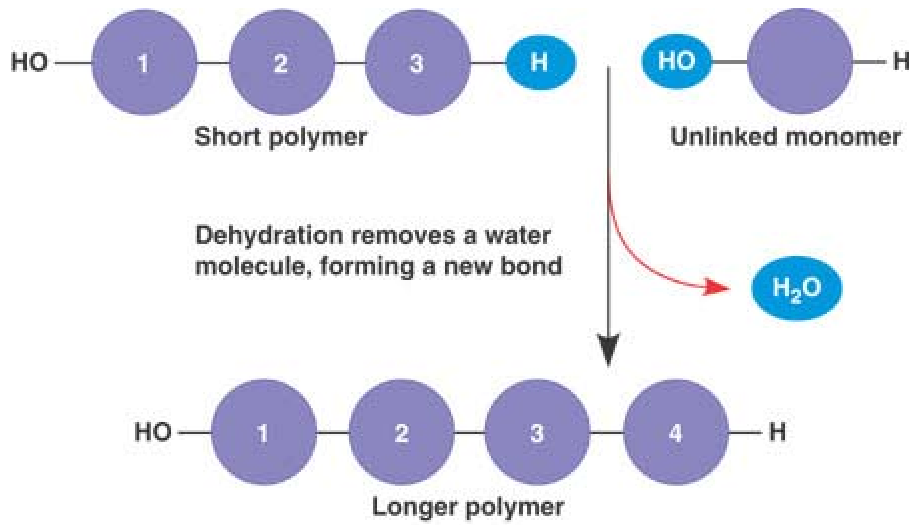
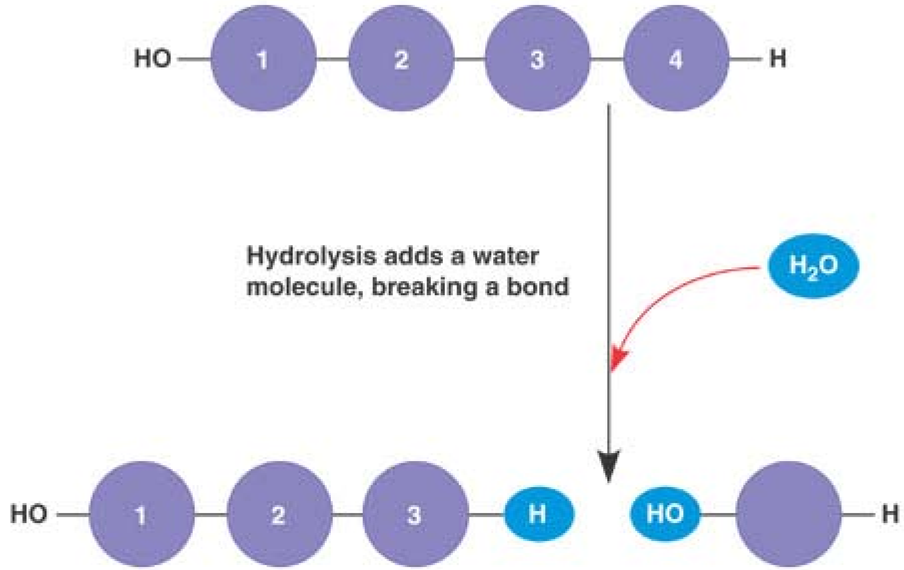
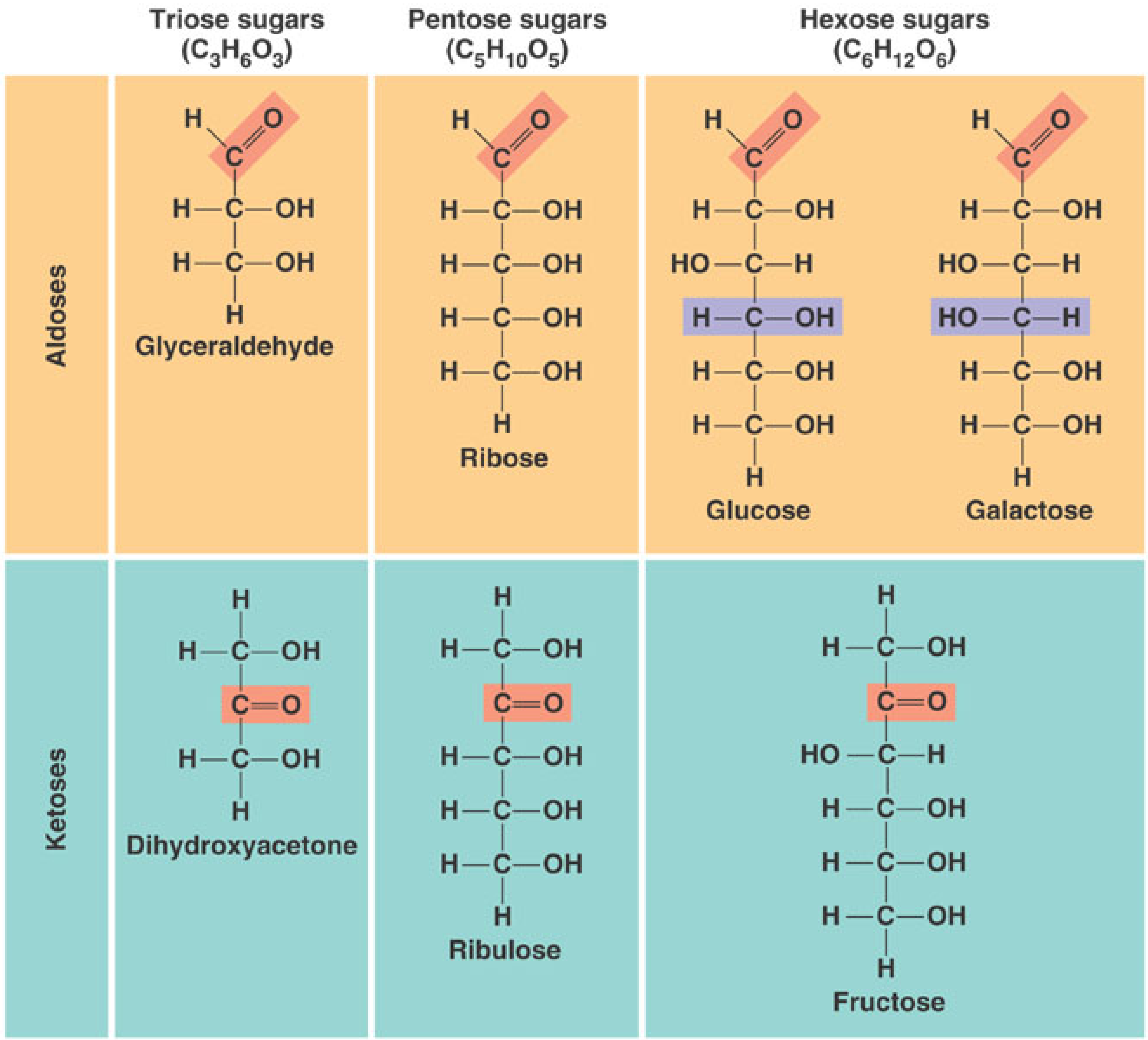
Chapter 5. The Structure and Function of Macromolecules



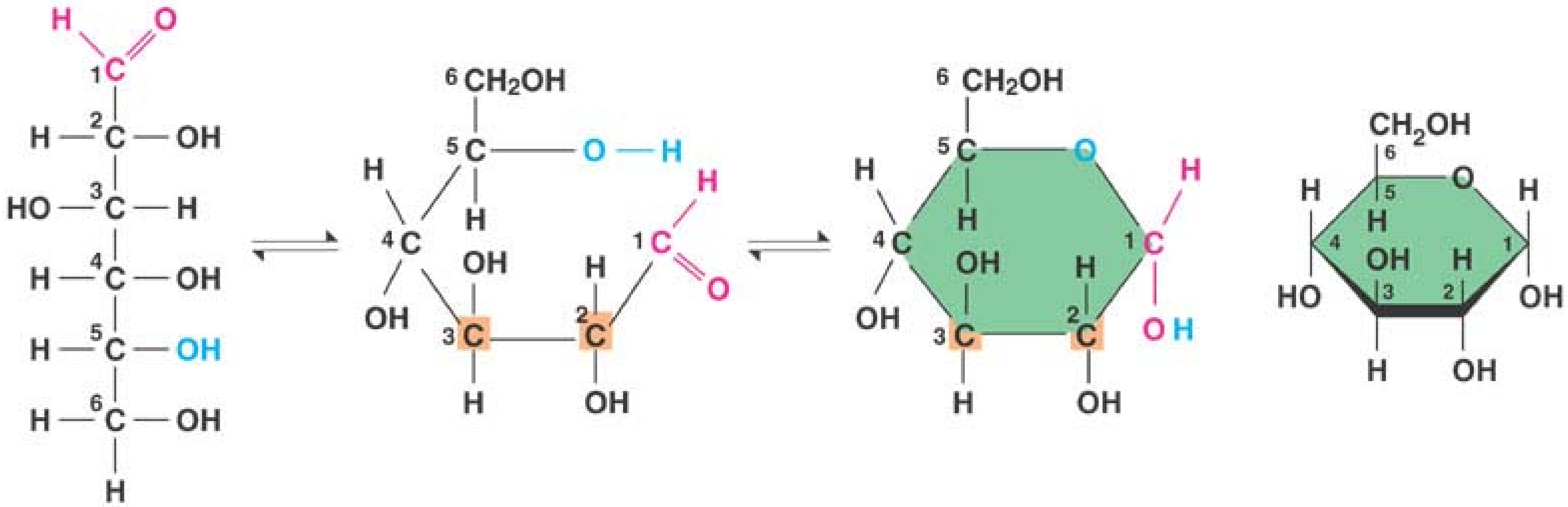
(a) Dehydration reaction in the synthesis of a polymer



(b) Hydrolysis of a polymer



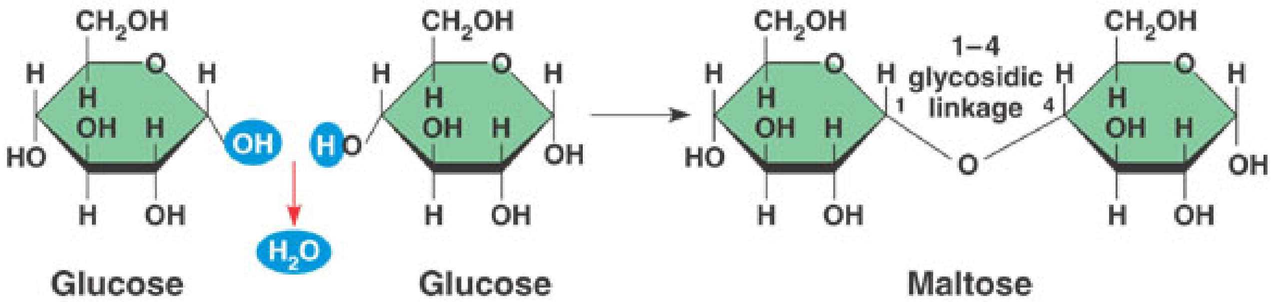
Triose sugars
($C_3H_6O_3$)
Pentose sugars
($C_5H_{10}O_5$)
Hexose sugars
($C_6H_{12}O_6$)
Aldoses
Glyceraldehyde
Ribose
Glucose
Galactose
Ketoses
Dihydroxyacetone
Ribulose
Fructose



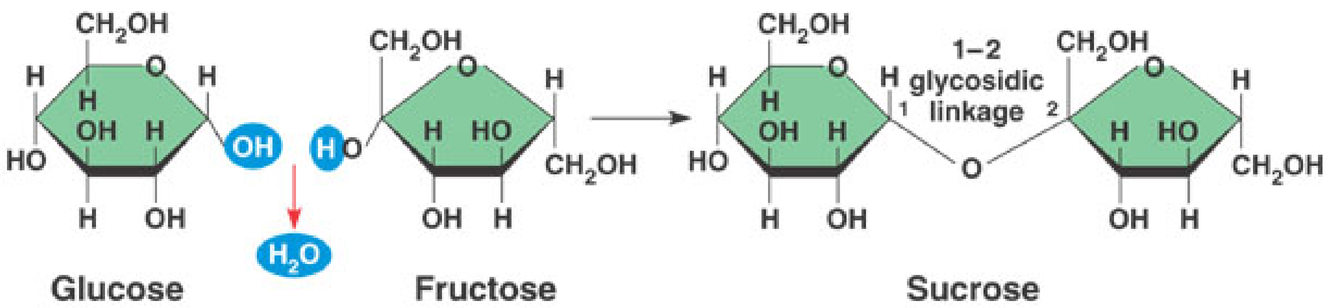
(a) Linear and ring forms

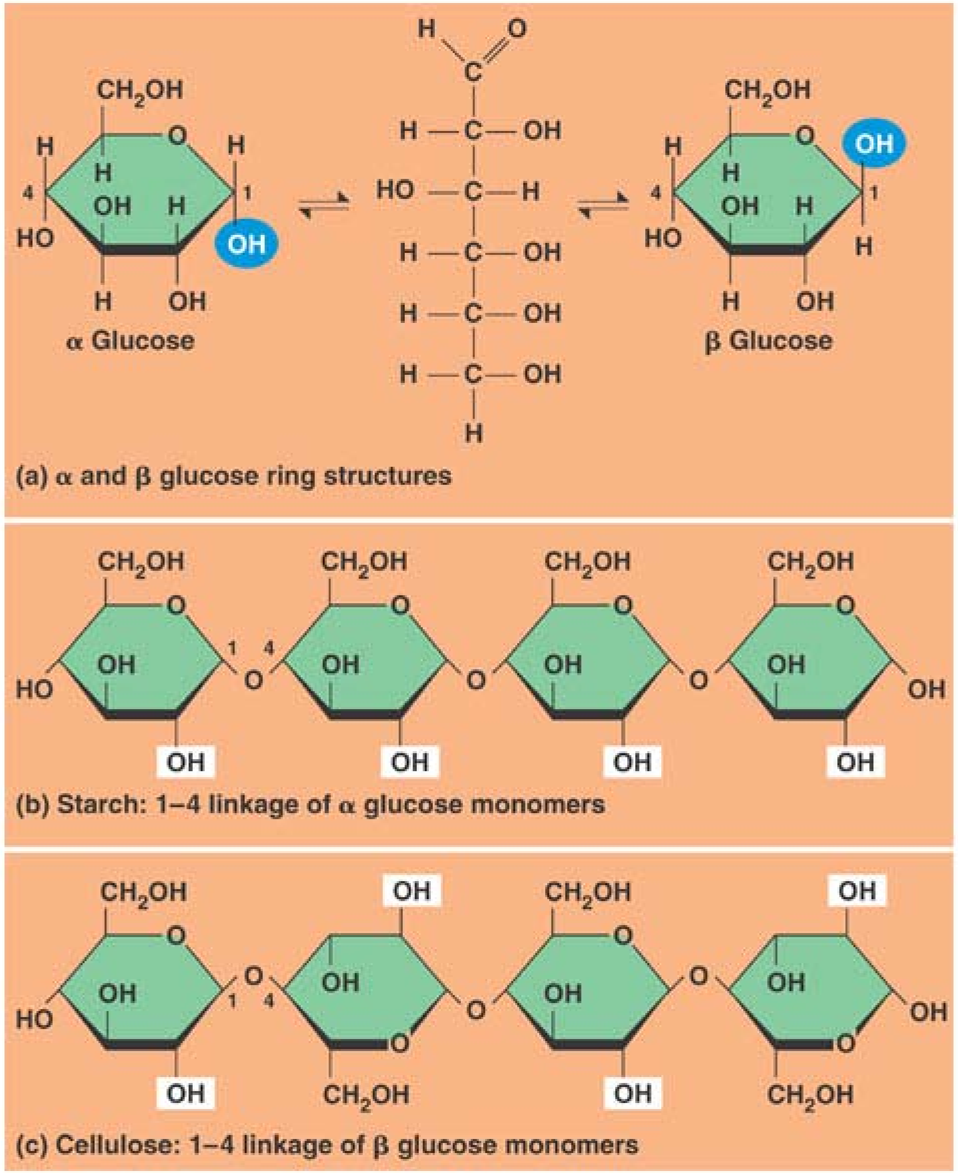
(b) Abbreviated ring structure

(a) Dehydration reaction in the synthesis of maltose



(b) Dehydration reaction in the synthesis of sucrose

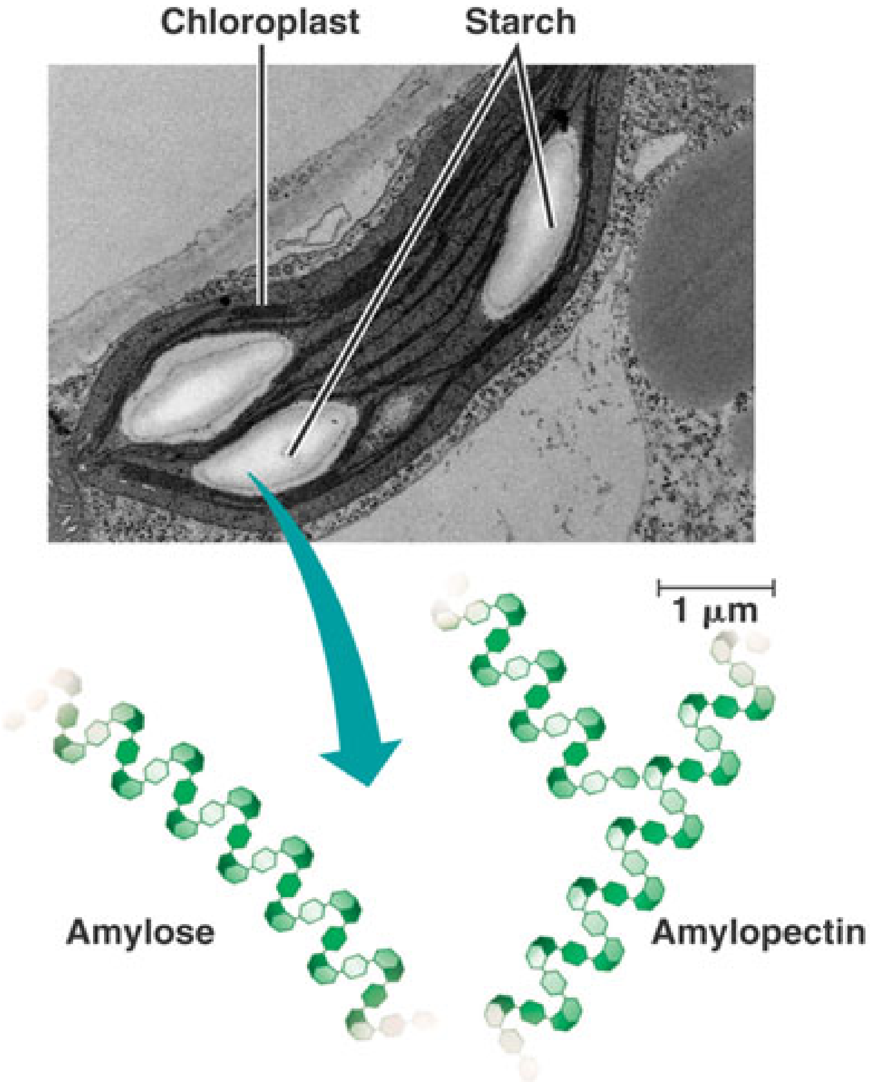




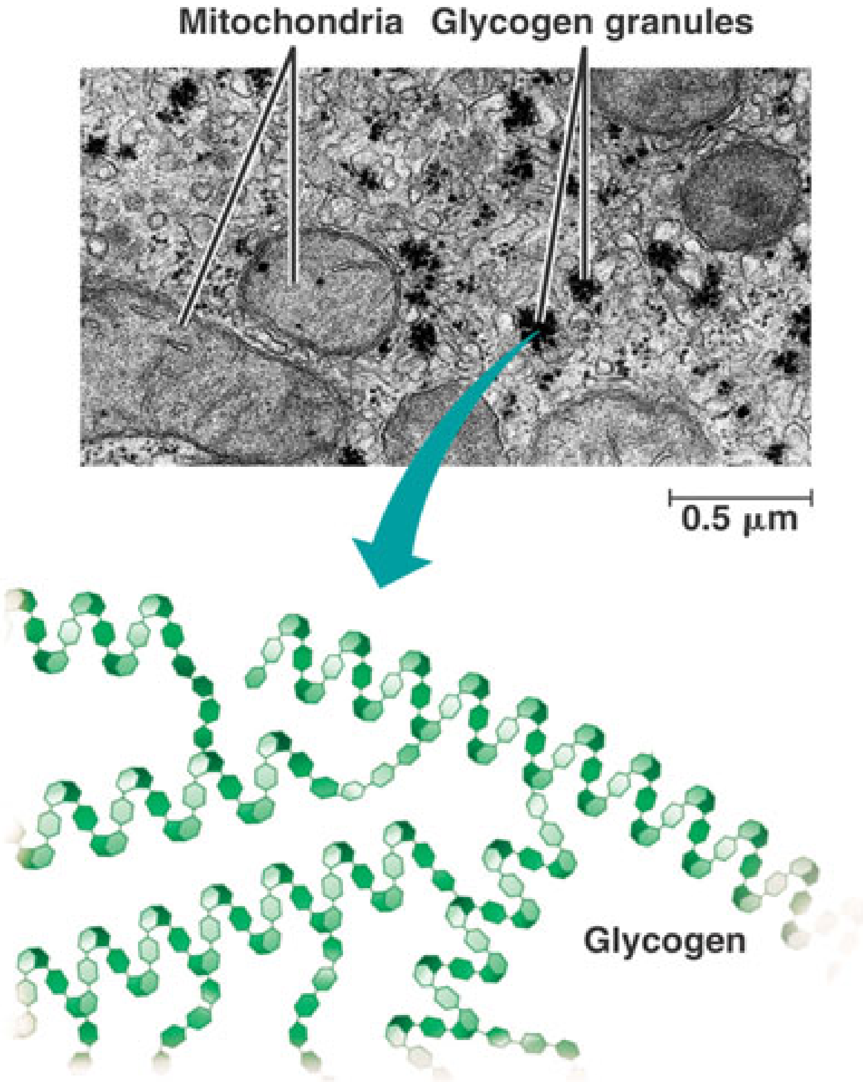
(a) α and β glucose ring structures

(b) Starch: 1–4 linkage of α glucose monomers

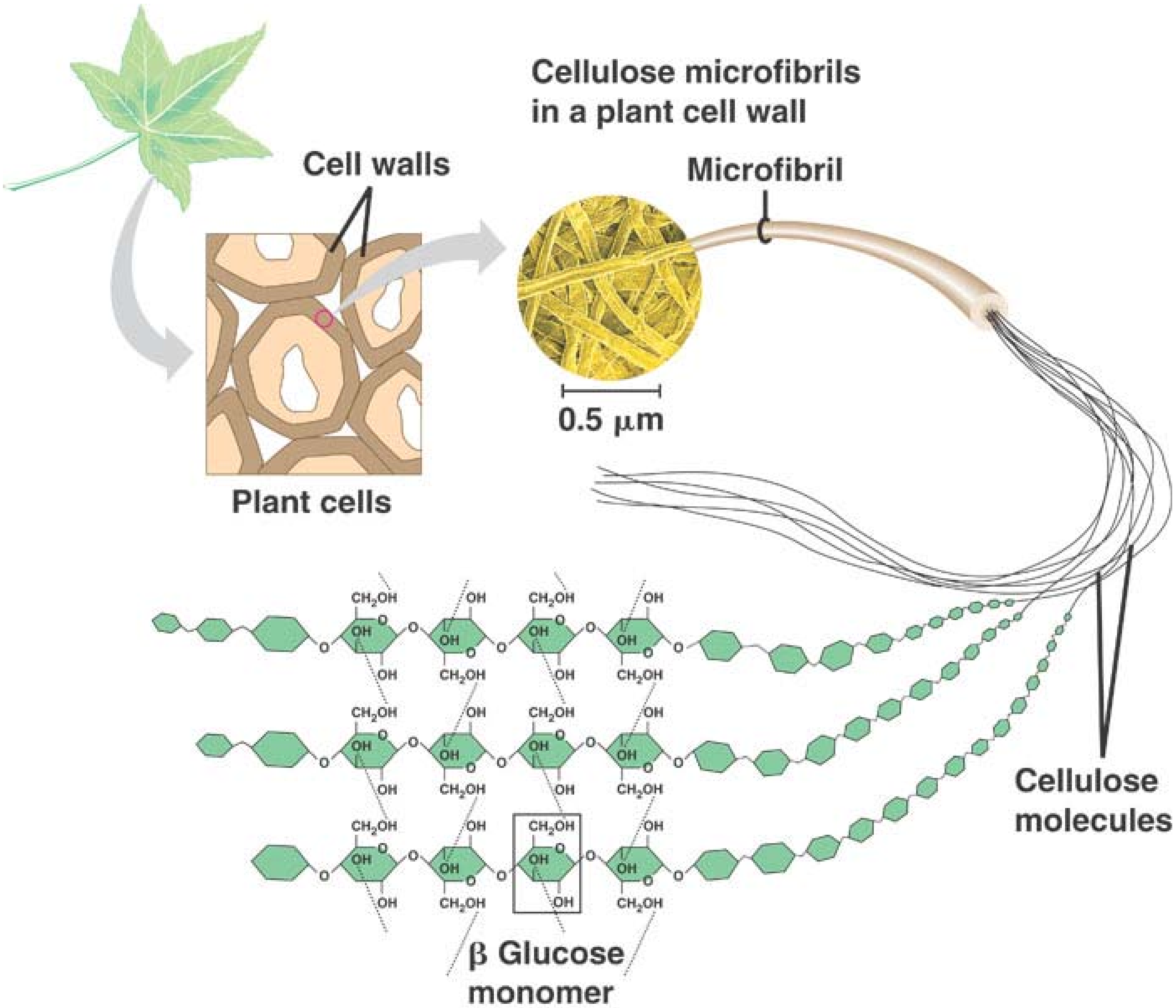
(c) Cellulose: 1–4 linkage of β glucose monomers



(a) Starch: a plant polysaccharide



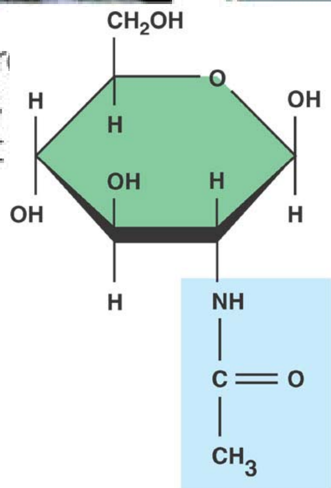
(b) Glycogen: an animal polysaccharide



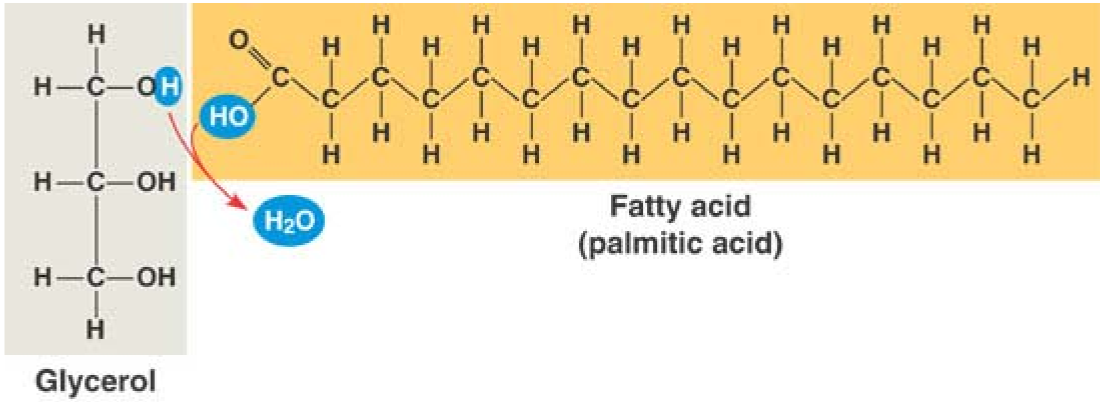
Cellulose microfibrils in a plant cell wall
Cell walls
Microfibril
0.5 µm
Plant cells
Cellulose molecules
β Glucose monomer

(b) Chitin forms the exoskeleton of arthr
This cicada is molting, shedding its
exoskeleton and emerging in adult

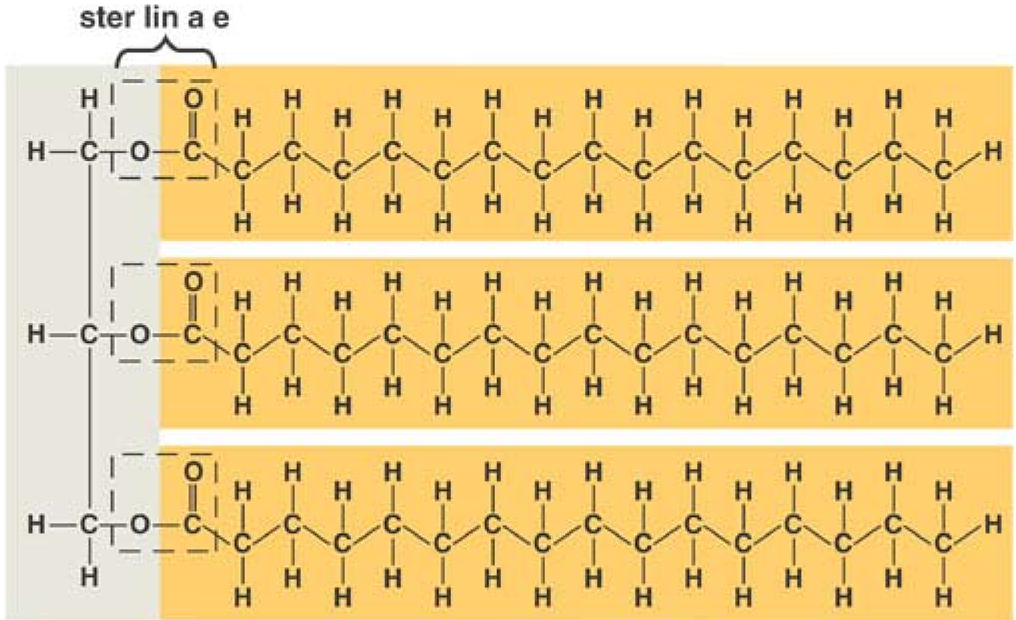
is used to make a strong and flexible
l thread that decomposes after the
l or incision heals.



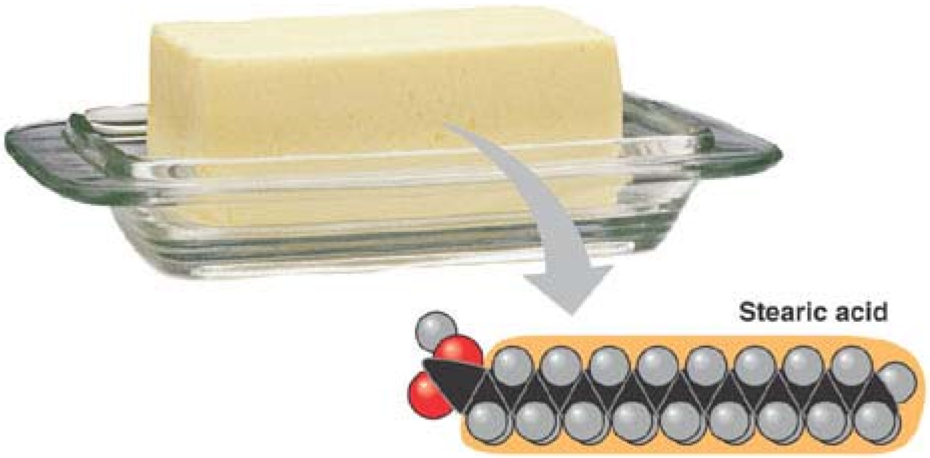
The structure of the chitin monomer



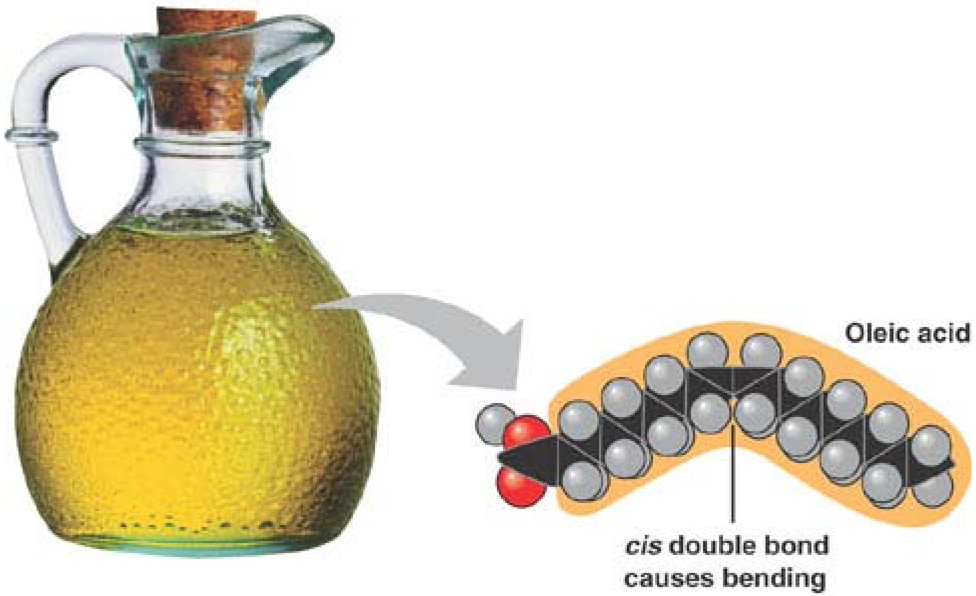
(a) Dehydration reaction in the synthesis of a fat



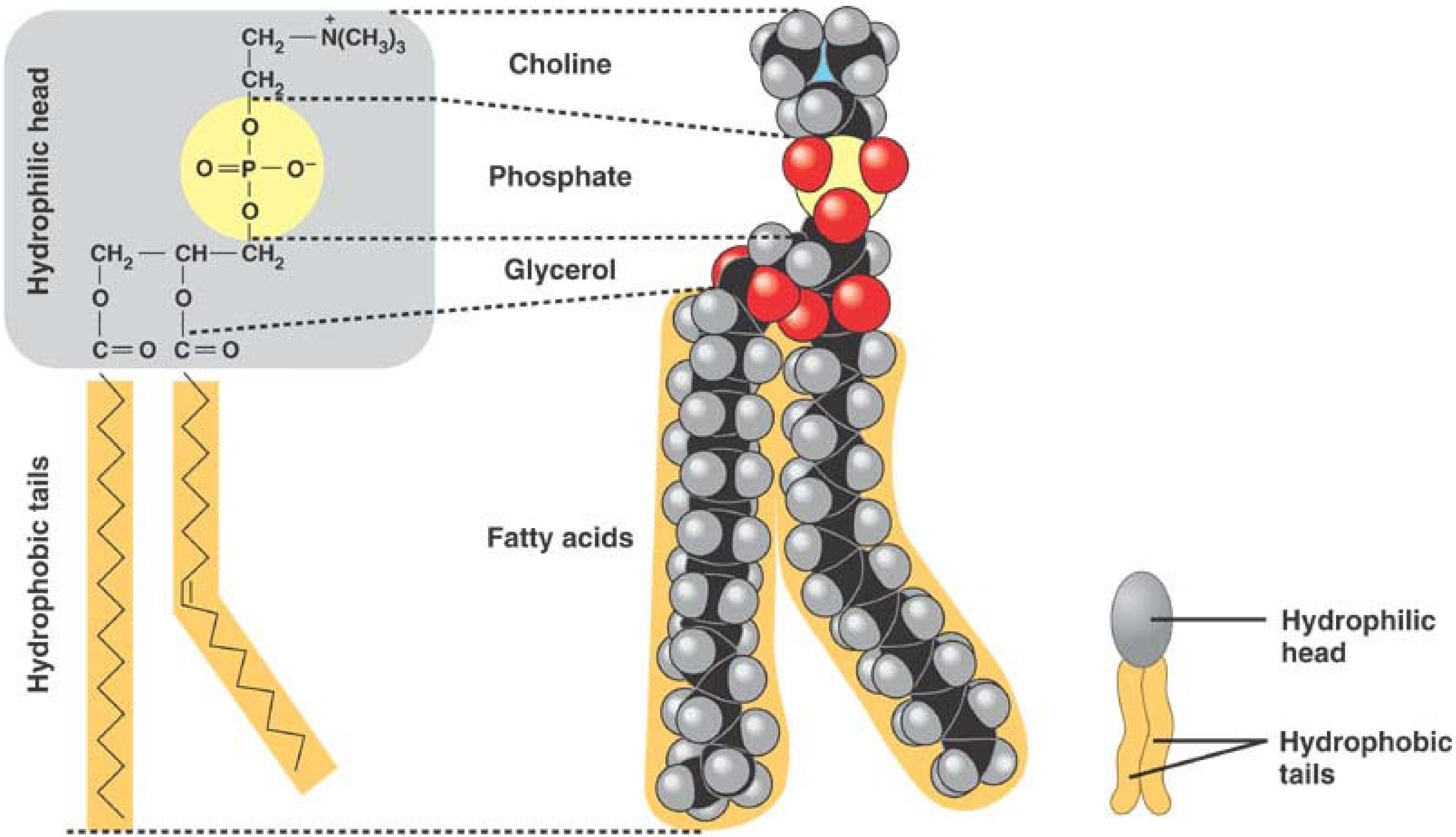
( ) Fat molec le (triacyl lycerol)



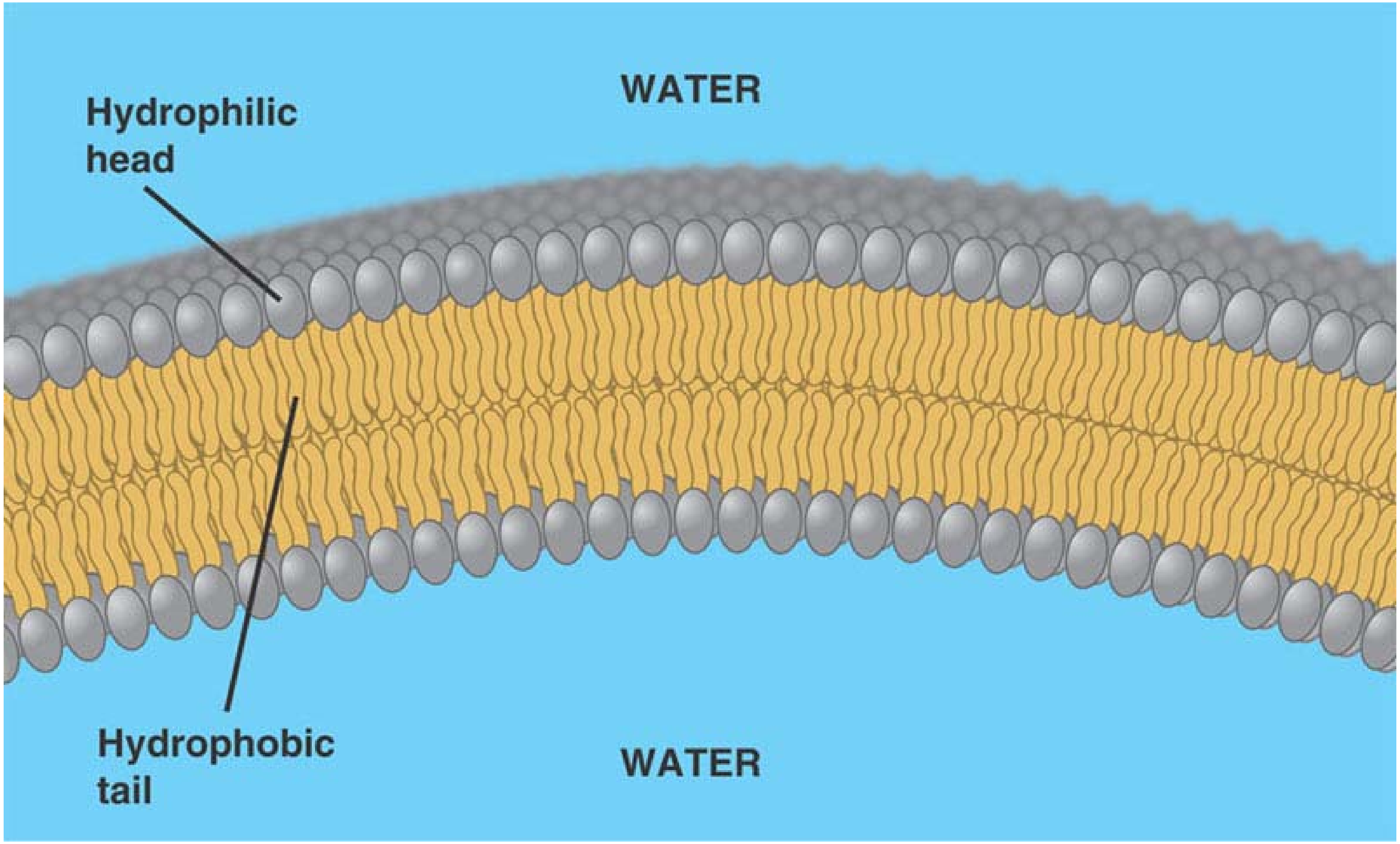
(a) Saturated fat and fatty acid

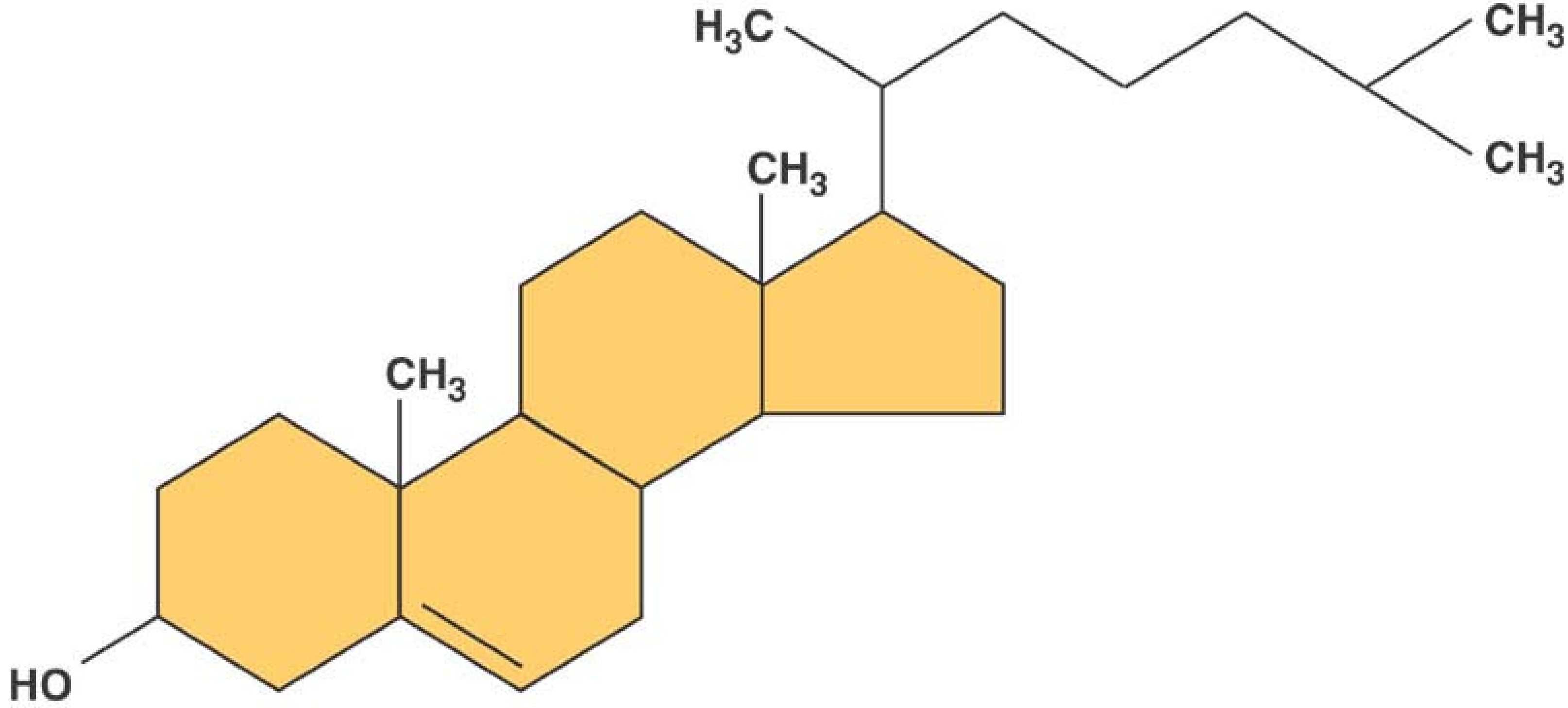


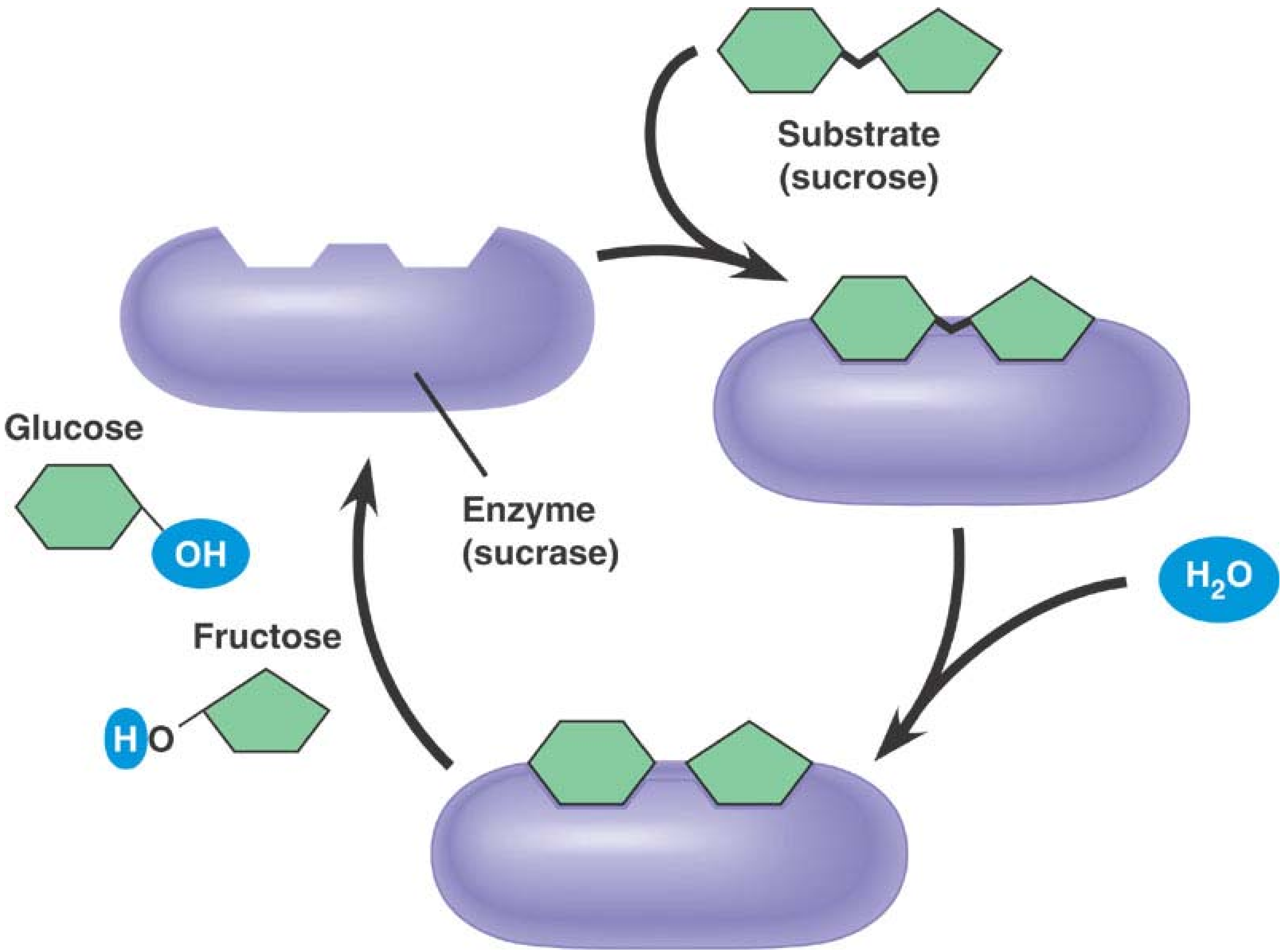
(b) Unsaturated fat and fatty acid

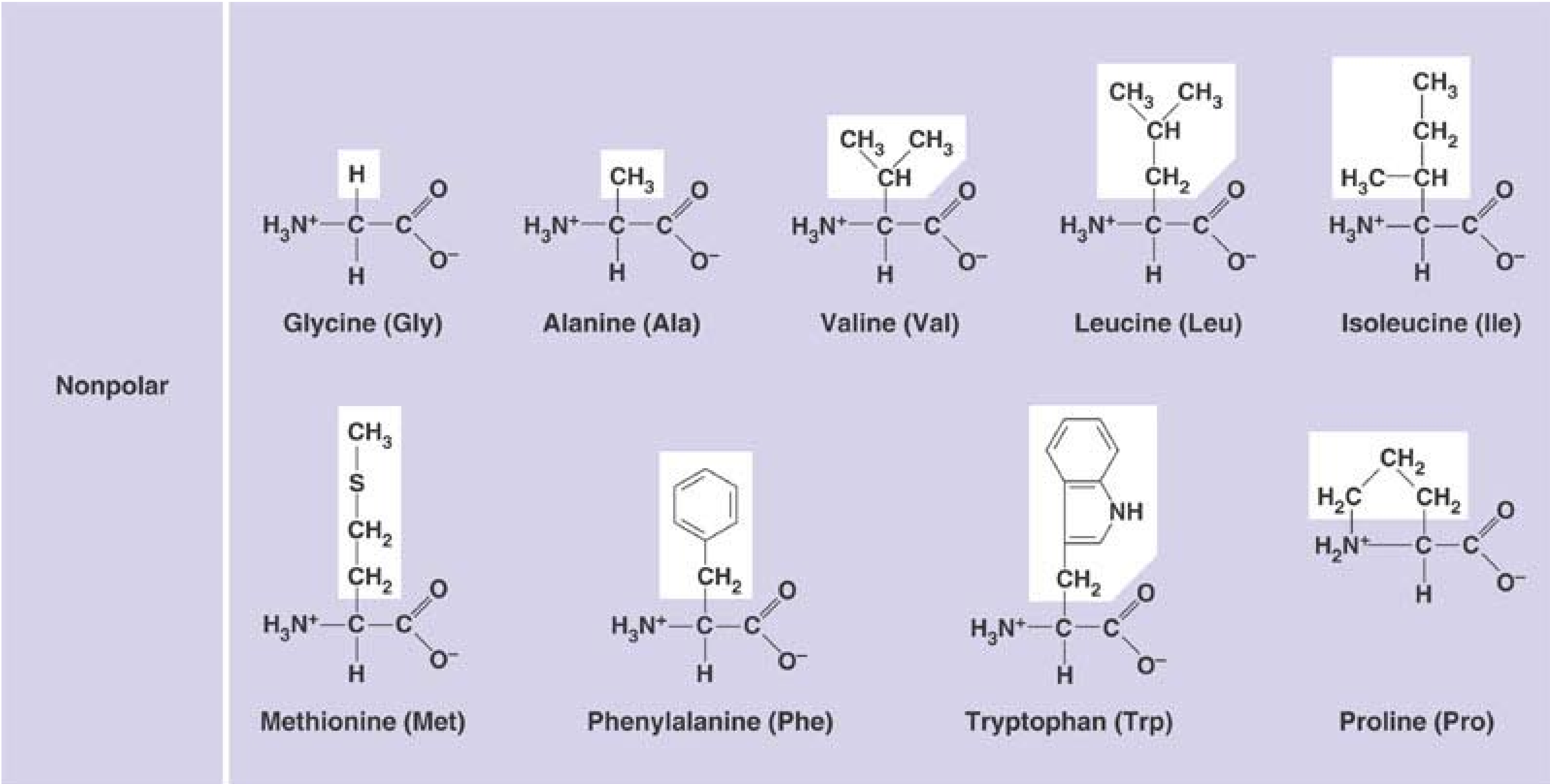


(a) Structural formula (b) Space-filling model (c) Phospholipid symbol

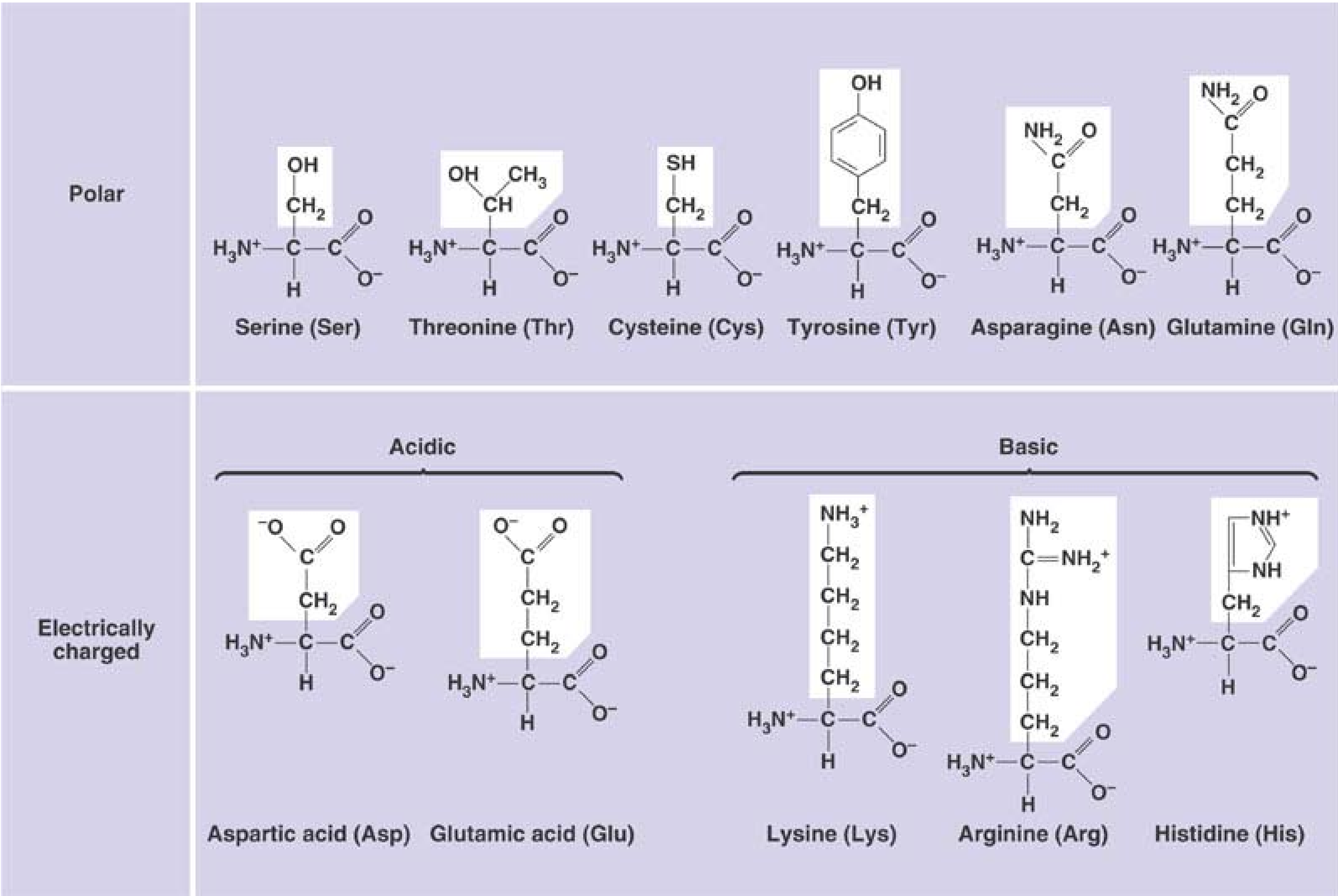

WATER
Hydrophilic head
Hydrophobic tail
WATER


H3C
CH3
CH3
CH3
CH3
HO

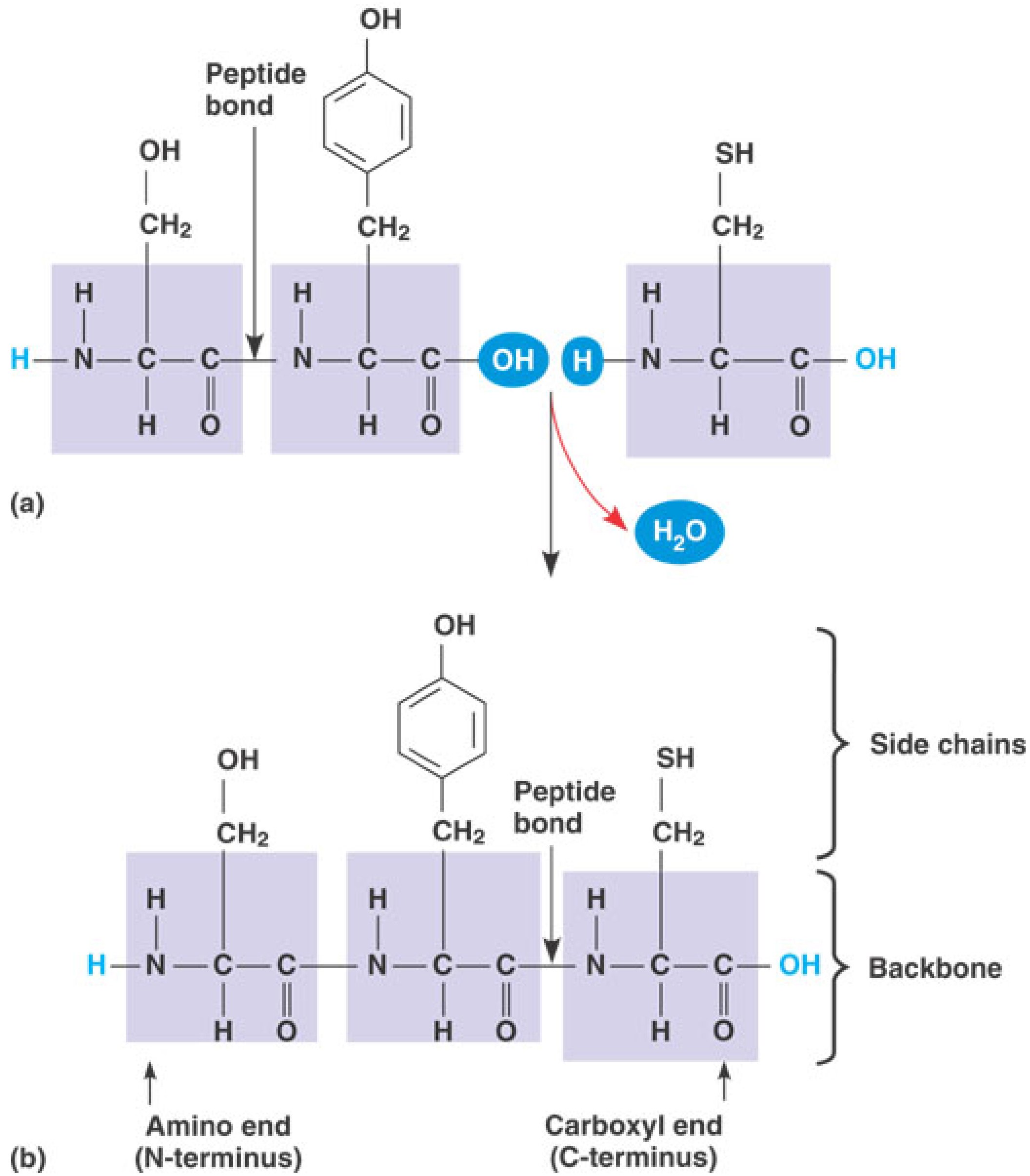

Substrate
(sucrose)
Glucose
OH
Enzyme
(sucrase)
H_2O
Fructose
HO



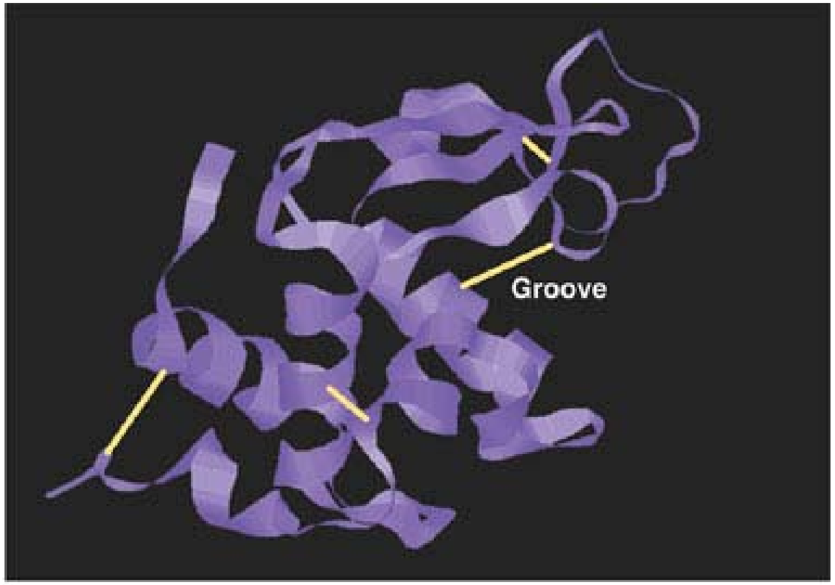
Nonpolar
Glycine (Gly)
Alanine (Ala)
Valine (Val)
Leucine (Leu)
Isoleucine (Ile)
Methionine (Met)
Phenylalanine (Phe)
Tryptophan (Trp)
Proline (Pro)



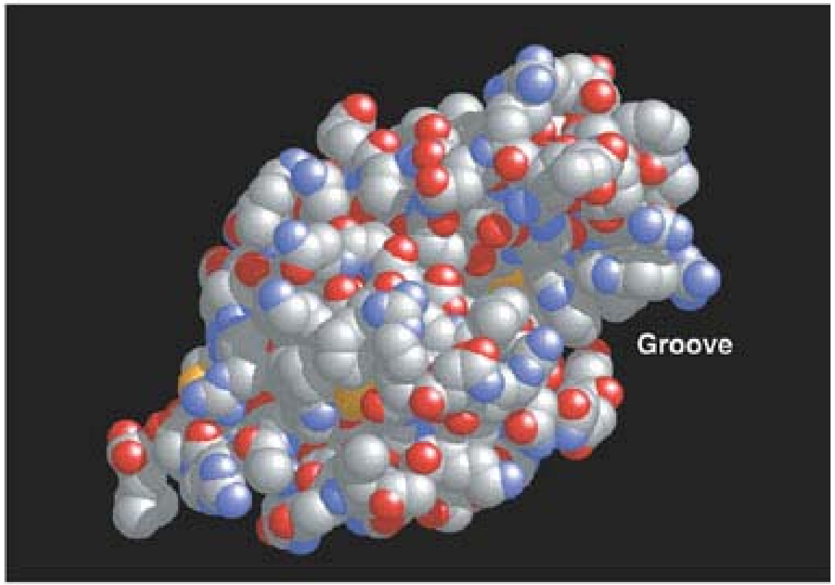
Polar
Serine (Ser)
Threonine (Thr)
Cysteine (Cys)
Tyrosine (Tyr)
Asparagine (Asn)
Glutamine (Gln)
Electrically charged
Acidic
Basic
Aspartic acid (Asp)
Glutamic acid (Glu)
Lysine (Lys)
Arginine (Arg)
Histidine (His)



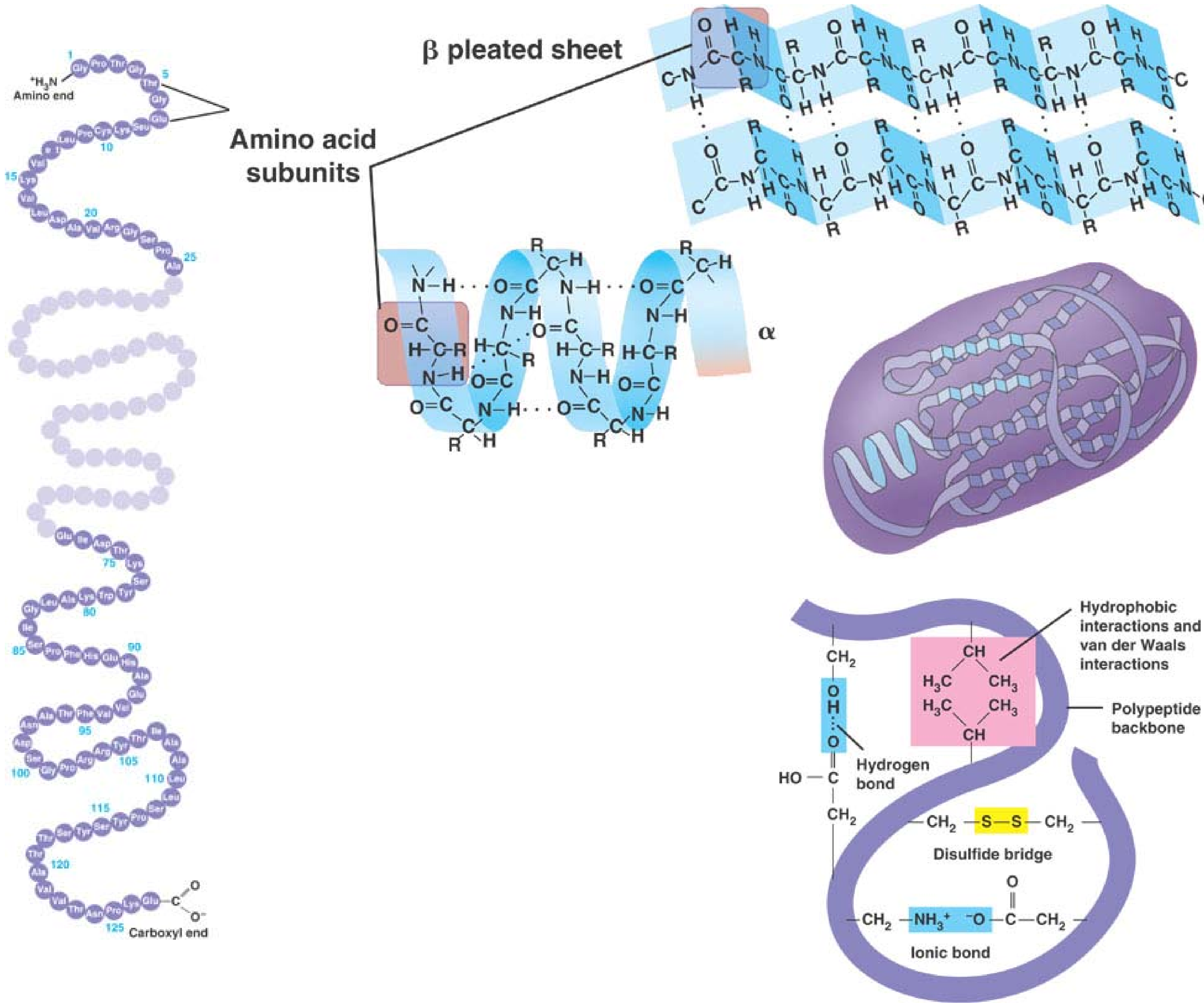
Peptide bond
OH
OH
CH2
CH2
SH
CH2
H
H
H
H—N—C—C—N—C—C—OH H—N—C—C—OH
H O H O H O
(a)
H2O
OH
OH
SH
Peptide bond
CH2
CH2
CH2
Side chains
H—N—C—C—N—C—C—N—C—C—OH
Backbone
Amino end (N-terminus)
Carboxyl end (C-terminus)
(b)



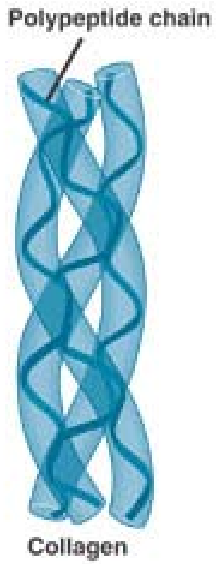
(a) A ribbon model

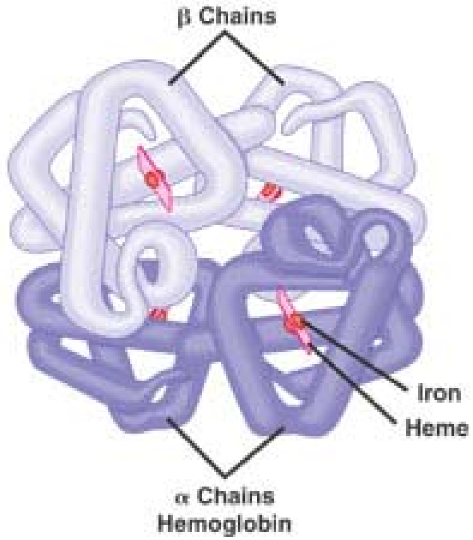


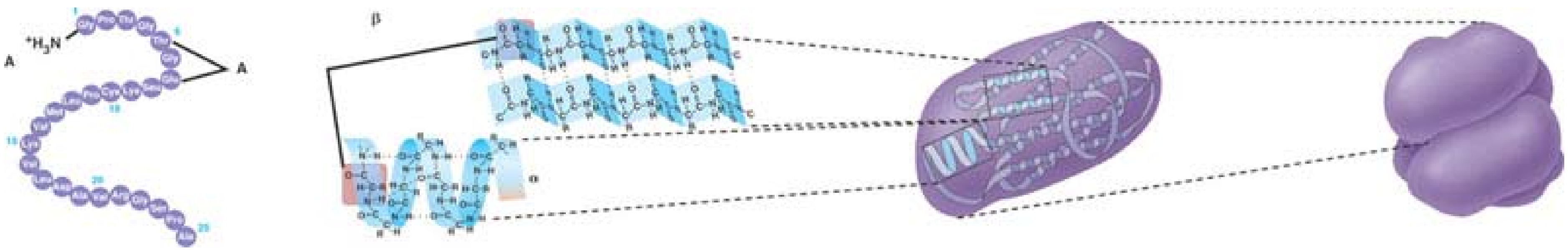
(b) A space-filling model

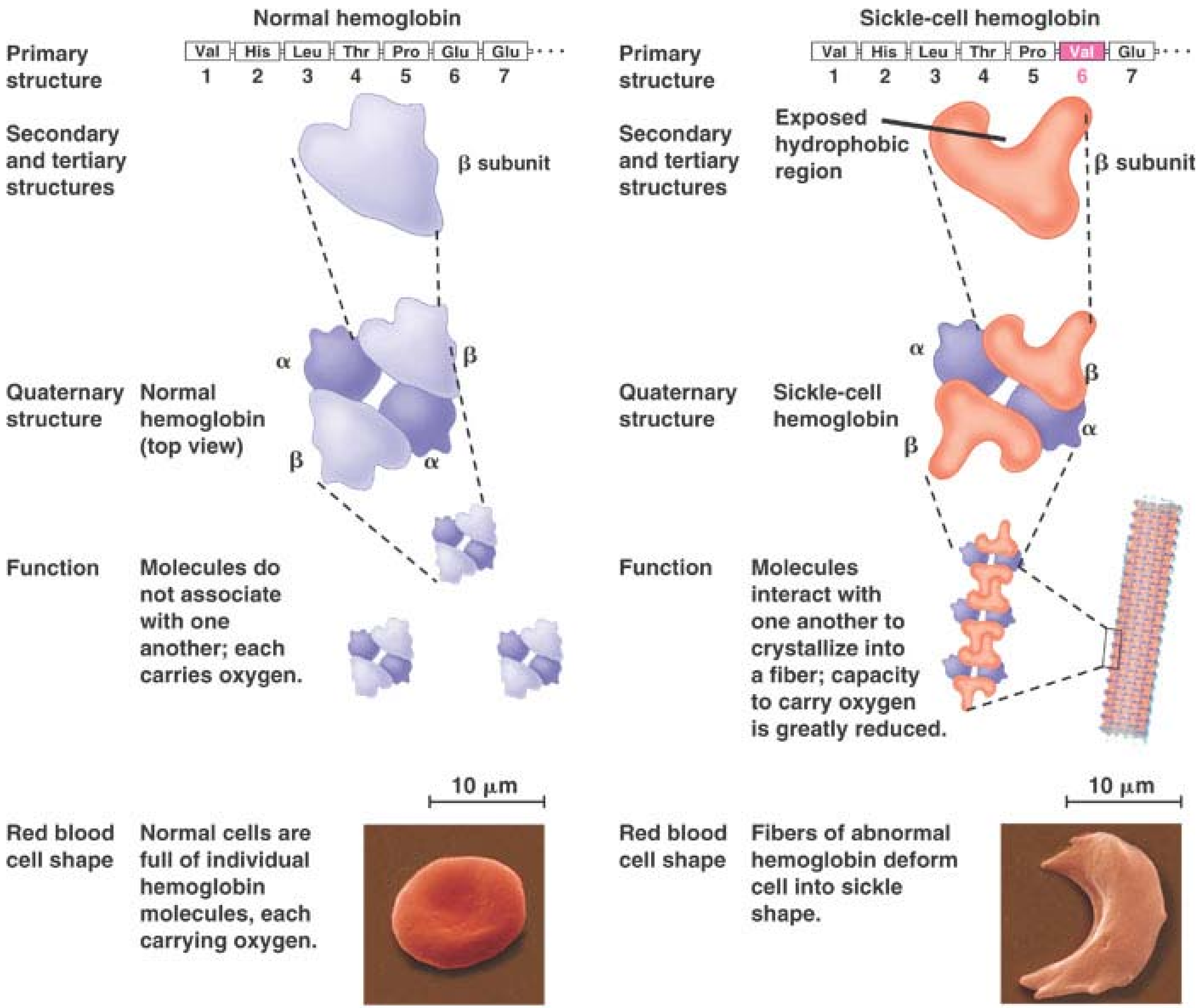


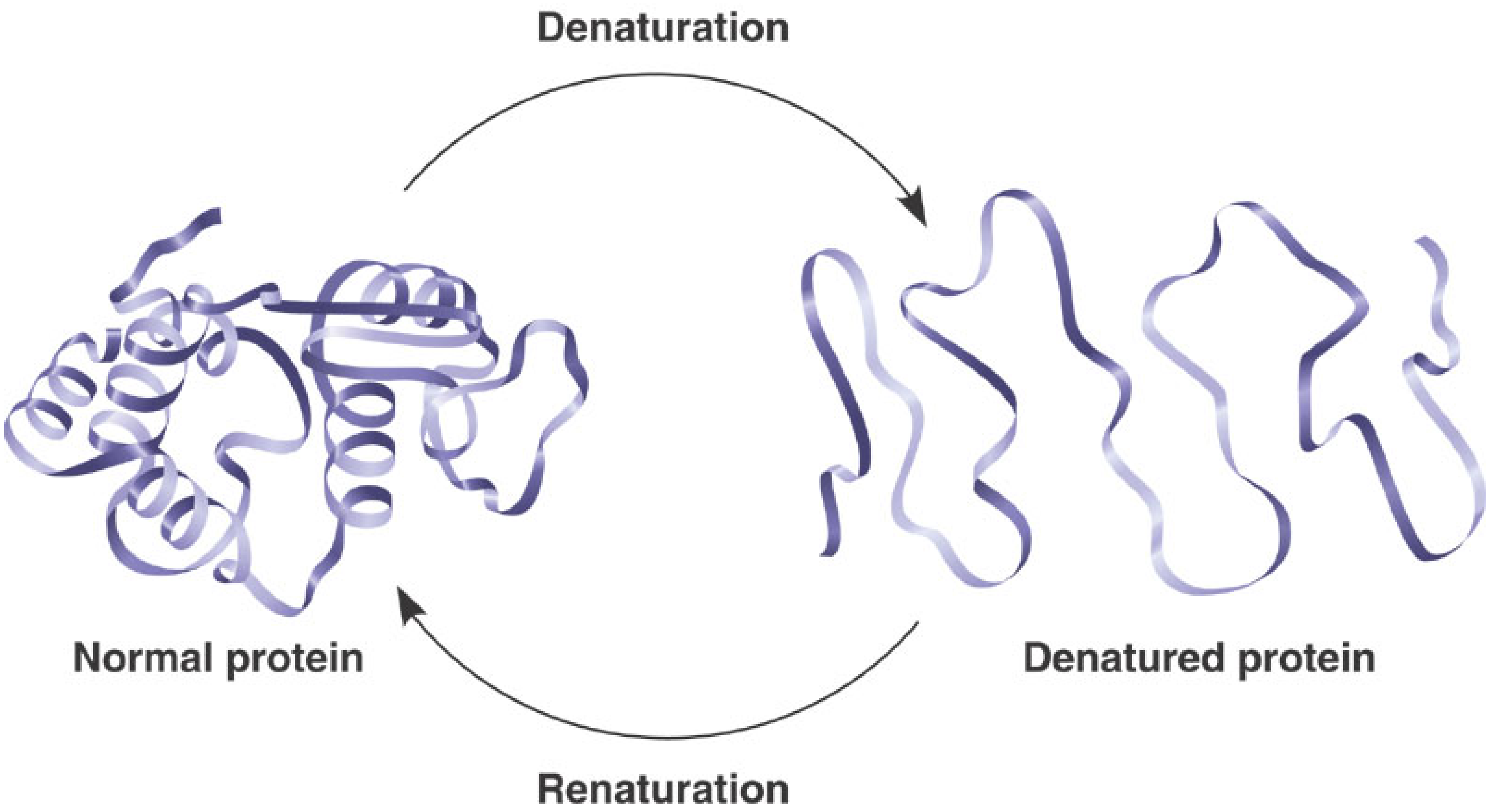
Amino end
Carboxyl end
Amino acid subunits
β pleated sheet
α
Hydrophobic interactions and van der Waals interactions
Polypeptide backbone
Hydrogen bond
Disulfide bridge
Ionic bond

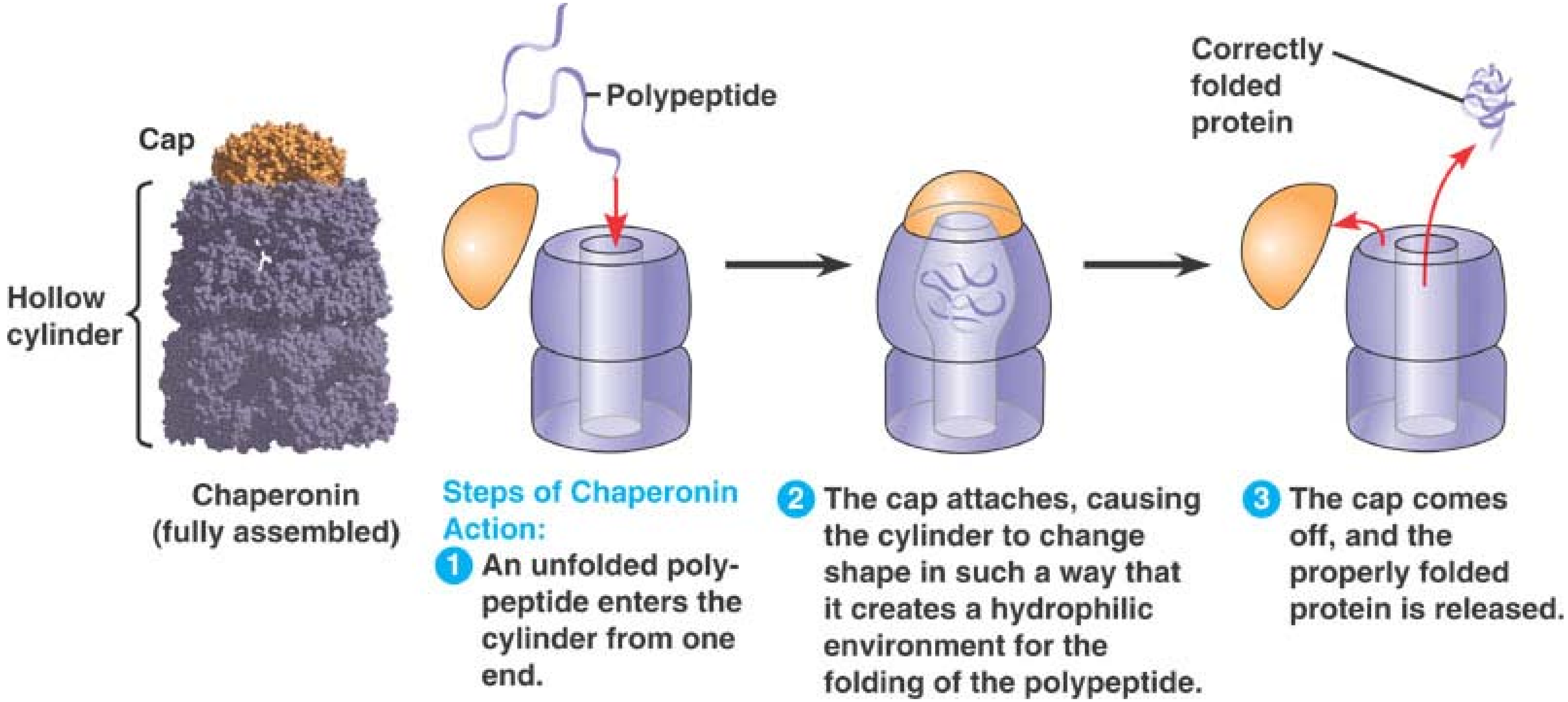

Polypeptide chain
Collagen

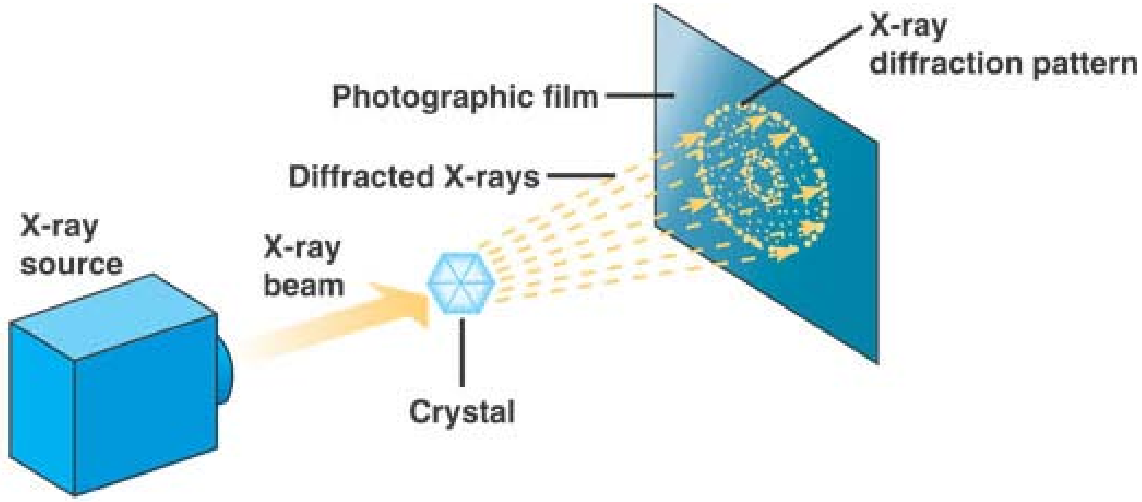

β Chains
Iron
Heme
α Chains
Hemoglobin

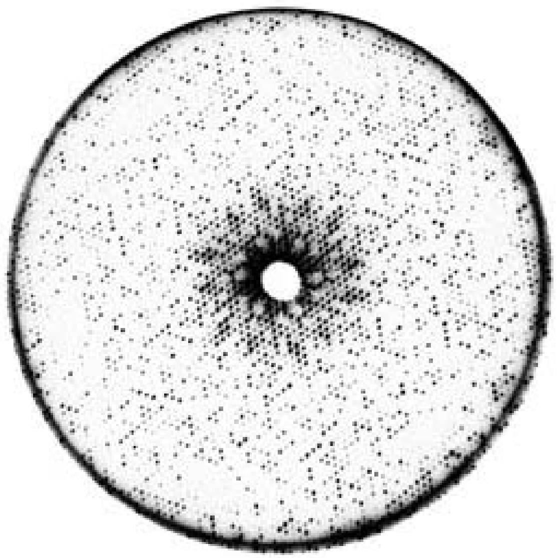

A
+H3N
A
1
5
10
15
20
25
β
α


Normal hemoglobin
Primary structure
Val His Leu Thr Pro Glu Glu ...
1 2 3 4 5 6 7
Secondary and tertiary structures
β subunit
Quaternary structure
Normal hemoglobin (top view)
α β β α
Function
Molecules do not associate with one another; each carries oxygen.
10 μm
Red blood cell shape
Normal cells are full of individual hemoglobin molecules, each carrying oxygen.
Sickle-cell hemoglobin
Primary structure
Val His Leu Thr Pro Val Glu ...
1 2 3 4 5 6 7
Secondary and tertiary structures
Exposed hydrophobic region
β subunit
Quaternary structure
Sickle-cell hemoglobin
α β β α
Function
Molecules interact with one another to crystallize into a fiber; capacity to carry oxygen is greatly reduced.
10 μm
Red blood cell shape
Fibers of abnormal hemoglobin deform cell into sickle shape.

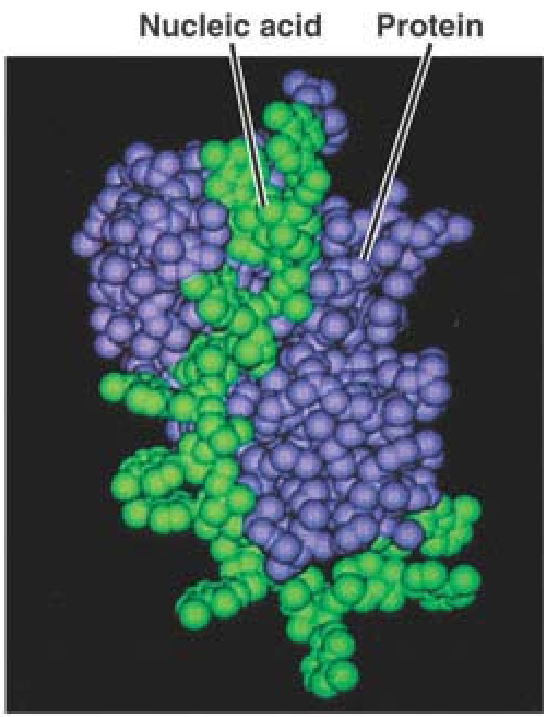

Denaturation
Normal protein
Denatured protein
Renaturation


Polypeptide
Correctly folded protein
Cap
Hollow cylinder
Chaperonin (fully assembled)
Steps of Chaperonin Action:
1 An unfolded polypeptide enters the cylinder from one end.
2 The cap attaches, causing the cylinder to change shape in such a way that it creates a hydrophilic environment for the folding of the polypeptide.
3 The cap comes off, and the properly folded protein is released.

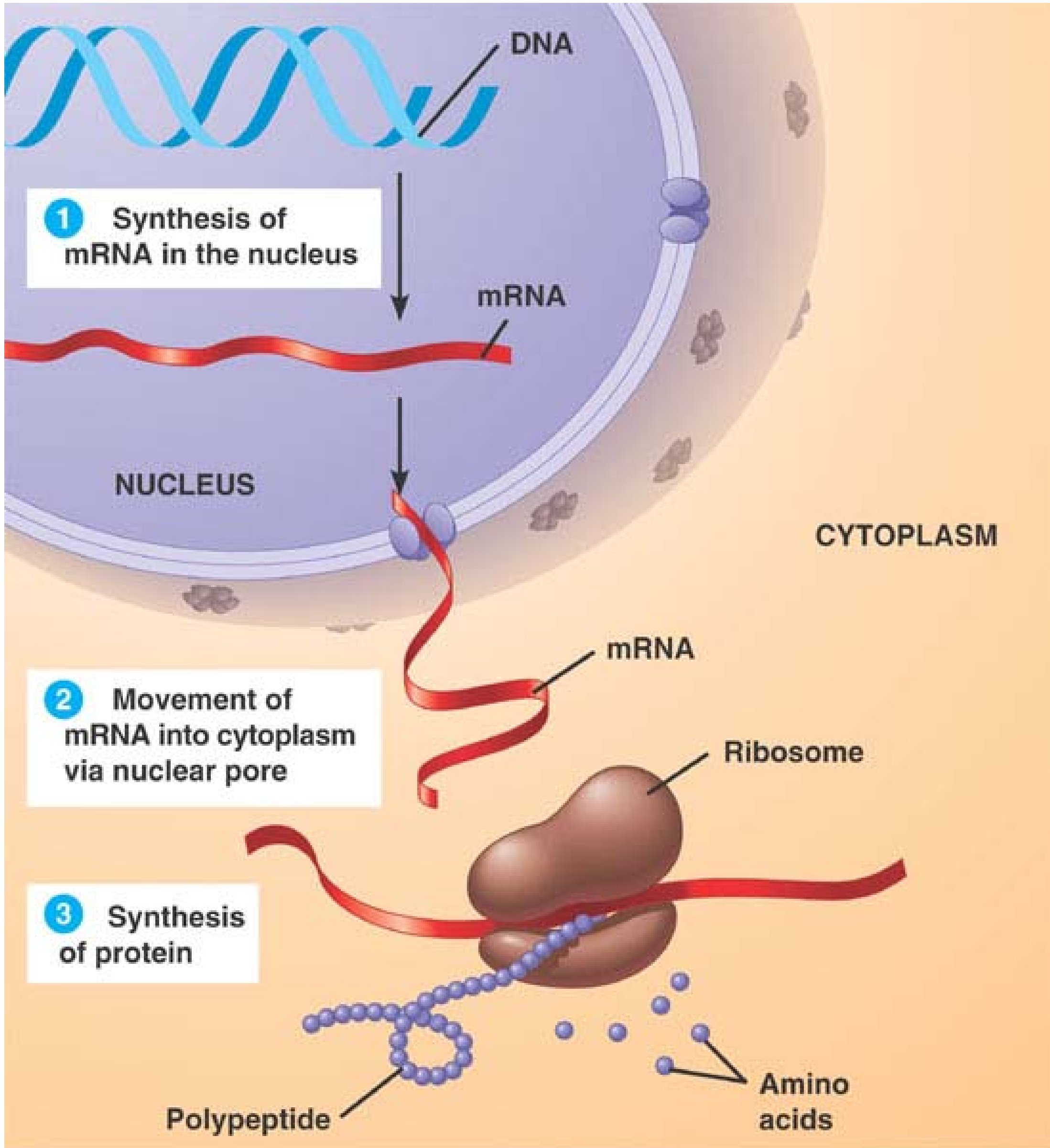


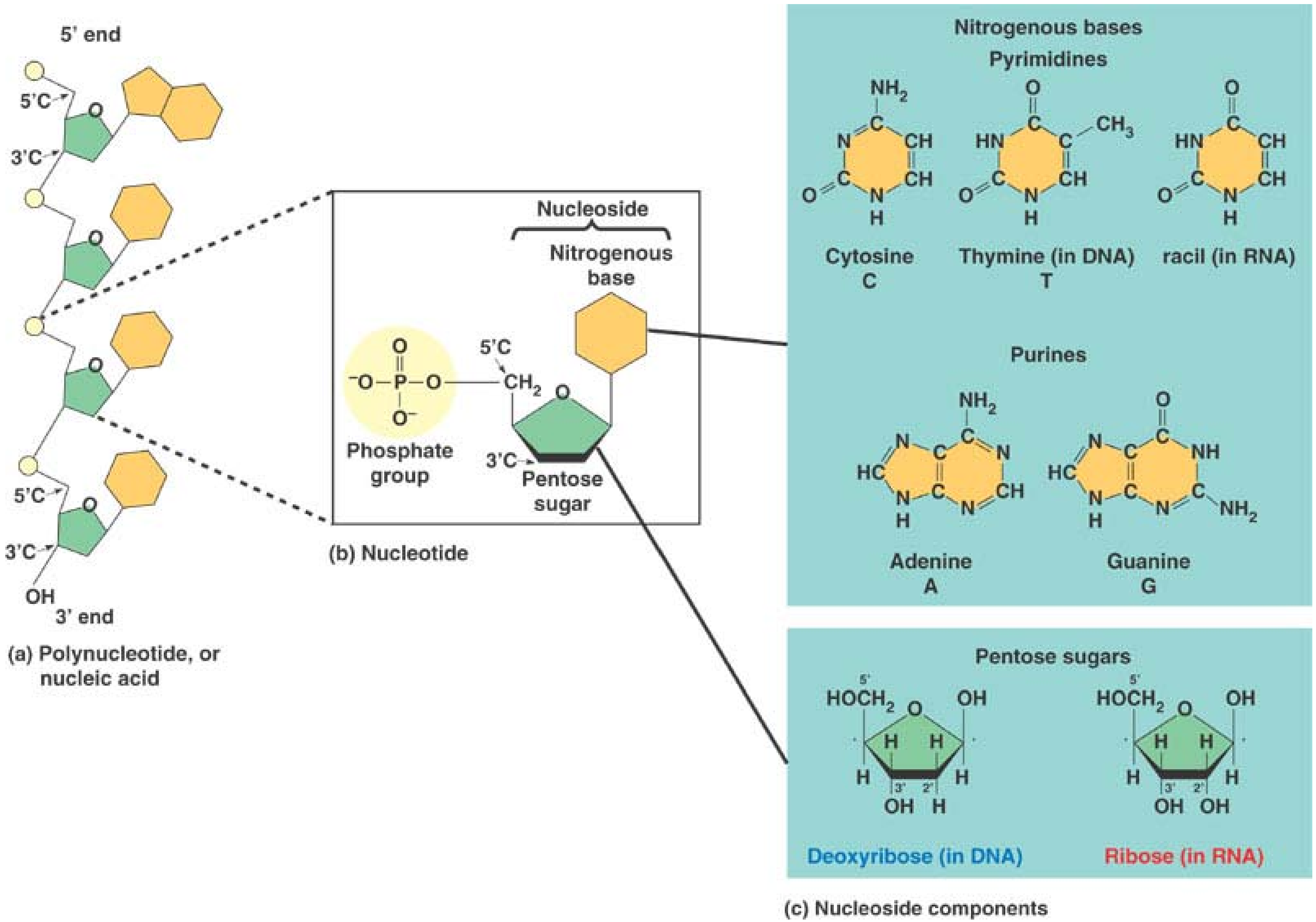


(a) X-ray diffraction pattern

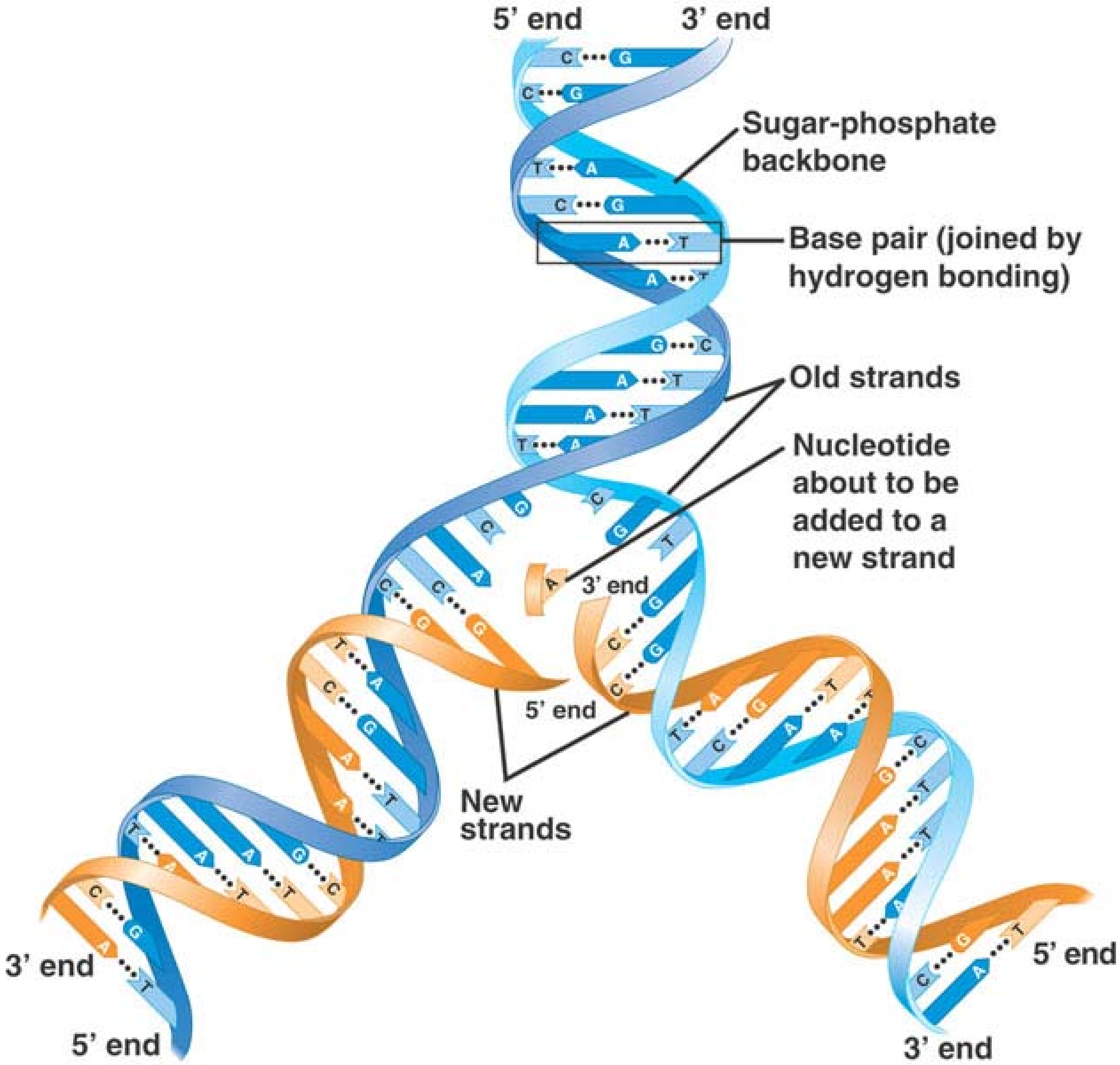


(b) 3D computer model


DNA
1 Synthesis of mRNA in the nucleus
mRNA
NUCLEUS
CYTOPLASM
mRNA
2 Movement of mRNA into cytoplasm via nuclear pore
Ribosome
3 Synthesis of protein
Polypeptide
Amino acids

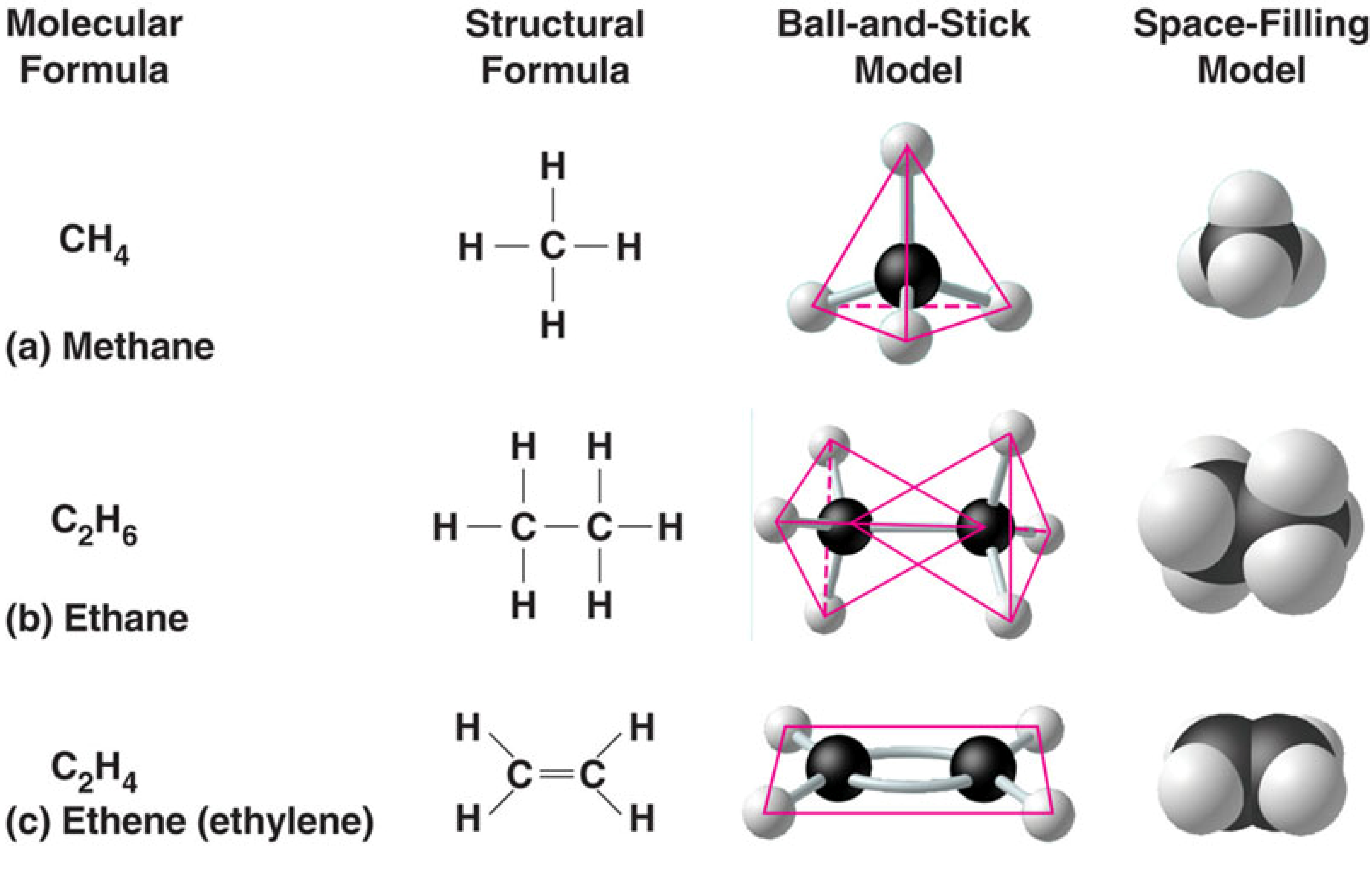


5' end
5'C
3'C
OH
3' end
(a) Polynucleotide, or nucleic acid
Nucleoside
Nitrogenous base
5'C
CH_2
O
3'C
Phosphate group
Pentose sugar
(b) Nucleotide
Nitrogenous bases
Pyrimidines
Cytosine C
Thymine (in DNA) T
racil (in RNA)
Purines
Adenine A
Guanine G
Pentose sugars
$HOCH_2$
OH
Deoxyribose (in DNA)
Ribose (in RNA)
(c) Nucleoside components

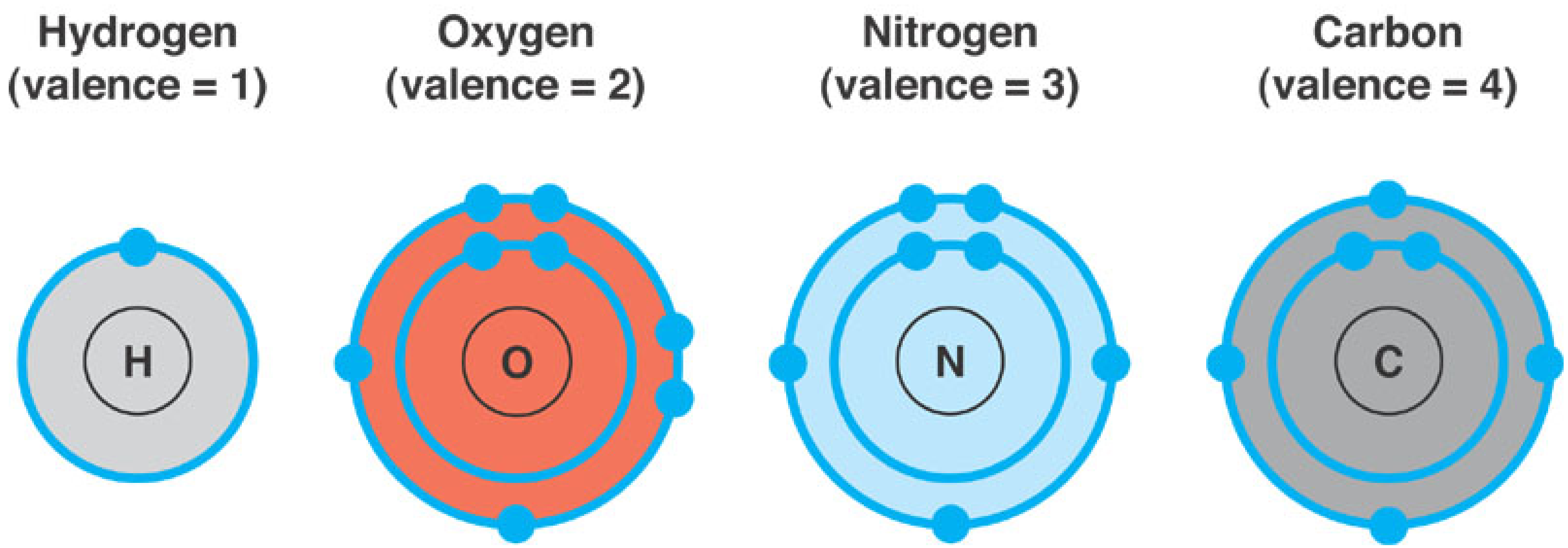


5’ end
3’ end
Sugar-phosphate backbone
Base pair (joined by hydrogen bonding)
Old strands
Nucleotide about to be added to a new strand
3’ end
5’ end
New strands
3’ end
5’ end
5’ end
3’ end

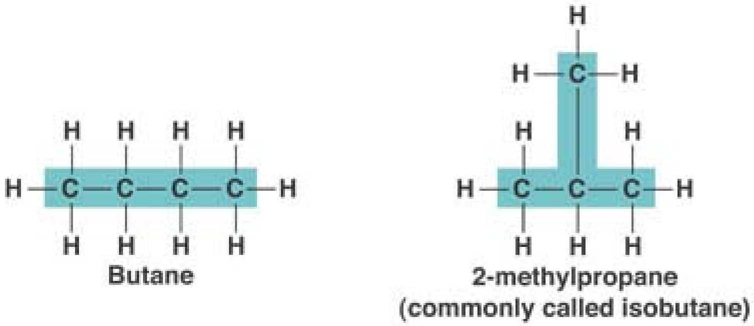
Chapter 4. Carbon and Molecular Diversity of Life



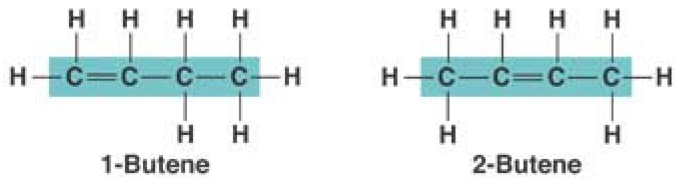
Molecular Formula
Structural Formula
Ball-and-Stick Model
Space-Filling Model
CH_4
(a) Methane
C_2H_6
(b) Ethane
C_2H_4
(c) Ethene (ethylene)


Hydrogen
(valence = 1)
Oxygen
(valence = 2)
Nitrogen
(valence = 3)
Carbon
(valence = 4)
H
O
N
C

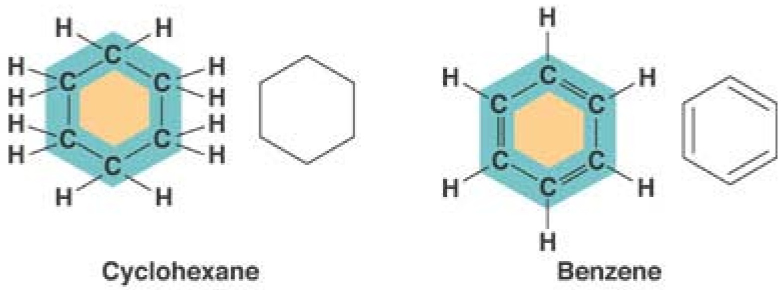
(a) Length



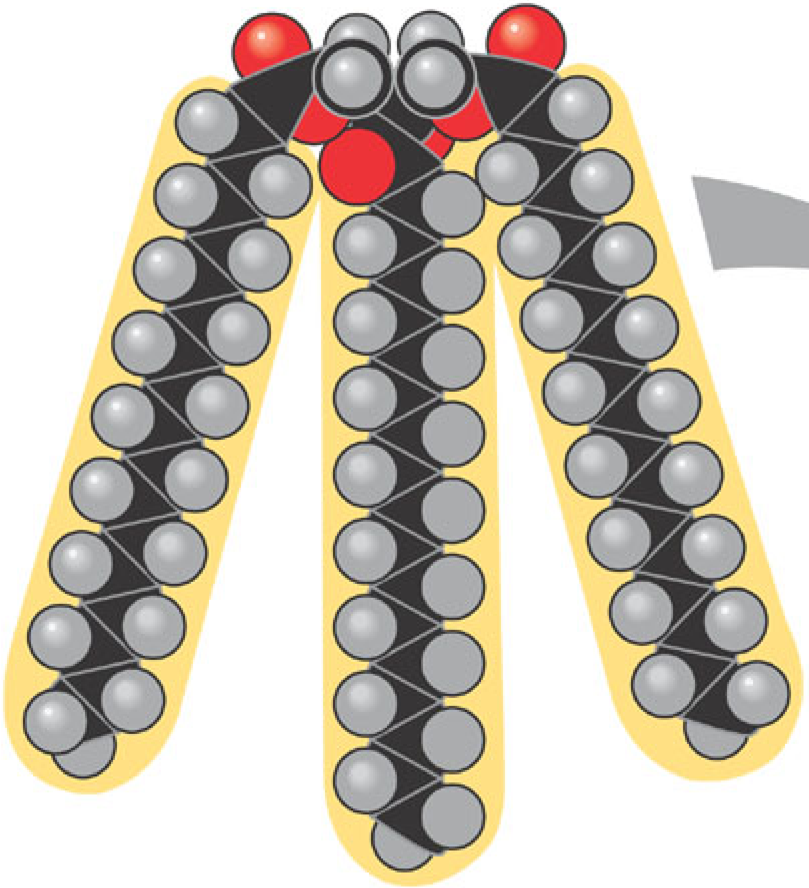
(b) Branching



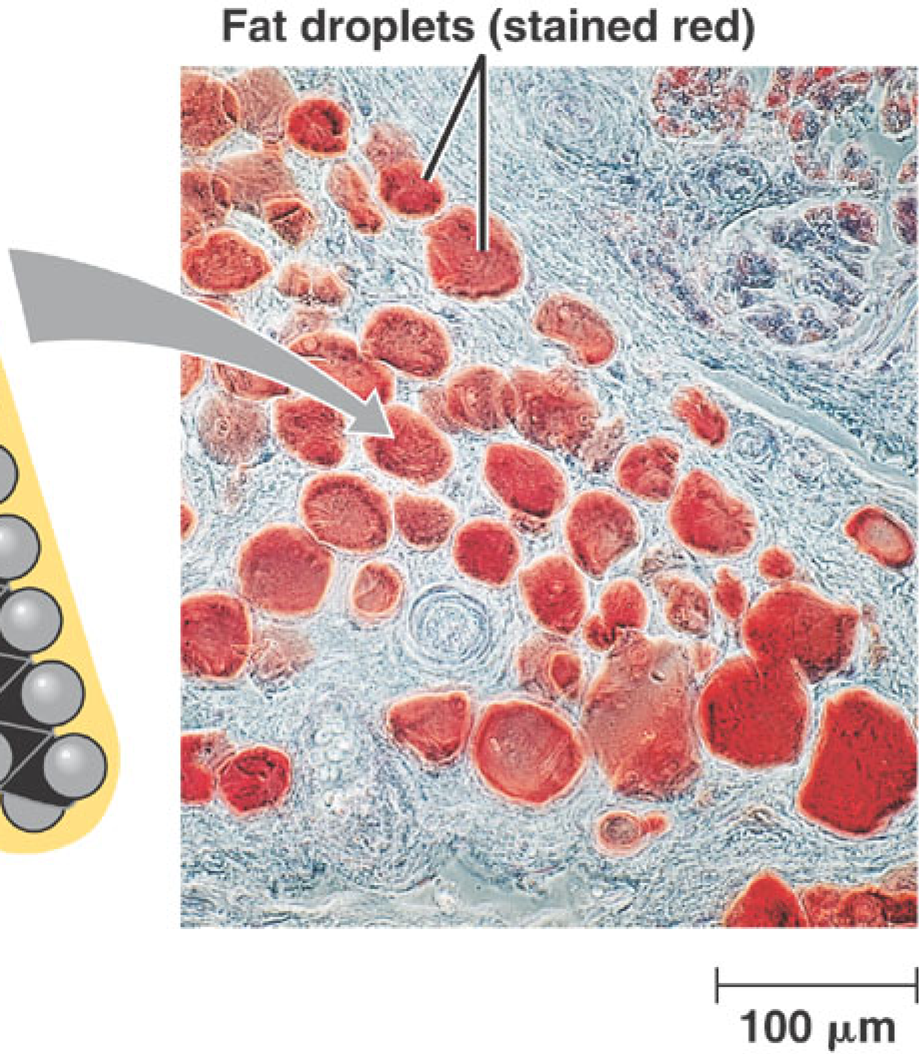
(c) Double bonds



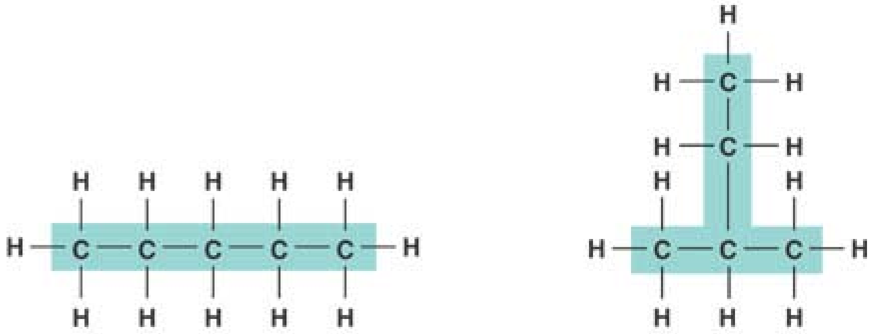
(d) Rings



(a) A fat molecule

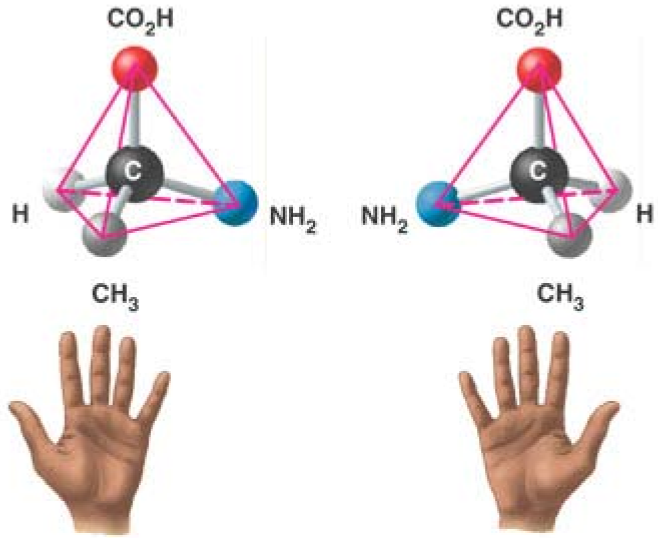


(b) Mammalian adipose cells

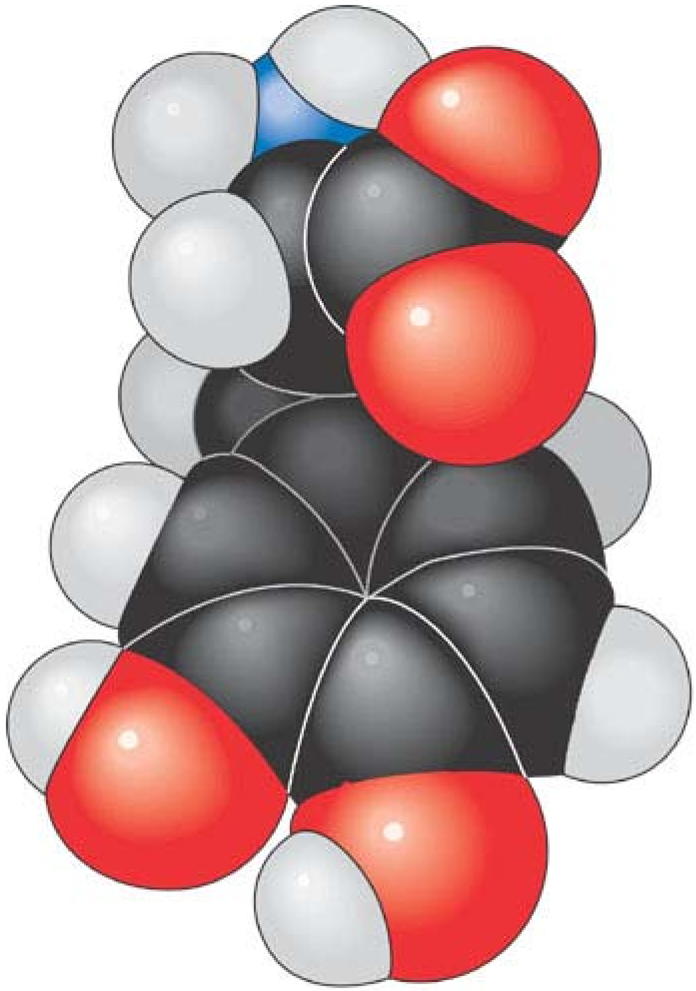


(a) Structural isomers

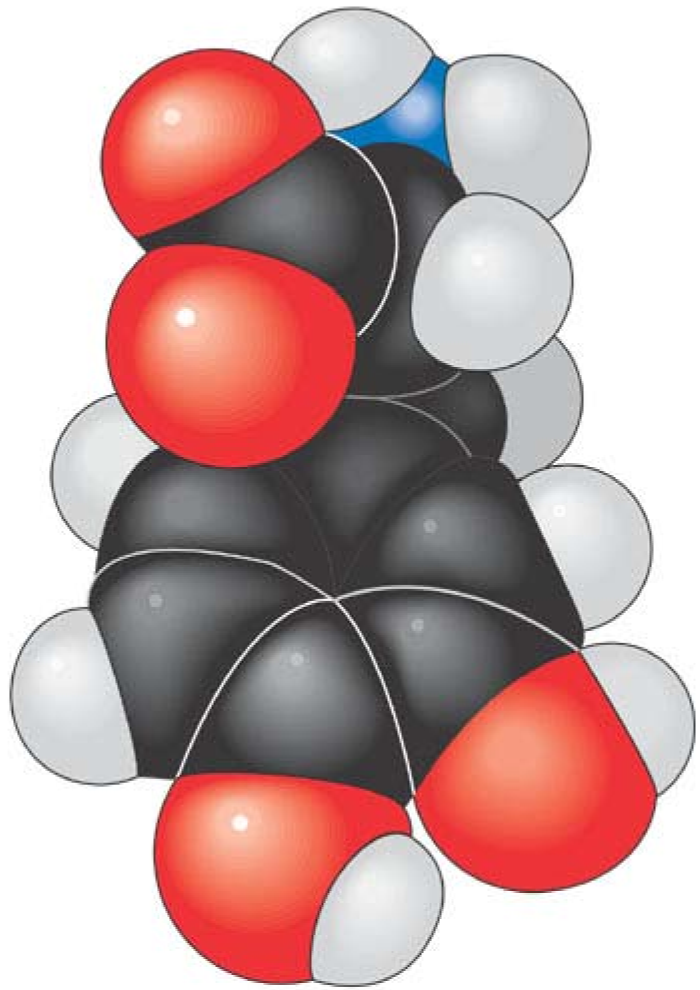
(b) Geometric isomers



(c) Enantiomers



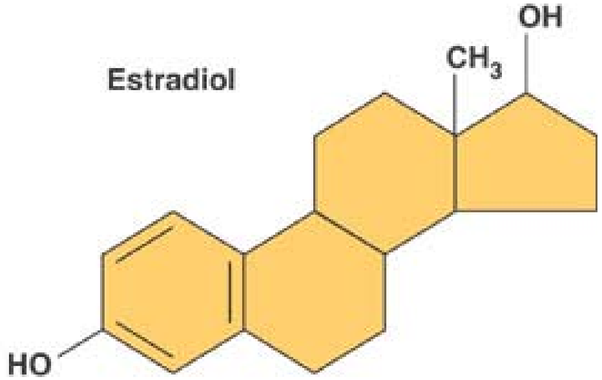
L-Dopa
(effective against
Parkinson's disease)

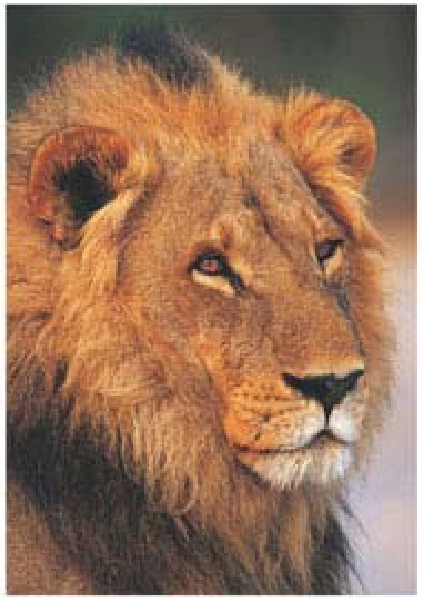


D-Dopa
(biologically
inactive)

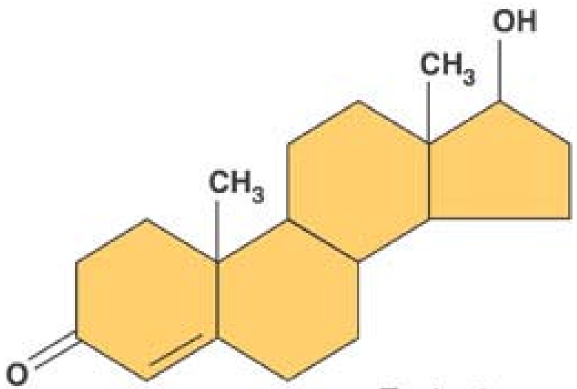
Female lion

Estradiol





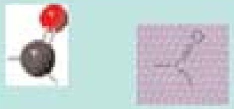
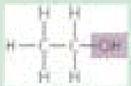
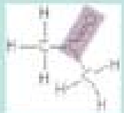
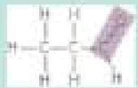
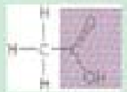
Male lion

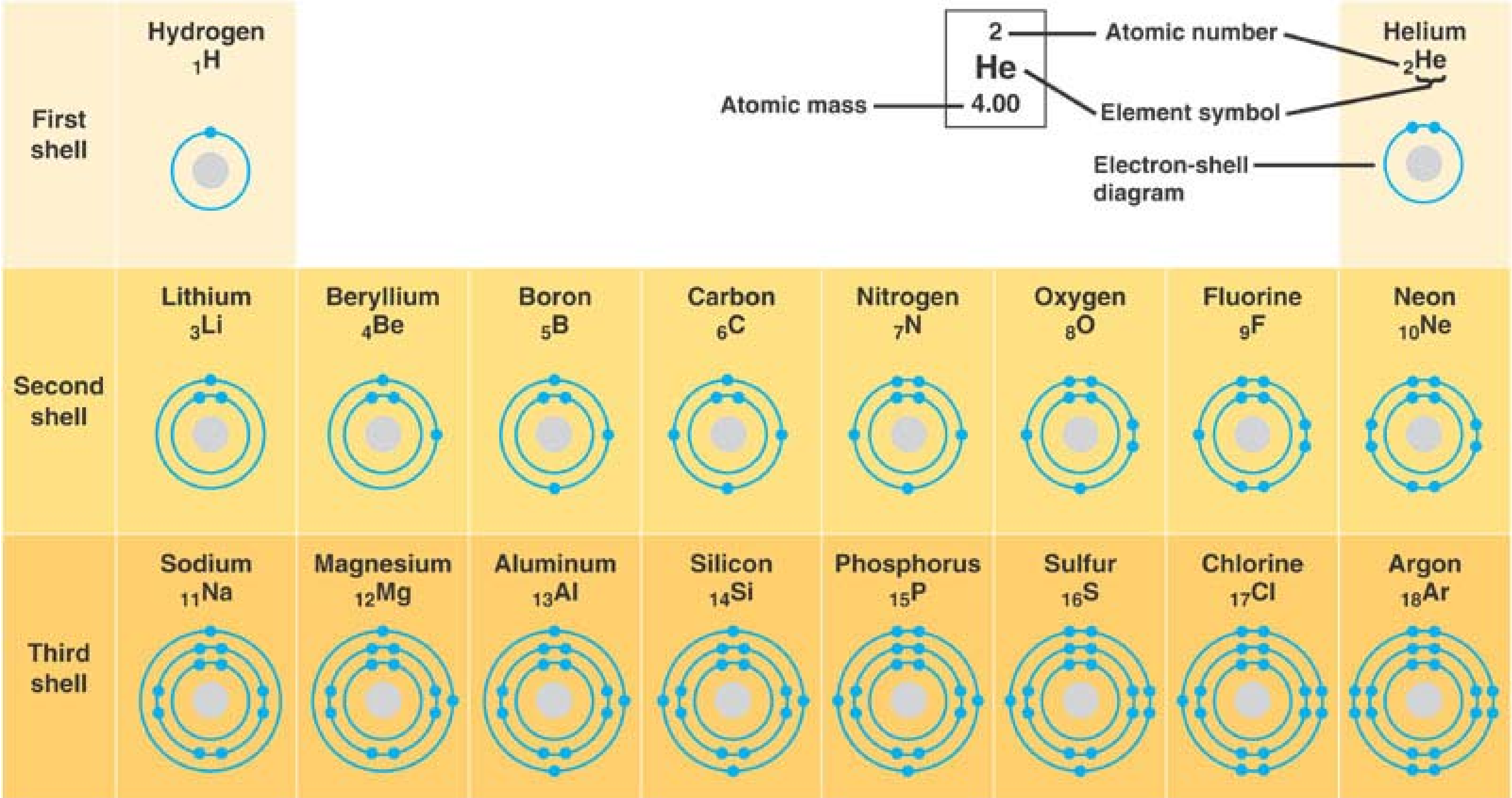


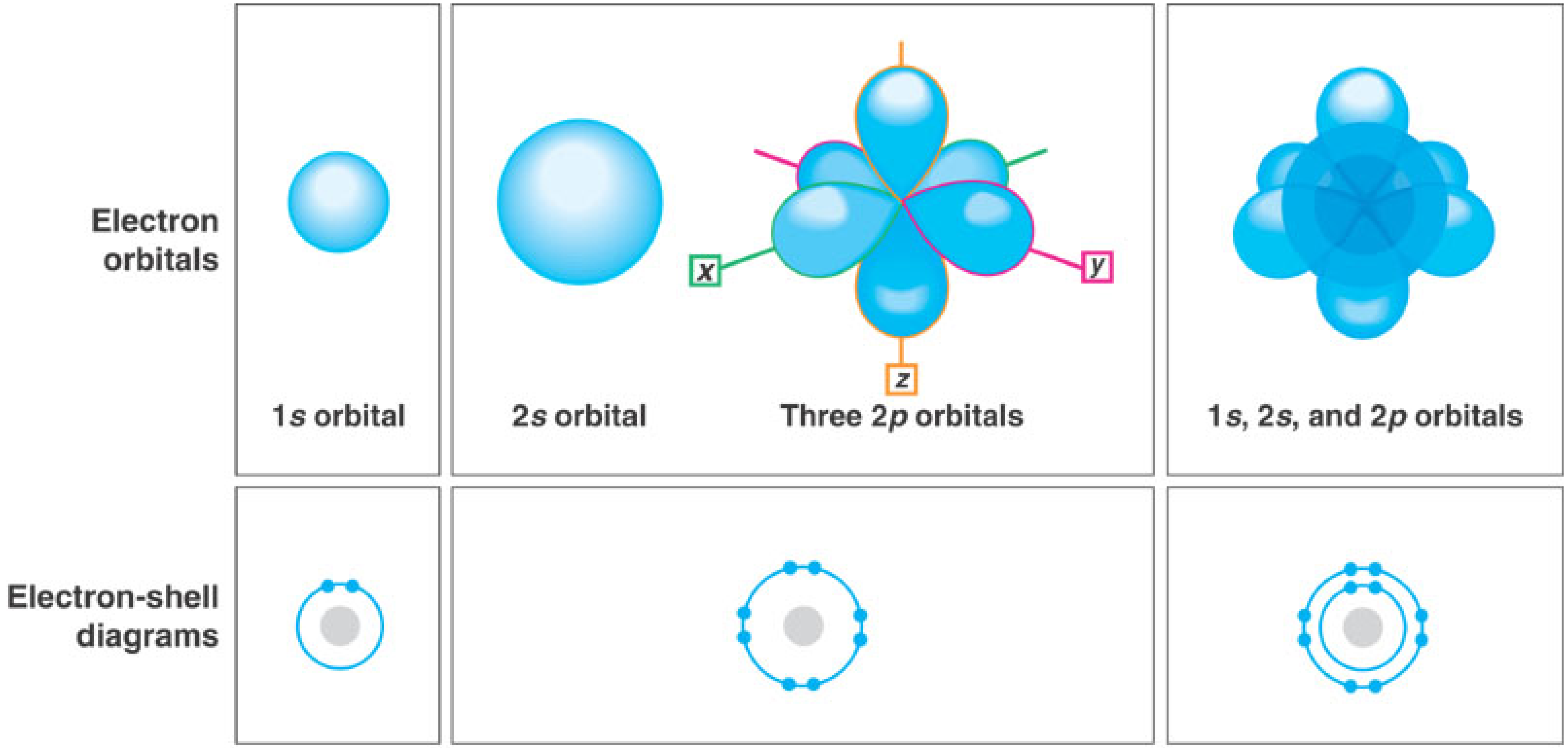
Testosterone

Figure 4.10

Exploring Some Important Functional Groups of Organic Compounds

FUNCTIONAL GROUP	HYDROXYL	CARBONYL	CARBOXYL
STRUCTURE	 In a **hydroxyl group** (—OH), a hydrogen atom is bonded to an oxygen atom, which in turn is bonded to the carbon skeleton of the organic molecule. (Do not confuse this functional group with the hydroxide ion, OH^-.)	 The **carbonyl group** (>CO) consists of a carbon atom joined to an oxygen atom by a double bond.	 When an oxygen atom is double-bonded to a carbon atom that is also bonded to a hydroxyl group, the entire assembly of atoms is called a **carboxyl group** (—COOH).
NAME OF COMPOUNDS	**Alcohols** (their specific names usually end in -ol)	**Ketones** if the carbonyl group is within a carbon skeleton **Aldehydes** if the carbonyl group is at the end of the carbon skeleton	**Carboxylic acids**, or organic acids
EXAMPLE	 **Ethanol**, the alcohol present in alcoholic beverages	 **Acetone**, the simplest ketone  **Propanal**, an aldehyde	 **Acetic acid**, which gives vinegar its sour taste
FUNCTIONAL PROPERTIES	► Is polar as a result of the electronegative oxygen atom drawing electrons toward itself. ► Attracts water molecules, helping dissolve organic compounds such as sugars (see Figure 5.3).	► A ketone and an aldehyde may be structural isomers with different properties, as is the case for acetone and propanal.	► Has acidic properties because it is a source of hydrogen ions. ► The covalent bond between oxygen and hydrogen is so polar that hydrogen ions (H^+) tend to dissociate reversibly; for example,  ► In cells, found in the ionic form, which is called a carboxylate group.

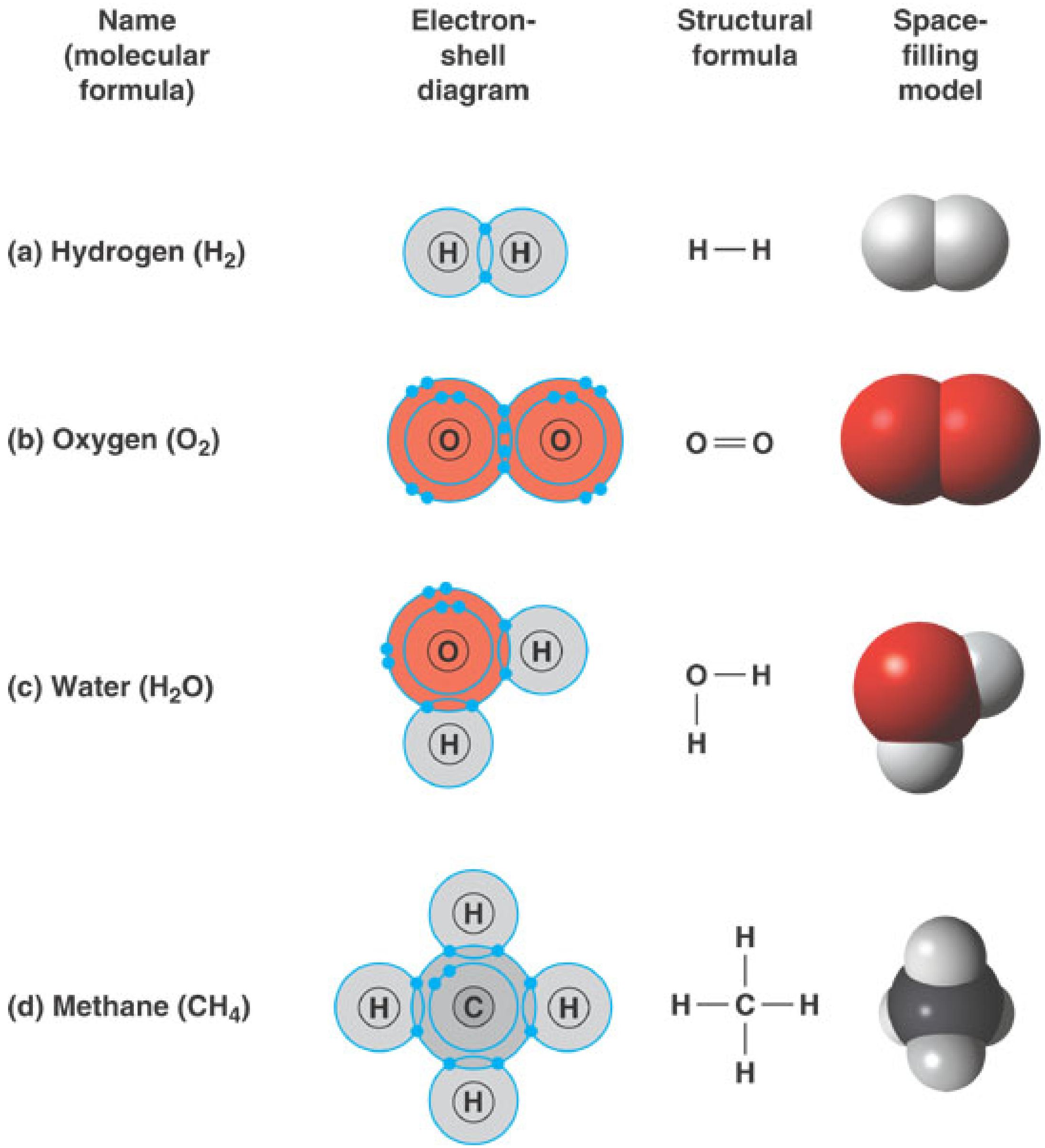

First shell
Second shell
Third shell
Hydrogen
1H
2
He
4.00
Atomic number
Atomic mass
Element symbol
Electron-shell diagram
Helium
2He
Lithium
3Li
Beryllium
4Be
Boron
5B
Carbon
6C
Nitrogen
7N
Oxygen
8O
Fluorine
9F
Neon
10Ne
Sodium
11Na
Magnesium
12Mg
Aluminum
13Al
Silicon
14Si
Phosphorus
15P
Sulfur
16S
Chlorine
17Cl
Argon
18Ar

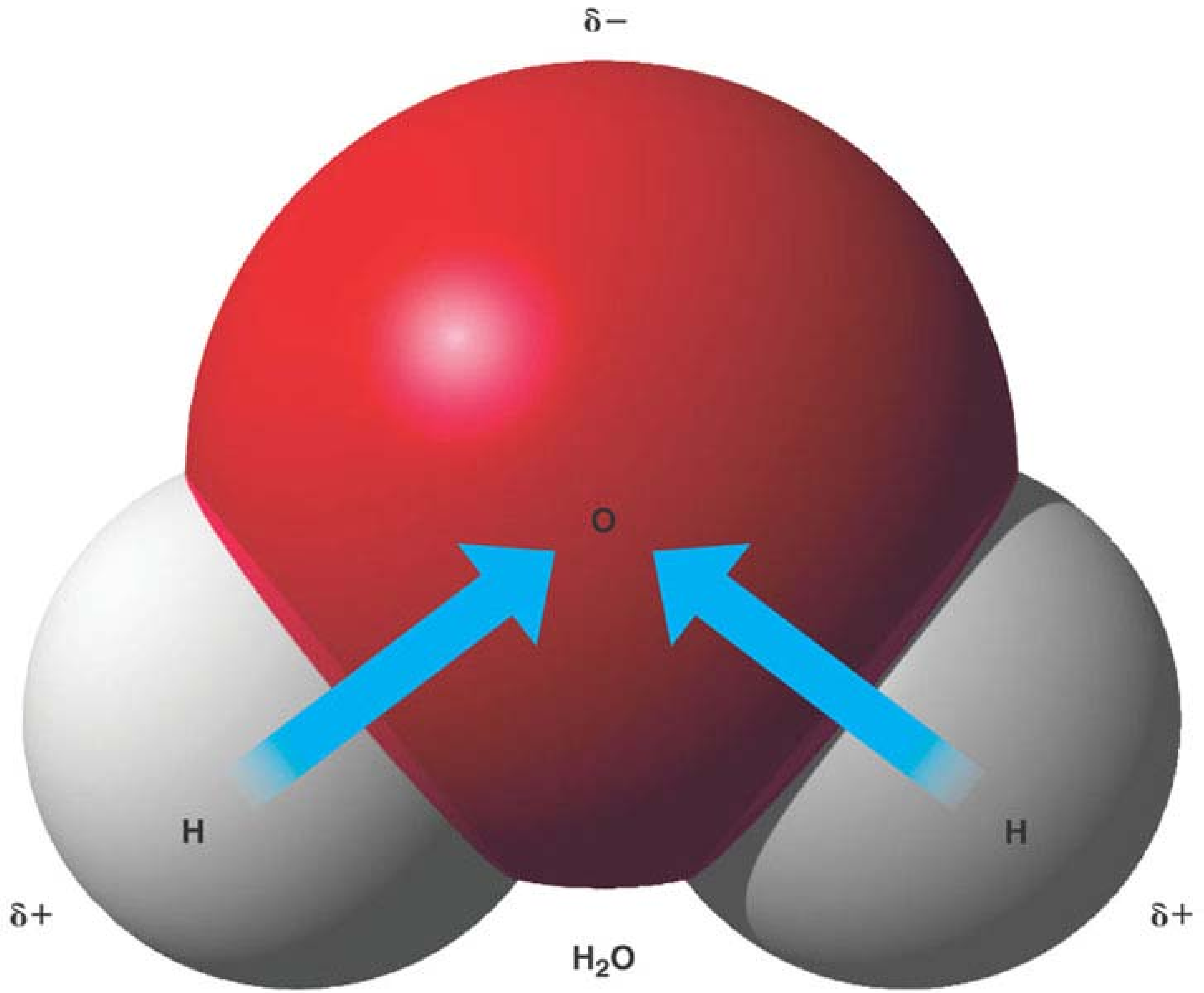


(a) First shell (maximum 2 electrons)

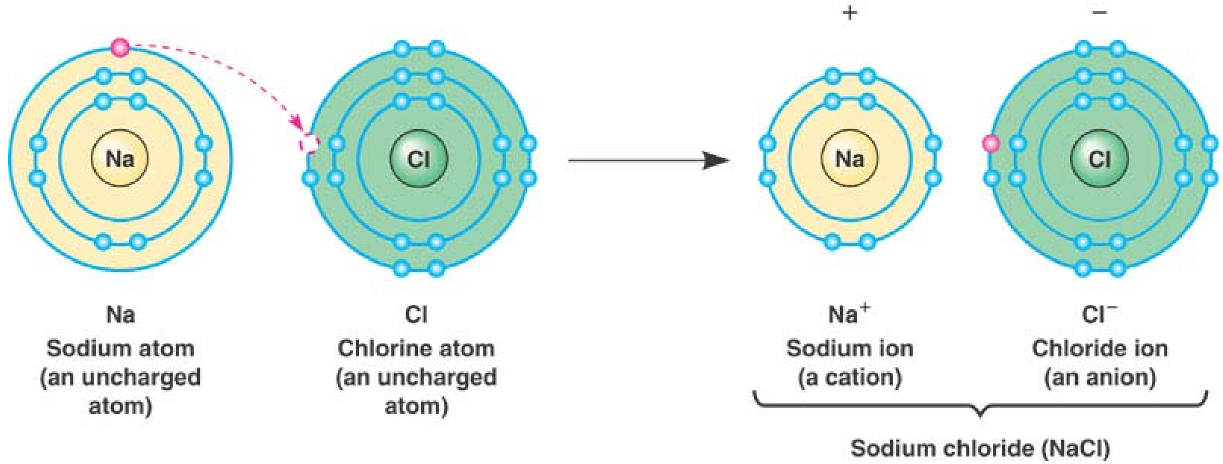
(b) Second shell (maximum 8 electrons)

(c) Neon, with two filled shells (10 electrons)

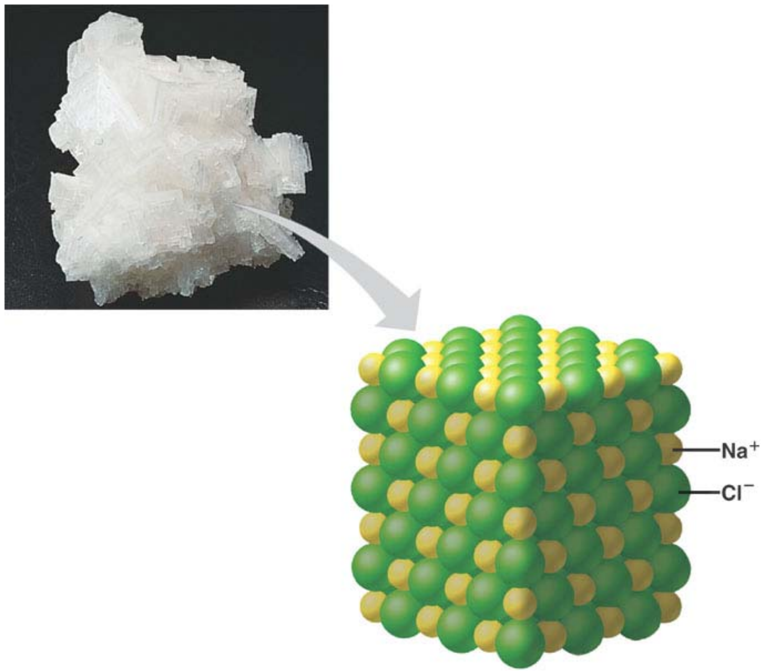

Name (molecular formula)
Electron-shell diagram
Structural formula
Space-filling model
(a) Hydrogen (H_2)
H H
H — H
(b) Oxygen (O_2)
O O
O ═ O
(c) Water (H_2O)
O H H
O — H
H
(d) Methane (CH_4)
H H C H H
H — C — H
H
H



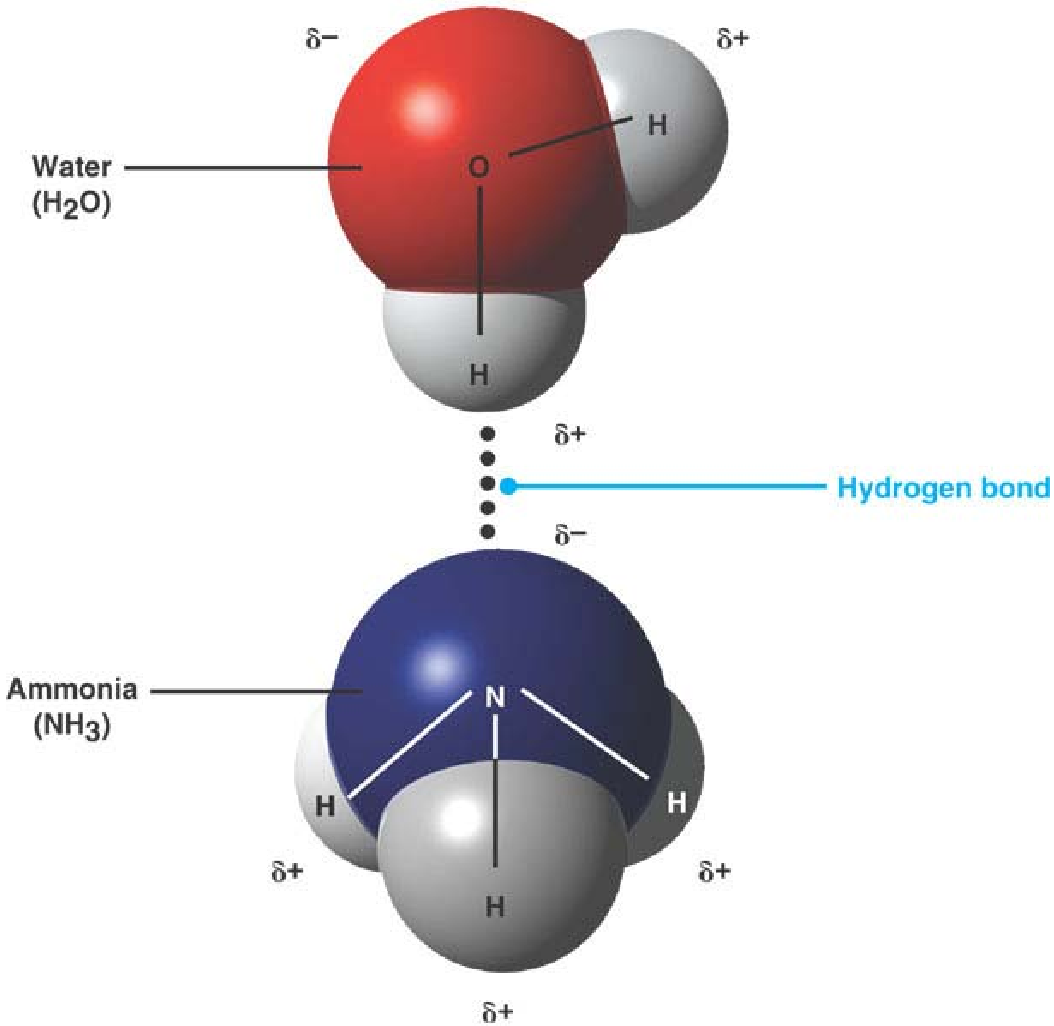
δ−
O
H
H
δ+
δ+
H_2O



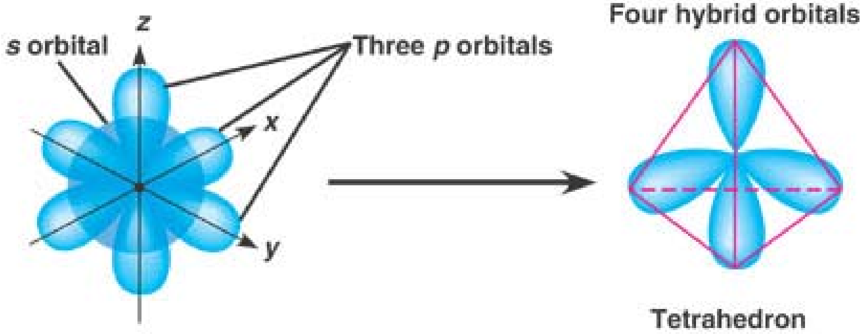
Na
Cl
+
−
Na
Cl
Na
Sodium atom
(an uncharged
atom)
Cl
Chlorine atom
(an uncharged
atom)
Na^+
Sodium ion
(a cation)
Cl^-
Chloride ion
(an anion)
Sodium chloride (NaCl)



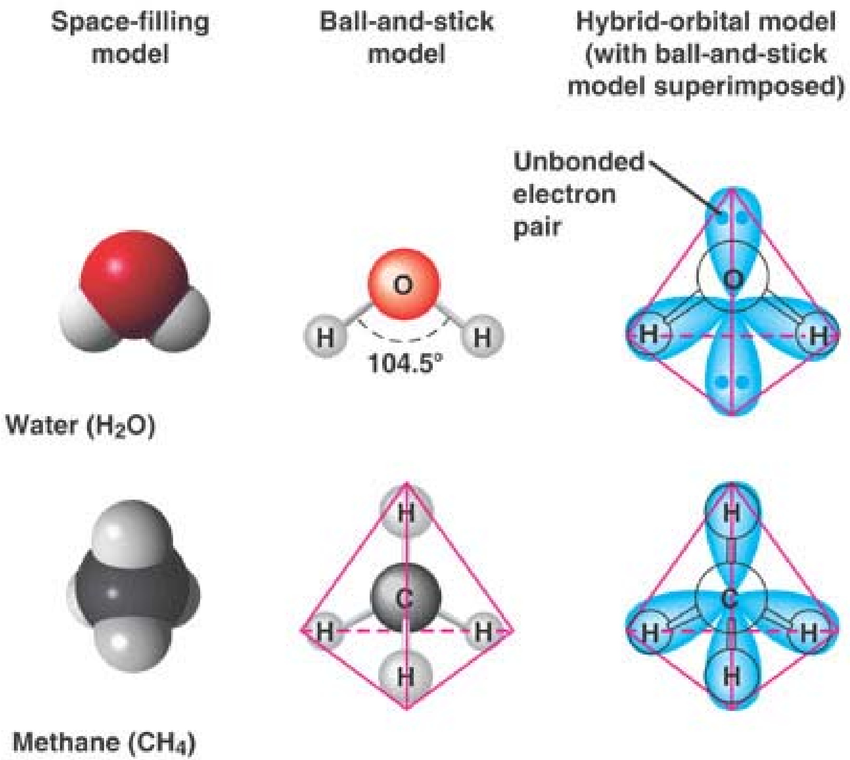
Na^+
Cl^-



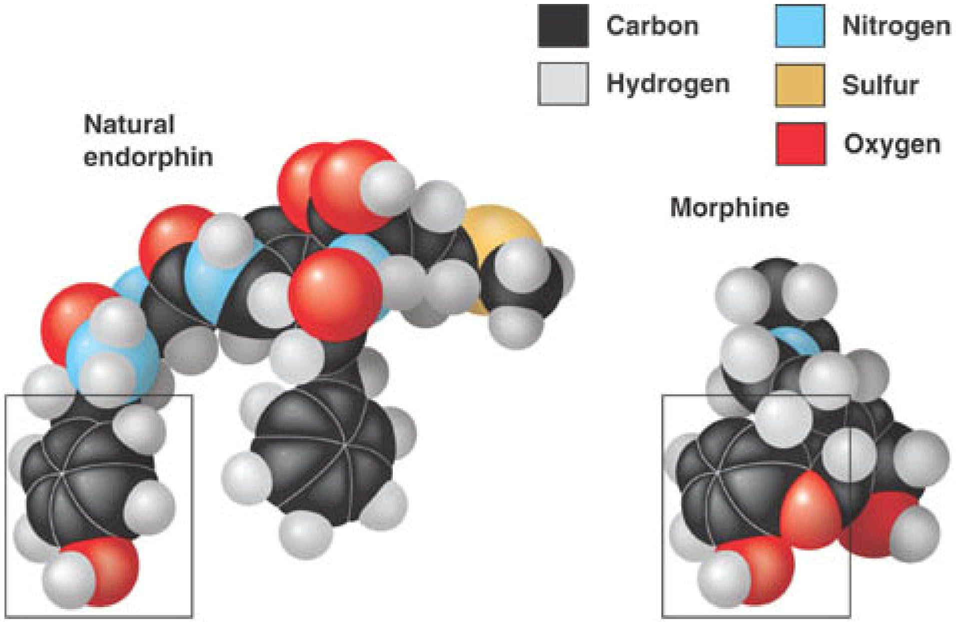
δ−
δ+
Water
(H_2O)
O
H
H
δ+
Hydrogen bond
δ−
Ammonia
(NH_3)
N
H
H
H
δ+
δ+
δ+



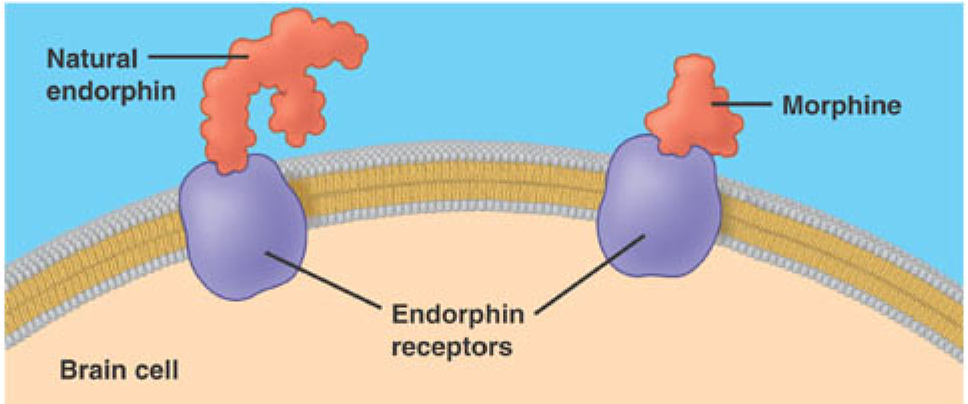
(a) Hybridization of orbitals



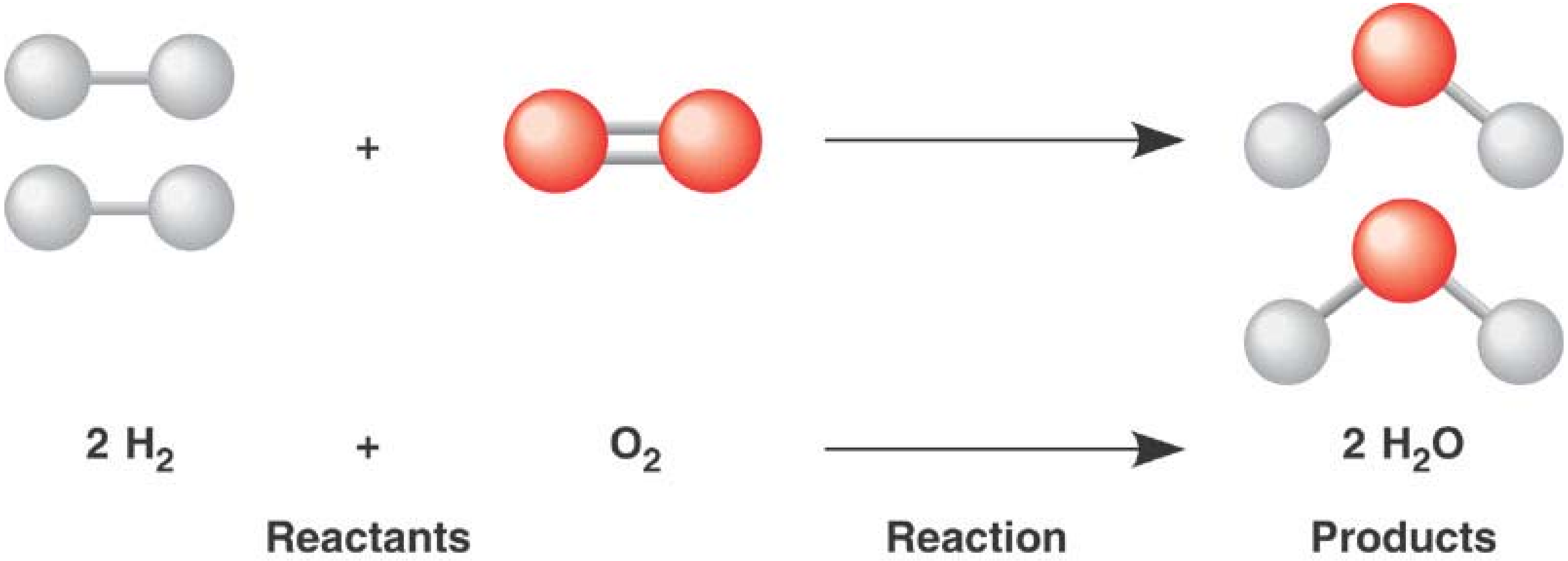
(b) Molecular shape models

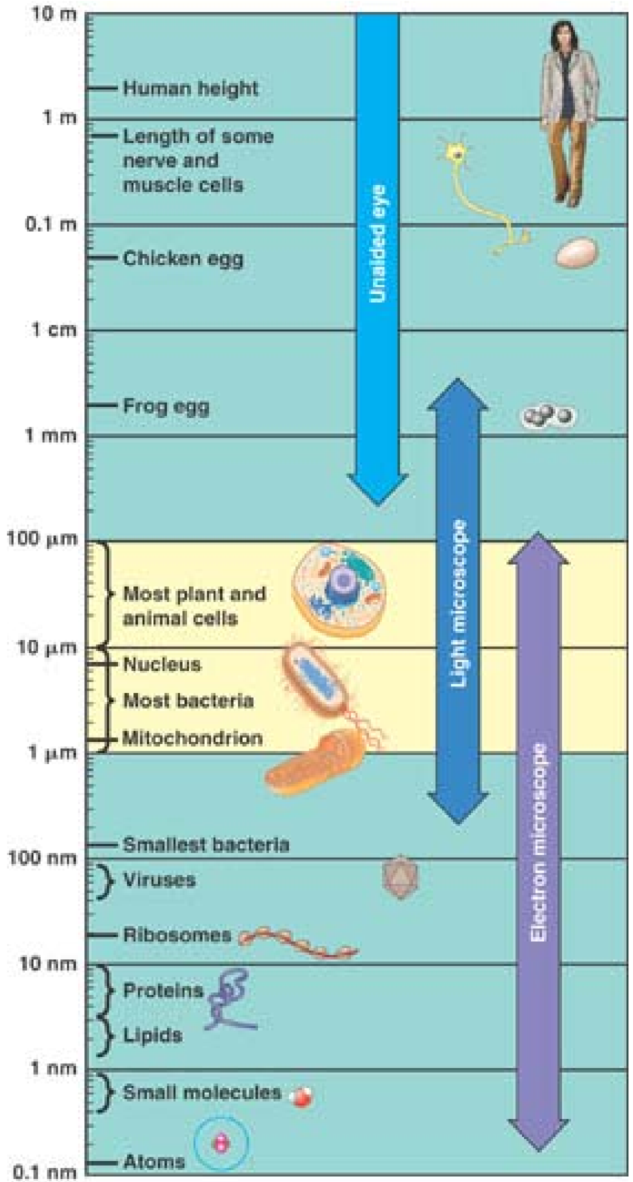


(a) Structures of endorphin and morphine

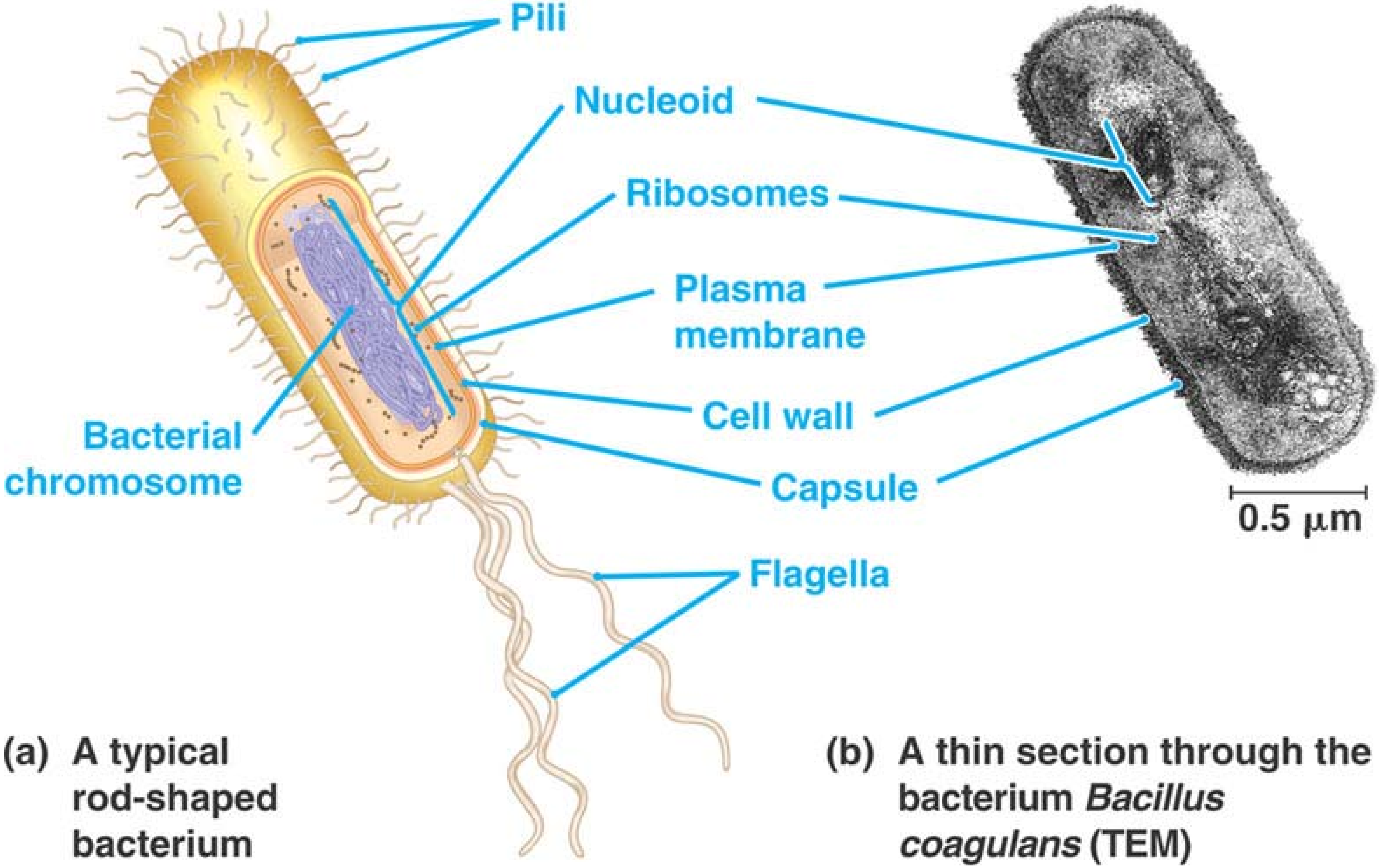


(b) Binding to endorphin receptors


2 H2 + O2 → 2 H2O
Reactants
Reaction
Products

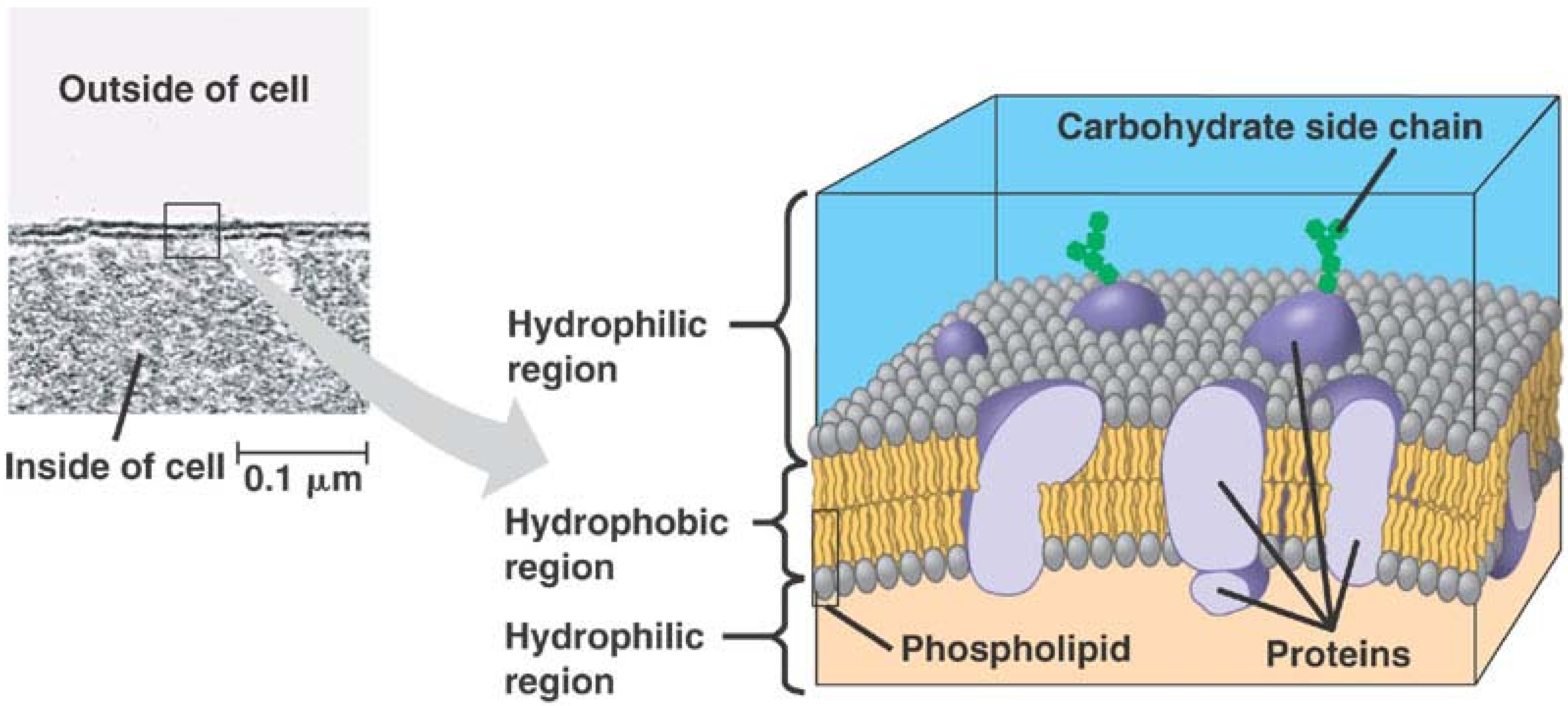


Measurements
1 centimeter (cm) = 10^{-2} meter (m) = 0.4 inch
1 millimeter (mm) = 10^{-3} m
1 micrometer (µm) = 10^{-3} mm = 10^{-6} m
1 nanometer (nm) = 10^{-3} µm = 10^{-9} m

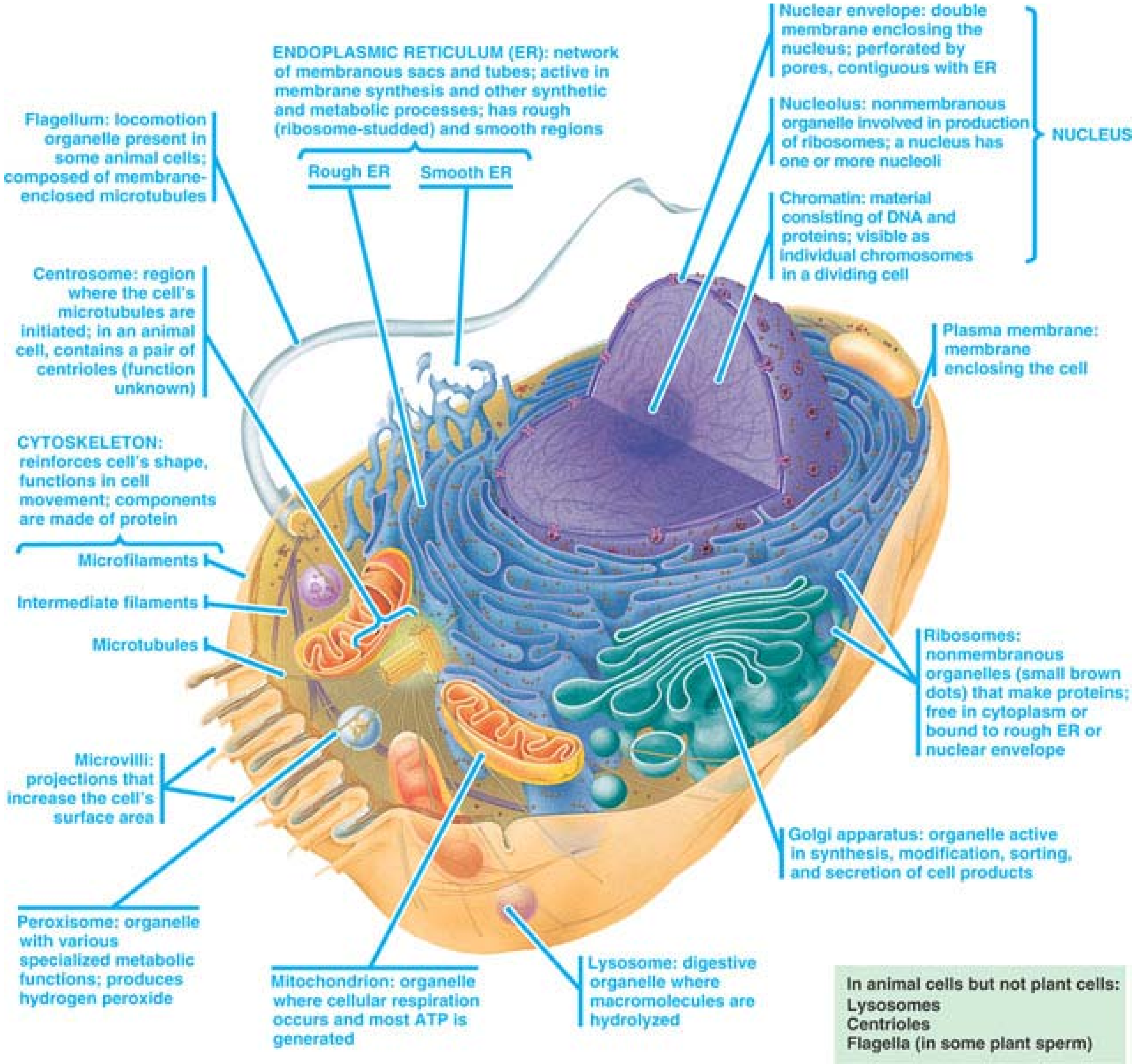


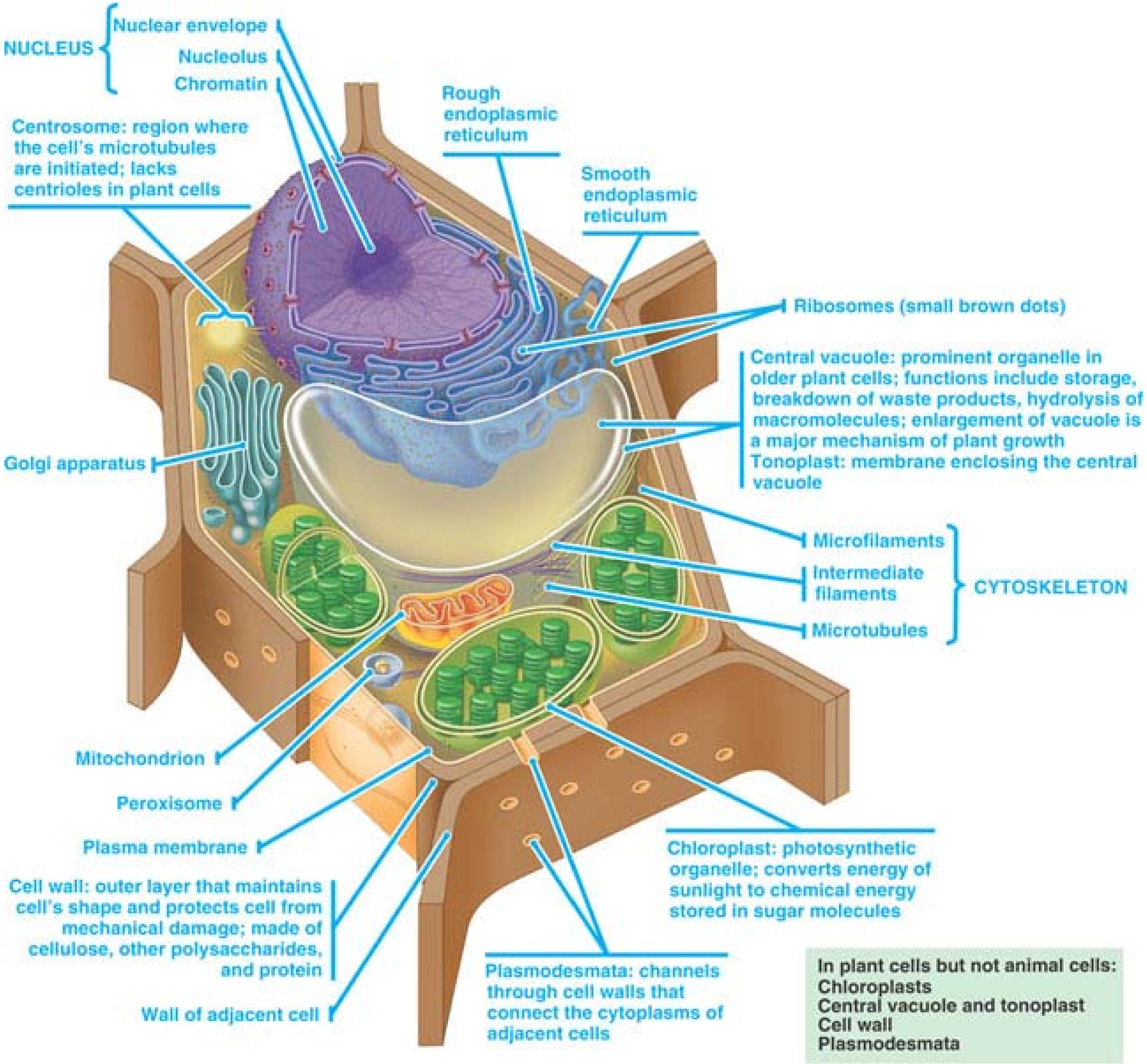
(a) A typical rod-shaped bacterium

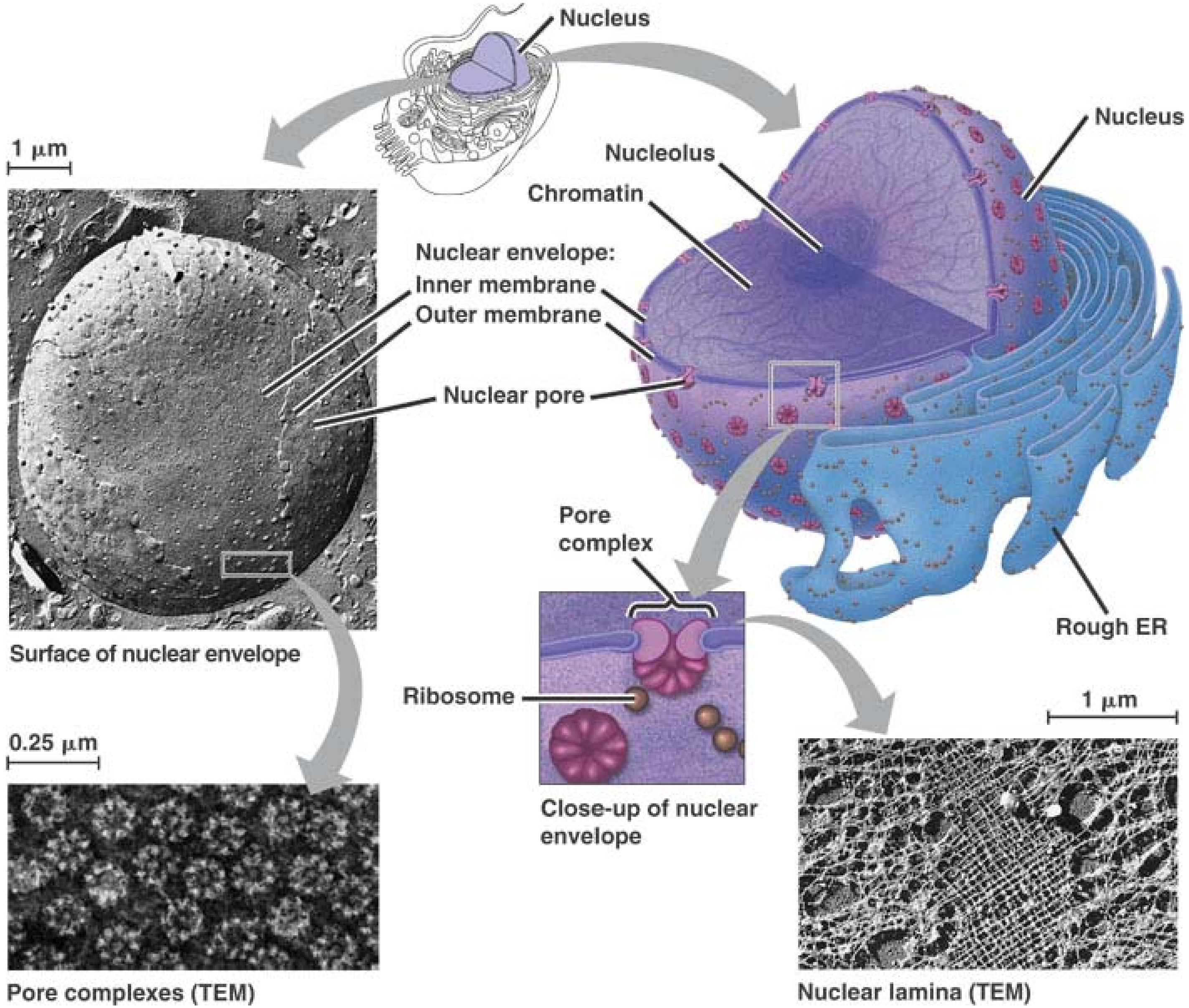
(b) A thin section through the bacterium *Bacillus coagulans* (TEM)



(a) TEM of a plasma membrane (b) Structure of the plasma membrane


ENDOPLASMIC RETICULUM (ER): network of membranous sacs and tubes; active in membrane synthesis and other synthetic and metabolic processes; has rough (ribosome-studded) and smooth regions
Rough ER
Smooth ER
Nuclear envelope: double membrane enclosing the nucleus; perforated by pores, contiguous with ER
Nucleolus: nonmembranous organelle involved in production of ribosomes; a nucleus has one or more nucleoli
Chromatin: material consisting of DNA and proteins; visible as individual chromosomes in a dividing cell
NUCLEUS
Flagellum: locomotion organelle present in some animal cells; composed of membrane-enclosed microtubules
Centrosome: region where the cell's microtubules are initiated; in an animal cell, contains a pair of centrioles (function unknown)
CYTOSKELETON: reinforces cell's shape, functions in cell movement; components are made of protein
Microfilaments
Intermediate filaments
Microtubules
Plasma membrane: membrane enclosing the cell
Ribosomes: nonmembranous organelles (small brown dots) that make proteins; free in cytoplasm or bound to rough ER or nuclear envelope
Microvilli: projections that increase the cell's surface area
Golgi apparatus: organelle active in synthesis, modification, sorting, and secretion of cell products
Peroxisome: organelle with various specialized metabolic functions; produces hydrogen peroxide
Mitochondrion: organelle where cellular respiration occurs and most ATP is generated
Lysosome: digestive organelle where macromolecules are hydrolyzed
In animal cells but not plant cells:
Lysosomes
Centrioles
Flagella (in some plant sperm)


NUCLEUS
Nuclear envelope
Nucleolus
Chromatin
Centrosome: region where the cell's microtubules are initiated; lacks centrioles in plant cells
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes (small brown dots)
Central vacuole: prominent organelle in older plant cells; functions include storage, breakdown of waste products, hydrolysis of macromolecules; enlargement of vacuole is a major mechanism of plant growth
Tonoplast: membrane enclosing the central vacuole
Golgi apparatus
Microfilaments
Intermediate filaments
Microtubules
CYTOSKELETON
Mitochondrion
Peroxisome
Plasma membrane
Cell wall: outer layer that maintains cell's shape and protects cell from mechanical damage; made of cellulose, other polysaccharides, and protein
Wall of adjacent cell
Plasmodesmata: channels through cell walls that connect the cytoplasms of adjacent cells
Chloroplast: photosynthetic organelle; converts energy of sunlight to chemical energy stored in sugar molecules
In plant cells but not animal cells:
Chloroplasts
Central vacuole and tonoplast
Cell wall
Plasmodesmata


Nucleus
Nucleus
1 µm
Nucleolus
Chromatin
Nuclear envelope:
Inner membrane
Outer membrane
Nuclear pore
Surface of nuclear envelope
Pore
complex
Rough ER
Ribosome
1 µm
0.25 µm
Close-up of nuclear
envelope
Pore complexes (TEM)
Nuclear lamina (TEM)