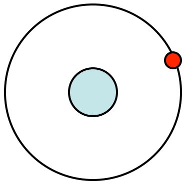
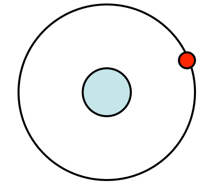
Bio 11

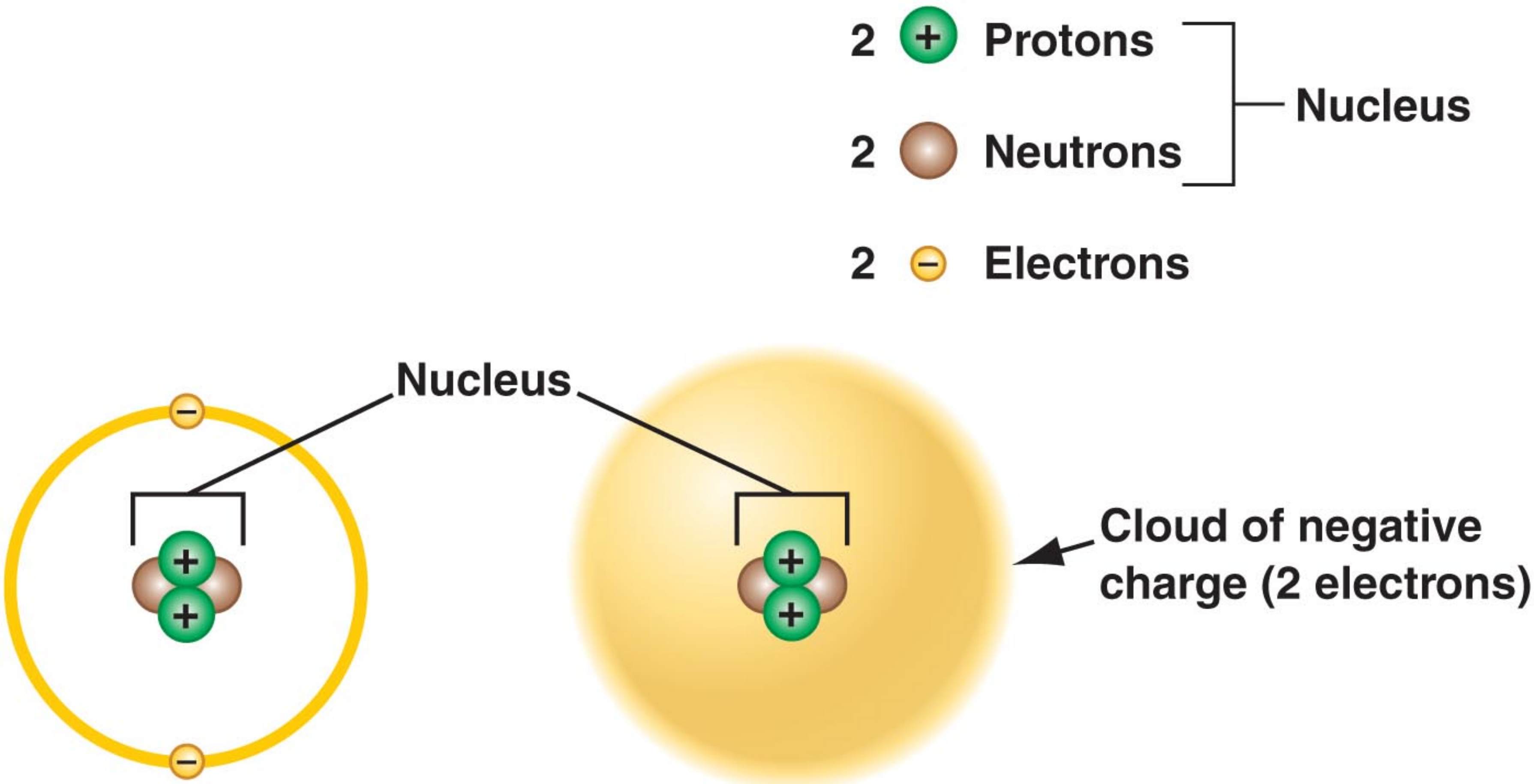
Chemistry



The Atom

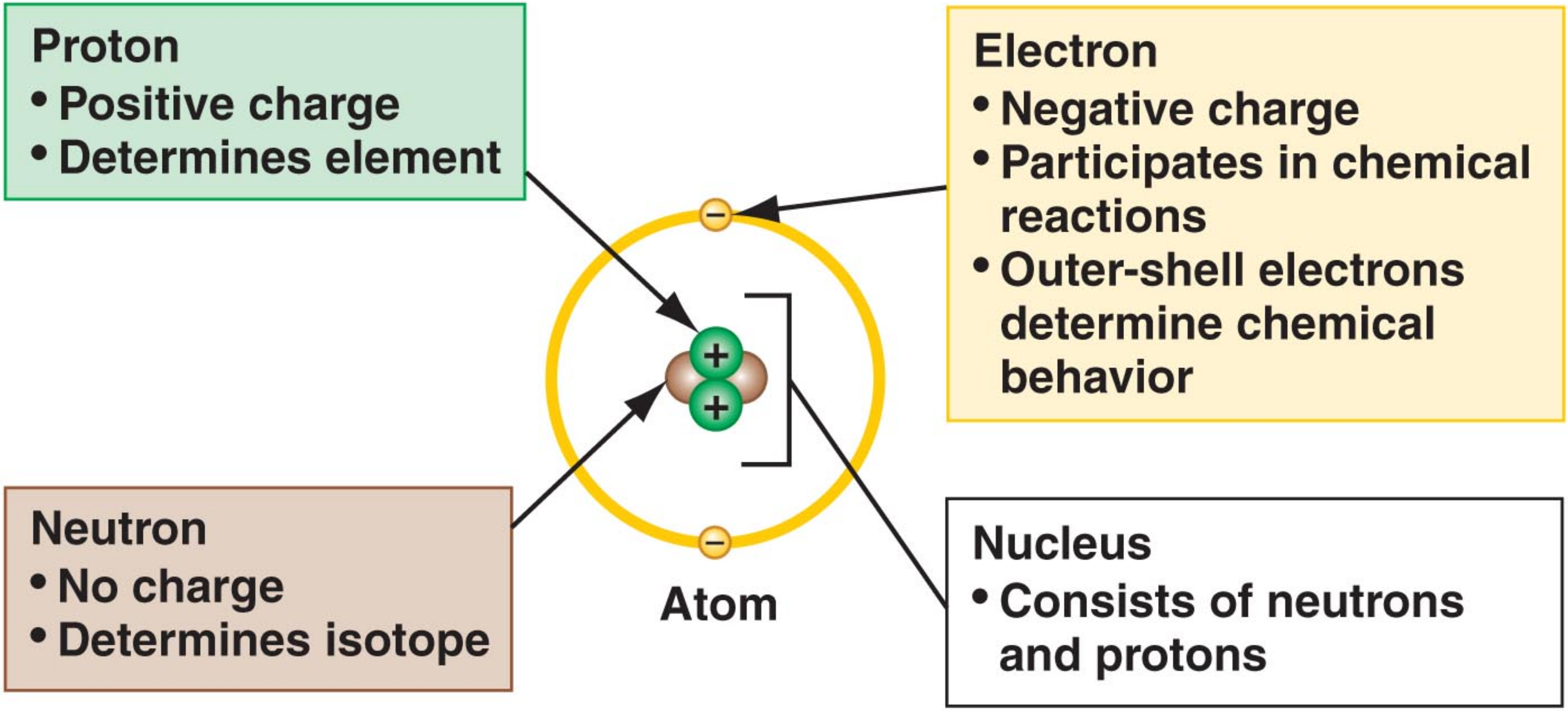


- The atom is the basic component of a molecule.
- It is composed of a nucleus which has positively charged protons and neutral neutrons.
- Orbiting around the nucleus are the electrons


2 Protons
2 Neutrons
Nucleus
2 Electrons
Nucleus
Cloud of negative charge (2 electrons)

Definitions

- Atomic number-- number of protons
- Mass number--number of protons and neutrons
- Atomic mass -- approximately equal to the number of protons and neutrons
- Isotopes -- same number of protons different number of neutrons.


Proton
• Positive charge
• Determines element
Electron
• Negative charge
• Participates in chemical reactions
• Outer-shell electrons determine chemical behavior
Neutron
• No charge
• Determines isotope
Atom
Nucleus
• Consists of neutrons and protons

Hydrogen and some of its isotopes

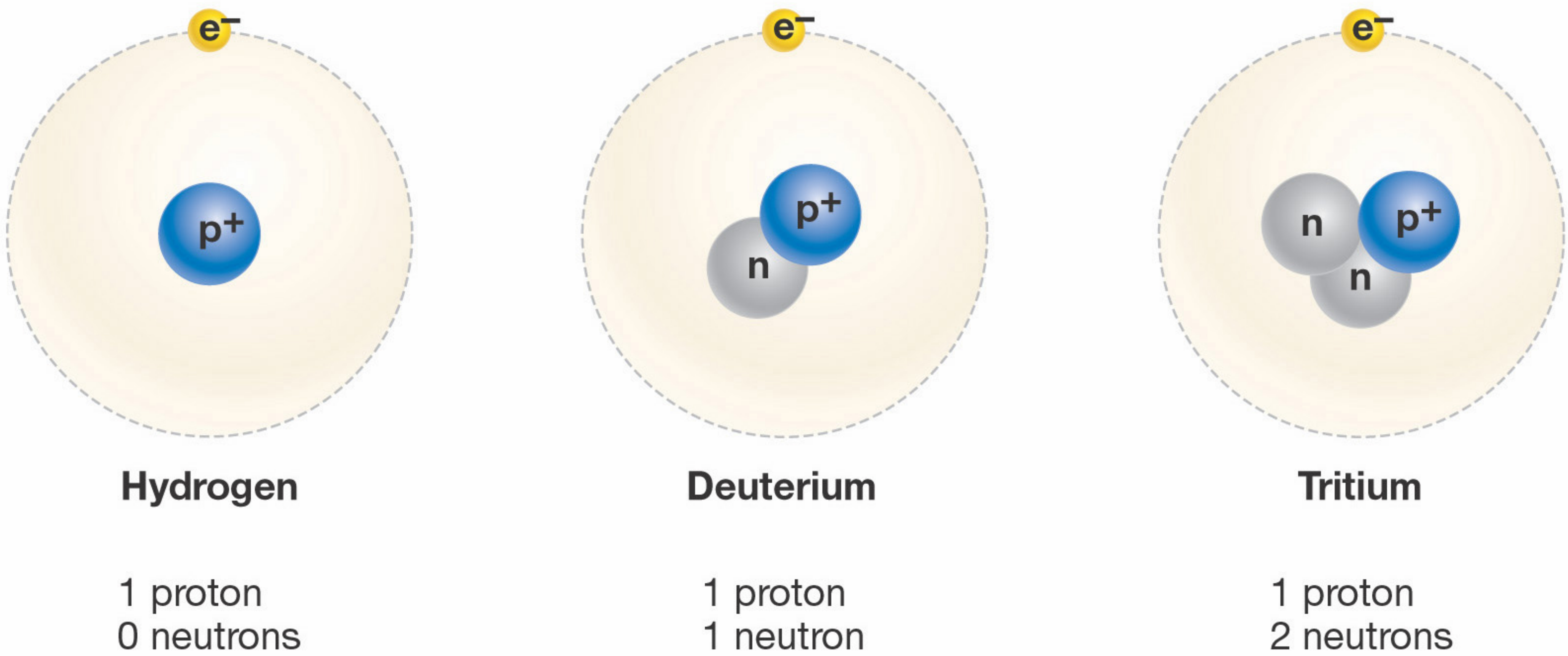
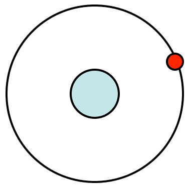
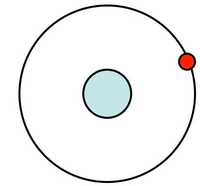


Table 2.1	Isotopes of Carbon		
	Carbon-12	**Carbon-13**	**Carbon-14**
Protons	6	6	6
Neutrons	6	7	8
(mass number)	12	13	14
Electrons	6	6	6



Periodic Table



- Atoms are arranged on the periodic table by rows and columns.
- Where an atom is on a periodic table will tell you about how it will react chemically.

The six elements highlighted in yellow make up 98% of the mass of any living organism.

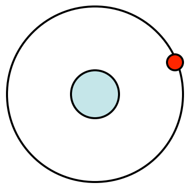
Chemical symbol
Atomic number
Atomic weight

Elements shown in orange are present in tiny amounts in many organisms.

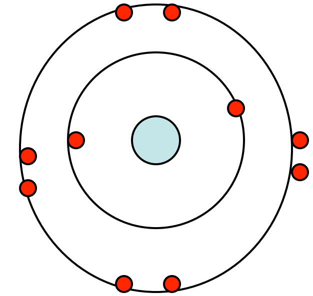
1 H 1.0079																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.4778	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.4	47 Ag 107.870	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	57–71 La–Lu	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.2	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	89–103 Ac–Lr	104	105	106	107	108	109									

Vertical columns have elements with similar properties.

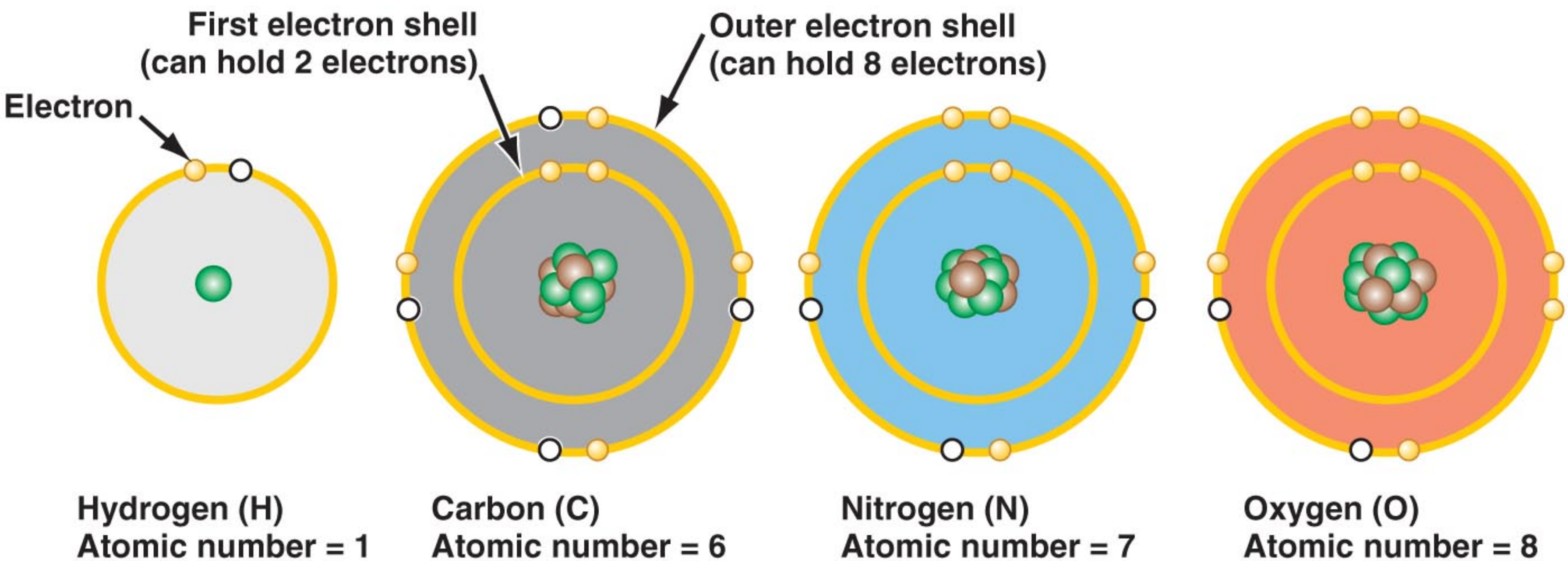
Lanthanide series	57 La 138.906	58 Ce 140.12	59 Pr 140.9077	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.924	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.97
Actinide series	89 Ac 227.028	90 Th 232.038	91 Pa 231.0359	92 U 238.02	93 Np 237.0482	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

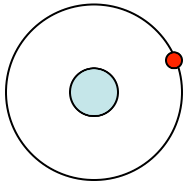


The Periodic Table

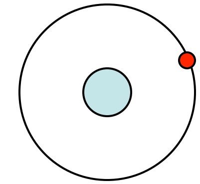


- The electrons in an atom are distributed into shells.
- The first shell or orbital can only hold two electron.
- The second shell or orbital can hold eight electrons.
- The third shell or orbital can hold eight electrons.

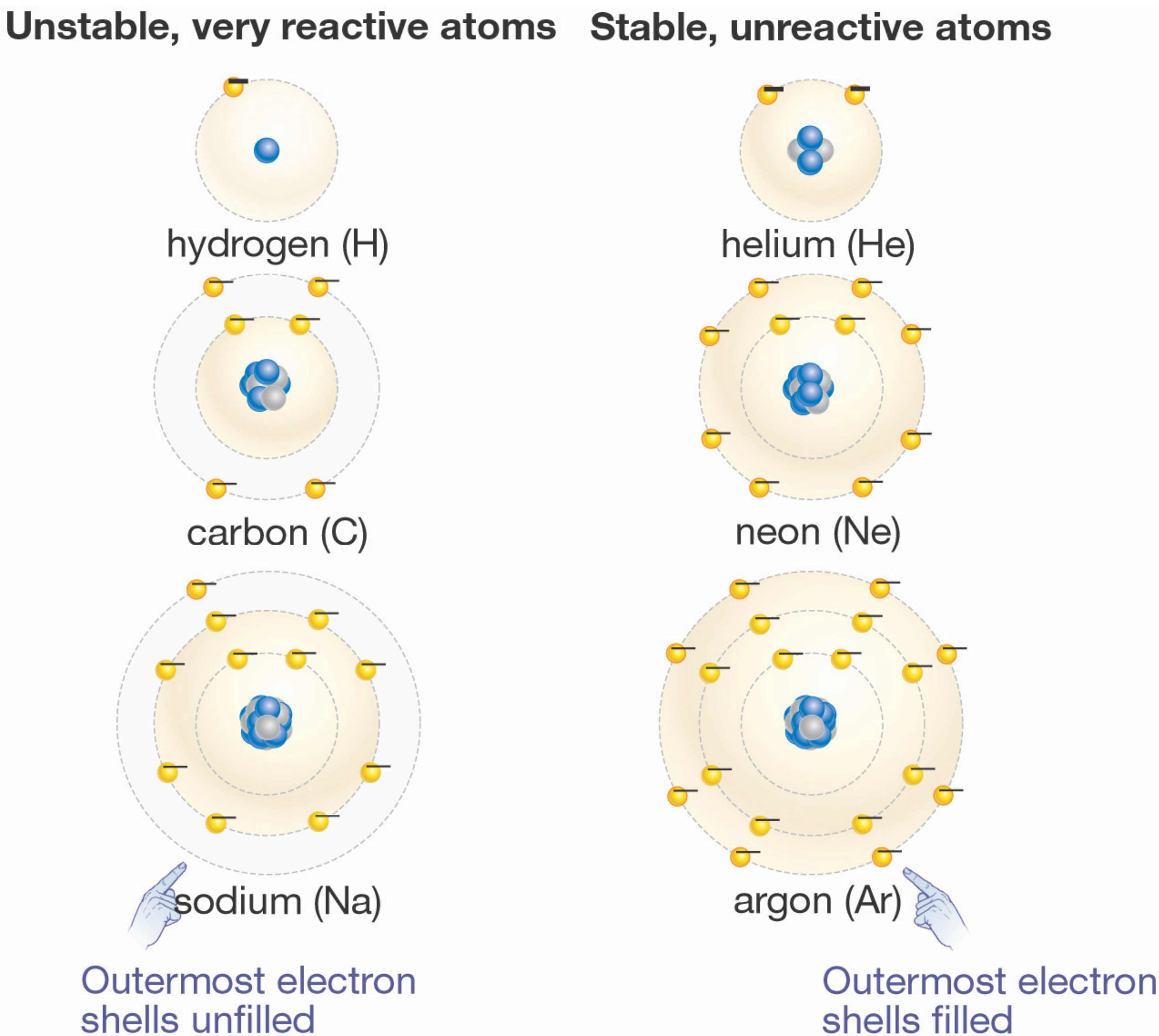

First electron shell
(can hold 2 electrons)
Outer electron shell
(can hold 8 electrons)
Electron
Hydrogen (H)
Atomic number = 1
Carbon (C)
Atomic number = 6
Nitrogen (N)
Atomic number = 7
Oxygen (O)
Atomic number = 8

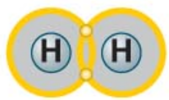
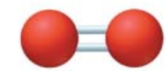
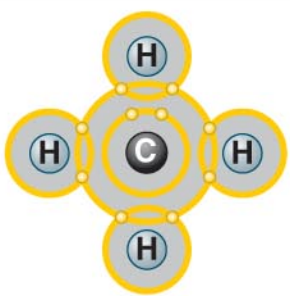
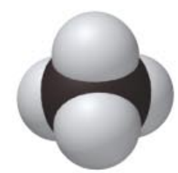


The Periodic Table



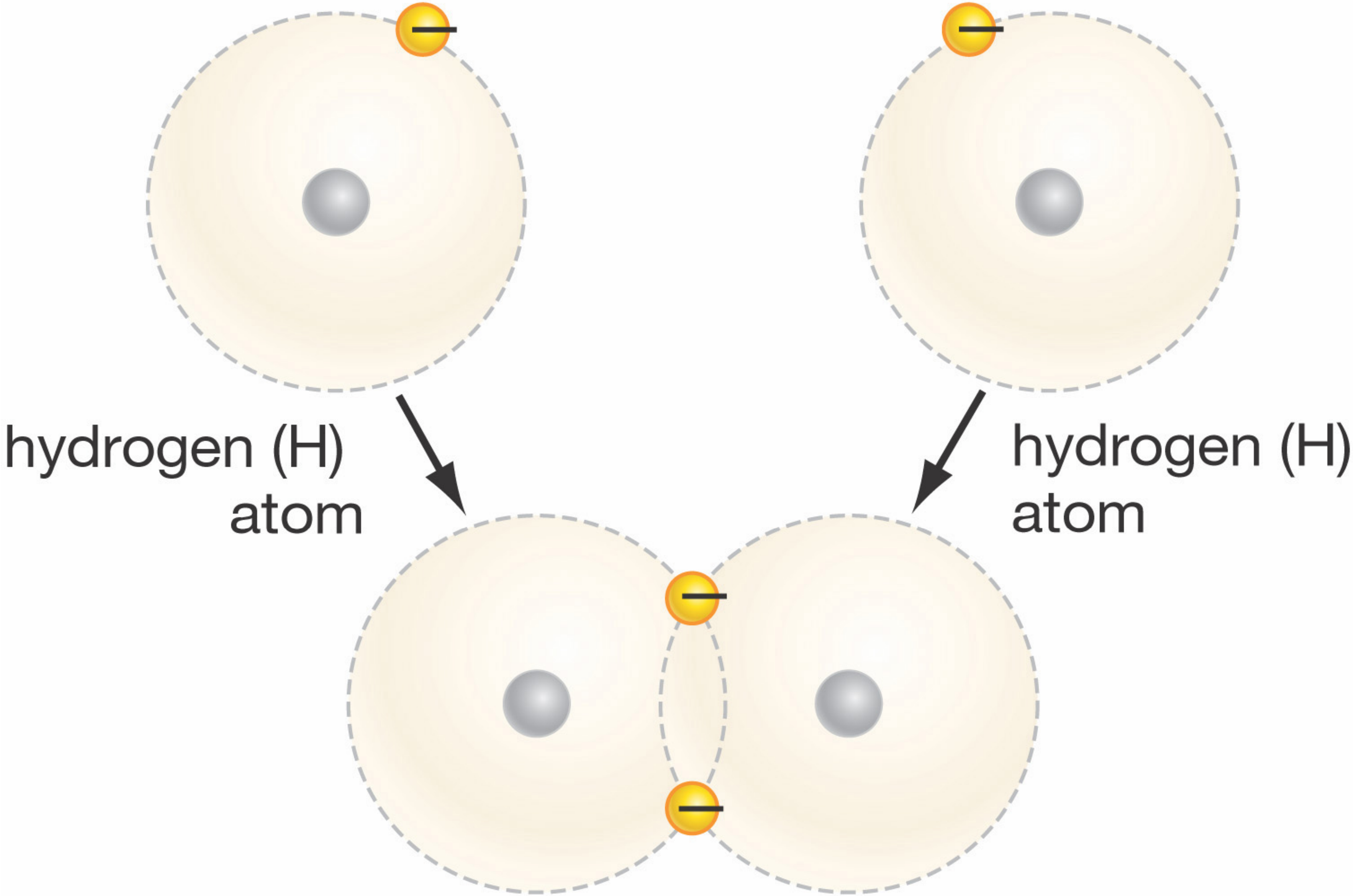
- The number of electrons in the outer shell determines how the atom will behave chemically.
- Also the number of electrons in the outer shell will determine which column the atom is in.
- The number of shells an electron has determines the row the atom is in.


Unstable, very reactive atoms
Stable, unreactive atoms
hydrogen (H)
helium (He)
carbon (C)
neon (Ne)
sodium (Na)
argon (Ar)
Outermost electron shells unfilled
Outermost electron shells filled

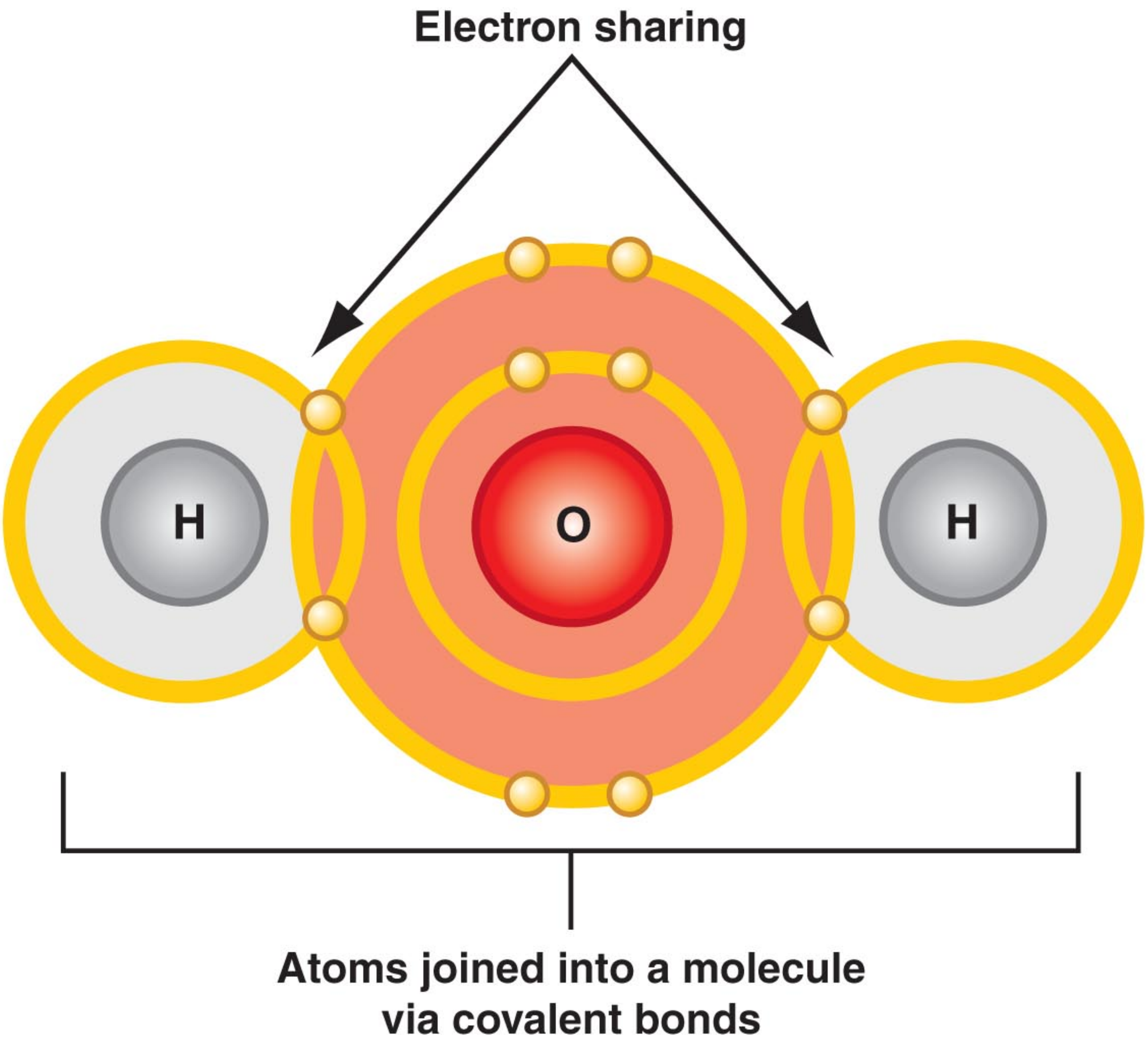
Name (molecular formula)	Electron configuration	Structural formula	Space-filling model	Ball-and-stick model
Hydrogen gas (H_2)		$H-H$ Single bond (a pair of shared electrons)		
Oxygen gas (O_2)		$O=O$ Double bond (two pairs of shared electrons)		
Methane (CH_4)		$\begin{array}{c} H \\ \mid \\ H-C-H \\ \mid \\ H \end{array}$		

Polar vs. non-polar covalent bonds

- In covalent bonds electrons are evenly shared between the two nuclei.
- In a polar covalent bond the electrons are shared unevenly. The atom with more electrons in its outer shell will “hog” the shared electrons while the one with fewer electrons in its outer shell will have less of the shared electrons time.

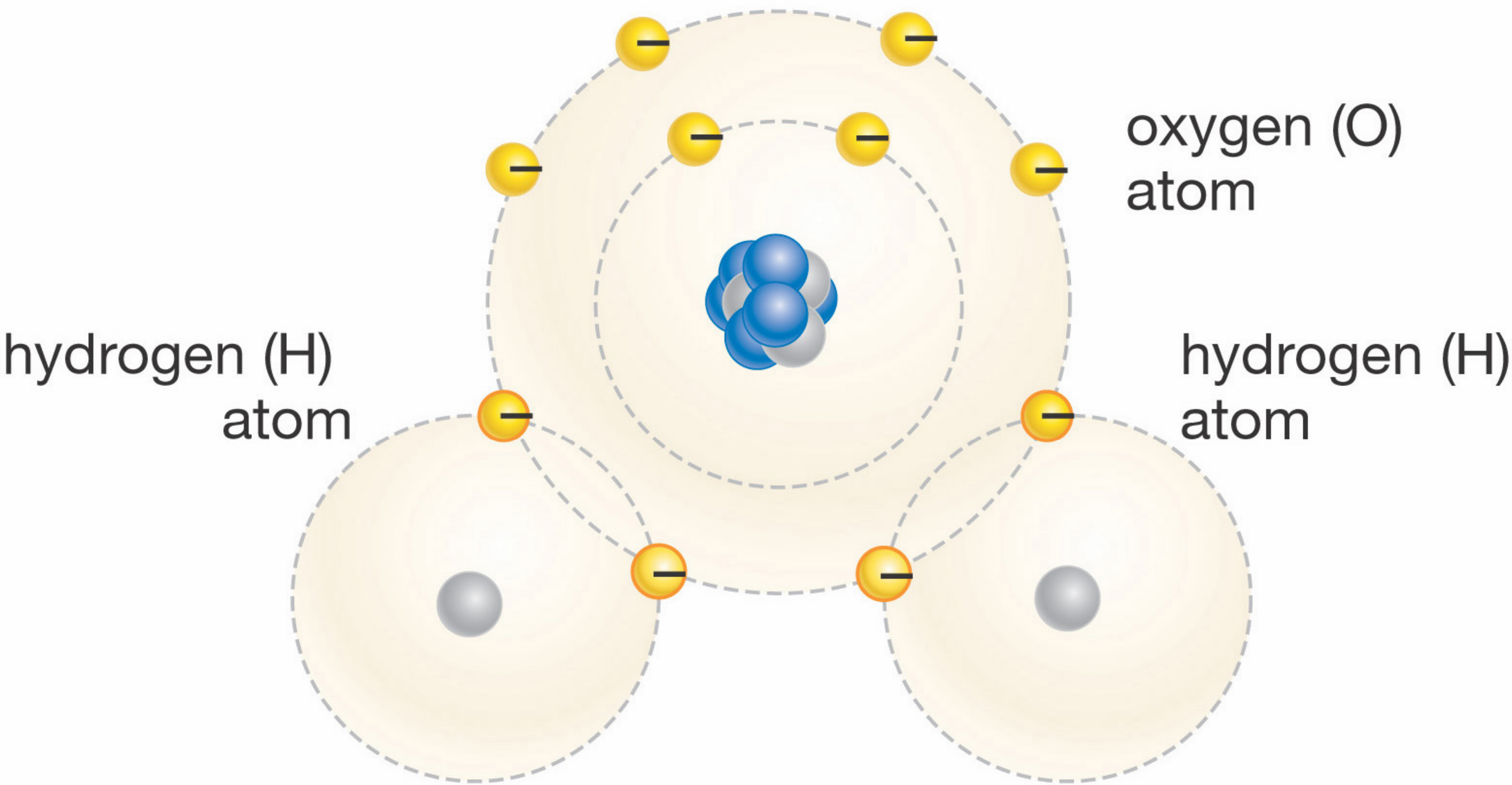


(a) Hydrogen molecule

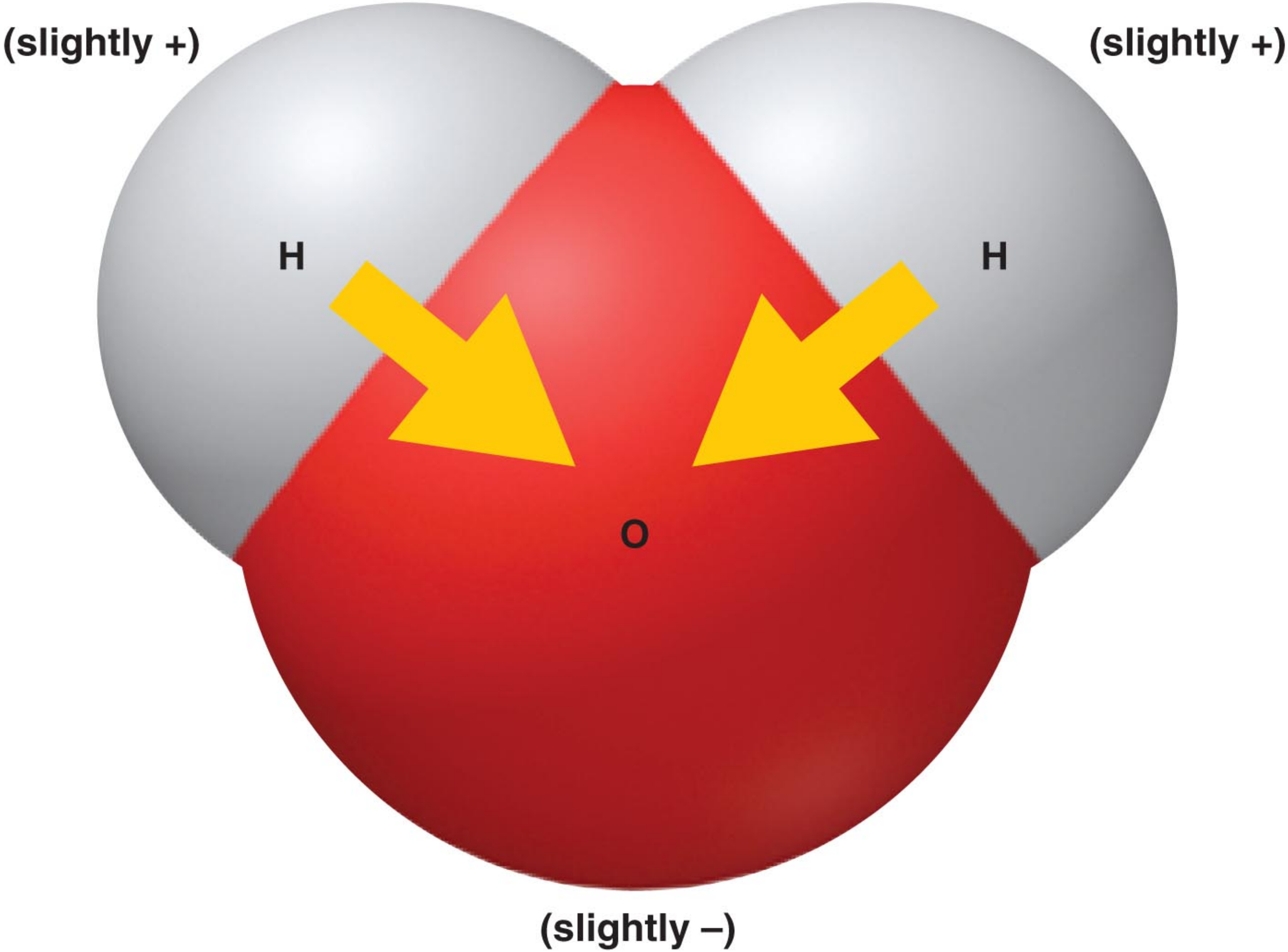

Electron sharing
H
O
H
Atoms joined into a molecule
via covalent bonds

Covalent bonds

- The number of bonds the atom can form is dictated by the number of valence (outer) electrons it needs to fill its outer orbital.

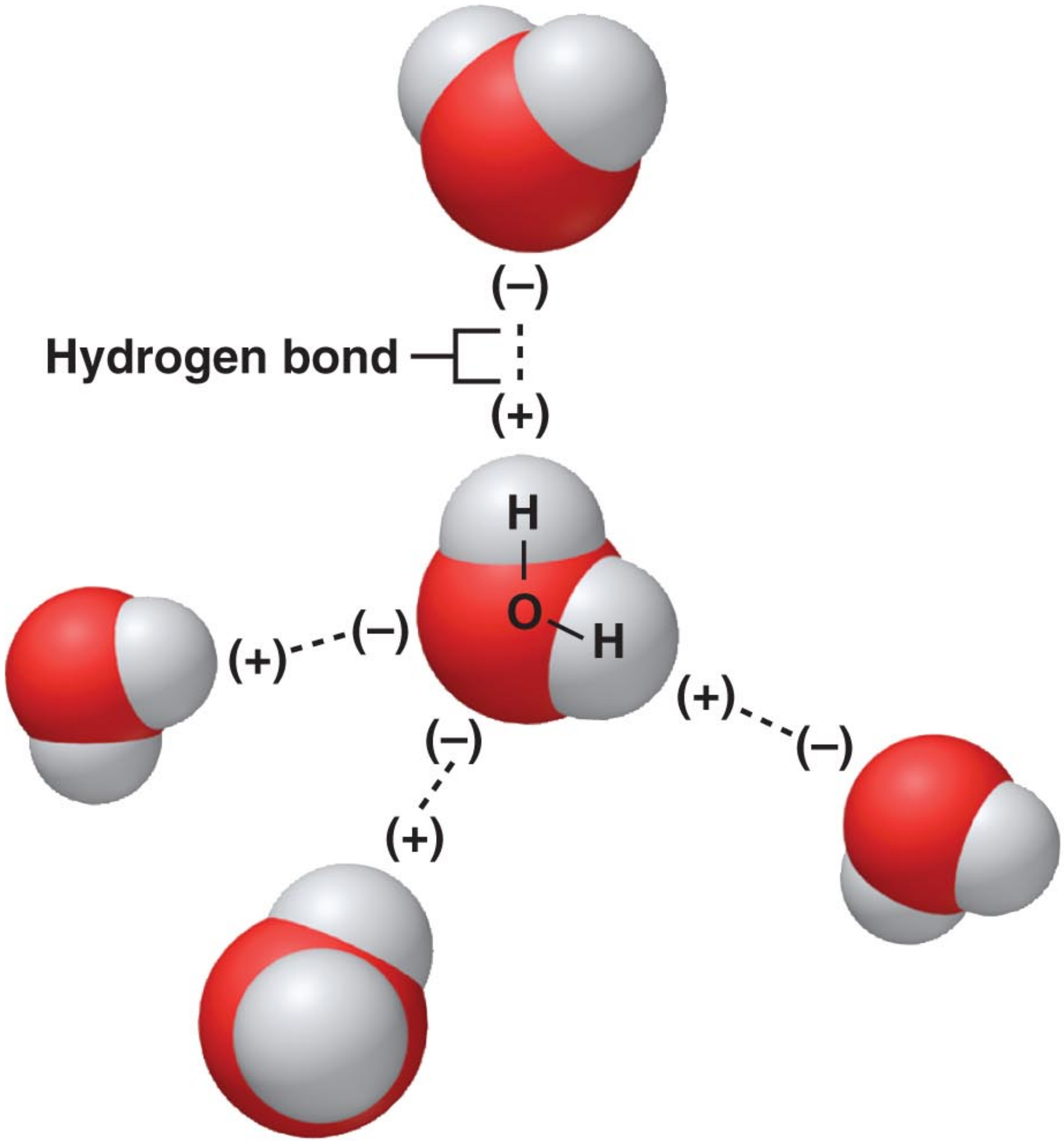


(b) Water molecule

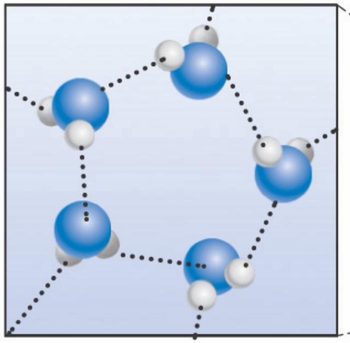

(slightly +)
(slightly +)
H
H
O
(slightly –)

Hydrogen bonds

- When a partially positive hydrogen is attracted to a negatively charged oxygen or nitrogen.
- Water is a good example of hydrogen bonding.

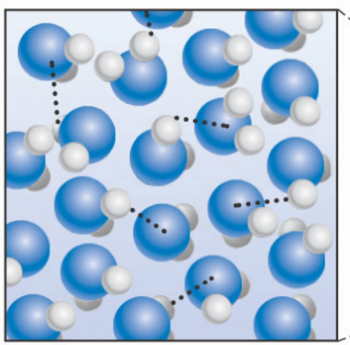

(–)
Hydrogen bond
(+)
H
O
H
(+)
(–)
(+)
(–)
(–)
(+)

ice

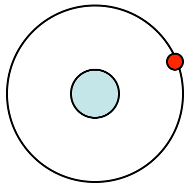


In ice, the maximum number of hydrogen bonds form, causing the molecules to be spread far apart.

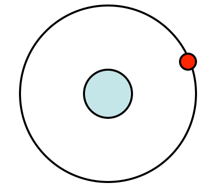
liquid water



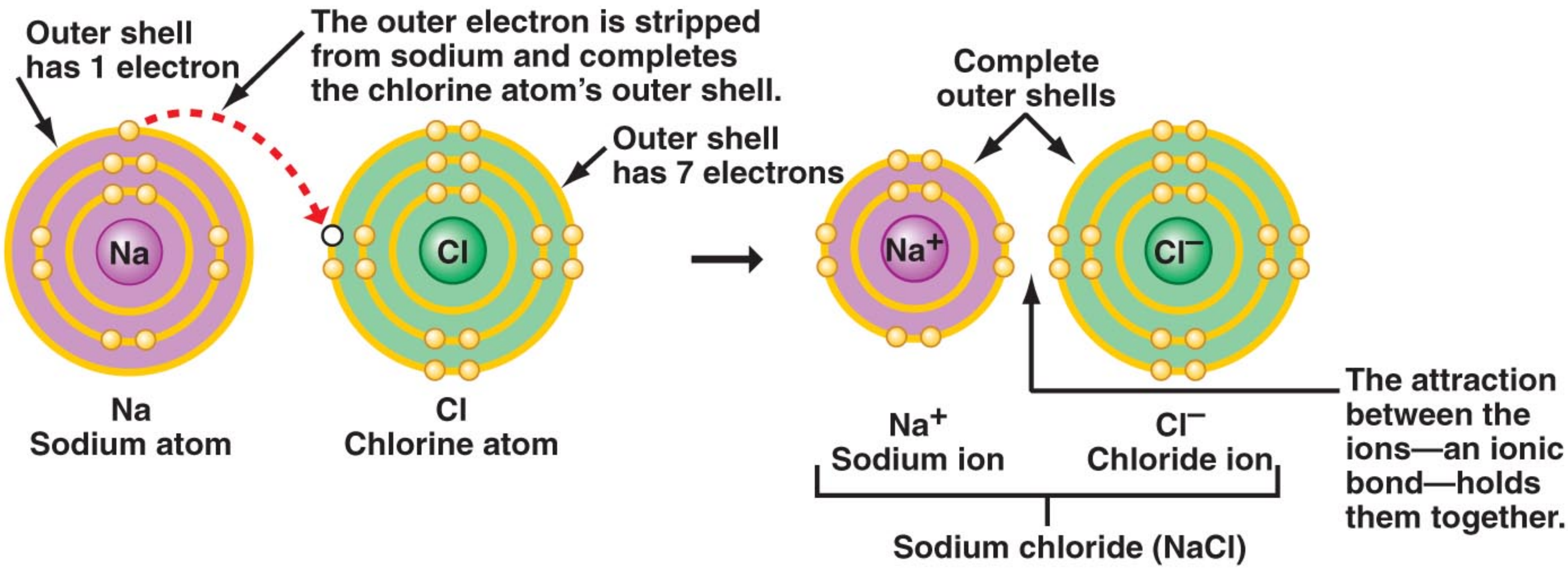
In liquid water, hydrogen bonds constantly break and reform, enabling a more dense spacing than in ice.

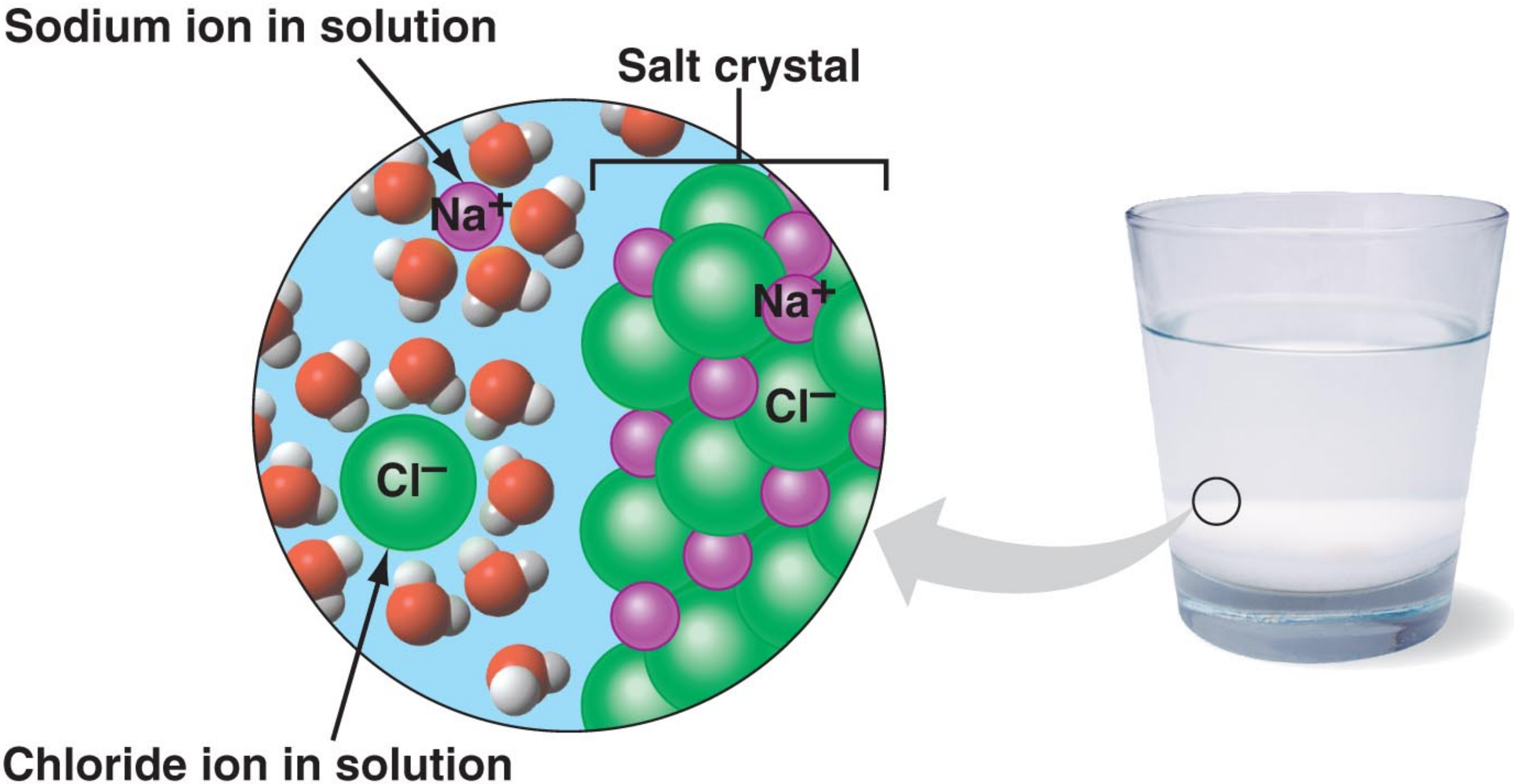


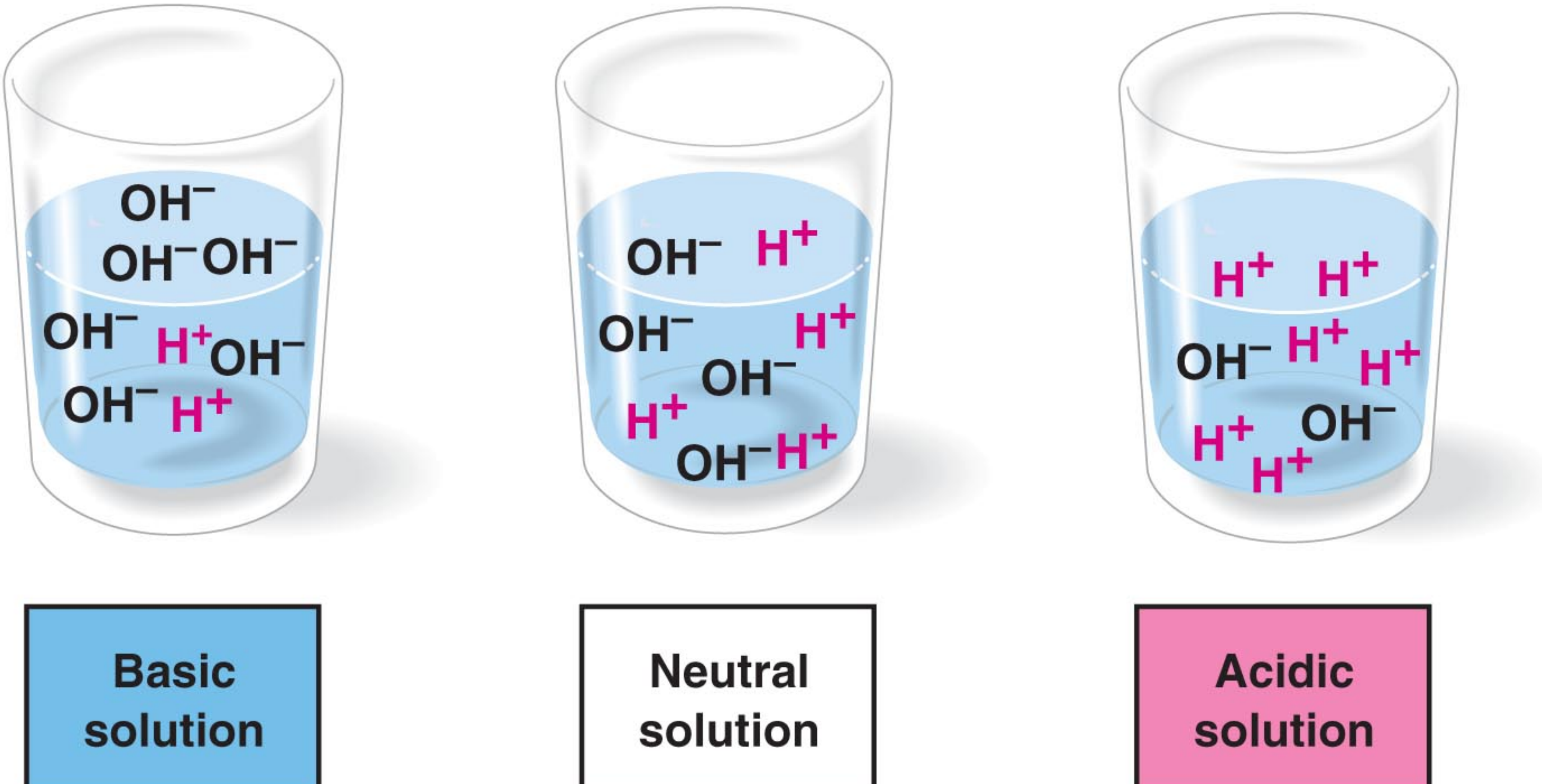
Ionic Bonds

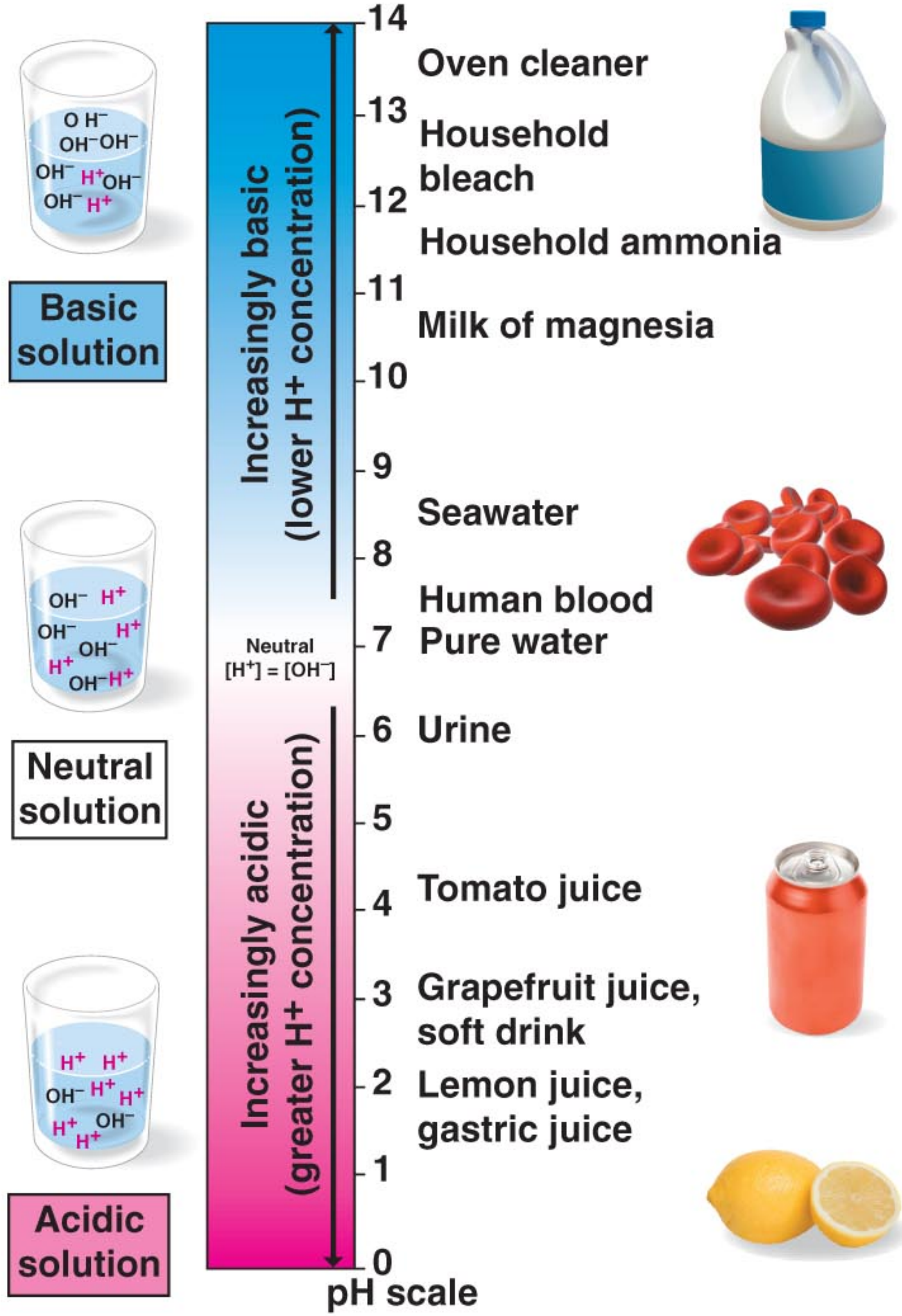


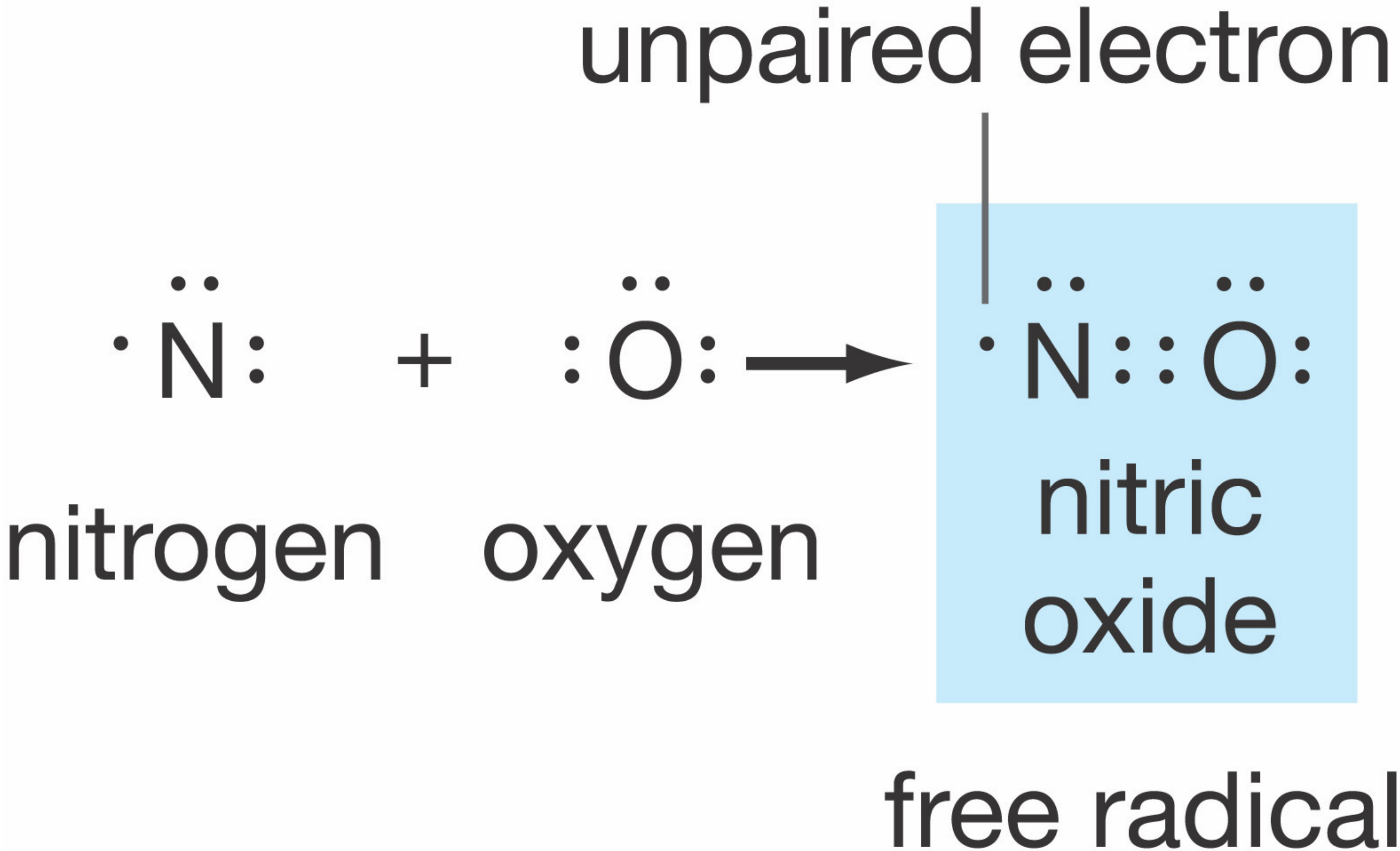
- No sharing of electrons one atom actually steals an electron from another atom.
- This leaves one atom positively charged and another atom negatively charged. Therefore they are attracted to each other.
- Solutions with ions (charged ions) can conduct electricity.


Outer shell has 1 electron
The outer electron is stripped from sodium and completes the chlorine atom's outer shell.
Outer shell has 7 electrons
Na
Cl
Na
Sodium atom
Cl
Chlorine atom
Complete outer shells
Na+
Cl−
Na+
Sodium ion
Cl−
Chloride ion
Sodium chloride (NaCl)
The attraction between the ions—an ionic bond—holds them together.


Sodium ion in solution
Salt crystal
Na+
Na+
Cl−
Cl−
Chloride ion in solution


OH⁻
OH⁻ OH⁻
OH⁻ H⁺ OH⁻
OH⁻ H⁺
Basic solution
OH⁻ H⁺
OH⁻ H⁺
OH⁻
H⁺
OH⁻ H⁺
Neutral solution
H⁺ H⁺
OH⁻ H⁺ H⁺
H⁺ OH⁻
H⁺
Acidic solution

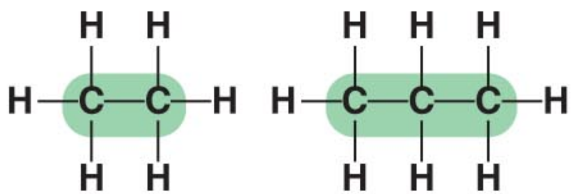

14
Oven cleaner
13
Household bleach
12
Household ammonia
11
Milk of magnesia
10
9
Seawater
8
Human blood
7
Pure water
6
Urine
5
Tomato juice
4
3
Grapefruit juice, soft drink
2
Lemon juice, gastric juice
1
0
pH scale
Increasingly basic (lower H+ concentration)
Neutral [H+] = [OH−]
Increasingly acidic (greater H+ concentration)
Basic solution
Neutral solution
Acidic solution


unpaired electron
nitrogen
oxygen
nitric
oxide
free radical

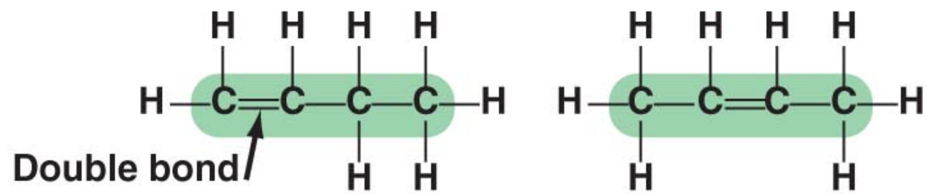
Important Biological Molecules

Vocabulary

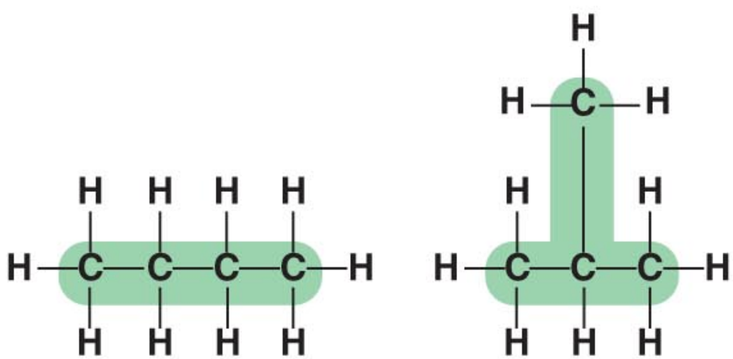
- Hydrocarbons (chains of C)
- Isomers (same molecular formula different shape)
- Functional groups
- Hydrophilic
- Hydrophobic



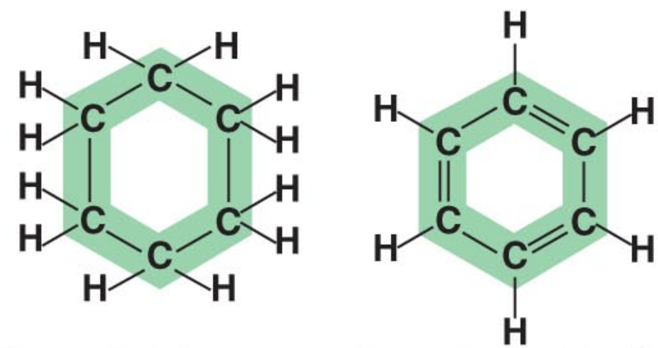
Carbon skeletons vary in length



Carbon skeletons may have double bonds, which can vary in location

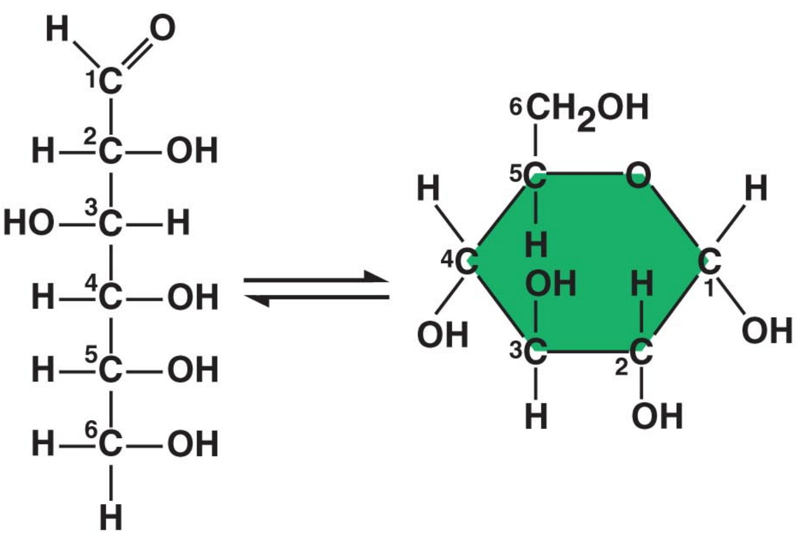


Carbon skeletons may be unbranched or branched

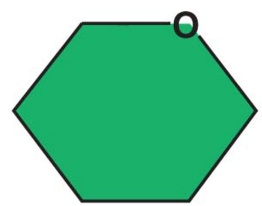


Carbon skeletons may be arranged in rings

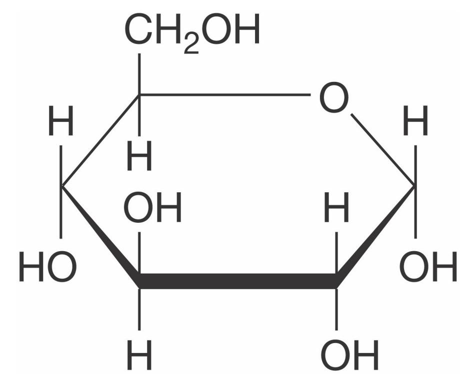
Different versions of the energy molecule Glucose (a carbohydrate)

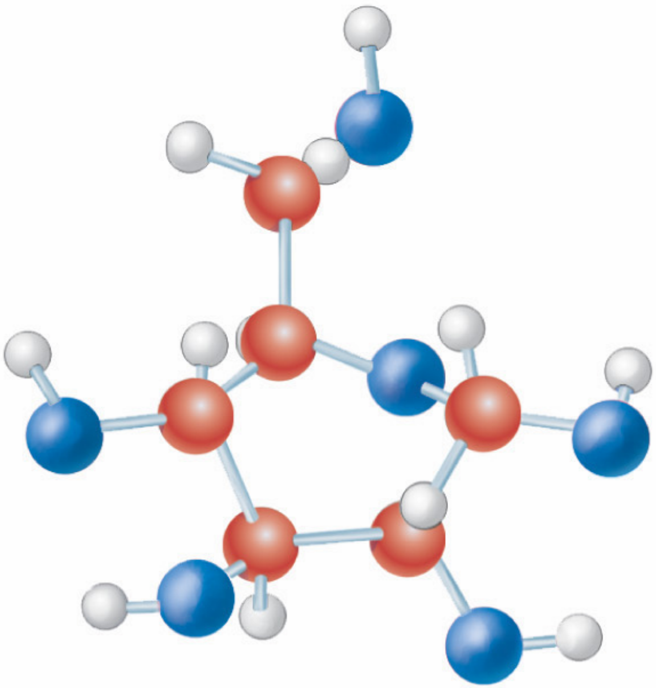


(a) Linear and ring structures

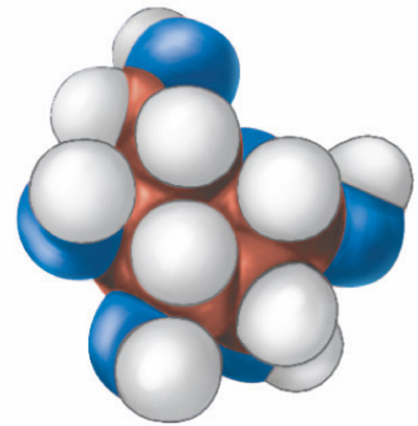


(b) Abbreviated ring structure





ball-and-stick model of glucose

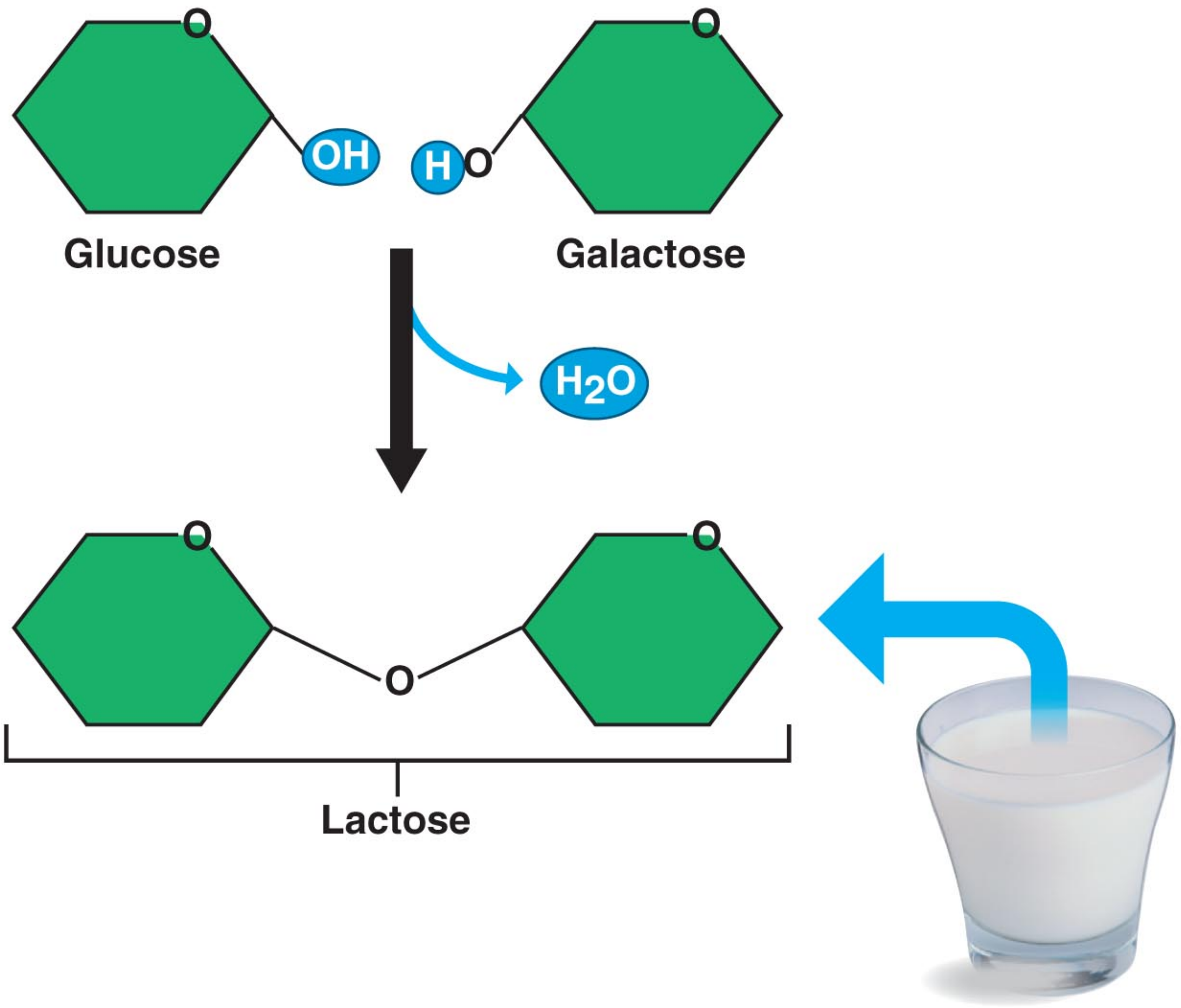


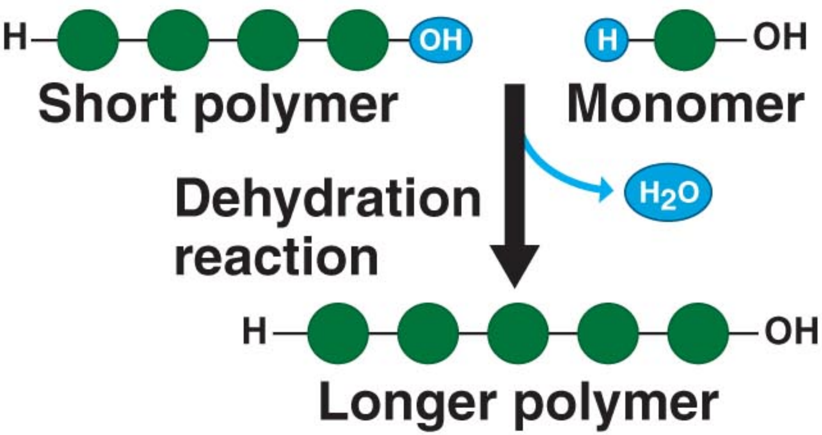
space-filling model of glucose

More vocabulary

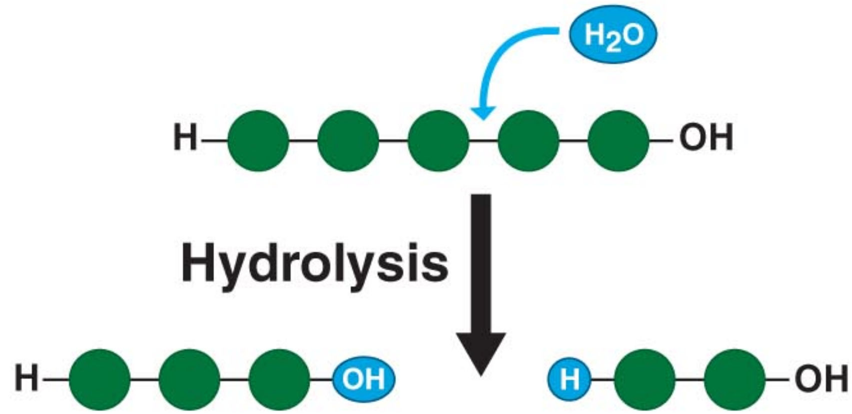
- Macromolecules
- Polymers
- Monomers
- Dehydration reaction
- Hydrolysis

Dehydration reaction

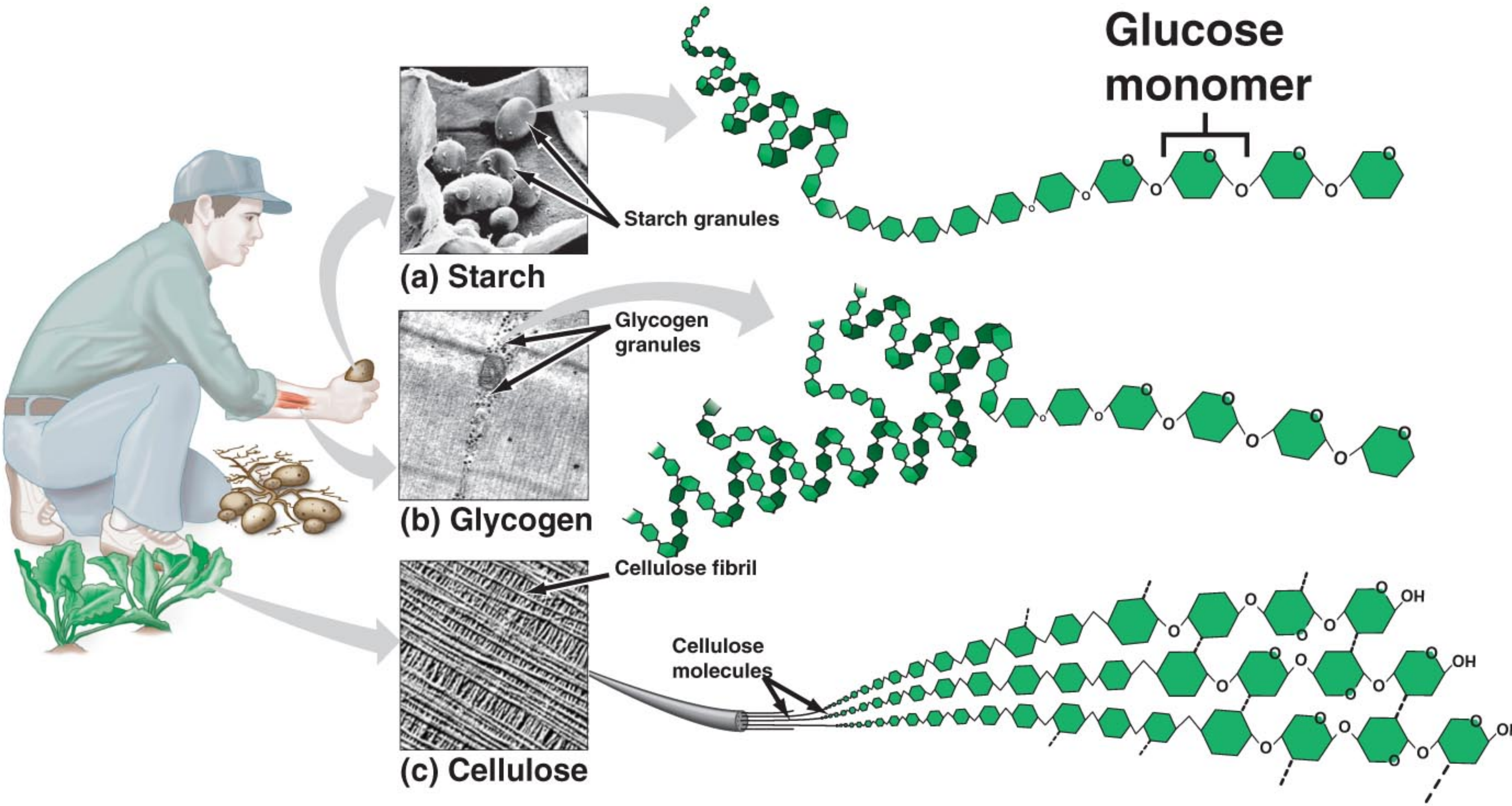


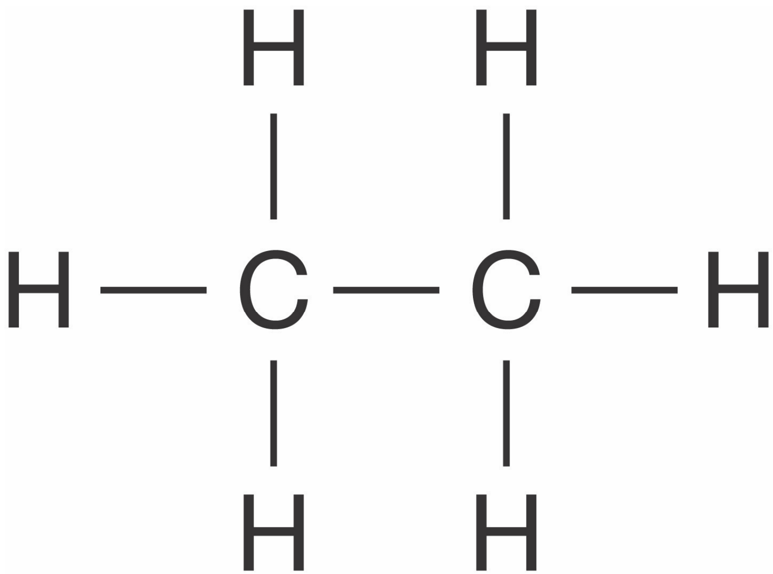


(a) Building a polymer chain



(b) Breaking a polymer chain


Glucose monomer
Starch granules
(a) Starch
Glycogen granules
(b) Glycogen
Cellulose fibril
Cellulose molecules
(c) Cellulose
O
OH



Additions of Functional Groups

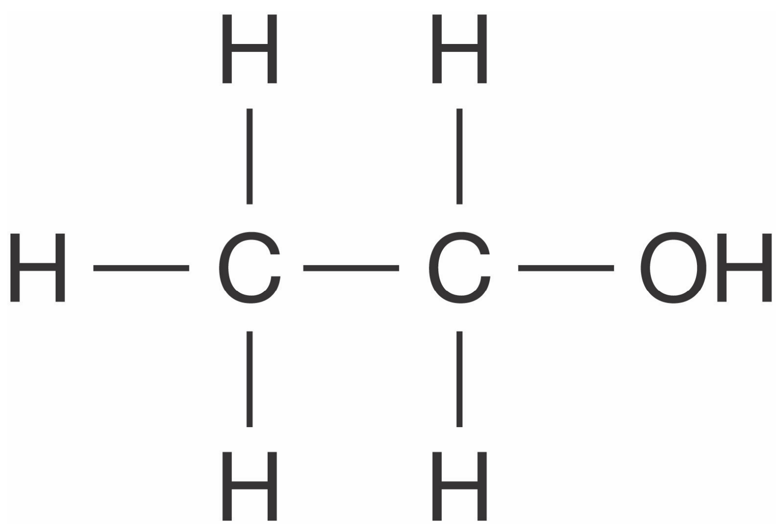
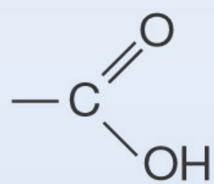
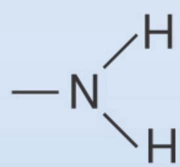
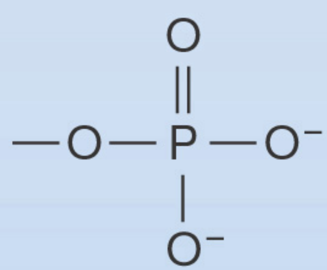
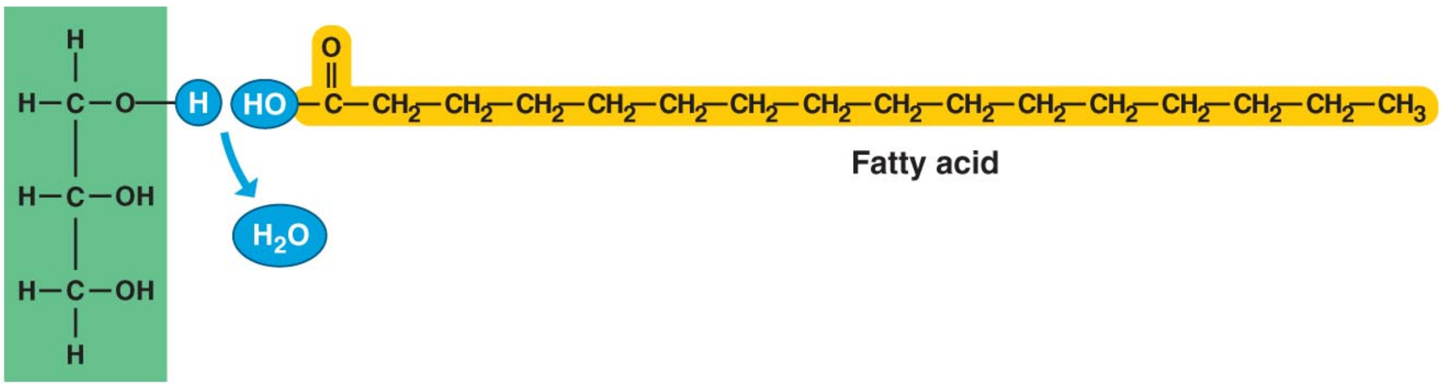


Table 3.1 Functional groups

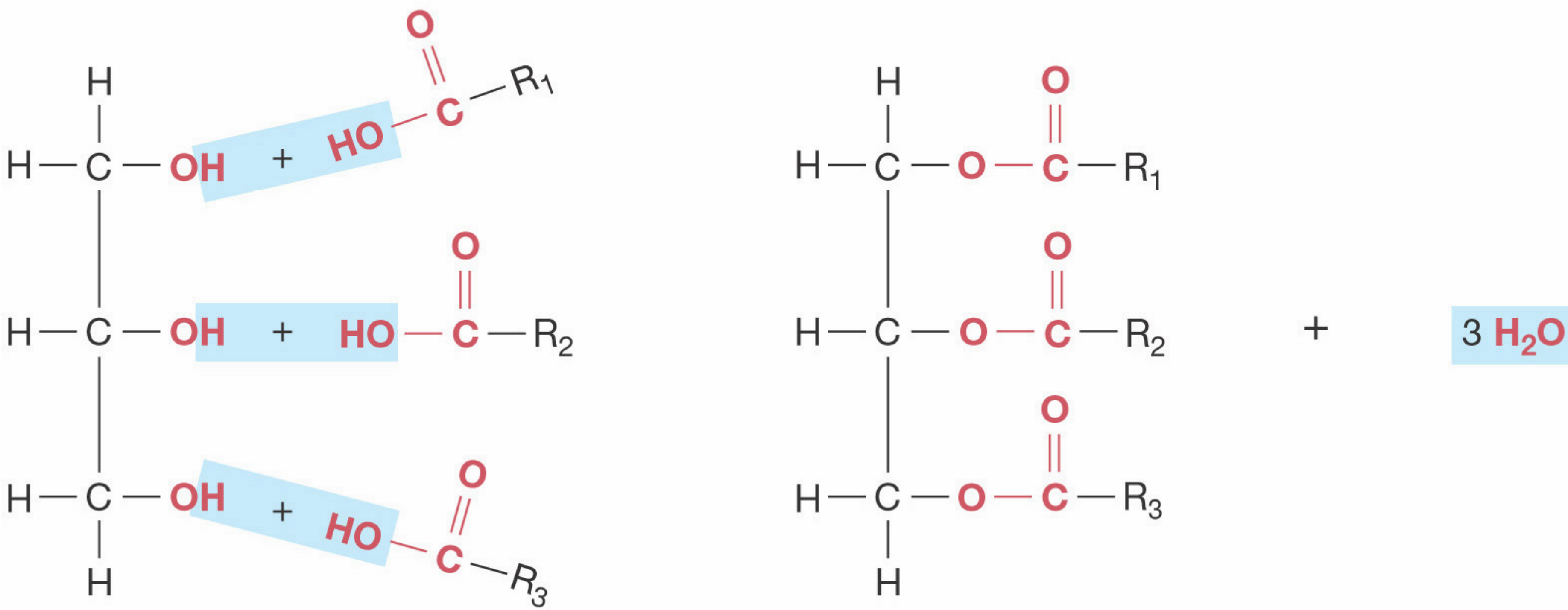
Group:	Structural formula:	Found in:
Carboxyl (—COOH)		fatty acids, amino acids
Hydroxyl (—OH)	—OH	alcohols, carbohydrates
Amino (—NH_2)		amino acids
Phosphate (—PO_4)		DNA, ATP

The makings of a Fatty Acid

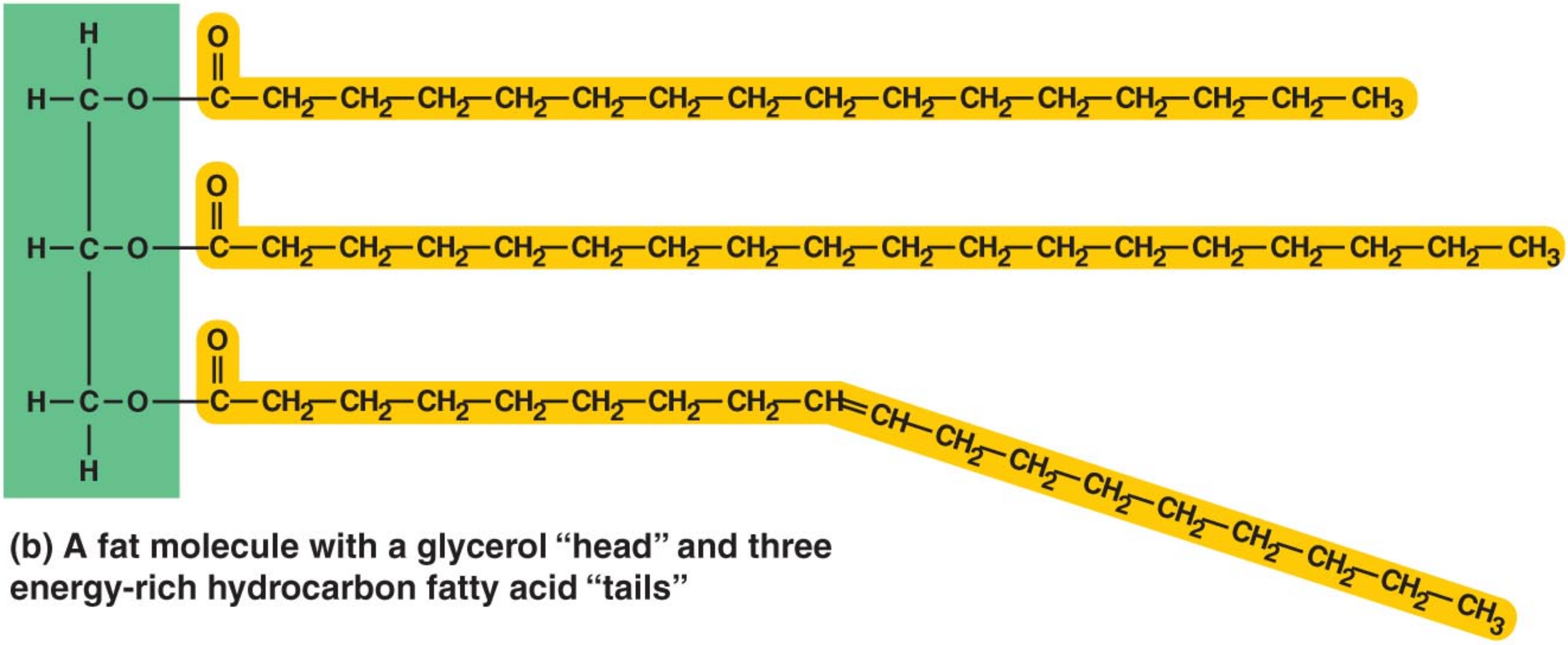


Glycerol

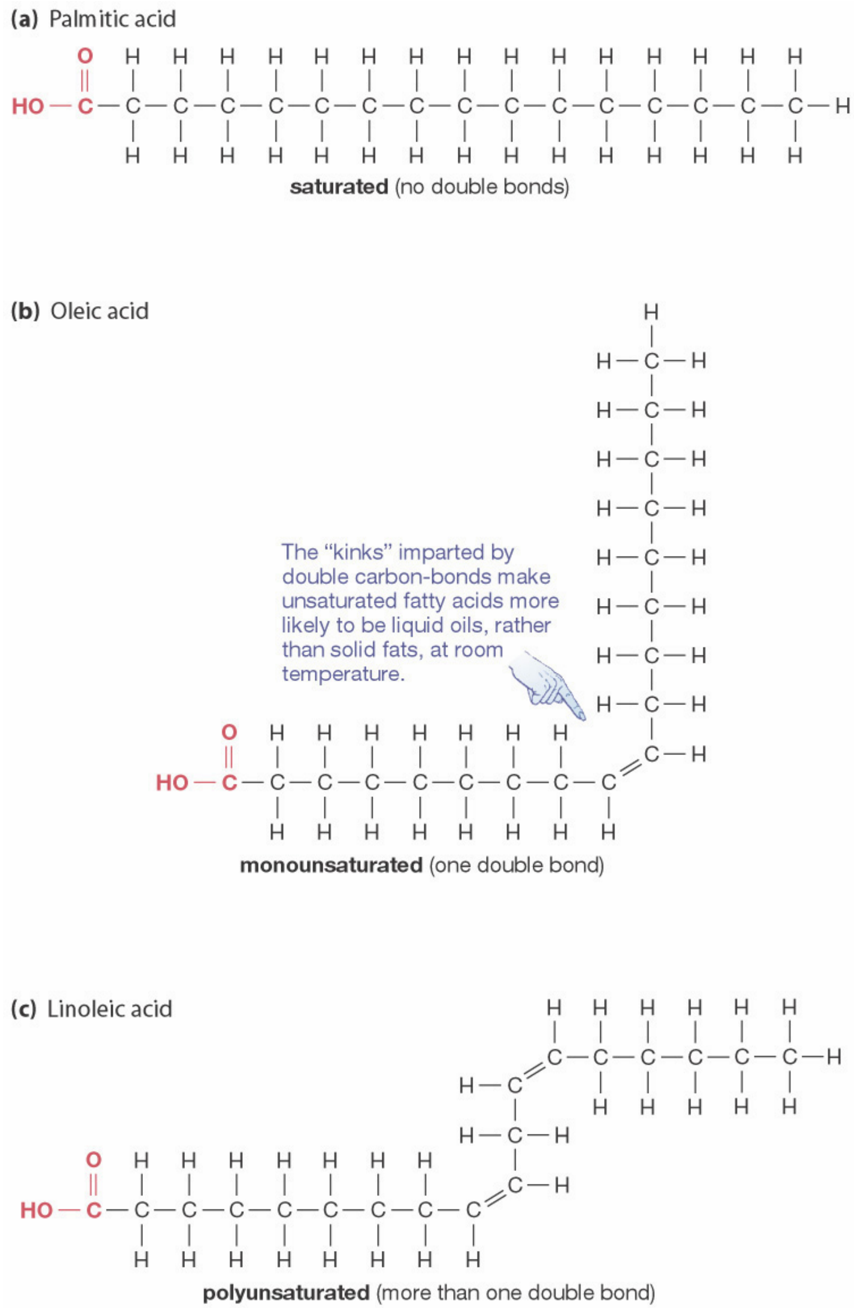
(a) A dehydration reaction linking a fatty acid to glycerol



glycerol + 3 fatty acids = triglyceride + water

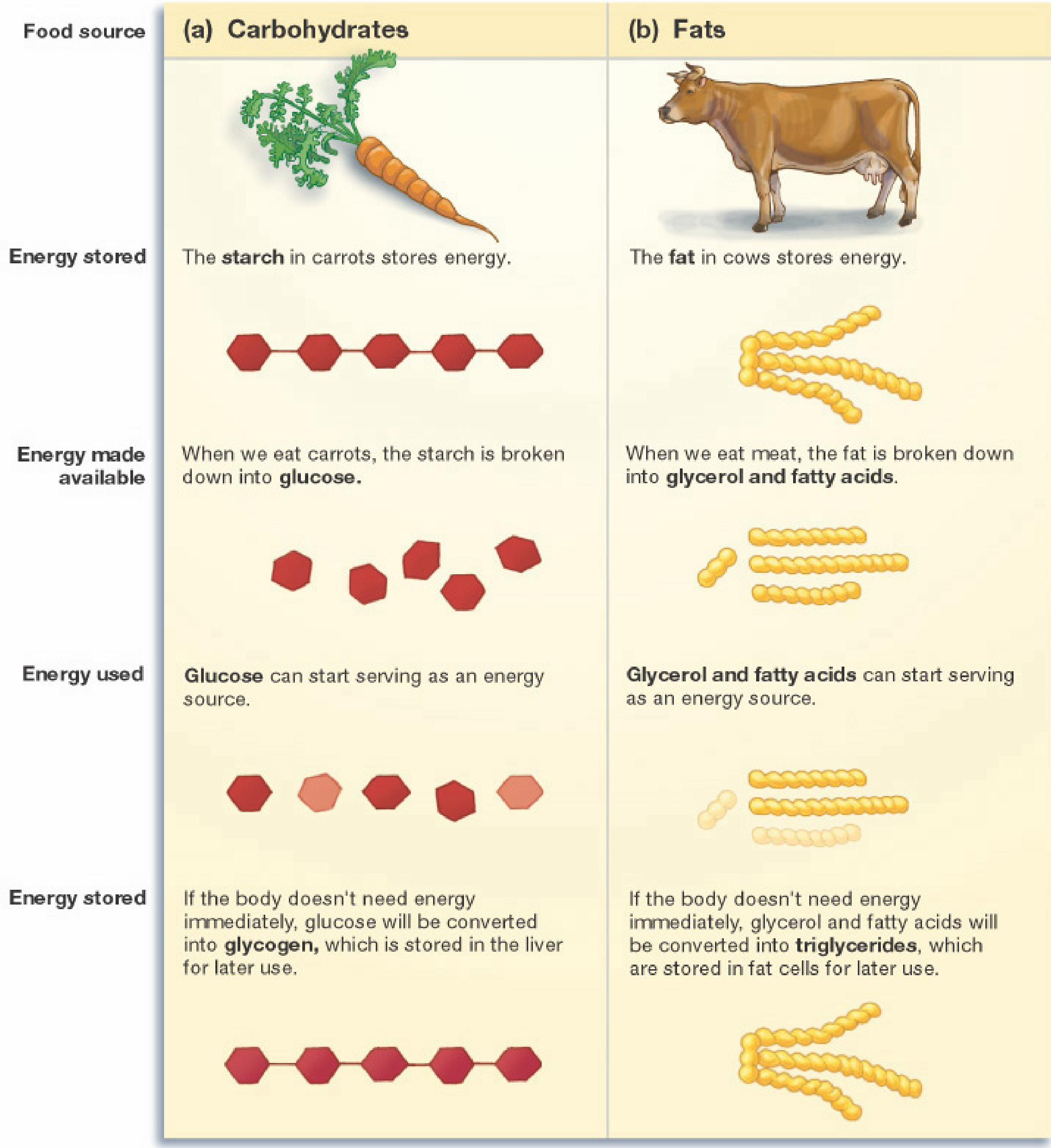


(b) A fat molecule with a glycerol "head" and three energy-rich hydrocarbon fatty acid "tails"



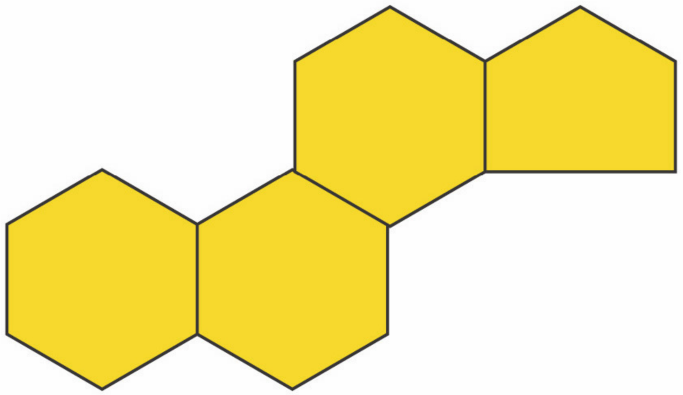
saturated

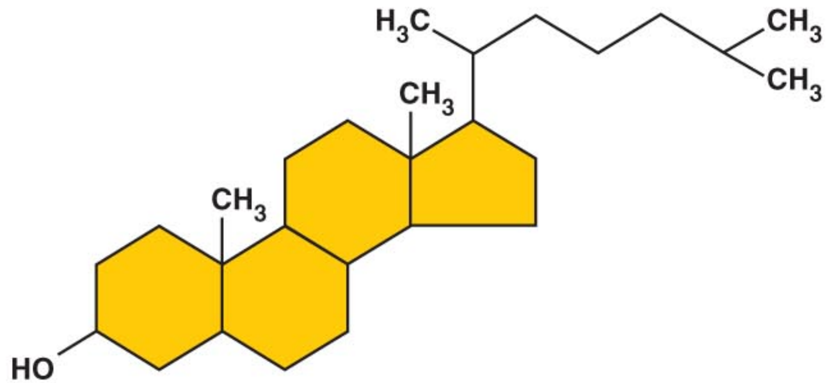
unsaturated


Food source
(a) Carbohydrates
(b) Fats
Energy stored
The starch in carrots stores energy.
The fat in cows stores energy.
Energy made available
When we eat carrots, the starch is broken down into glucose.
When we eat meat, the fat is broken down into glycerol and fatty acids.
Energy used
Glucose can start serving as an energy source.
Glycerol and fatty acids can start serving as an energy source.
Energy stored
If the body doesn't need energy immediately, glucose will be converted into glycogen, which is stored in the liver for later use.
If the body doesn't need energy immediately, glycerol and fatty acids will be converted into triglycerides, which are stored in fat cells for later use.

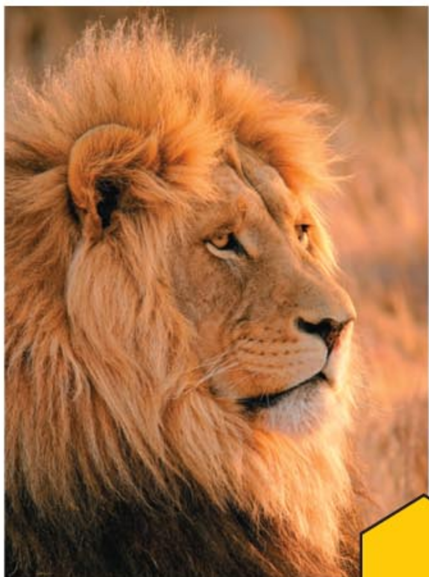
Basic structure for many hormones

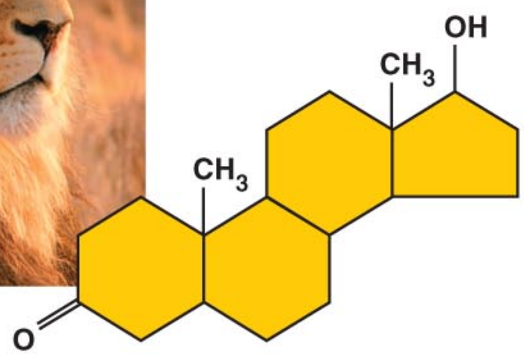
(a) Four-ring steroid structure



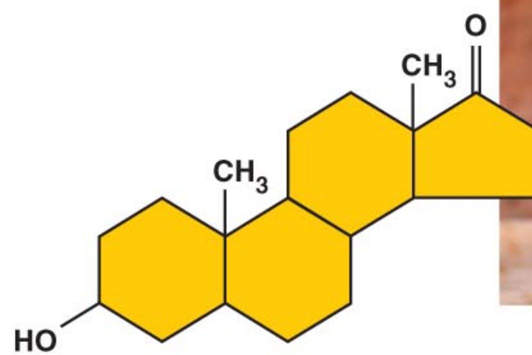


Cholesterol

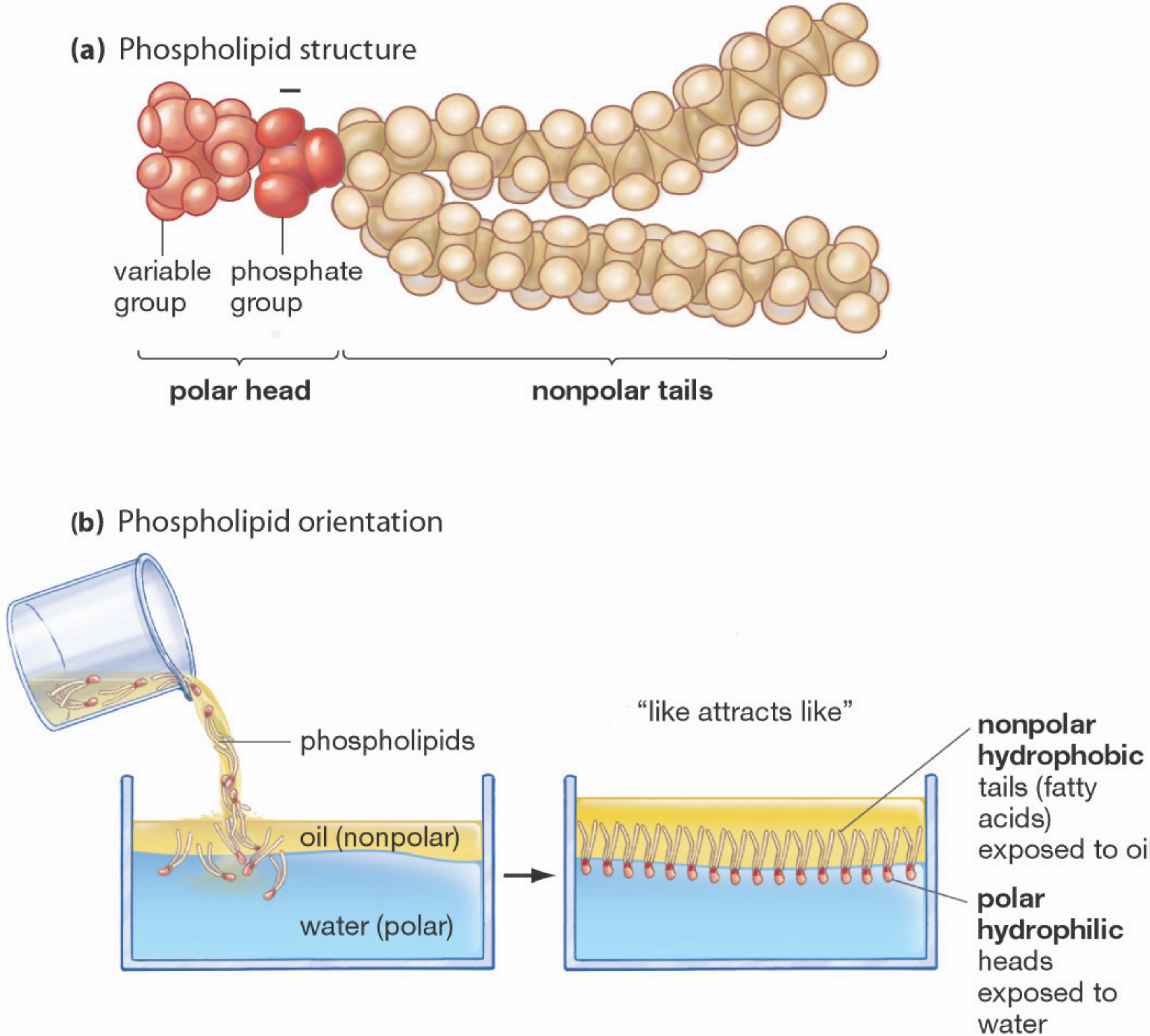


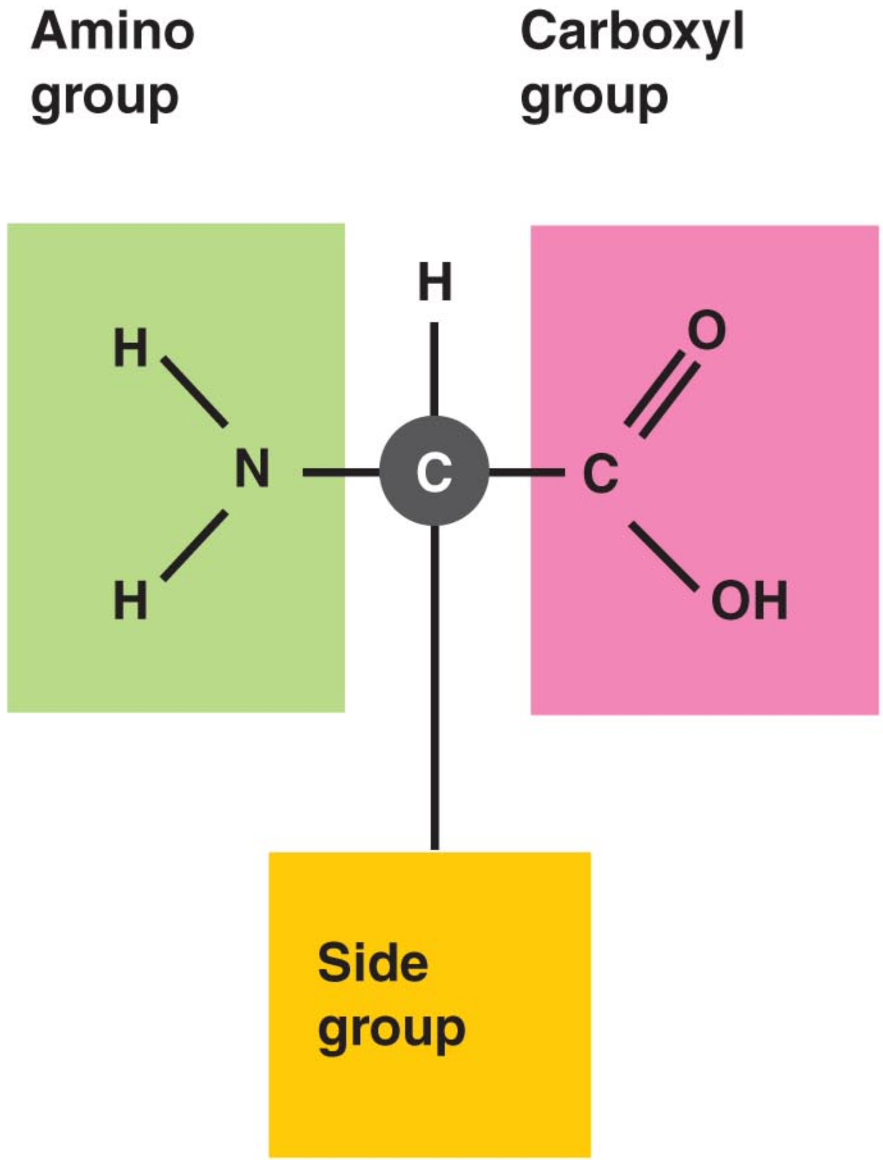


Testosterone

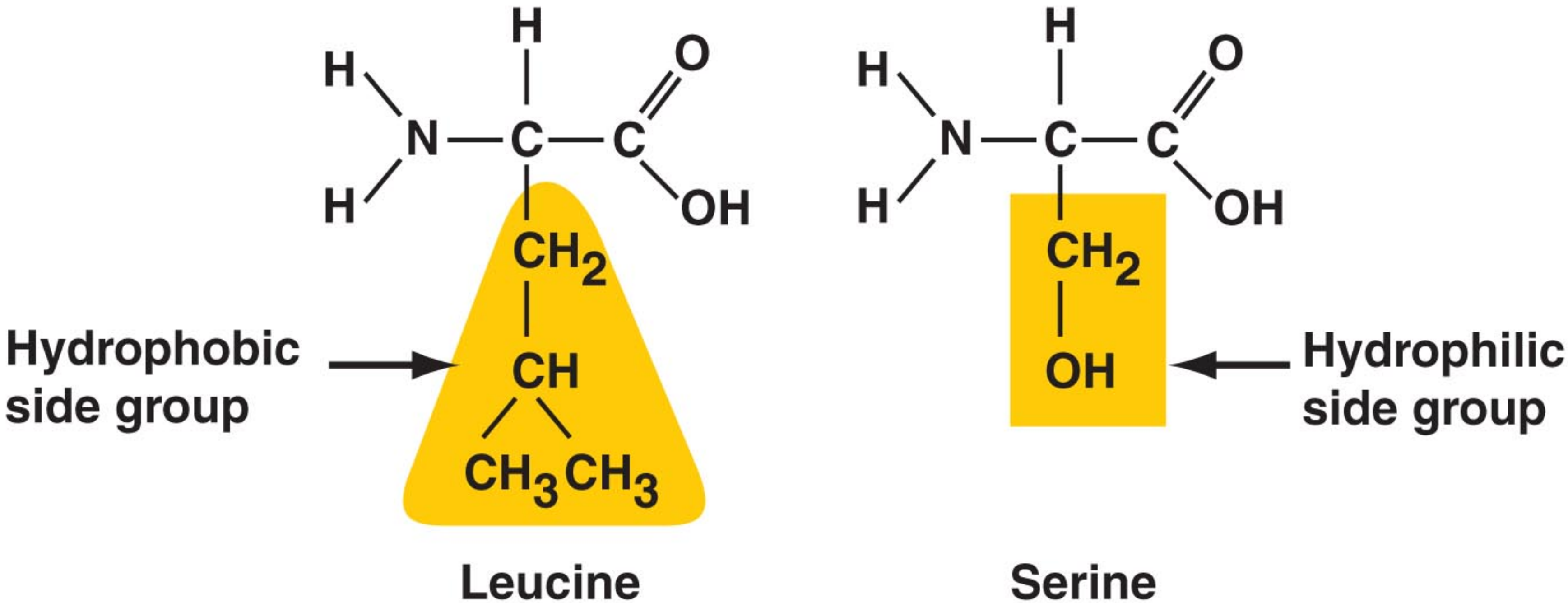


A type of estrogen

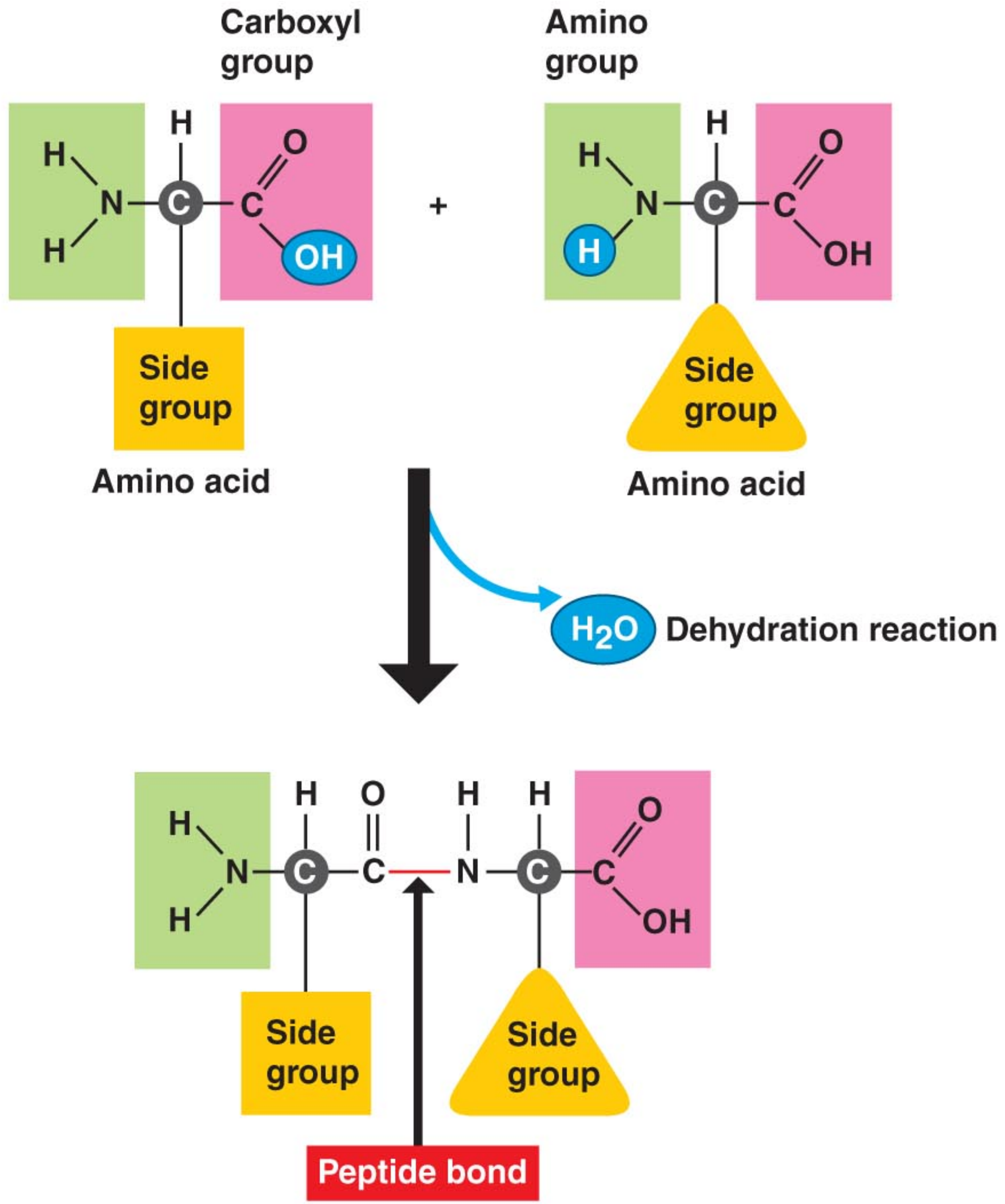

(a) Phospholipid structure
–
variable group
phosphate group
polar head
nonpolar tails
(b) Phospholipid orientation
phospholipids
oil (nonpolar)
water (polar)
"like attracts like"
nonpolar hydrophobic tails (fatty acids) exposed to oil
polar hydrophilic heads exposed to water

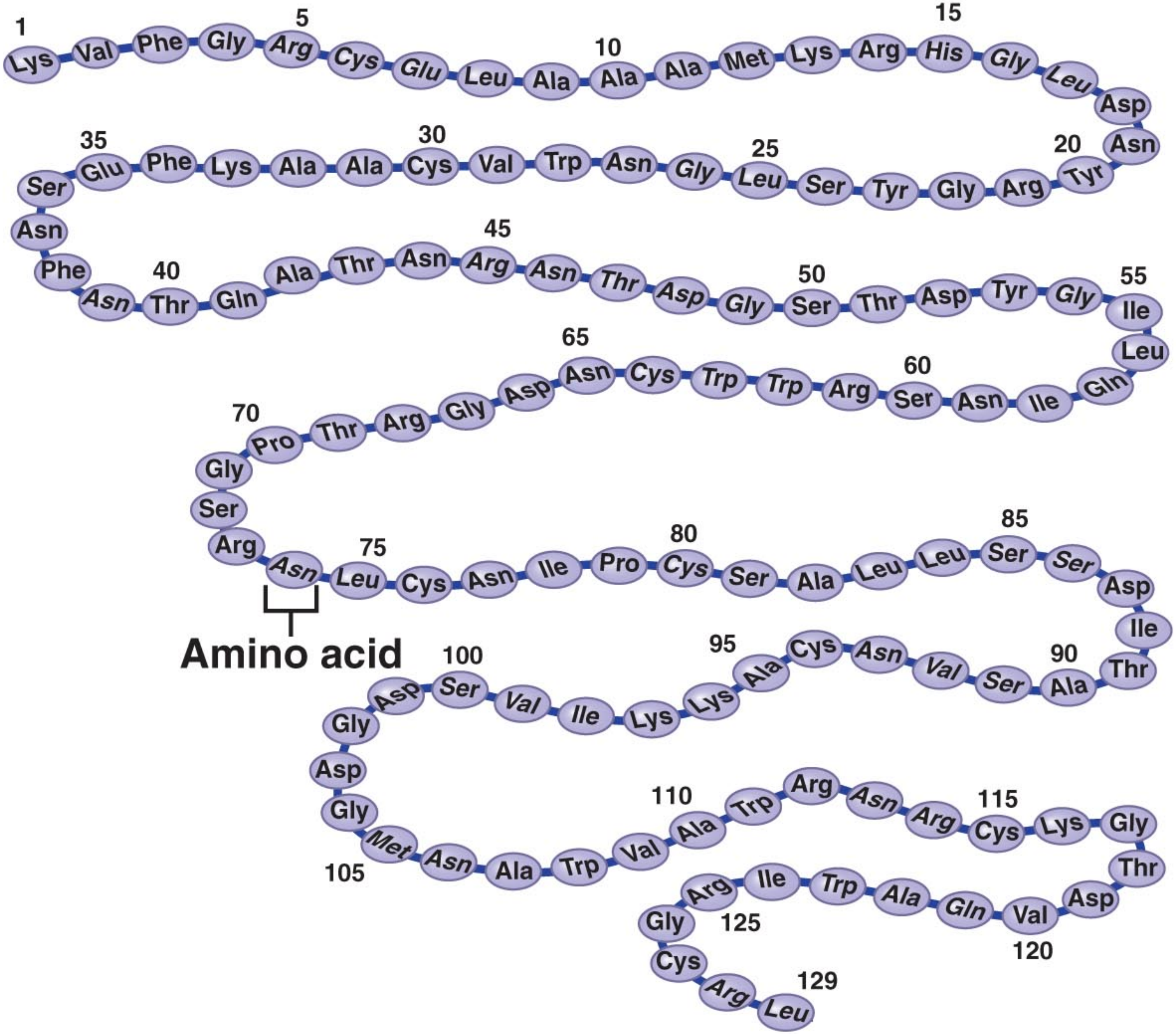


(a) The general structure of an amino acid



(b) Examples of amino acids with hydrophobic and hydrophilic side groups


Carboxyl group
Amino group
H
O
N
C
OH
+
Side group
Amino acid
Amino acid
H_2O
Dehydration reaction
Peptide bond


1
5
10
15
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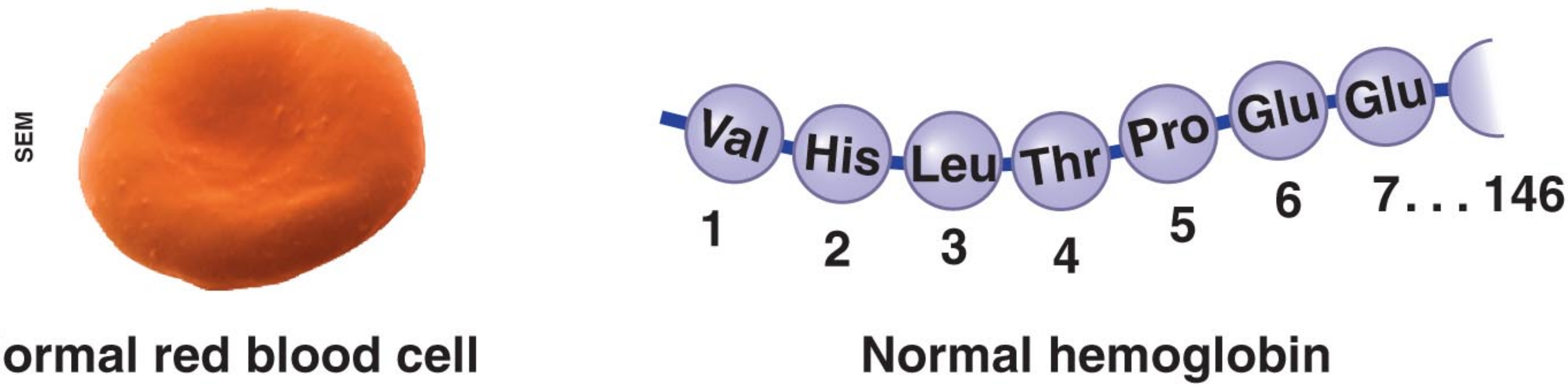
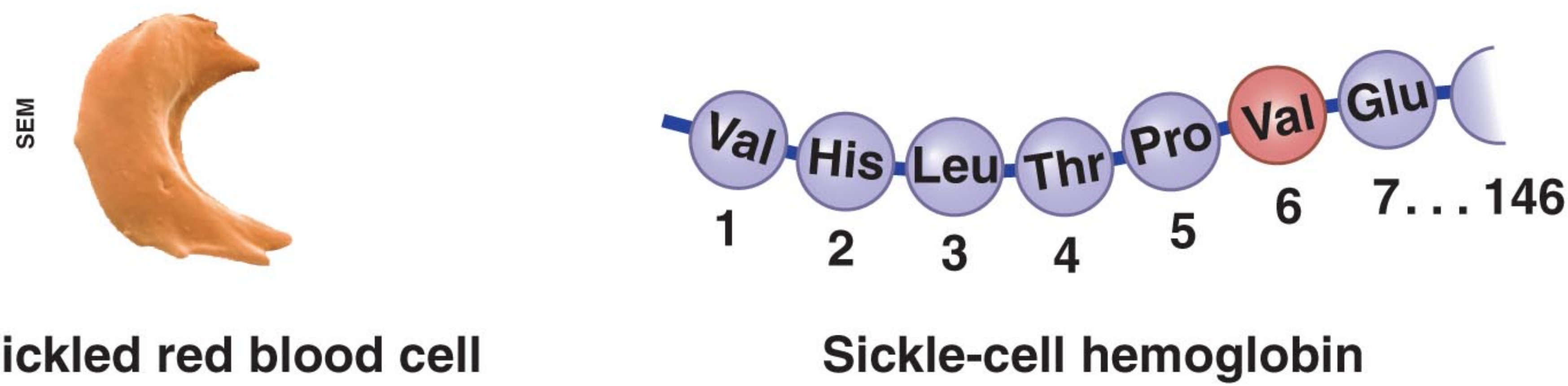
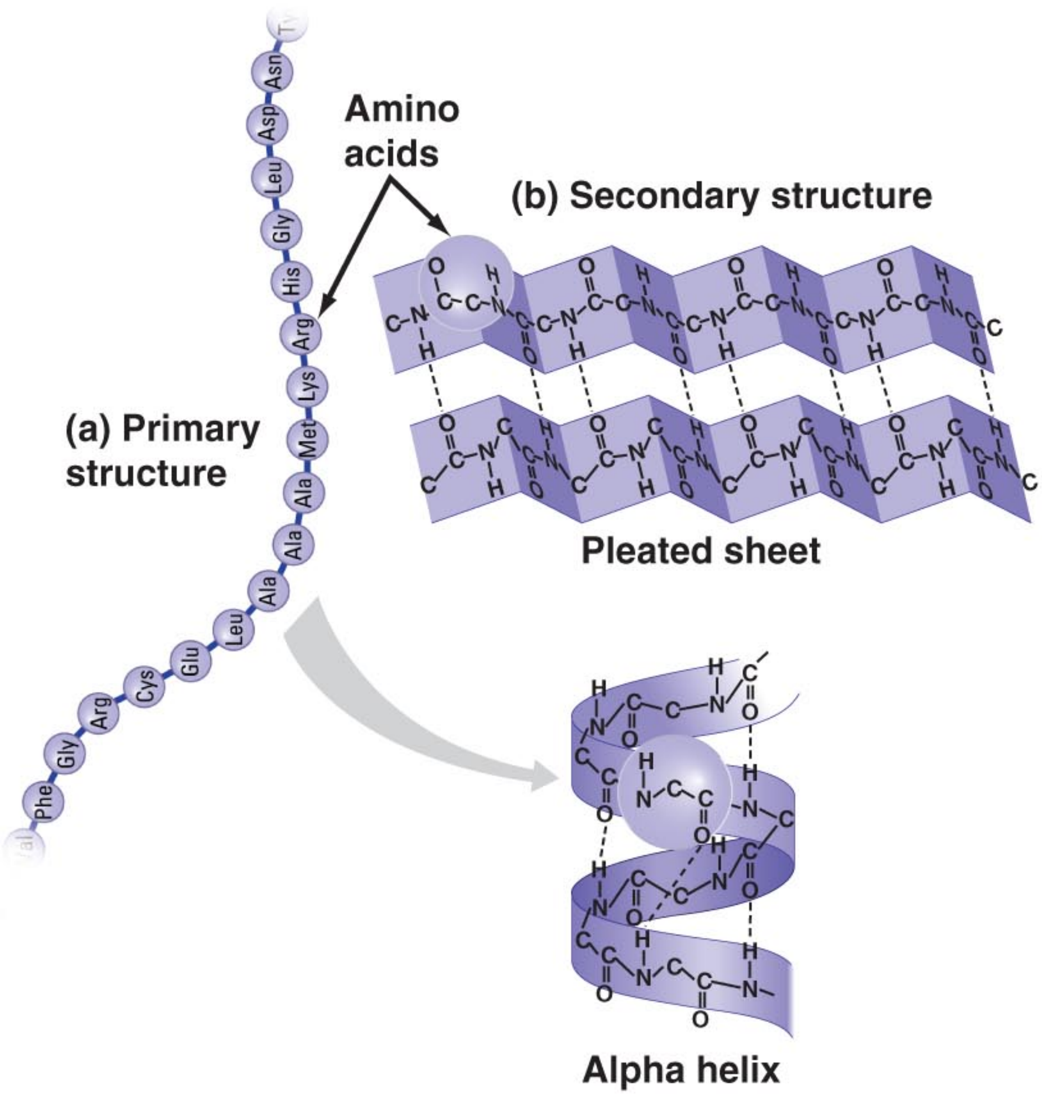
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
129
Amino acid
Lys Val Phe Gly Arg Cys Glu Leu Ala Ala Ala Met Lys Arg His Gly Leu Asp Asn Tyr Arg Gly Tyr Ser Leu Gly Asn Trp Val Cys Ala Ala Lys Phe Glu Ser Asn Phe Asn Thr Gln Ala Thr Asn Arg Asn Thr Asp Gly Ser Thr Asp Tyr Gly Ile Leu Gln Ile Asn Ser Arg Trp Trp Cys Asn Asp Gly Arg Thr Pro Gly Ser Arg Asn Leu Cys Asn Ile Pro Cys Ser Ala Leu Leu Ser Ser Asp Ile Thr Ala Ser Val Asn Cys Ala Lys Lys Ile Val Ser Asp Gly Asp Gly Met Asn Ala Trp Val Ala Trp Arg Asn Arg Cys Lys Gly Thr Asp Val Gln Ala Trp Ile Arg Gly Cys Arg Leu

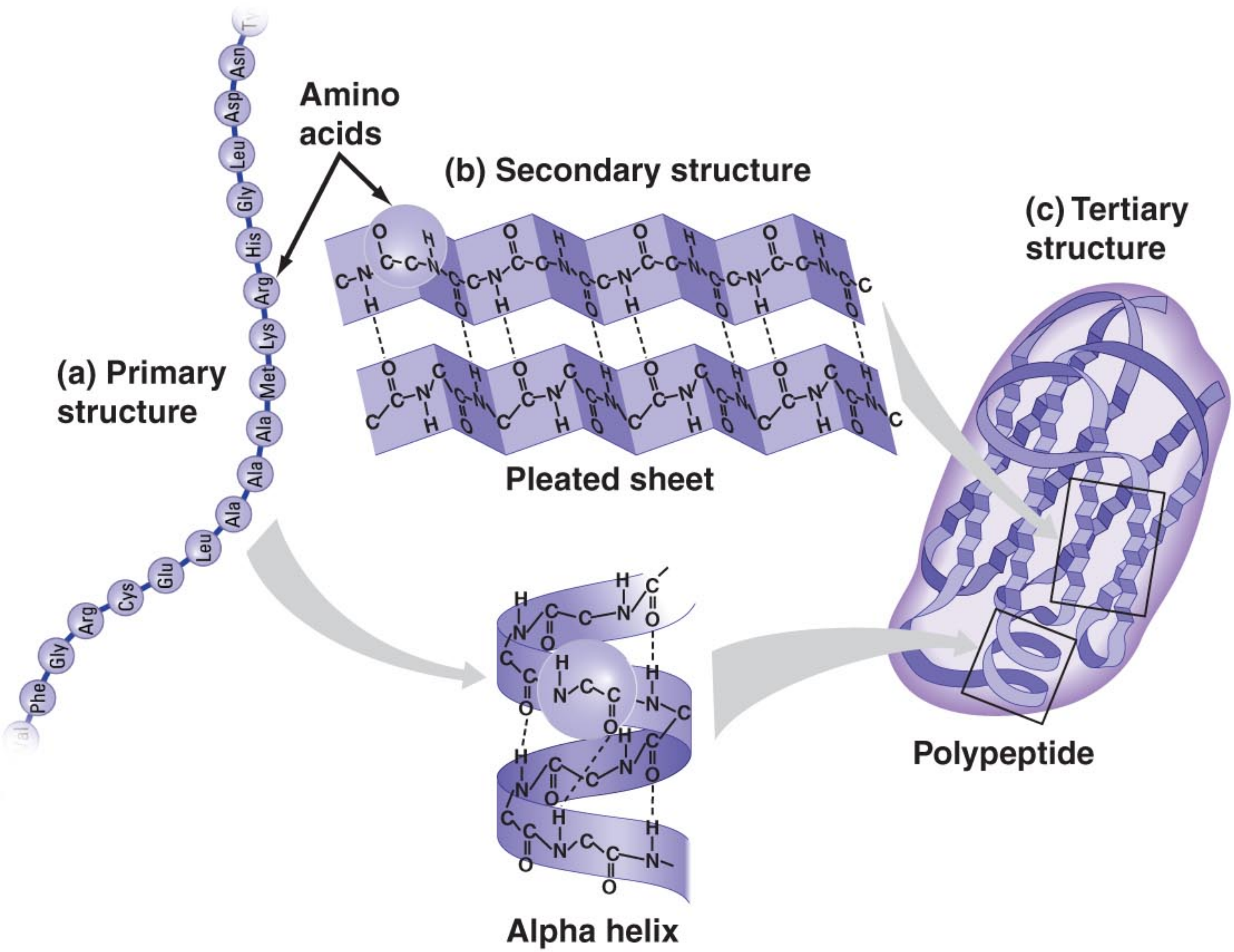


(a) Normal hemoglobin

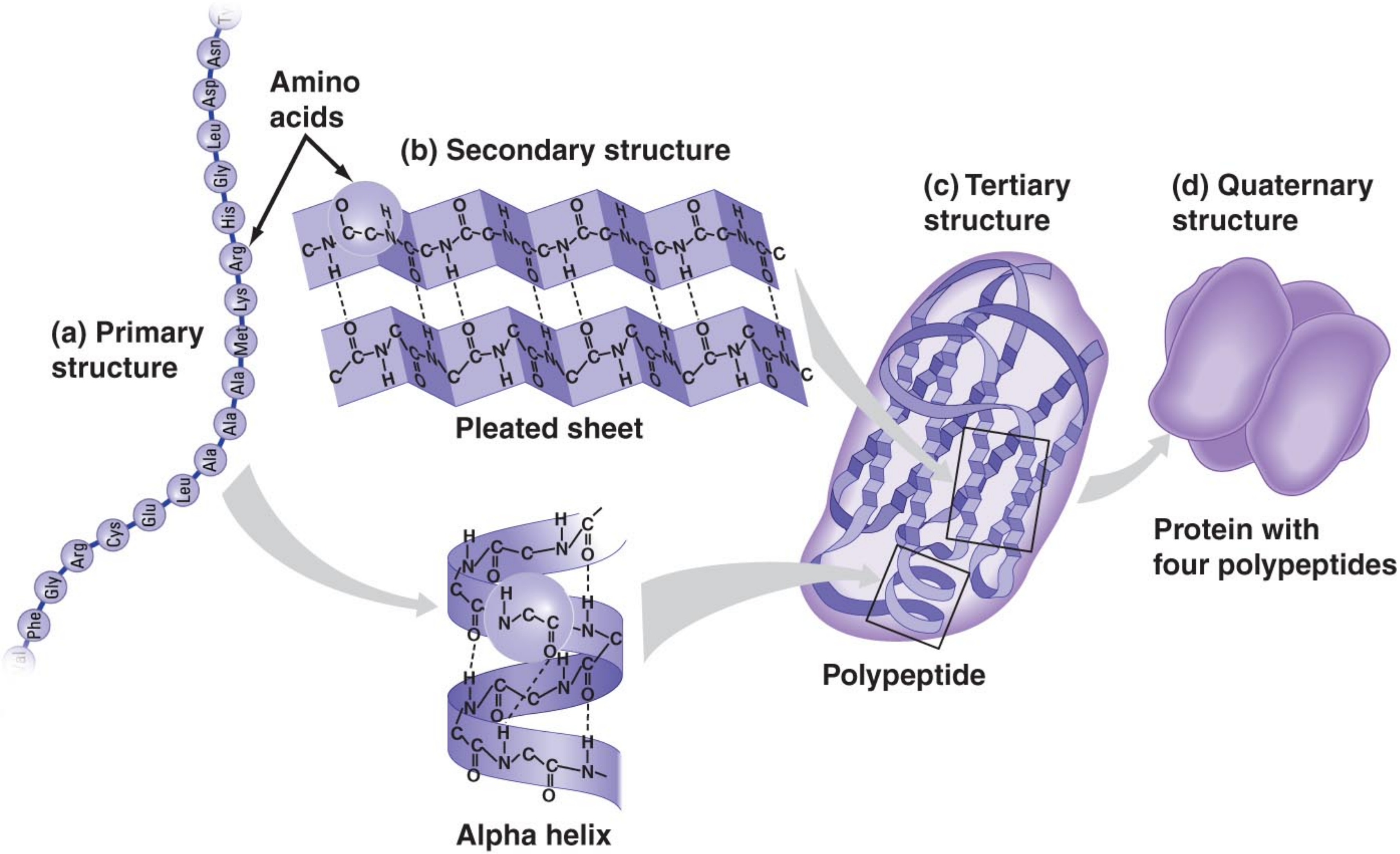


(b) Sickle-cell hemoglobin


Amino acids
(a) Primary structure
(b) Secondary structure
Pleated sheet
Alpha helix
Phe
Gly
Arg
Cys
Glu
Leu
Ala
Ala
Ala
Met
Lys
Arg
His
Gly
Leu
Asp
Asn

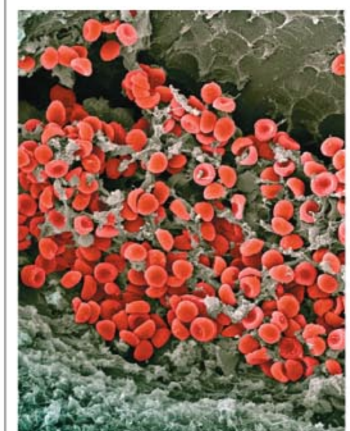


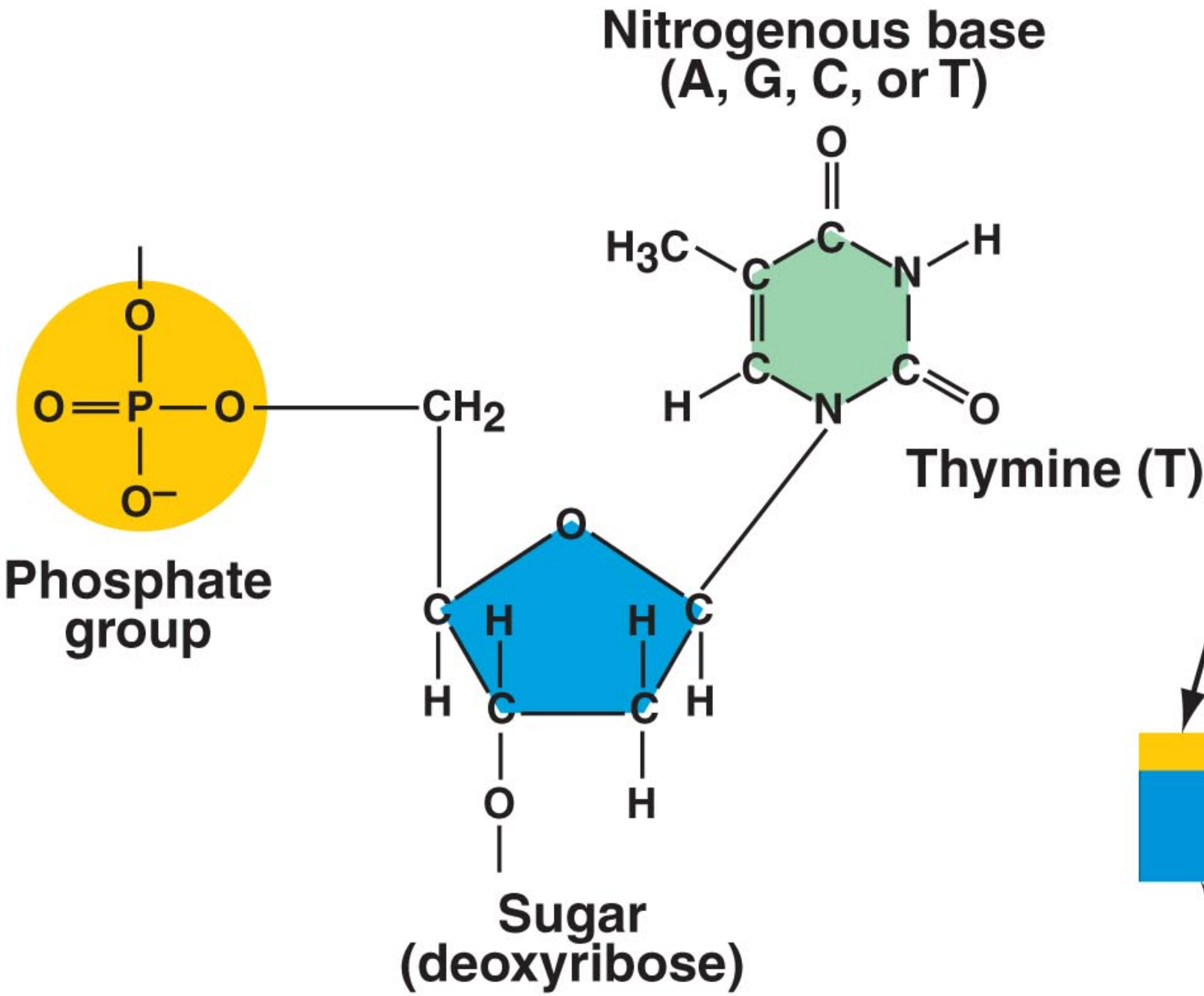
Amino acids
(a) Primary structure
(b) Secondary structure
(c) Tertiary structure
Pleated sheet
Alpha helix
Polypeptide
Asn
Asp
Leu
Gly
His
Arg
Lys
Met
Ala
Ala
Ala
Leu
Glu
Cys
Arg
Gly
Phe


Amino acids
(a) Primary structure
Phe
Gly
Arg
Cys
Glu
Leu
Ala
Ala
Ala
Met
Lys
Arg
His
Gly
Leu
Asp
Asn
(b) Secondary structure
Pleated sheet
Alpha helix
(c) Tertiary structure
Polypeptide
(d) Quaternary structure
Protein with four polypeptides

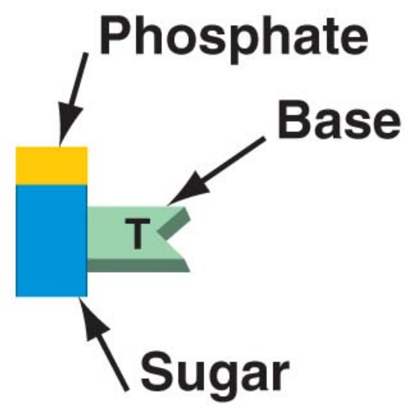
MAJOR TYPES OF PROTEINS

Structural Proteins	Storage Proteins	Contractile Proteins	Transport Proteins	Enzymes

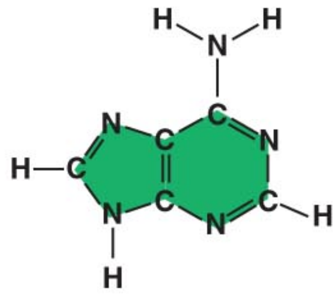




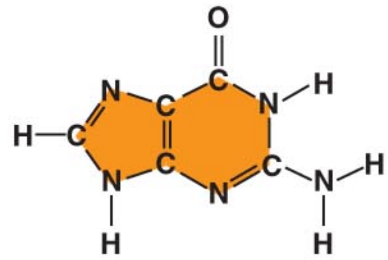
(a) Atomic structure



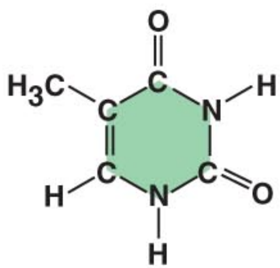
(b) Symbol used in this book



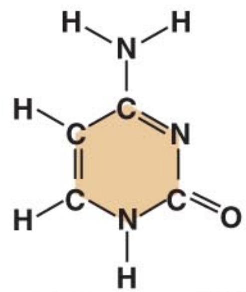
Adenine (A)



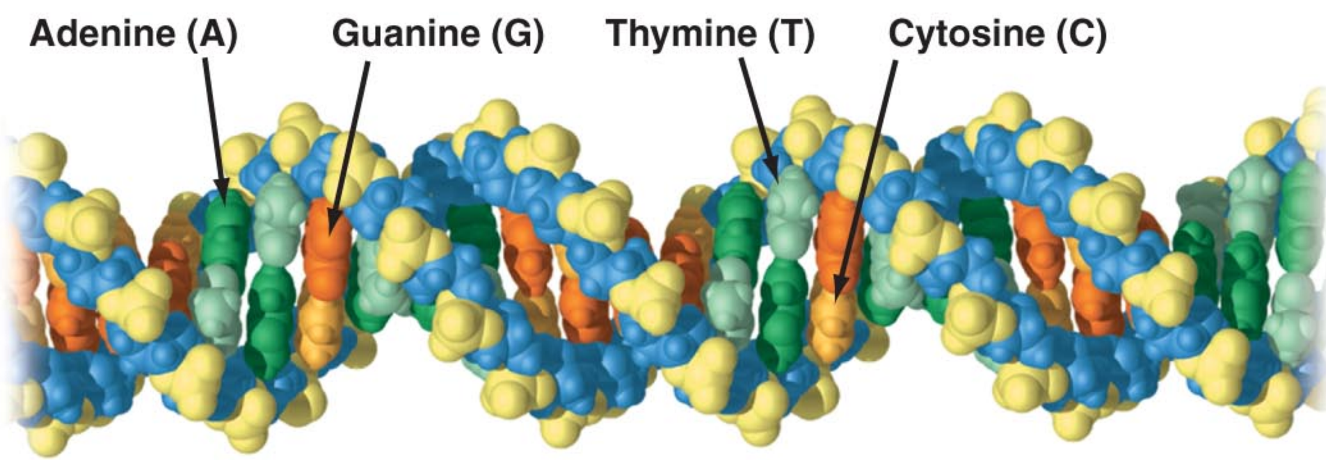
Guanine (G)



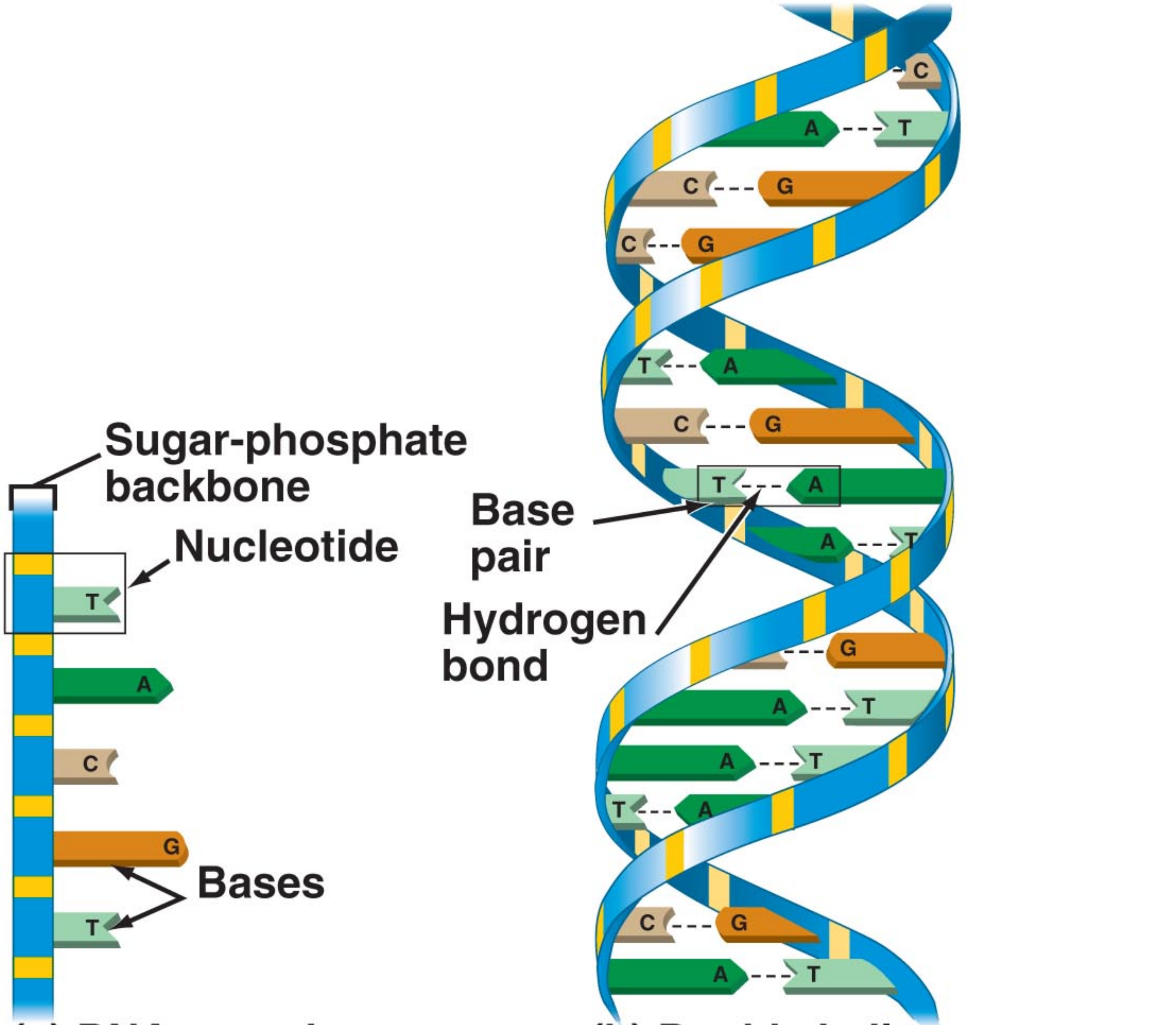
Thymine (T)



Cytosine (C)



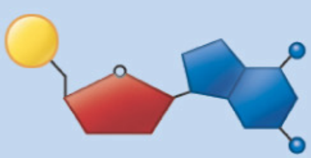
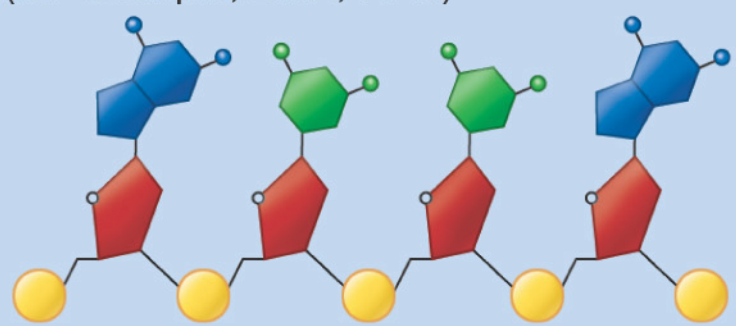
Space-filling model of DNA

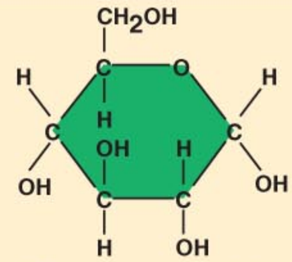
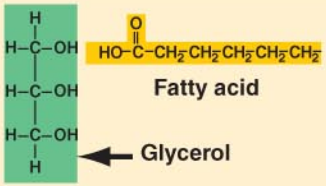
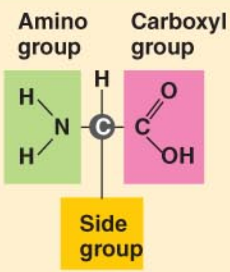
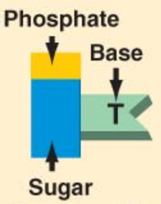


(a) DNA strand
(polynucleotide)

(b) Double helix
(two polynucleotide strands)

Table 3.2 Monomers, Polymers

If the monomer is...	The polymer is...
A **monosaccharide** (for example, glucose, fructose) 	A **polysaccharide** (for example, starch, glycogen, cellulose) 
An **amino acid** (for example, arginine, leucine) 	A **polypeptide** or **protein** (A- and B-chains of insulin are polypeptides and insulin is a protein) 
A **nucleotide** (sugar, phosphate, base in combination) 	A **nucleic acid** (for example, DNA, RNA) 

Large biological molecules	Functions	Components	Examples
Carbohydrates	Dietary energy; storage; plant structure	 Monosaccharide	Monosaccharides: glucose, fructose Disaccharides: lactose, sucrose Polysaccharides: starch, cellulose
Lipids	Long-term energy storage (fats); hormones (steroids)	 Components of a triglyceride	Fats (triglycerides); Steroids (testosterone, estrogen)
Proteins	Enzymes, structure, storage, contraction, transport, and others	 Amino acid	Lactase (an enzyme), hemoglobin (a transport protein)
Nucleic acids	Information storage	 Nucleotide	DNA, RNA