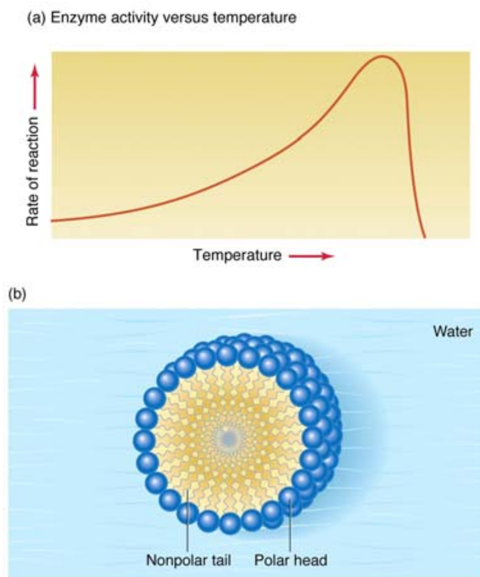
Lecture 3, 23 Jan 2008

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

Kevin Bonine & Kevin Oh

1. Biochem Blitz (Chap 2)
   - -Cells
   - -Membranes
   - -Molecules
   - -Pathways



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

1

Housekeeping, 23 January 2008

Upcoming Readings

today: Textbook, chapter 2&3
LAB Wed 23 Jan: Lienhard et al. 1992, Nesse & Williams 1998
(see website for links to papers, or get via email)
Fri 25 Jan: Textbook chapter 3
Mon 28 Jan: Ch 10

Lab discussion leaders: 23 Jan
1pm – Allison, Rachel
3pm – Kelsey, Sean

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

2

Organism-level
Approaches

- Physiological State

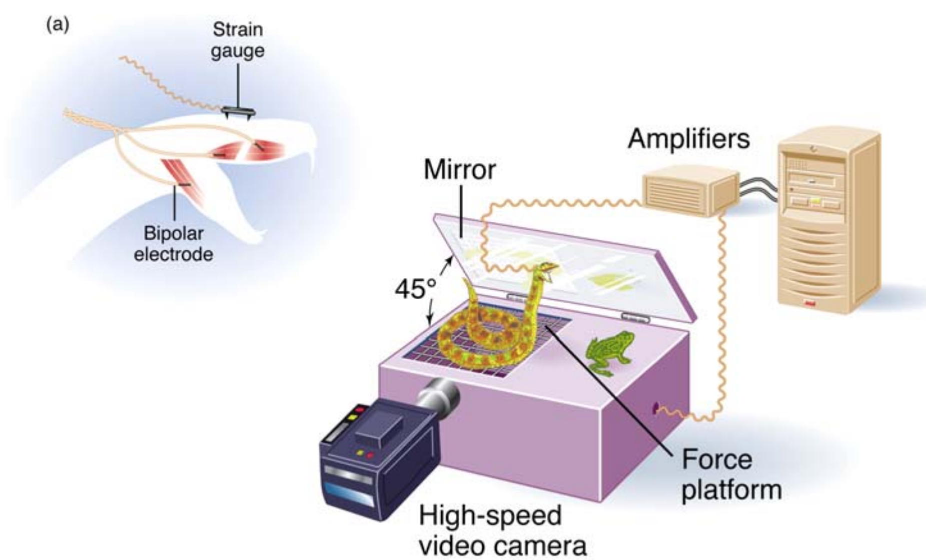
- Age
- Sex
- Season
- Reproductive Condition

- Sleeping
- Resting
- Alert
- Exercising
- Stress-level
- Fasting or Fed

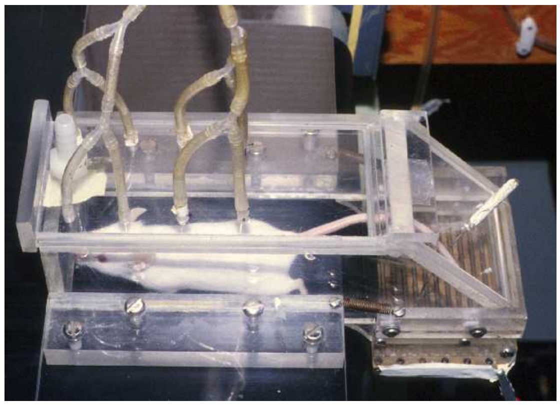
- BMR
- RMR

3

Behavior



Doing Physiology



5

Scientific Literature 1/4

Table 1-2 A sampling of scientific journals that publish physiological research papers

Name	Abbreviation*	Topics covered
General journals		
American Journal of Physiology	*Am. J. Physiol.*	Broad areas of physiology from the cell to organ systems
Pflügers Archiv für Physiologie (now *European Journal of Physiology*)	*Pflugers Arch. Physiol.* (*Eur. J. Physiol.*)	
Journal of Physiology	*J. Physiol.*	
Journal of General Physiology	*J. Gen. Physiol.*	Physiological and biophysical studies at the cellular and subcellular level
Comparative Physiology and Biochemistry	*Comp. Physiol. Biochem.*	Many different areas, with emphasis on lower vertebrates and invertebrates
Journal of Comparative Physiology	*J. Comp. Physiol.*	
Journal of Experimental Biology	*J. Exp. Biol.*	
Physiological and Biochemical Zoology	*Physiol. Biochem. Zool.*	

*Single-word journal names are not abbreviated.

Randall et al. 2002

6

Scientific Literature 2/4

Table 1-2 A sampling of scientific journals that publish physiological research papers

Name	Abbreviation*	Topics covered
Specialty journals		
Brain, Behavior, and Evolution	*Brain Behav. Evol.*	Research related to specific areas or processes indicated by journal's name
Cell		
Circulation Research	*Circ. Res.*	
Evolution and Development	*Evol. Dev.*	
Endocrinology		
Gastroenterology		
Journal of Cell Physiology	*J. Cell Physiol.*	
Journal of Membrane Biology	*J. Membr. Biol.*	
Journal of Neurophysiology	*J. Neurophysiol.*	
Journal of Neuroscience	*J. Neurosci.*	
Molecular Endocrinology	*Mol. Endocrinol.*	
Nephron		
Respiration Physiology	*Respir. Physiol.*	

*Single-word journal names are not abbreviated.

Randall et al. 2002

7

Scientific Literature 3/4

Table 1-2 A sampling of scientific journals that publish physiological research papers

Name	Abbreviation*	Topics covered
Annual reviews		
Annual Review of Neuroscience	*Annu. Rev. Neurosci.*	Summaries and evaluations of original papers on particular topics published in other journals
Annual Review of Physiology	*Annu. Rev. Physiol.*	
Federation Proceedings	*Fed. Proc.*	
Physiological Reviews	*Physiol. Rev.*	

*Single-word journal names are not abbreviated.

Randall et al. 2002

8

Scientific Literature 4/4

Table 1-2 **A sampling of scientific journals that publish physiological research papers**

Name	Abbreviation*	Topics covered
Taxonomy-oriented journals		
Auk		Physiology and other topics related to birds
Condor		
Emu		
Crustaceana		Physiology and other topics related to crustaceans
Copeia		Amphibian and reptilian physiology
Herpetologica		
Journal of Herpetology	*J. Herpetol.*	
Journal of Mammalogy	*J. Mammal.*	Physiology and other topics dealing with mammals
Weekly journals		
Nature		Preliminary reports about topics of general interest to the scientific community
Science		

*Single-word journal names are not abbreviated.

Randall et al. 2002

9

Hill et al. Chapter 2

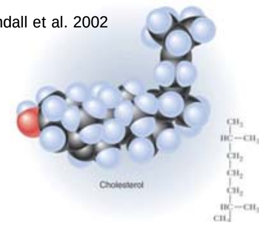
Biochem Blitz

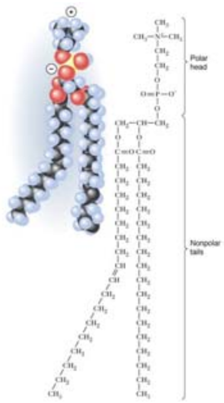
Cells, Membranes, Molecules, Pathways

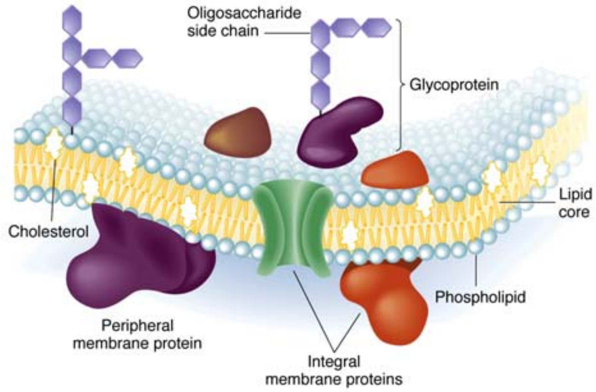
10

- MEMBRANES

4-4 Randall et al. 2002







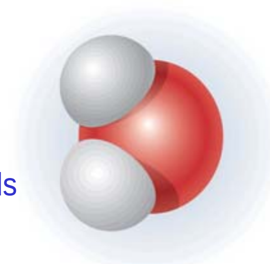
4-2 Randall et al. 2002

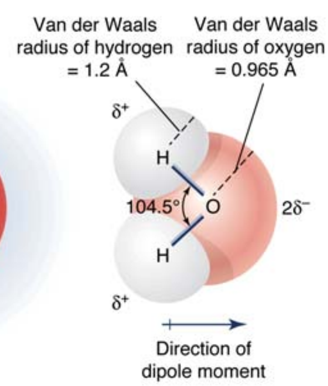
11

4-3 Randall et al. 2002

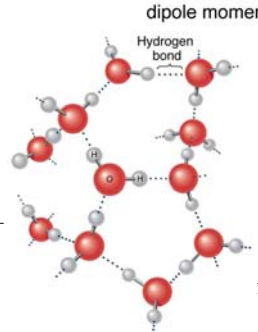
H_2O

- Origins of Life
- Universal Solvent
- Polar Covalent Bonds
- Dipole





- H bonds between molecules
  - transient and weak, but many
  - high specific heat
  - surface tension, cohesiveness



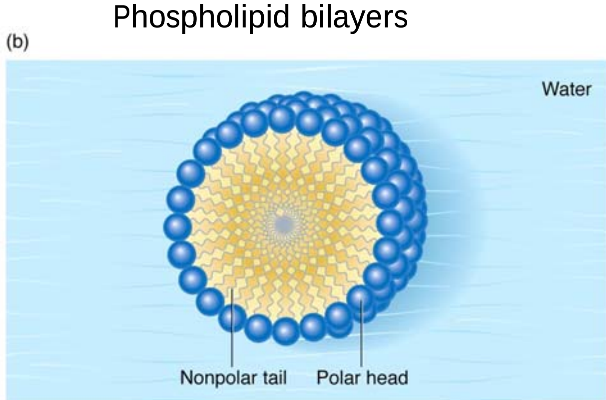
- Density changes

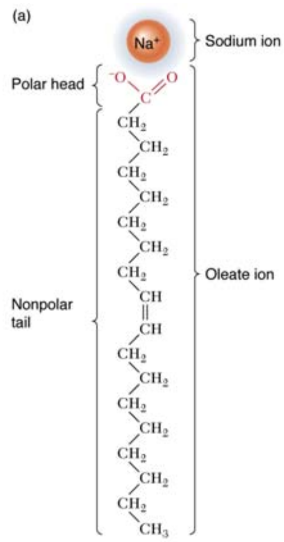
12

In Water:

- hydrophilic
- hydrophobic

-amphipathic molecules
e.g., micelles
Phospholipid bilayers



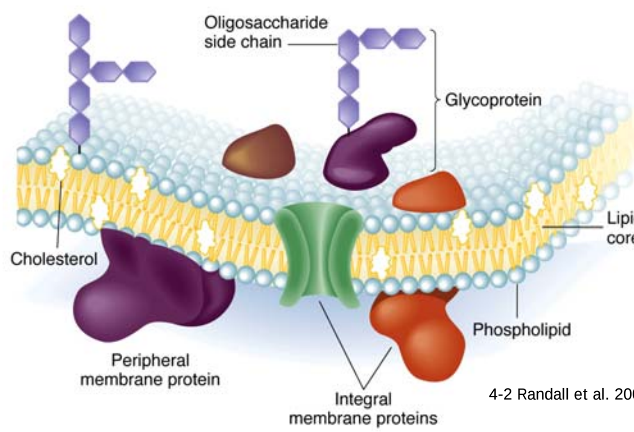


Membrane Structure and Composition

1 Phospholipids
   bilayer, fluidity

2 Cholesterol
   stabilizer

3 Proteins
   - integral
   - peripheral

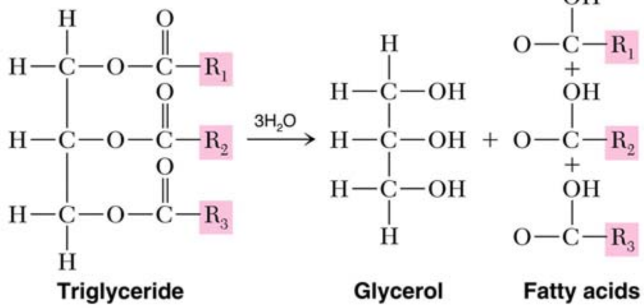


4-2 Randall et al. 2002

Biological Molecules

3-13 Randall et al. 2002

1- Lipids



- saturated -> cholesterol

  No double bonds in side chains
  (saturated with hydrogens)
  ~solid at room temperature

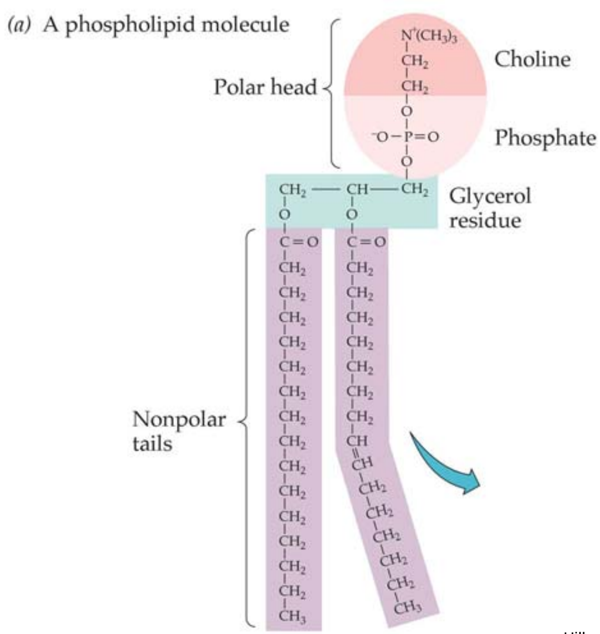
- high energy/ gram
- phospholipids

Table 3-3 The energy content of the three major categories of foodstuffs

Substrate		Energy content ($kcal \cdot g^{-1}$)
Carbohydrates		4.0
Proteins	Migrating bird?	4.5
Fats		9.5

Randall et al. 2002

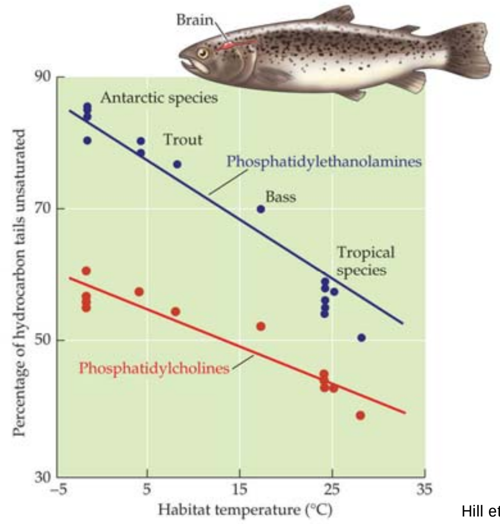
Figure 2.2 The structure of membrane phospholipid molecules



Hill et al. 2004

ANIMAL PHYSIOLOGY, Figure 2.2 (Part 1) © 2004 Sinauer Associates, Inc.

Figure 2.3
Degree of unsaturation of brain phospholipids in fish varies with habitat temperature



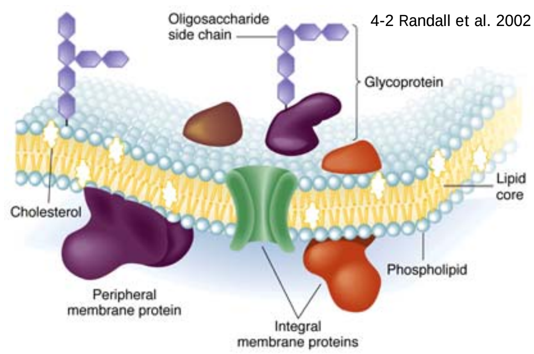
Hill et al. 2004

17

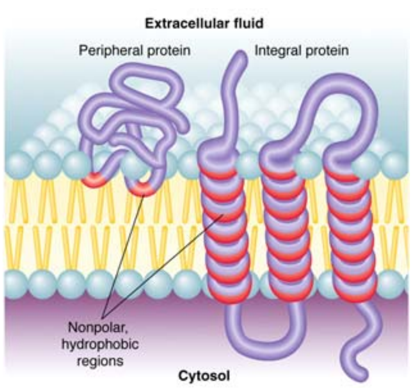
ANIMAL PHYSIOLOGY, Figure 2.3 © 2004 Sinauer Associates, Inc.

Membrane Structure and Composition

4-2 Randall et al. 2002



Protein Structure



4-5 Randall et al. 2002

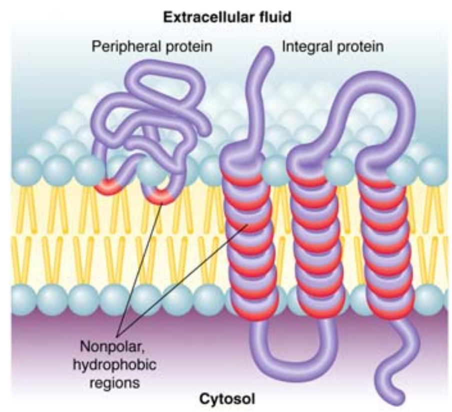
Fluid Mosaic Model

- -Type of lipids
- -Length of tails
- -Amount of cholesterol
- -Amount and type of protein
- -"Sided"

18

Discussion Question

How do scientists come up with the protein conformations such as pictured here:



5-25 nm thick

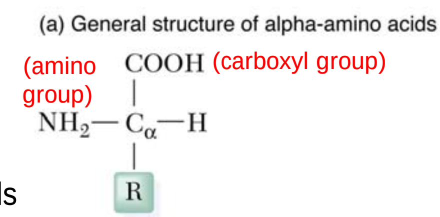
4-5 Randall et al. 2002

19

Biological Molecules

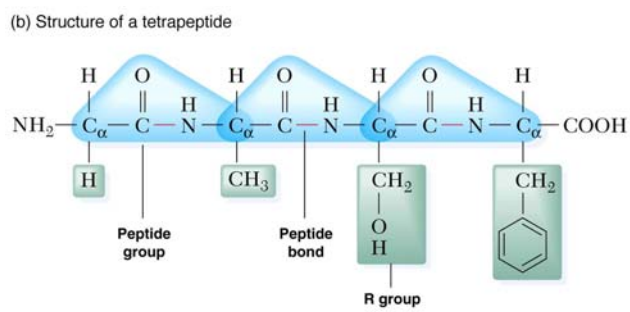
2- <u>Proteins</u>

- linear chains of amino acids



3-17 Randall et al. 2002

- 20 common alpha-amino acids
- amphoteric
- peptide bonds
- polypeptide chains
- 1 °, 2 °, 3 °, 4°

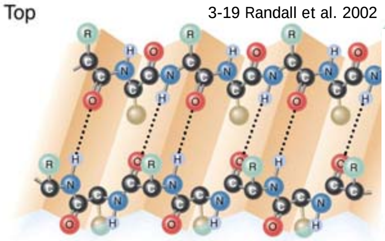


Biological Molecules Top

- Proteins

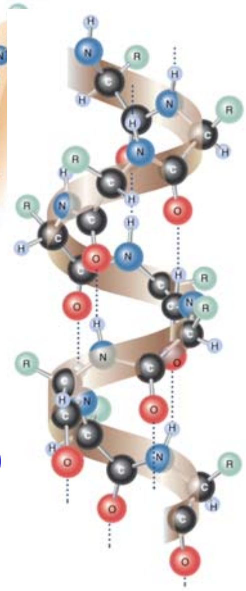
- 1 °, 2 °, 3 °, 4°

3-19 Randall et al. 2002

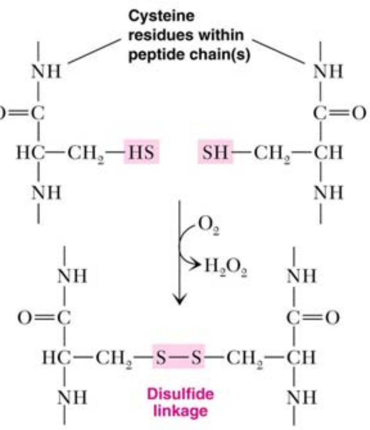


beta

3-18 Randall et al. 2002



alpha

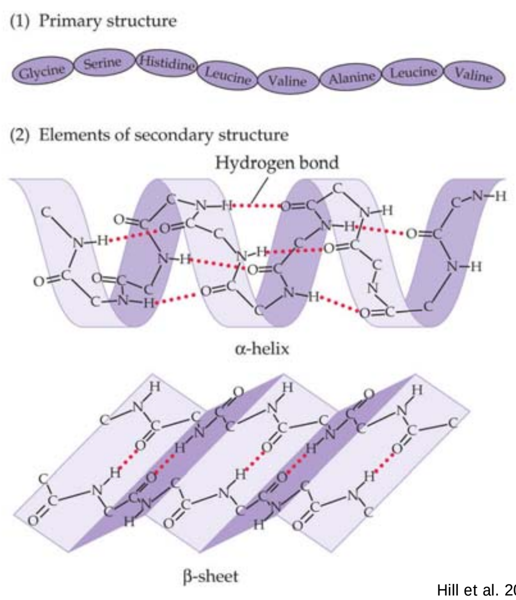


3-20 Randall et al. 2002

-Covalent (strong)
-Ionic
-H bonds
-Van der Waals
-Hydrophobic

Box 2.1, Figure A The structural hierarchy of **proteins**

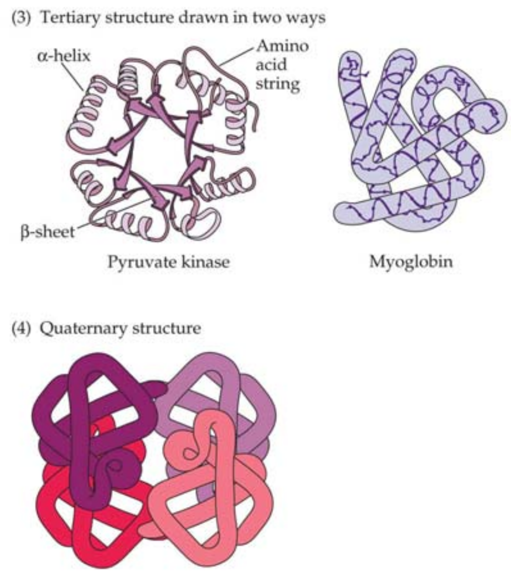
-linear chains of amino acids



Hill et al. 2004

ANIMAL PHYSIOLOGY, Box 2.1, Figure A (Part 1) © 2004 Sinauer Associates, Inc.

Box 2.1, Figure A The structural hierarchy of **proteins**



-Denaturation
-Chaperone Proteins
(e.g., HSPs)

Hill et al. 2004

ANIMAL PHYSIOLOGY, Box 2.1, Figure A (Part 2) © 2004 Sinauer Associates, Inc.

23

TABLE 2.1 The five functional types of membrane proteins and the functions they perform

Functional type	Function performed (defining property)
Channel	Permits simple or quasi-simple diffusion of solutes in aqueous solution (page 70)—or osmosis of water (page 87)—through a membrane; a simplified view of a channel is that it creates a direct water path from one side to the other of a membrane (i.e., an aqueous pore) through which solutes in aqueous solution may diffuse or water may undergo osmosis
Transporter (carrier)	Binds noncovalently and reversibly with specific molecules or ions to move them intact across a membrane; the transport through the membrane is *active transport* (page 74) if it employs metabolic energy; it is *facilitated diffusion* (page 74) if metabolic energy is not employed
Enzyme	Catalyzes a chemical reaction in which covalent bonds are made or broken (page 41)
Receptor	Binds noncovalently with specific molecules and as a consequence of this binding, initiates a change in membrane permeability or cell metabolism; receptor proteins mediate the responses of a cell to chemical messages (signals) arriving at the outside face of the cell membrane (page 56)
Structural protein	Attaches to other molecules (e.g., other proteins) to anchor intracellular elements (e.g., cytoskeleton filaments) to the cell membrane, creates junctions between adjacent cells (Figure 2.7), or establishes other structural relations

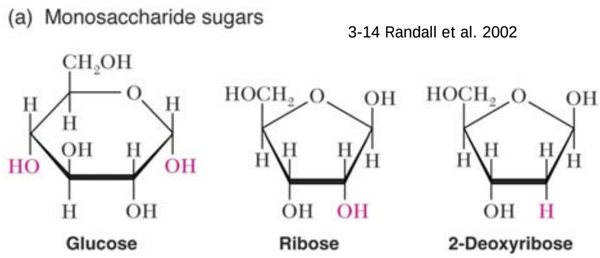
Hill et al. 2004

ANIMAL PHYSIOLOGY, Table 2.1 © Sinauer Associates, Inc.

Biological Molecules

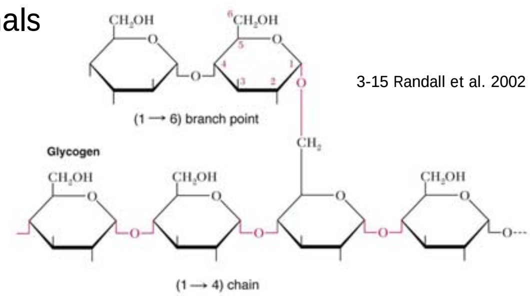
3- Carbohydrates

- $(CH_2O)_n$



3-14 Randall et al. 2002

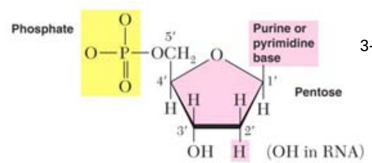
- monosaccharides, (disaccharides)
- glucose is common metabolic currency from plants to animals
- glycogen (storage)



3-15 Randall et al. 2002

Biological Molecules

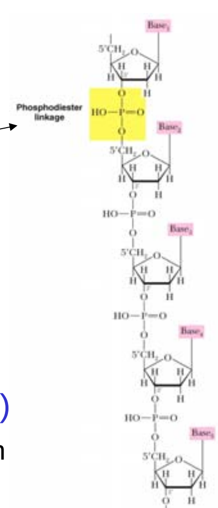
4- Nucleic Acids

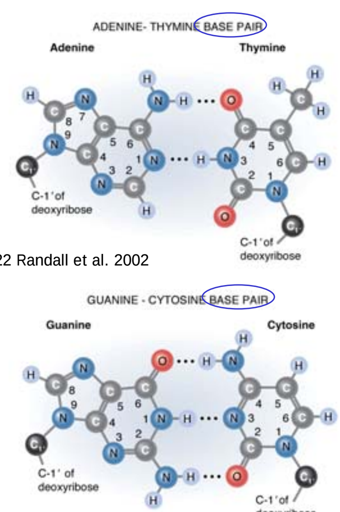


3-21 Randall et al. 2002

- pyrimidine (T,C) or
- purine (A,G)

-Phosphodiester linkages between adjacent





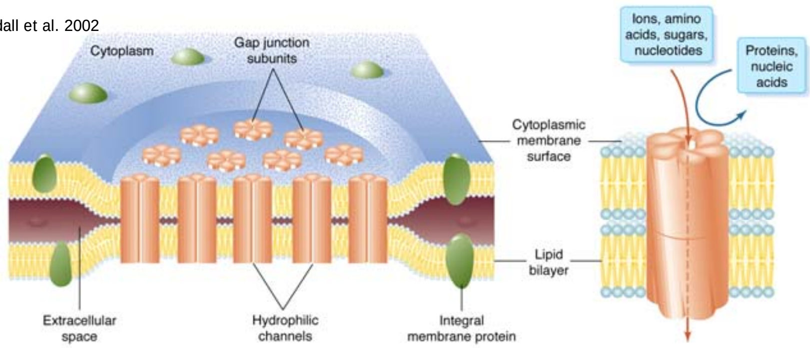
3-22 Randall et al. 2002

- transcription (nucleus)
  DNA -> mRNA
- translation (ribosome)
  mRNA -> tRNA -> protein
  (genetic code)

Junctions between cells

1. Gap
~linked

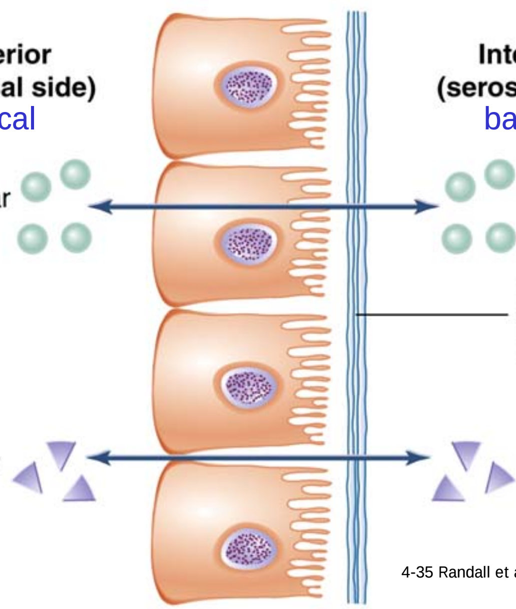
4-32 Randall et al. 2002



2. Tight
~ impermeable barriers

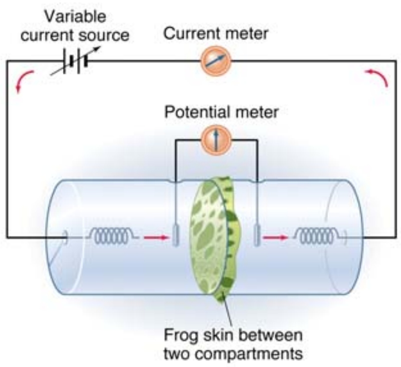
27

Junctions between cells and solute movement

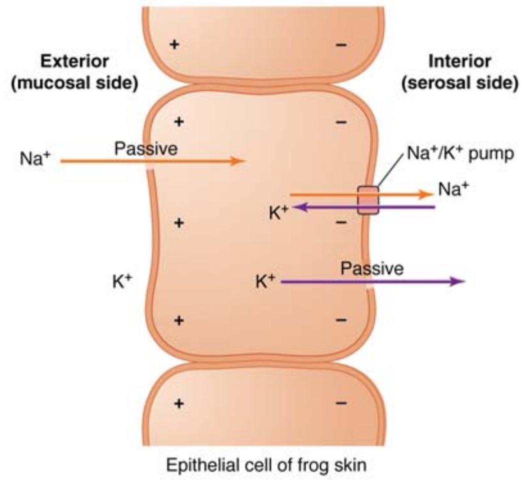


4-35 Randall et al. 2002

Solute movement and variability of membrane properties



4-36 Randall et al. 2002

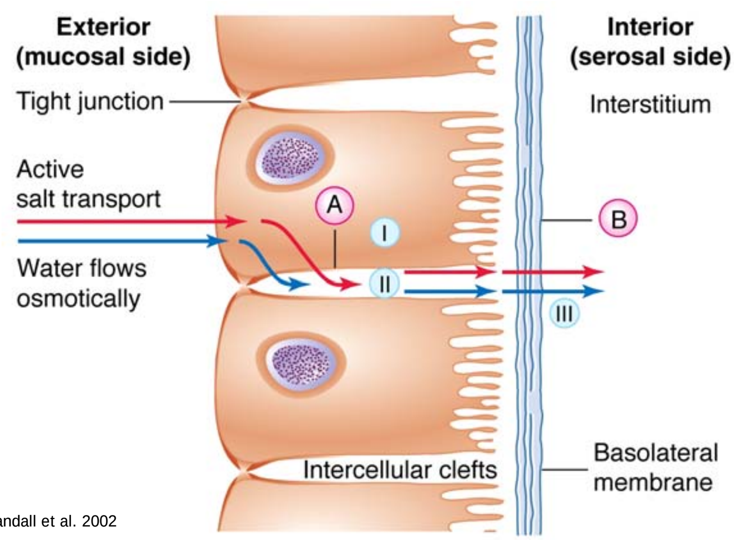


4-37 Randall et al. 2002

29

Solute movement and subsequent water movement

Osmosis



4-39 Randall et al. 2002

30

Enzymes and Energetics
(Hill et al. Ch 2, con't)

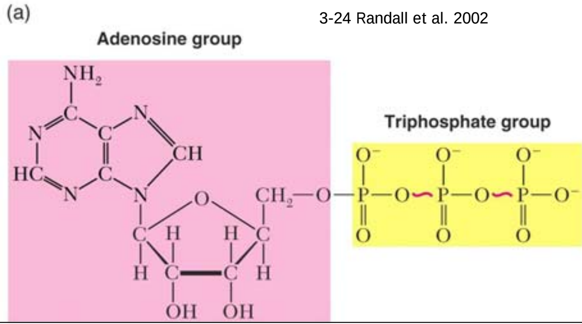
31

Energetics (sun is origin)

- metabolism
  - energy/ATP
  - building blocks
  - small, controlled oxidation steps

3-24 Randall et al. 2002

(a)



- 1^{st} law – energy neither created or destroyed
- 2^{nd} law – entropy will reign

- free energy ΔG (energy available to do useful work)

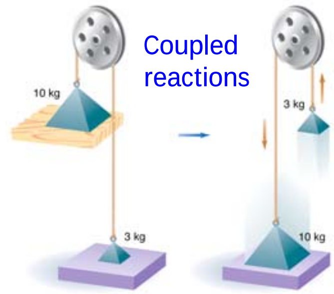
$-\ \Delta G$	- exergonic (~liberate heat)
$+\ \Delta G$	- endergonic (uphill)

32

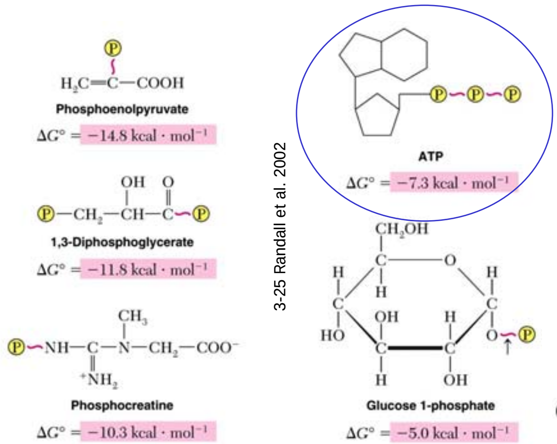
Energetics

- exergonic (liberate heat) - ΔG
- endergonic (uphill) + ΔG

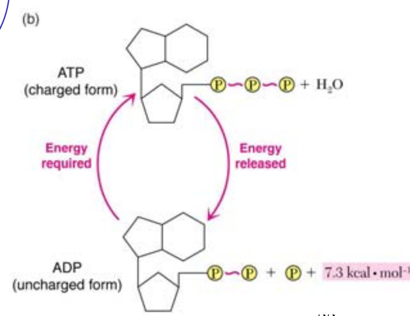
3-23 Randall et al. 2002



Coupled reactions



3-25 Randall et al. 2002



3-24 Randall et al. 2002

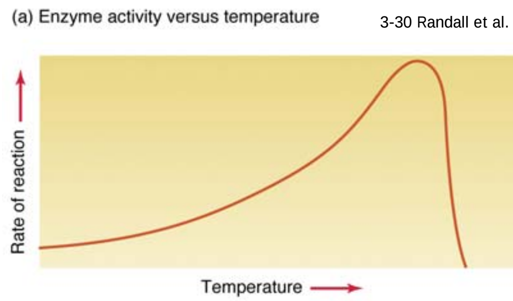
33

Phosphorylation
-Protein Kinases
-Protein Phosphatases

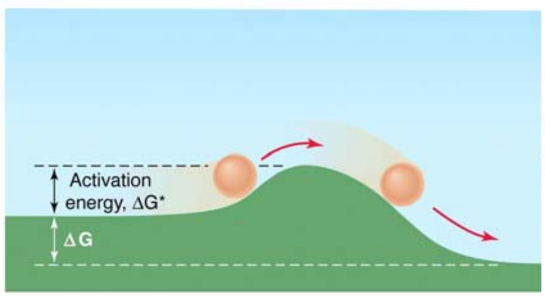
34

Energetics

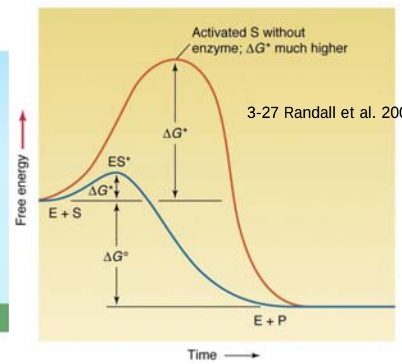
- Activation Energy
- Enzymes
  CATALYSTS
- Temperature
- ⇑ Reaction Rates



3-30 Randall et al. 2002

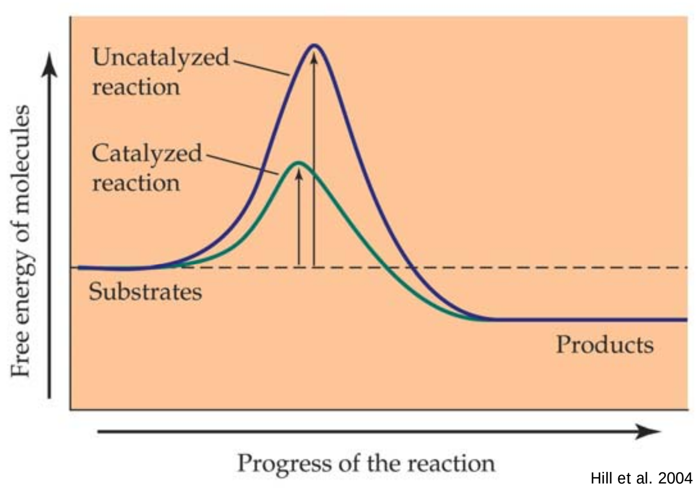


3-26 Randall et al. 2002



3-27 Randall et al. 2002

Figure 2.13 Enzymes speed reactions by lowering the needed activation energy



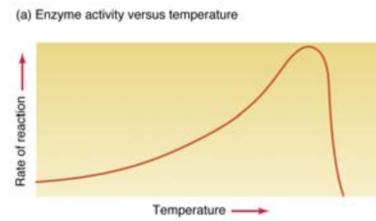
Hill et al. 2004

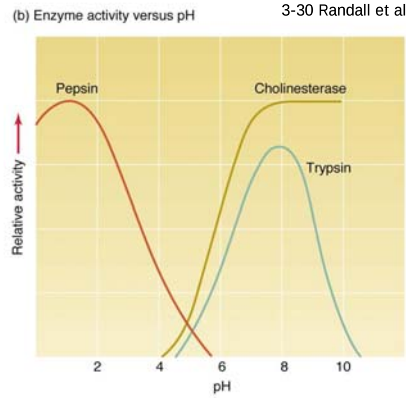
36

ANIMAL PHYSIOLOGY, Figure 2.13 © 2004 Sinauer Associates, Inc.

Enzymes

- pH, temperature
- Cofactors
  (often vitamins)





3-30 Randall et al. 2002

Randall et al. 2002

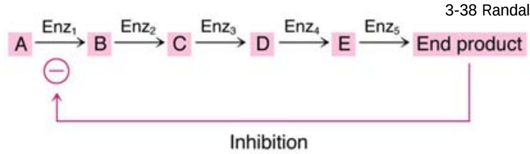
Table 3-6 Metal ions functioning as cofactors

Metal ion	Some enzymes requiring this cofactor
Ca^{2+}	Phosphodiesterase
	Protein kinase C
Cu^{2+} (Cu^{+})	Cytochrome oxidase
	Tyrosinase
Fe^{2+} or Fe^{3+}	Catalase
	Cytochromes
	Ferredoxin
	Peroxidase
K^{+}	Pyruvate phosphokinase (also requires Mg^{2+})
Mg^{2+}	Phosphohydrolases
	Phosphotransferases
Mn^{2+}	Arginase
	Phosphotransferases
Na^{+}	Plasma membrane ATPase (also requires K^{+} and Mg^{2+})
Zn^{2+}	Alcohol dehydrogenase
	Carbonic anhydrase
	Carboxypeptidase

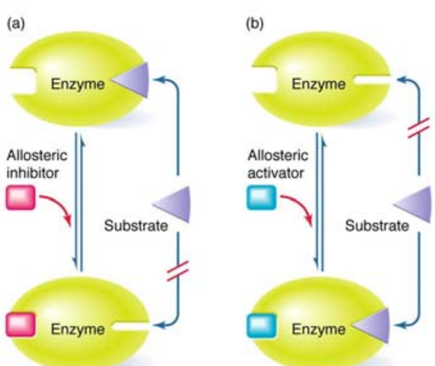
Source: Adapted from Nelson and Cox, 2000.

Enzymes

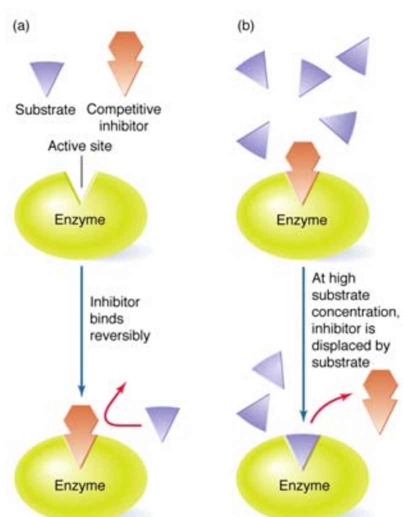
3-38 Randall et al. 2002



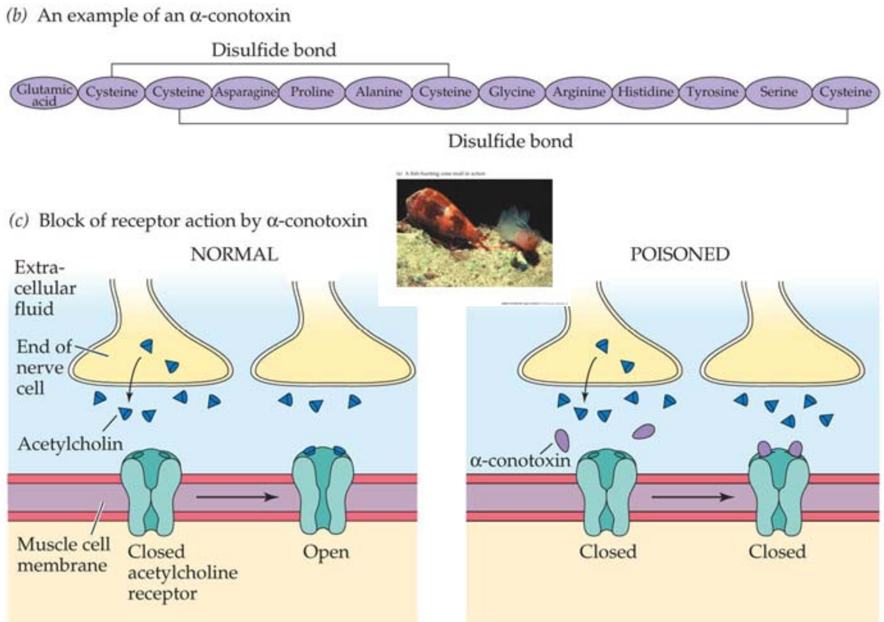
- Regulation
  1 - Competitive
  2 - Allosteric



3-37 Randall et al. 2002

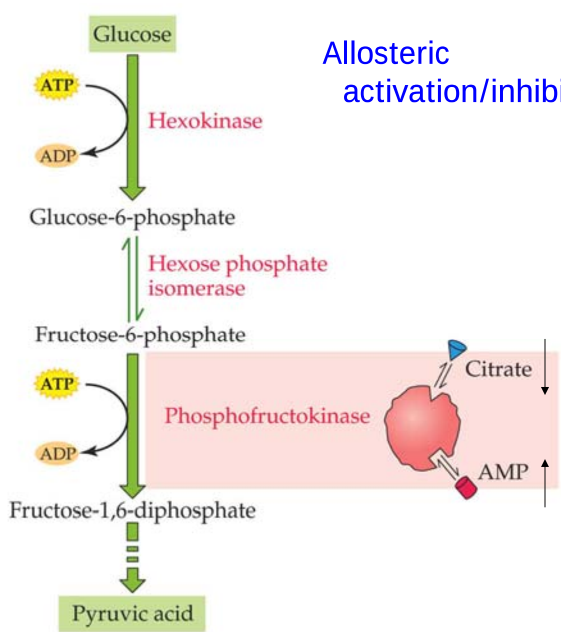


3-35 Randall et al. 2002



Hill et al. 2004
ANIMAL PHYSIOLOGY, Figure 2.24 (Part 2) © 2004 Sinauer Associates, Inc.

Allosteric activation/inhibition

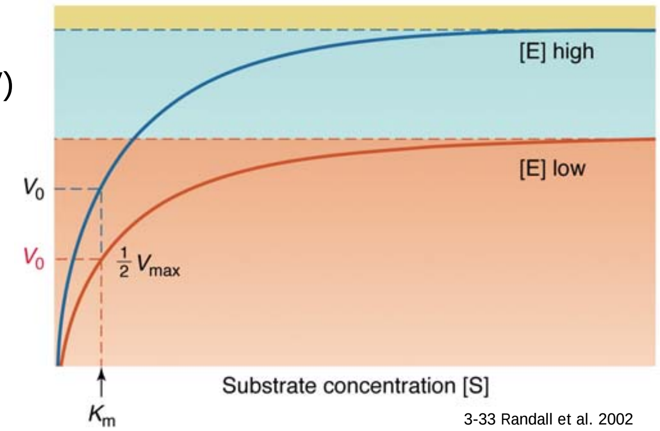


Hill et al. 2004
ANIMAL PHYSIOLOGY, Figure 2.18 © 2004 Sinauer Associates, Inc.

Enzymes

- Rates of Rxn (V)

- MM constant
  (Km)



3-33 Randall et al. 2002

- Michaelis-Menten equation

$$V_o = \frac{V_{max}[S]}{K_m + [S]}$$

41