Biochemistry

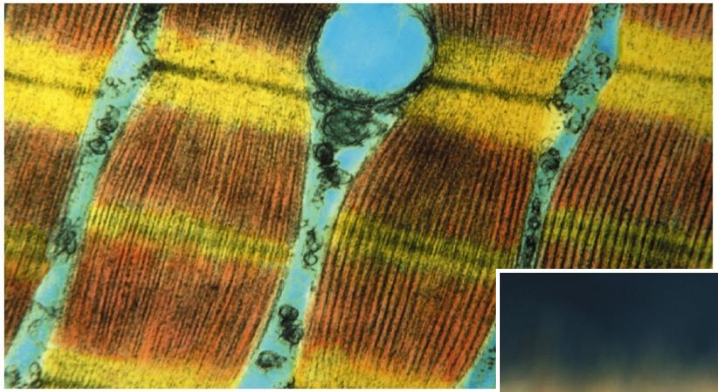
Science concerned with the chemical constituents of living cells and with the reaction and process that they undergo.

The Foundations of Biochemistry

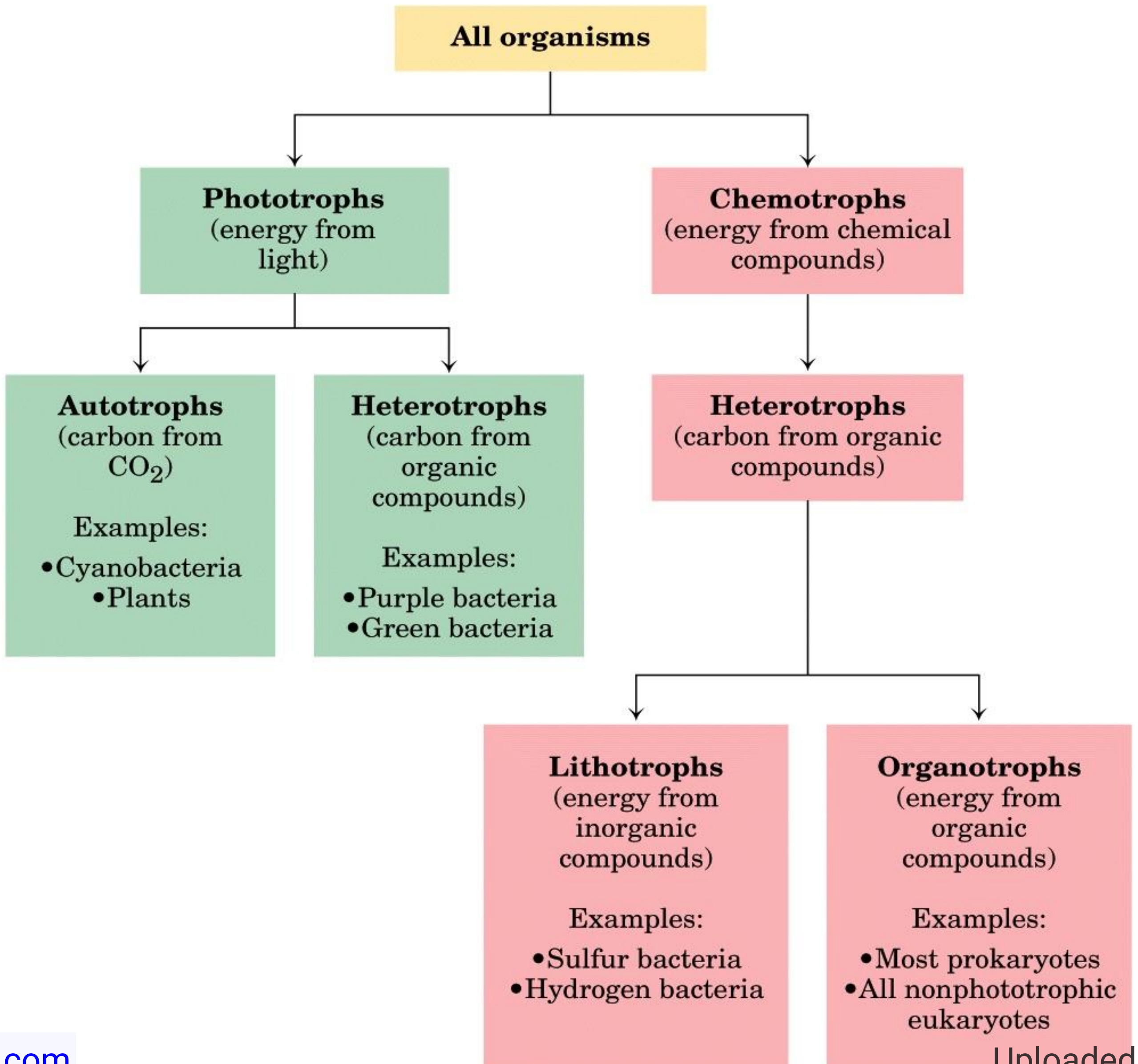
- Cellular Foundations
- Chemical Foundations
- Genetic Foundations
- Physical Foundations

- **CELLULAR FOUNDATION.**

What distinguishes living organisms from inanimate matter ?



Classification of organisms according to their source of energy

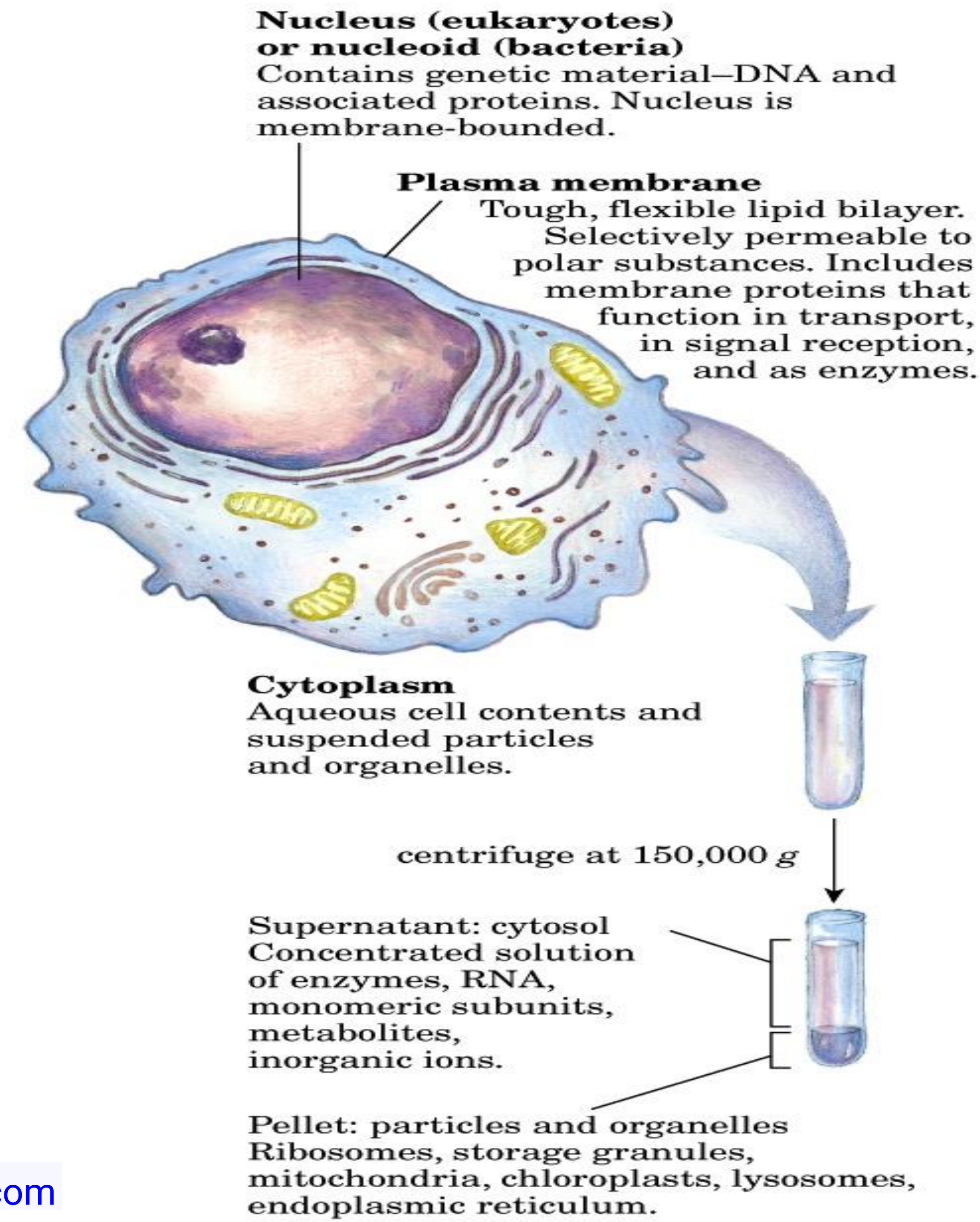


Diverse living organisms share common biochemical features

What are cells ???

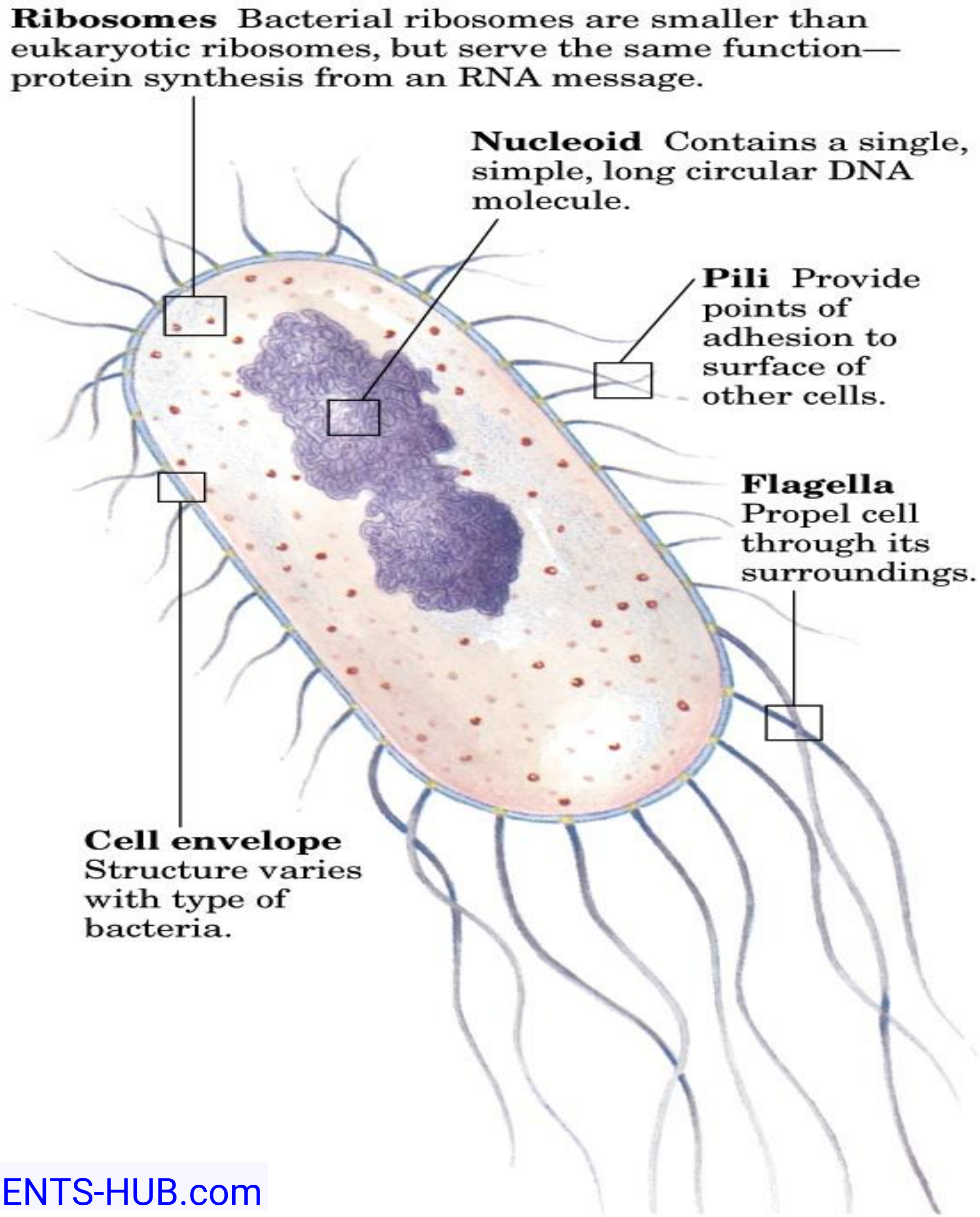
The structural and functional units of living organisms

Features of living cells

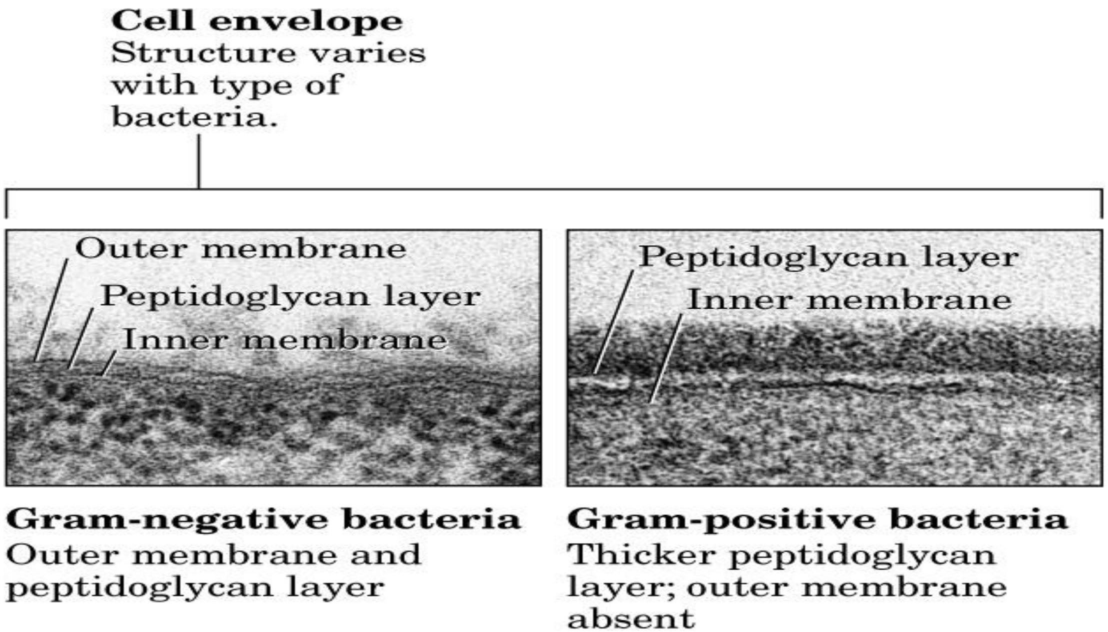


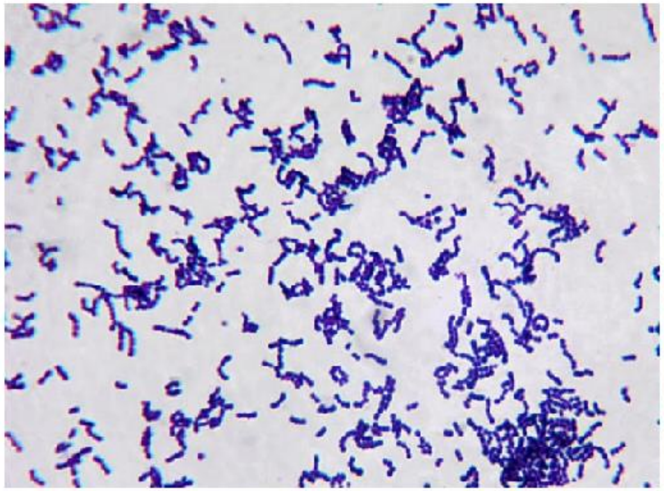
Unicellular

Common structural features of bacterial cell

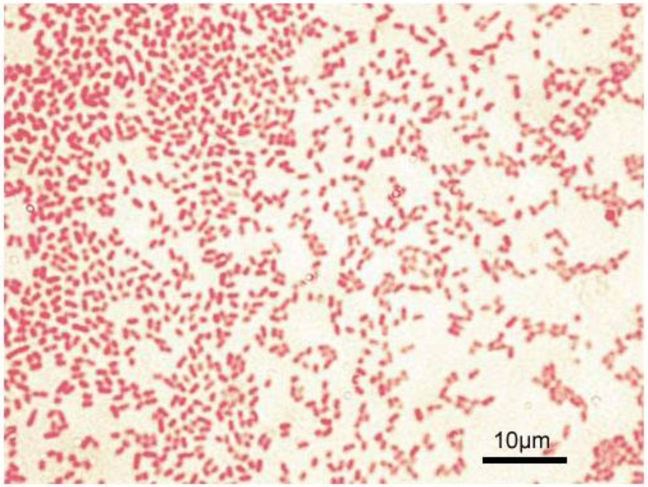


Gram Positive vs. Gram Negative





Gram Positive Bacteria



Gram Negative Bacteria

Eukaryotic cell structure: Animal vs. Plant cells

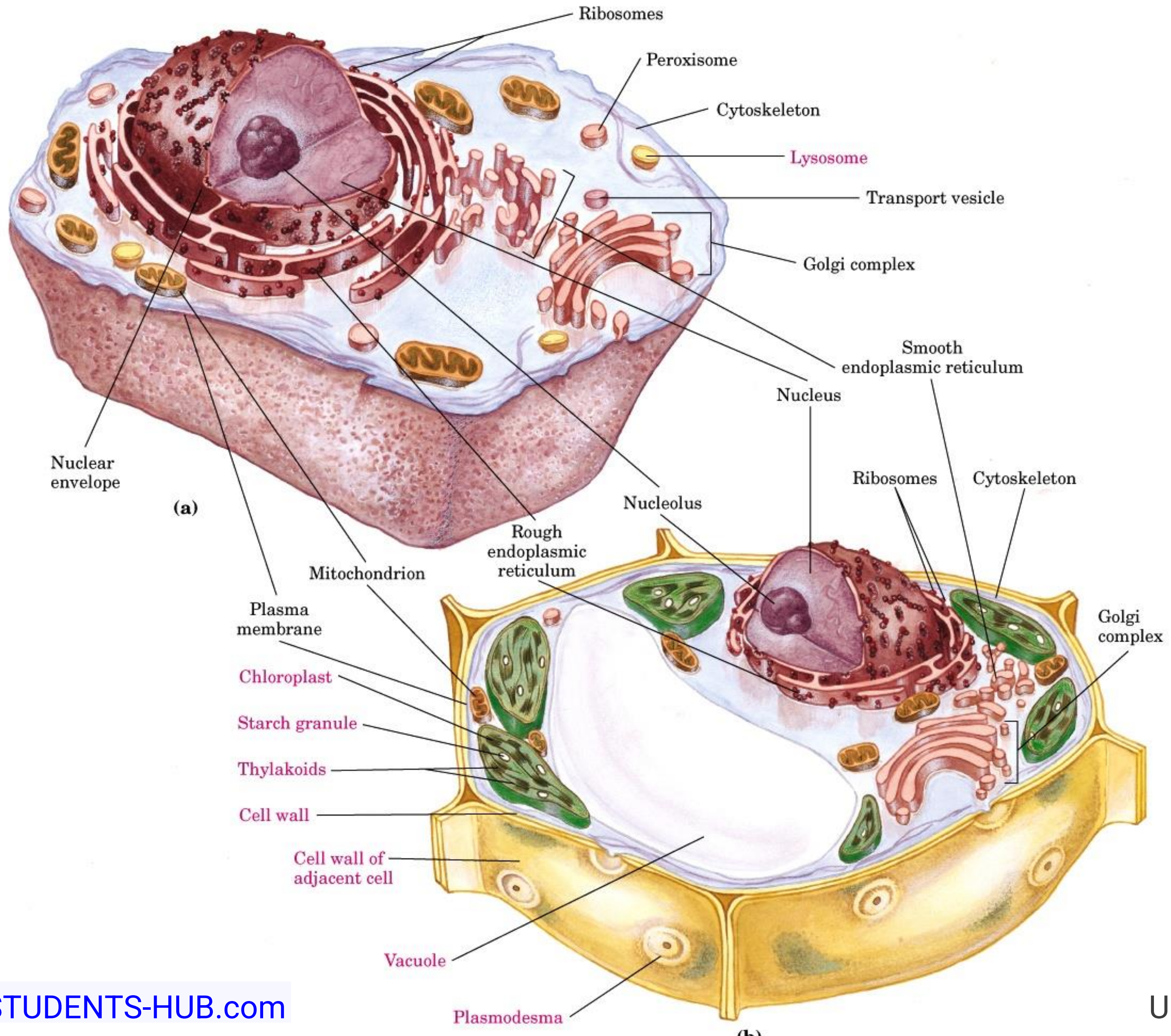


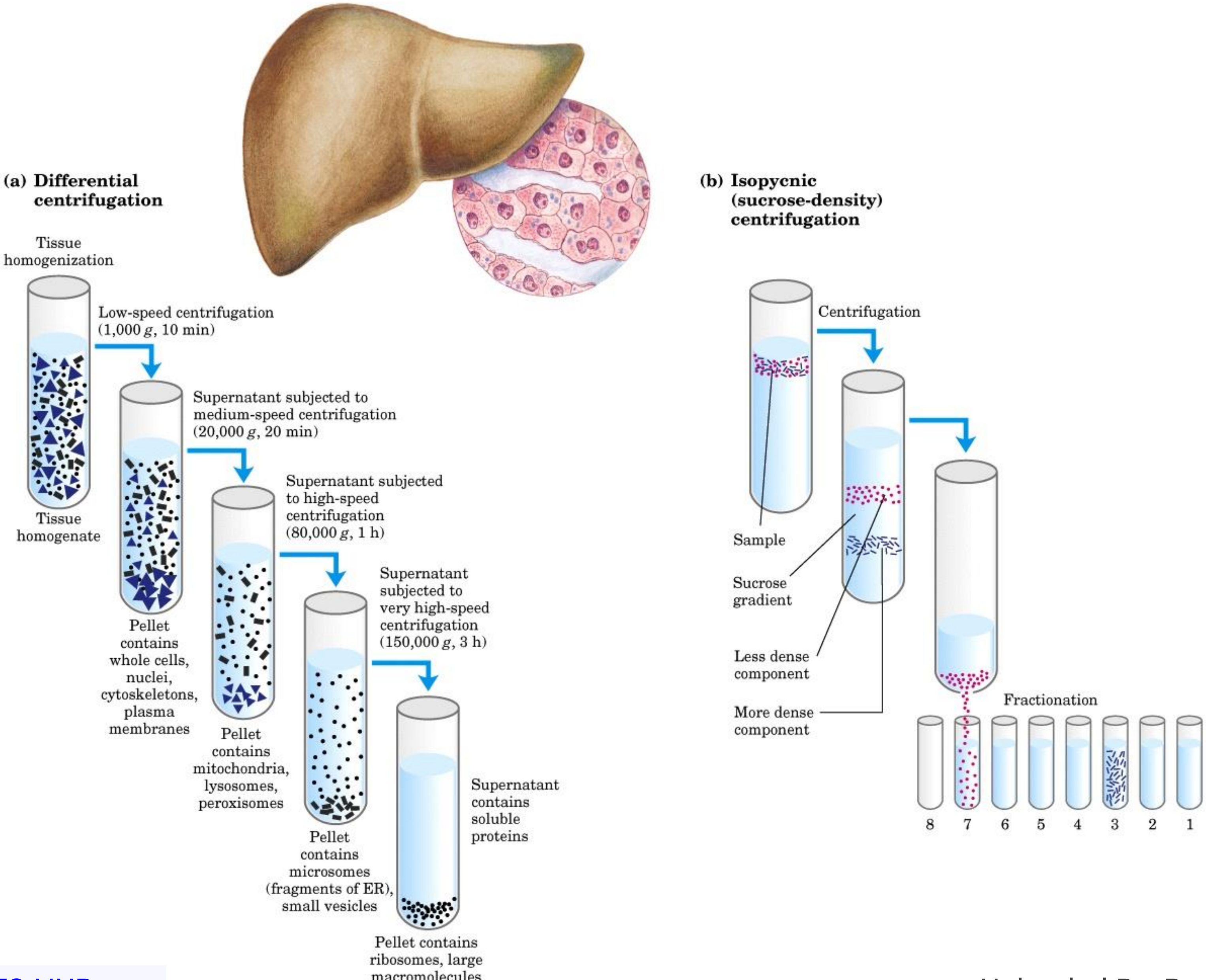
table 2–1

Comparison of Prokaryotic and Eukaryotic Cells

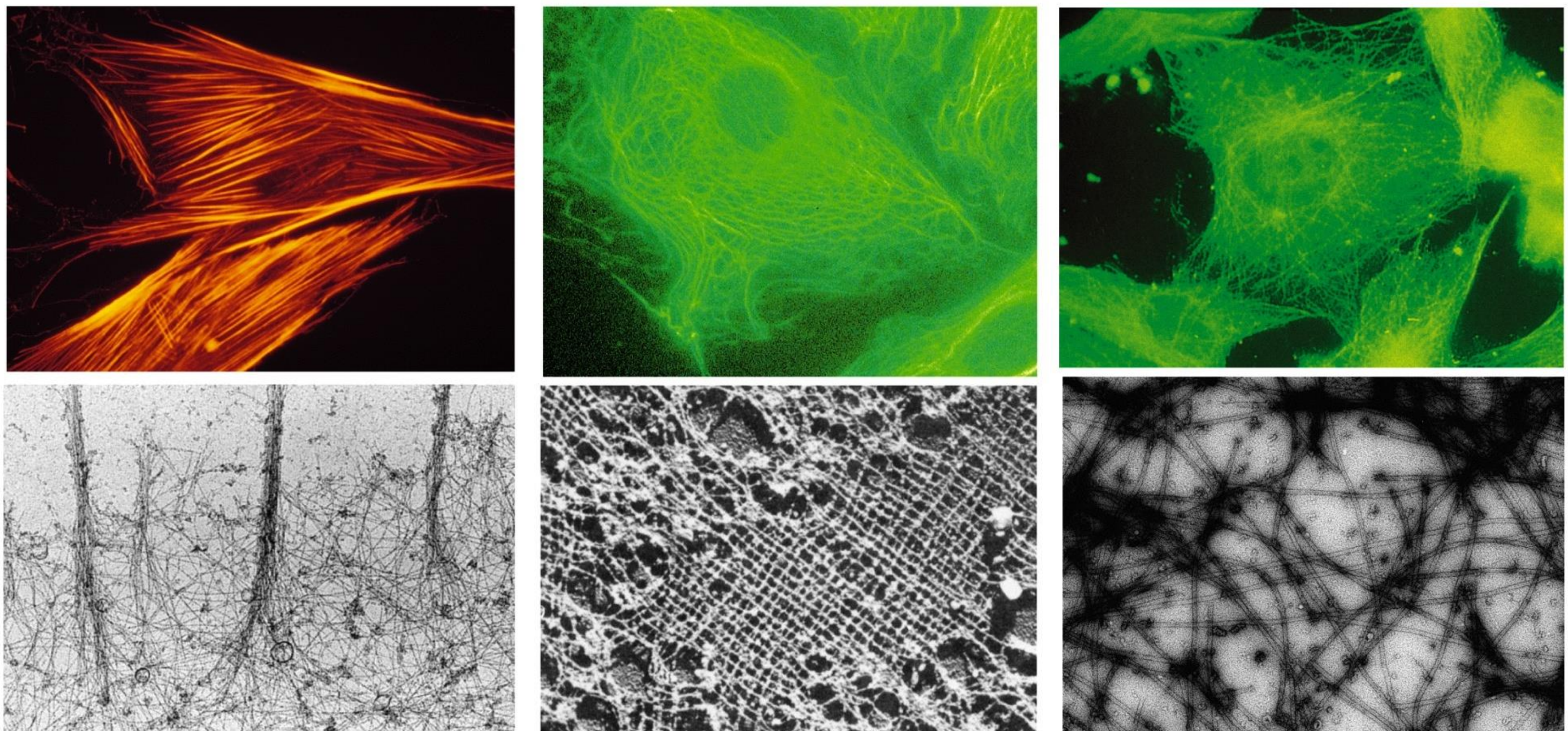
Characteristic	Prokaryotic cell	Eukaryotic cell
Size	Generally small (1–10 μm)	Generally large (5–100 μm)
Genome	DNA with nonhistone protein; genome in nucleoid, not surrounded by membrane	DNA complexed with histone and nonhistone proteins in chromosomes; chromosomes in nucleus with membranous envelope
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



Cytoskeleton



Actin stress fibers
(a)

Intermediate filaments
(c)

Microtubules
(b)

Macromolecules & Monomeric subunits

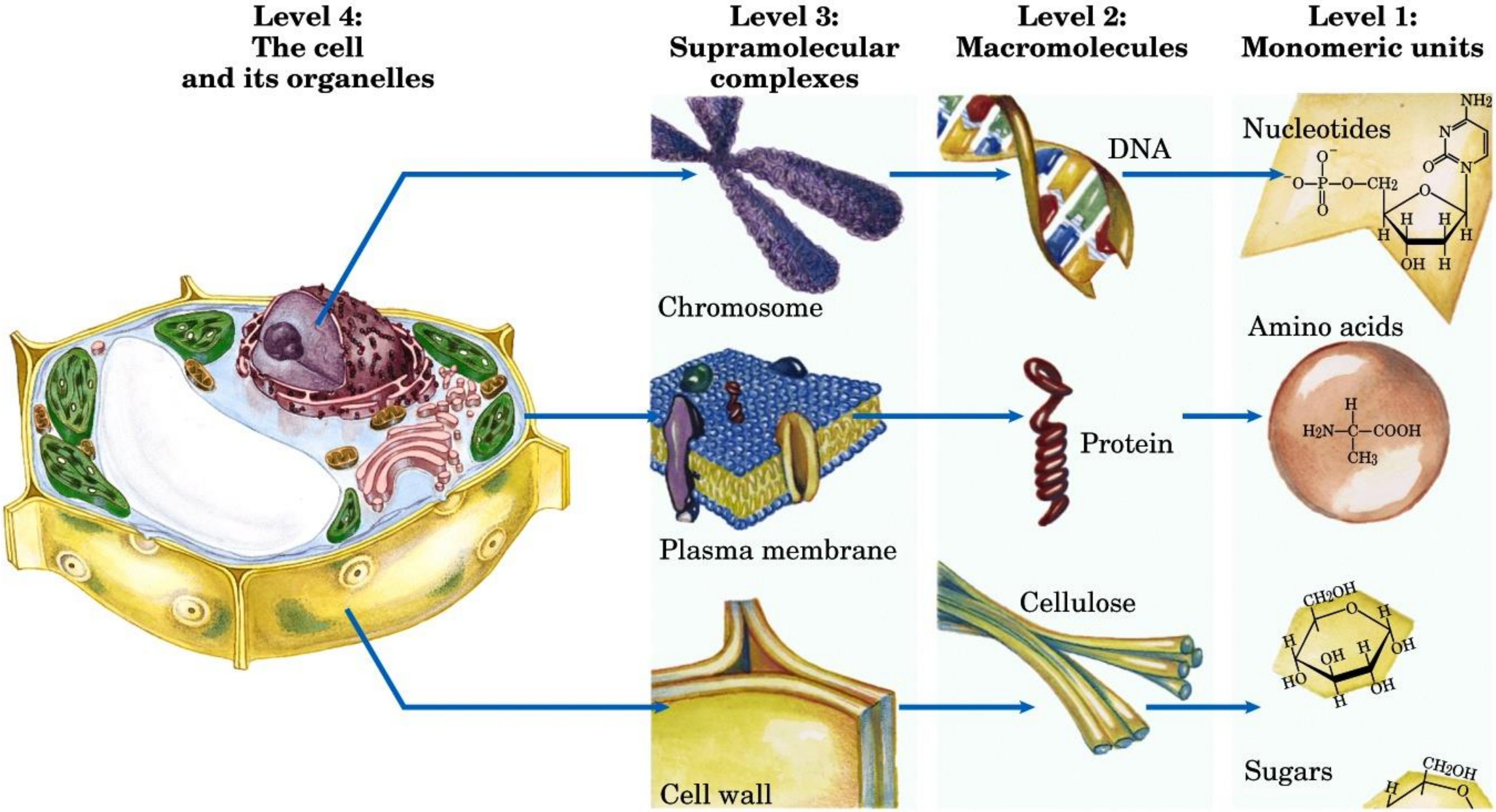
Amino acids
- → Proteins
- → Peptide hormones
- → Neurotransmitters
- → Toxic alkaloids

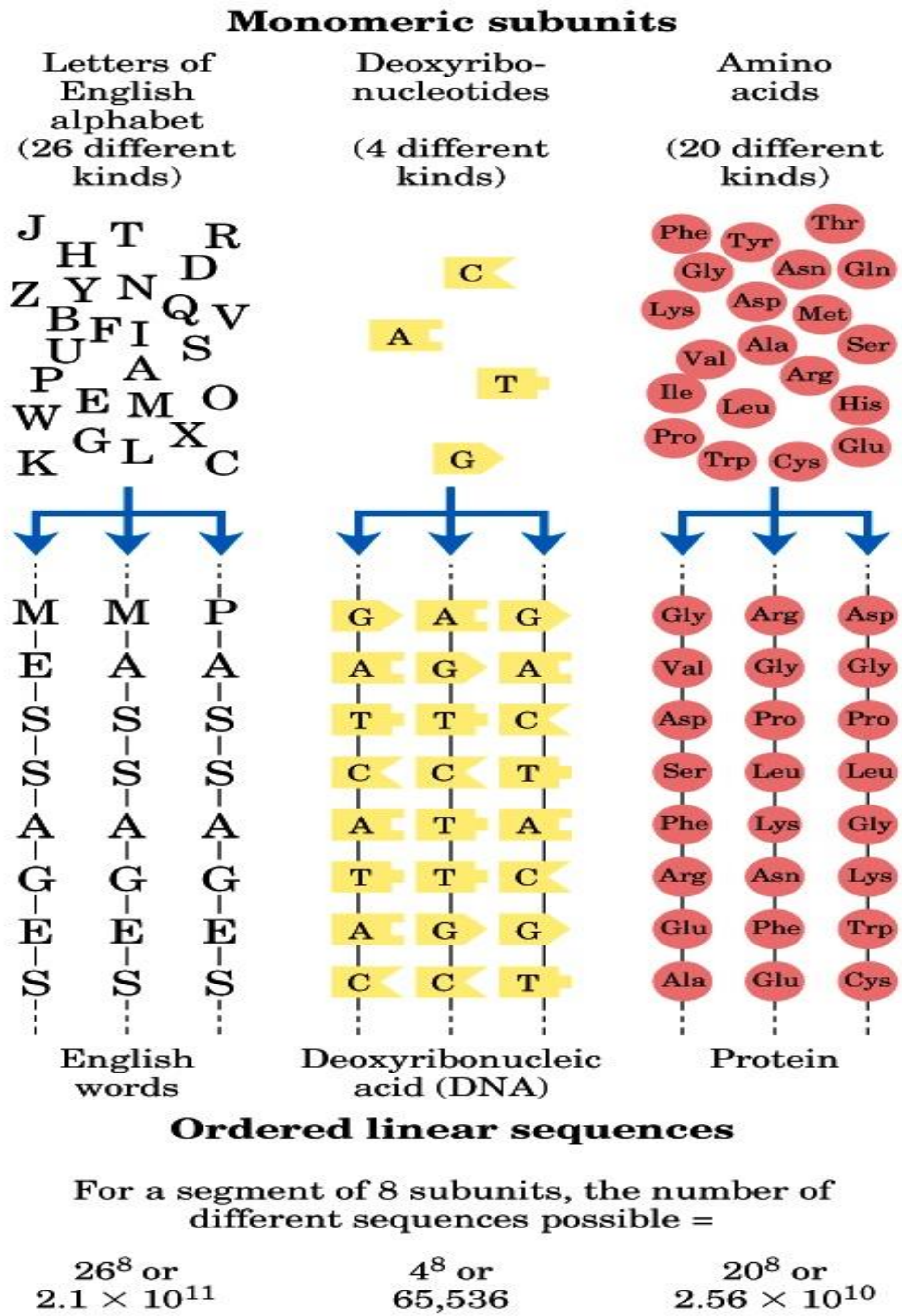
Adenine
- → Nucleic acids
- → ATP
- → Coenzymes
- → Neurotransmitters

Palmitic acid
- → Membrane lipids
- → Fats
- → Waxes

Glucose
- → Cellulose
- → Starch
- → Fructose
- → Mannose
- → Sucrose
- → Lactose

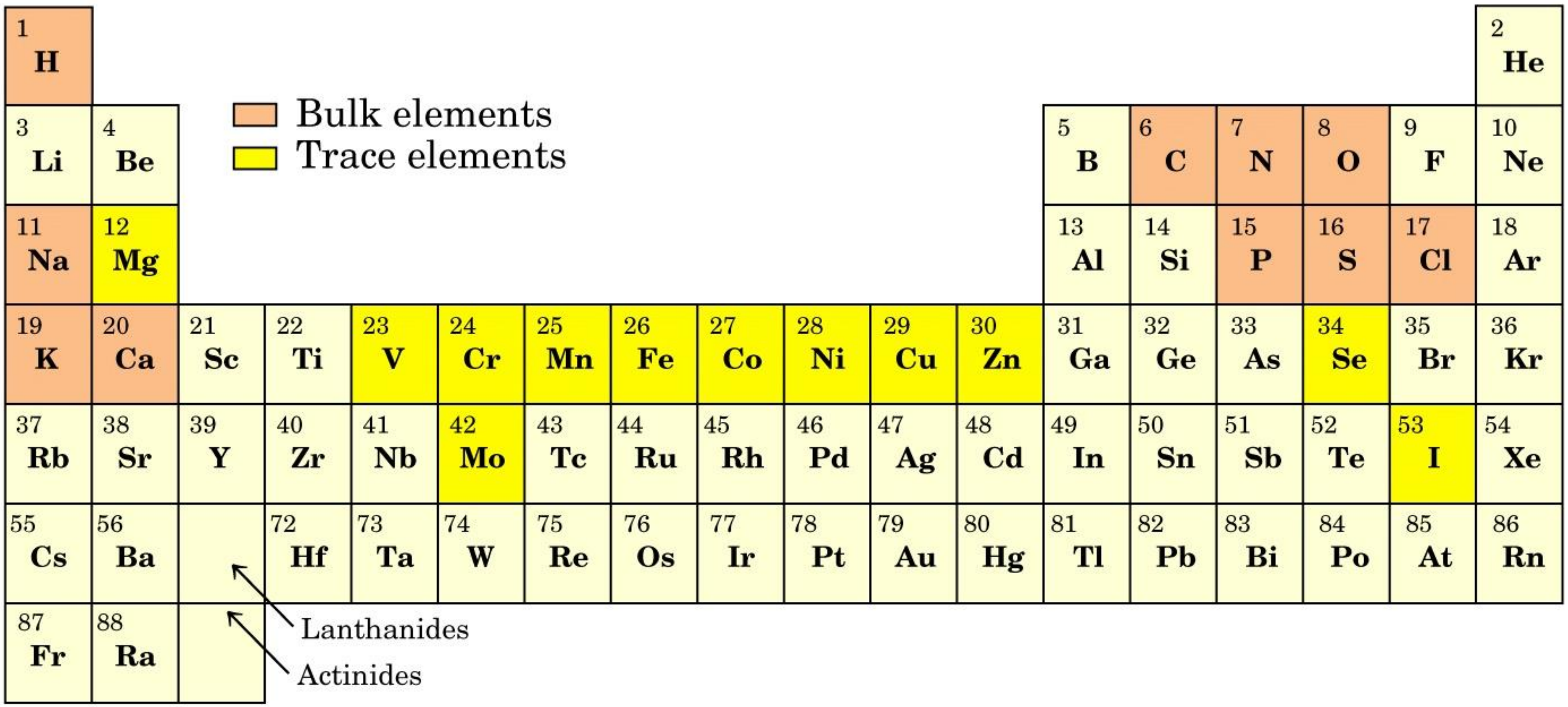
Structural Hierarchy



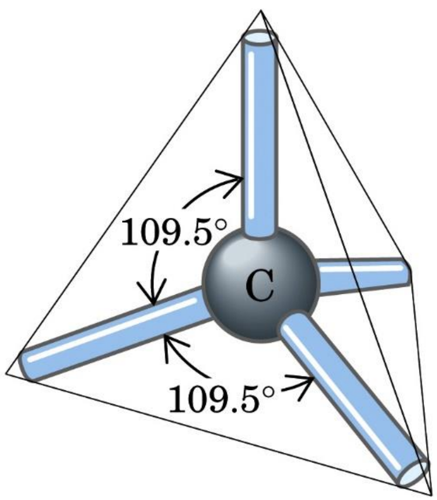

Monomeric subunits
Letters of English alphabet (26 different kinds)
Deoxyribonucleotides (4 different kinds)
Amino acids (20 different kinds)
J H T R D Z Y N Q V B F I U S P A W E M O K G L X C
C A T G
Phe Tyr Thr Gly Asn Gln Lys Asp Met Val Ala Ser Arg Ile Leu His Pro Trp Cys Glu
M E S S A G E S
M A S S A G E S
P A S S A G E S
G A T C A T A C
A G T C T T G C
G A C T A C G T
Gly Val Asp Ser Phe Arg Glu Ala
Arg Gly Pro Leu Lys Asn Phe Glu
Asp Gly Pro Leu Gly Lys Trp Cys
English words
Deoxyribonucleic acid (DNA)
Protein
Ordered linear sequences
For a segment of 8 subunits, the number of different sequences possible =
26^8 or 2.1 × 10^11
4^8 or 65,536
20^8 or 2.56 × 10^10

- **CHEMICAL FOUNDATION**

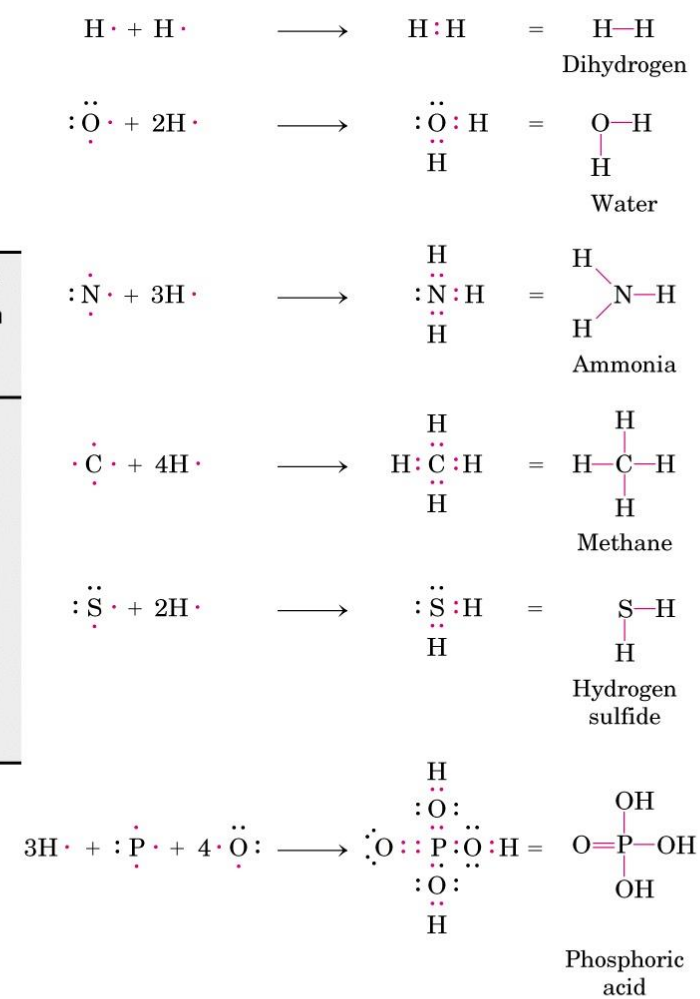
Elements essential to life and health



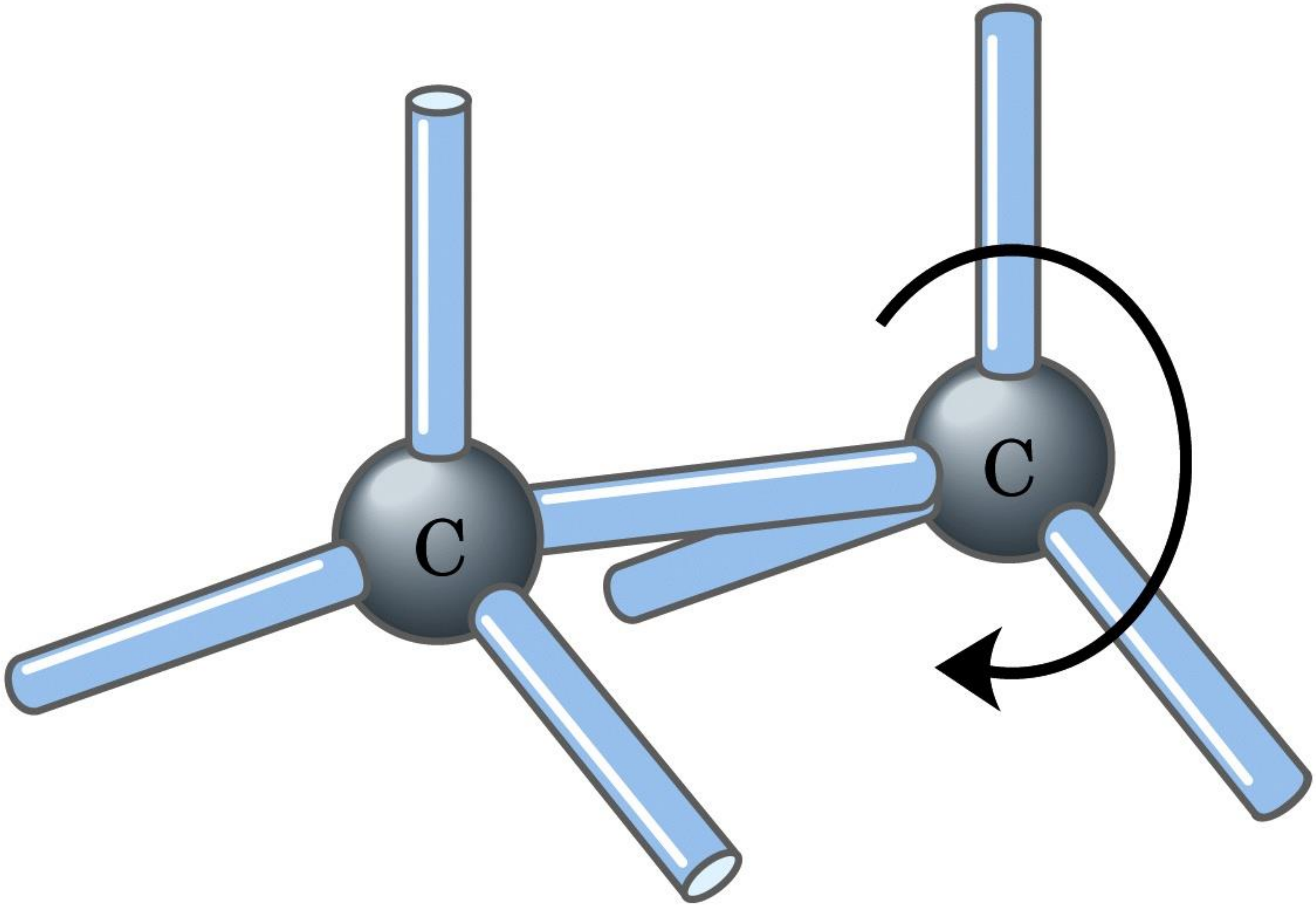
Carbon



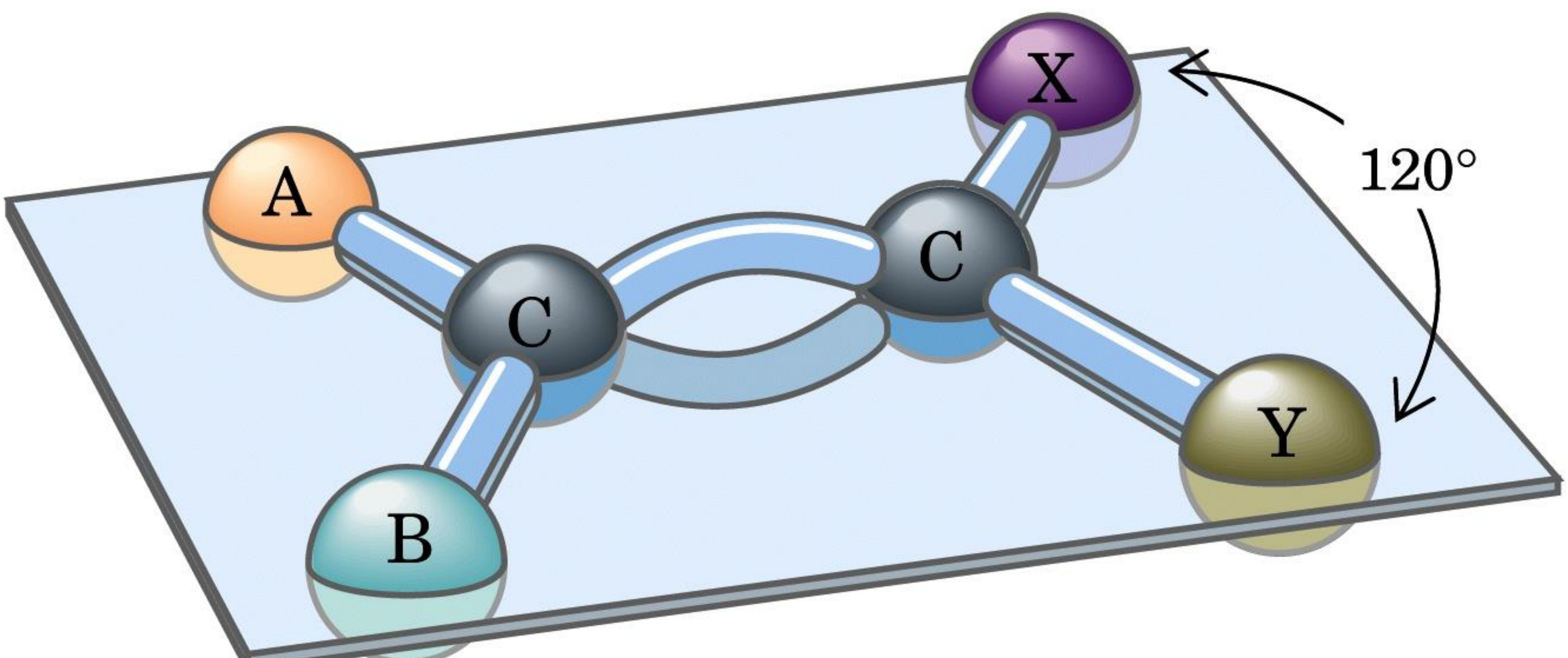
Atom	Number of unpaired electrons (in red)	Number of electrons in complete outer shell
H·	1	2
:O·	2	8
:N·	3	8
·C·	4	8
:S·	2	8
:P·	3	8



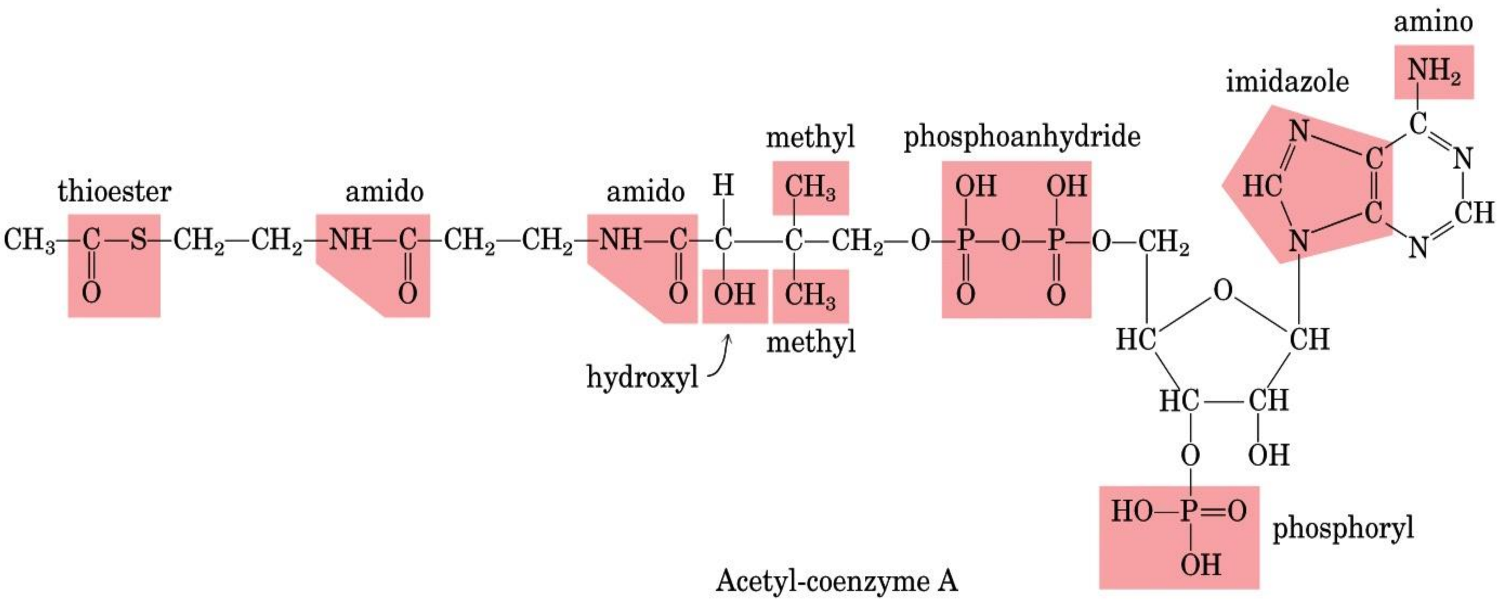
Single bonds vs. Double bonds



Single bonds vs. Double bonds

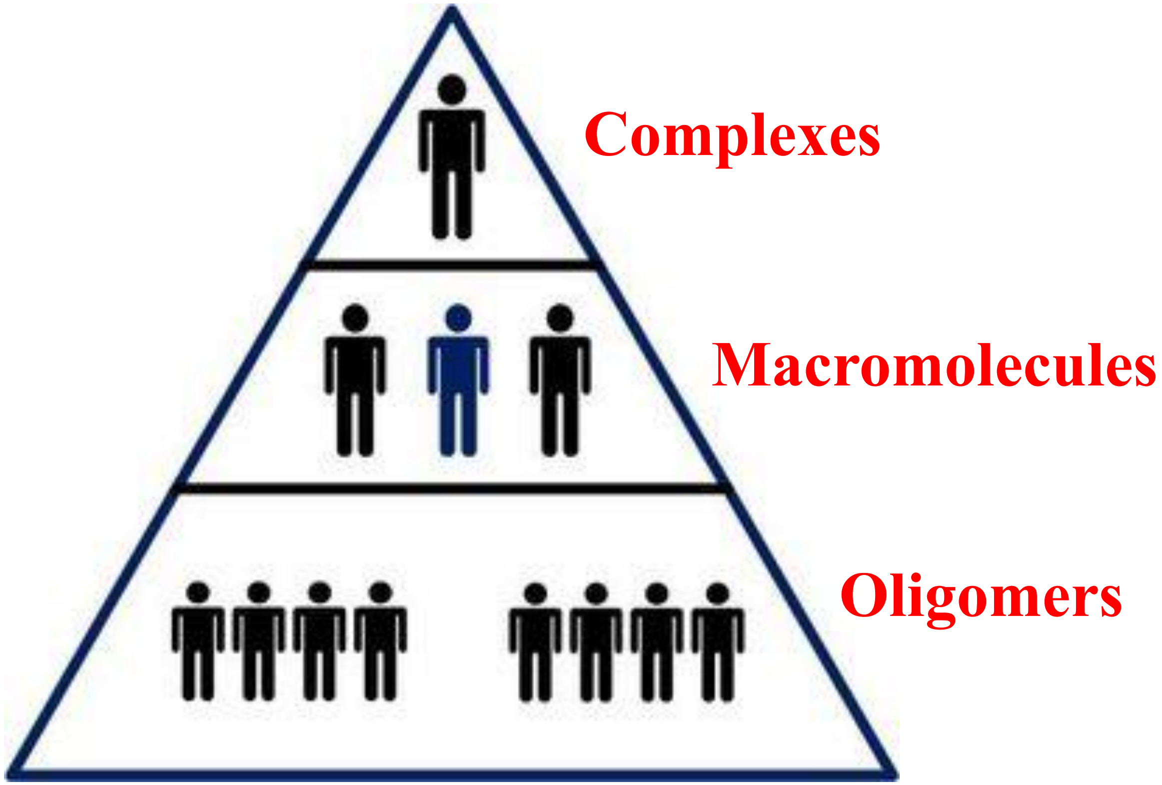


Functional group



Acetyl-coenzyme A

Structural Hierarchy



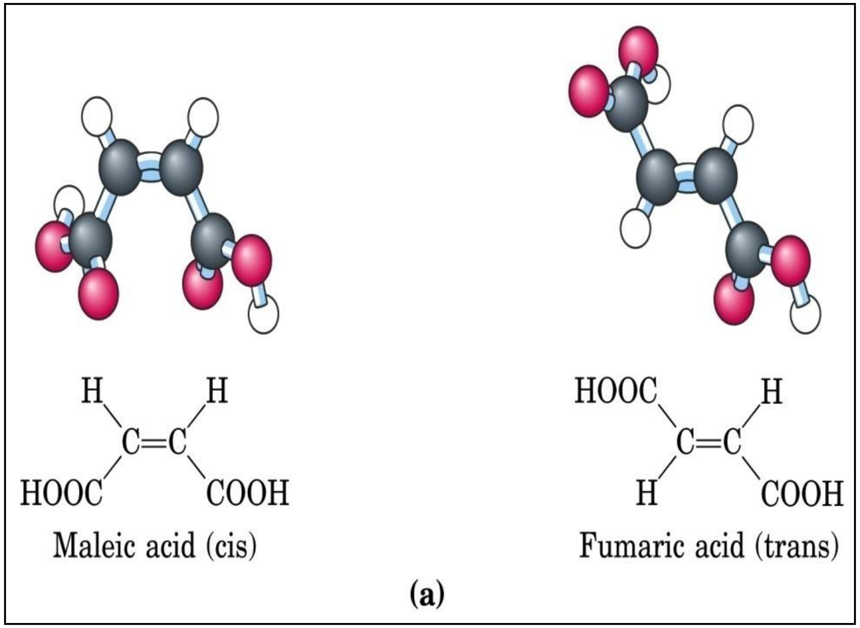
Structural Hierarchy

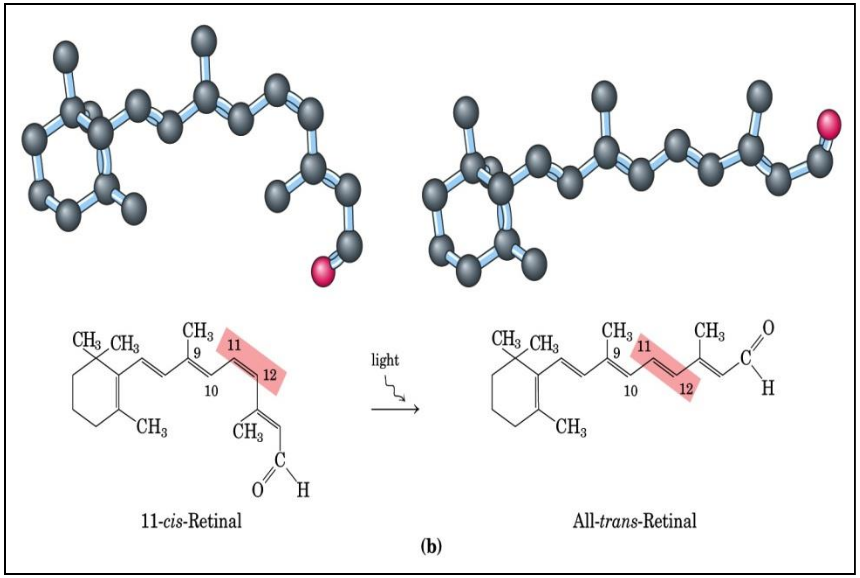
Oligomers

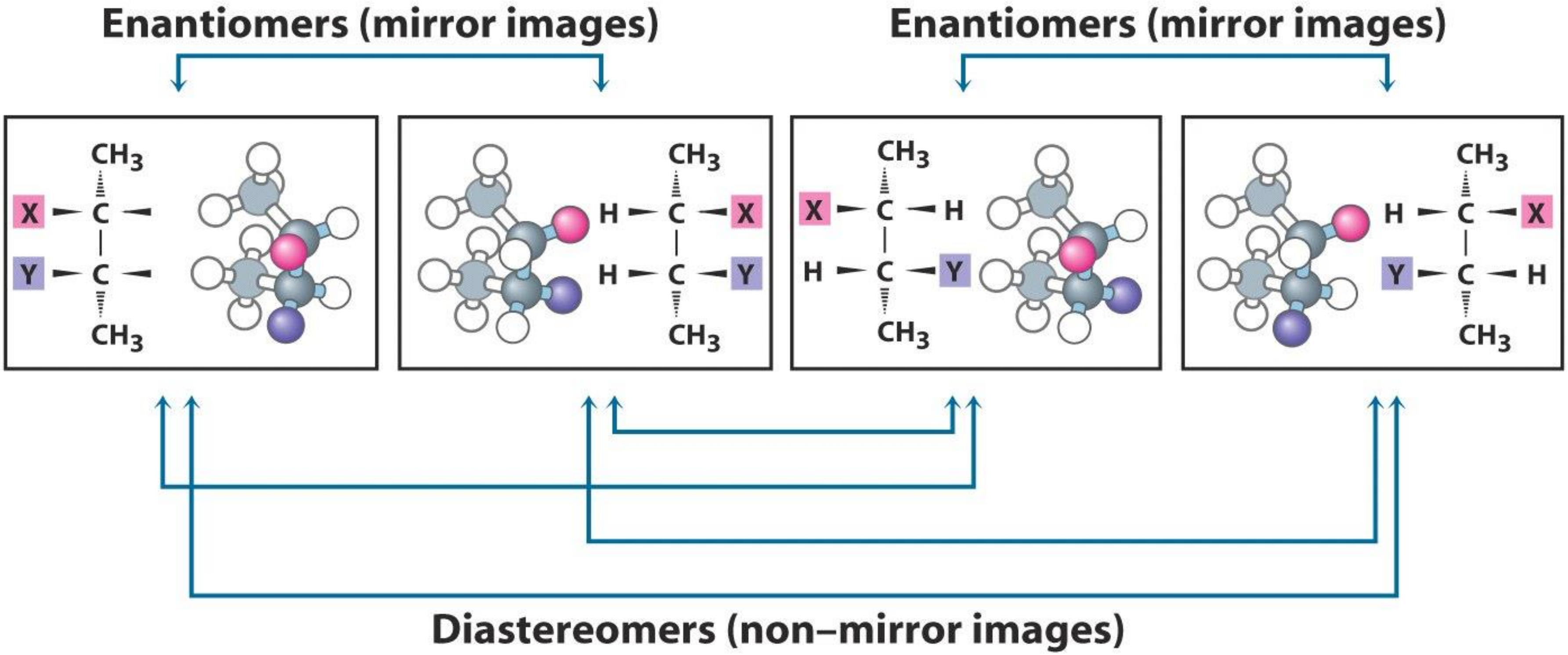
Macromolecules

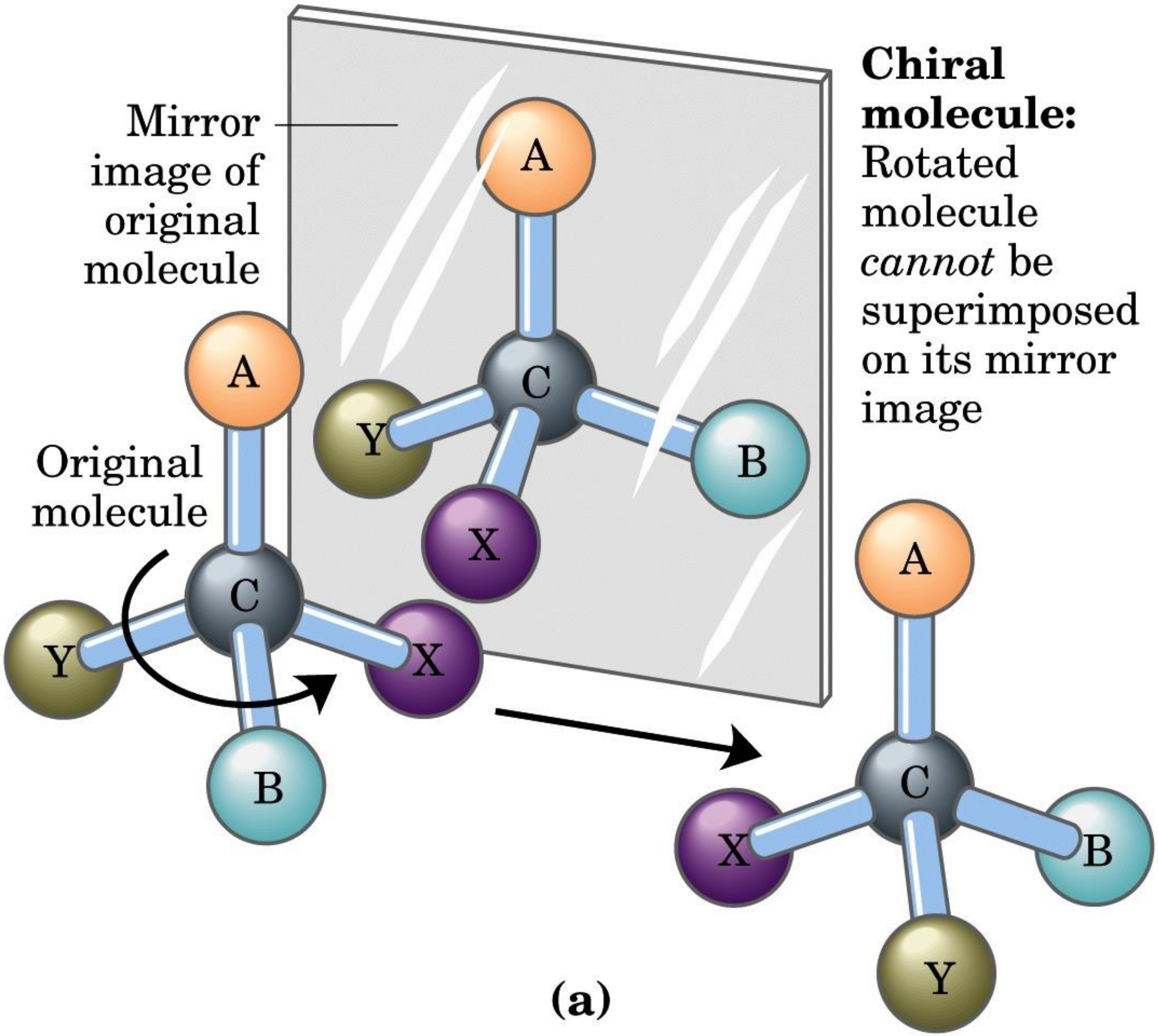
Supramolecular Complexes

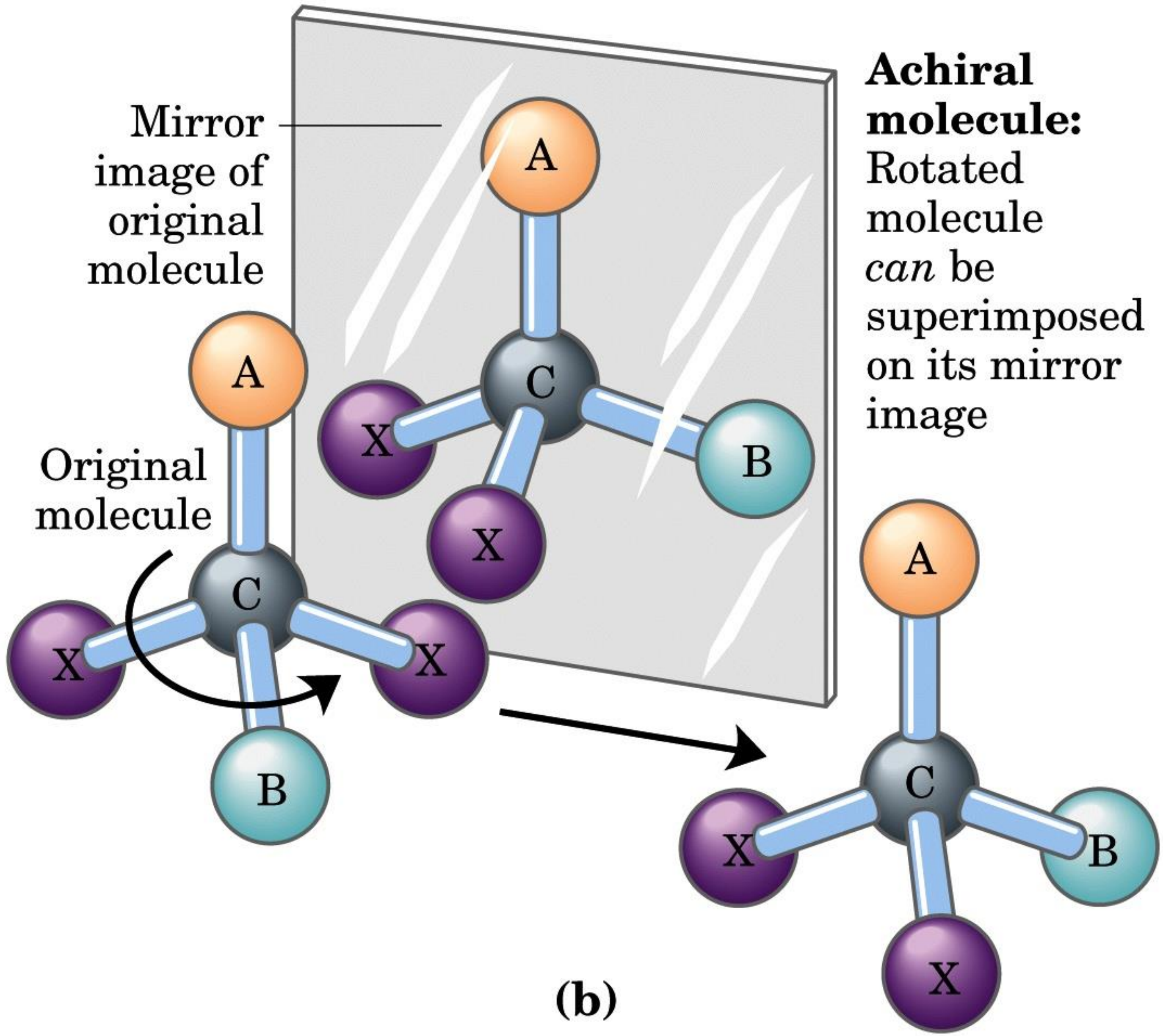
Configurations of geometric isomers






Enantiomers (mirror images)
Enantiomers (mirror images)
CH3
X
C
Y
C
CH3
CH3
H
C
X
H
C
Y
CH3
CH3
X
C
H
H
C
Y
CH3
CH3
H
C
X
Y
C
H
CH3
Diastereomers (non–mirror images)


Mirror image of original molecule
Original molecule
Chiral molecule: Rotated molecule *cannot* be superimposed on its mirror image
A
C
Y
X
B
(a)

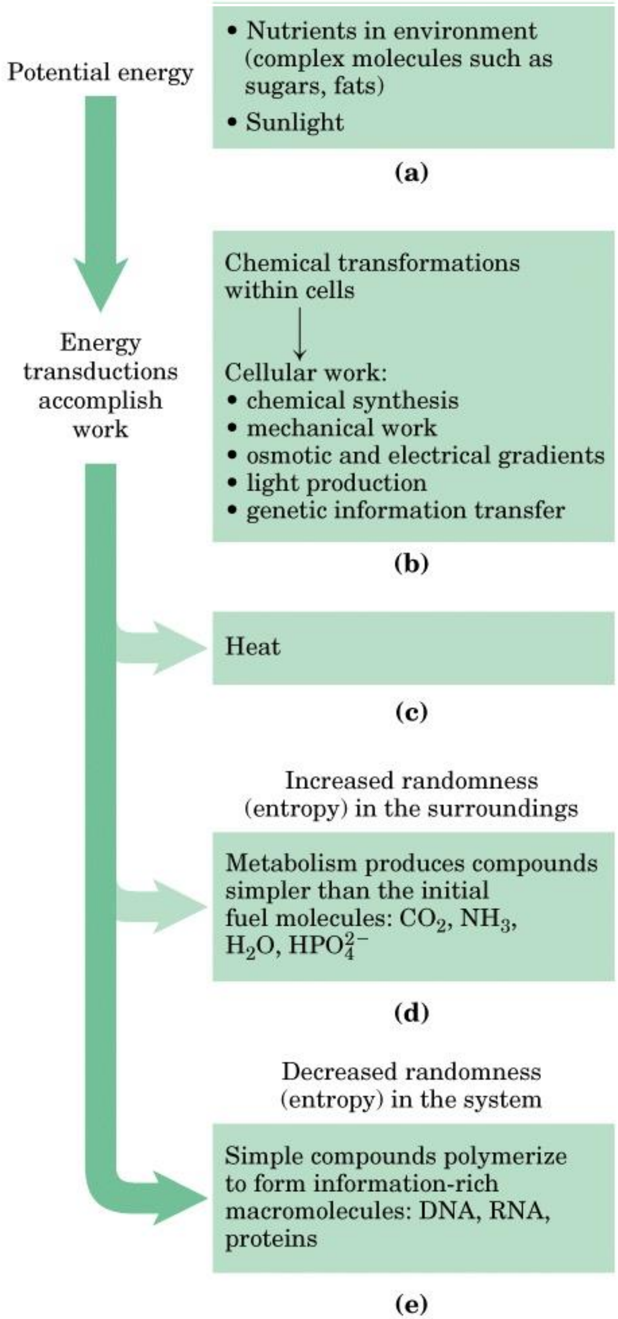


Mirror
image of
original
molecule
Original
molecule
A
C
X
X
B
A
C
X
X
B
A
C
X
B
X
Achiral molecule:
Rotated molecule *can* be superimposed on its mirror image

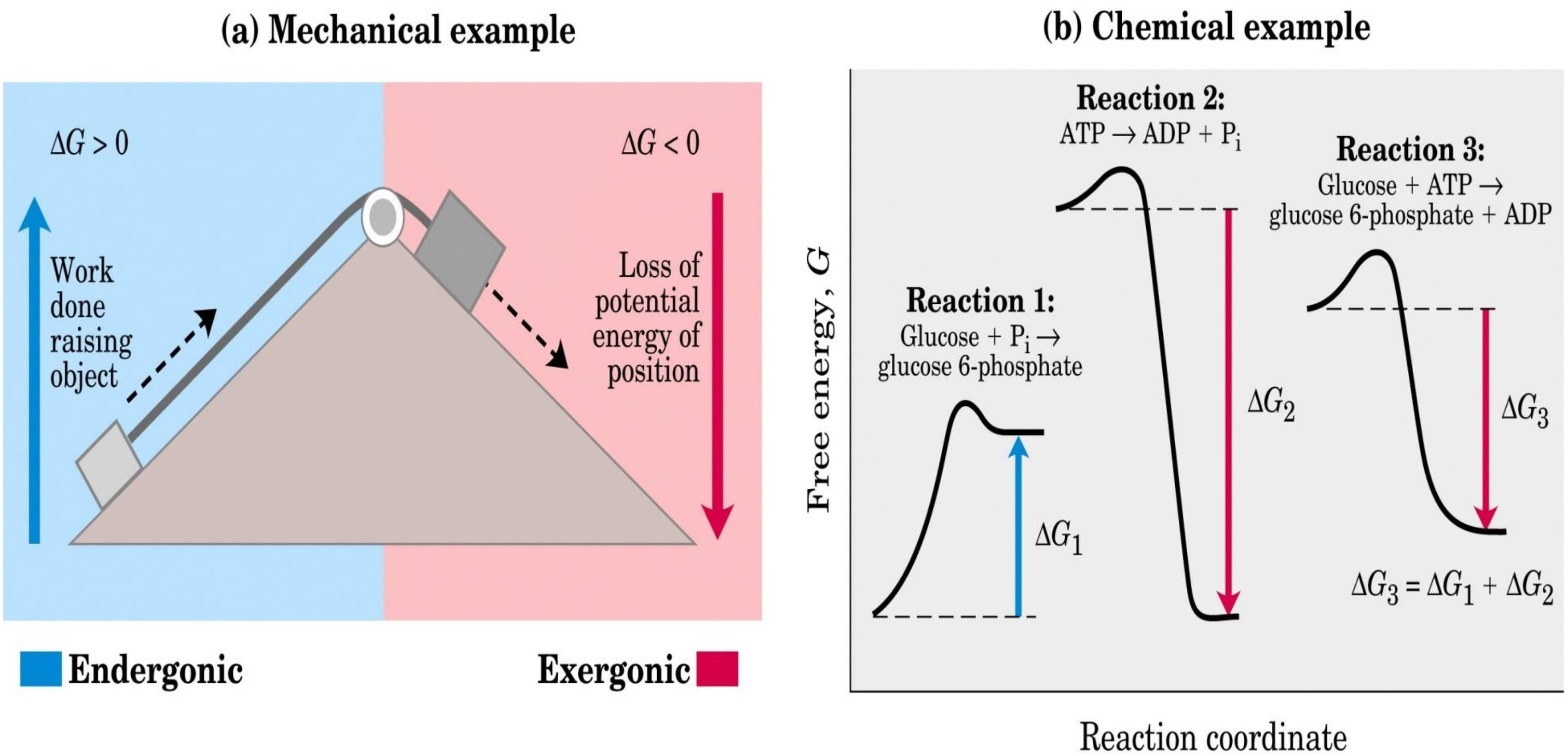
(b)

- **PHYSICAL FOUNDATION.**

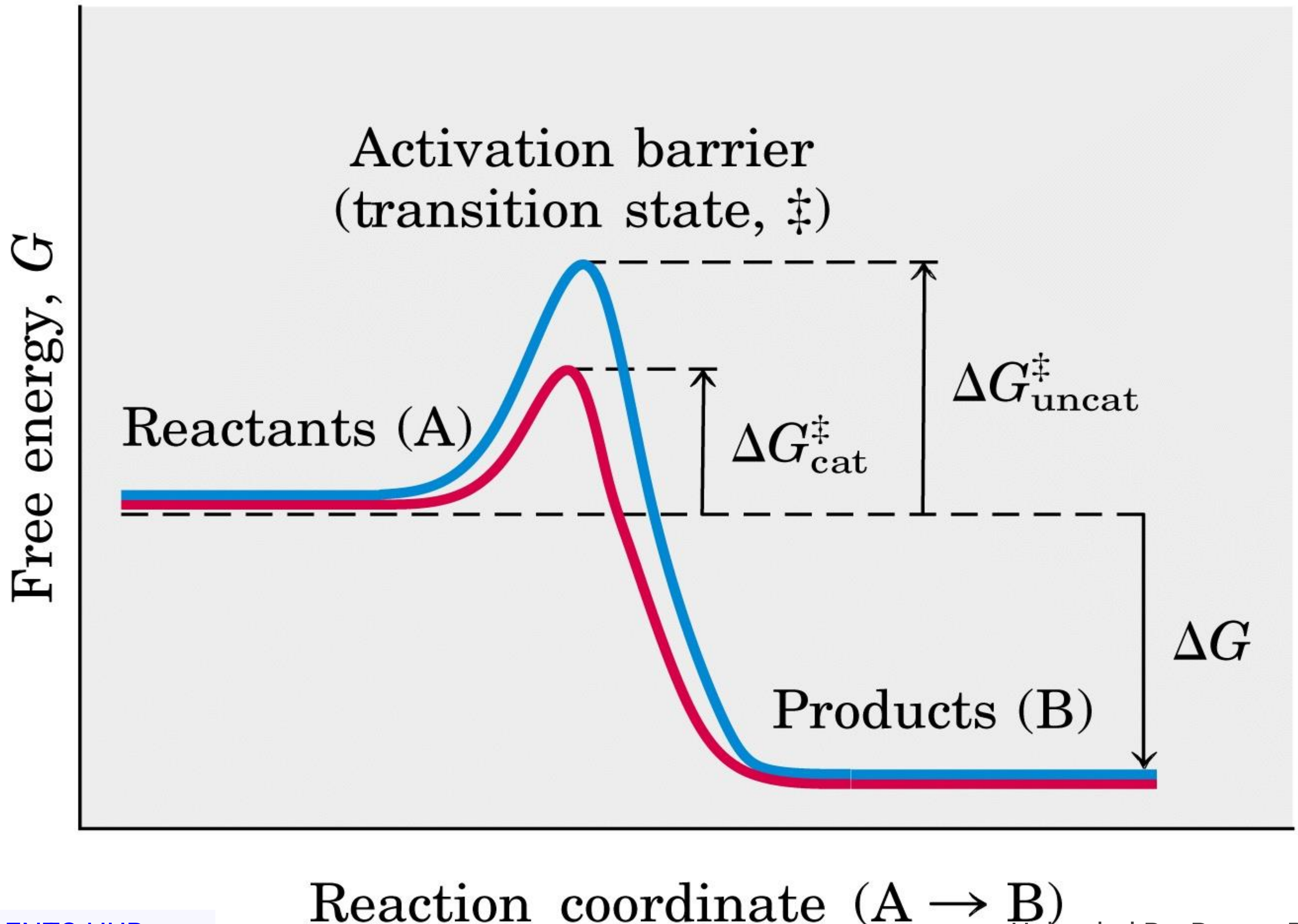
Some energy interconversion in living organisms



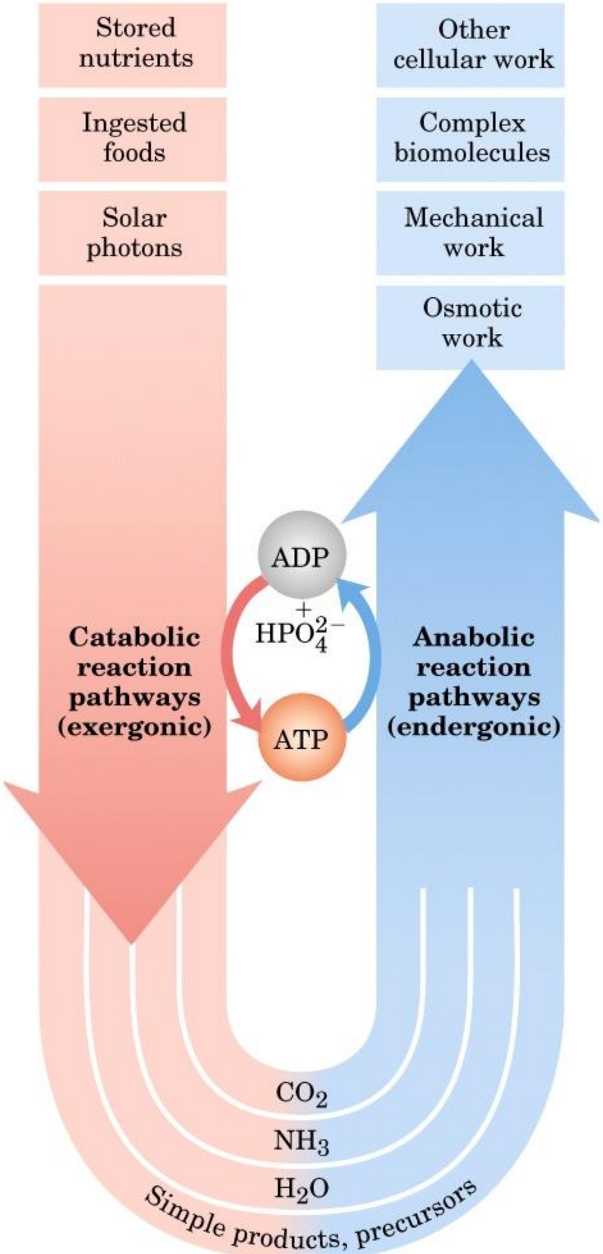
Energy coupling in mechanical and chemical processes



Energy changes during a chemical reaction

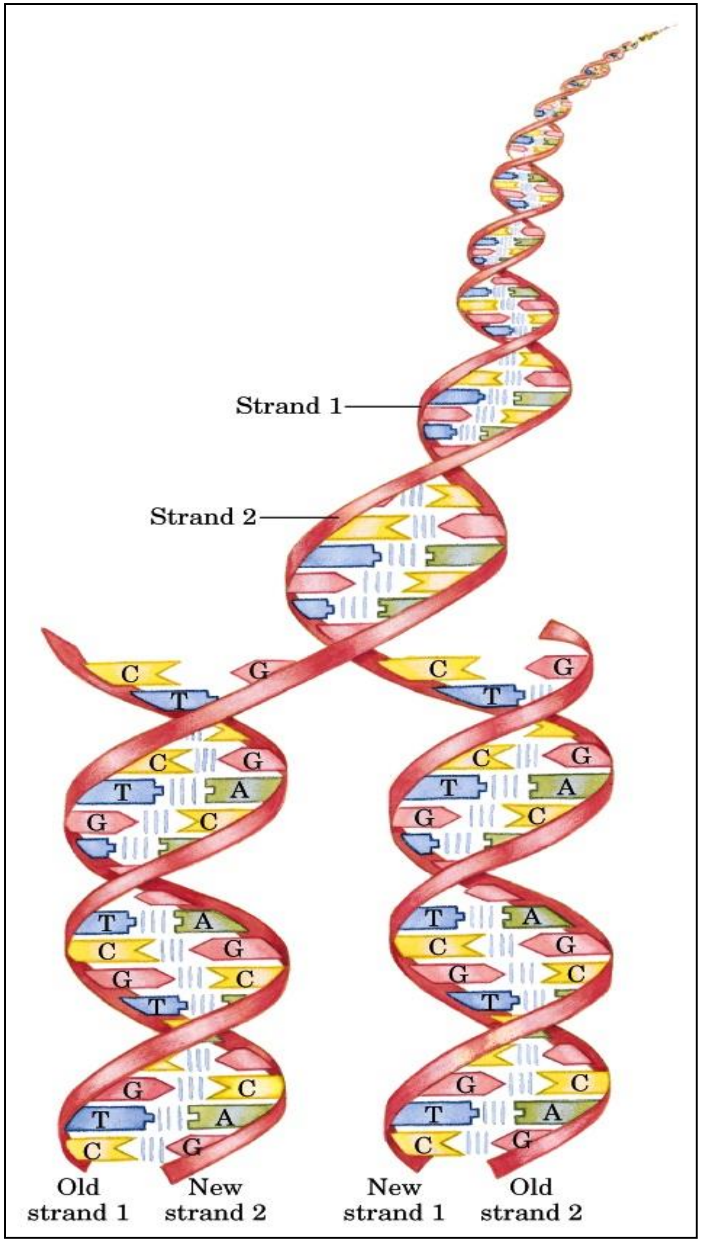


The central role of ATP in metabolism

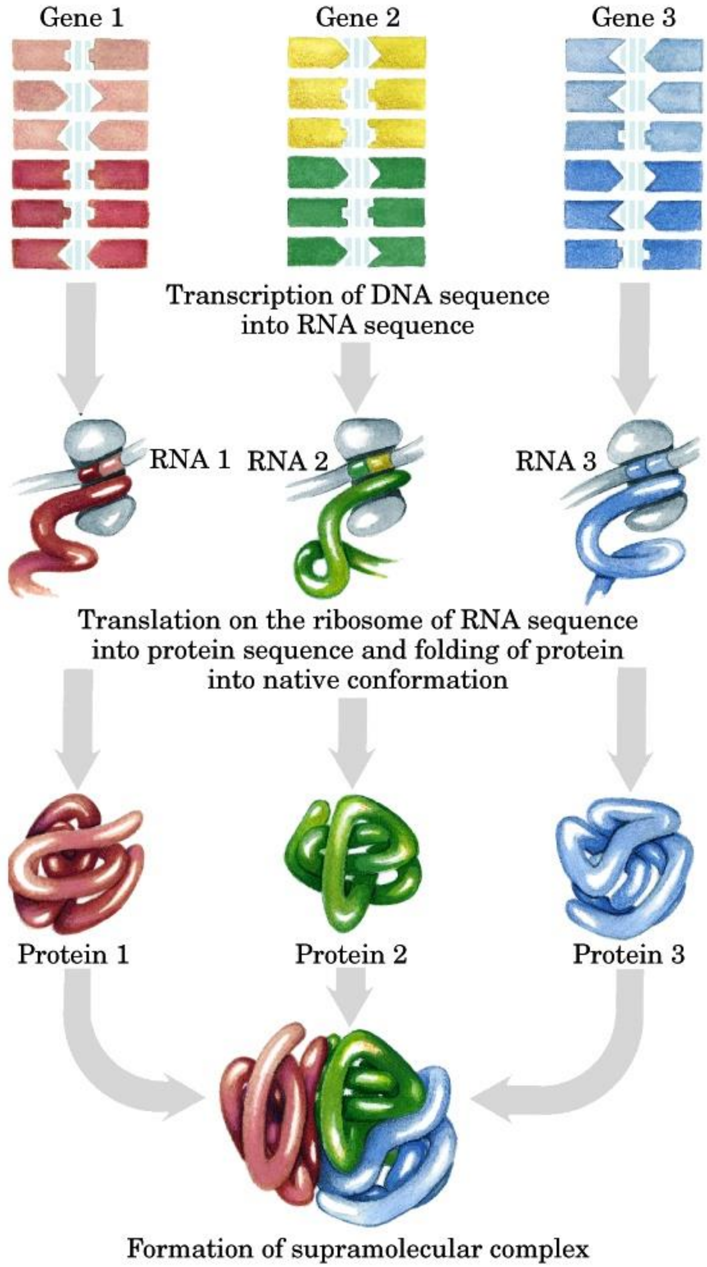


- **GENETIC FOUNDATION**

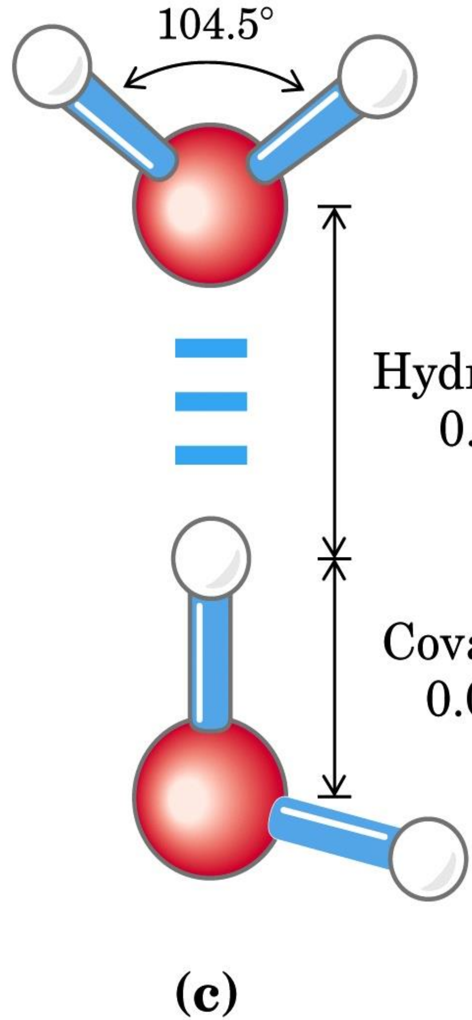
Complementarity between the two strands of DNA



DNA to RNA to Protein

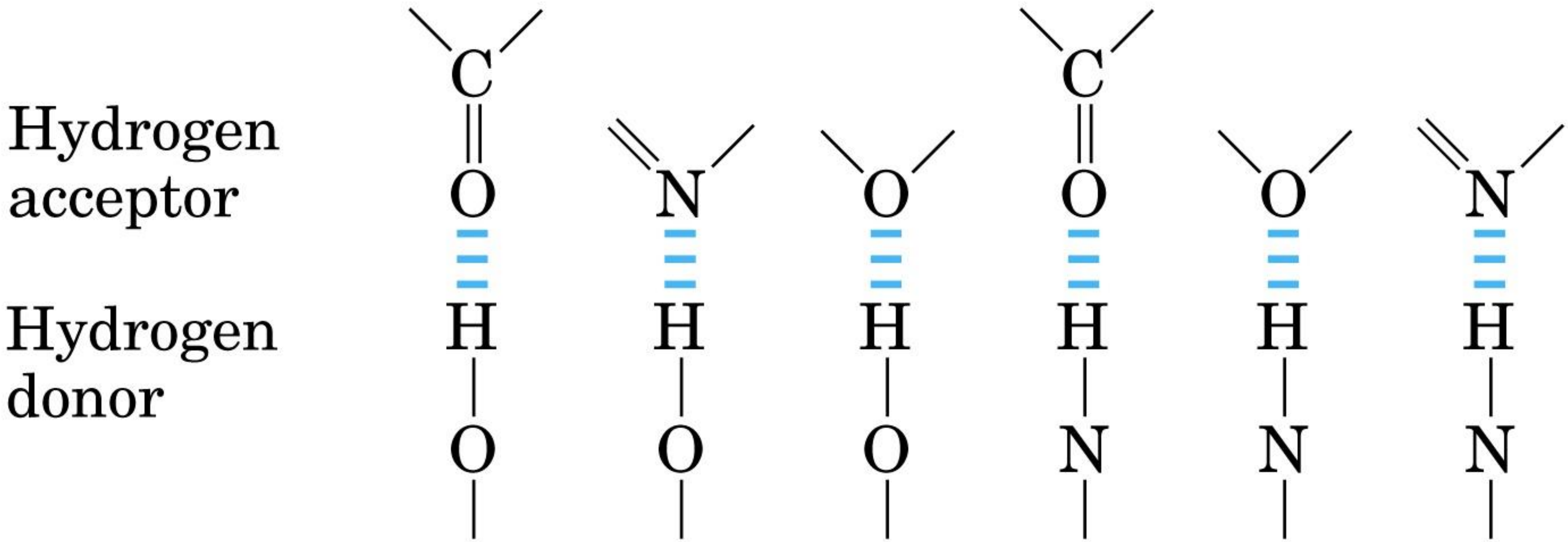


Hydrogen bonds



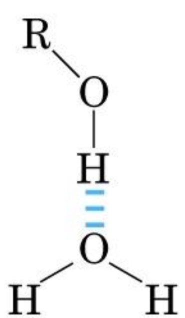
Structure of the water molecule

Common hydrogen bonds in biological systems

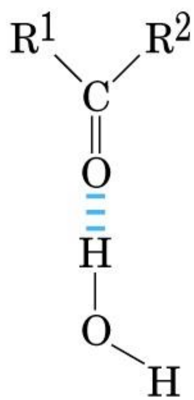


Some biologically important hydrogen bonds

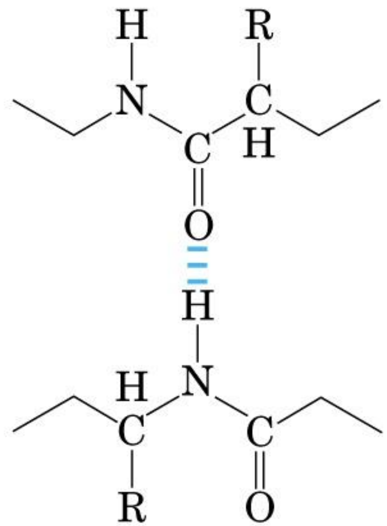
Between the hydroxyl group of an alcohol and water



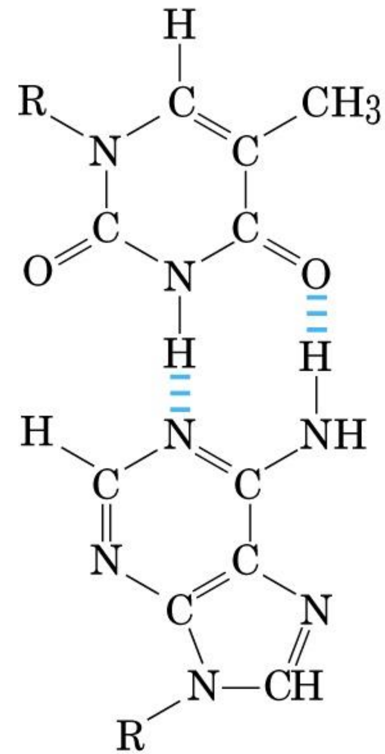
Between the carbonyl group of a ketone and water



Between peptide groups in polypeptides



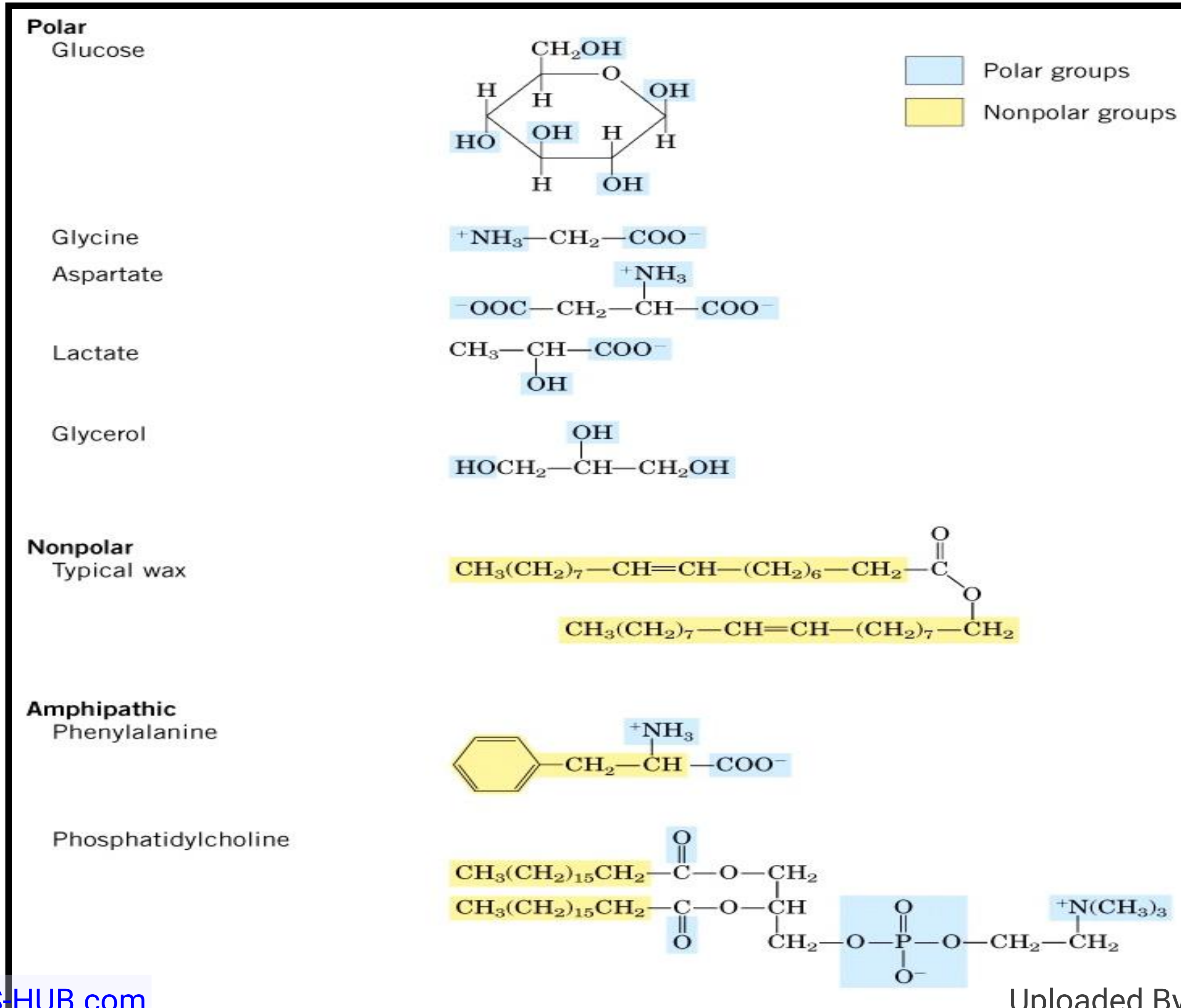
Between complementary bases of DNA



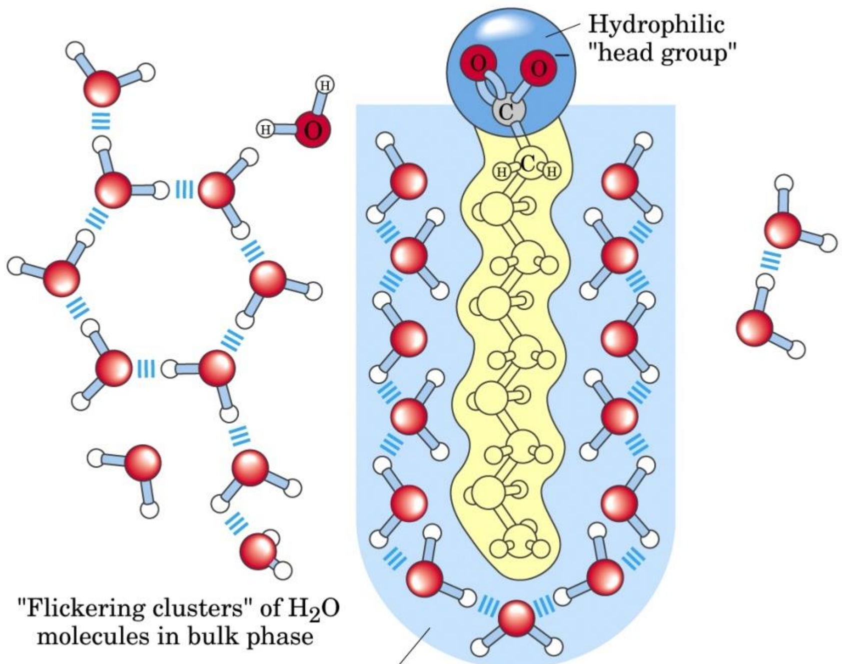
Thymine

Adenine

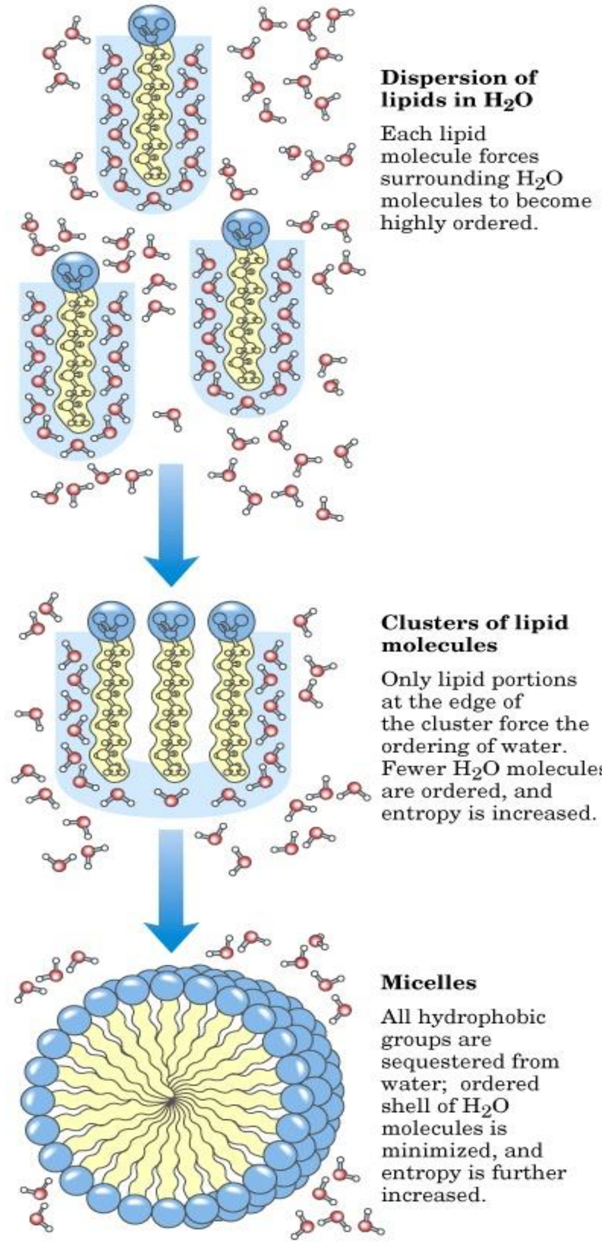
Some Examples of Polar, Nonpolar, and Amphipathic Biomolecules (shown as ionic forms at pH 7)



Amphipathic compounds in aqueous solution: (a) long chain fatty acids and (b) clusters of fatty acids in micelles

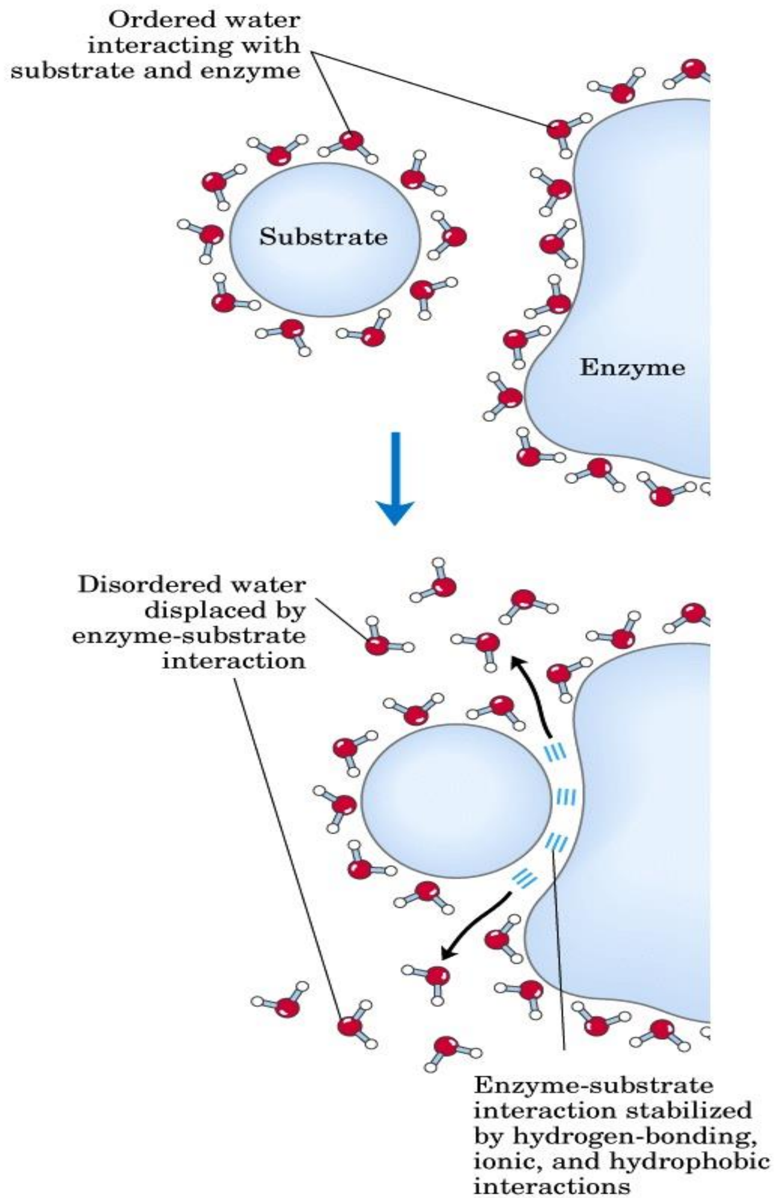


(a)

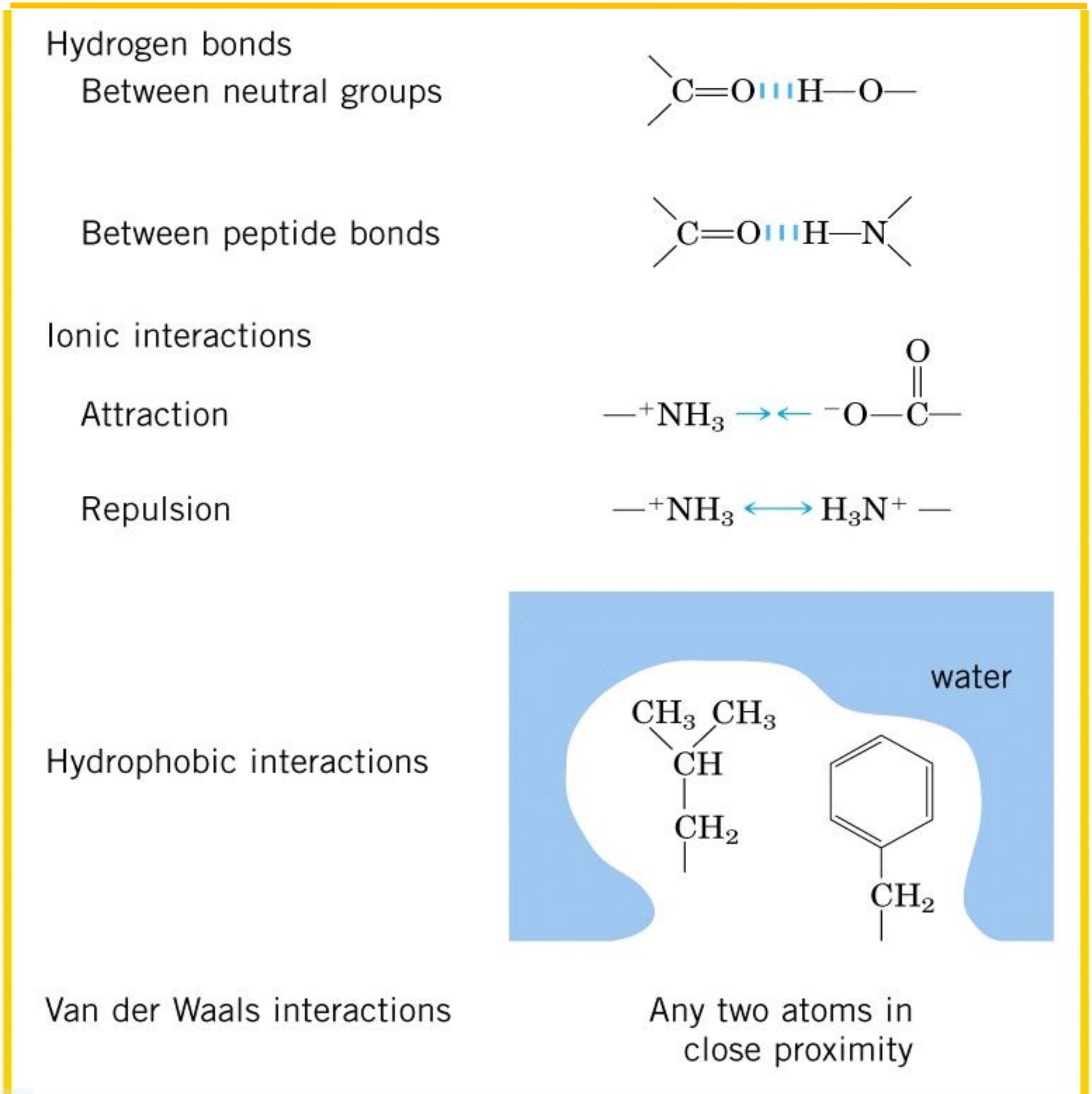


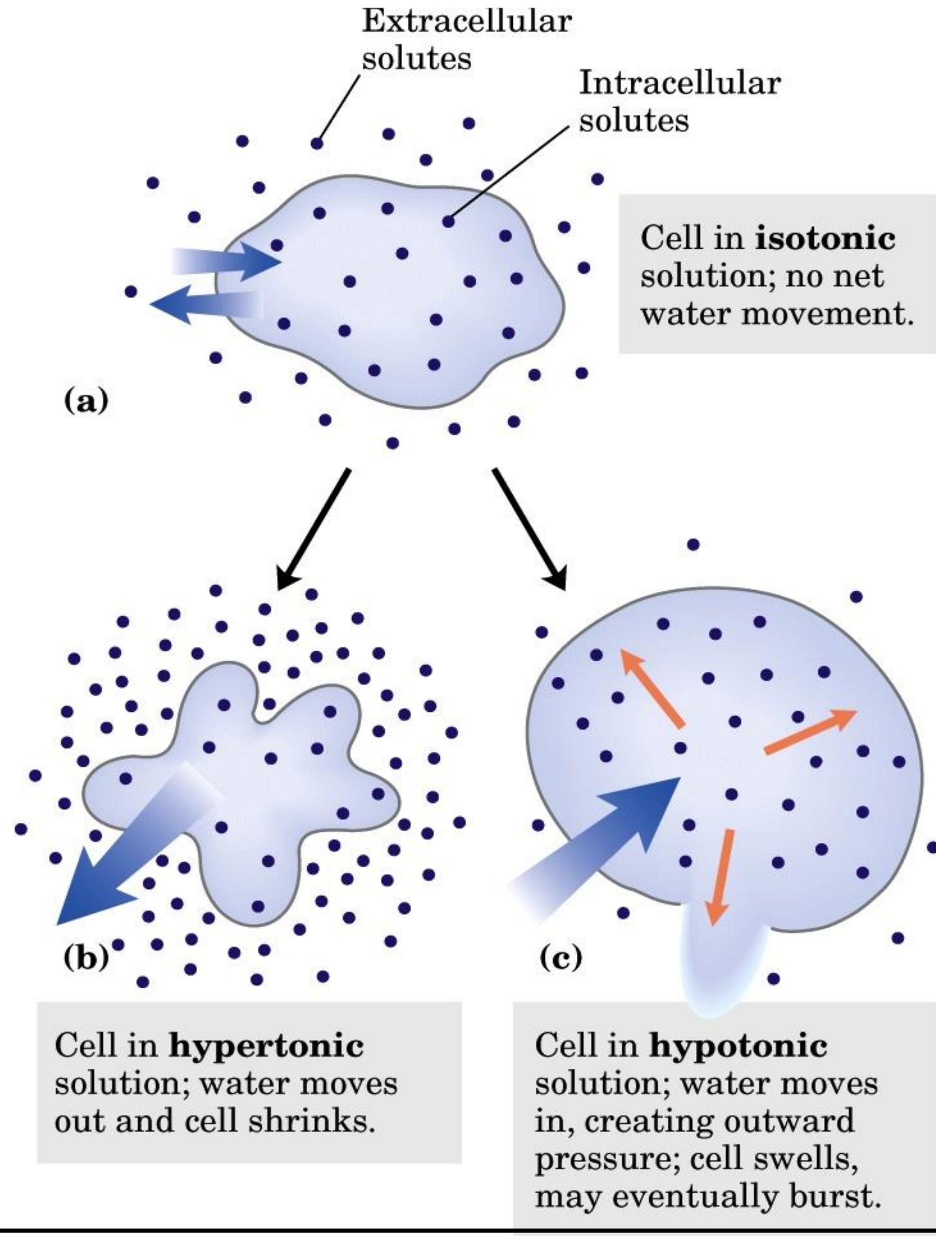
(b)

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



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





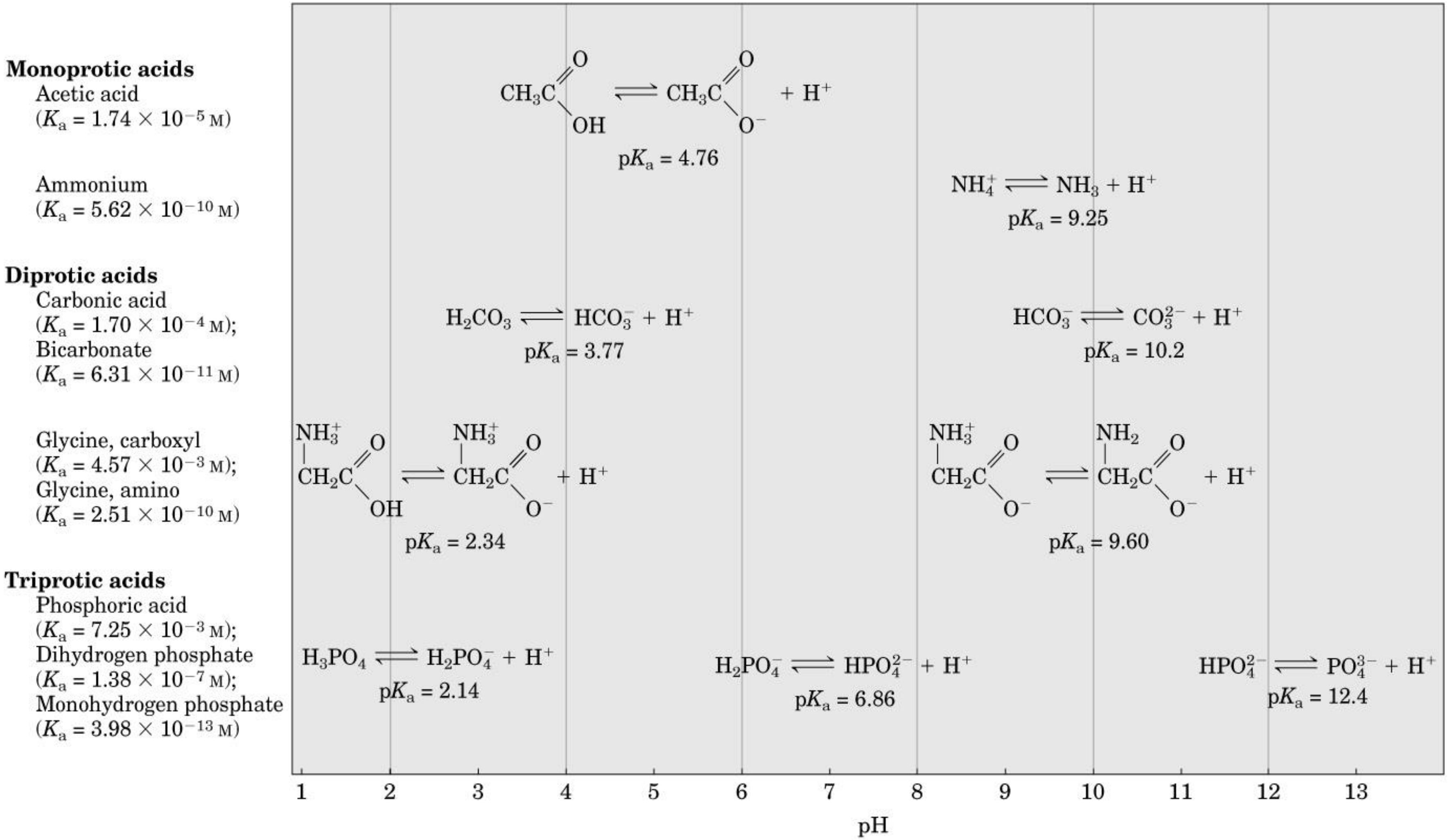
Effect of extracellular osmolarity on water movement across a plasma membrane: (a) isotonic, (b) hypertonic and (c) hypotonic solutions

pH Scale

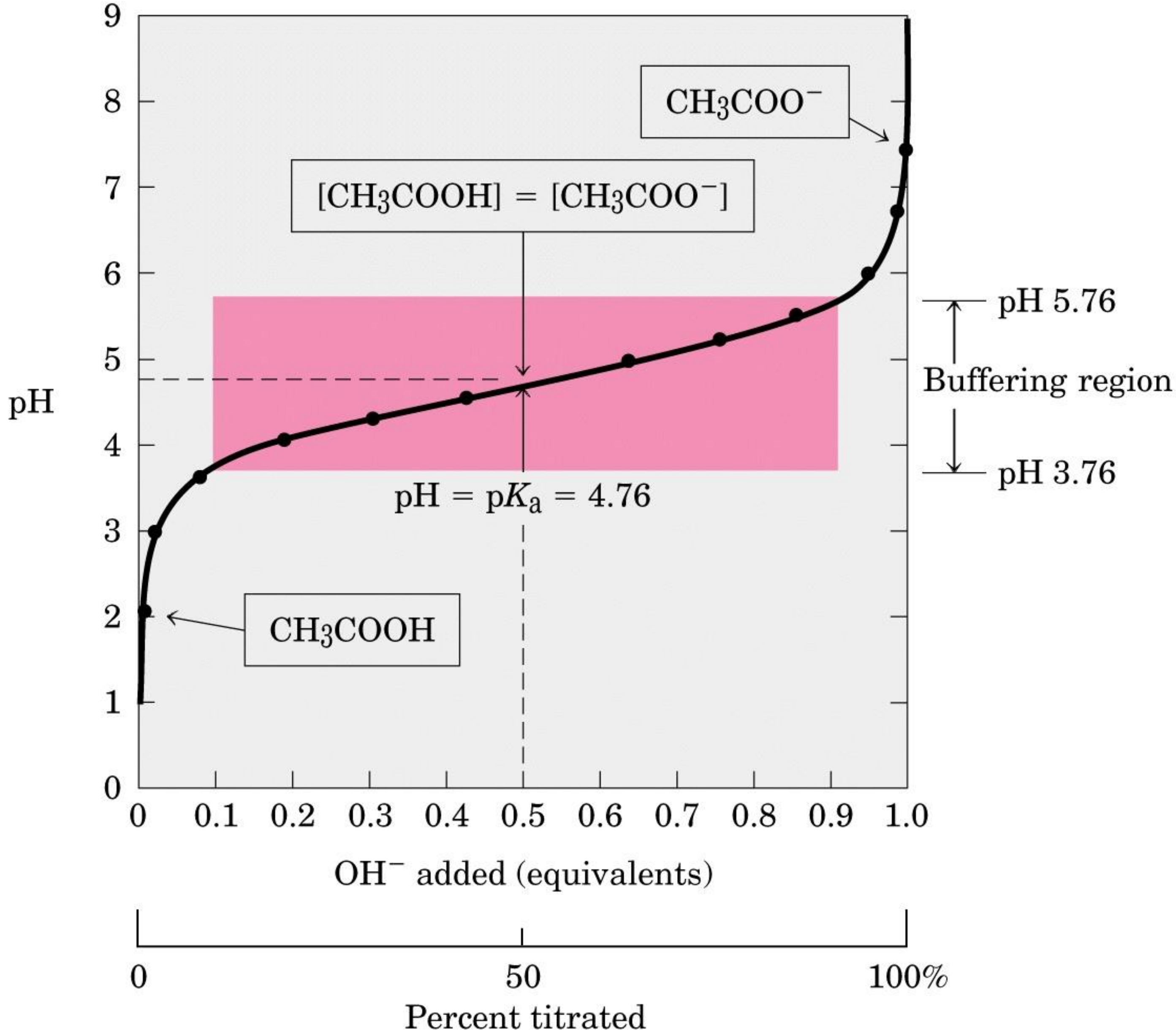
The pH Scale

$[H^+]$ (M)	pH	$[OH^-]$ (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

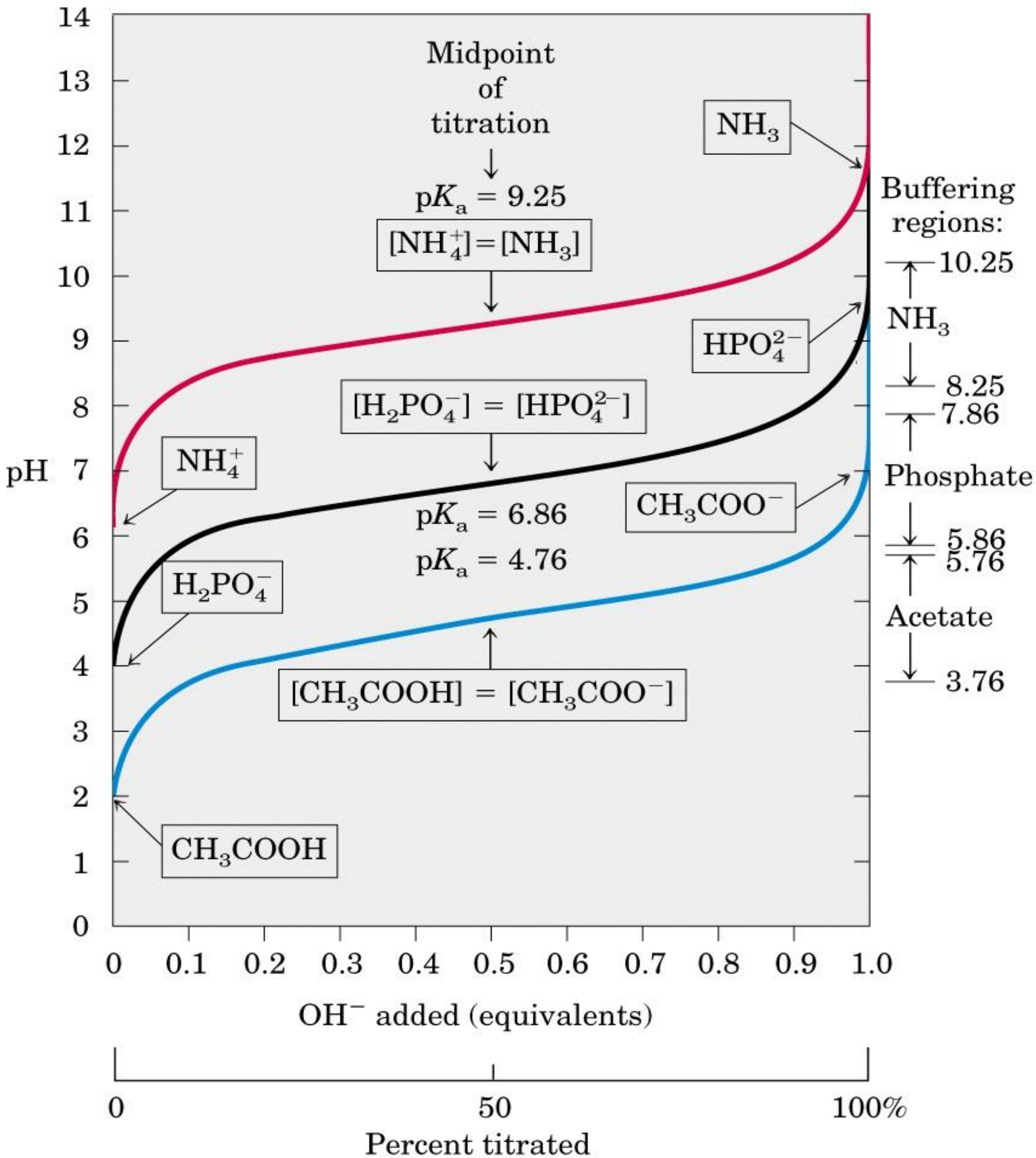
*The expression pOH is sometimes used to describe the basicity, or OH^- concentration, of a solution; pOH is defined by the expression $pOH = -\log [OH^-]$, which is analogous to the expression for pH. Note that in all cases, pH + pOH = 14.



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

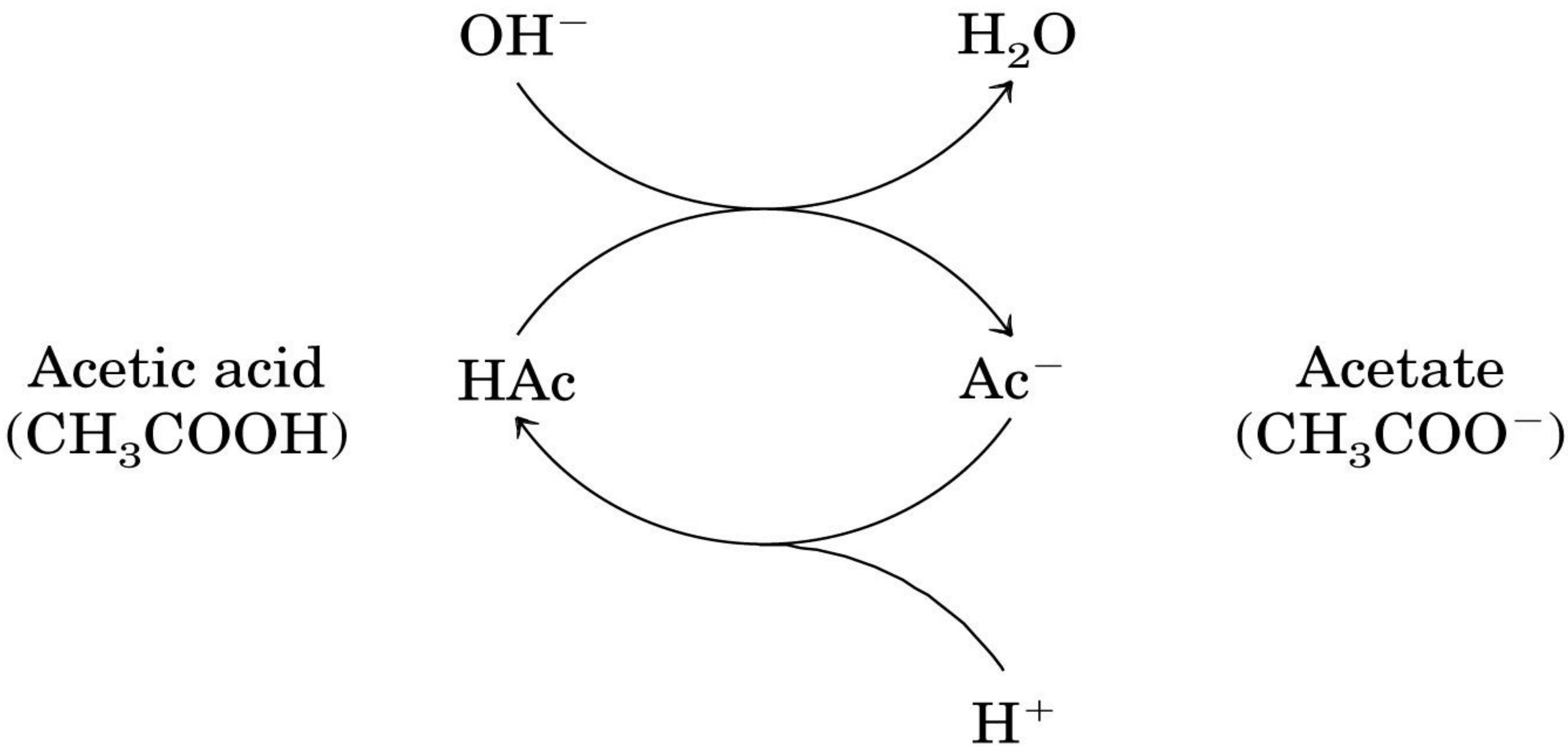


The titration curve of acetic acid



Comparison of the titration curves of three weak acids

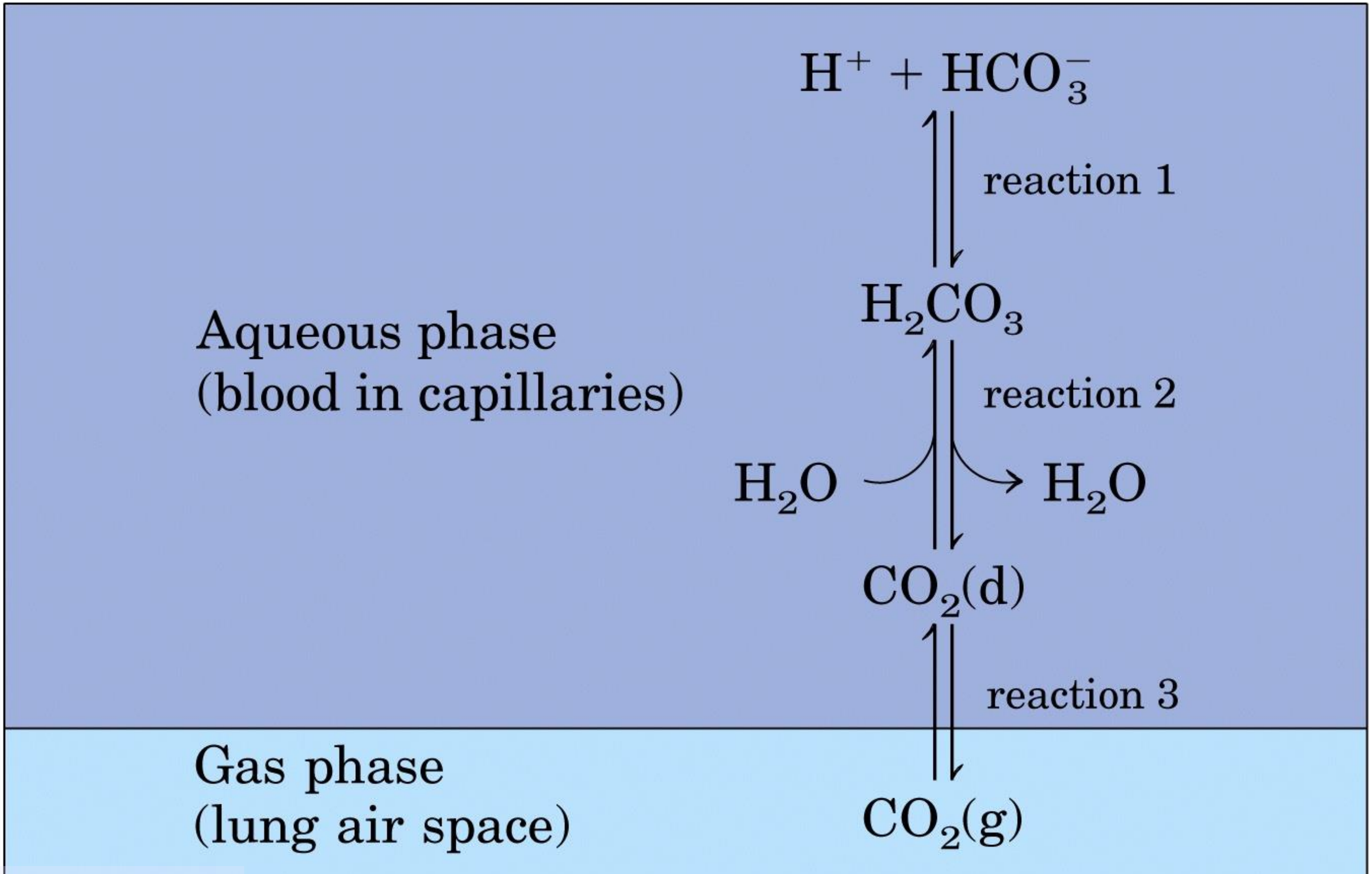
$$K_w = [H^+][OH^-]$$

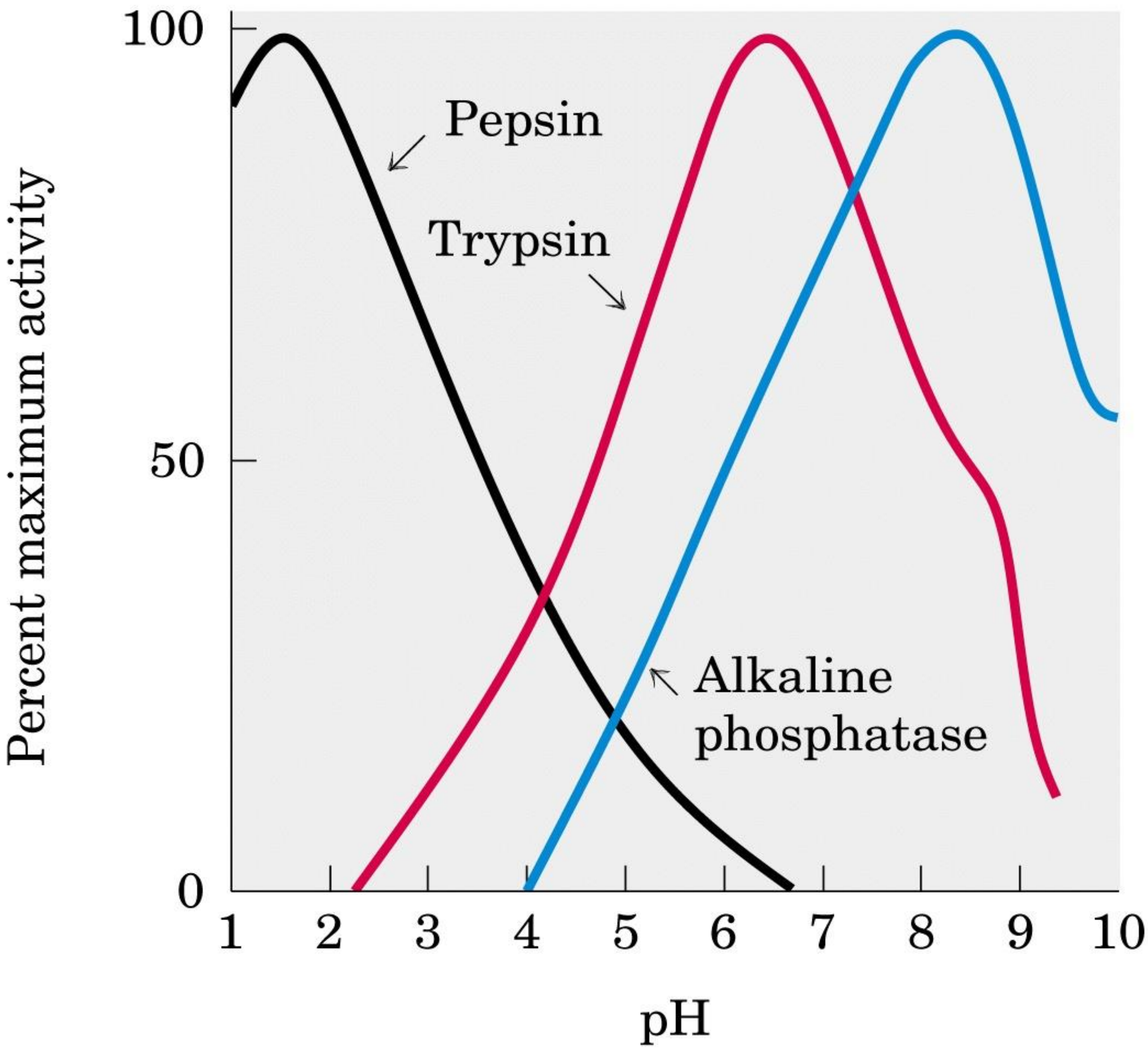


$$K_a = \frac{[H^+][Ac^-]}{[HAc]}$$

The acetic acid – acetate pair as a buffer system

The CO2 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