

Biochemistry

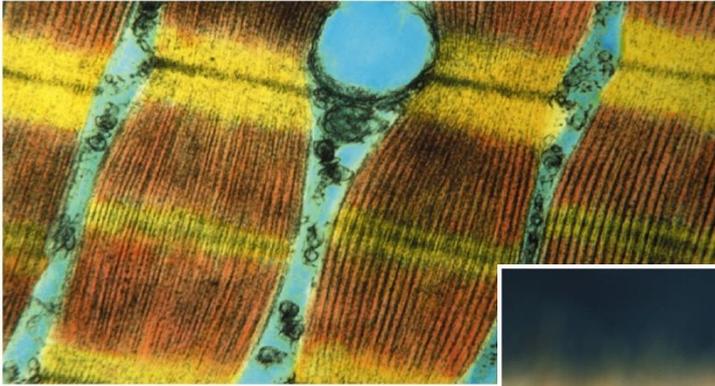
Science concerned with the chemical constituents of living cells and with the reaction and process that they undergo.

The Foundations of Biochemistry

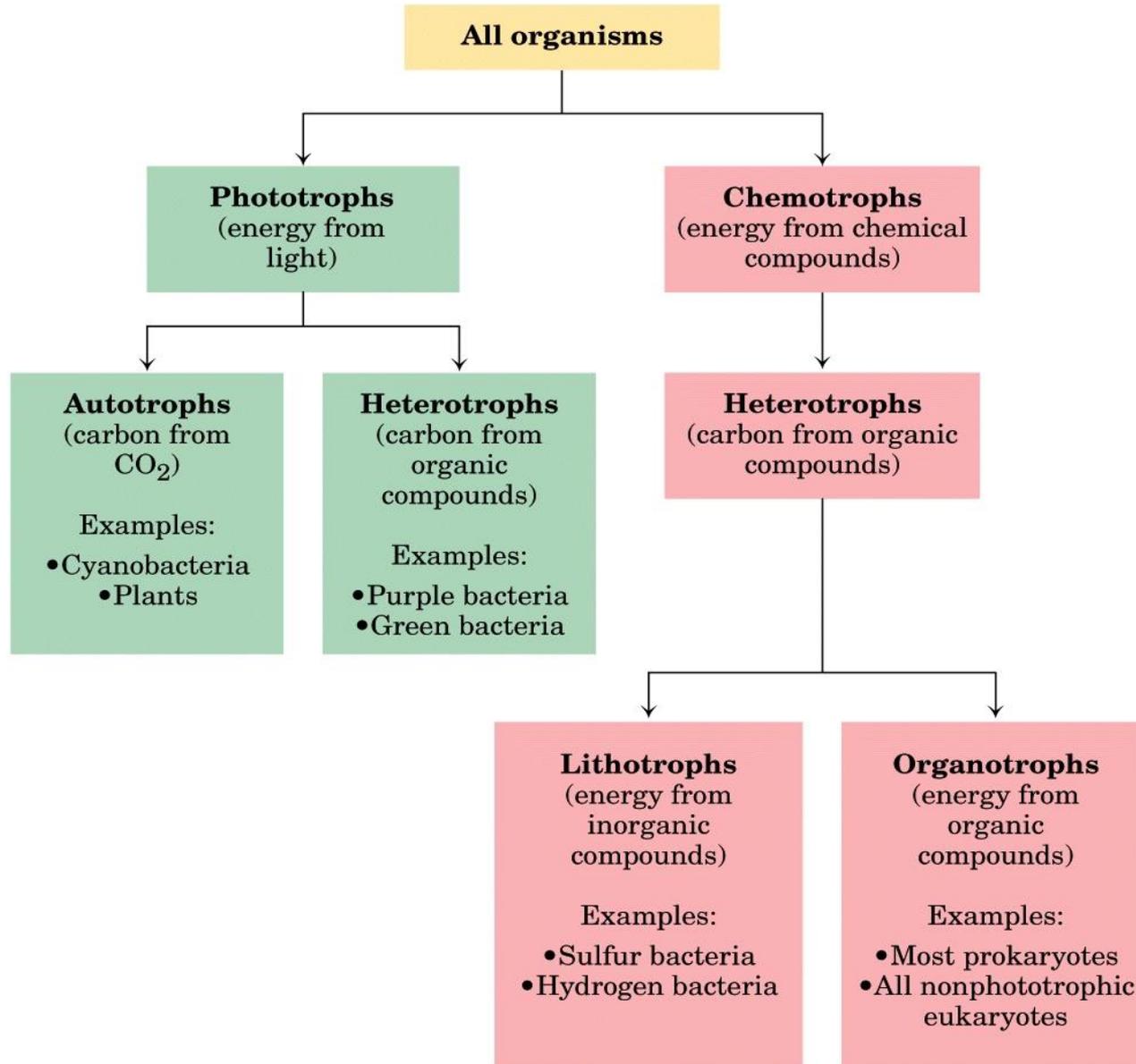
- Cellular Foundations
- Chemical Foundations
- Genetic Foundations
- Physical Foundations

- **CELLULAR FOUNDATION.**

What distinguishes living organisms from inanimate matter ?



Classification of organisms according to their source of energy



Diverse living organisms share common biochemical features



What are cells ???



0.6 μm

The structural and functional units of living organisms

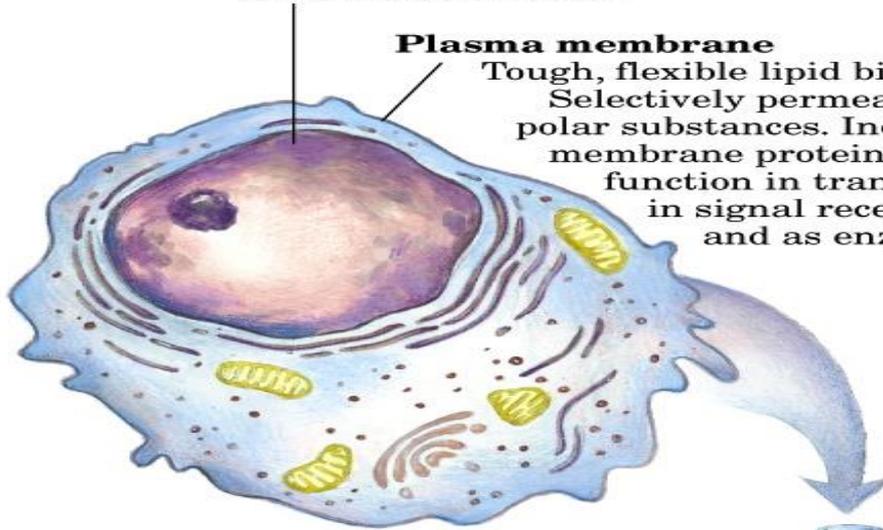
Features of living cells

Nucleus (eukaryotes) or nucleoid (bacteria)

Contains genetic material—DNA and associated proteins. Nucleus is membrane-bounded.

Plasma membrane

Tough, flexible lipid bilayer. Selectively permeable to polar substances. Includes membrane proteins that function in transport, in signal reception, and as enzymes.



Cytoplasm

Aqueous cell contents and suspended particles and organelles.

centrifuge at 150,000 *g*

Supernatant: cytosol
Concentrated solution of enzymes, RNA, monomeric subunits, metabolites, inorganic ions.

Pellet: particles and organelles
Ribosomes, storage granules, mitochondria, chloroplasts, lysosomes, endoplasmic reticulum.



Unicellular

Common structural features of bacterial cell

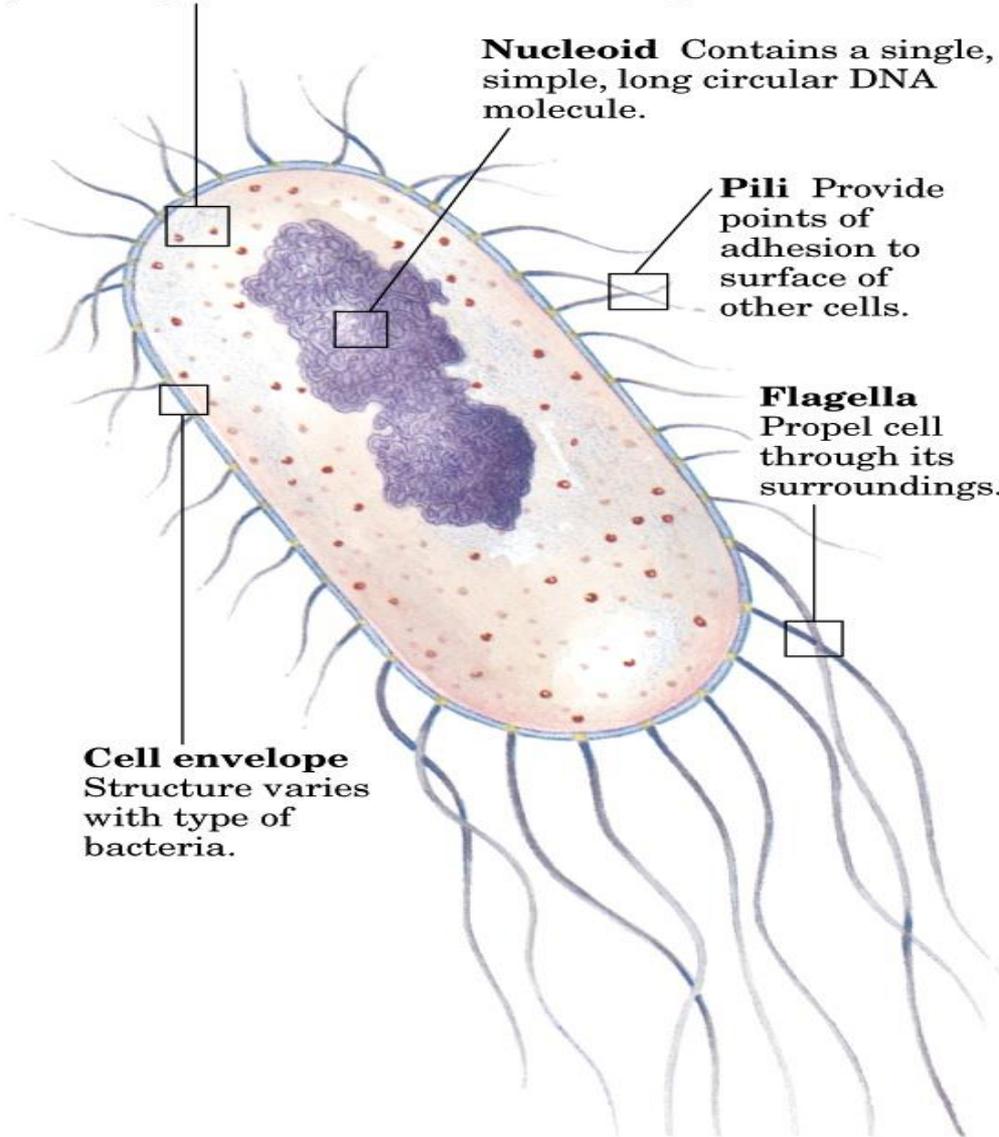
Ribosomes Bacterial ribosomes are smaller than eukaryotic ribosomes, but serve the same function—protein synthesis from an RNA message.

Nucleoid Contains a single, simple, long circular DNA molecule.

Pili Provide points of adhesion to surface of other cells.

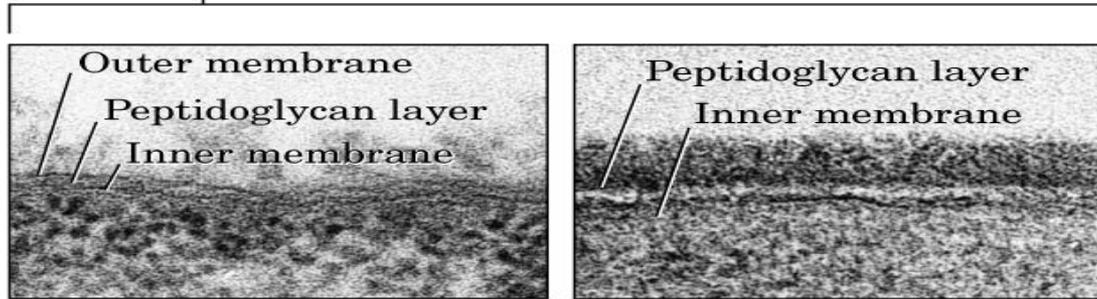
Flagella Propel cell through its surroundings.

Cell envelope
Structure varies with type of bacteria.



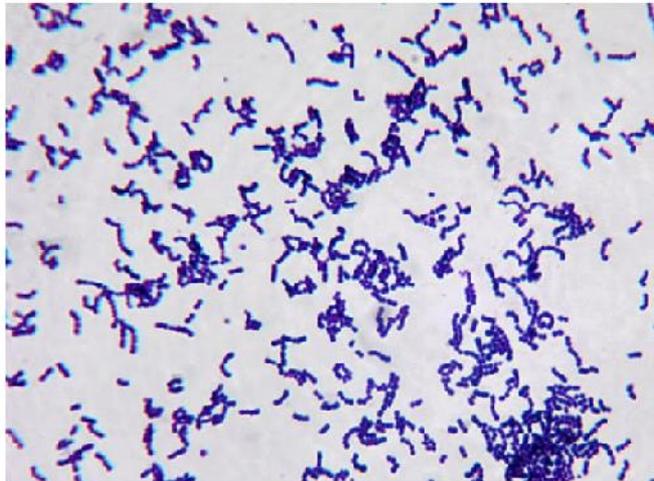
Gram Positive vs. Gram Negative

Cell envelope
Structure varies
with type of
bacteria.

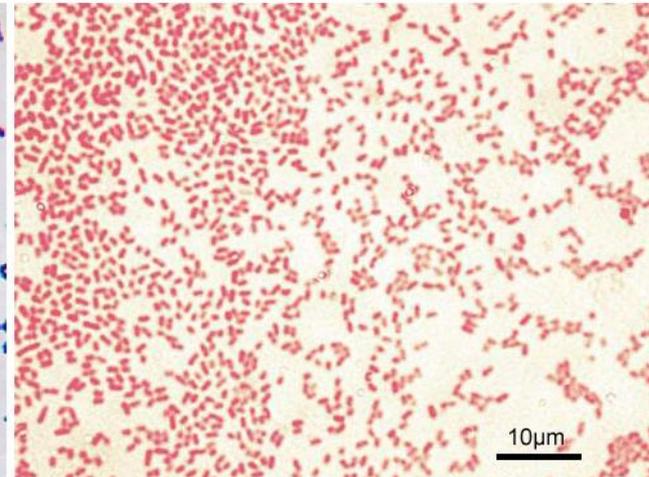


Gram-negative bacteria
Outer membrane and
peptidoglycan layer

Gram-positive bacteria
Thicker peptidoglycan
layer; outer membrane
absent



Gram Positive Bacteria



Gram Negative Bacteria

Eukaryotic cell structure: Animal vs. Plant cells

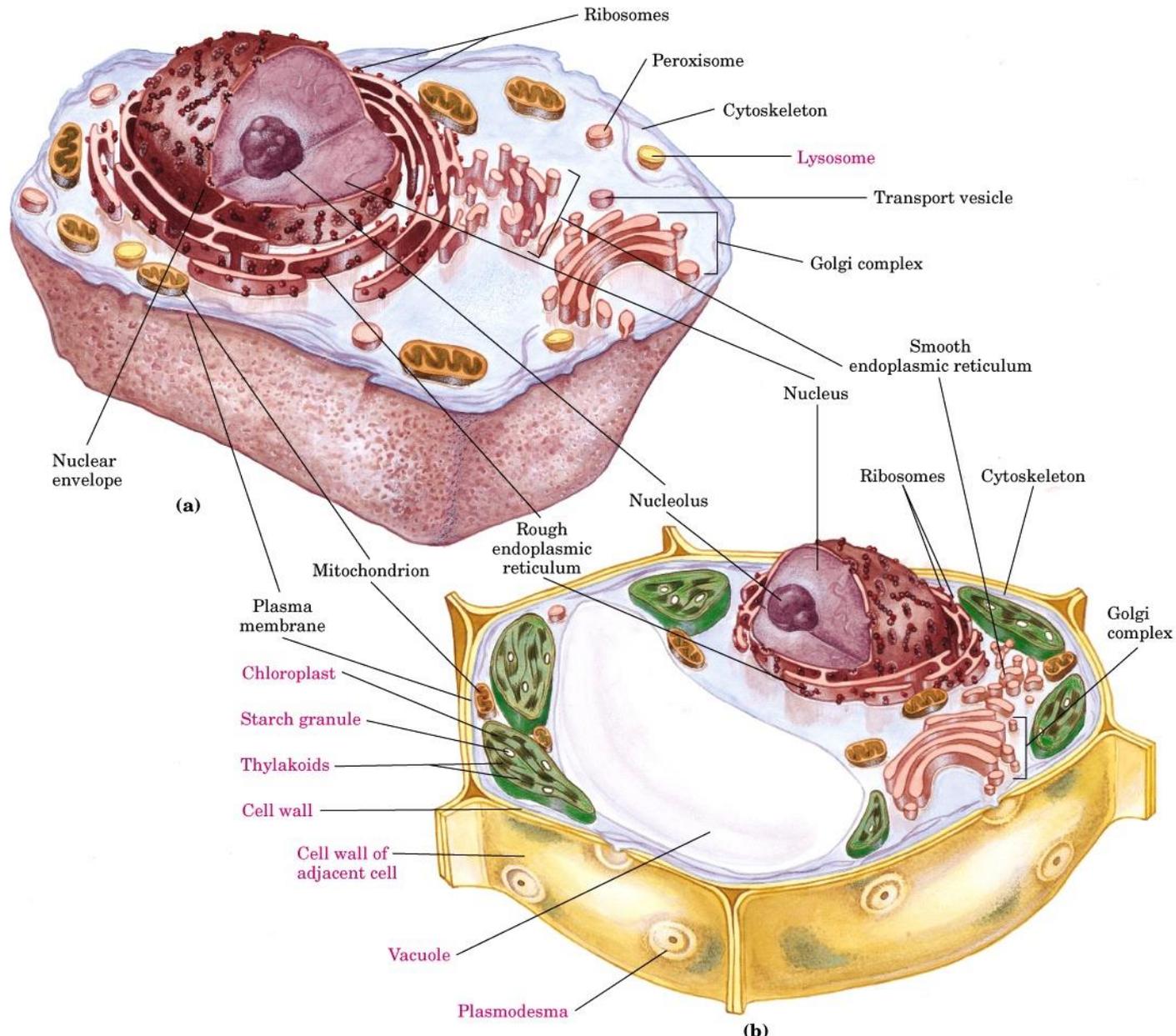
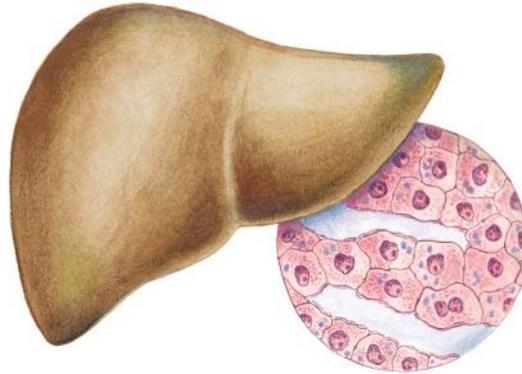


table 2–1**Comparison of Prokaryotic and Eukaryotic Cells**

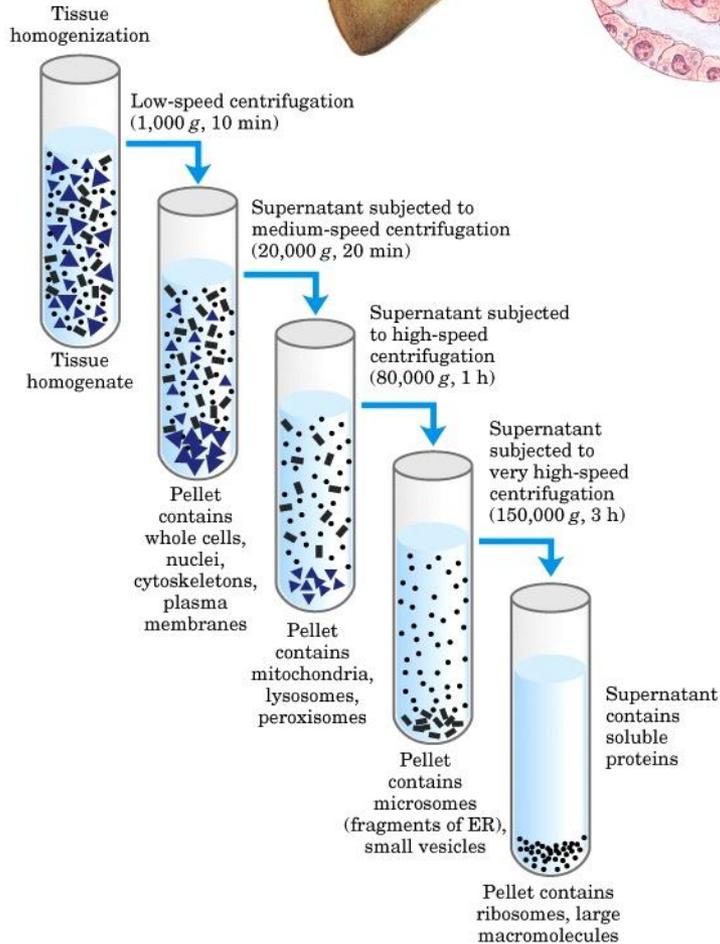
Characteristic	Prokaryotic cell	Eukaryotic cell
Size	Generally small (1–10 μm)	Generally large (5–100 μm)
Genome	DNA with nonhistone protein; genome in nucleoid, not surrounded by membrane	DNA complexed with histone and nonhistone proteins in chromosomes; chromosomes in nucleus with membranous envelope
Cell division	Fission or budding; no mitosis	Mitosis including mitotic spindle; centrioles in many species
Membrane-bounded organelles	Absent	Mitochondria, chloroplasts (in plants, some algae), endoplasmic reticulum, Golgi complexes, lysosomes (in animals), etc.
Nutrition	Absorption; some photosynthesis	Absorption, ingestion; photosynthesis in some species
Energy metabolism	No mitochondria; oxidative enzymes bound to plasma membrane; great variation in metabolic pattern	Oxidative enzymes packaged in mitochondria; more unified pattern of oxidative metabolism
Cytoskeleton	None	Complex, with microtubules, intermediate filaments, actin filaments
Intracellular movement	None	Cytoplasmic streaming, endocytosis, phagocytosis, mitosis, vesicle transport

Source: Modified from Hickman, C.P., Roberts, L.S., & Hickman, F.M. (1990) *Biology of Animals*, 5th edn, p. 30, Mosby–Yearbook, Inc., St. Louis, MO.

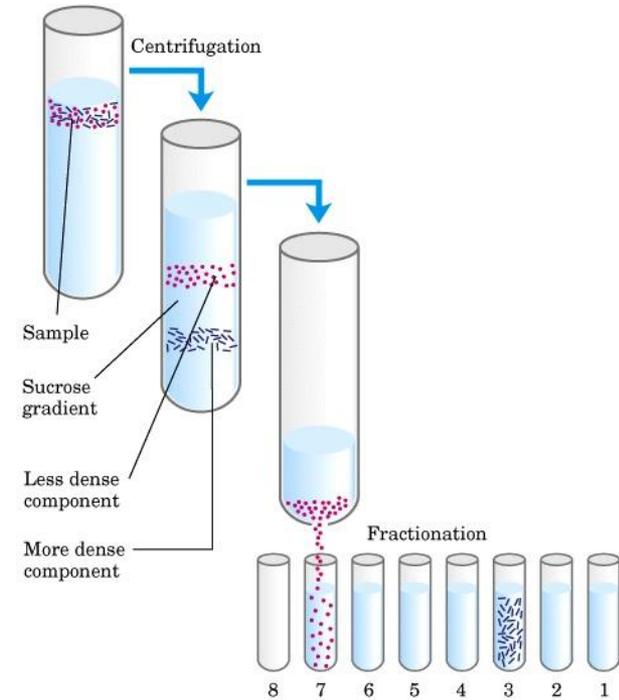
Study of cellular components



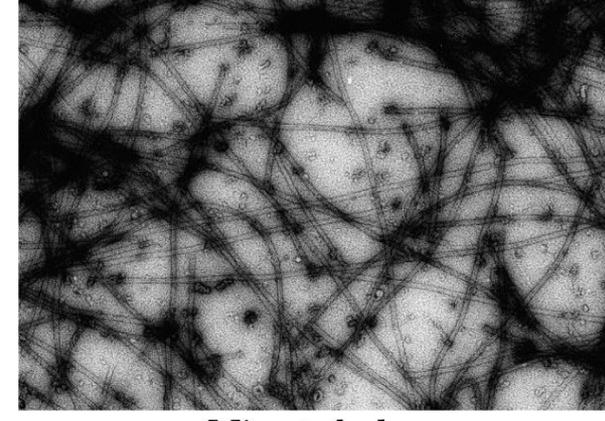
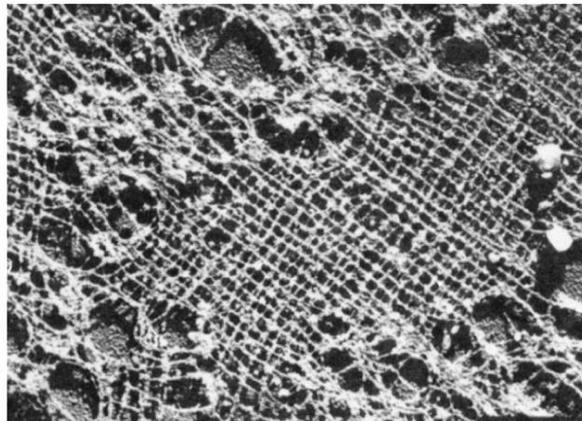
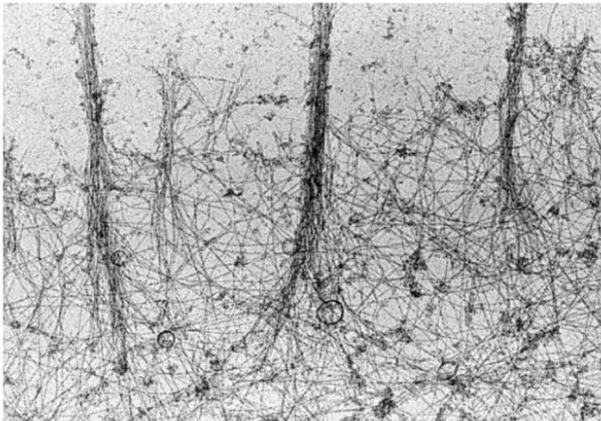
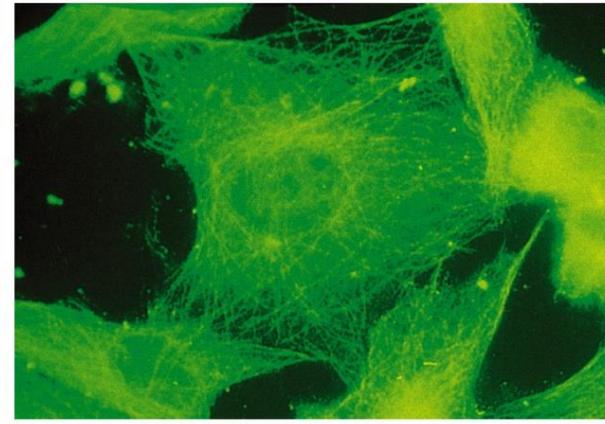
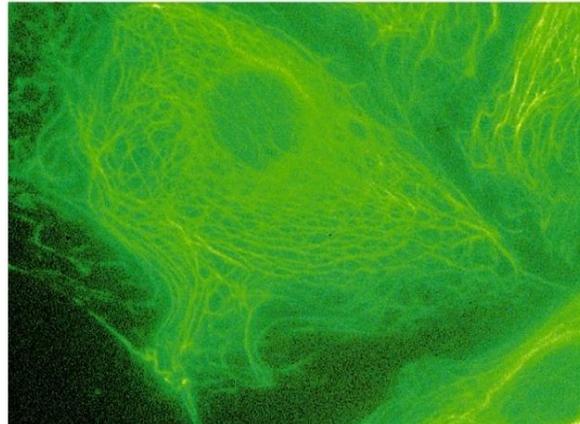
(a) Differential centrifugation



(b) Isopycnic (sucrose-density) centrifugation



Cytoskeleton

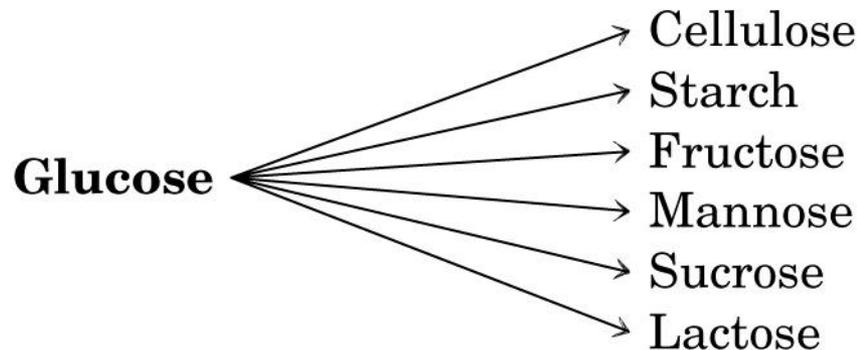
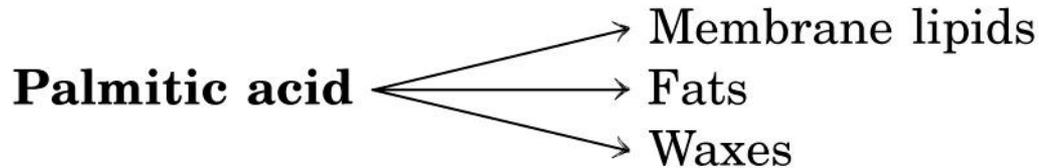
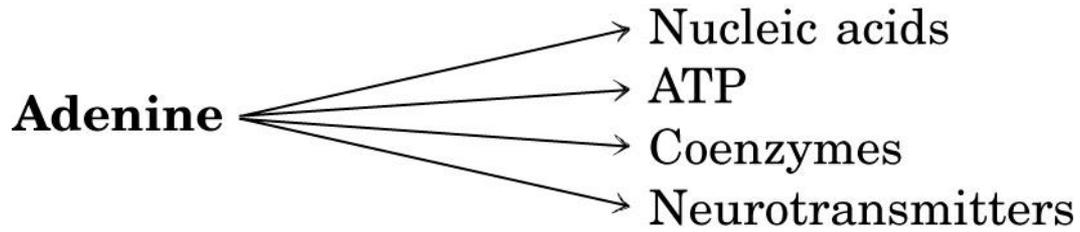
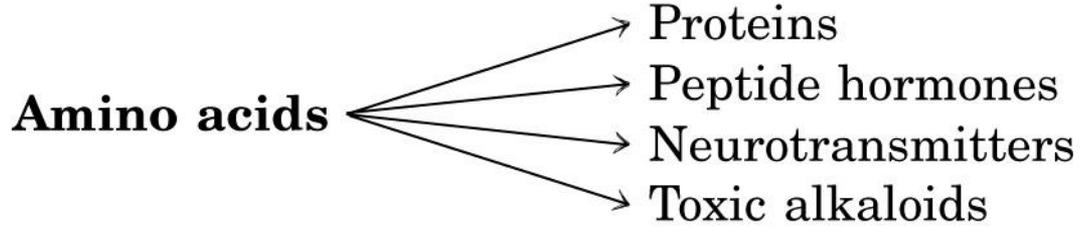


Actin stress fibers
(a)

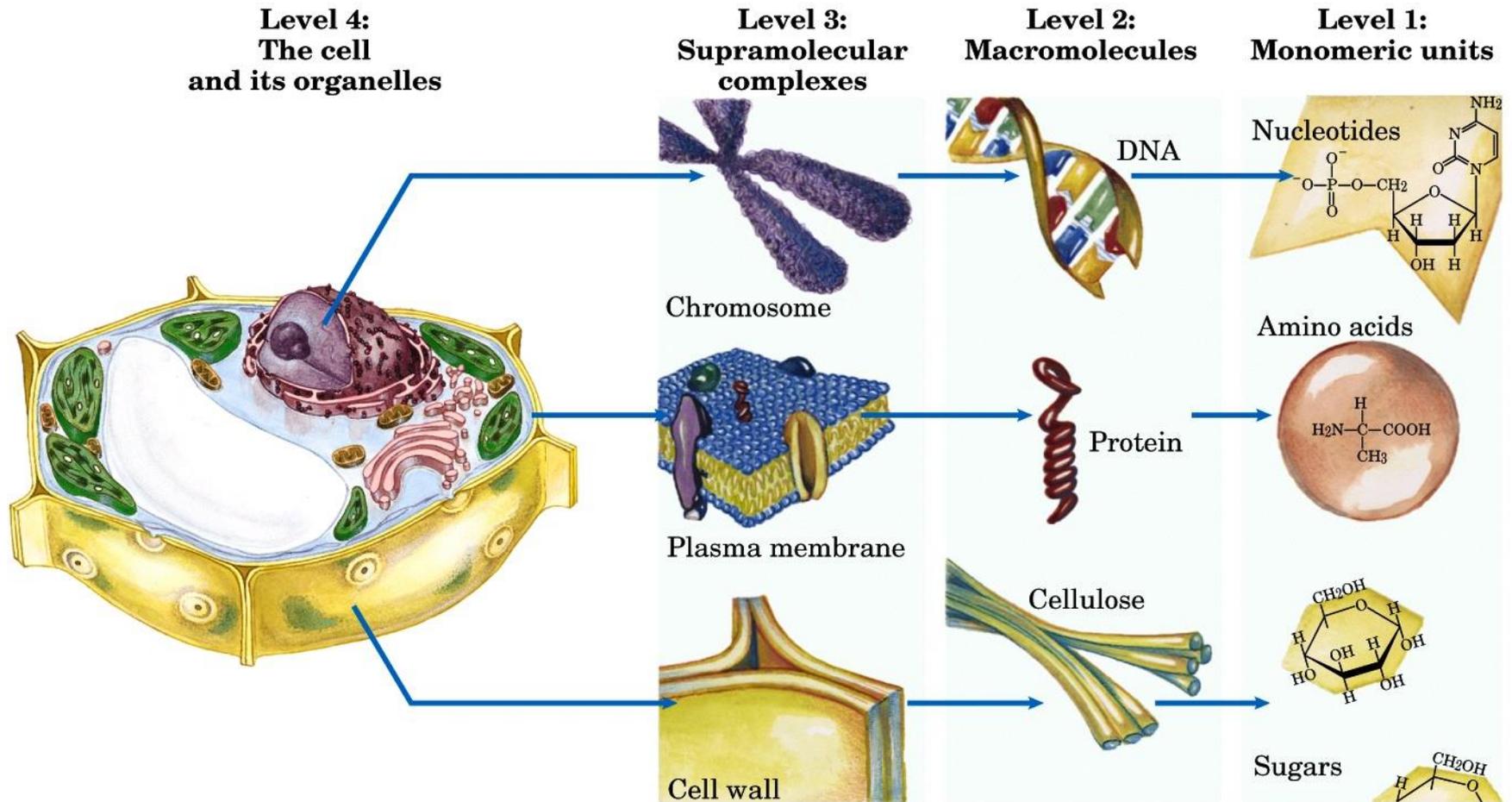
Intermediate filaments
(c)

Microtubules
(b)

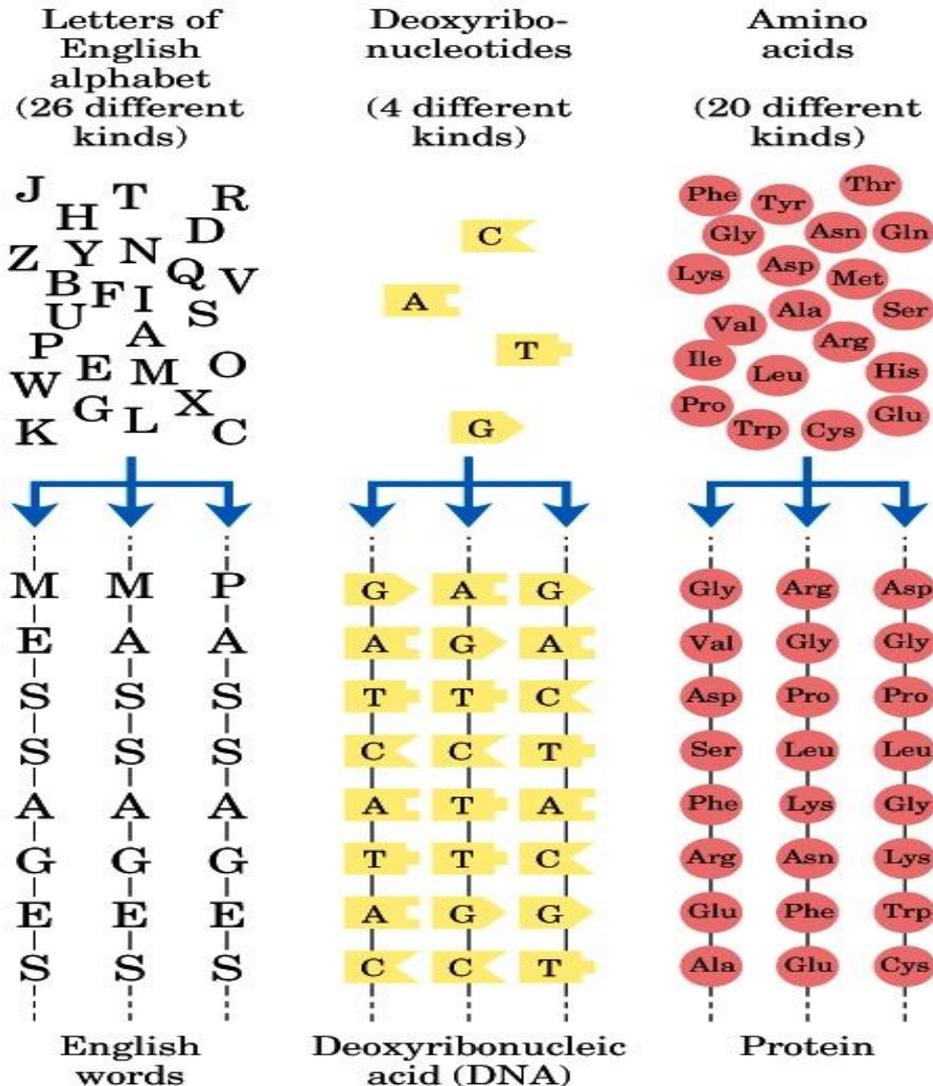
Macromolecules & Monomeric subunits



Structural Hierarchy



Monomeric subunits



Ordered linear sequences

For a segment of 8 subunits, the number of different sequences possible =

$$26^8 \text{ or } 2.1 \times 10^{11}$$

$$4^8 \text{ or } 65,536$$

$$20^8 \text{ or } 2.56 \times 10^{10}$$

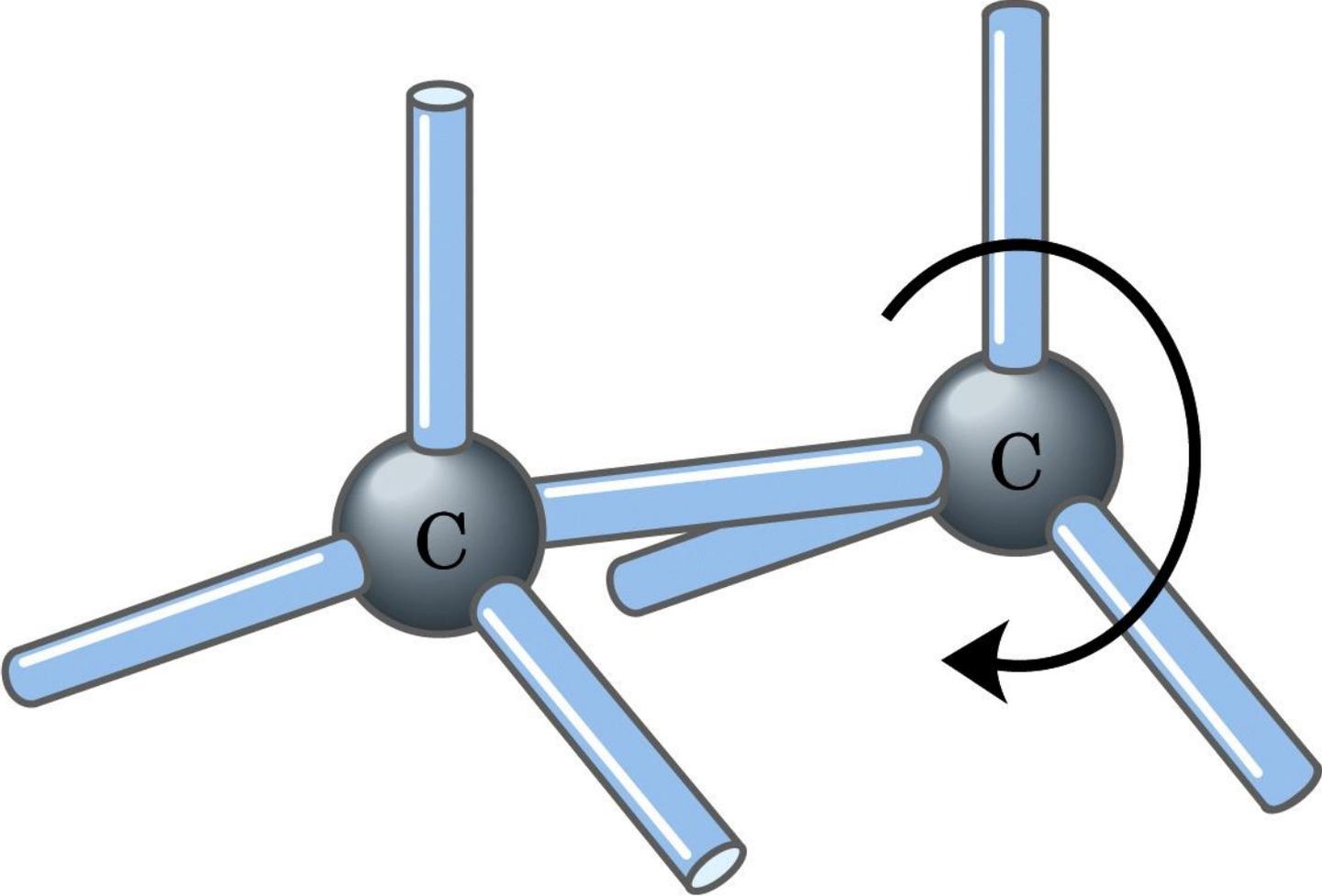
- **CHEMICAL FOUNDATION**

Elements essential to life and health

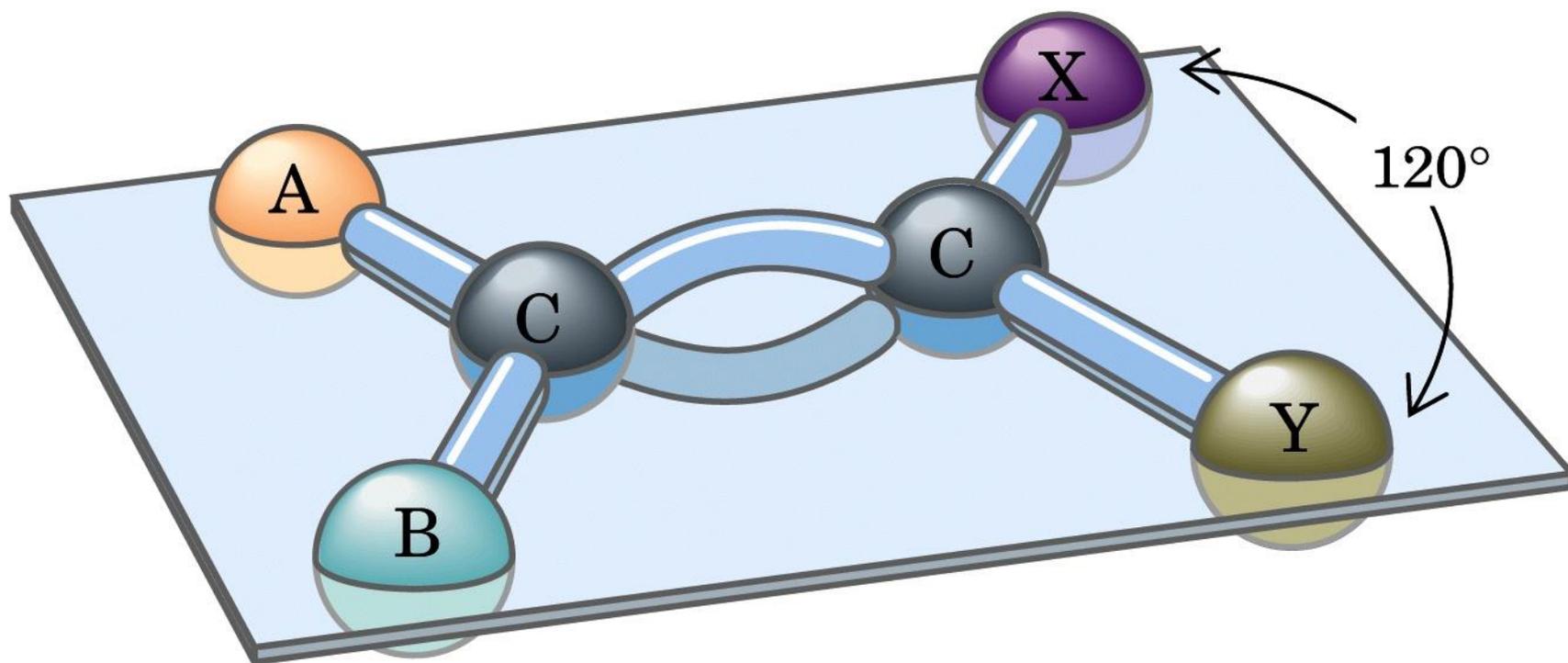
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra		Lanthanides Actinides														

Bulk elements
 Trace elements

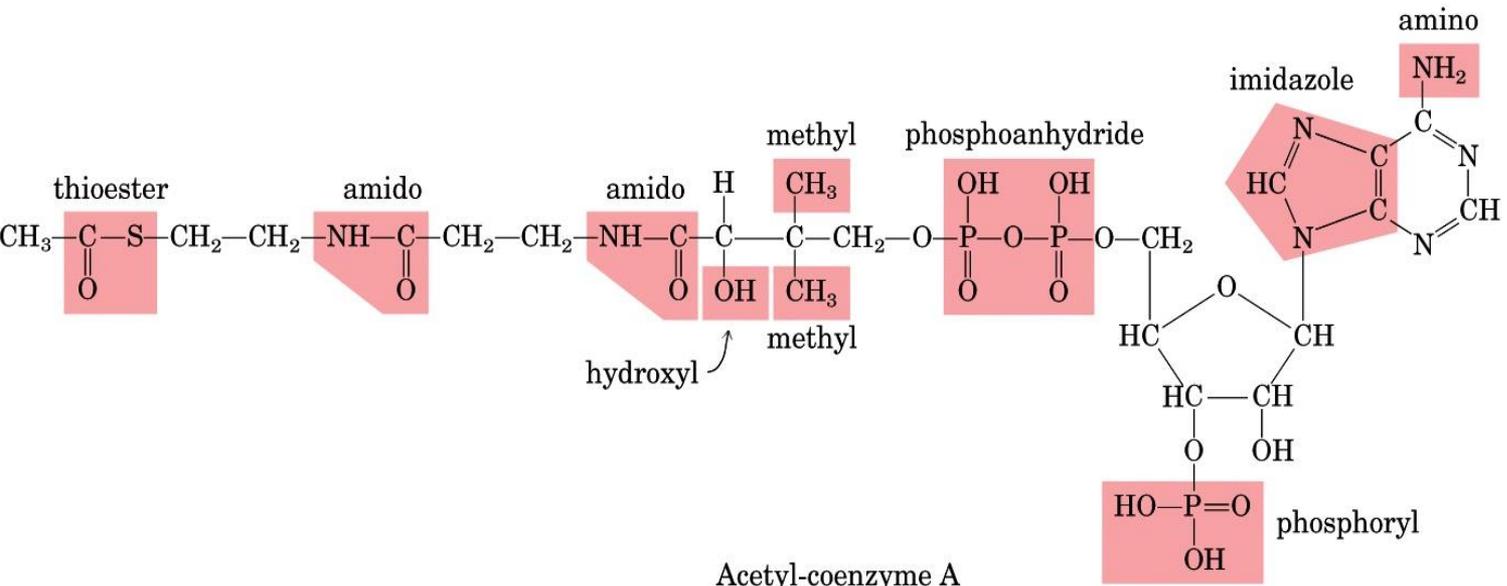
Single bonds vs. Double bonds



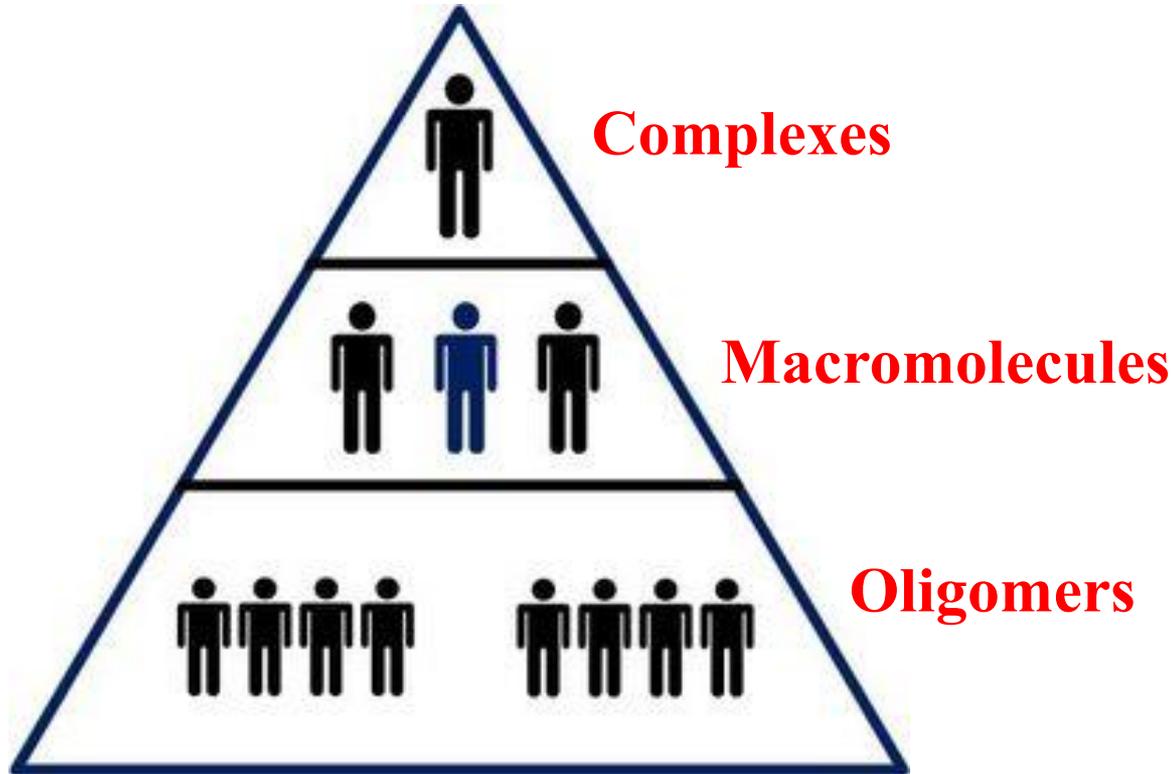
Single bonds vs. Double bonds



Functional group



Structural Hierarchy



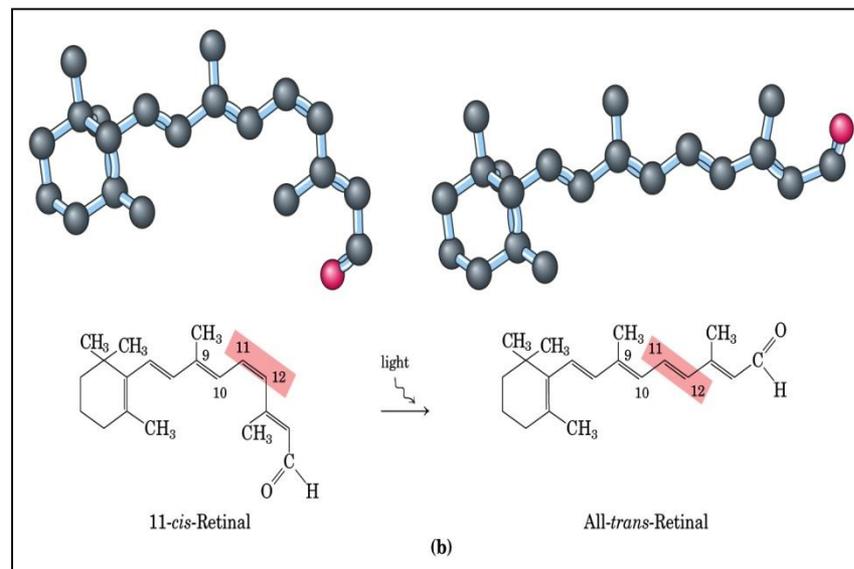
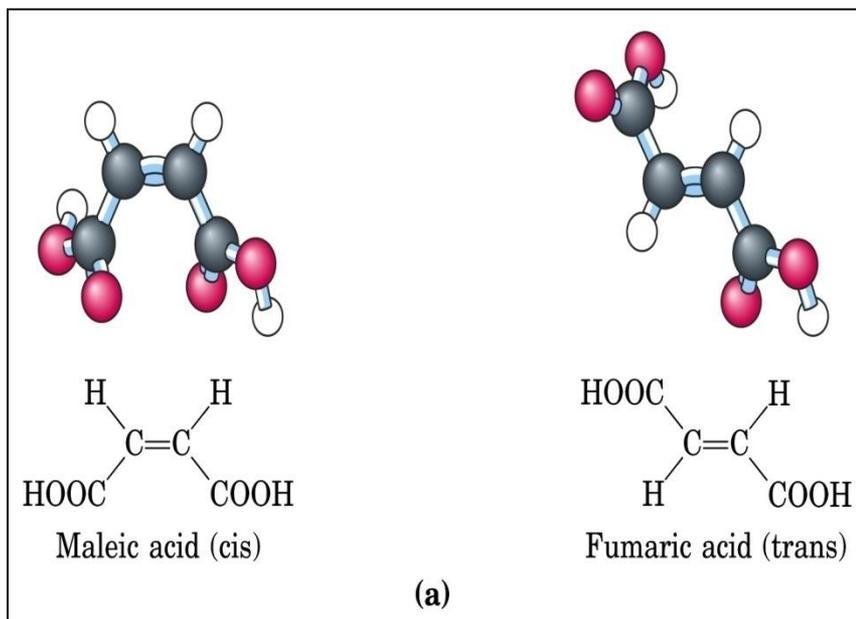
Structural Hierarchy

Oligomers

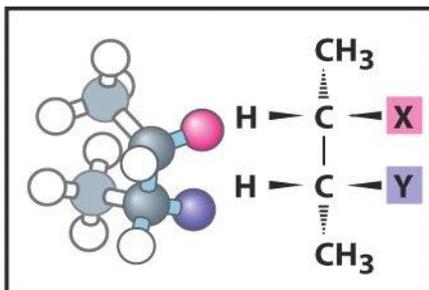
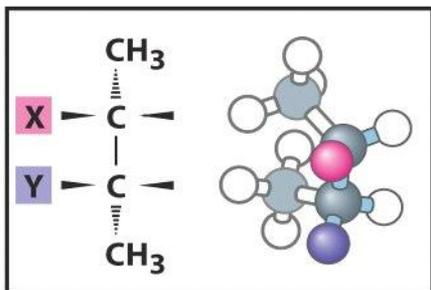
Macromolecules

Supramolecular Complexes

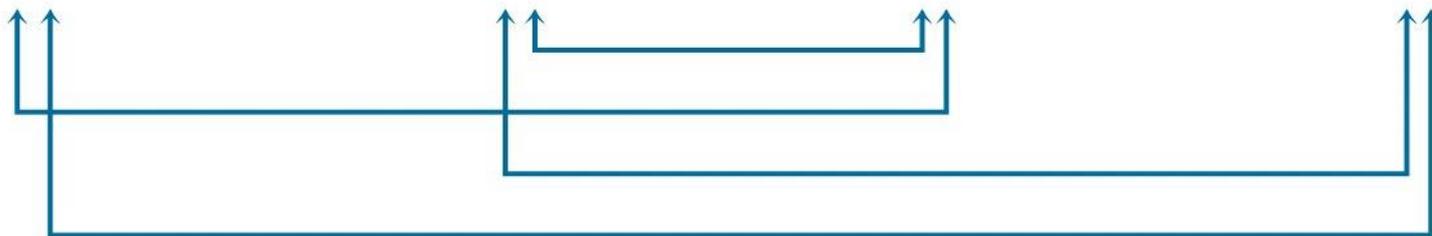
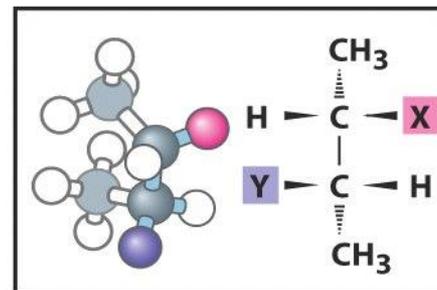
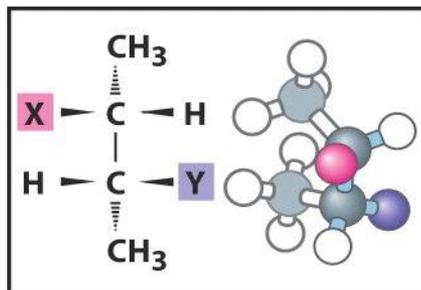
Configurations of geometric isomers



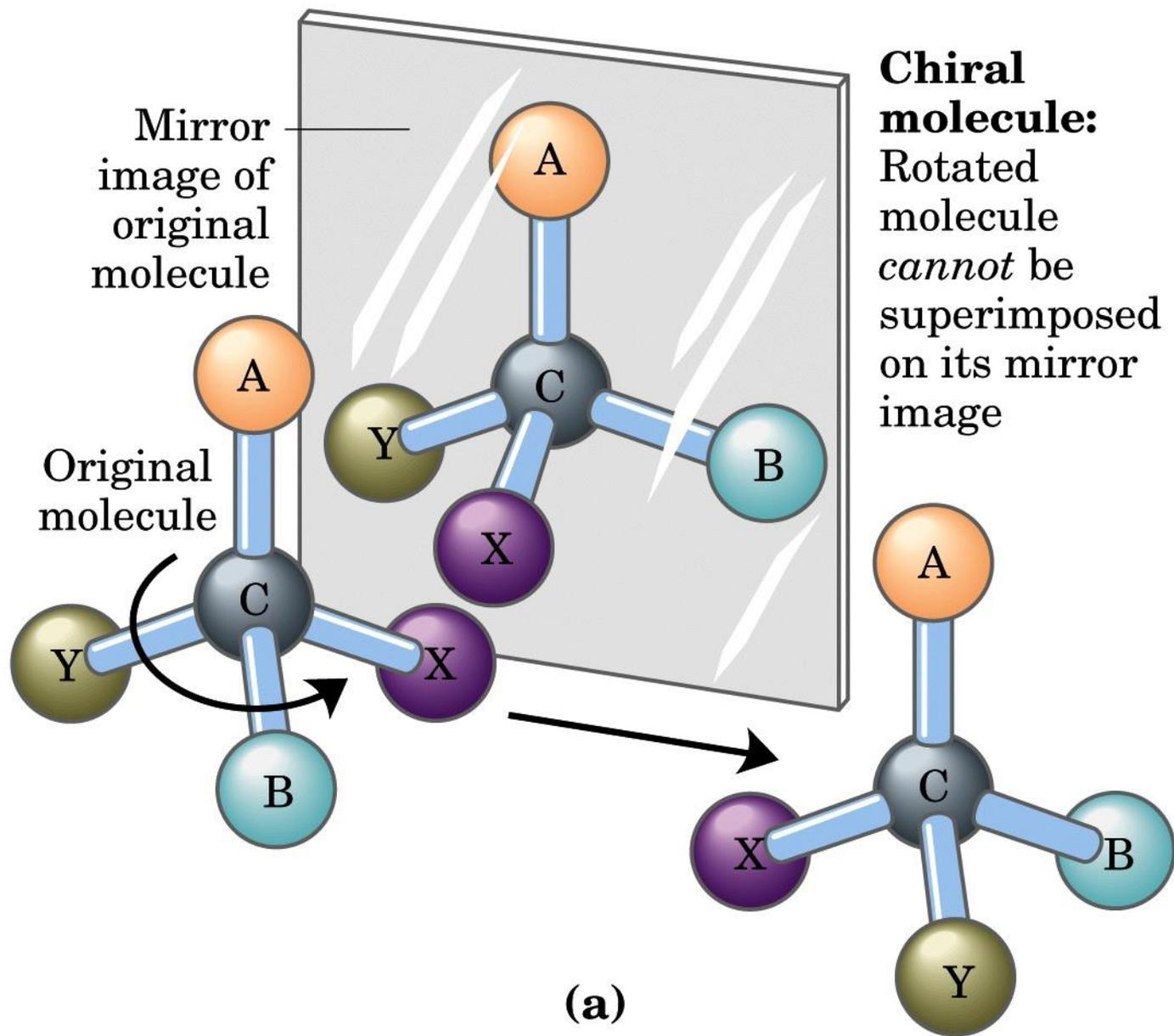
Enantiomers (mirror images)

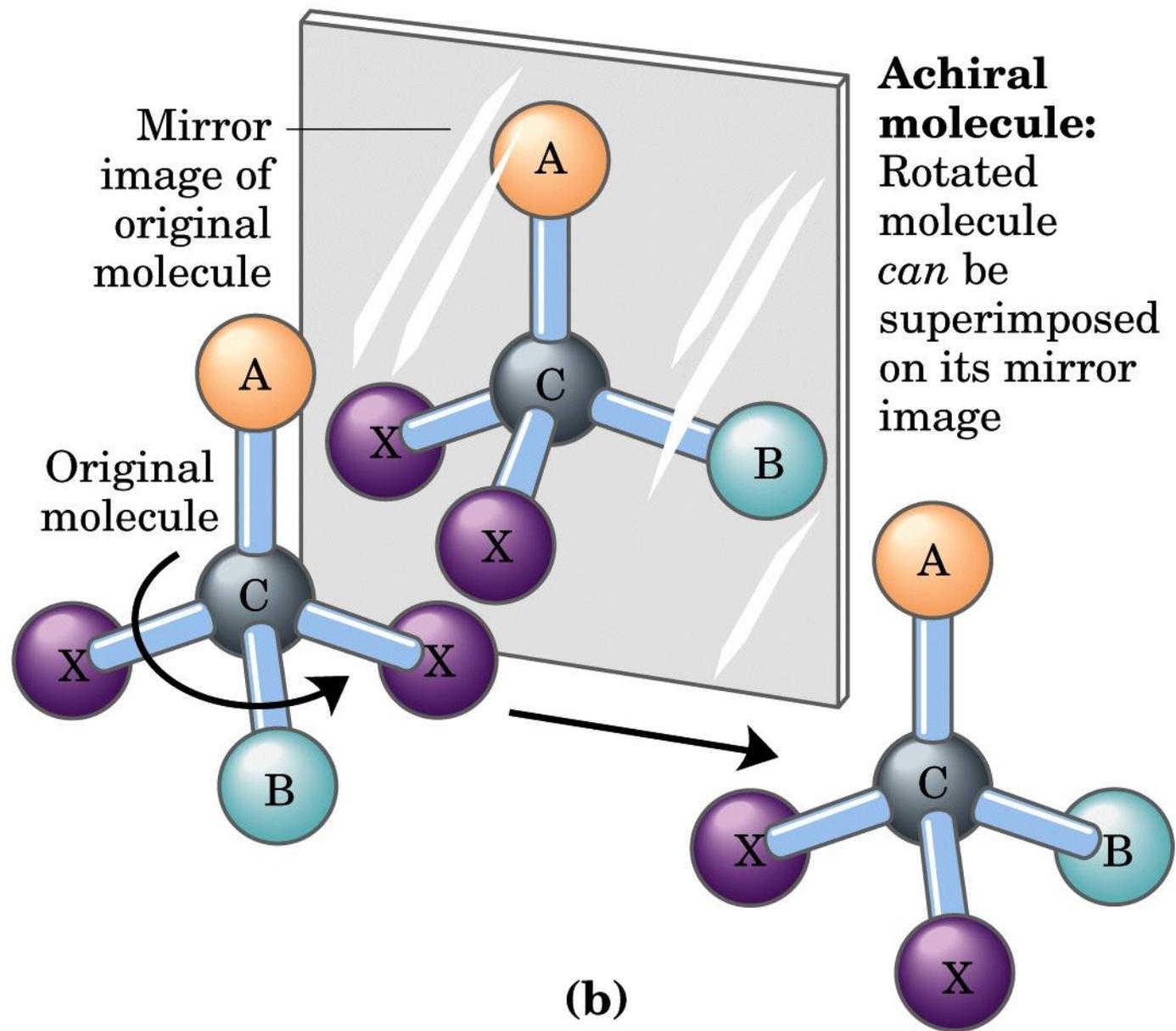


Enantiomers (mirror images)



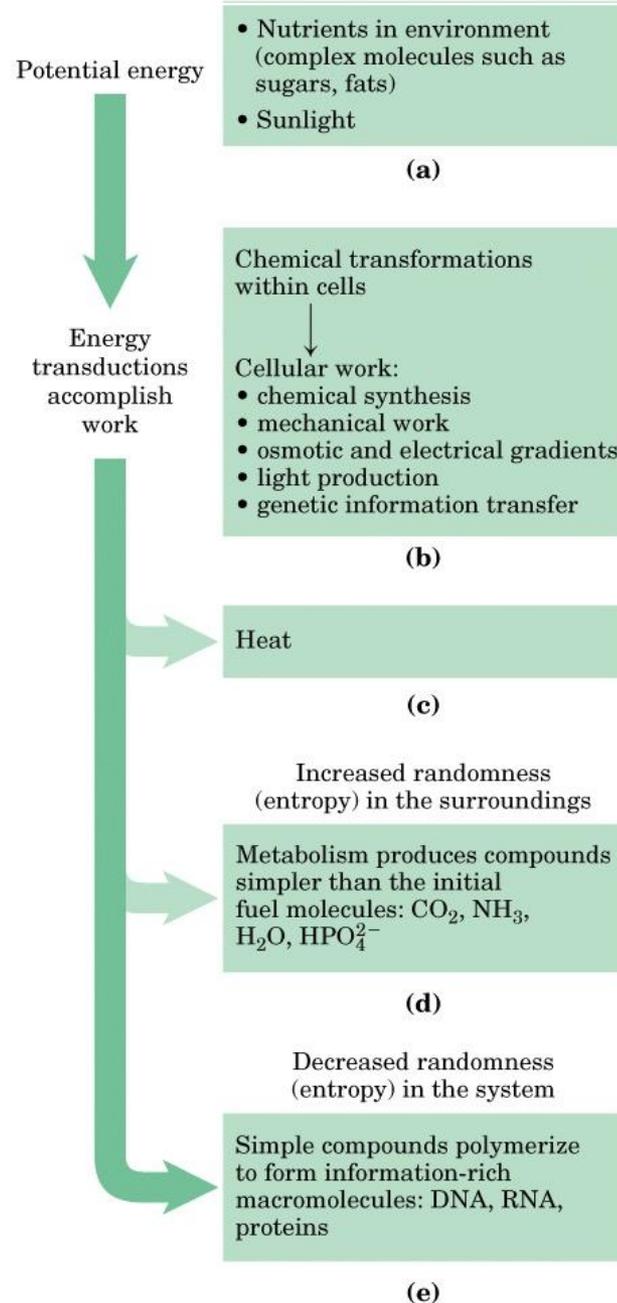
Diastereomers (non-mirror images)





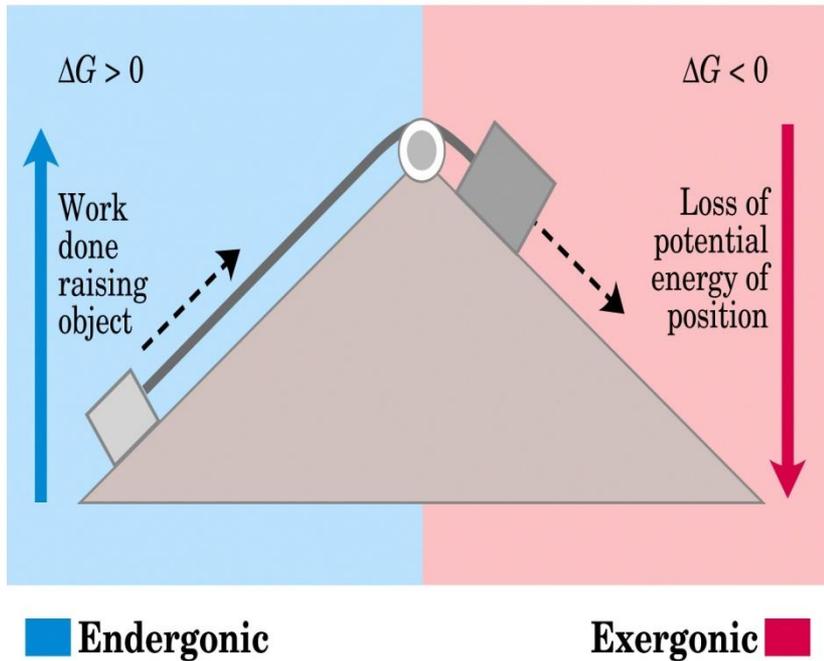
- **PHYSICAL FOUNDATION.**

Some energy interconversion in living organisms

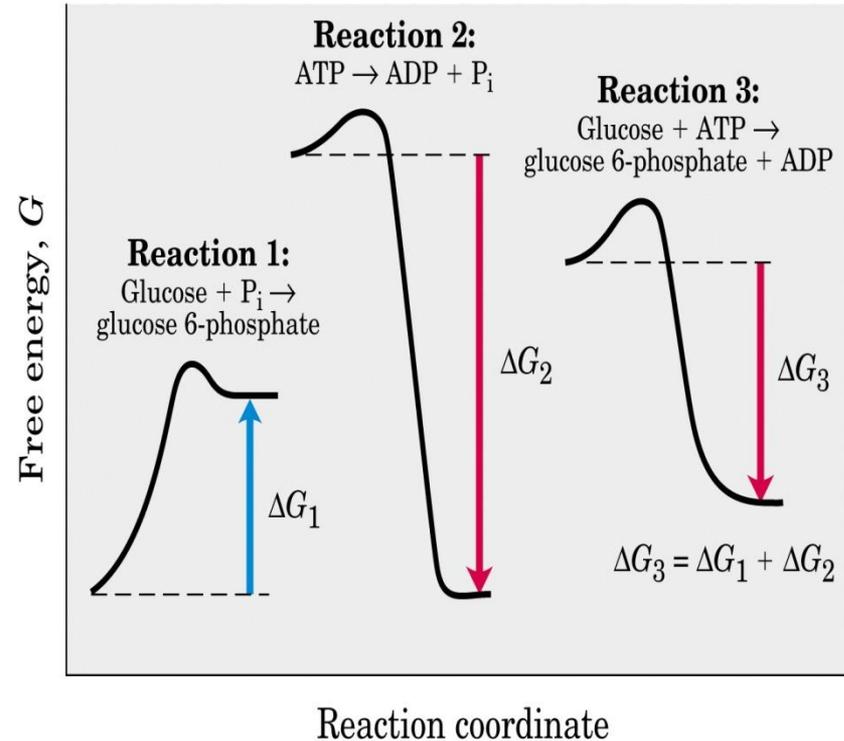


Energy coupling in mechanical and chemical processes

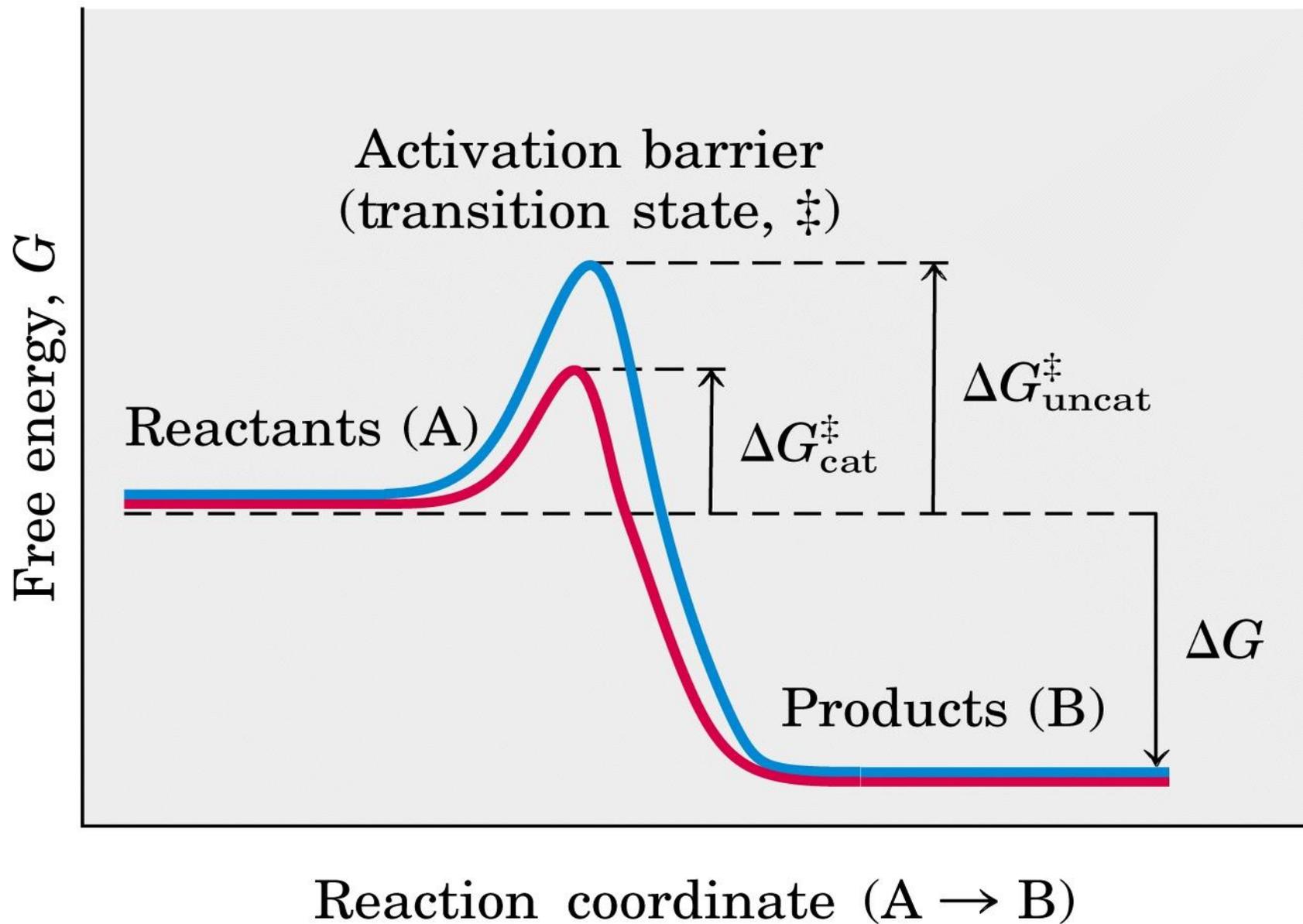
(a) Mechanical example



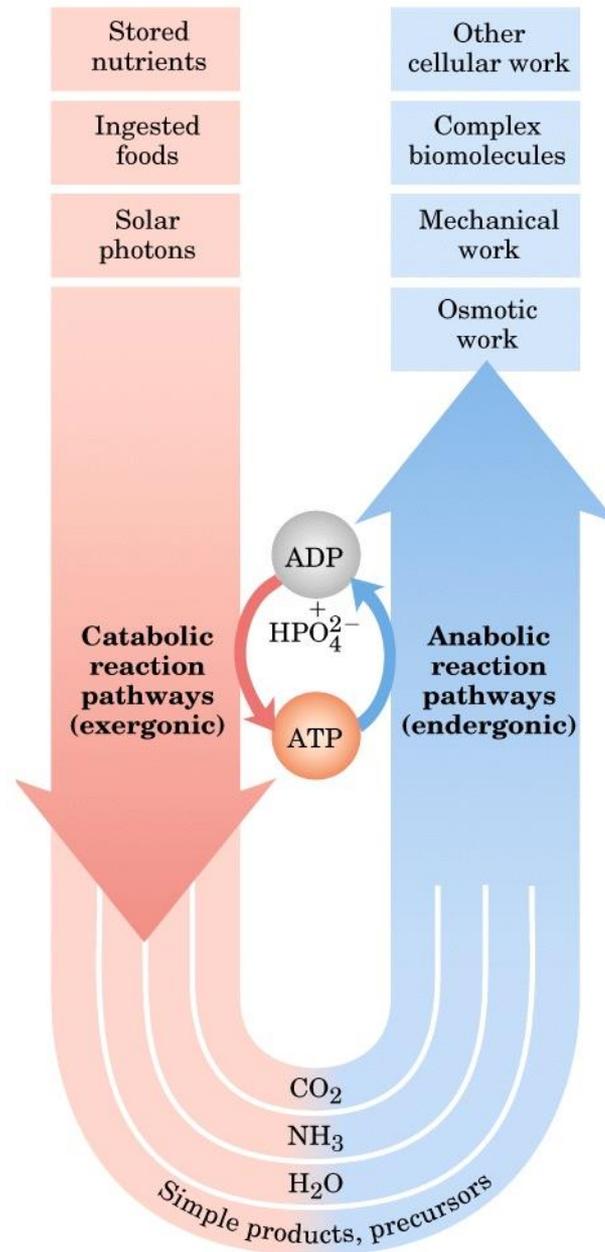
(b) Chemical example



Energy changes during a chemical reaction

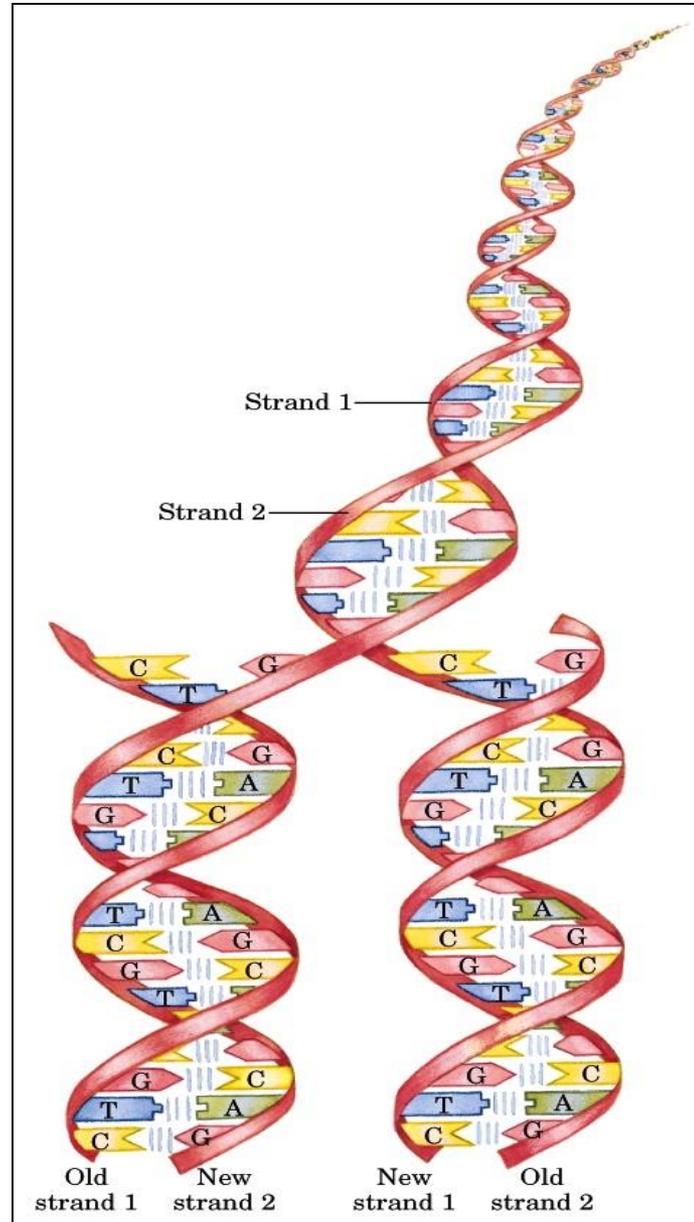


The central role of ATP in metabolism

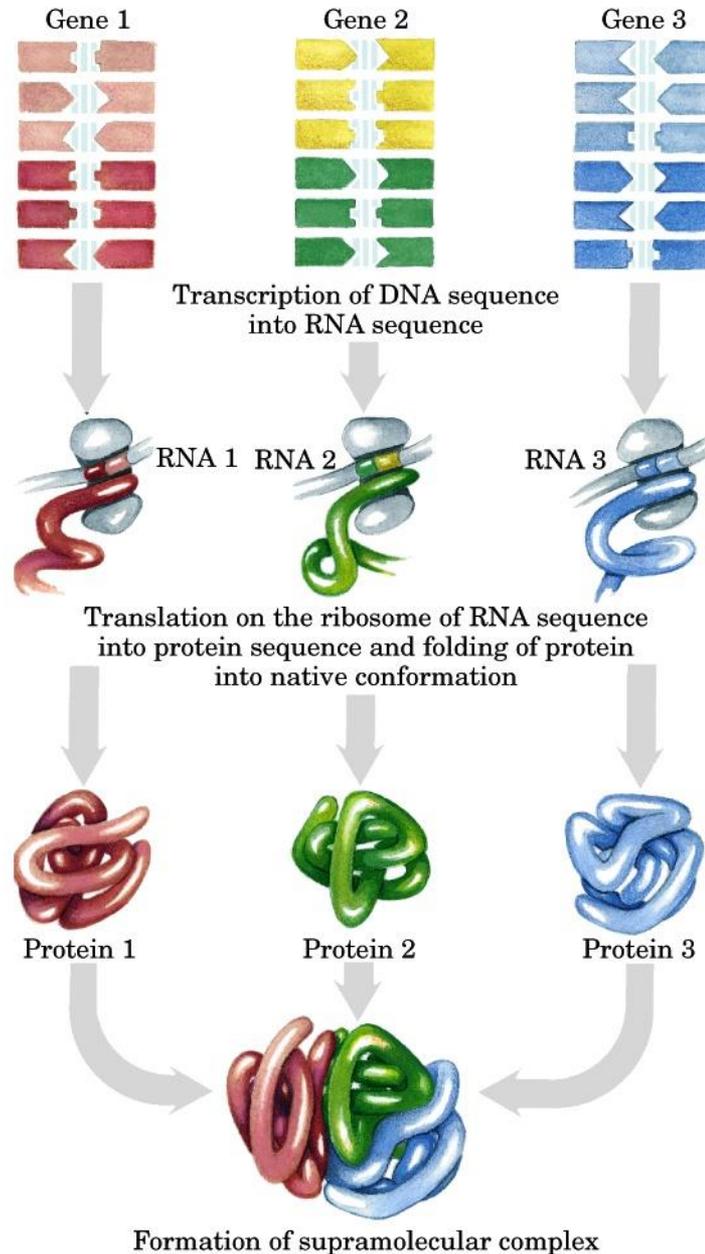


- **GENETIC FOUNDATION**

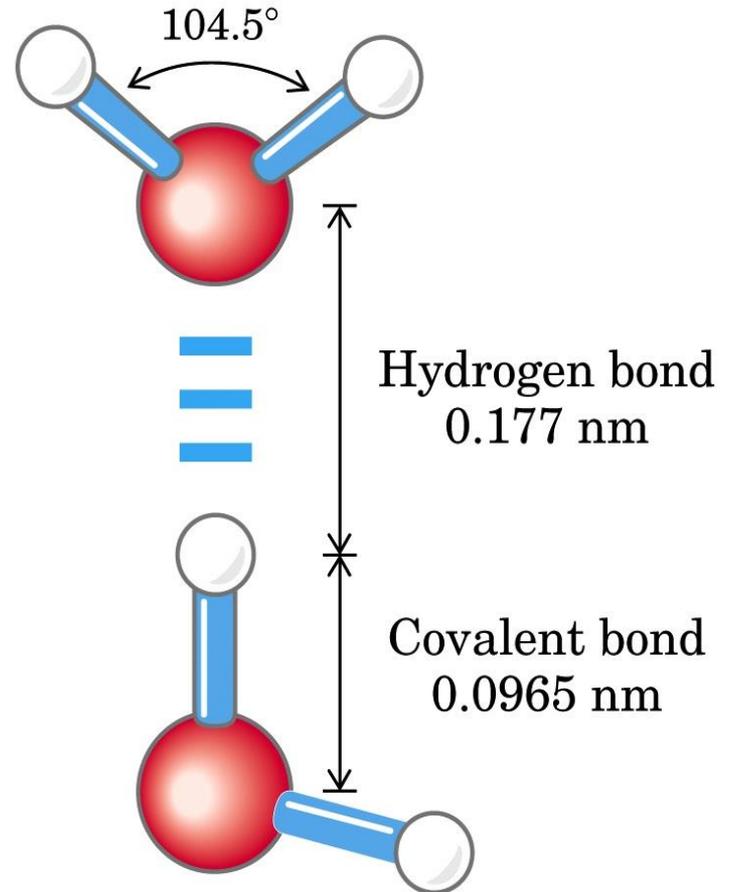
Complementarity between the two strands of DNA



DNA to RNA to Protein



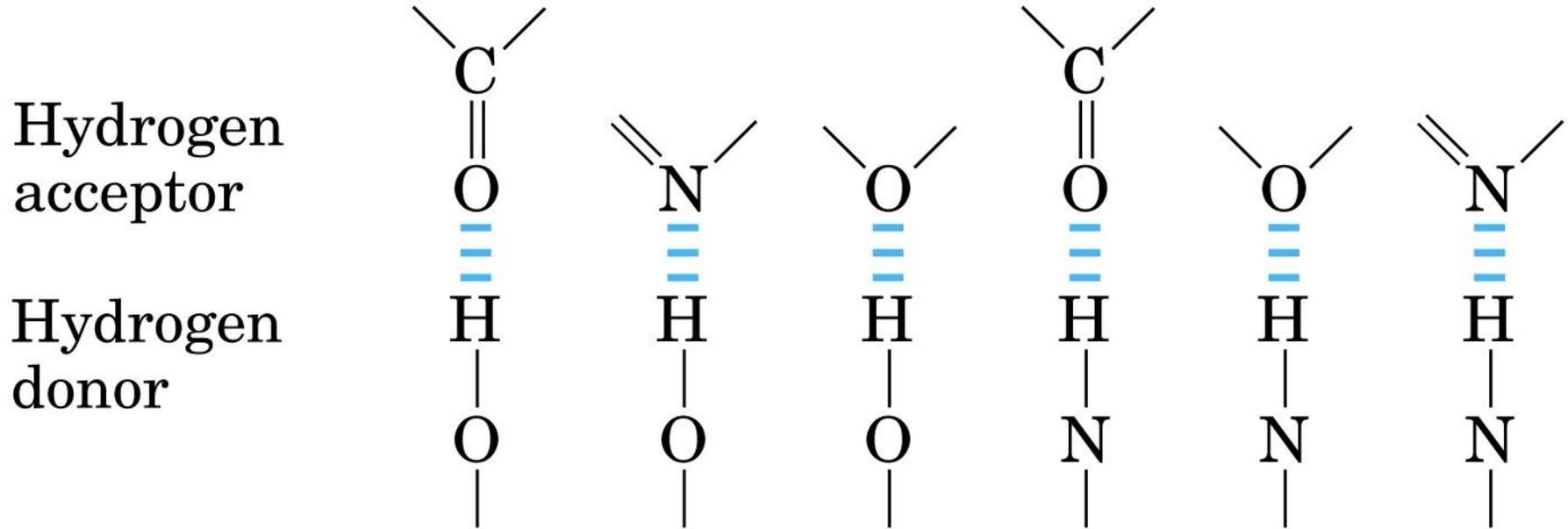
Hydrogen bonds



(c)

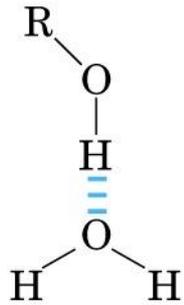
Structure of the water molecule

Common hydrogen bonds in biological systems

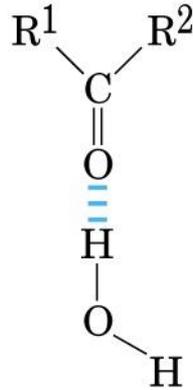


Some biologically important hydrogen bonds

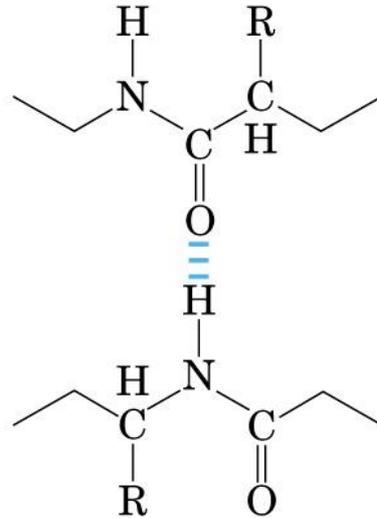
Between the hydroxyl group of an alcohol and water



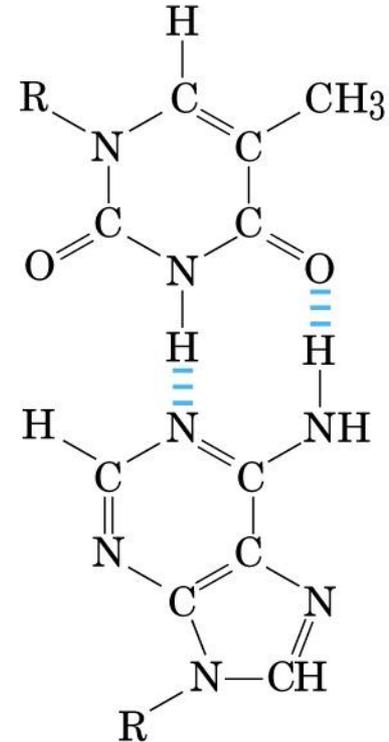
Between the carbonyl group of a ketone and water



Between peptide groups in polypeptides



Between complementary bases of DNA



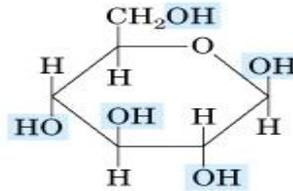
Thymine

Adenine

Some Examples of Polar, Nonpolar, and Amphipathic Biomolecules (shown as ionic forms at pH 7)

Polar

Glucose

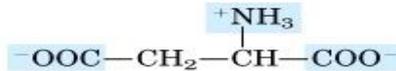


Polar groups
 Nonpolar groups

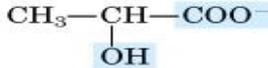
Glycine



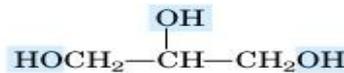
Aspartate



Lactate

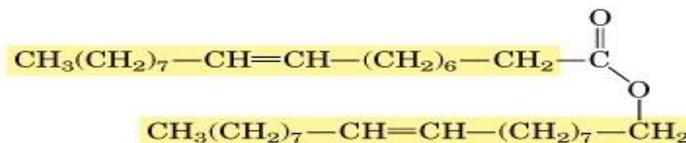


Glycerol



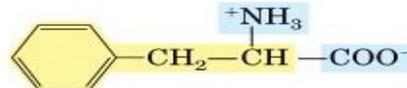
Nonpolar

Typical wax

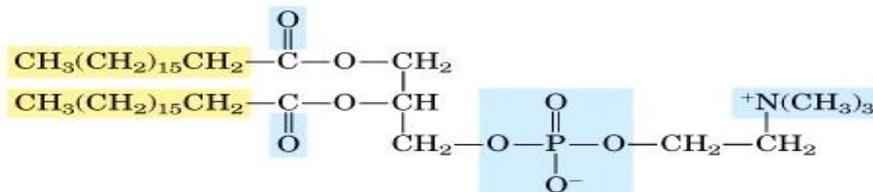


Amphipathic

Phenylalanine

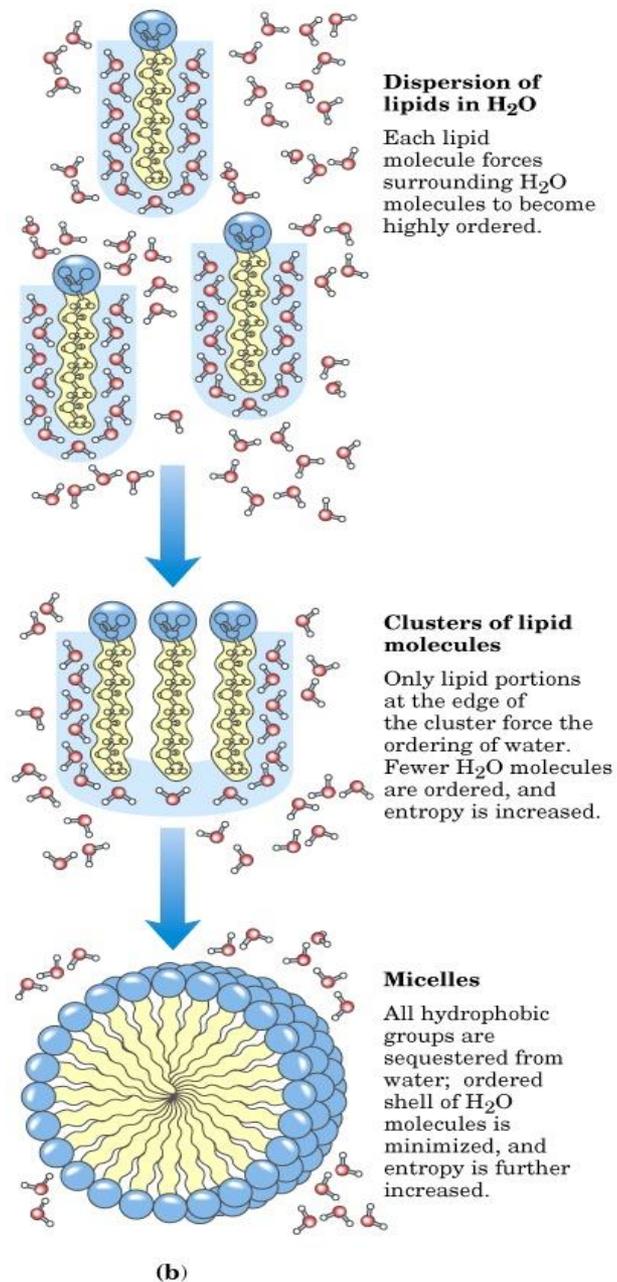
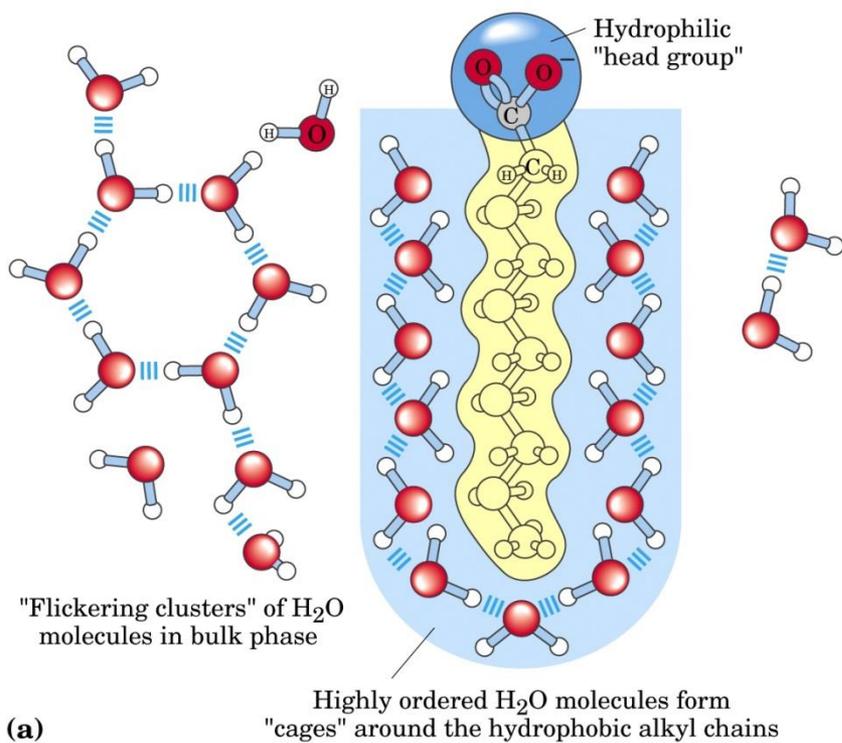


Phosphatidylcholine

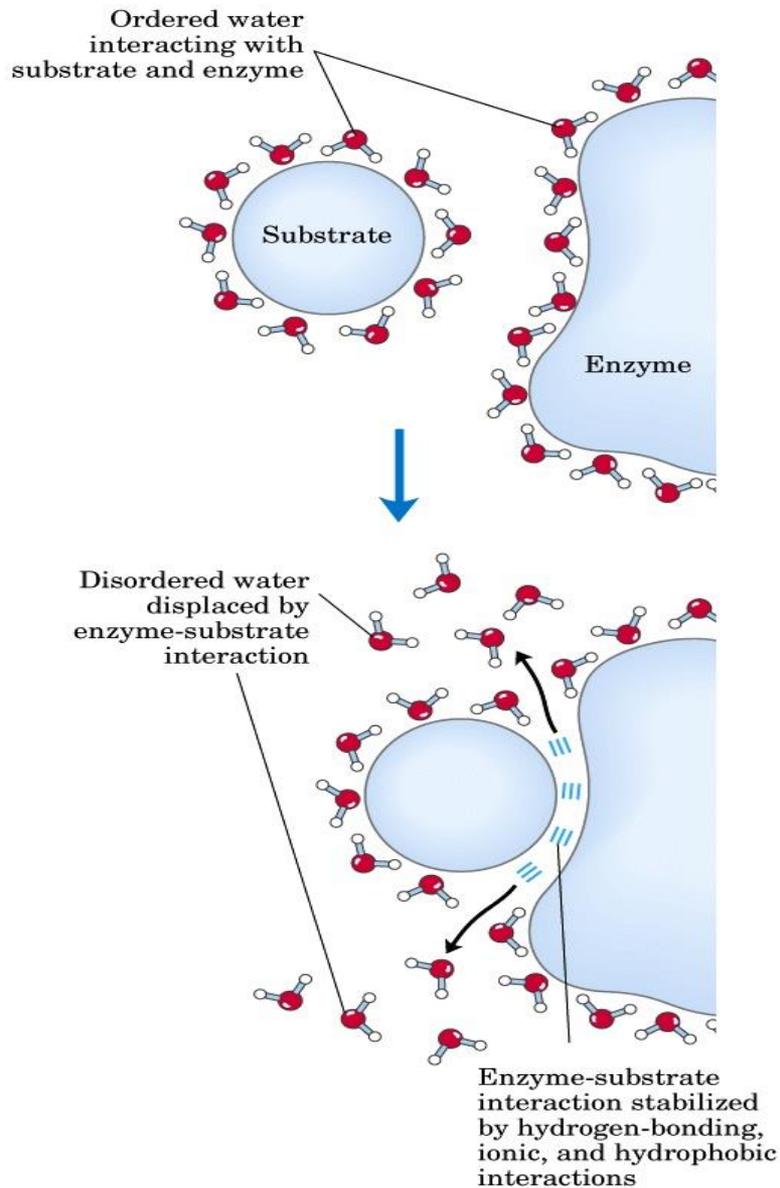


Amphipathic compounds in aqueous solution:

(a) long chain fatty acids and (b) clusters of fatty acids in micelles



Release of ordered water favors formation of an enzyme-substrate complex



Four Types of Noncovalent (“weak”) interactions among Biomolecules in aqueous Solvent

Hydrogen bonds

Between neutral groups



Between peptide bonds



Ionic interactions

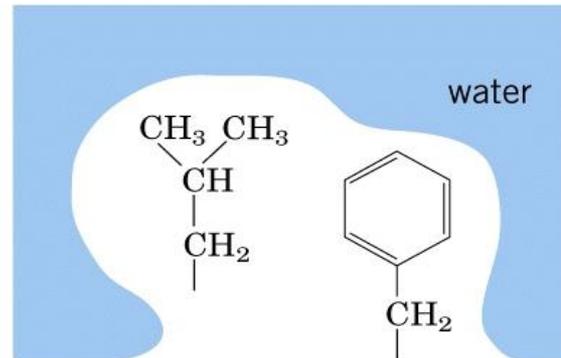
Attraction



Repulsion

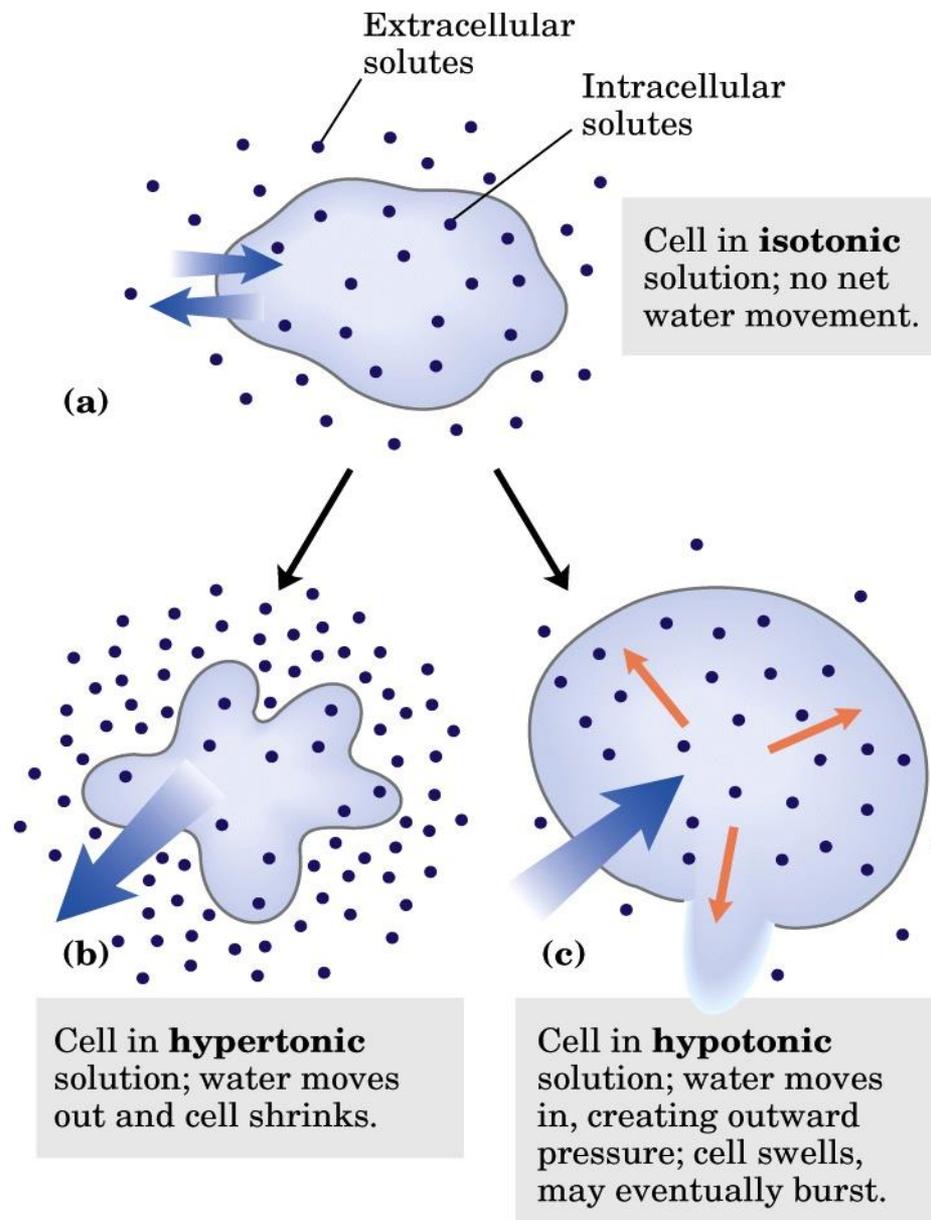


Hydrophobic interactions



Van der Waals interactions

Any two atoms in close proximity



Effect of extracellular osmolarity on water movement across a plasma membrane: (a) isotonic, (b) hypertonic and (c) hypotonic solutions

pH Scale

The pH Scale

$[\text{H}^+]$ (M)	pH	$[\text{OH}^-]$ (M)	pOH*
10^0 (1)	0	10^{-14}	14
10^{-1}	1	10^{-13}	13
10^{-2}	2	10^{-12}	12
10^{-3}	3	10^{-11}	11
10^{-4}	4	10^{-10}	10
10^{-5}	5	10^{-9}	9
10^{-6}	6	10^{-8}	8
10^{-7}	7	10^{-7}	7
10^{-8}	8	10^{-6}	6
10^{-9}	9	10^{-5}	5
10^{-10}	10	10^{-4}	4
10^{-11}	11	10^{-3}	3
10^{-12}	12	10^{-2}	2
10^{-13}	13	10^{-1}	1
10^{-14}	14	10^0 (1)	0

*The expression pOH is sometimes used to describe the basicity, or OH^- concentration, of a solution; pOH is defined by the expression $\text{pOH} = -\log [\text{OH}^-]$, which is analogous to the expression for pH. Note that in all cases, $\text{pH} + \text{pOH} = 14$.

Monoprotic acids

Acetic acid
($K_a = 1.74 \times 10^{-5} \text{ M}$)

Ammonium
($K_a = 5.62 \times 10^{-10} \text{ M}$)

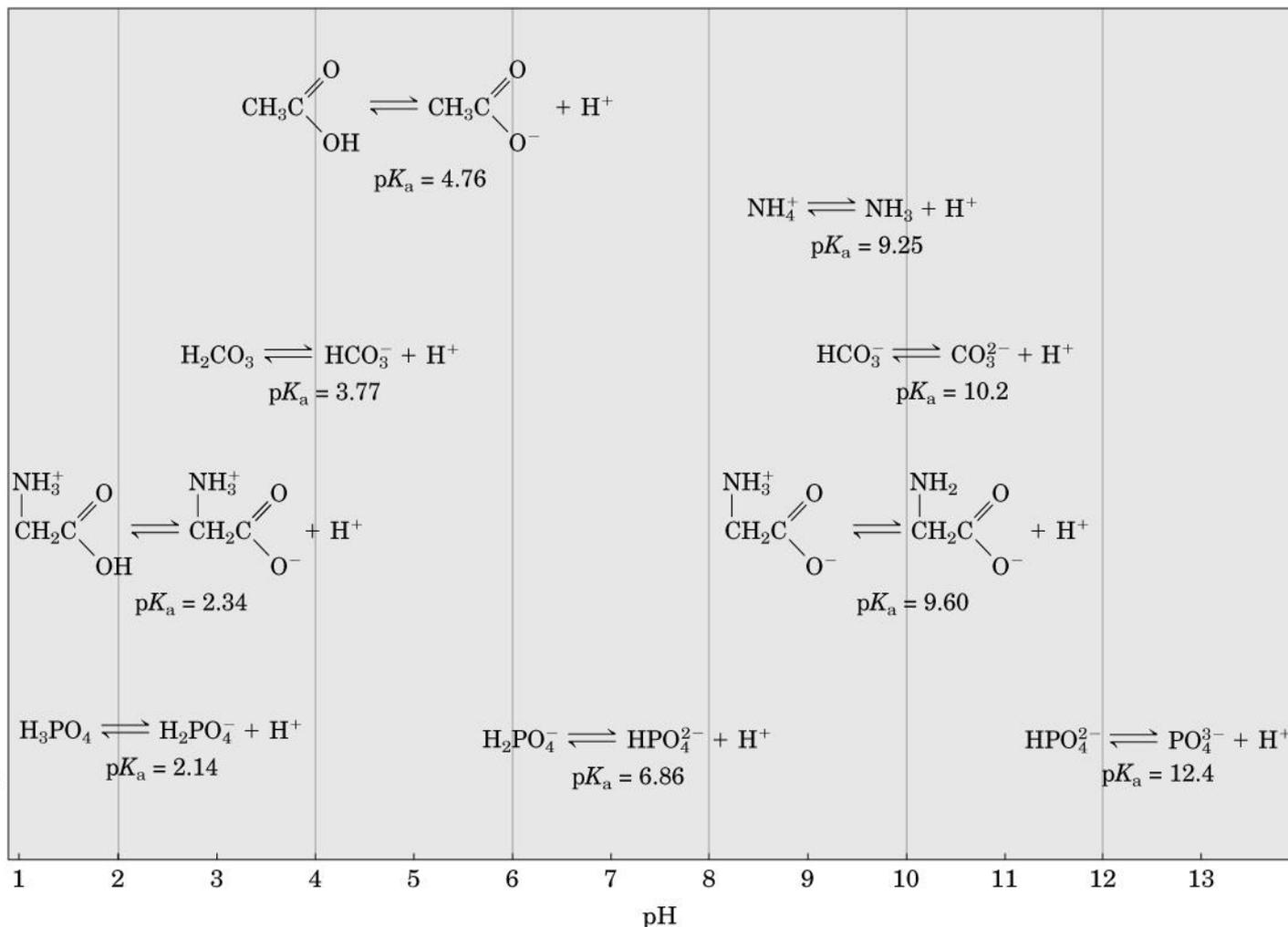
Diprotic acids

Carbonic acid
($K_a = 1.70 \times 10^{-4} \text{ M}$);
Bicarbonate
($K_a = 6.31 \times 10^{-11} \text{ M}$)

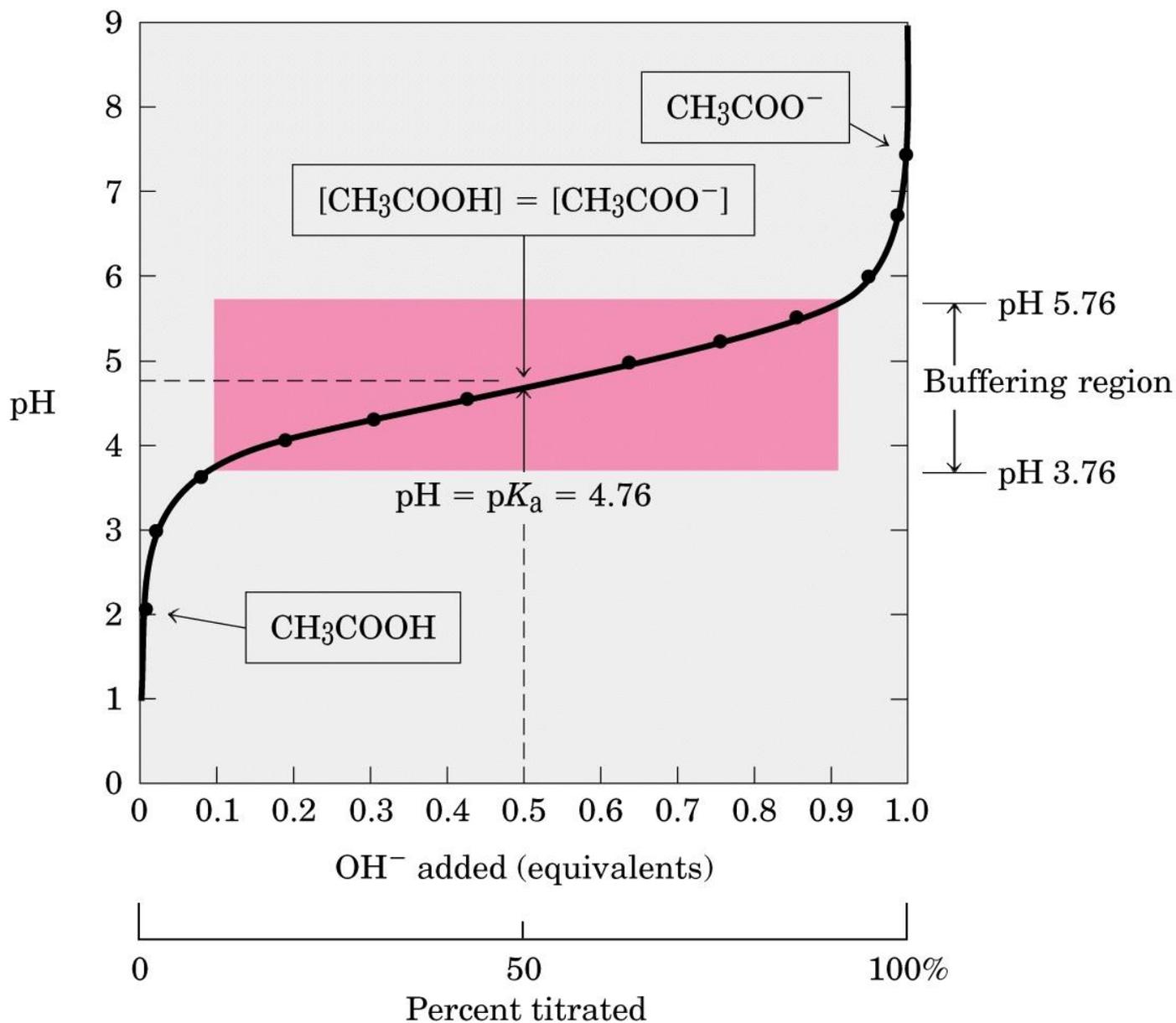
Glycine, carboxyl
($K_a = 4.57 \times 10^{-3} \text{ M}$);
Glycine, amino
($K_a = 2.51 \times 10^{-10} \text{ M}$)

Triprotic acids

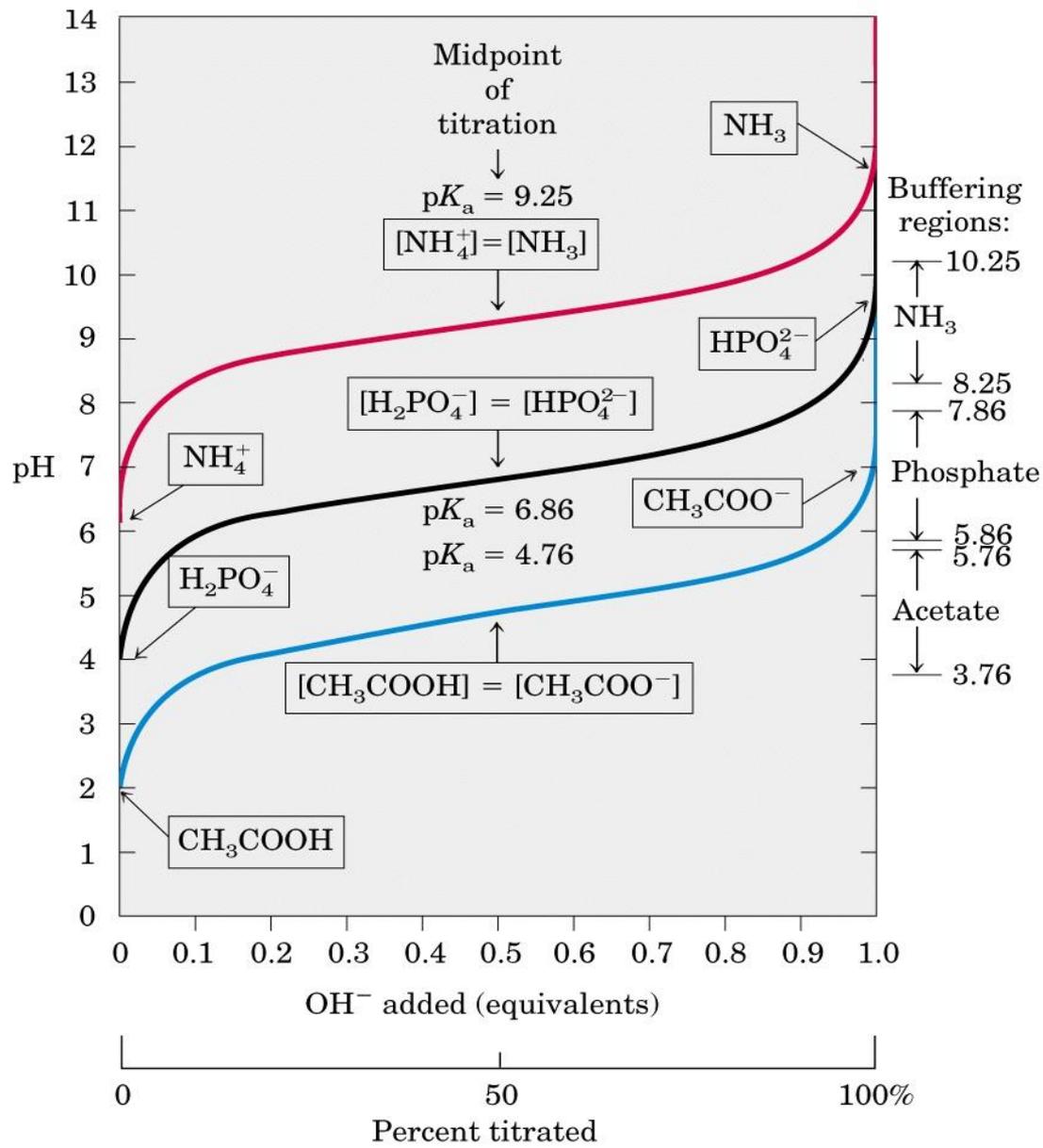
Phosphoric acid
($K_a = 7.25 \times 10^{-3} \text{ M}$);
Dihydrogen phosphate
($K_a = 1.38 \times 10^{-7} \text{ M}$);
Monohydrogen phosphate
($K_a = 3.98 \times 10^{-13} \text{ M}$)



Conjugate acid-base pairs consist of a proton donor and a proton acceptor

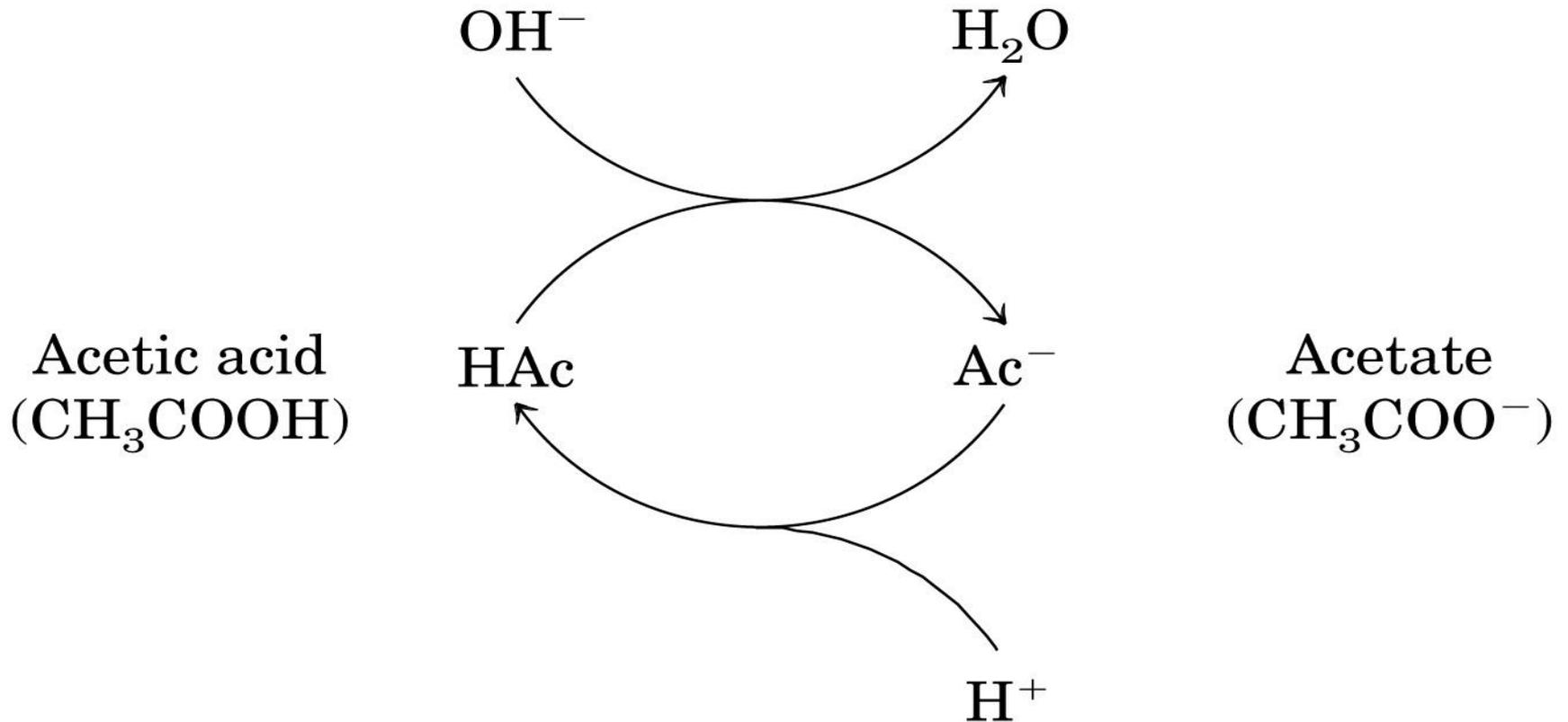


The titration curve of acetic acid



Comparison of the titration curves of three weak acids

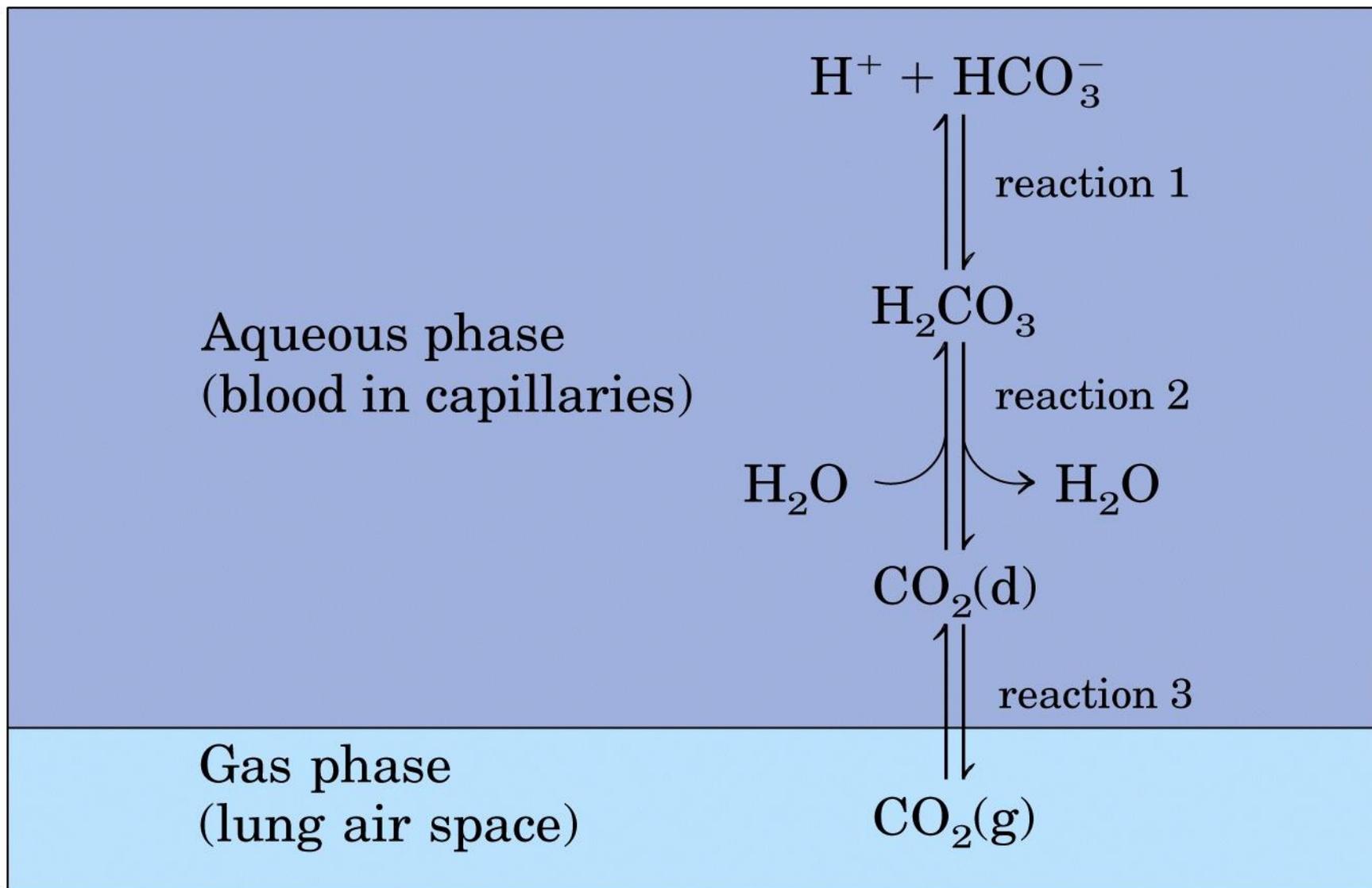
$$K_w = [\text{H}^+][\text{OH}^-]$$

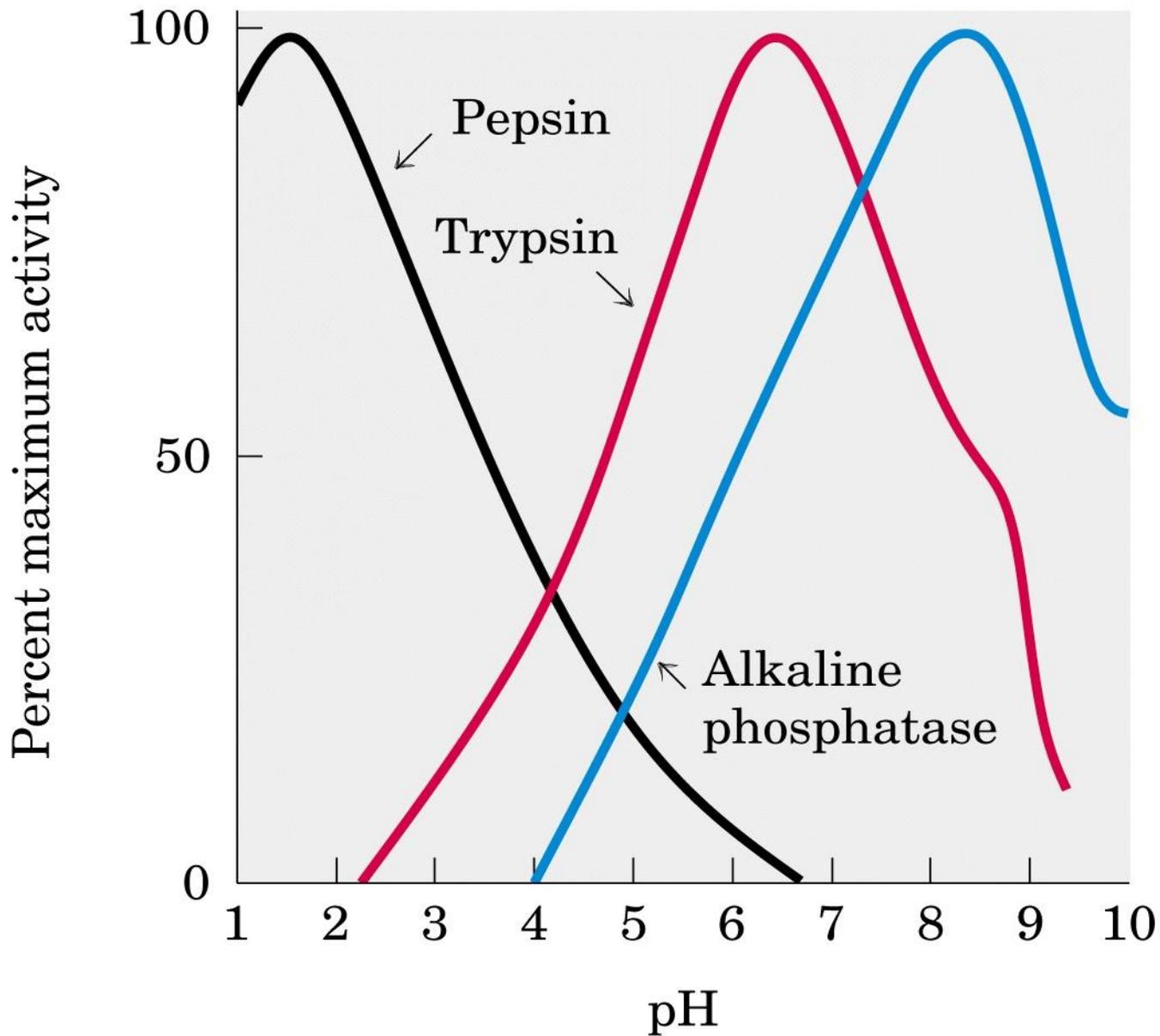


$$K_a = \frac{[\text{H}^+][\text{Ac}^-]}{[\text{HAc}]}$$

The acetic acid – acetate pair as a buffer system

The CO_2 in the air space of the lungs is in equilibrium with the bicarbonate buffer in the blood plasma passing through the lung capillaries





The pH optima of some enzymes