "food"

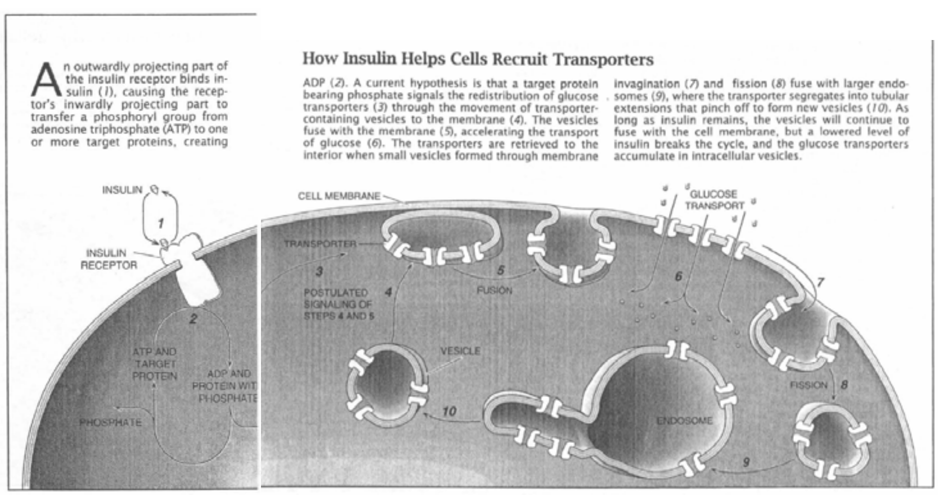
36



Hill et al 2004

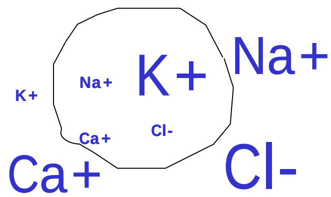
ANIMAL PHYSIOLOGY, Figure 3.12 (Part 3) © 2004 Sinauer Associates, Inc.

Leinhard et al. 1992

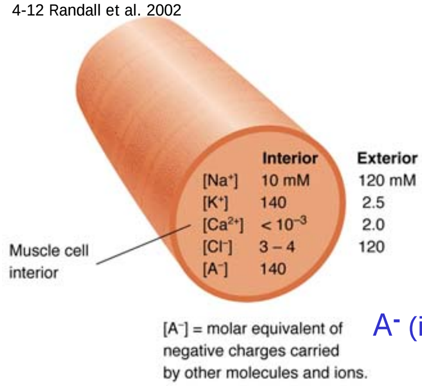


38

Osmotic Properties of Cells and Relative Ion Concentrations



4-12 Randall et al. 2002

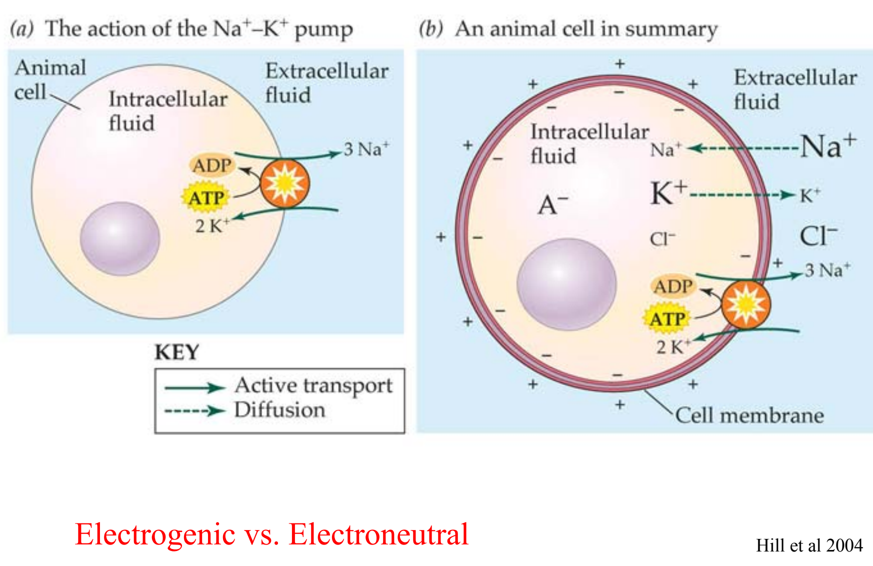


Permeabilities

$K^+ >> Na^+ ; Cl^-$

A^- (includes proteins, phosphate groups, etc.)

39

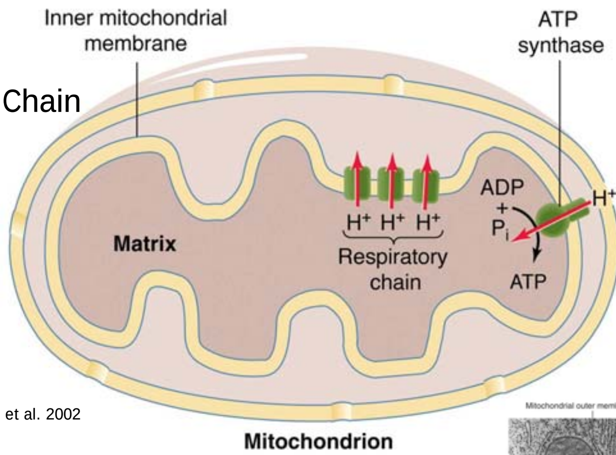


Electrogenic vs. Electroneutral

Hill et al 2004

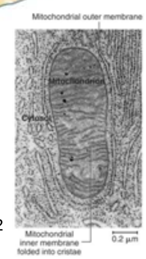
Ion Gradients as an Energy Source

CET example:
-Metabolism
-Electron Transport Chain
-ATP creation
energy currency



4-27 Randall et al. 2002

1 Move molecules
2 Electrical Signalling
3 Chemiosmotic Energy Transduction



3-42 Randall et al. 2002

Just add water…

How does water move across membranes?

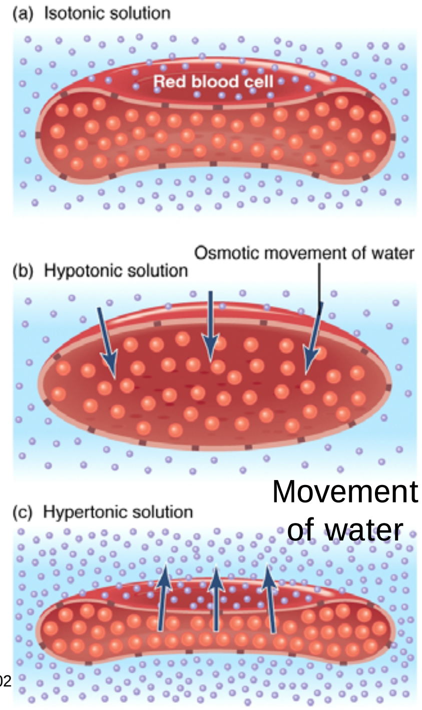
aquaporins

Movement Across Membranes

Iso
Hypo osmotic
Hyper

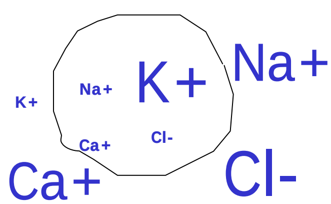
In specific tissues and cells:

Iso
Hypo tonic
Hyper

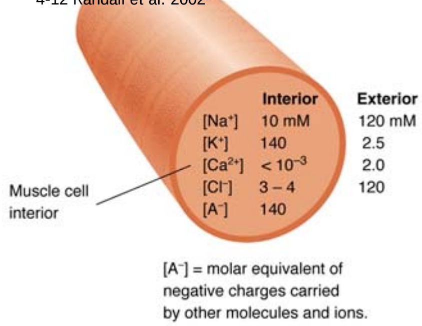


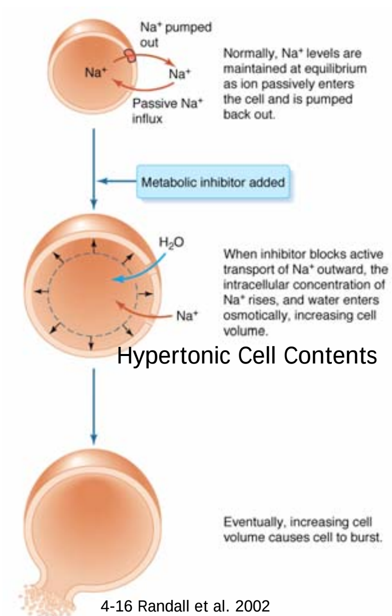
4-14 Randall et al. 2002

Osmotic Properties of Cells and Relative Ion Concentrations



4-12 Randall et al. 2002

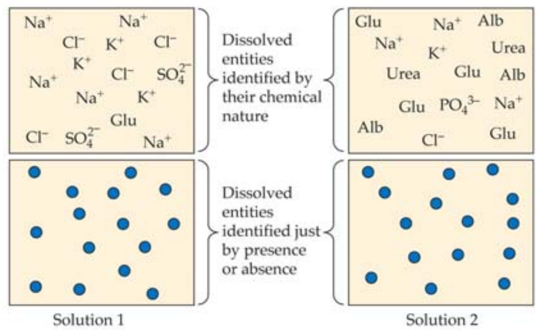




4-16 Randall et al. 2002

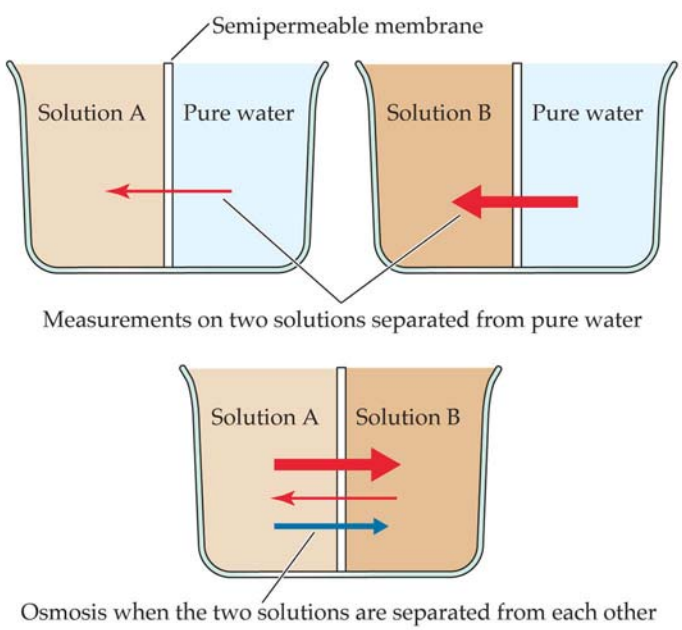
Colligative Properties

- Osmotic Pressure
- Freezing Point
- Water Vapor Pressure (boiling point; evaporation)



Hill et al 2004

45



Hill et al 2004

ANIMAL PHYSIOLOGY, Figure 3.17 © 2004 Sinauer Associates, Inc.

6×10^{23}

Osmolarity

1 osmolar solution (Osm)

has 1 Avogadro's number of dissolved particles/liter solvent

1 milliosmolar solution (mOsm)
has 0.001 Avogadro's number of dissolved particles/liter solvent

47

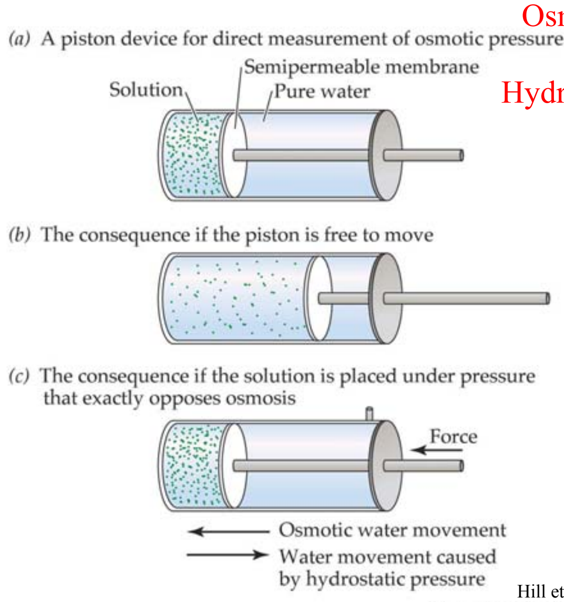
What osmolarity do you get if you add 6×10^{23} molecules of glucose to a liter of water?

What osmolarity do you get if you add 6×10^{23} molecules of table salt to a liter of water?

NaCl (strong electrolyte)

48

Osmotic Pressure
Vs.
Hydrostatic Pressure



Hill et al 2004

ANIMAL PHYSIOLOGY, Figure 3.16 © 2004 Sinauer Associates, Inc.

49

Difference in osmotic potential

$$\text{Rate of Osmosis} = K \frac{\Pi_1 - \Pi_2}{X}$$

Proportionality Coefficient (~ permeability and temp)

Distance between solutions

50

Electrochemical equilibrium

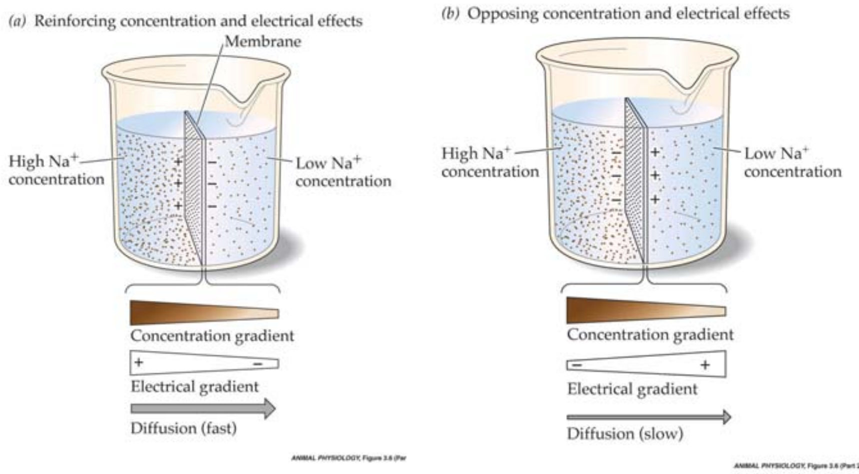


Fig 3.6, Hill et al 2004

51

Movement Across Membranes

Electrochemical Gradient

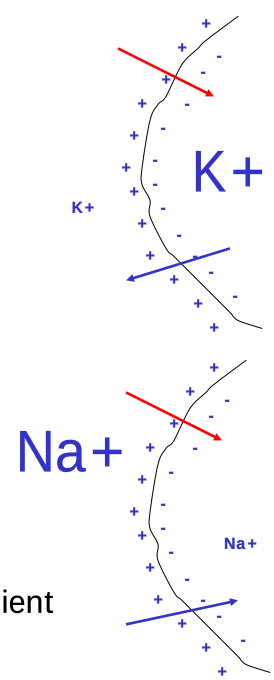
Electrical gradient

Concentration gradient

Electrochemical
equilibrium

Equilibrium potential (E_x in mV)

when [X] gradient = electrical gradient

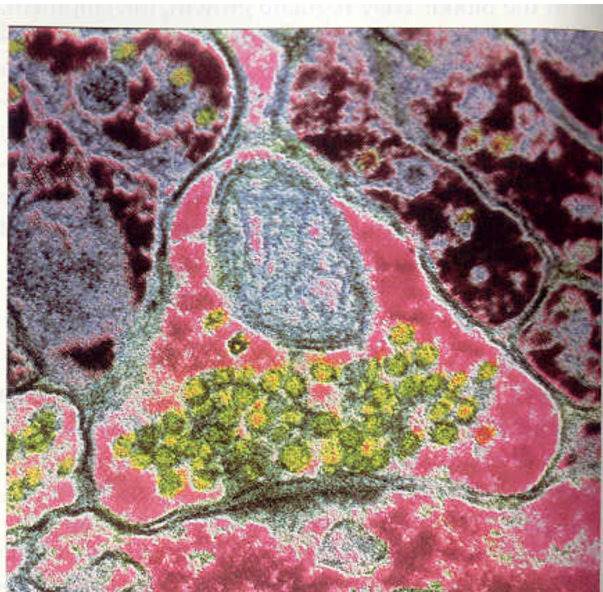


52

Equilibrium potential (E_x in mV)

"Every ion's goal in life is to make the membrane potential equal its own equilibrium potential (E_x in mV)"

53



Vesicles filled with neurotransmitter (green) cluster near the end of
neuron as it synapses on its target.

p. 214, Silverthorn 2001. 2nd ed. Human Physiology. Prentice Hall

54