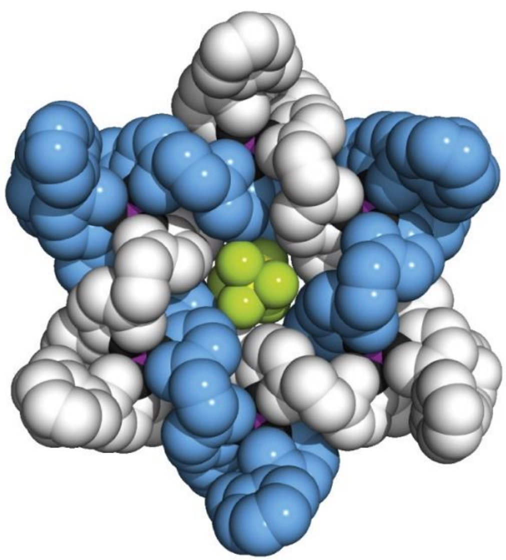
Chapter 2 – Chemical Foundations

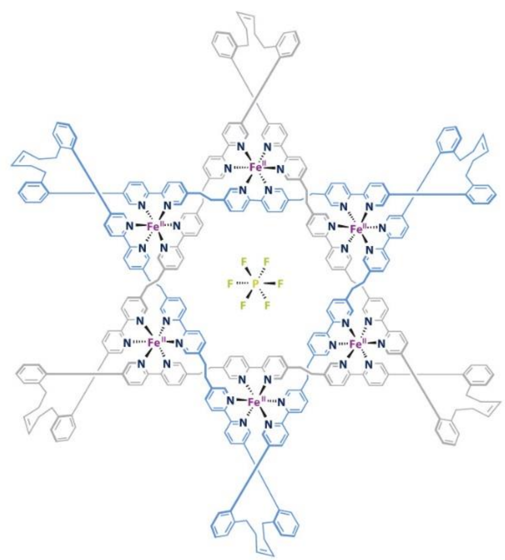
2.1 Covalent Bonds and Noncovalent Interactions

2.2 Chemical Building Blocks of Cells

2.3 Chemical Reactions and Chemical Equilibrium

2.4 Biochemical Energetics





Chapter 2 Opener
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“Star of David” catenane.

Link for the book: https://shorturl.at/ZZSwX

Molecular complementarity

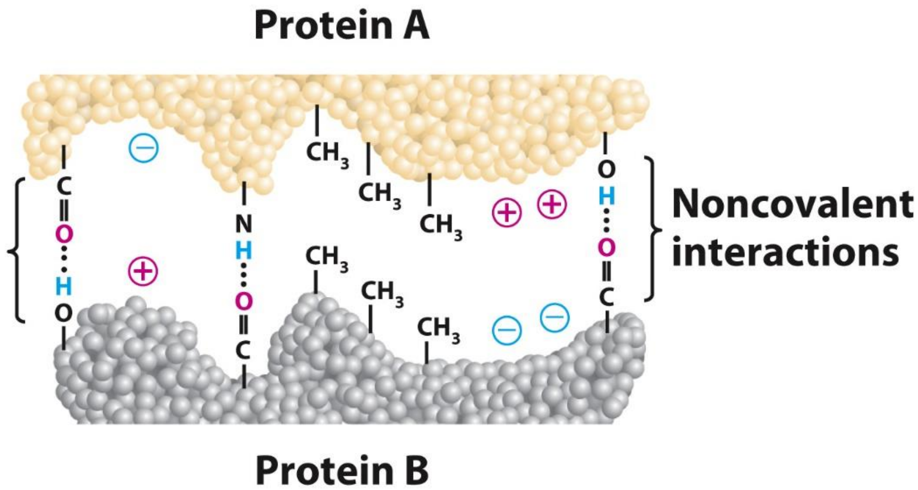

Figure 2-1a
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Chemical building blocks

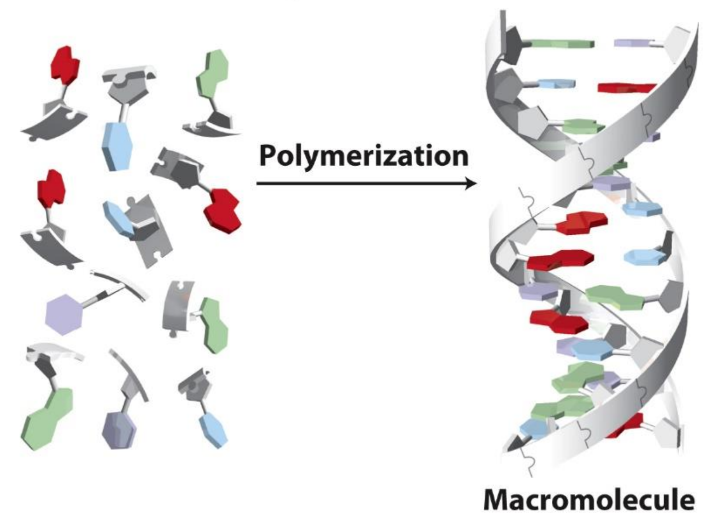

Figure 2-1b
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Chemical equilibrium

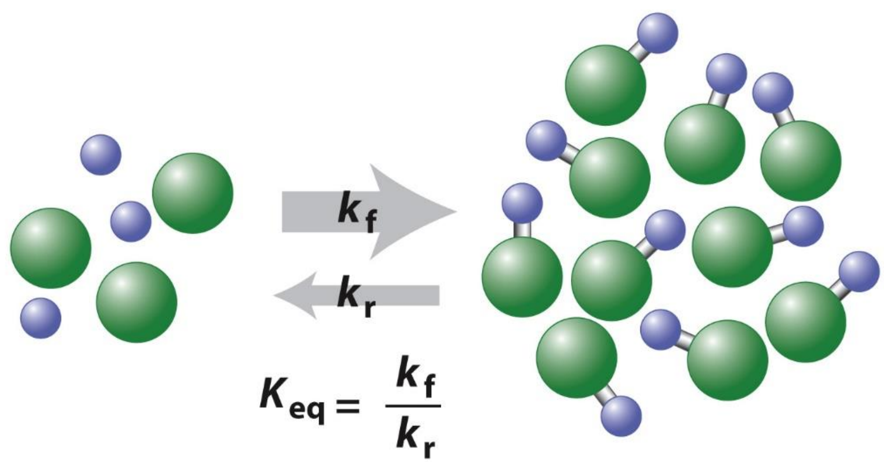

Figure 2-1c
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Chemical bond energy

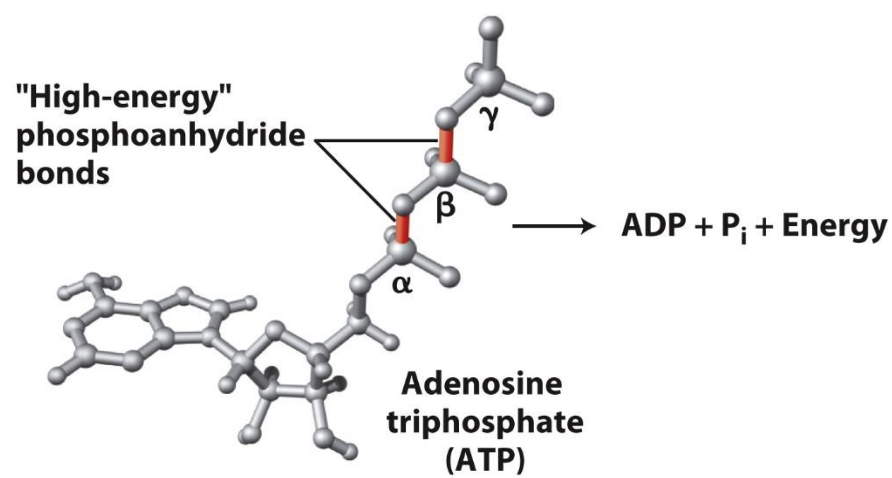

Figure 2-1d
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Chapter 2 – Chemical Foundations

- 2.1 Covalent Bonds and Noncovalent Interactions
  - Molecules: hydrophilic, hydrophobic, and amphipathic
  - Covalent bonds: shared electron pairs arrange specific molecular geometries such as stereoisomers around asymmetric carbons; unequal electron sharing yields polar covalent bonds with partial charges; more stable than weaker noncovalent interactions
  - Four types of biological noncovalent interactions: ionic bonds (electrostatic interactions), hydrogen bonds (nonbonding electron hydrogen attraction), van der Waals interactions (transient dipole interactions) , and hydrophobic effect interactions (reduces contact with water)
  - Molecular complementarity: fit between molecular shapes, charges, and other physical properties

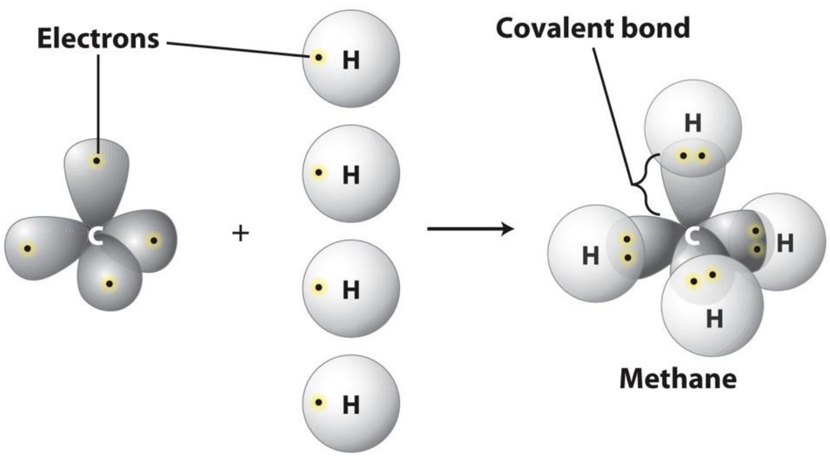

Figure 2-2
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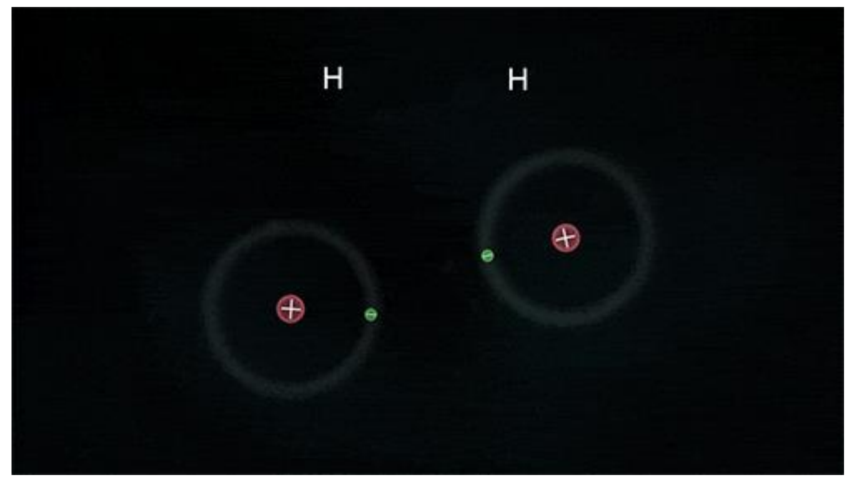

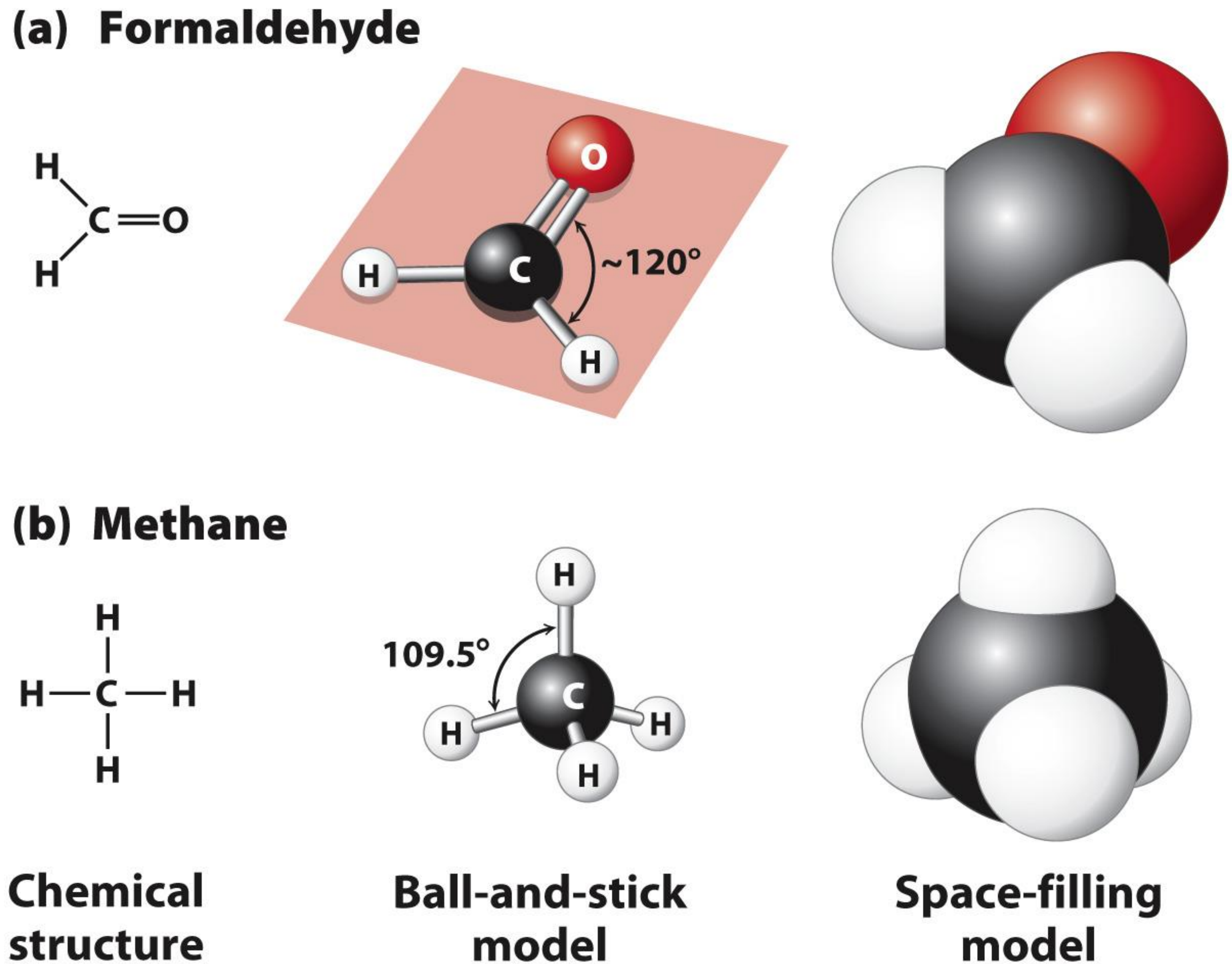

Figure 2-3
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TABLE 2-1 Bonding Properties of Atoms Most Abundant in Biomolecules

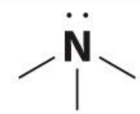
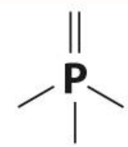
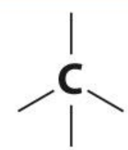
Atom and Outer Electrons	Usual Number of Covalent Bonds	Typical Bond Geometry
H	1	
O	2	
S	2, 4, or 6	
N	3 or 4	
P	5	
C	4	

Table 2-1
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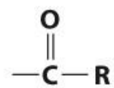
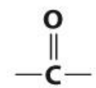
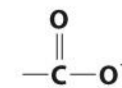
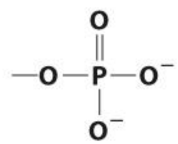
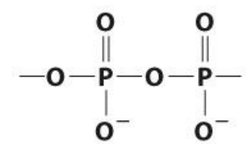
TABLE 2-2 Common Functional Groups and Linkages in Biomolecules

Functional Groups			
$-OH$ **Hydroxyl** **(alcohol)**	 **Acyl** **(triacylglycerol)**	 **Carbonyl** **(ketone)**	 **Carboxyl** **(carboxylic acid)**
$-SH$ **Sulfhydryl** **(thiol)**	$-NH_2$ or $-\overset{+}{N}H_3$ **Amino** **(amines)**	 **Phosphate** **(phosphorylated molecule)**	 **Pyrophosphate** **(diphosphate)**

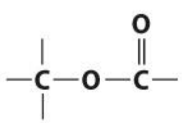
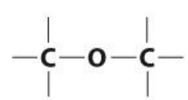
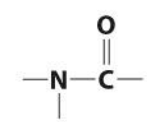
Linkages		
 **Ester**	 **Ether**	 **Amide**

Table 2-2

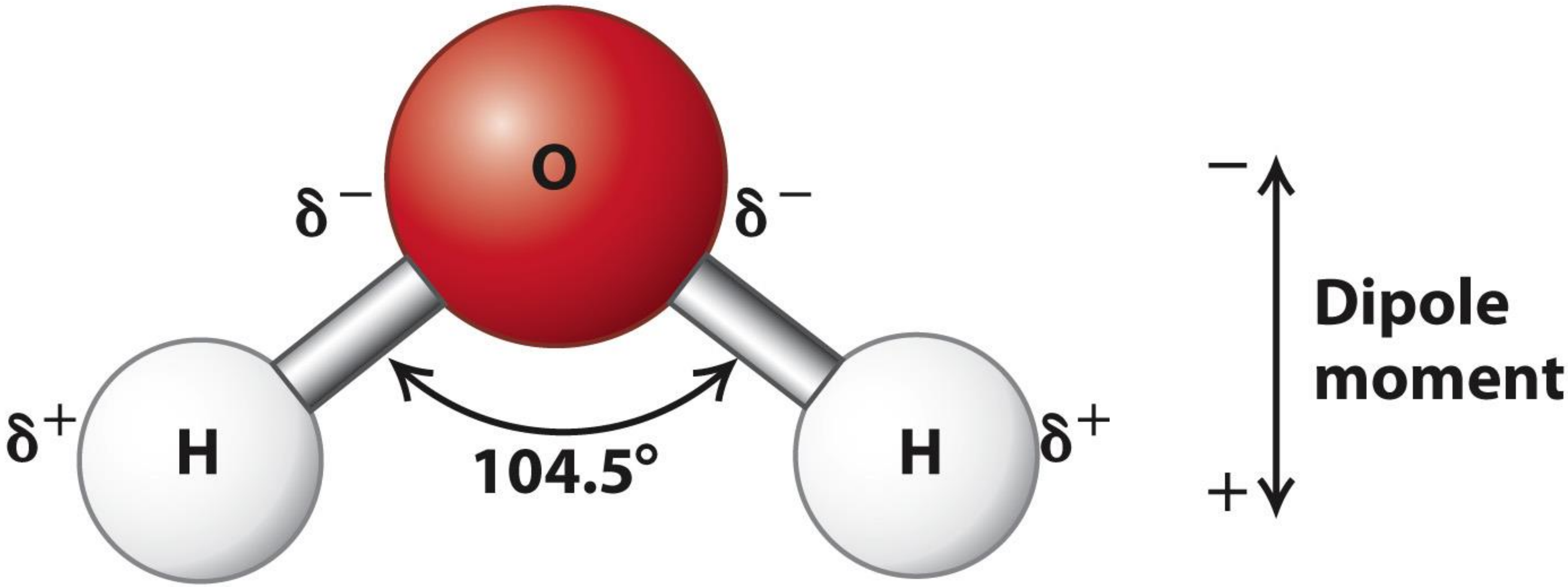


Figure 2-5
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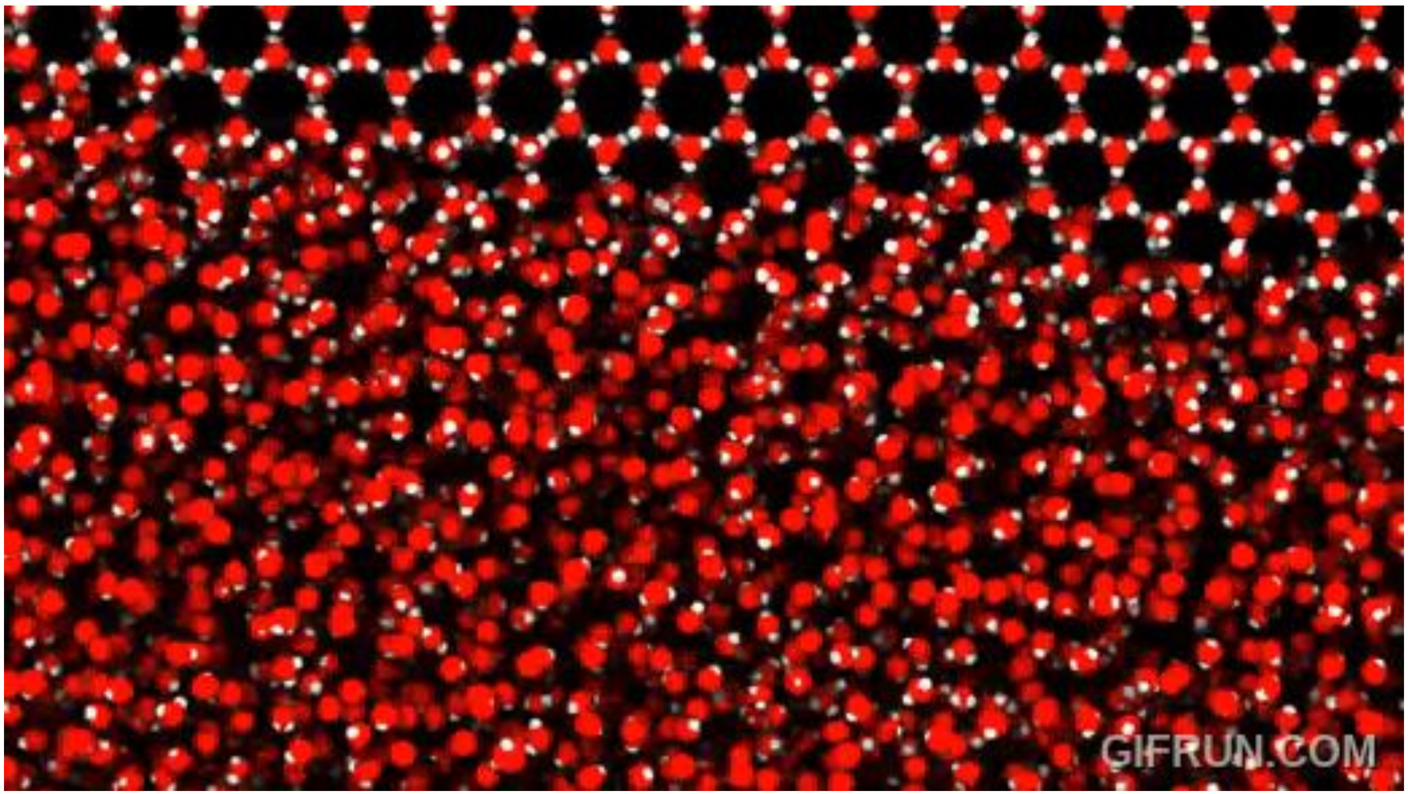
Simulation of ice formation



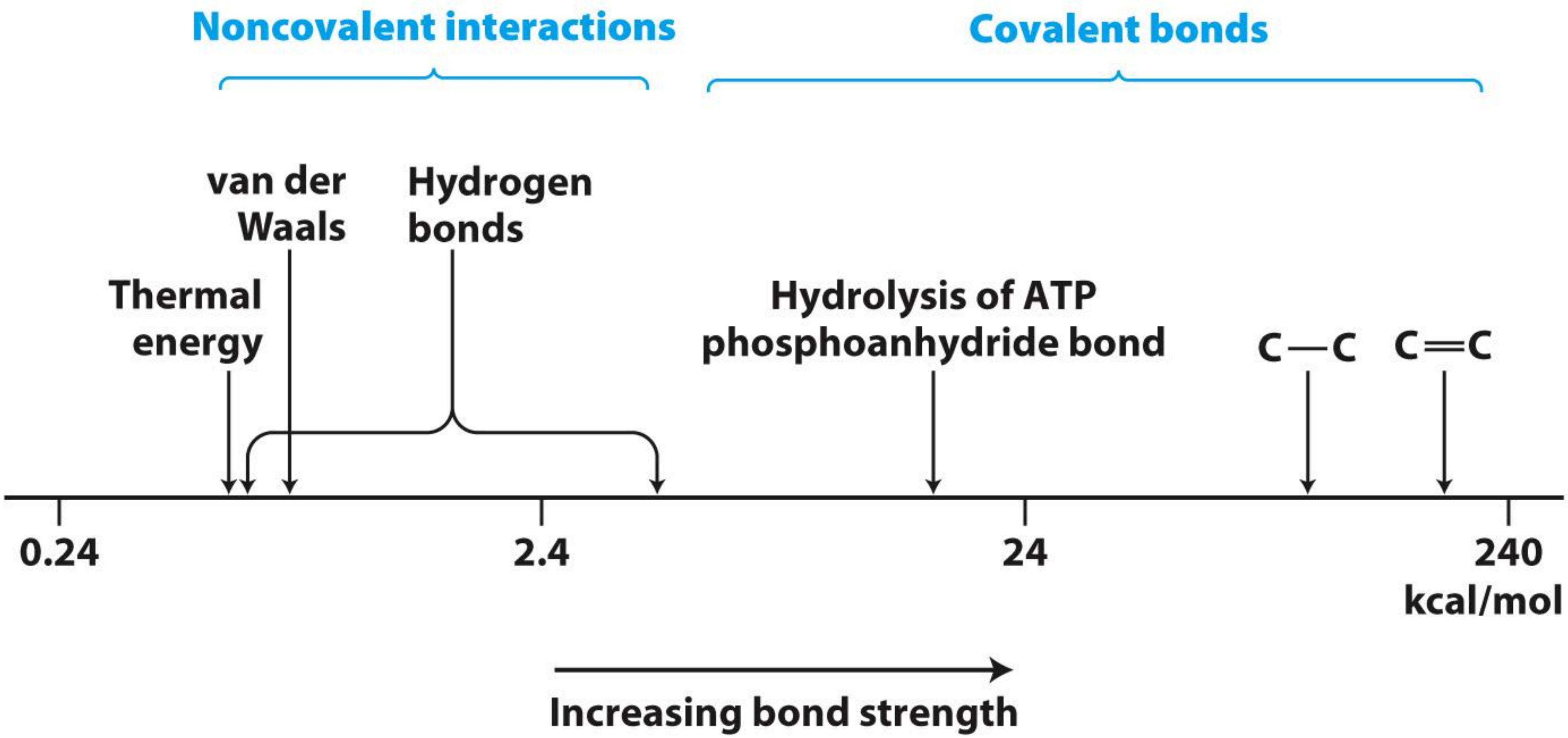


Figure 2-6
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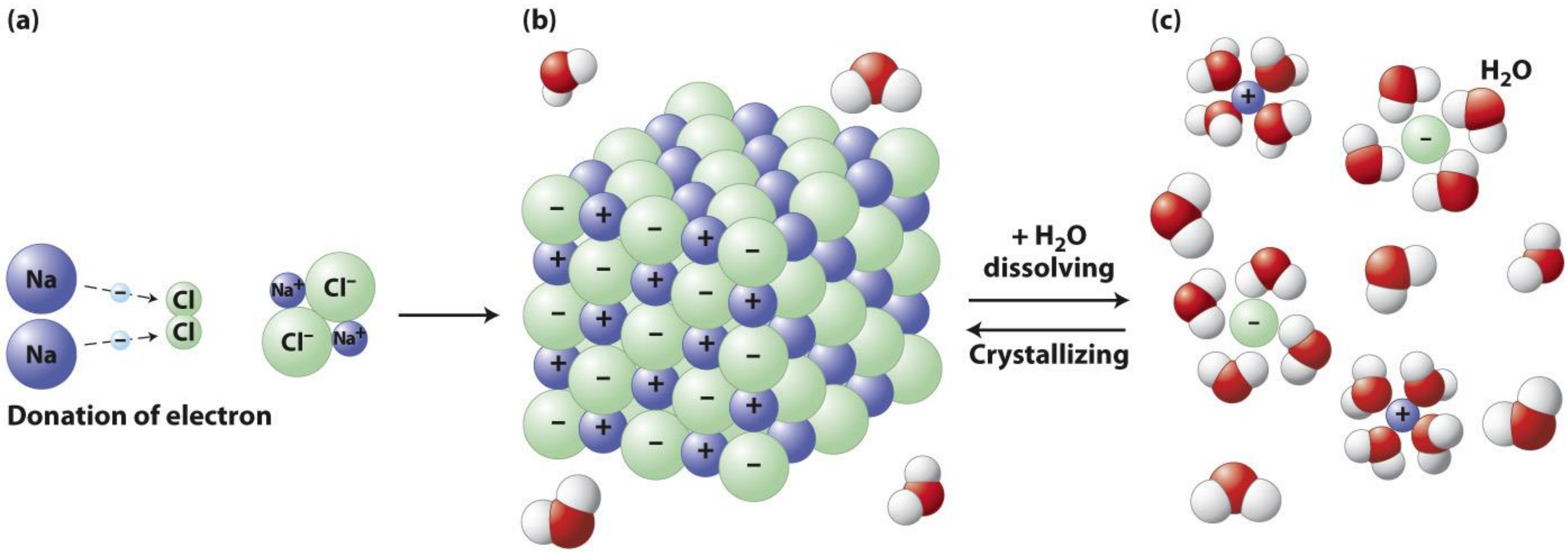

Figure 2-7
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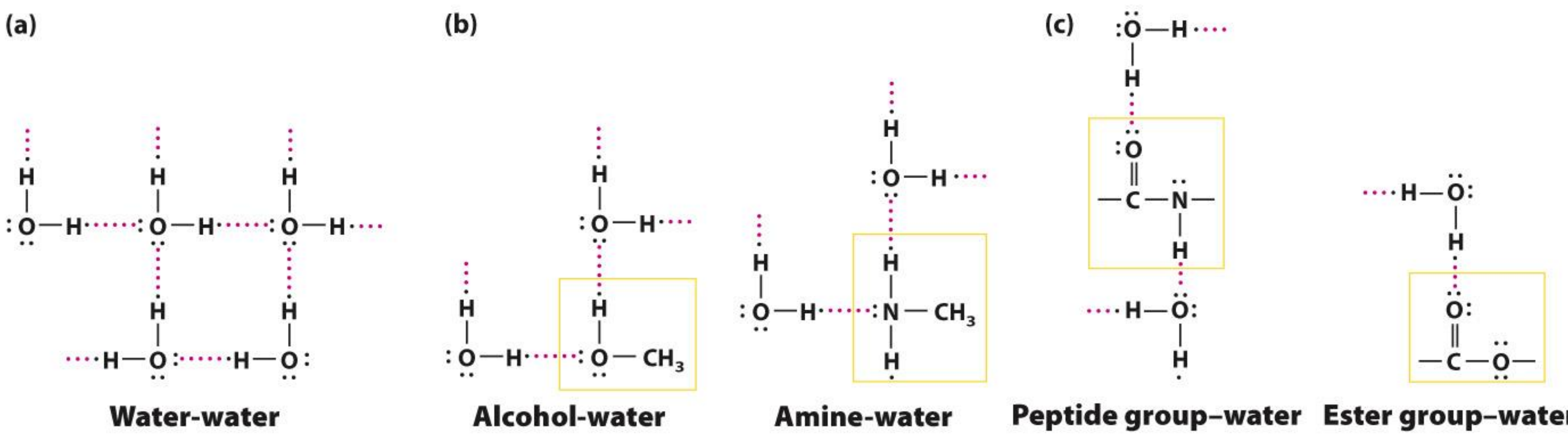

Figure 2-8
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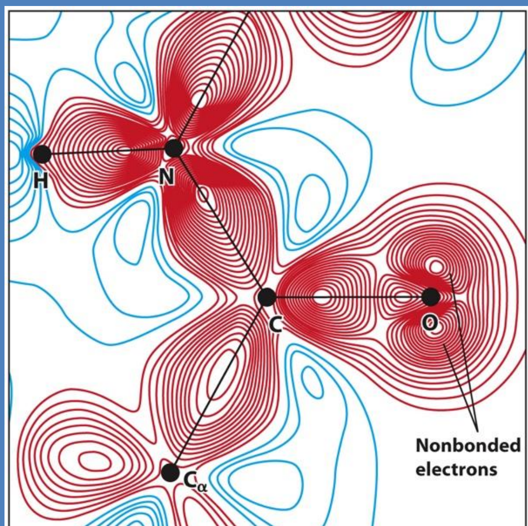

Figure 2-9
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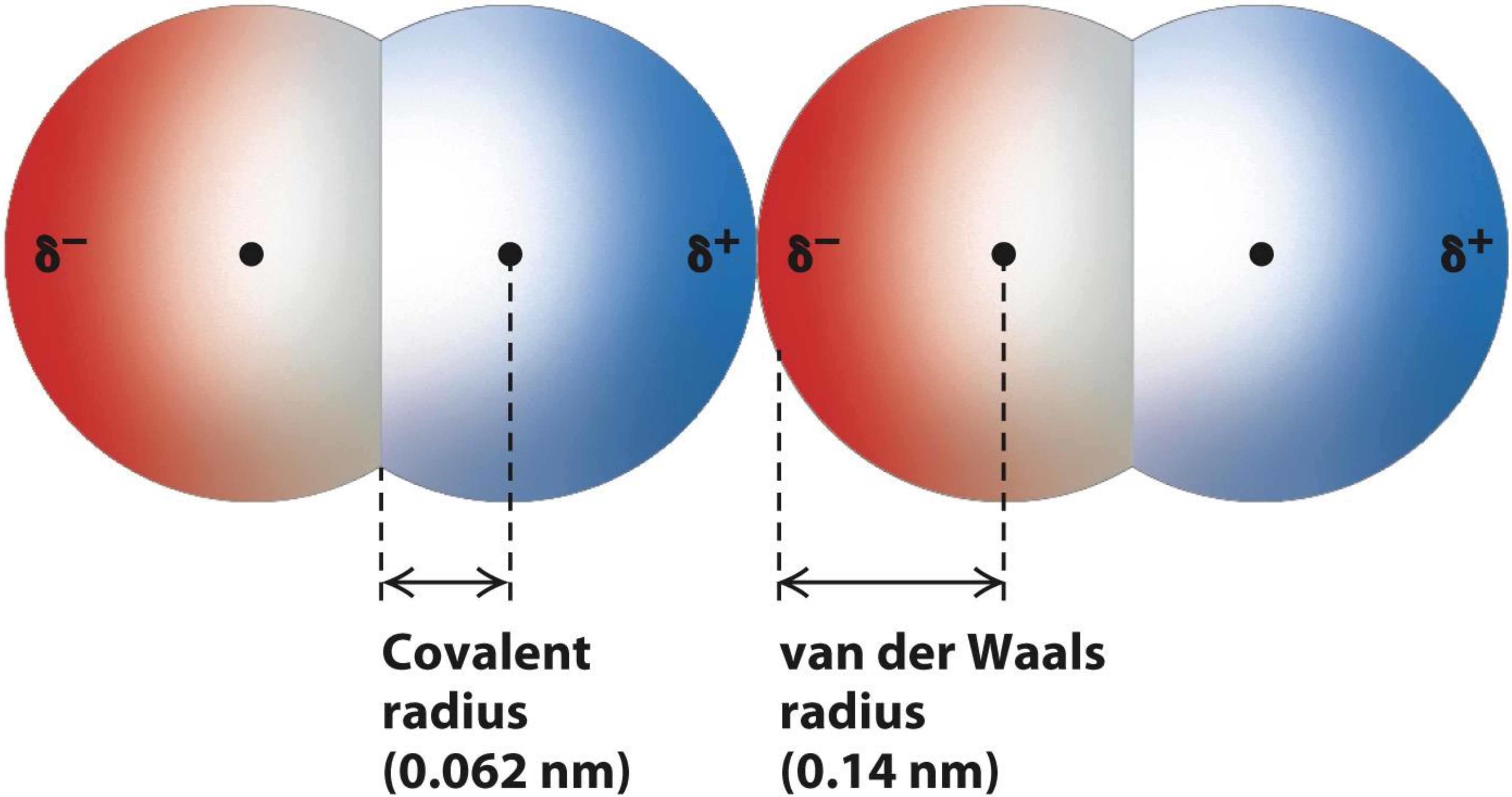

Figure 2-10
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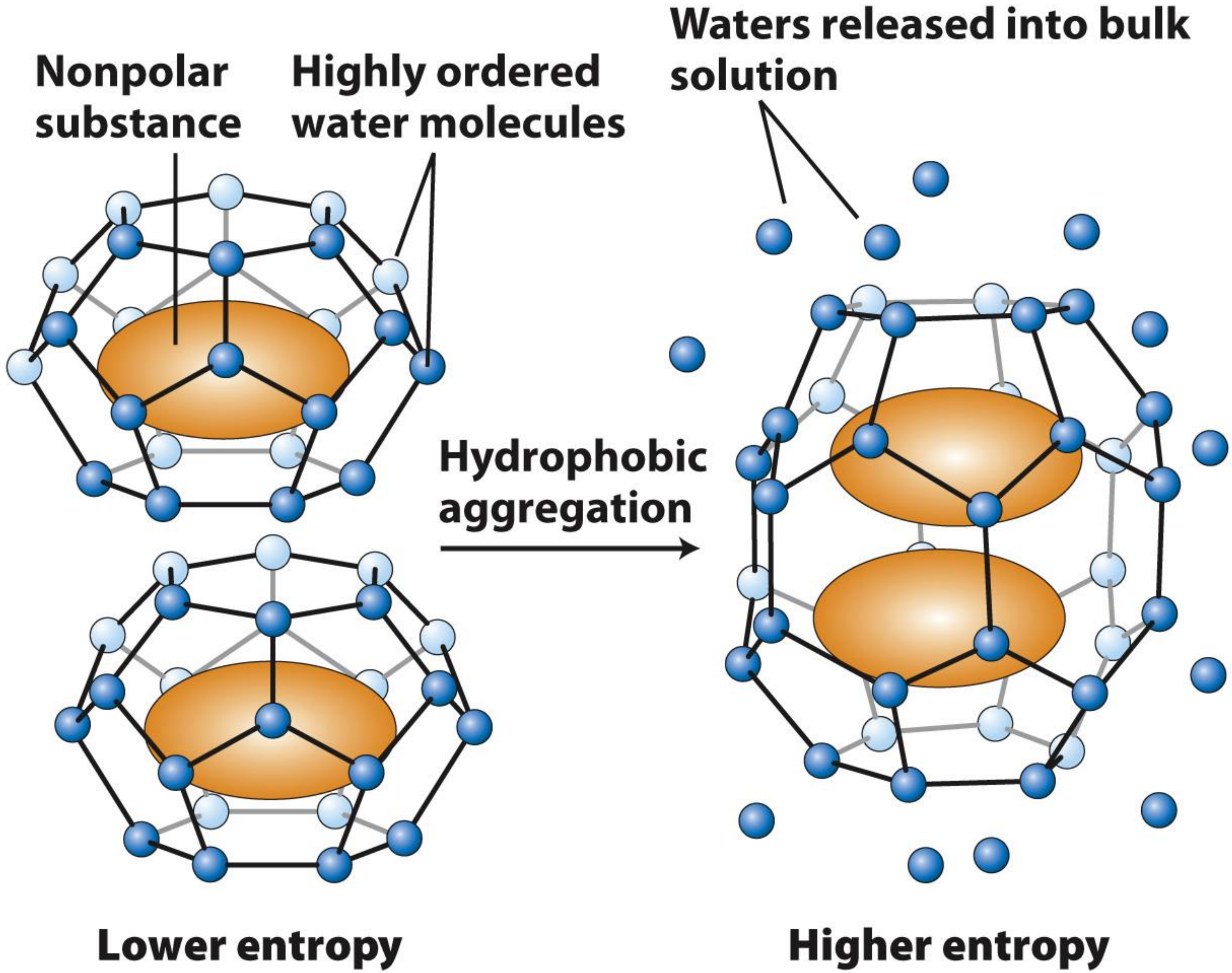

Figure 2-11
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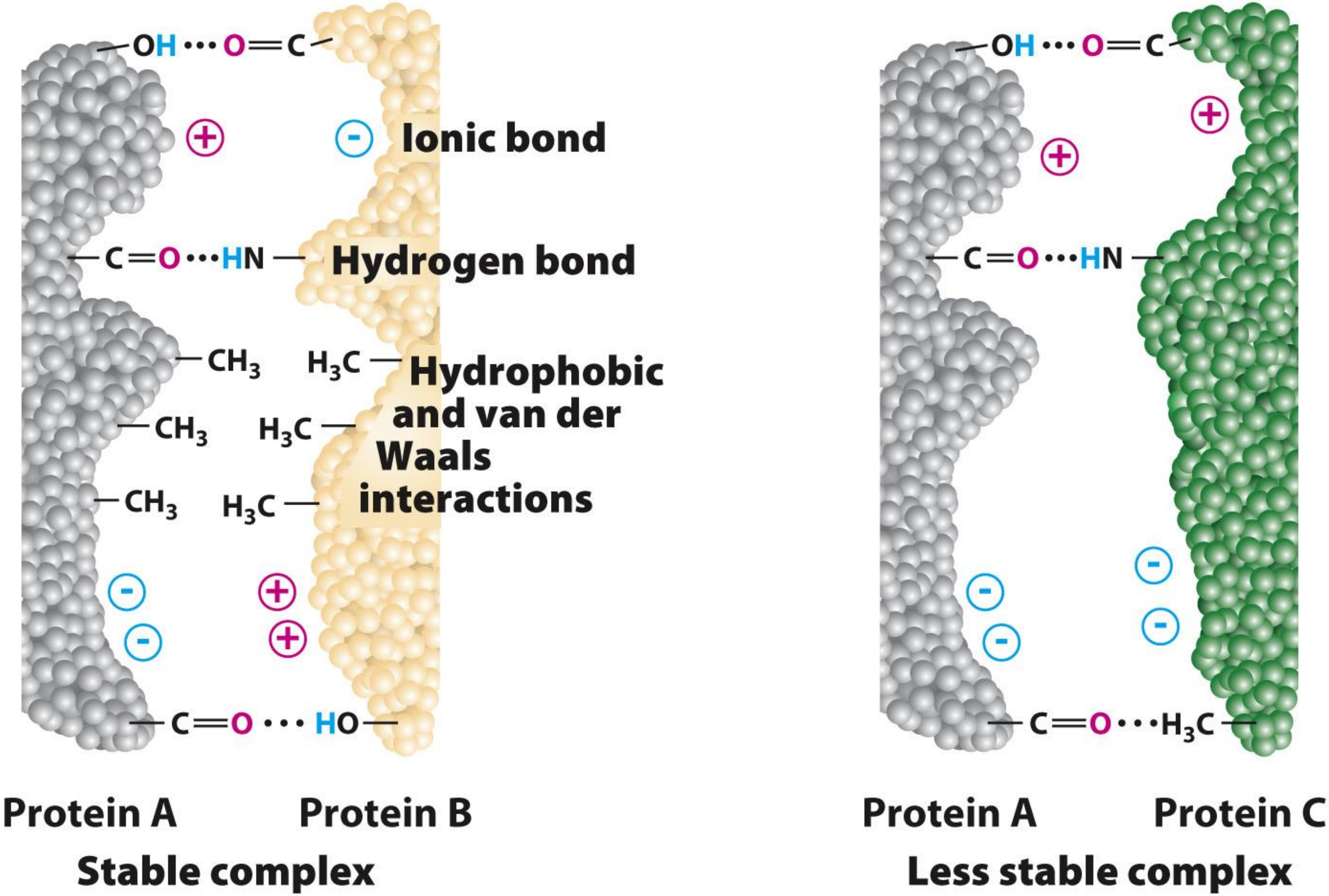

Figure 2-12
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2.1 Covalent Bonds and Noncovalent Interactions

2.2 Chemical Building Blocks of Cells

2.3 Chemical Reactions and Chemical Equilibrium

2.4 Biochemical Energetics

- Macromolecule polymers of monomer subunits: proteins-amino acids; nucleic acids-nucleotides; polysaccharides-monosaccharides
- Proteins: differences in size, shape, charge, hydrophobicity, and reactivity of the 20 common amino acid side chains determine protein chemical and structural properties
- Nucleic acids: purine A and G, and pyrimidine C, T (DNA), and U (RNA) nucleotide bases comprise DNA and RNA
- Polysaccharides: hexoses (glucose and others) linked by two types of bonds
- Membranes: amphipathic phospholipids with saturated or unsaturated tails associate noncovalently to form bilayer membrane structure

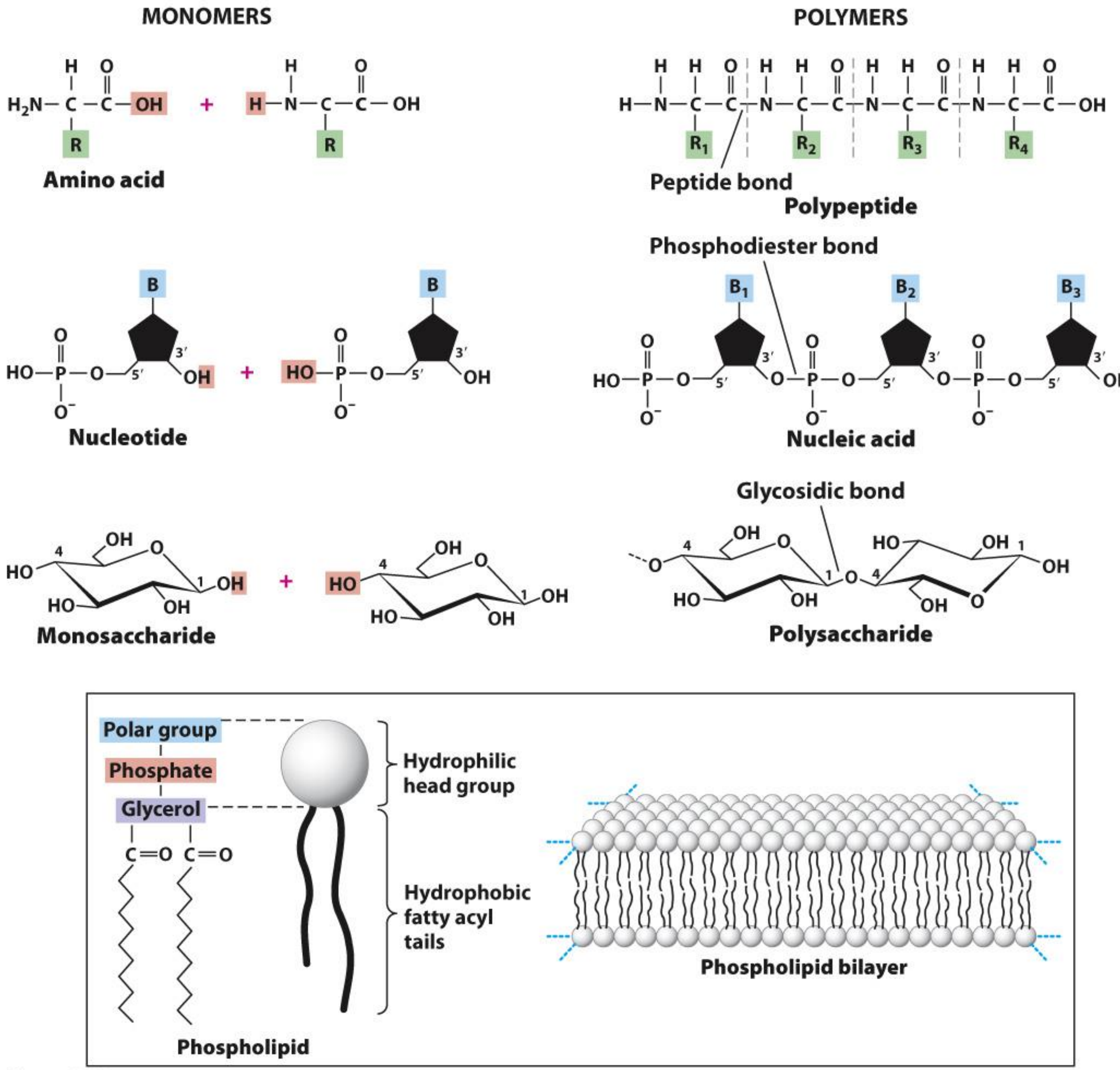

Figure 2-13

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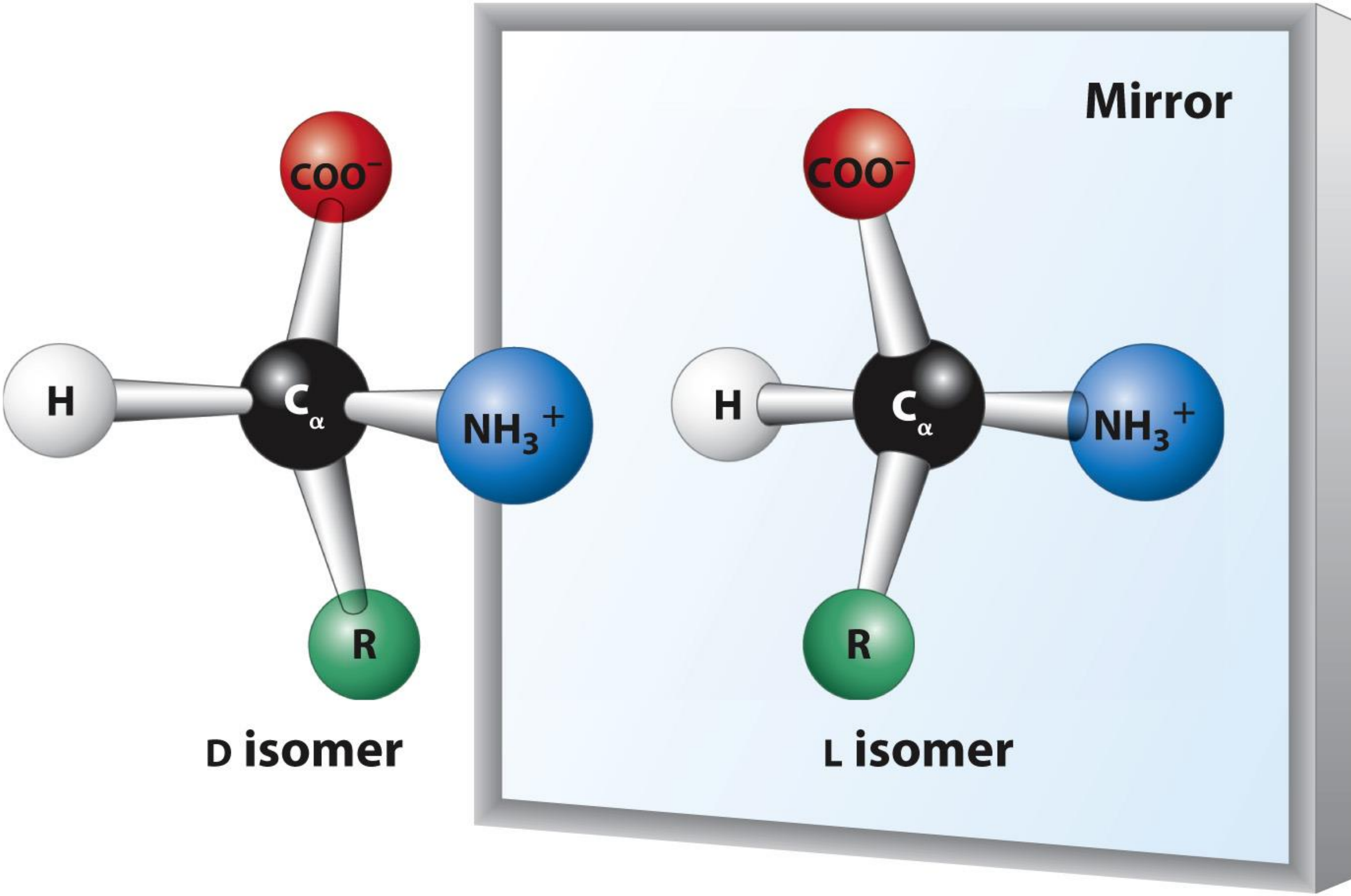

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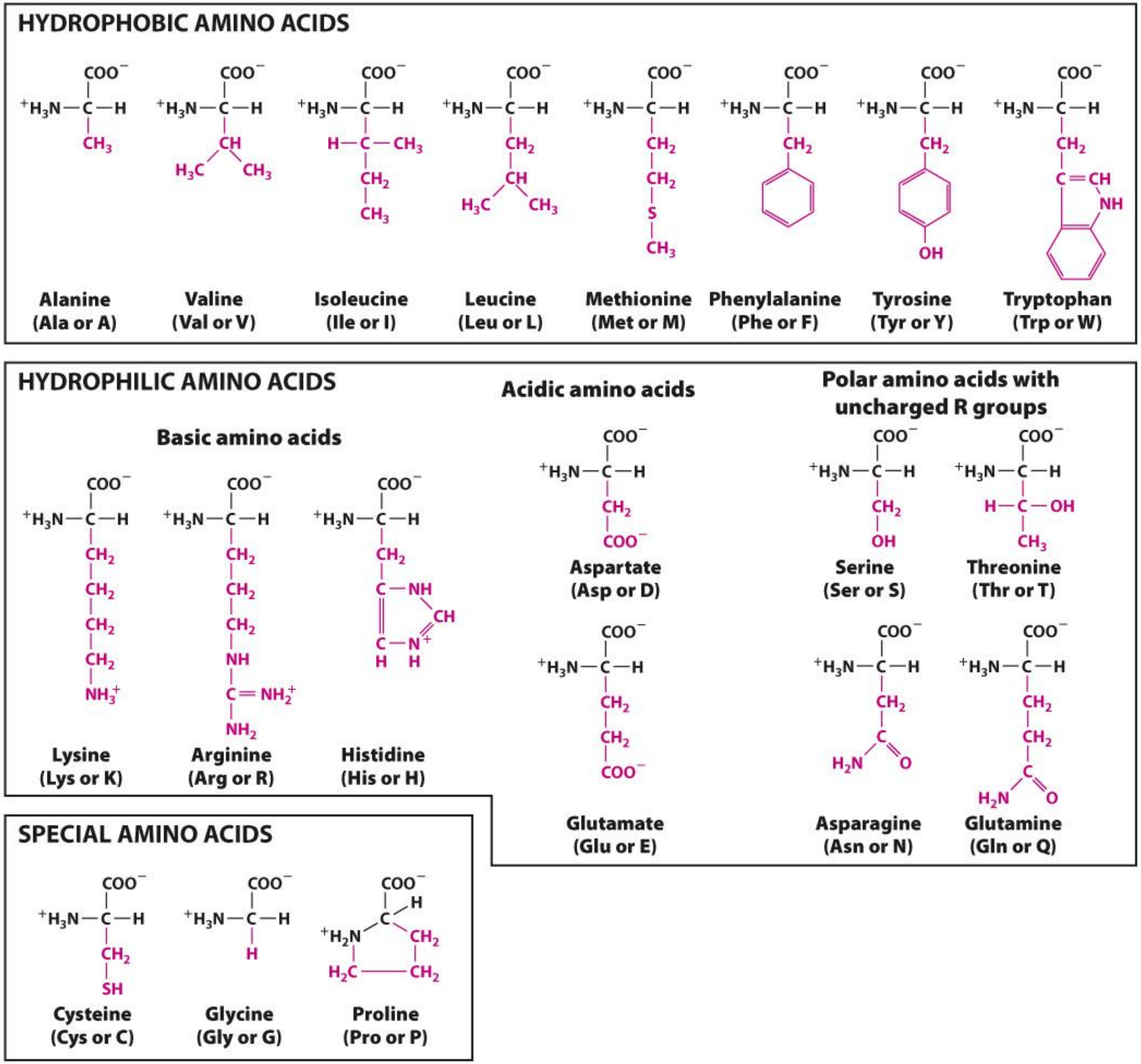

Figure 2-14

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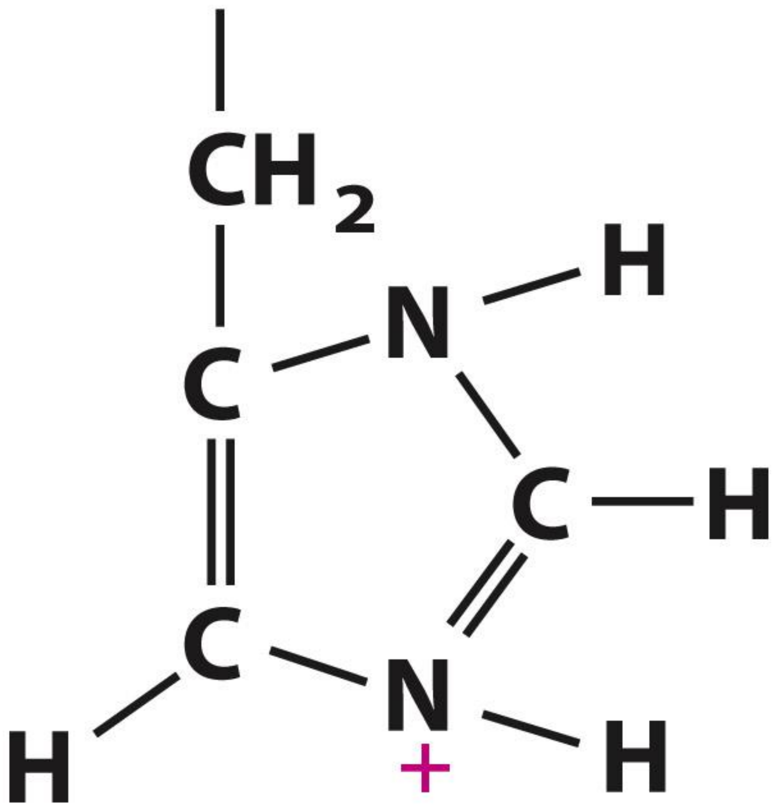
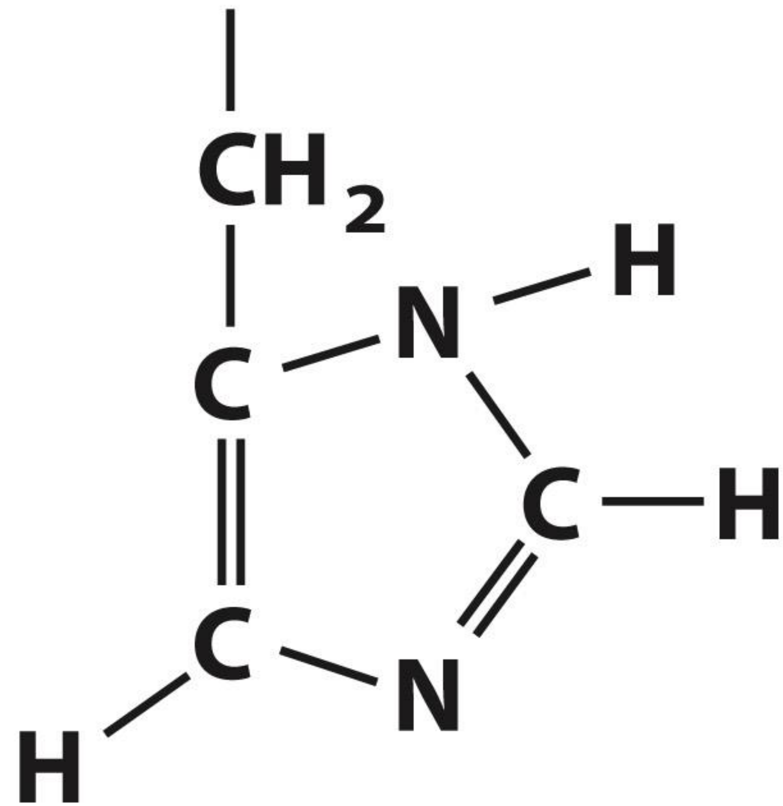
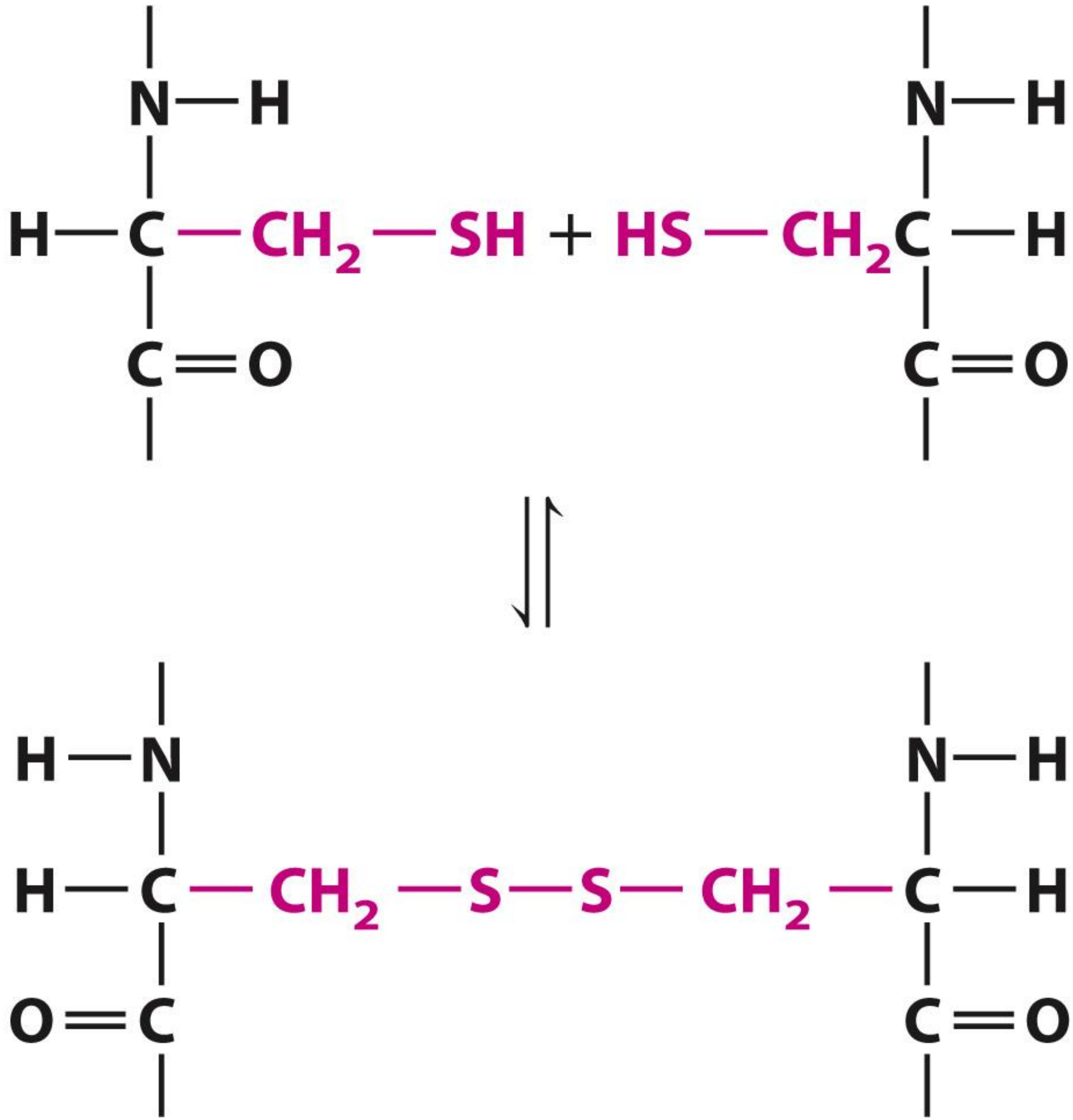


pH 5.8



pH 7.8



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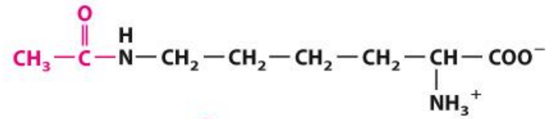
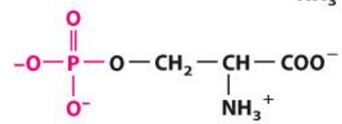
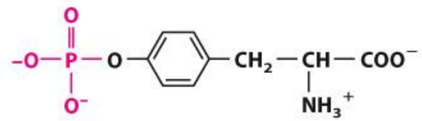
Acetyl lysine



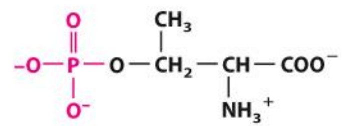
Phosphoserine



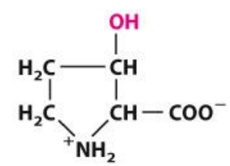
Phosphotyrosine



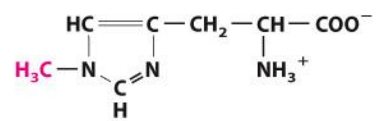
Phosphothreonine



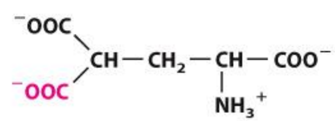
3–Hydroxyproline



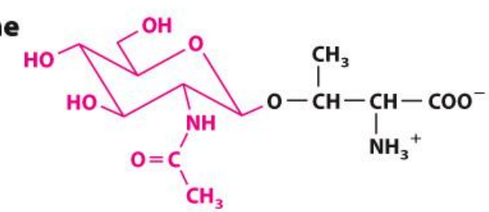
3–Methylhistidine



γ–Carboxyglutamate



O–GlcNAc–threonine



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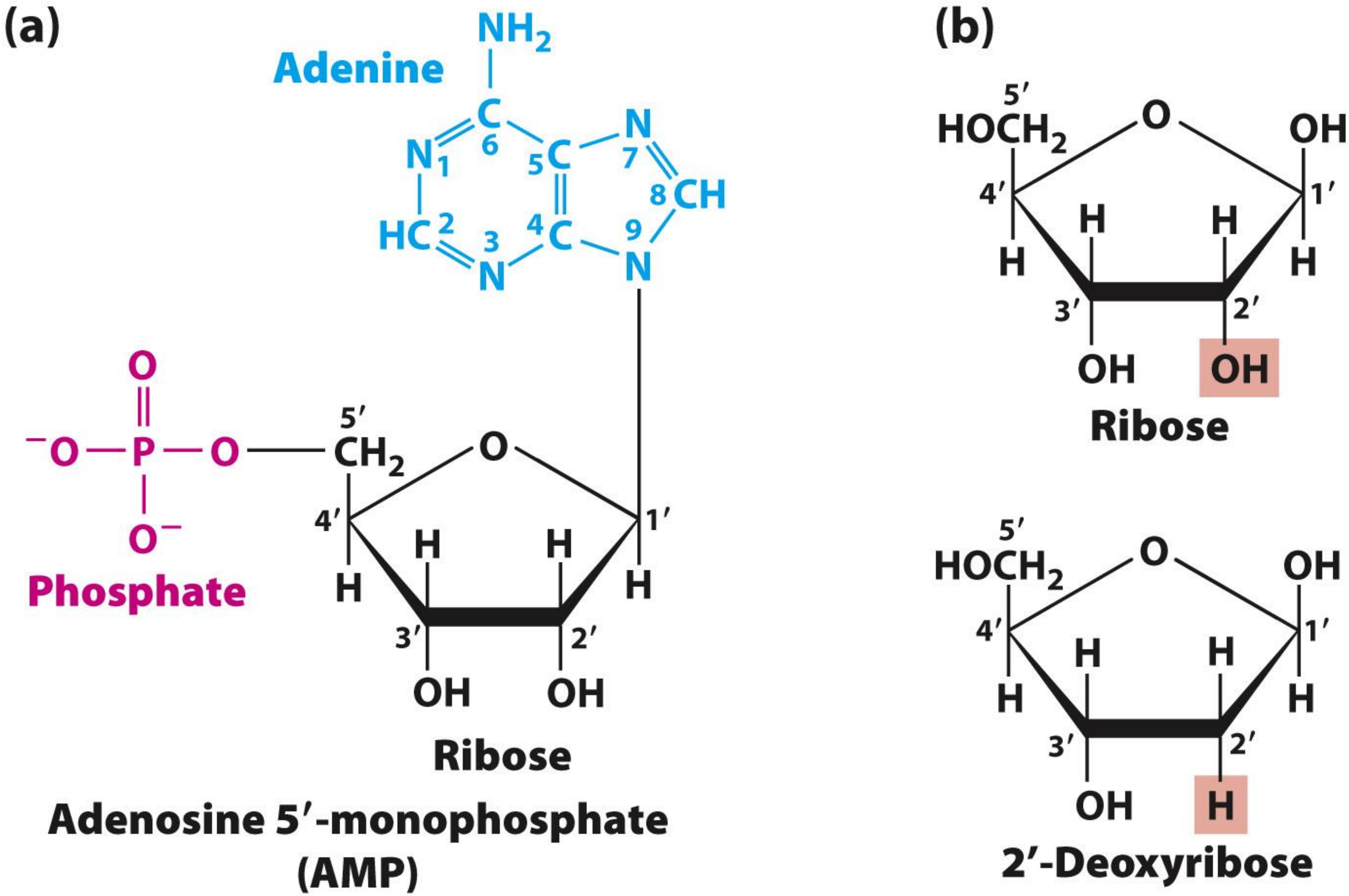

Figure 2-16
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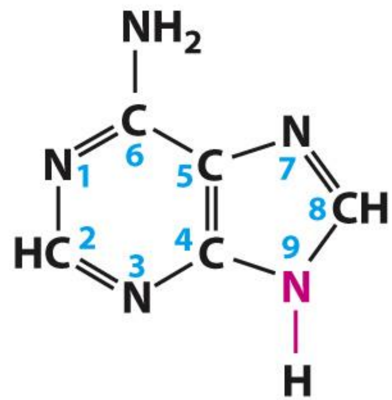
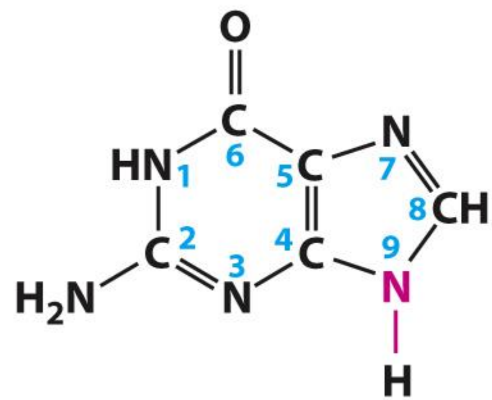
PURINES

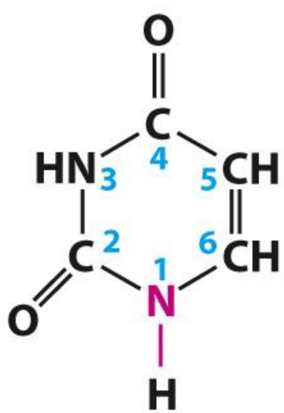


Adenine (A)

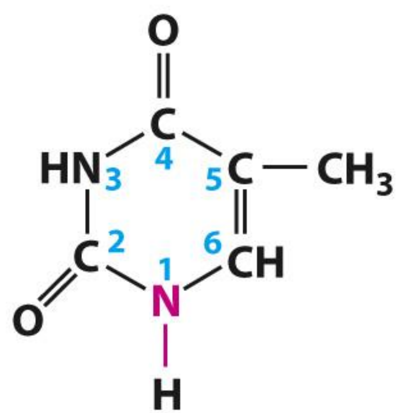


Guanine (G)

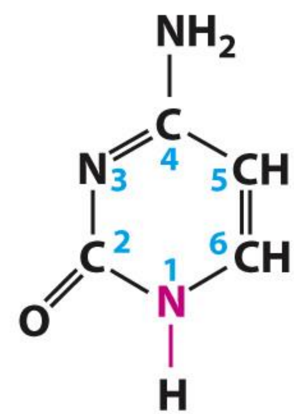
PYRIMIDINES



Uracil (U)



Thymine (T)



Cytosine (C)

Figure 2-17
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TABLE 2-3 Terminology of Nucleosides and Nucleotides

		Purines		Pyrimidines	
Bases		Adenine (A)	Guanine (G)	Cytosine (C)	Uracil (U) Thymine (T)
Nucleosides	in RNA	Adenosine	Guanosine	Cytidine	Uridine
	in DNA	Deoxyadenosine	Deoxyguanosine	Deoxycytidine	Deoxythymidine
Nucleotides	in RNA	Adenylate	Guanylate	Cytidylate	Uridylate
	in DNA	Deoxyadenylate	Deoxyguanylate	Deoxycytidylate	Deoxythymidylate
Nucleoside monophosphates		AMP	GMP	CMP	UMP
Nucleoside diphosphates		ADP	GDP	CDP	UDP
Nucleoside triphosphates		ATP	GTP	CTP	UTP
Deoxynucleoside mono-, di-, and triphosphates		dAMP, etc.	dGMP, etc.	dCMP, etc.	dTMP, etc.

Table 2-3
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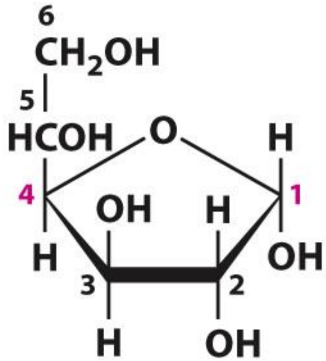
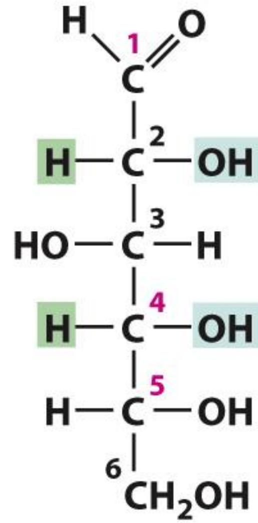
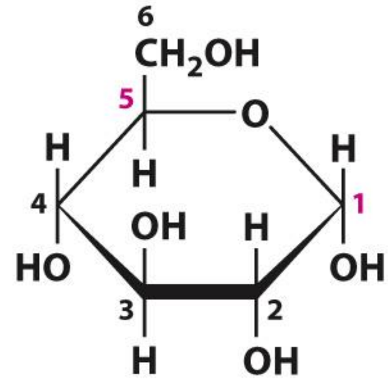
(a)



D-Glucofuranose (rare)

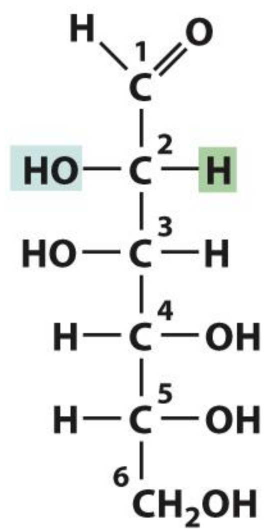


D-Glucose

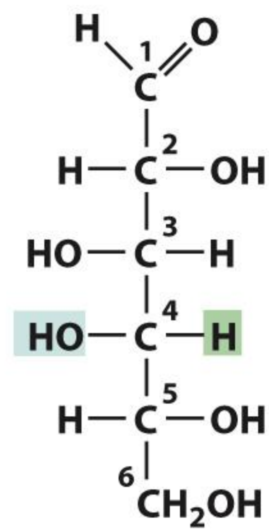


D-Glucopyranose (common)

(b)



D-Mannose



D-Galactose

Figure 2-18
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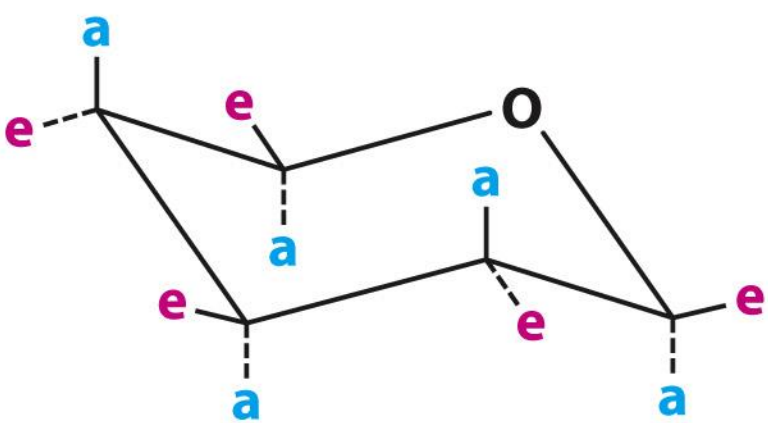
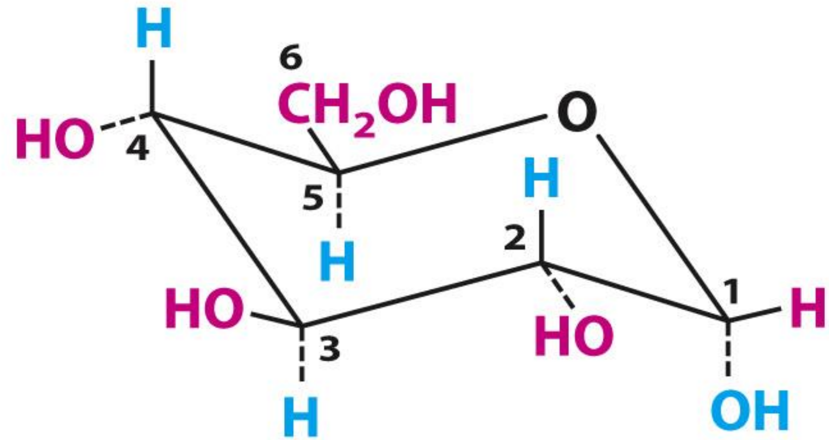


Pyranoses



α-D-Glucopyranose

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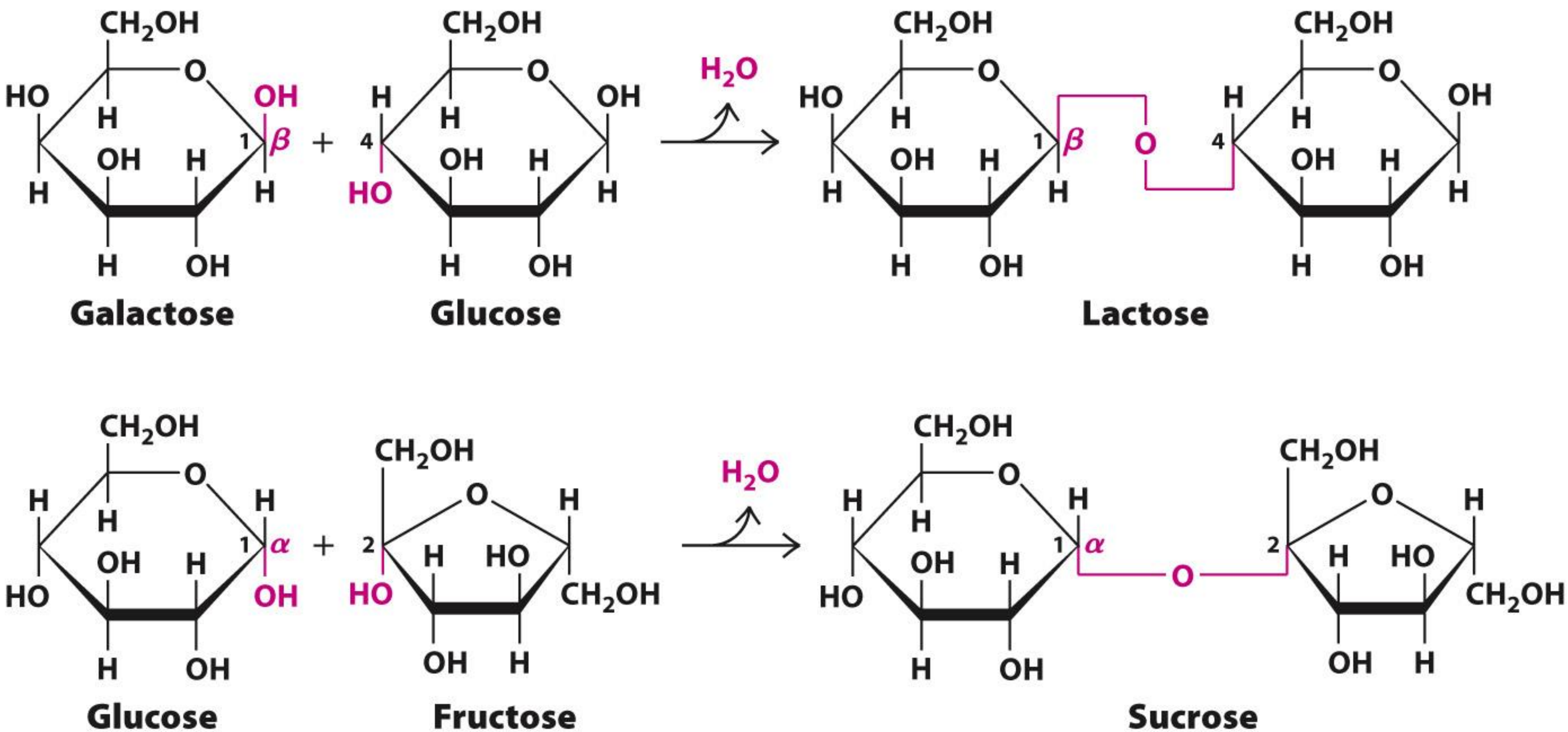

Figure 2-19

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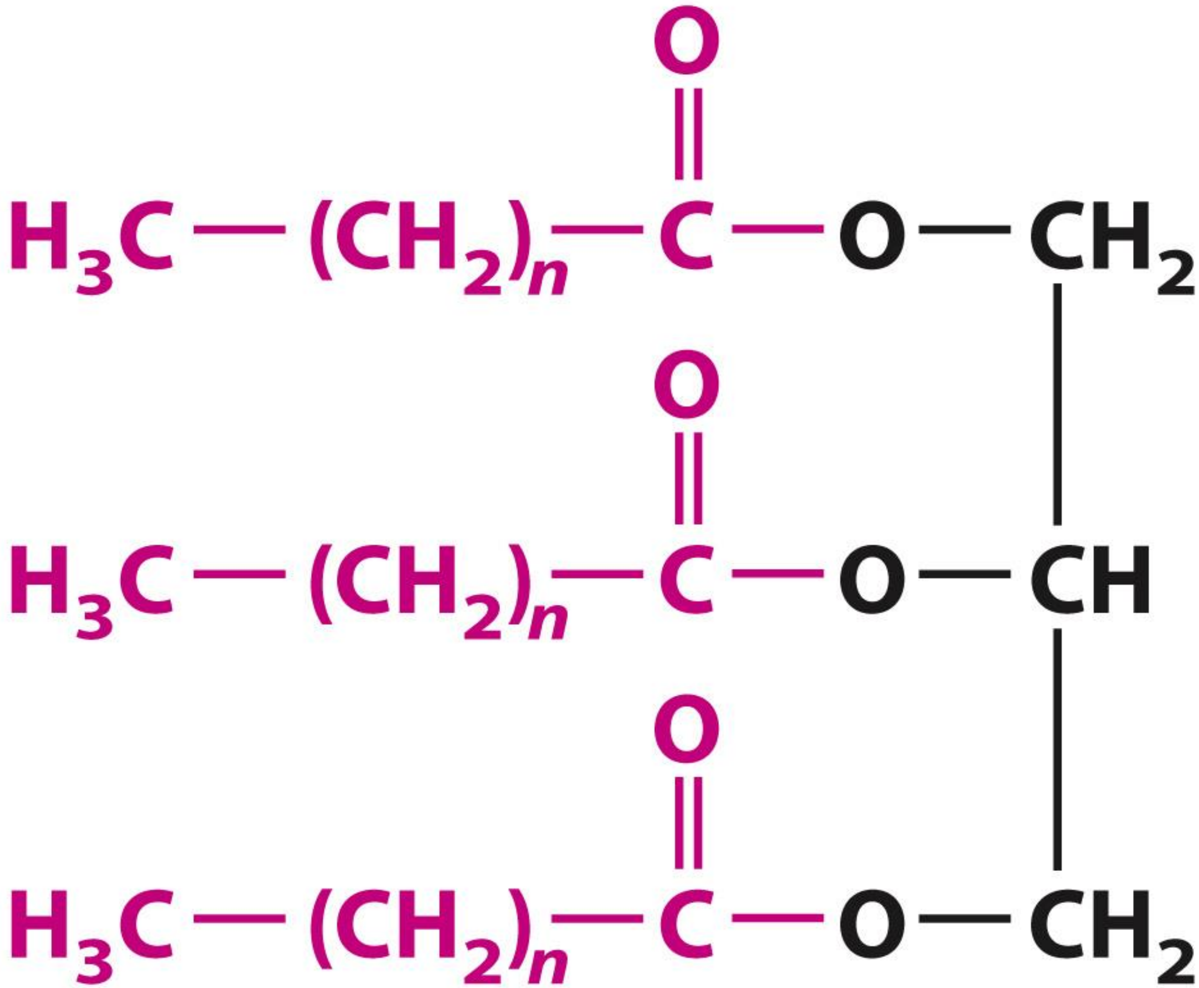

Triacylglycerol

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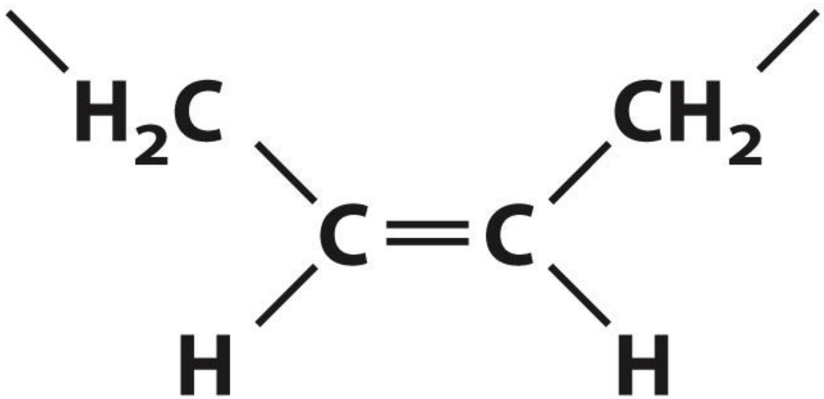
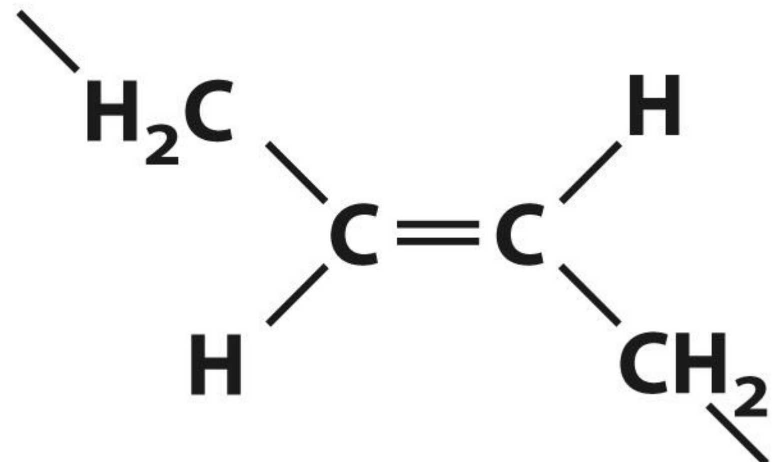


Cis



Trans

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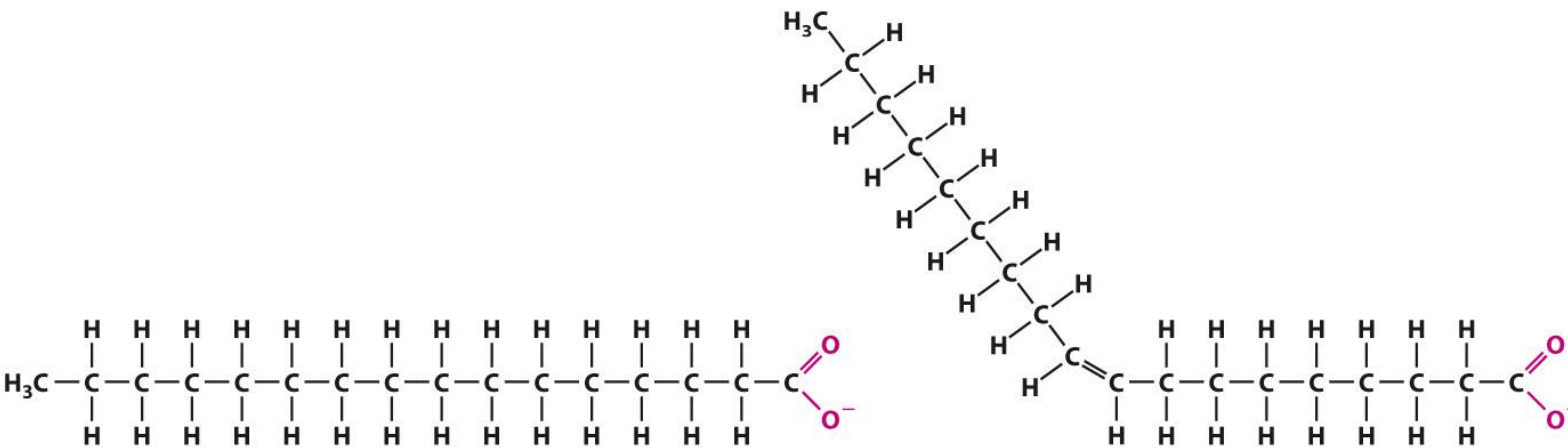

Palmitate
(ionized form of palmitic acid)

Oleate
(ionized form of oleic acid)

Figure 2-21
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TABLE 2-4 Fatty Acids That Predominate in Phospholipids

Common Name of Acid (ionized form in parentheses)	Abbreviation	Chemical Formula
Saturated Fatty Acids		
Myristic (myristate)	C14:0	$CH_3(CH_2)_{12}COOH$
Palmitic (palmitate)	C16:0	$CH_3(CH_2)_{14}COOH$
Stearic (stearate)	C18:0	$CH_3(CH_2)_{16}COOH$
Unsaturated Fatty Acids		
Oleic (oleate)	C18:1	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
Linoleic (linoleate)	C18:2	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$
Arachidonic (arachidonate)	C20:4	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

Table 2-4
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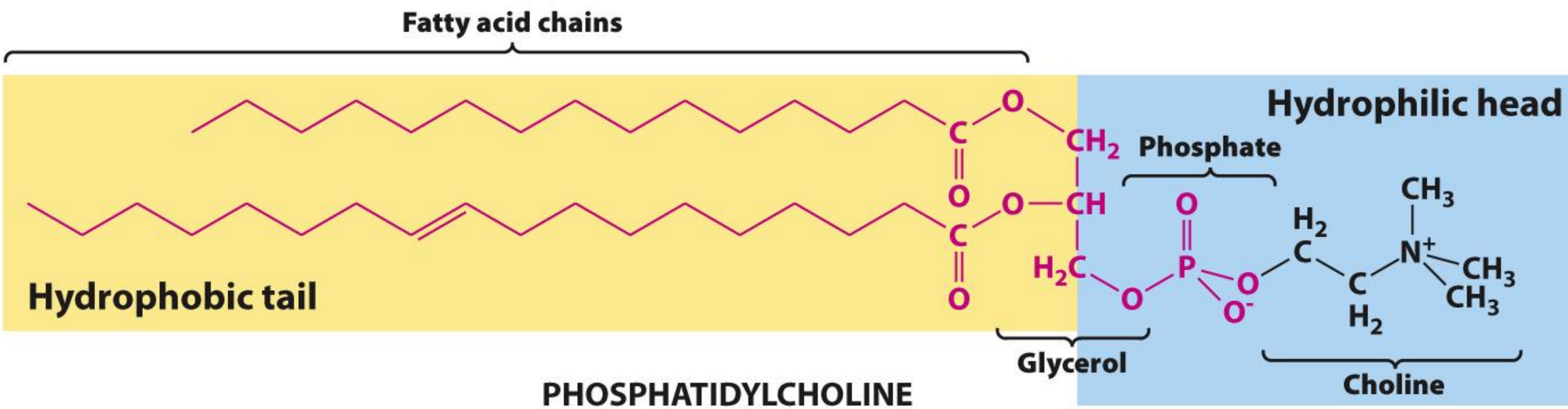

PHOSPHATIDYLCHOLINE

Figure 2-20
Molecular Cell Biology, Eighth Edition

Clicker Question 2-1

Which of the following represent covalent interactions?

A. peptide bond formation during the translation of epidermal growth factor (EGF)
B. disulfide formation during folding of the newly translated EGF
C. ionic bond formation during folding of the newly translated EGF
D. hydrogen bond formation during folding of the newly translated EGF
E. Both A and B

Clicker Question 2-1

Which of the following represent covalent interactions?

A. peptide bond formation during the translation of epidermal growth factor (EGF)
B. disulfide formation during folding of the newly translated EGF
C. ionic bond formation during folding of the newly translated EGF
D. hydrogen bond formation during folding of the newly translated EGF
E. Both A and B

Clicker Question 2-2

Which of the following accurately describe the molecule shown below?

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$$

A. hydrophilic

B. hydrophobic

C. polyunsaturated

D. saturated

E. None of the above

Clicker Question 2-2

Which of the following accurately describes the molecule shown below?

$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$

A. hydrophilic

B. hydrophobic

C. polyunsaturated

D. saturated

E. None of the above

Because of the single double carbon bond, oleate is a monounsaturated fatty acid.

Clicker Question 2-3

Which of the following cell monomers do NOT form structures using covalent bonds?

A) Amino acids

B) Nucleotides

C) Phospholipids

D) Monosaccharides

E) Actually, these all polymerize using covalent bonds.

Clicker Question 2-3

Which of the following cell monomers do NOT form structures using covalent bonds?

A) Amino acids Amino acids are linked by peptide bonds.

B) Nucleotides

C) Phospholipids

D) Monosaccharides

E) Actually, these all polymerize using covalent bonds.

2.1 Covalent Bonds and Noncovalent Interactions

2.2 Chemical Building Blocks of Cells

2.3 Chemical Reactions and Chemical Equilibrium

2.4 Biochemical Energetics

- Chemical reactions: K_{eq}=product/reactant ratio when forward and reverse rates are equal
- Cell linked reactions are at steady state not equilibrium
- Dissociation constant(K_d) is measure of noncovalent interactions
- pH (-log[H^+]): cytoplasm (pH 7.2-7.4) but lower in some organelles (lysosome, pH 4.5)
- Acids release protons (H^+); base bind protons
- Biological system uses weak acid/base buffers to maintain pH in narrow ranges.

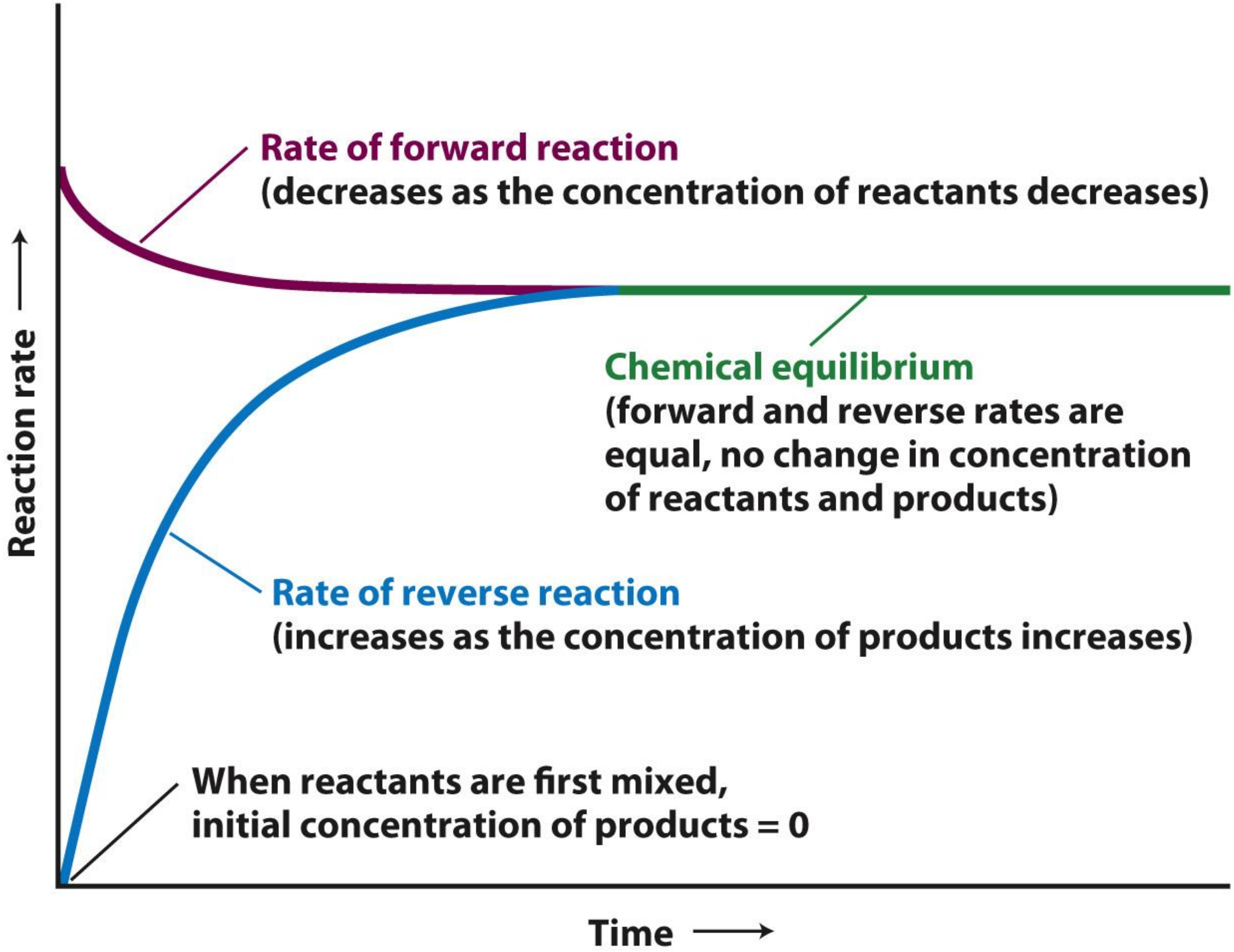

Figure 2-22
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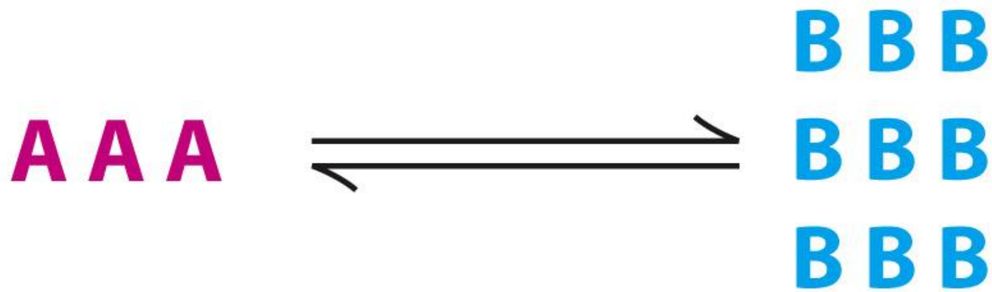
(a) Test tube equilibrium concentrations



(b) Intracellular steady-state concentrations

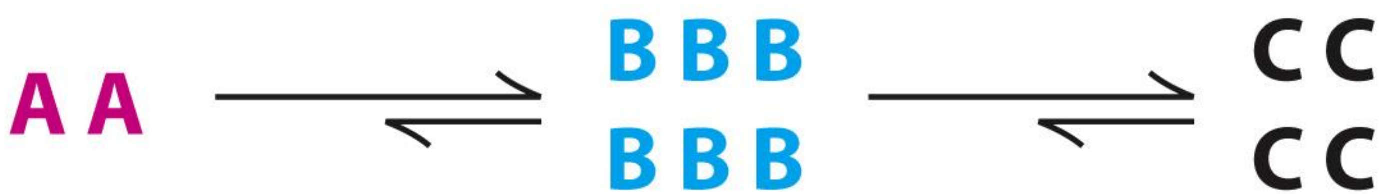


Figure 2-23
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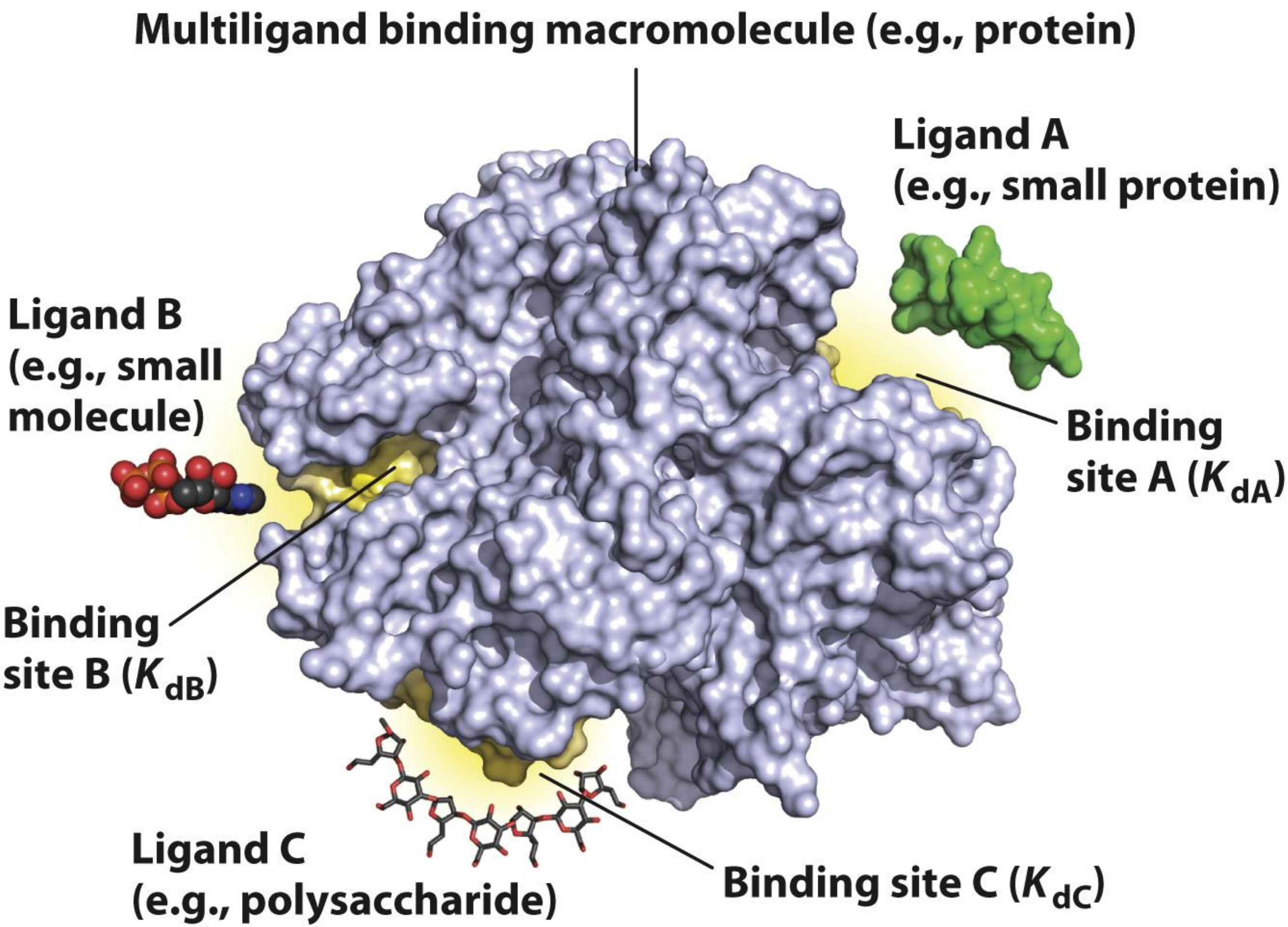

Figure 2-24
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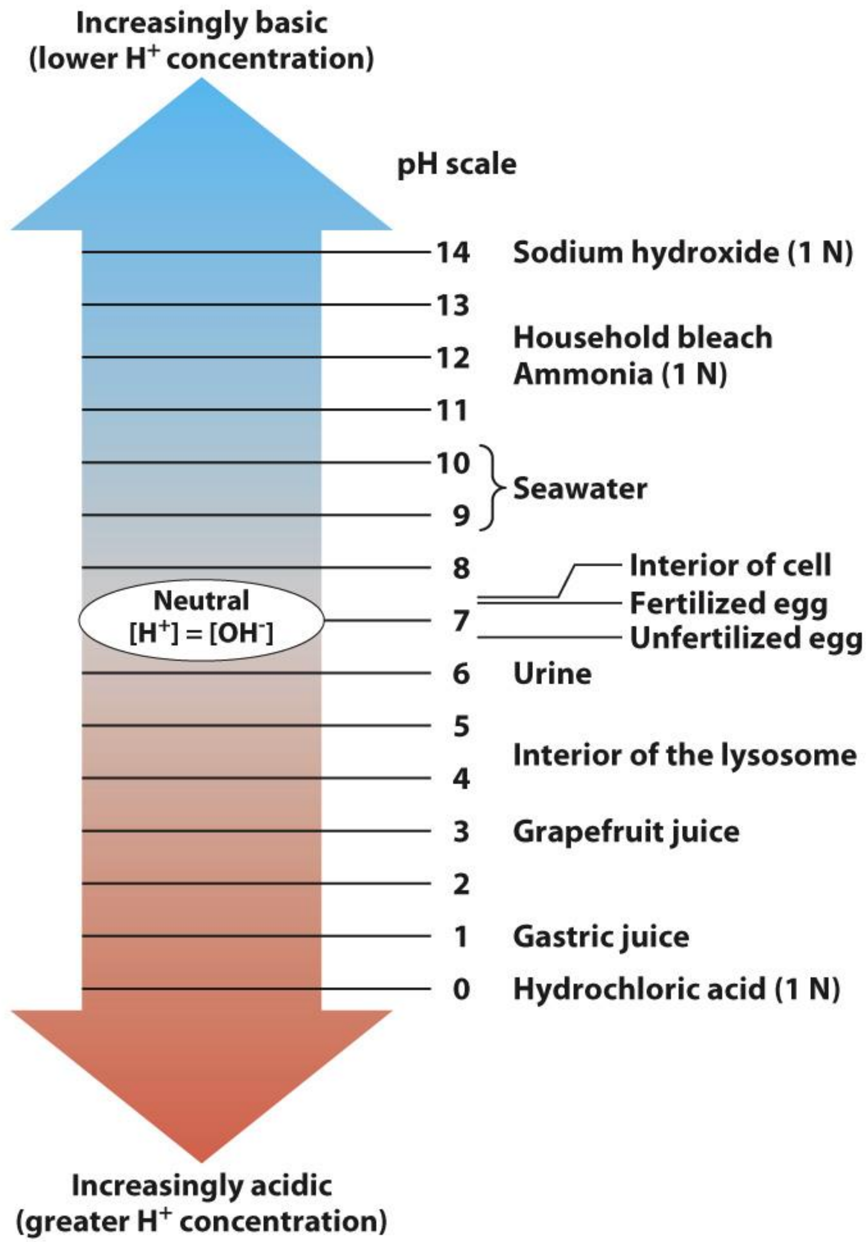

Figure 2-25
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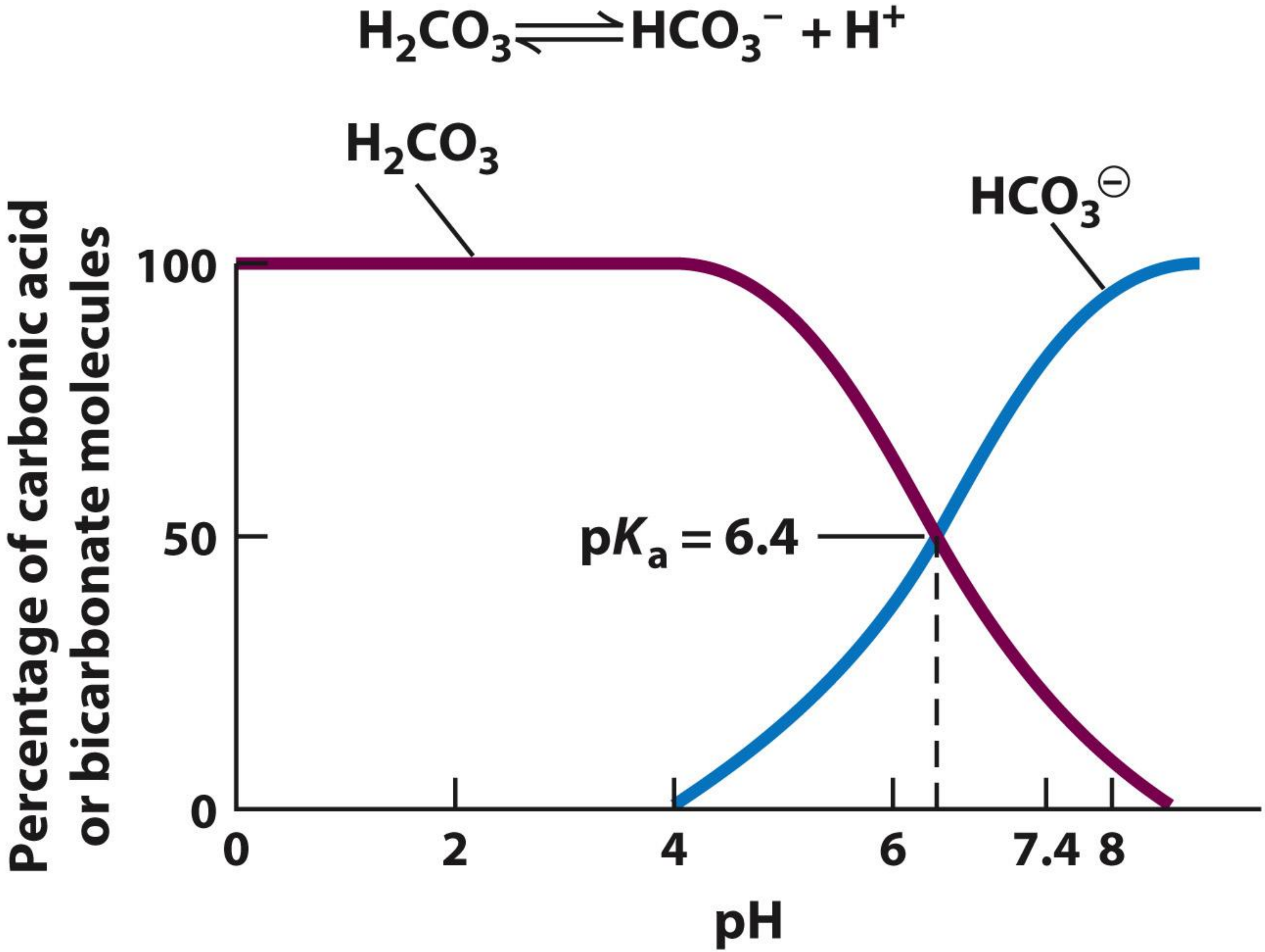

Figure 2-26
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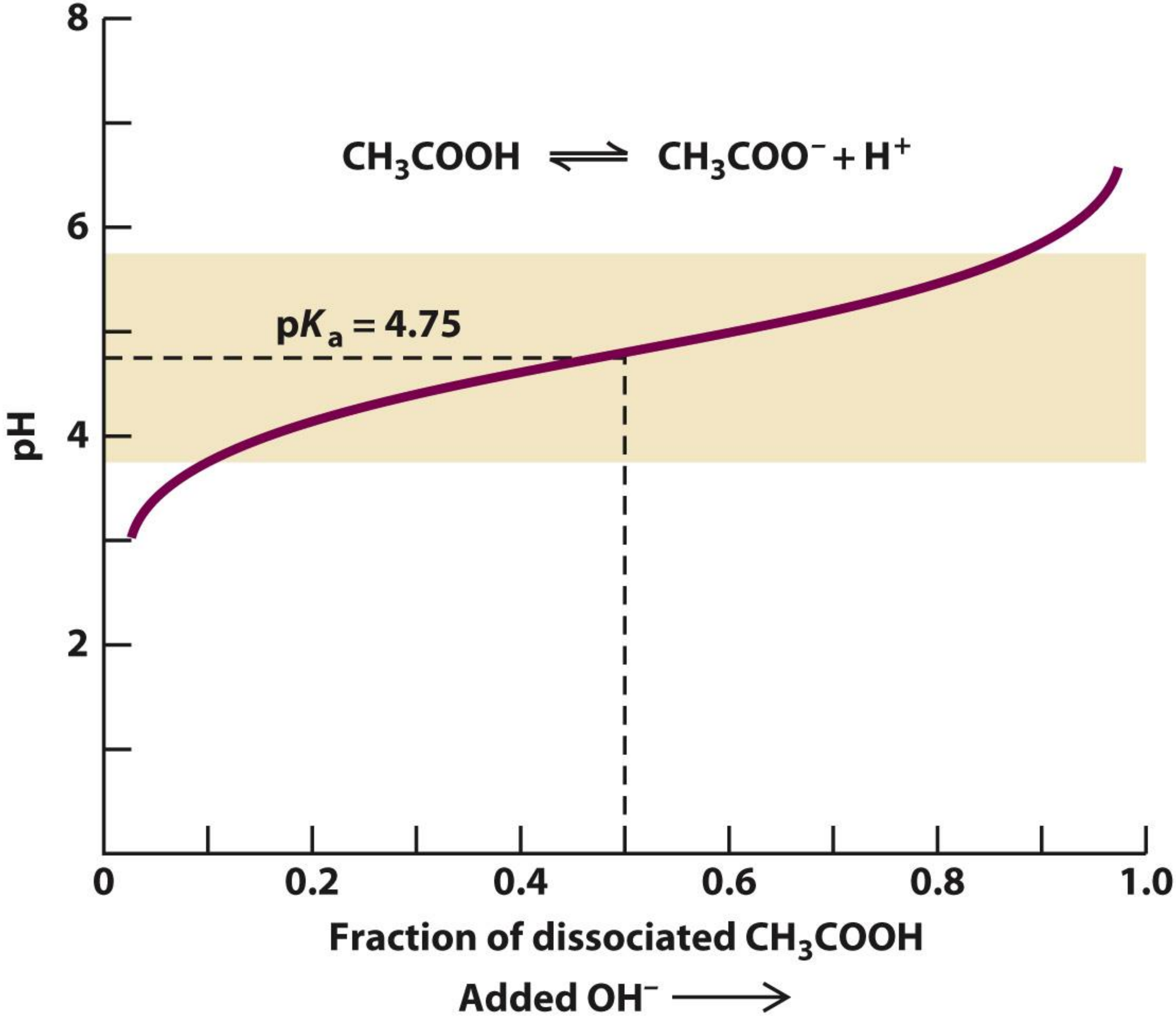

Figure 2-27
Molecular Cell Biology, Eighth Edition

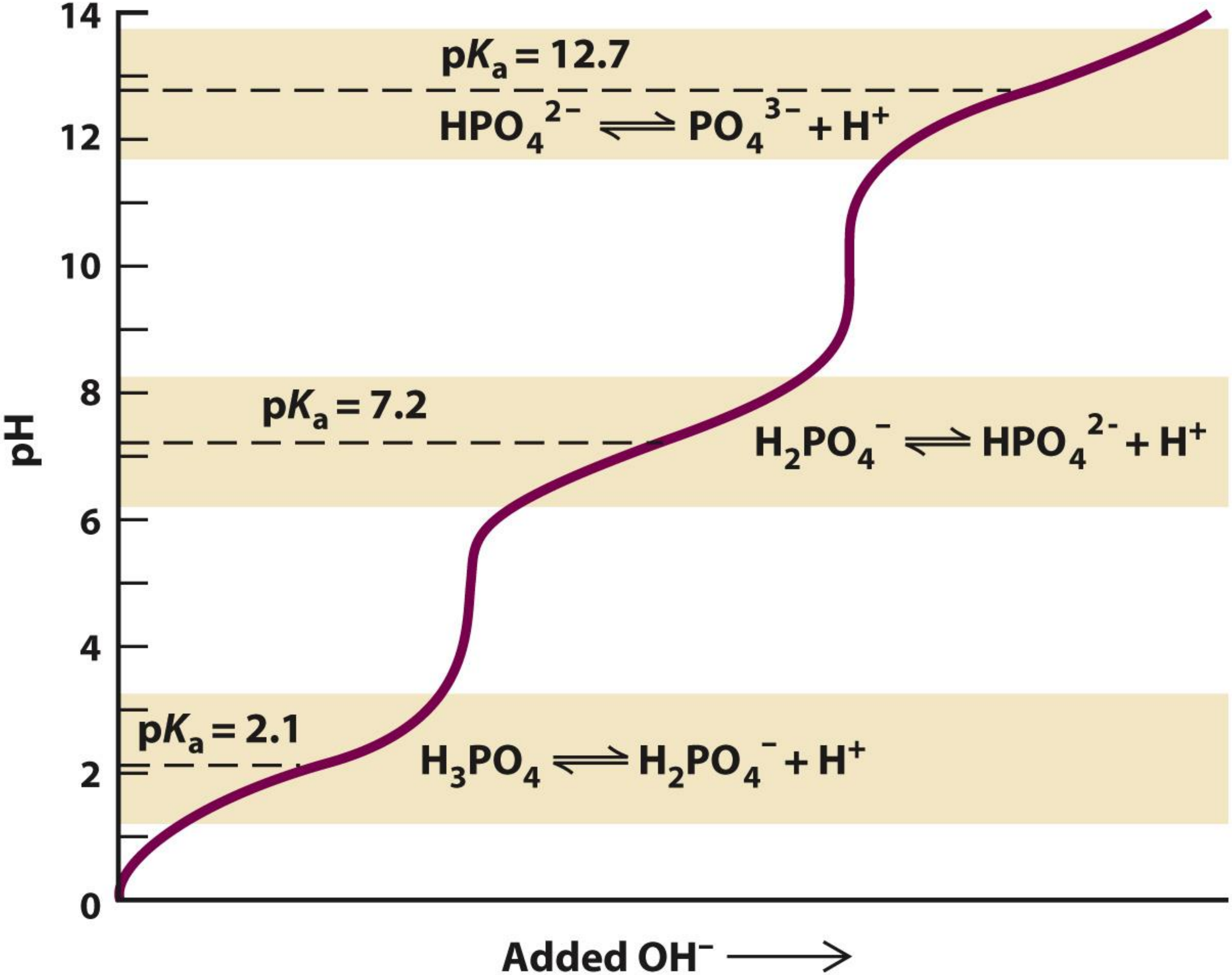

Figure 2-28
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2.1 Covalent Bonds and Noncovalent Interactions

2.2 Chemical Building Blocks of Cells

2.3 Chemical Reactions and Chemical Equilibrium

2.4 Biochemical Energetics

- ΔG: measure of reaction change in free energy; -ΔG reactions are thermodynamically favorable; +ΔG reactions are not
- free energy change $\Delta G^{0\prime}$ (-2.3 $RT\log K_{eq}$): calculated from reactants/products at equilibrium
- rate of reaction: depends on activation energy; lowered by a catalyst
- $-\Delta G$ reaction such as ATP hydrolysis to ADP + P_i can drive coupled +ΔG reaction.
- sun light energy captured by photosynthesis is ultimate source of all cell energy
- coenzyme (NAD+, FAD) oxidation (loss of e^-) and reduction (gain of e^-) electron transfer stores and transfers cell energy

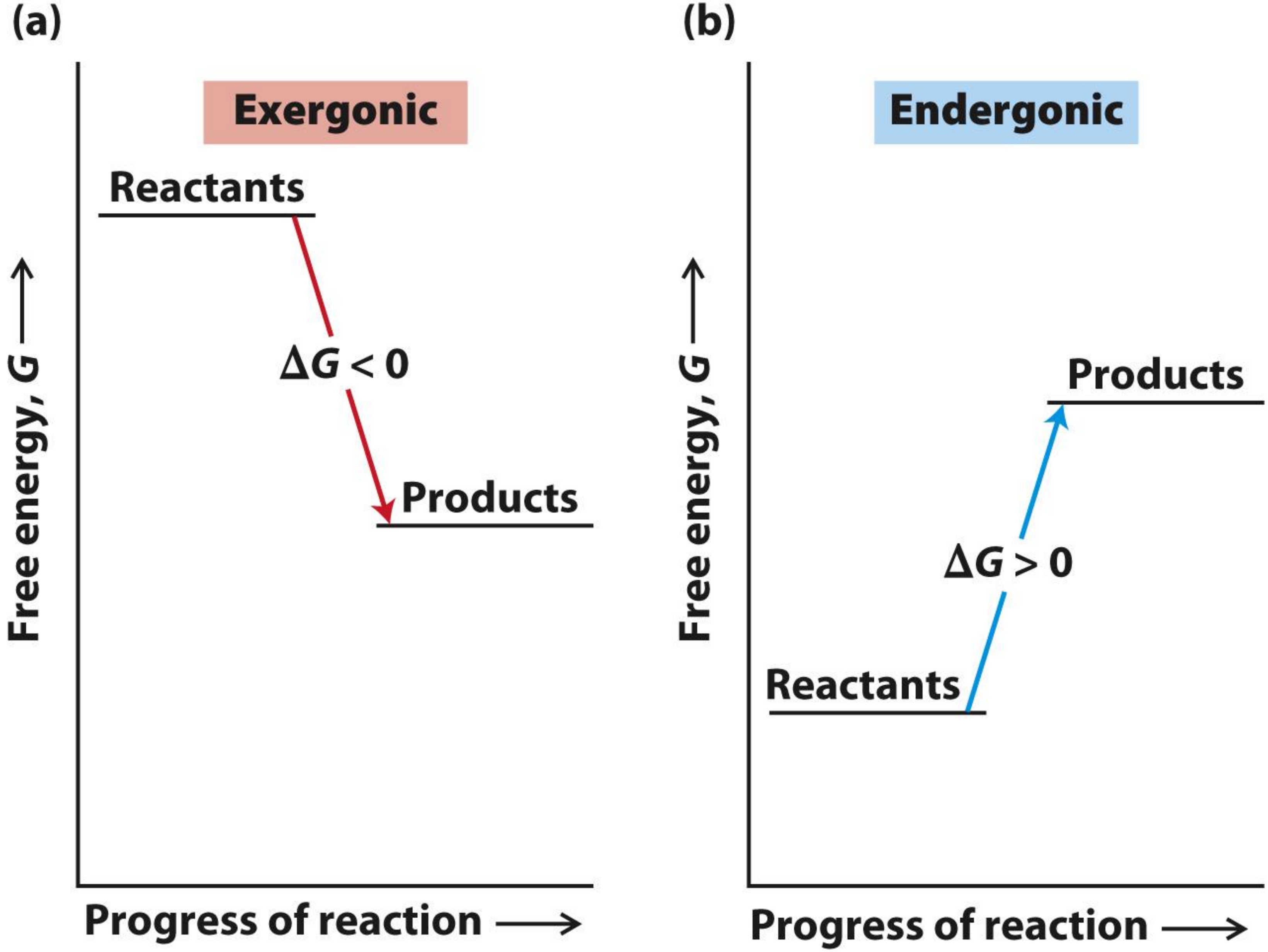

Figure 2-29
Molecular Cell Biology, Eighth Edition

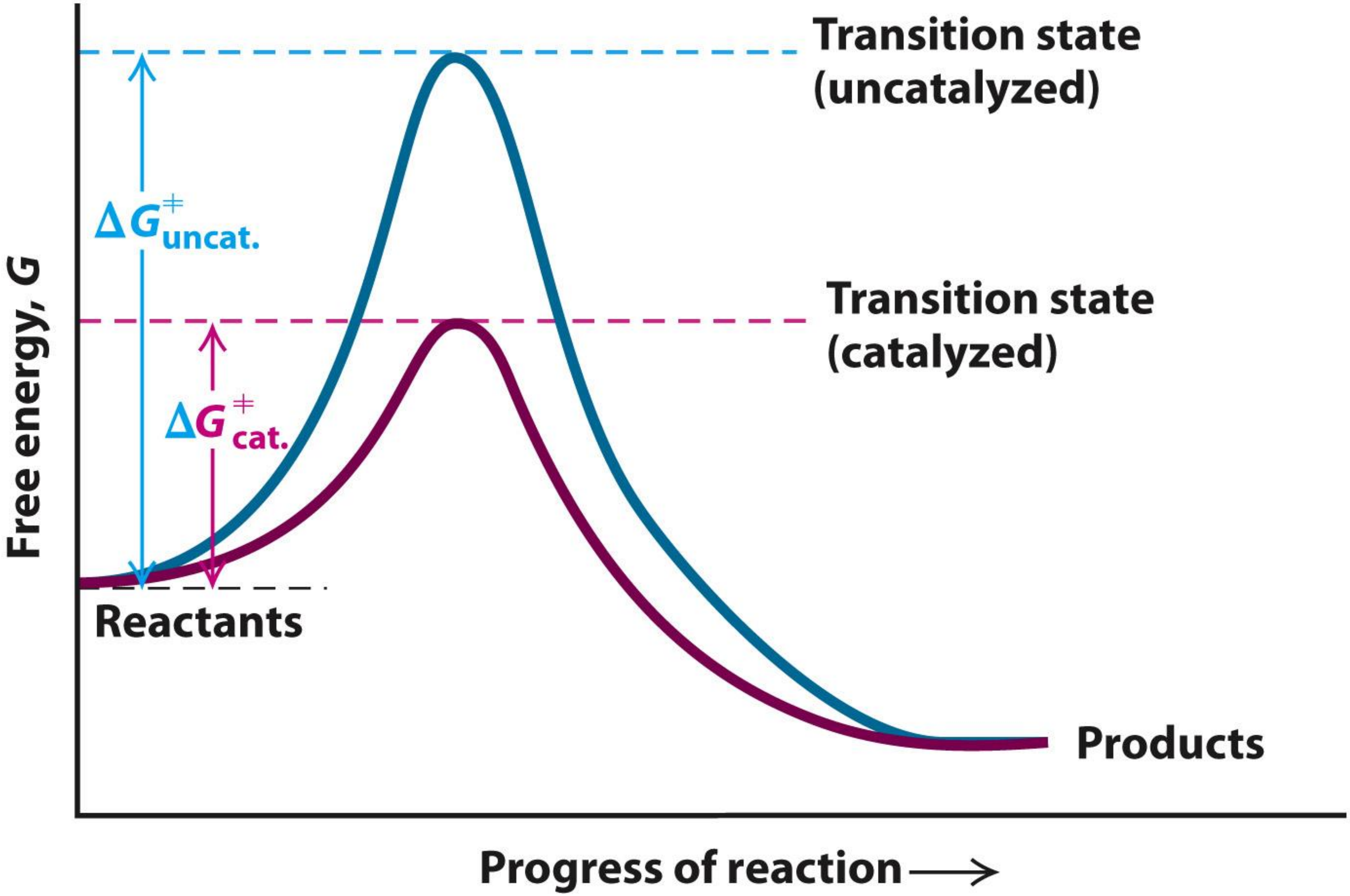

Figure 2-30
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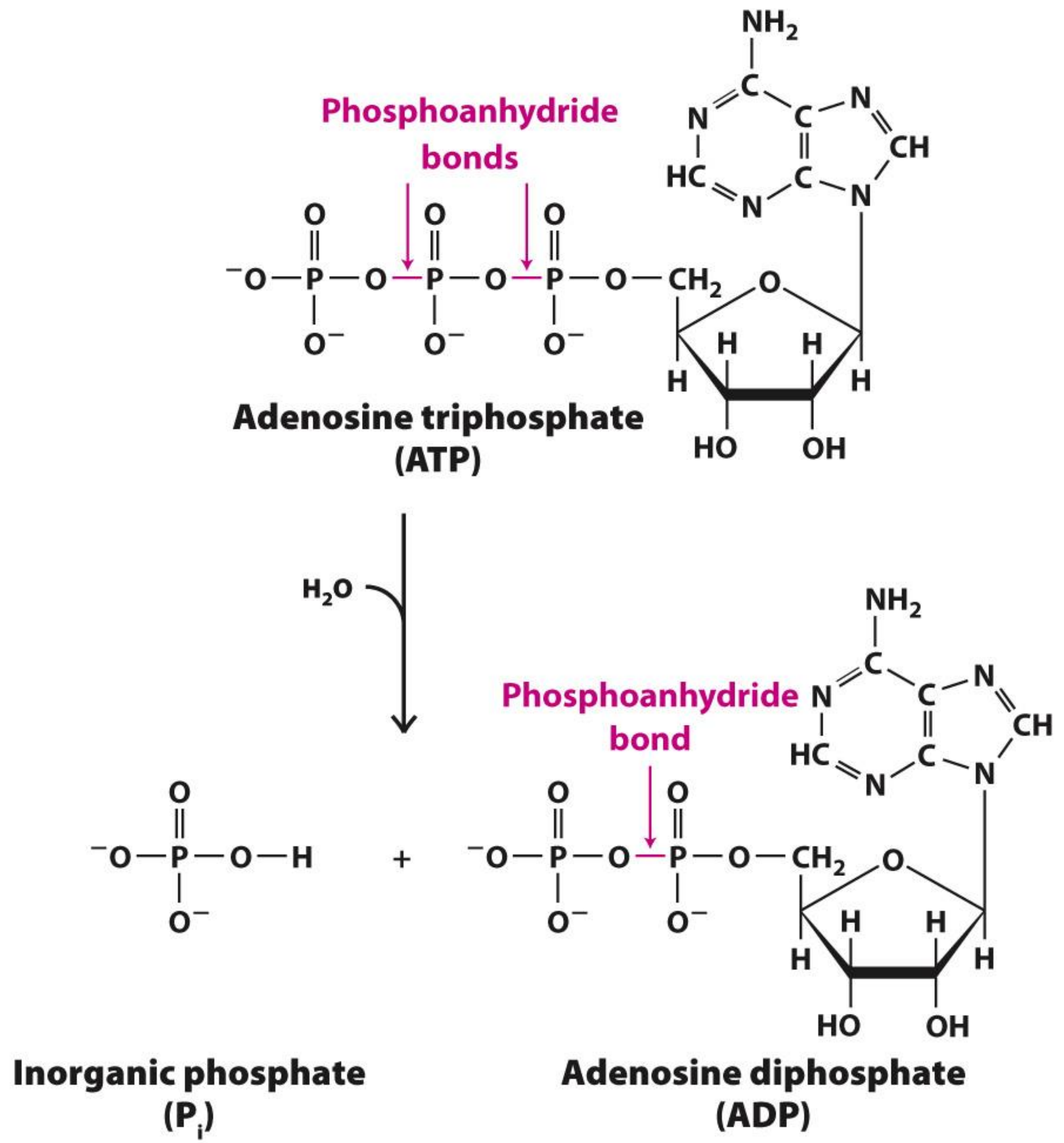
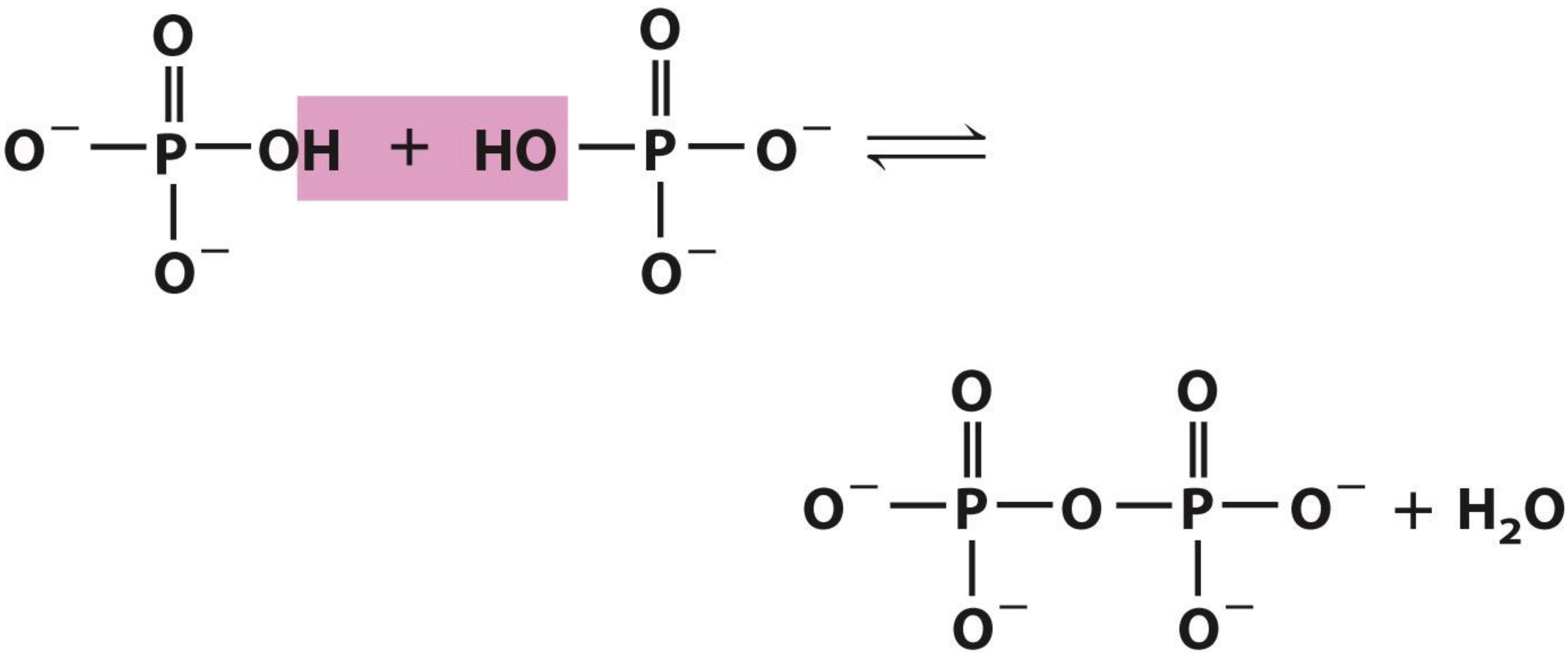


Figure 2-31
Molecular Cell Biology, Eighth Edition



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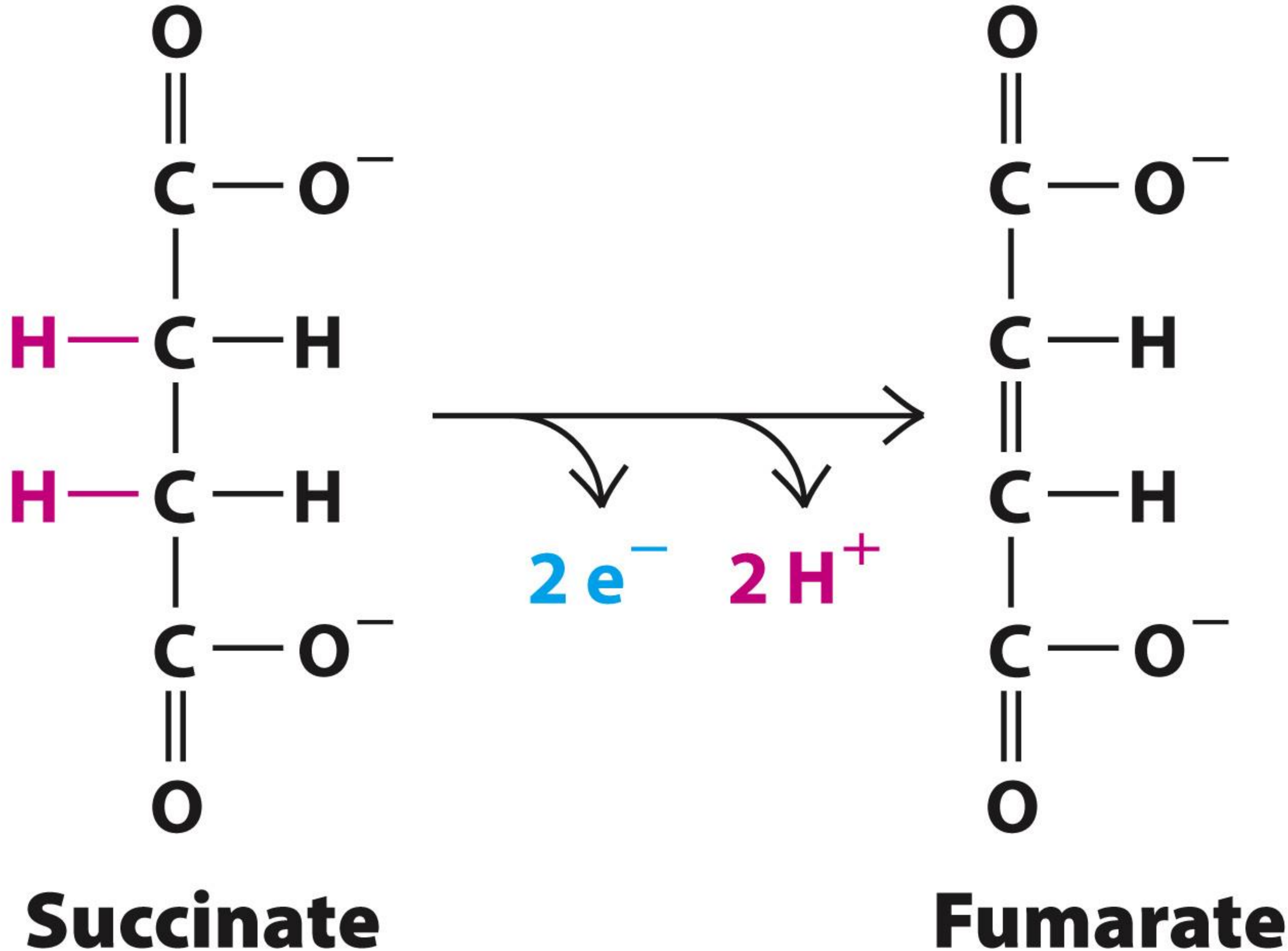
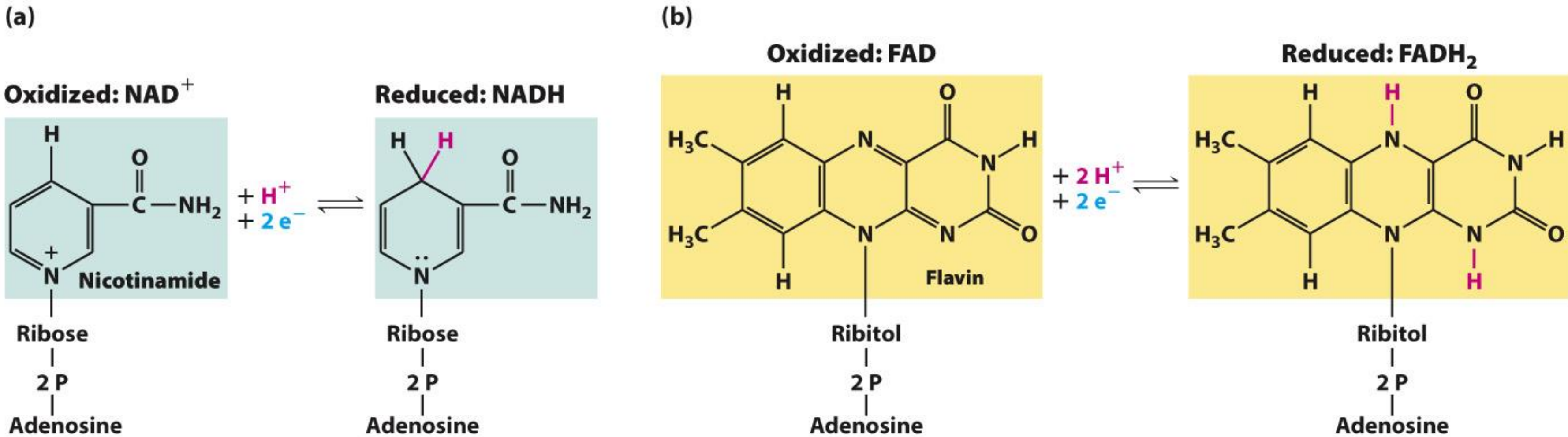


Figure 2-32
Molecular Cell Biology, Eighth Edition



$$NAD^+ + H^+ + 2\,e^- \rightleftharpoons NADH$$

$$FAD + 2\,H^+ + 2\,e^- \rightleftharpoons FADH_2$$

Figure 2-33
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