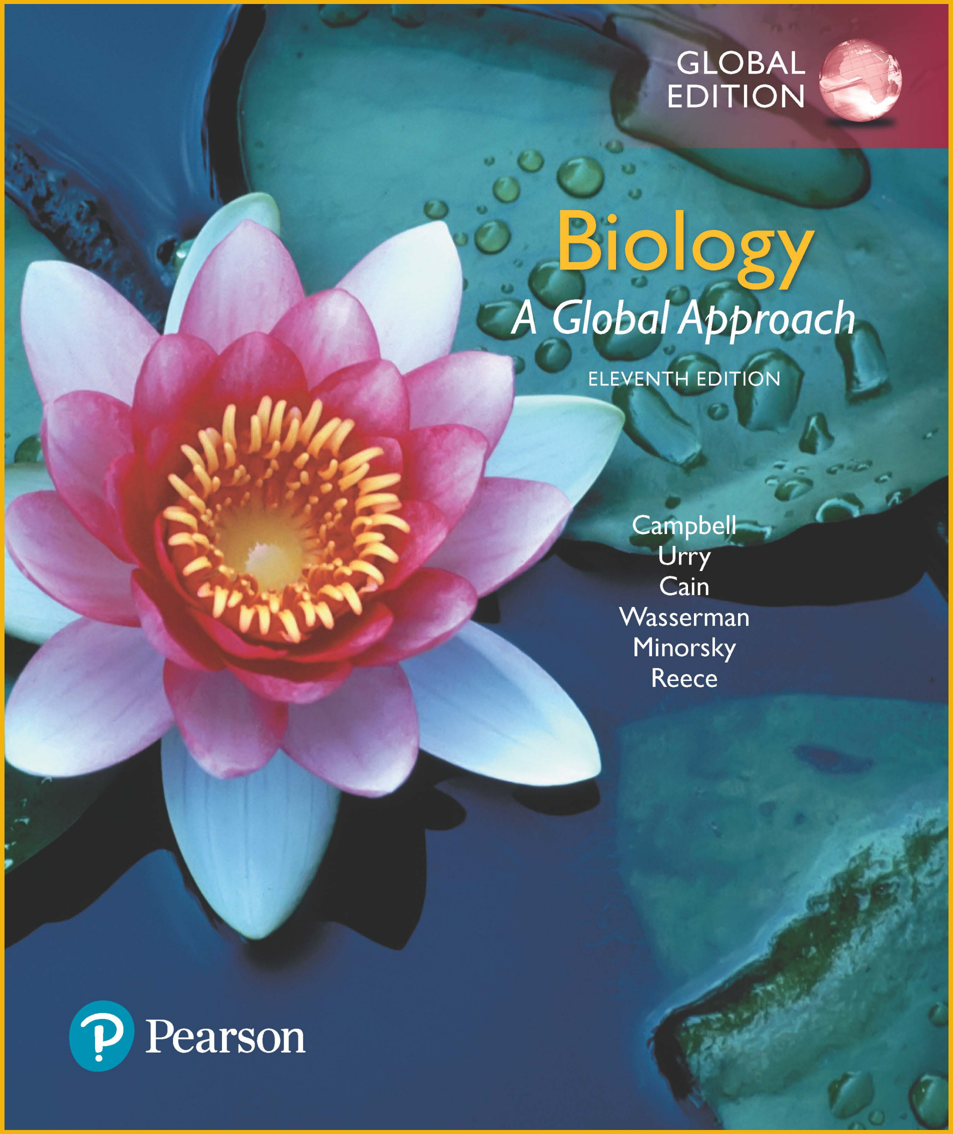



# Chapter 5

# Biological Macromolecules and Lipids

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

# he Molecules of Life

- All living things are made up of four classes of large biological molecules: carbohydrates, lipids, proteins, and nucleic acids
- **Macromolecules** are large molecules and are complex
- Large biological molecules have unique properties that arise from the orderly arrangement of their atoms

Figure 5.1

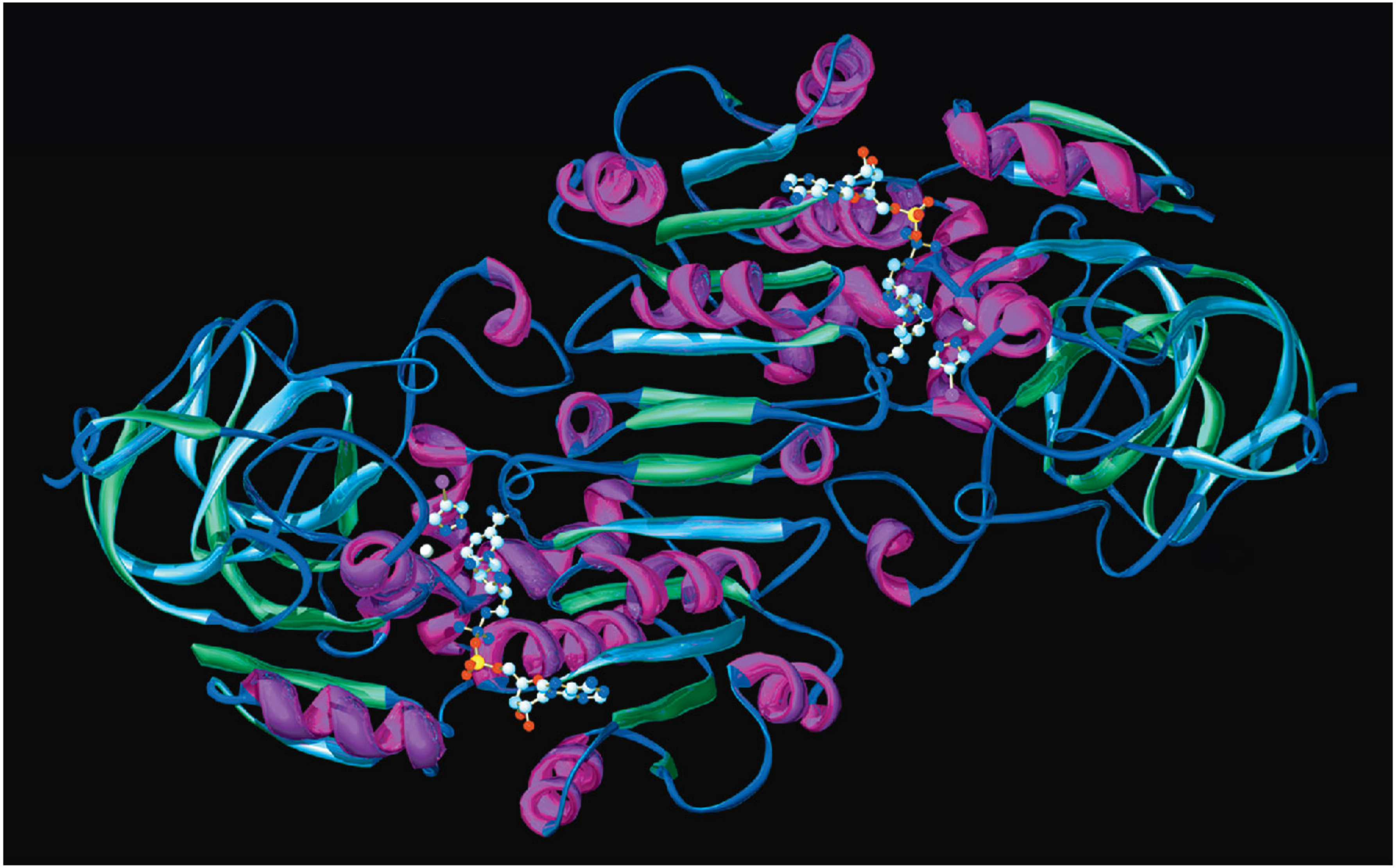


Figure 5.1a

The scientist in the foreground is using 3-D glasses to help her visualize the structure of the protein displayed on her screen.

# oncept 5.1: Macromolecules are polymers, built from monomers

- A **polymer** is a long molecule consisting of many similar building blocks → not necissarily identical
- The repeating units that serve as building blocks are called **monomers**
- Carbohydrates, proteins, and nucleic acids are polymers
  ① ② ③

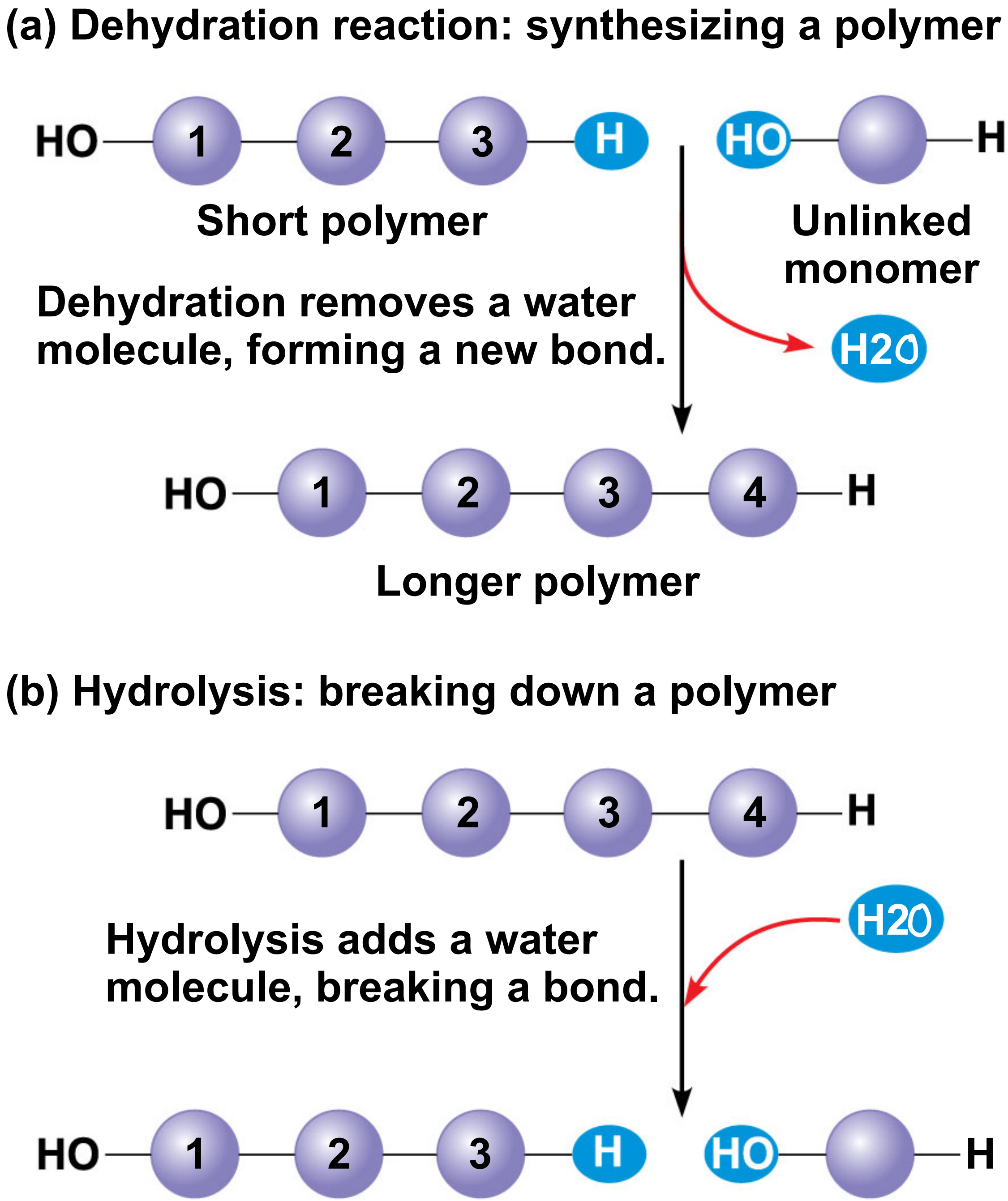
* lipids are not polymers

# he Synthesis and Breakdown of Polymers

- **Enzymes** are specialized macromolecules that speed up chemical reactions such as those that make or break down polymers
- A **dehydration reaction** (✱) occurs when two monomers bond together through the loss of a water molecule
- Polymers are disassembled to monomers by **hydrolysis**, a reaction that is essentially the reverse of the dehydration reaction

(✱) Dehydration is a type of condensation reactions.

Figure 5.2


(a) Dehydration reaction: synthesizing a polymer
HO
1
2
3
H
HO
H
Short polymer
Unlinked monomer
Dehydration removes a water molecule, forming a new bond.
H2O
HO
1
2
3
4
H
Longer polymer
(b) Hydrolysis: breaking down a polymer
HO
1
2
3
4
H
H2O
Hydrolysis adds a water molecule, breaking a bond.
HO
1
2
3
H
HO
H

# he Diversity of Polymers

- A cell has thousands of different macromolecules
- Macromolecules vary among cells of an organism, vary more within a species, and vary even more between species
- A huge variety of polymers can be built from a small set of monomers

$n$ = no. of different monomers

$r$ = no. of monomers in the polymer

$n^r$ = different possibilities

# oncept 5.2: Carbohydrates serve as fuel and building material

- **Carbohydrates** include sugars and the polymers of sugars
- The simplest carbohydrates are monosaccharides, or simple sugars
- Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks

# ugars

- **Monosaccharides** have molecular formulas that are usually multiples of CH2O empirical formula

$(CH_2O)_n$ General Formula

- Glucose (C6H12O6) is the most common monosaccharide
- Monosaccharides are classified by
  - The location of the carbonyl group (as aldose or ketose)
  - The number of carbons in the carbon skeleton

aldehyde sugar

ketone sugar

Ranges from 3 to 7 atoms "C".

Figure 5.3

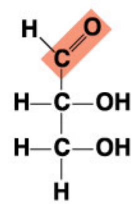
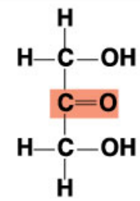
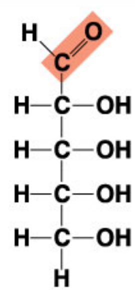
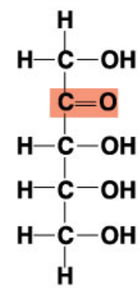
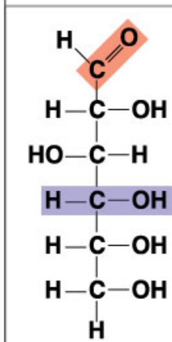
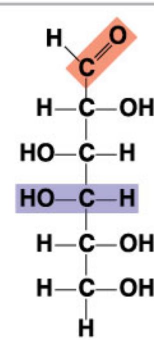
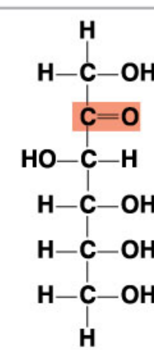
| Aldoses (Aldehyde Sugars) | Ketoses (Ketone Sugars) |
|---|---|
| **Trioses: three-carbon sugars ($C_3H_6O_3$)** | |
|  Glyceraldehyde |  Dihydroxyacetone |
| **Pentoses: five-carbon sugars ($C_5H_{10}O_5$)** | |
|  Ribose |  Ribulose |
| **Hexoses: six-carbon sugars ($C_6H_{12}O_6$)** | |
|  Glucose  Galactose |  Fructose |

Figure 5.3a

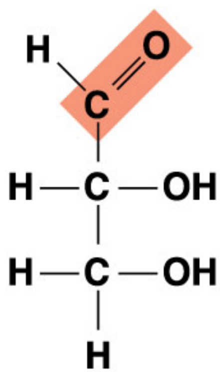
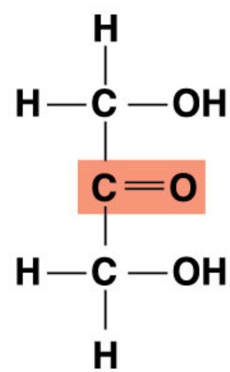
| Aldose (Aldehyde Sugar) | Ketose (Ketone Sugar) |
|---|---|
| Trioses: three-carbon sugars (C3H6O3) | |
|  |  |
| Glyceraldehyde | Dihydroxyacetone |

Figure 5.3b

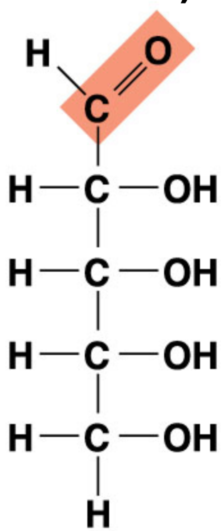
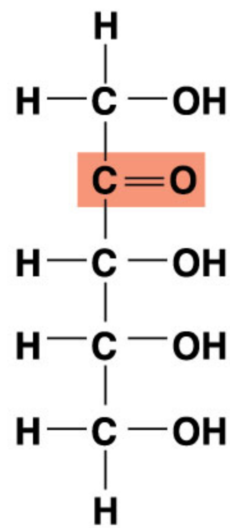
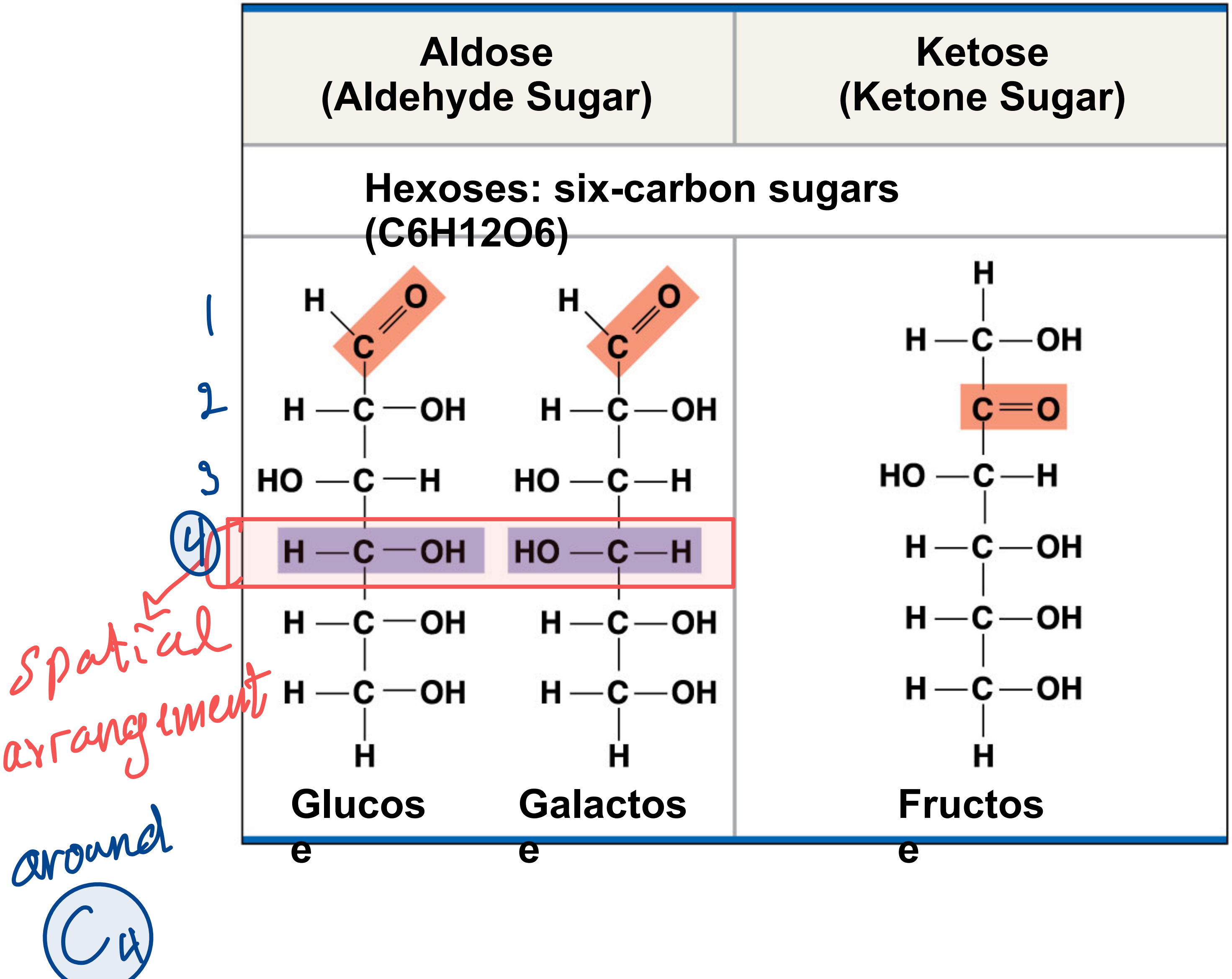
| **Aldose (Aldehyde Sugar)** | **Ketose (Ketone Sugar)** |
|---|---|
| **Pentoses: five-carbon sugars (C5H10O5)** | |
|  |  |
| **Ribose** | **Ribulose** |

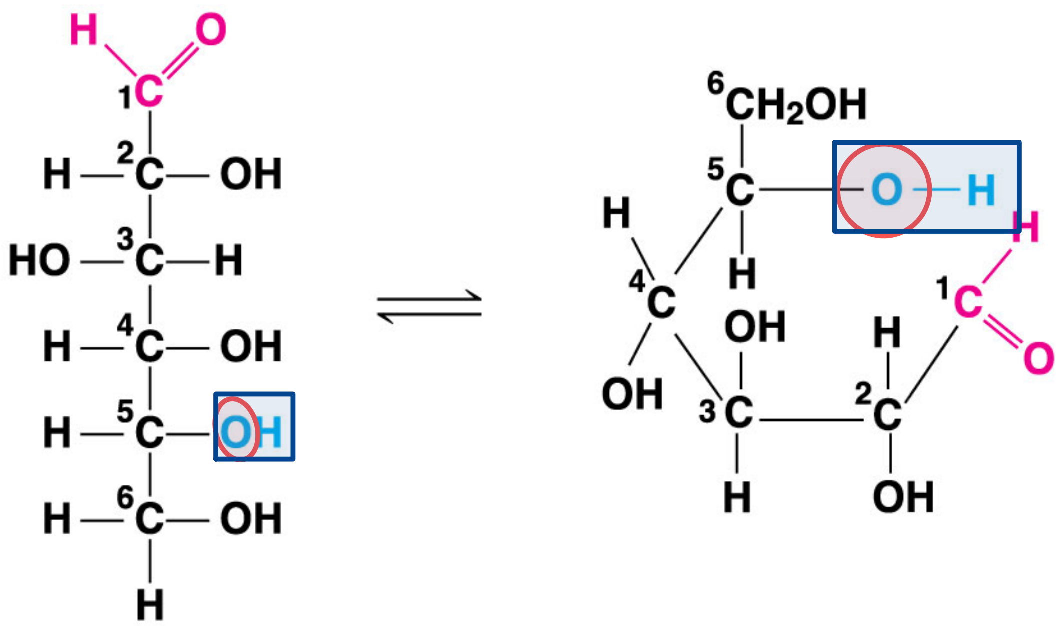
Figure 5.3c


Aldose
(Aldehyde Sugar)
Ketose
(Ketone Sugar)
Hexoses: six-carbon sugars
(C6H12O6)
Glucos
e
Galactos
e
Fructos
e
spatial arrangement
around
C4

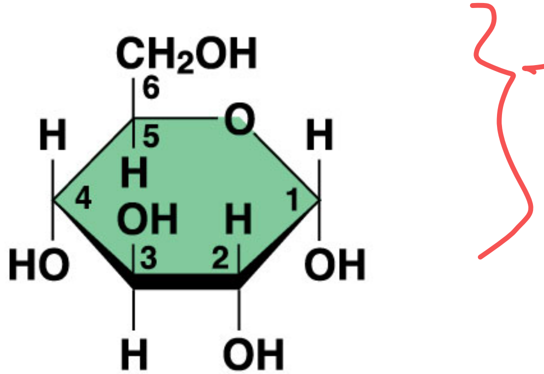
- Though often drawn as linear skeletons, in aqueous solutions many sugars form rings ⊛
- Monosaccharides serve as a major fuel for cells (1) and as raw material for building molecules (2)

⊛ Rings are more stable than linear structures in aqueous solutions.

Figure 5.4



(a) Linear and ring forms



α-glucose (later)

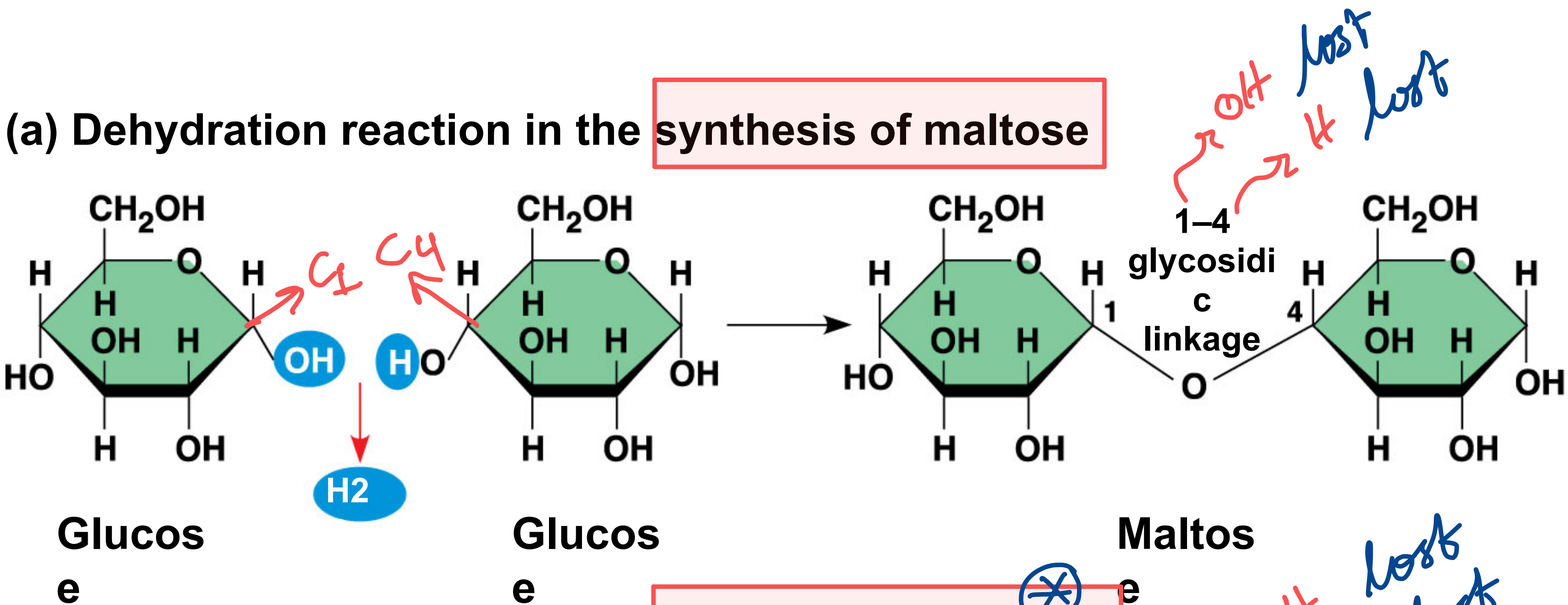
(b) Abbreviated ring structure : Empty angles represent carbon atoms.

- A **disaccharide** is formed when a dehydration reaction joins two monosaccharides
- This covalent bond is called a **glycosidic linkage**

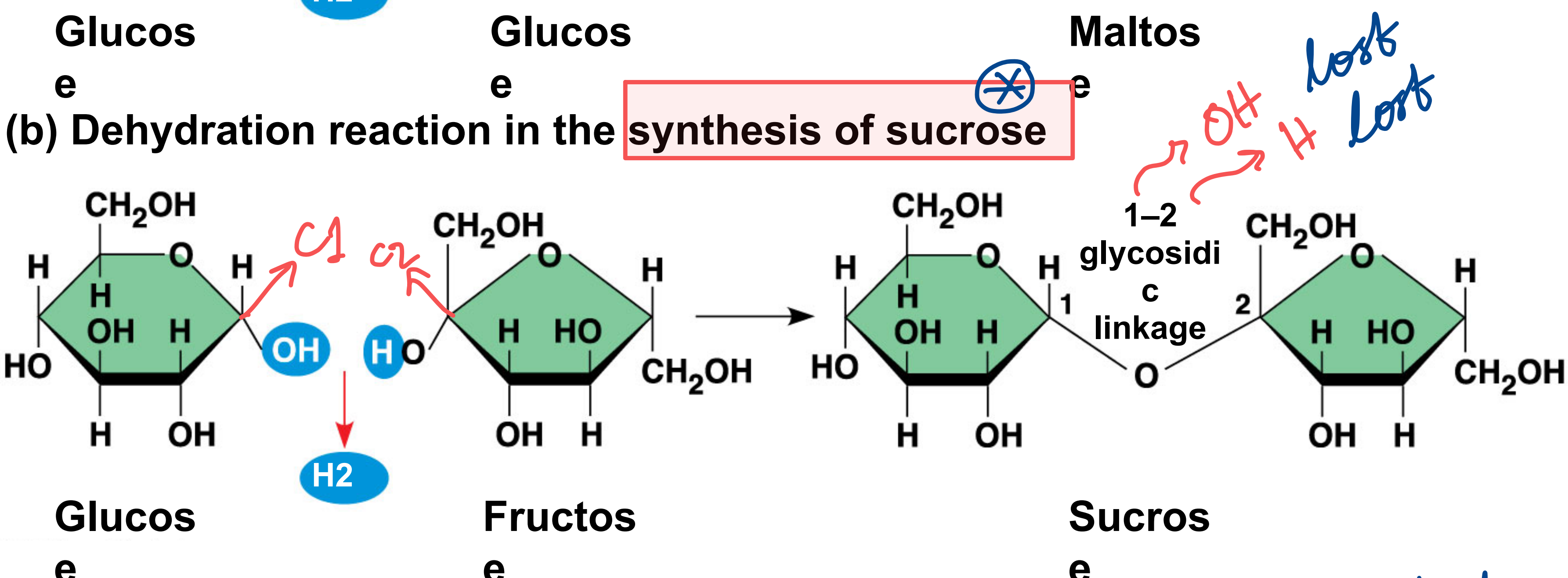
Hydroxyl – Hydroxyl linkage

Figure 5.5

## (a) Dehydration reaction in the synthesis of maltose




## (b) Dehydration reaction in the synthesis of sucrose




* sucrose: used in plants when transporting carbohydrates to non-photosynthetic organs — roots ...

# olysaccharides

- **Polysaccharides**, the polymers of sugars, have storage (1) and structural (2) roles
- The architecture (1) and function (2) of a polysaccharide are determined by its sugar monomers (1) and the positions of its glycosidic linkages (2)

(+) additional Disaccharide example:

Lactose (milk sugar): glucose + galactose

# torage Polysaccharides

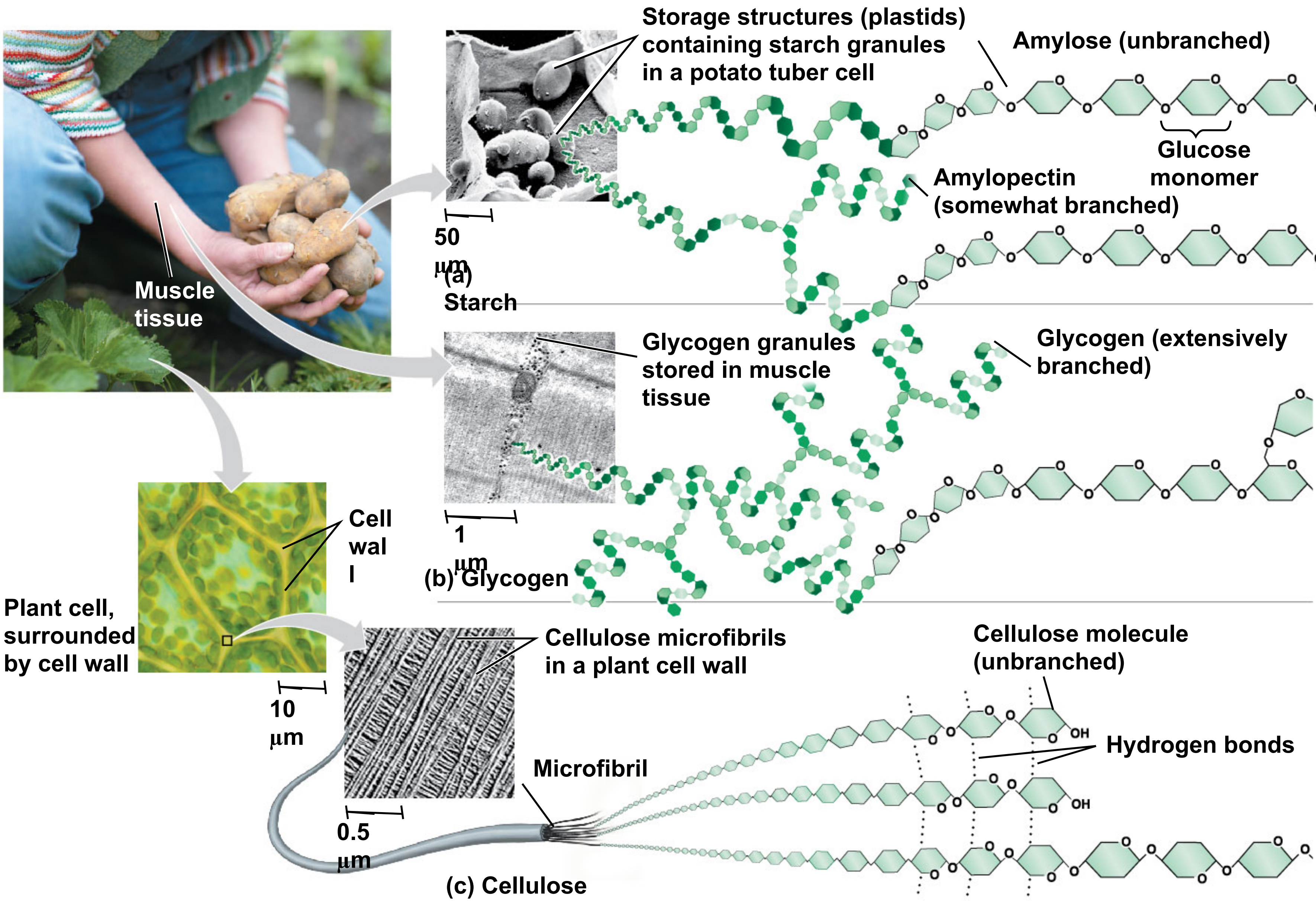
- **Starch**, a storage polysaccharide of plants, consists of glucose monomers
- Plants store surplus starch as granules within chloroplasts and other plastids
- The simplest form of starch is amylose

excess

small particles

(unbranched)

Figure 5.6



Muscle tissue
Storage structures (plastids) containing starch granules in a potato tuber cell
50 µm
(a) Starch
Amylose (unbranched)
Glucose monomer
Amylopectin (somewhat branched)
Glycogen granules stored in muscle tissue
1 µm
(b) Glycogen
Glycogen (extensively branched)
Cell wall
Plant cell, surrounded by cell wall
10 µm
Cellulose microfibrils in a plant cell wall
0.5 µm
Microfibril
(c) Cellulose
Cellulose molecule (unbranched)
Hydrogen bonds
OH

Figure 5.6a

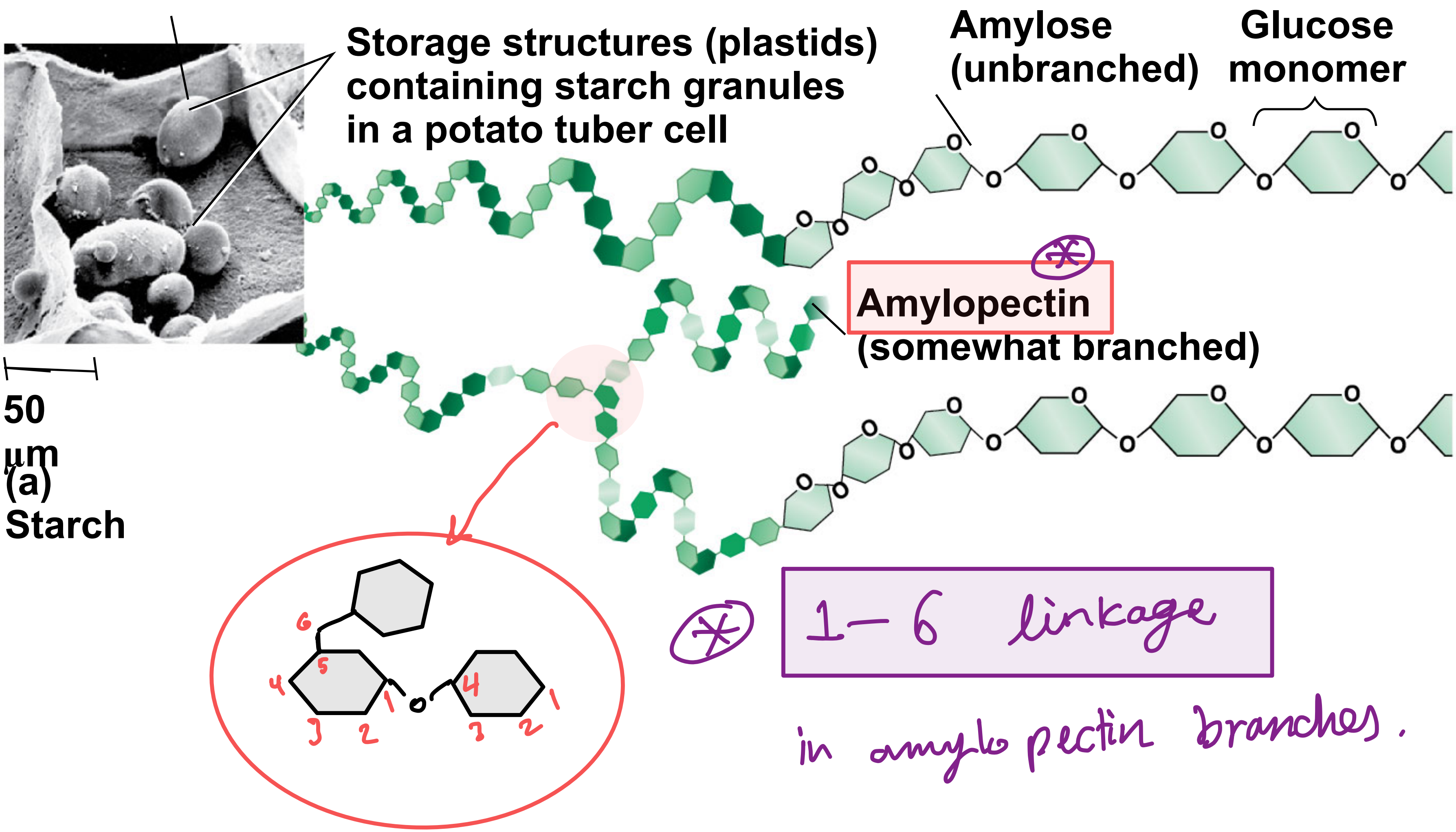
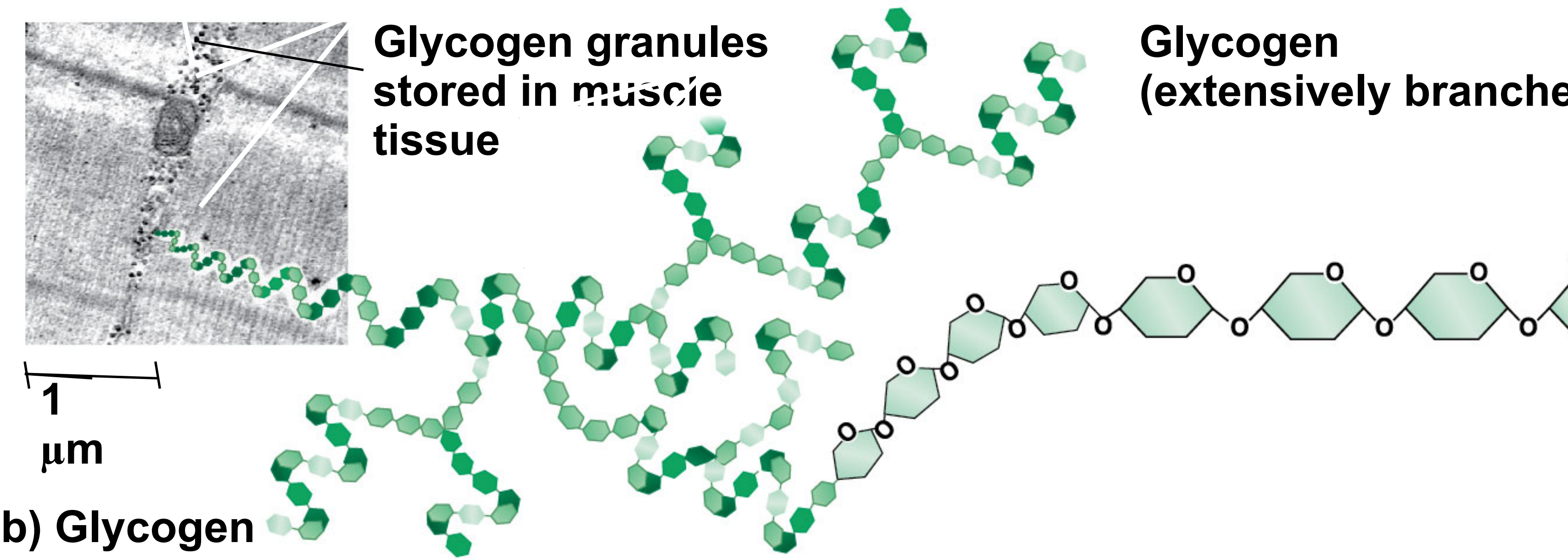
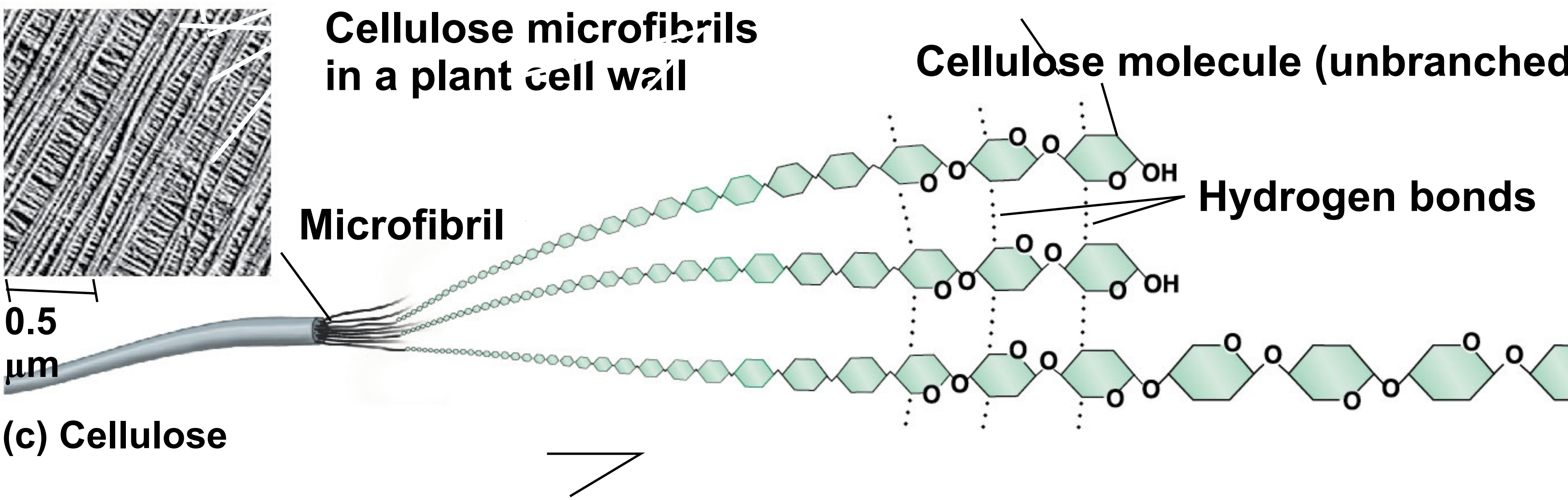

Storage structures (plastids) containing starch granules in a potato tuber cell
Amylose (unbranched)
Glucose monomer
Amylopectin (somewhat branched)
50 µm
(a) Starch
1–6 linkage
in amylo pectin branches.

Figure 5.6b



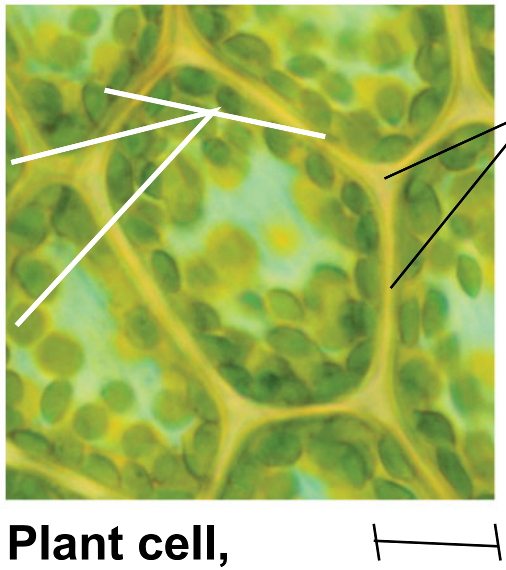

(b) Glycogen

Figure 5.6c




(c) Cellulose

Figure 5.6d




Plant cell,
surrounded
by cell wall

Not long sustaining (unlike starch)

- **Glycogen** is a storage polysaccharide in animals
- Glycogen is stored mainly in liver and muscle cells
- Hydrolysis of glycogen in these cells releases glucose when the demand for sugar increases

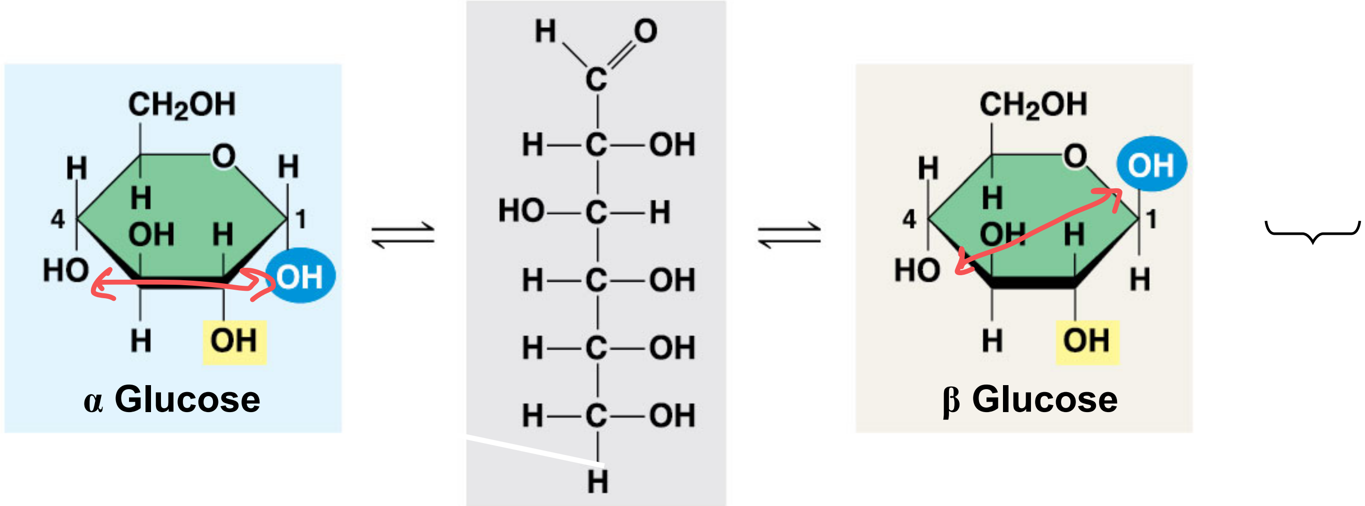
# tructural Polysaccharides

Annually → $10^{14}$ kg   the most abundant organic compound on Earth.

- The polysaccharide **cellulose** is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ } → important
- The difference is based on two ring forms for glucose: alpha (α) and beta (β)

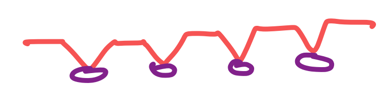
⊗ The linear structure of glucose does not differ

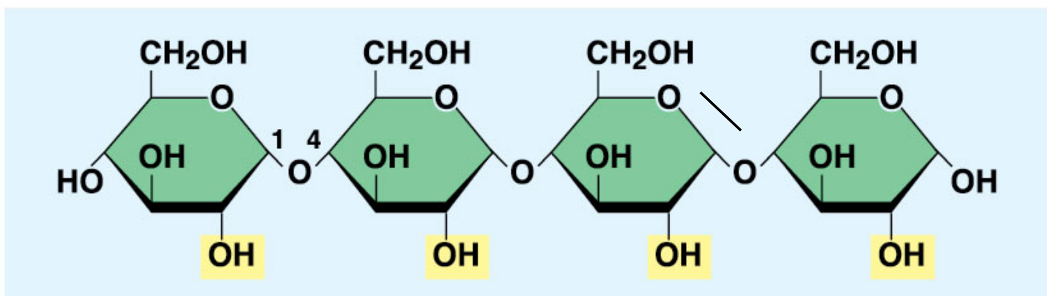
Figure 5.7




(a) α and β glucose ring structures

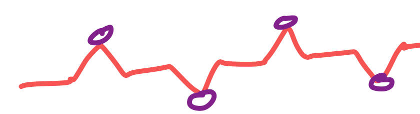
corresponding



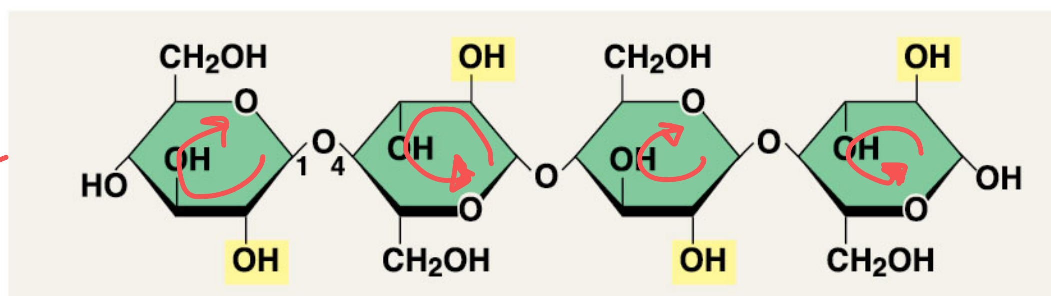



(b) Starch: 1–4 linkage of α glucose monomers

Alternating



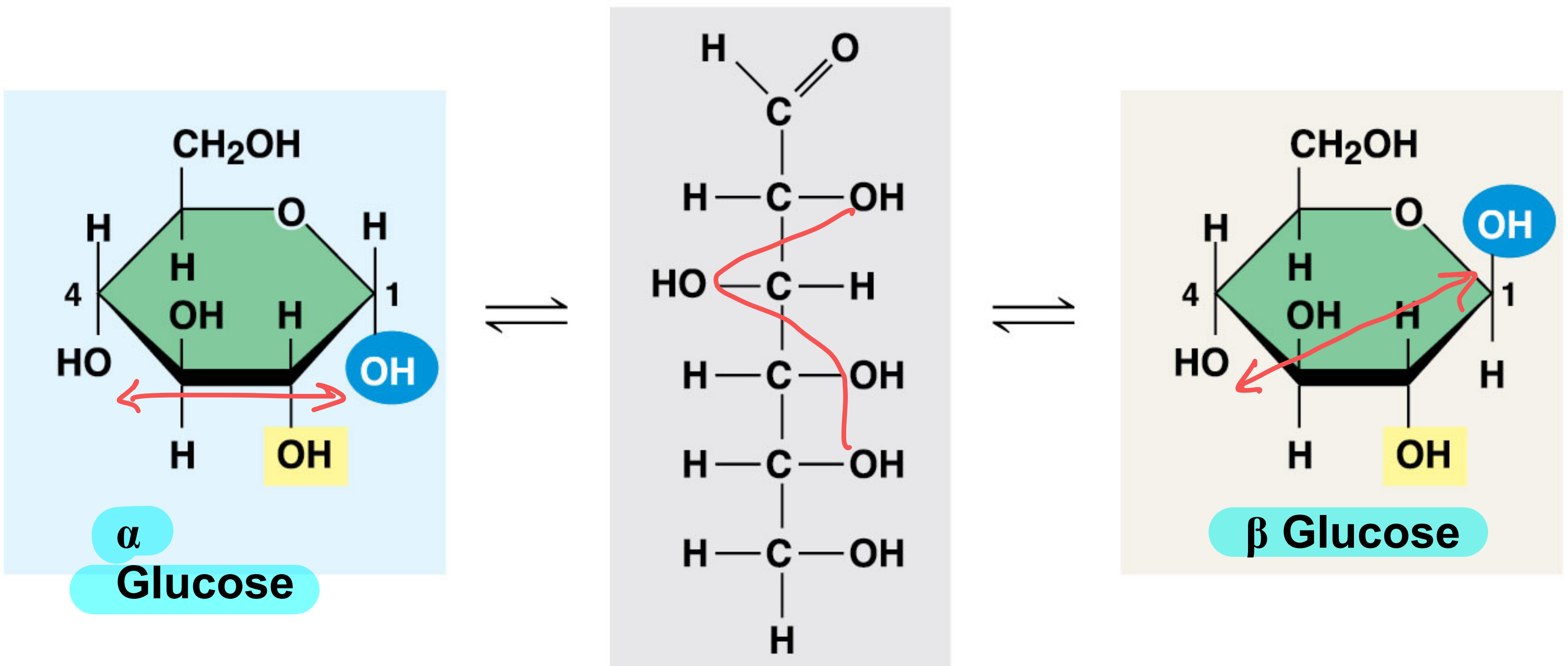
arrows are for numbering of Carbon atoms




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

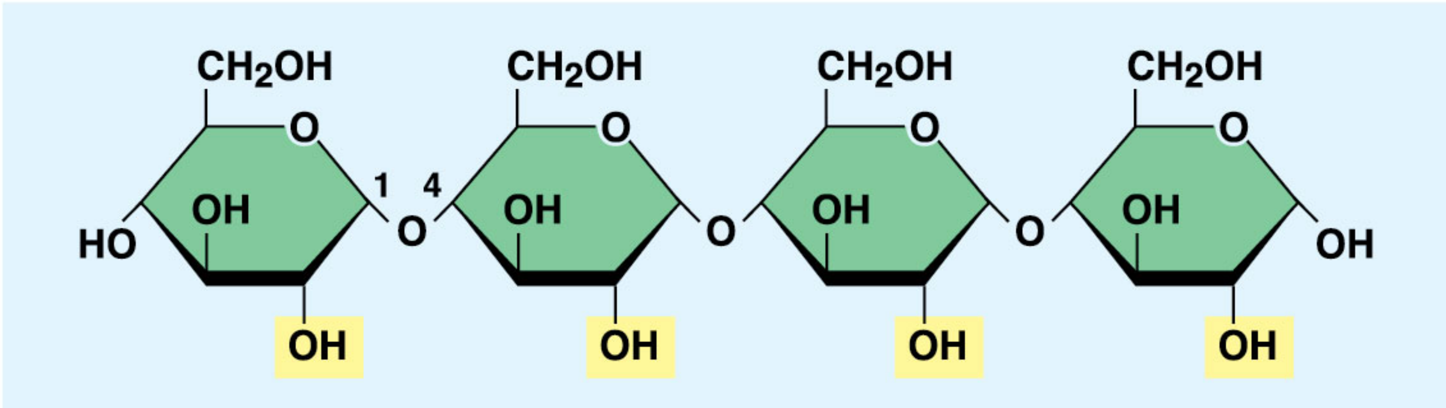
Figure 5.7a

⊛ Both α & β Share the same linear Configuration

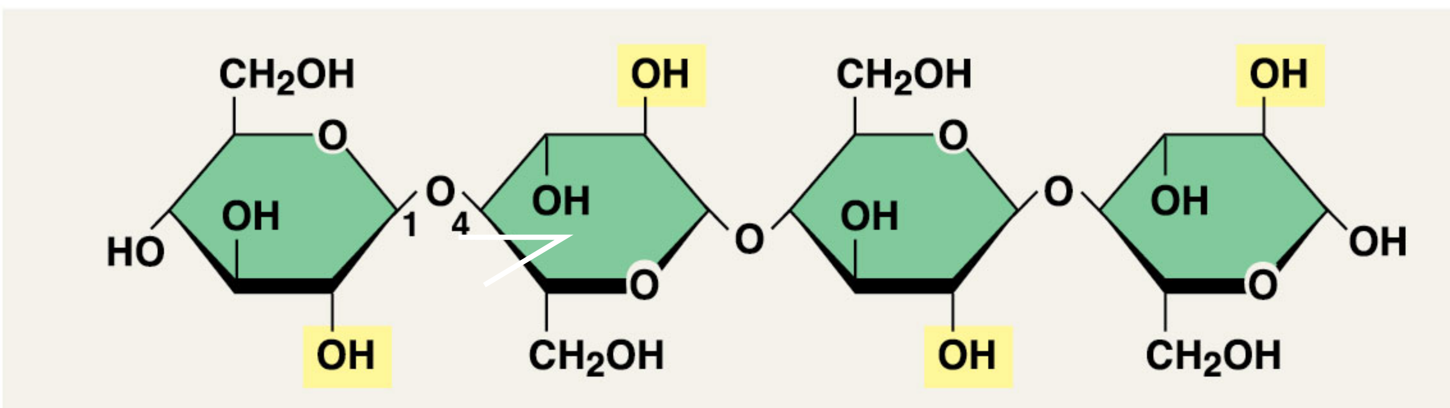



(a) α and β glucose ring structures

Figure 5.7b




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

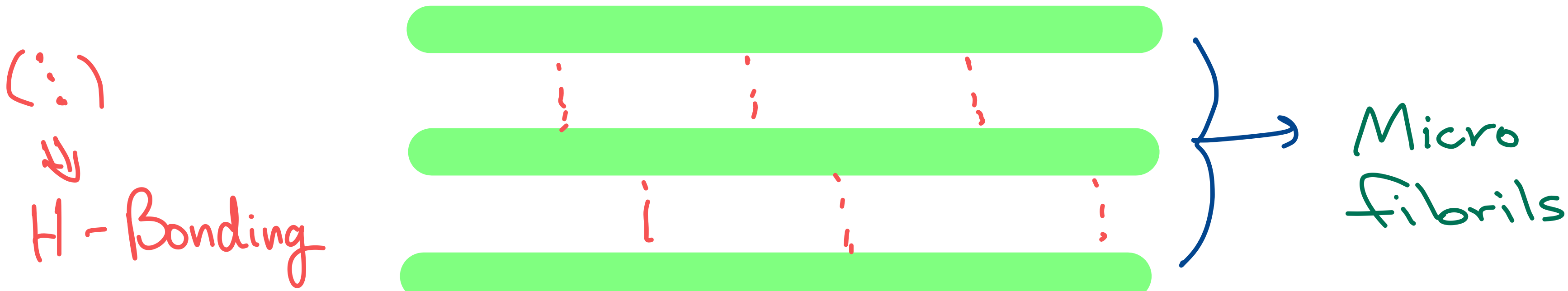



**(c) Cellulose: 1–4 linkage of β glucose monomers**

Starch (α configuration) is largely helical

Cellulose molecules (β configuration) are straight and unbranched

Some hydroxyl groups on the monomers of cellulose can hydrogen-bond with hydroxyls of parallel cellulose molecules



- Enzymes that digest starch by hydrolyzing α linkages can’t hydrolyze β linkages in cellulose
- The cellulose in human food passes through the digestive tract as “insoluble fiber”
- Some microbes use enzymes to digest cellulose
- Many herbivores, from cows to termites, have symbiotic relationships with these microbes

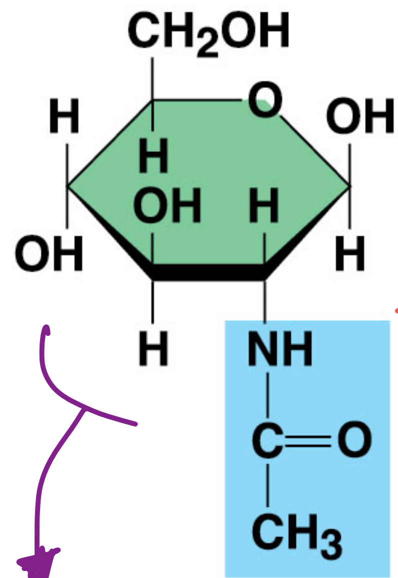
(Kaitin)

like Cellulose

- **Chitin**, another structural polysaccharide, is found in the exoskeleton of arthropods
- Chitin also provides structural support for the cell walls of many fungi

Figure 5.8

(*) Chitin is decomposed using a different enzyme than cellulase ⇒ Chitinase




**The structure of the chitin monomer**

Nitrogen-containing group.

Similar to glucose (β)

Because Chitin is like cellulose

◀ **Chitin, embedded in proteins, forms the exoskeleton ~~of~~ arthropods.**

# oncept 5.3: Lipids are a diverse group of hydrophobic molecules

- **Lipids** are the one class of large biological molecules that does not include true polymers (*)
- The unifying feature of lipids is that they mix poorly, if at all, with water
- Lipids consist mostly of hydrocarbon regions
- The most biologically important lipids are fats, (1) phospholipids (2), and steroids (3)

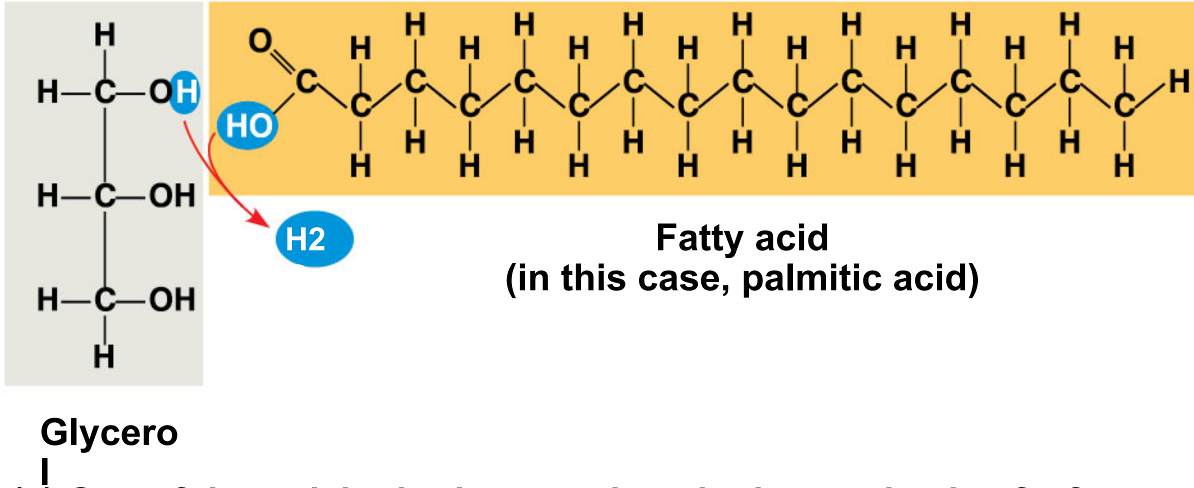
(*) That is why lipids are excluded from the title of the chapter unlike other macromolecules → Carbohydrates → Proteins → Nucleic acids.

# ats

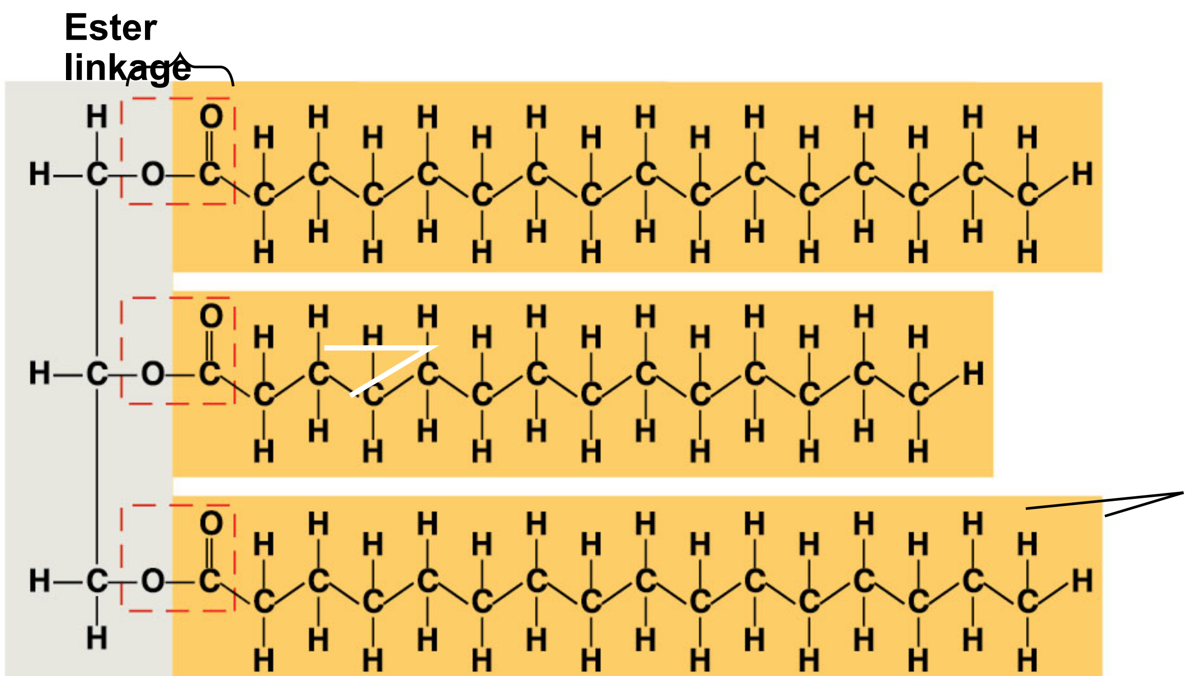
- **Fats** are constructed from two types of smaller molecules: glycerol ① and fatty acids ②
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon
- A **fatty acid** consists of a carboxyl group attached to a long carbon skeleton

usually 16 or 18 carbon atoms.

Figure 5.9

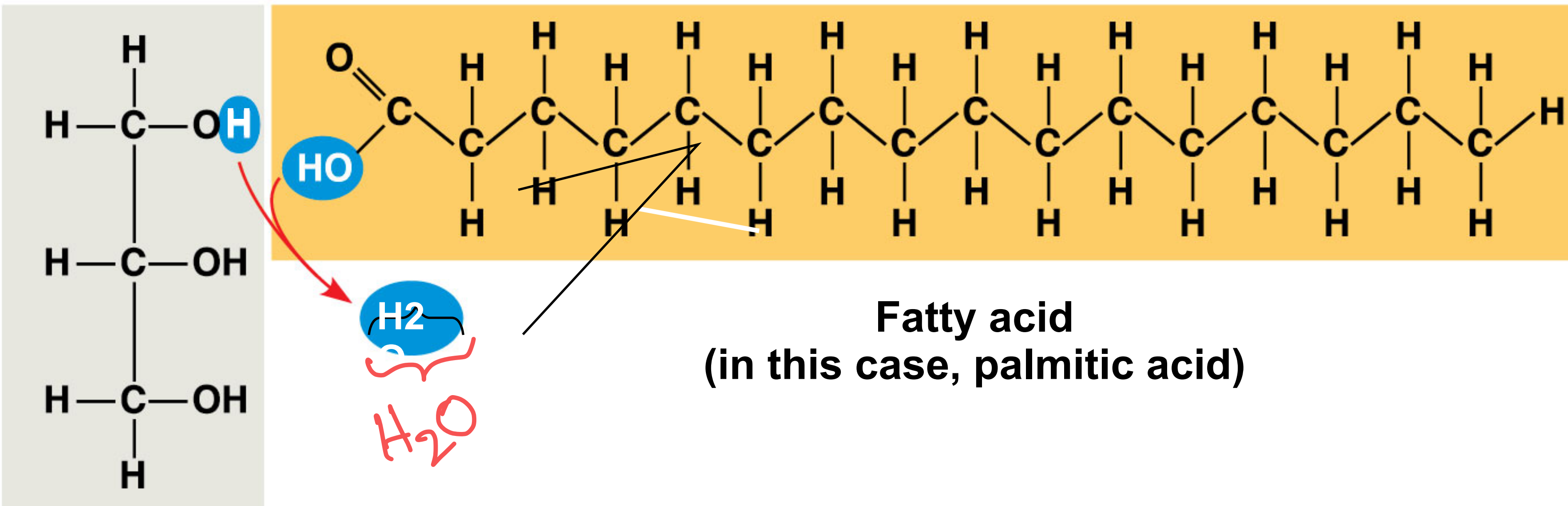



(a) One of three dehydration reactions in the synthesis of a fat




(b) Fat molecule (triacylglycerol)

Figure 5.9a

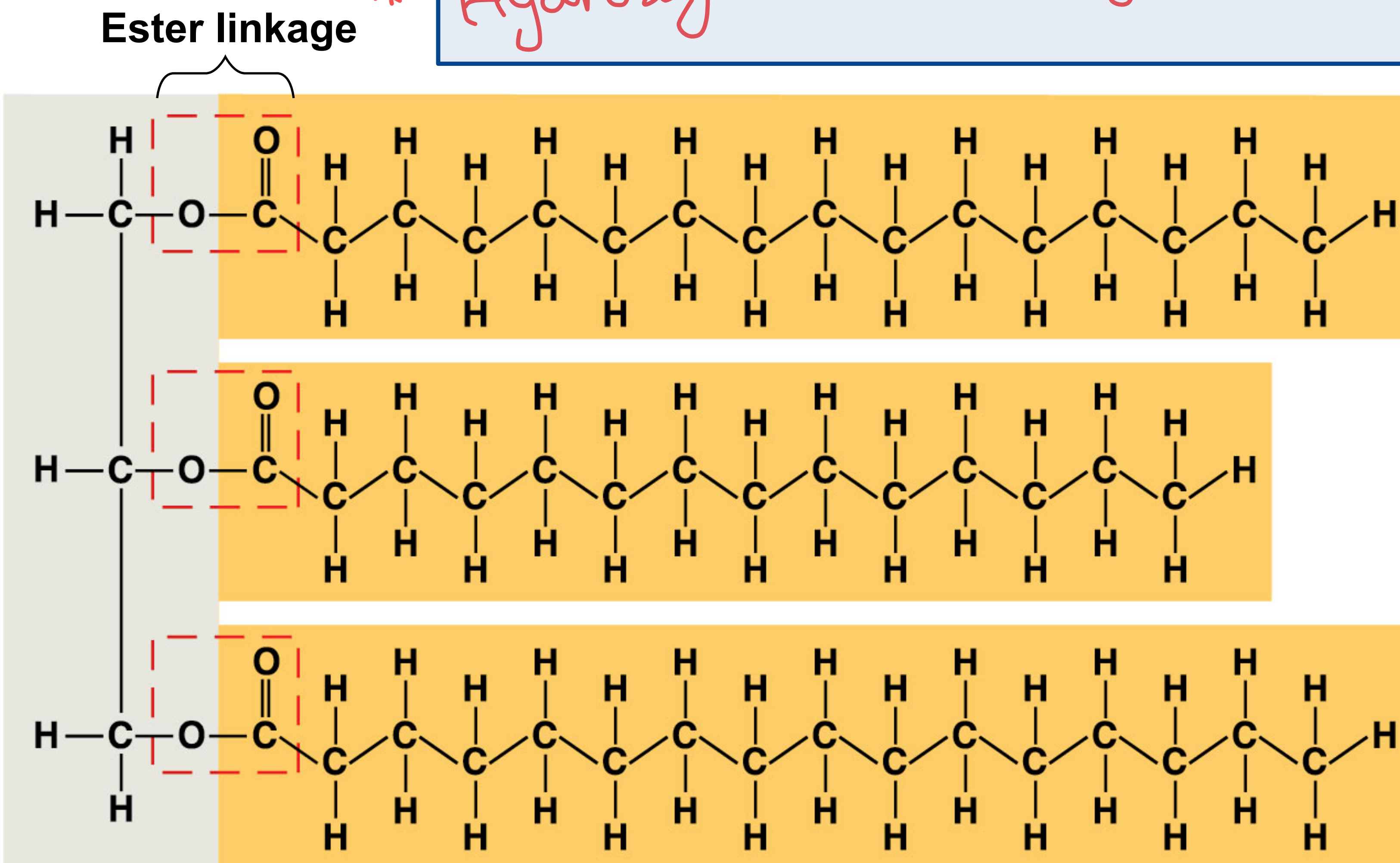



Glycero
l

**(a) One of three dehydration reactions in the synthesis of a fat**

Figure 5.9b

* Hydroxyl — carboxyl linkage




**(b) Fat molecule (triacylglycerol)**

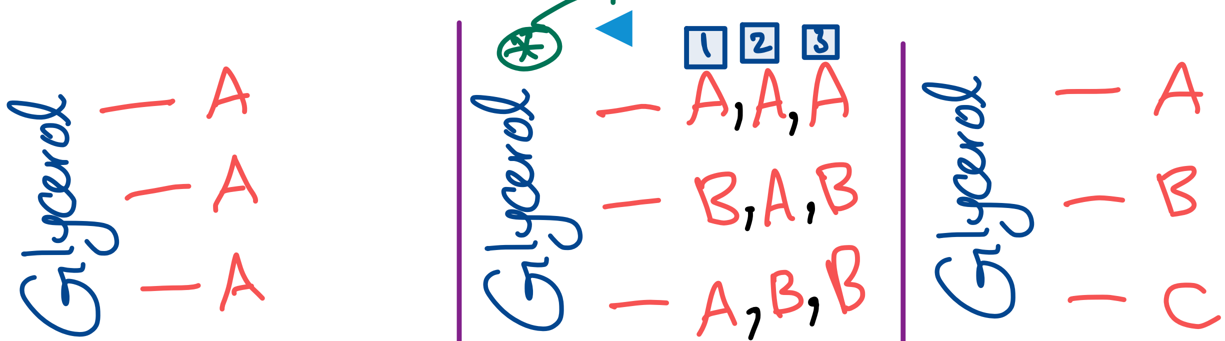
C–H : non-polar covalent bond.

Fats separate from water because water molecules hydrogen-bond to each other and exclude the fats

In a fat, three fatty acids are joined to glycerol by an ester linkage, creating a **triacylglycerol**, or triglyceride

The fatty acids in a fat can be all the same or of two or three different kinds

with all possible configurations



- Fatty acids vary in length (number of carbons) and in the number and locations of double bonds
- **Saturated fatty acids** have the maximum number of hydrogen atoms possible and no double bonds
- **Unsaturated fatty acids** have one or more double bonds

Figure 5.10

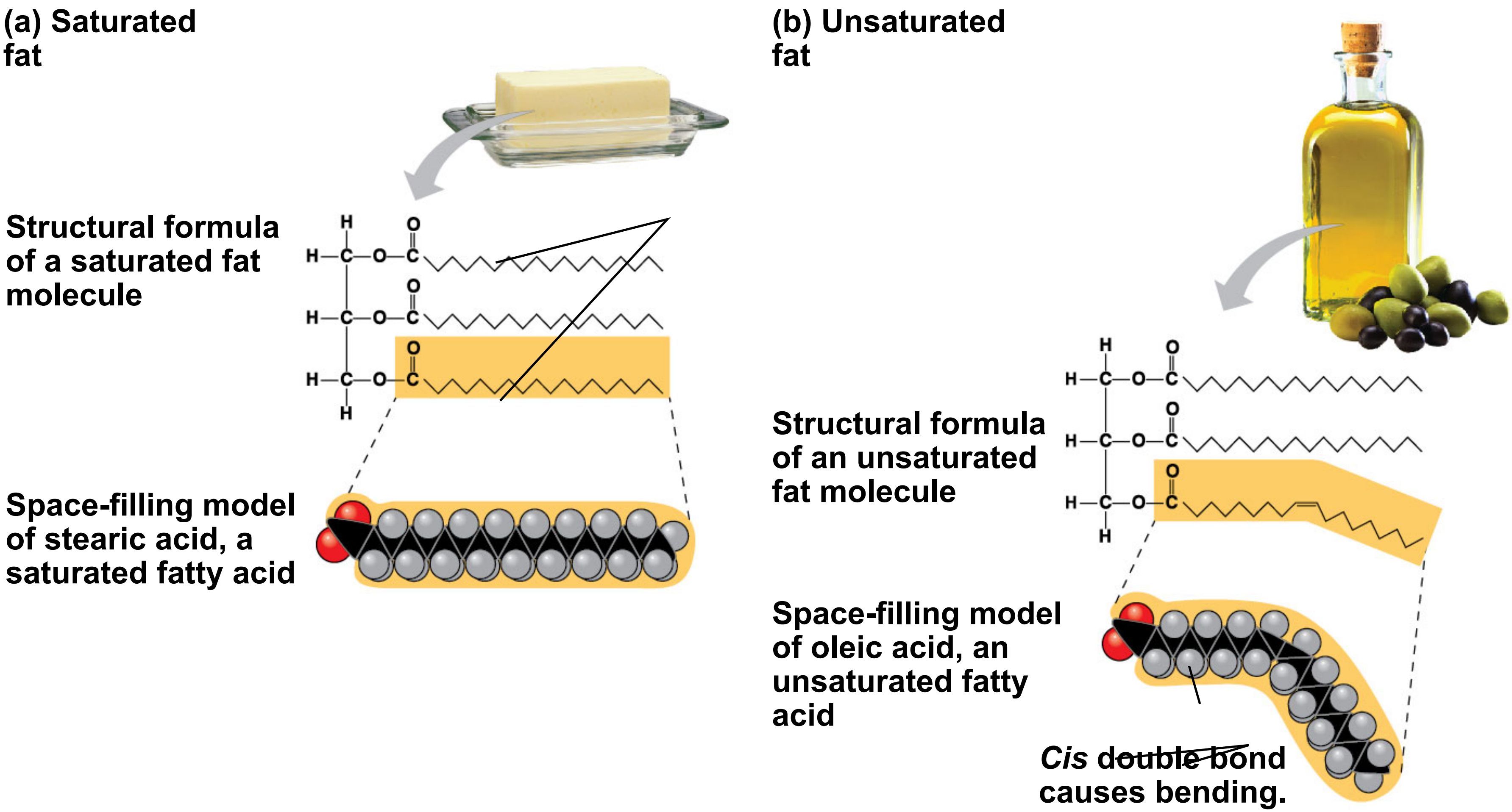
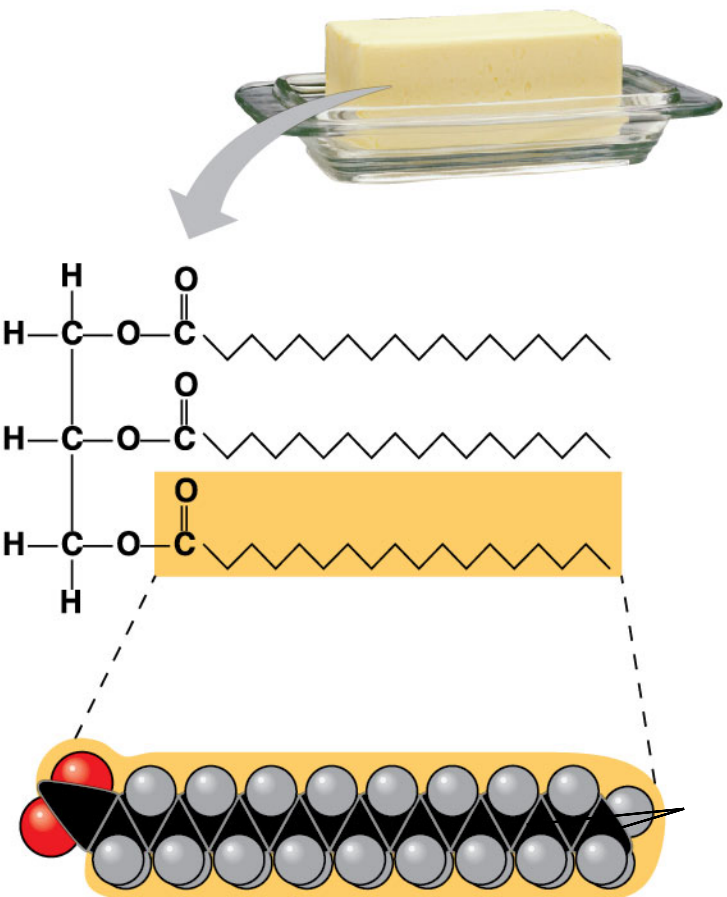

(a) Saturated fat
Structural formula of a saturated fat molecule
Space-filling model of stearic acid, a saturated fatty acid
(b) Unsaturated fat
Structural formula of an unsaturated fat molecule
Space-filling model of oleic acid, an unsaturated fatty acid
*Cis* double bond causes bending.

Figure 5.10a

## (a) Saturated fat

Structural formula of a saturated fat molecule

Space-filling model of stearic acid, a saturated fatty acid

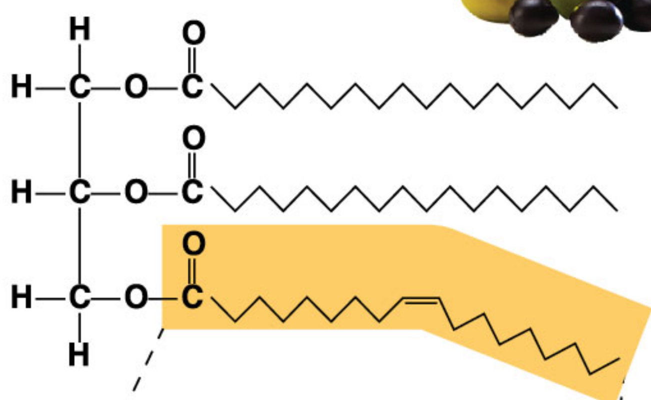


⊛ High Hydrophobic interactions between saturated fats.

Figure 5.10b

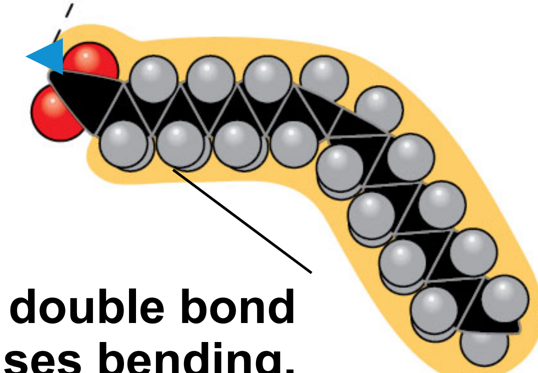
## (b) Unsaturated fat

**Structural formula of an unsaturated fat molecule**



(*) Low Hydrophobic interactions Between unsaturated fats.

**Space-filling model of oleic acid, an unsaturated fatty acid**



***Cis*** **double bond causes bending.**

- Fats made from saturated fatty acids are called saturated fats and are solid at room temperature
- Most animal fats are saturated
- Fats made from unsaturated fatty acids are called unsaturated fats or oils and are liquid at room temperature
- Plant fats and fish fats are usually unsaturated

⊕ levels of Triacylglycerol are reported when blood is tested for lipids.

- A diet rich in saturated fats may contribute to cardiovascular disease through plaque deposits
- Hydrogenation is the process of converting unsaturated fats to saturated fats by adding hydrogen
- Hydrogenating vegetable oils also creates unsaturated fats with *trans* double bonds
- These ***trans* fats** may contribute more than saturated fats to cardiovascular disease

trans fats are Worse than Saturated fats

- The major function of fats is energy storage ⊛
- Humans and other mammals store their long-term food reserves in adipose cells
- Adipose tissue also cushions vital organs and insulates the body

1

2

Adipose ≡ Fatty

⊛ A gram of fat stores more than double the amount of energy of carbohydrates.

a gram of

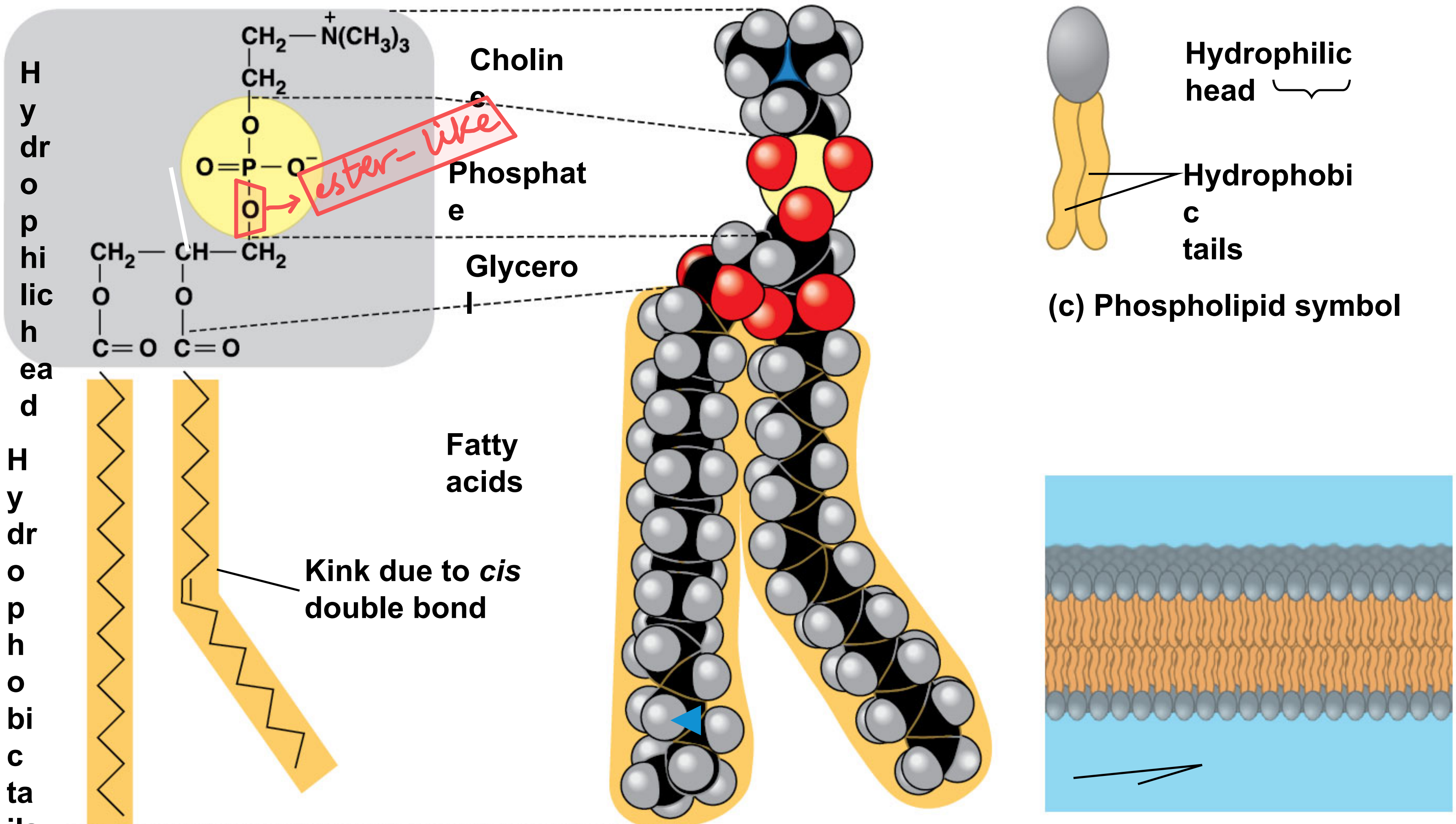
# hospholipids

- In a **phospholipid**, two fatty acids and a phosphate group are attached to glycerol
- The two fatty acid tails are hydrophobic, but the phosphate group and its attachments form a hydrophilic head

→ Choline or other groups

(*) interaction between glycerol and a phosphate group is called a phosphoester linkage

Figure 5.11




(a) Structural formula

(b) Space-filling model

(c) Phospholipid symbol

(d) Phospholipid bilayer



※ Next 3 slides are fake: images
send to back to see highlights

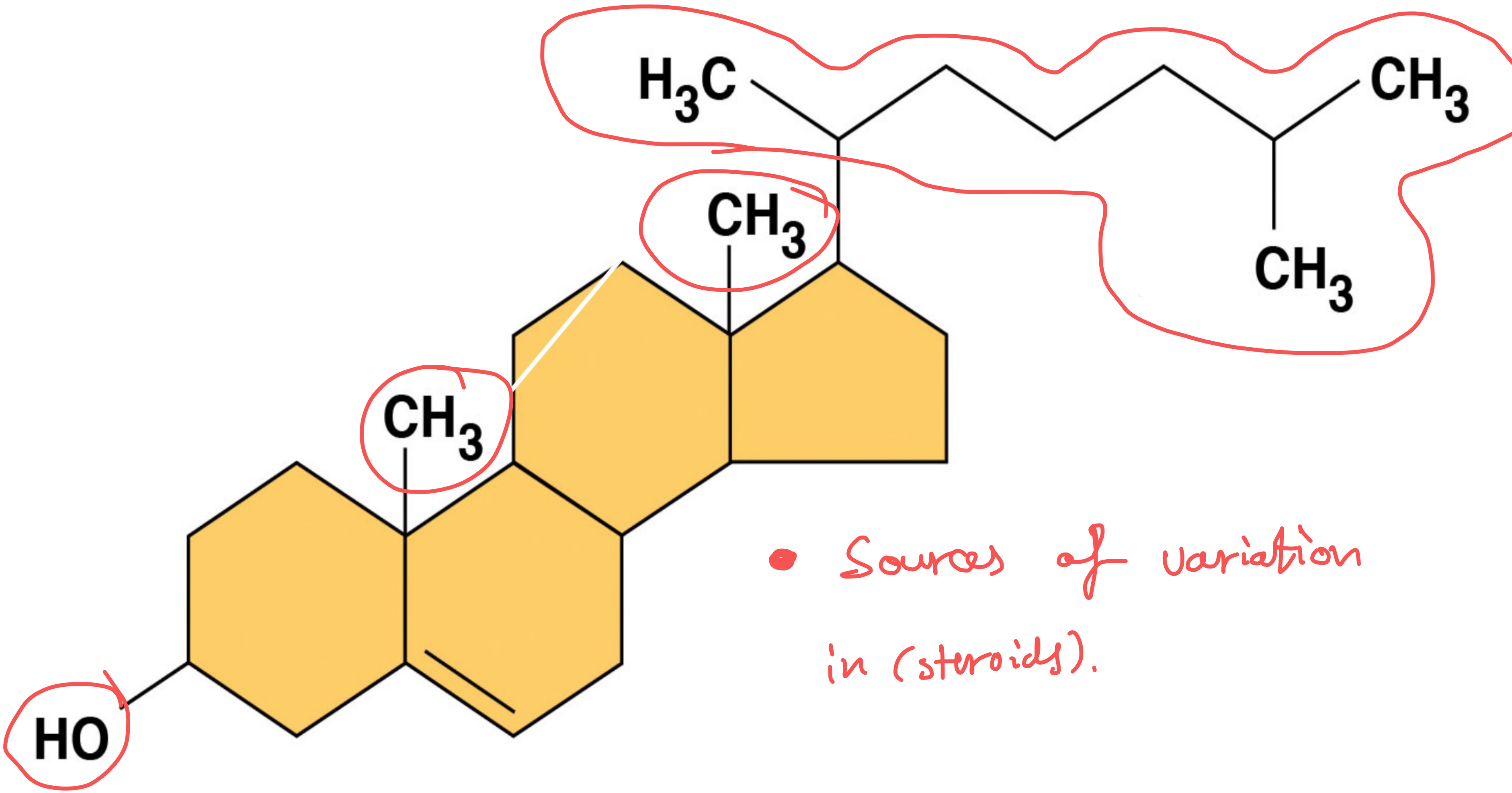
- When phospholipids are added to water, they self-assemble into double-layered sheets called bilayers
- At the surface of a cell, phospholipids are also arranged in a bilayer, with the hydrophobic tails pointing toward the interior
- The phospholipid bilayer forms a boundary between the cell and its external environment

# teroids

- **Steroids** are lipids characterized by a carbon skeleton consisting of four fused rings
- **Cholesterol**, a type of steroid, is a component in animal cell membranes and a precursor from which other steroids are synthesized "raw material"
- A high level of cholesterol in the blood may contribute to cardiovascular disease ⊛

⊛ Atherosclerosis : a vascular disease caused by High levels of : Saturated Fat or Cholesterol.

Figure 5.12




- Sources of variation in (steroids).

# oncept 5.4: Proteins include a diversity of structures, resulting in a wide range of functions

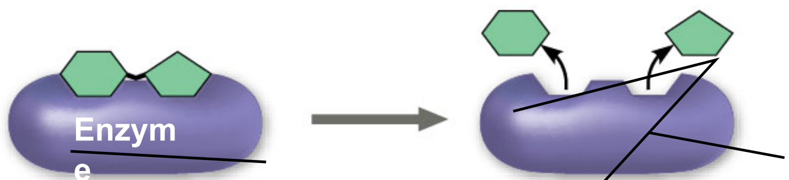
- Proteins account for more than 50% of the dry mass of most cells
- Some proteins speed up chemical reactions } enzymes
- Other protein functions include defense (1), storage (2), transport (3), cellular communication (4), movement (5), and structural support (6)

Figure 5.13a

## Enzymatic proteins

**Function:** Selective acceleration of chemical reactions

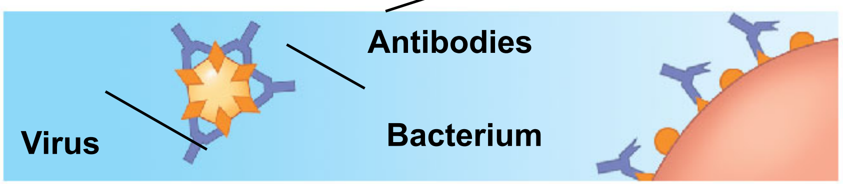
**Example:** Digestive enzymes catalyze the hydrolysis of bonds in food molecules.




## Defensive proteins

**Function:** Protection against disease

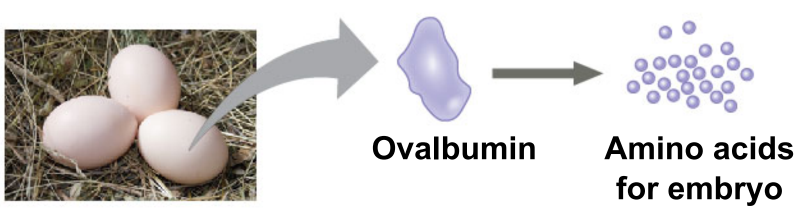
**Example:** Antibodies inactivate and help destroy viruses and bacteria.




## Storage proteins

**Function:** Storage of amino acids

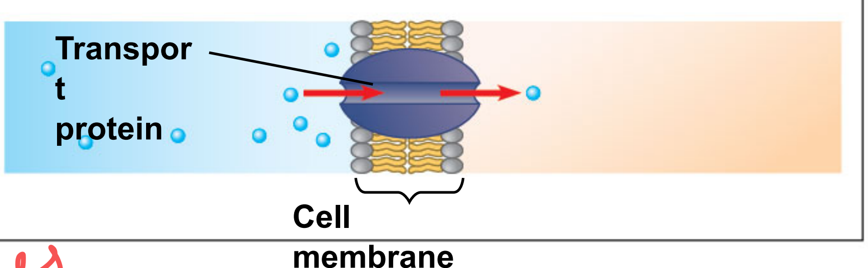
**Examples:** Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.




## Transport proteins

**Function:** Transport of substances

**Examples:** Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.



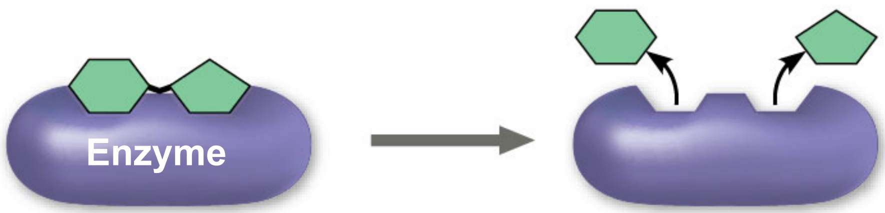

* see specific slides
(SSS)

Figure 5.13aa

**Enzymatic proteins**

**Function: Selective acceleration of chemical reactions**

**Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.**




Such as maltase

catalyzes (maltose + $H_2O$ → 2 glucose)

Figure 5.13ab

## Defensive proteins

**Function: Protection against disease**

**Example: Antibodies inactivate and help destroy viruses and bacteria.**

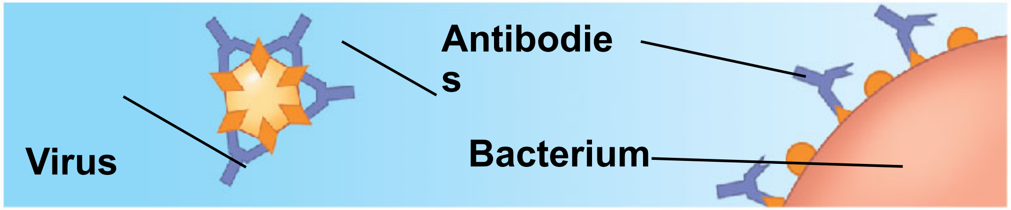


Figure 5.13ac

## Storage proteins

**Function:** Storage of amino acids

**Examples:** Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.

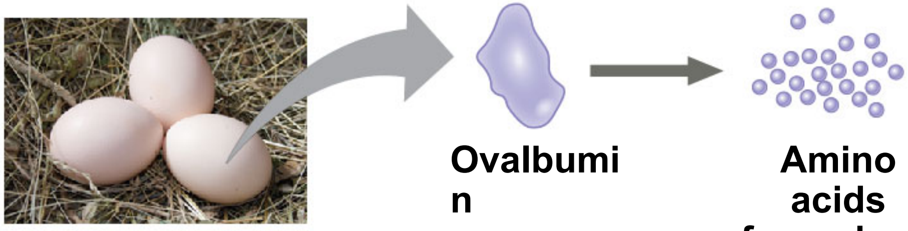
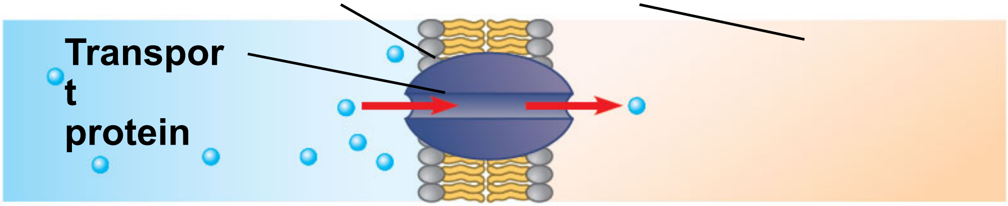


Figure 5.13ad

## Transport proteins

**Function:** Transport of substances

**Examples:** Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.



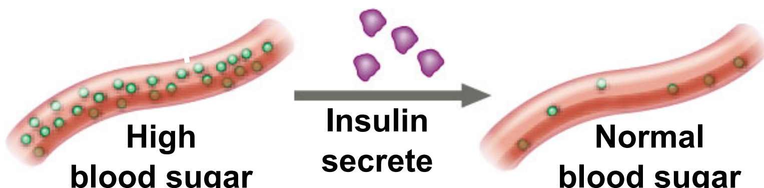

Cell membrane

Figure 5.13b

## Hormonal proteins

**Function: Coordination of an organism's activities**

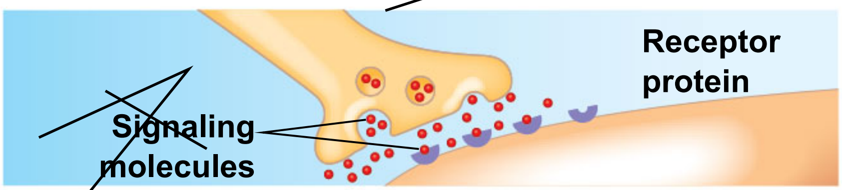
**Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.**




## Receptor proteins

**Function: Response of cell to chemical stimuli**

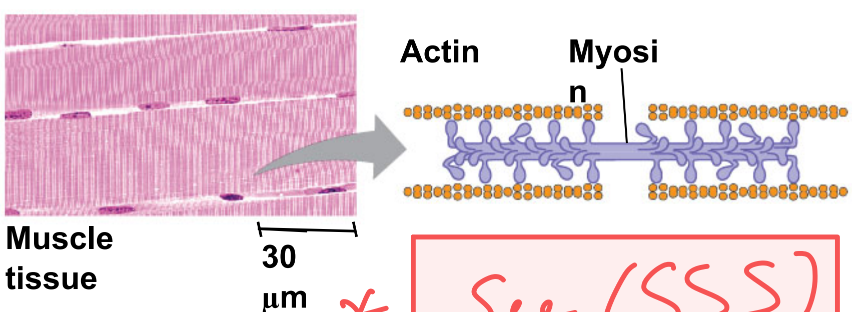
**Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.**




## Contractile and motor proteins

**Function: Movement**

**Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.**




* See (SSS)

## Structural proteins

**Function: Support**

**Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.**

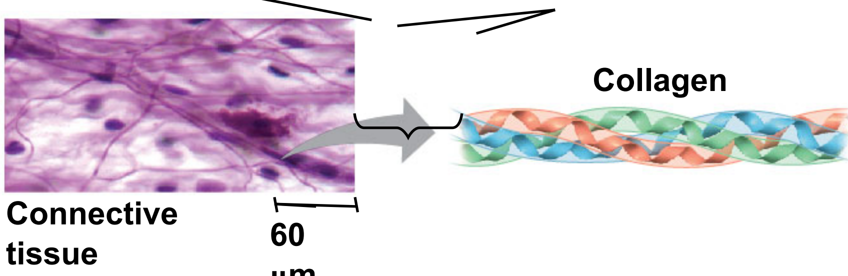


Figure 5.13ba

## Hormonal proteins

**Function:** Coordination of an organism's activities

**Example:** Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.

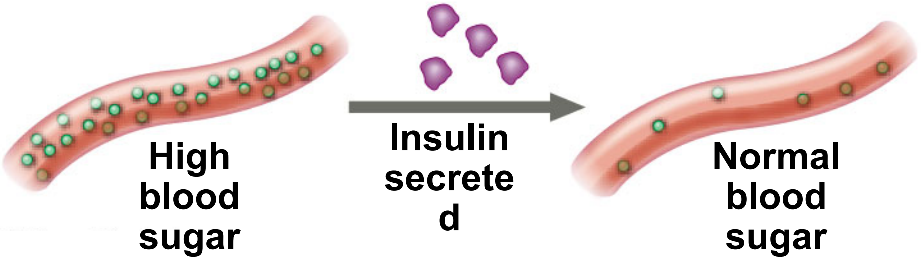


Figure 5.13bb

## Receptor proteins

**Function:** Response of cell to chemical stimuli

**Example:** Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.

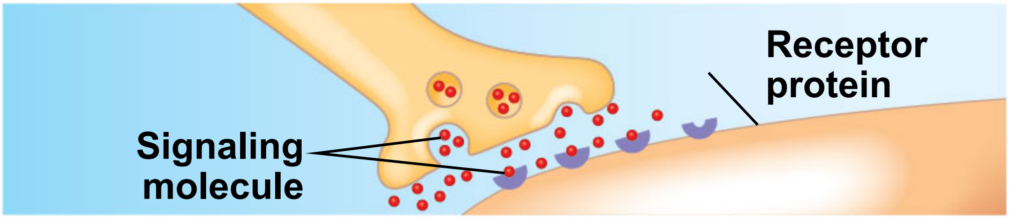


Figure 5.13bc

# Contractile and motor proteins

**Function:** Movement

**Examples:** Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.

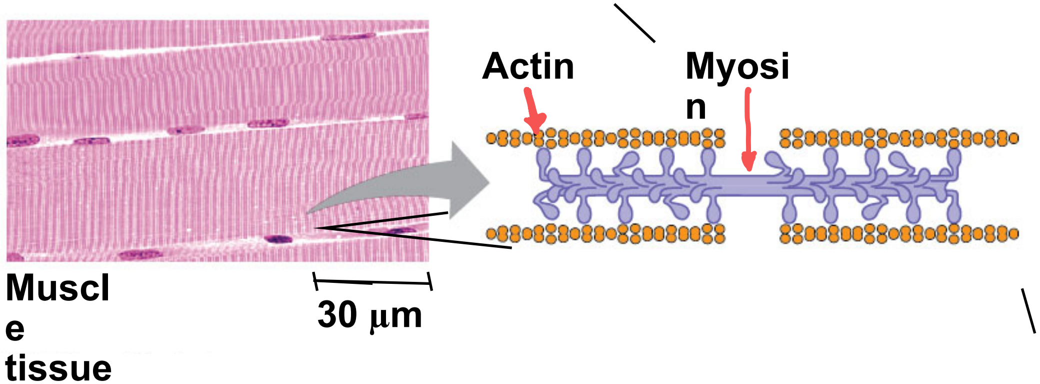
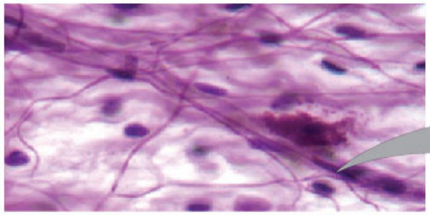


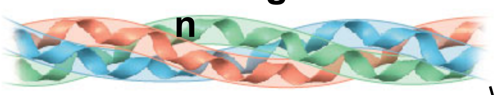
Figure 5.13bd

## Structural proteins

**Function:** Support

**Examples:** Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.



- Enzymes are proteins that act as **catalysts** to speed up chemical reactions
- Enzymes can perform their functions repeatedly, functioning as workhorses that carry out the processes of life

Because they are not consumed during the Chemical Reaction.

- Proteins are all constructed from the same set of 20 amino acids
- **Polypeptides** are unbranched polymers built from these amino acids

Primary structure

- A **protein** is a biologically functional molecule that consists of one or more polypeptides

# Amino Acid Monomers

- **Amino acids** are organic molecules with amino and carboxyl groups
- Amino acids differ in their properties due to differing side chains, called R groups

⊕ all amino acids are in Ionized Form since aqueous solutions and pH and other conditions are mostly suitable for.

for ex:

Acidic A. Acids → (−)
Basic 〃 → (+)
carboxyl group → $COO^-$
Amino group → $NH_3^+$

Figure 5.UN01

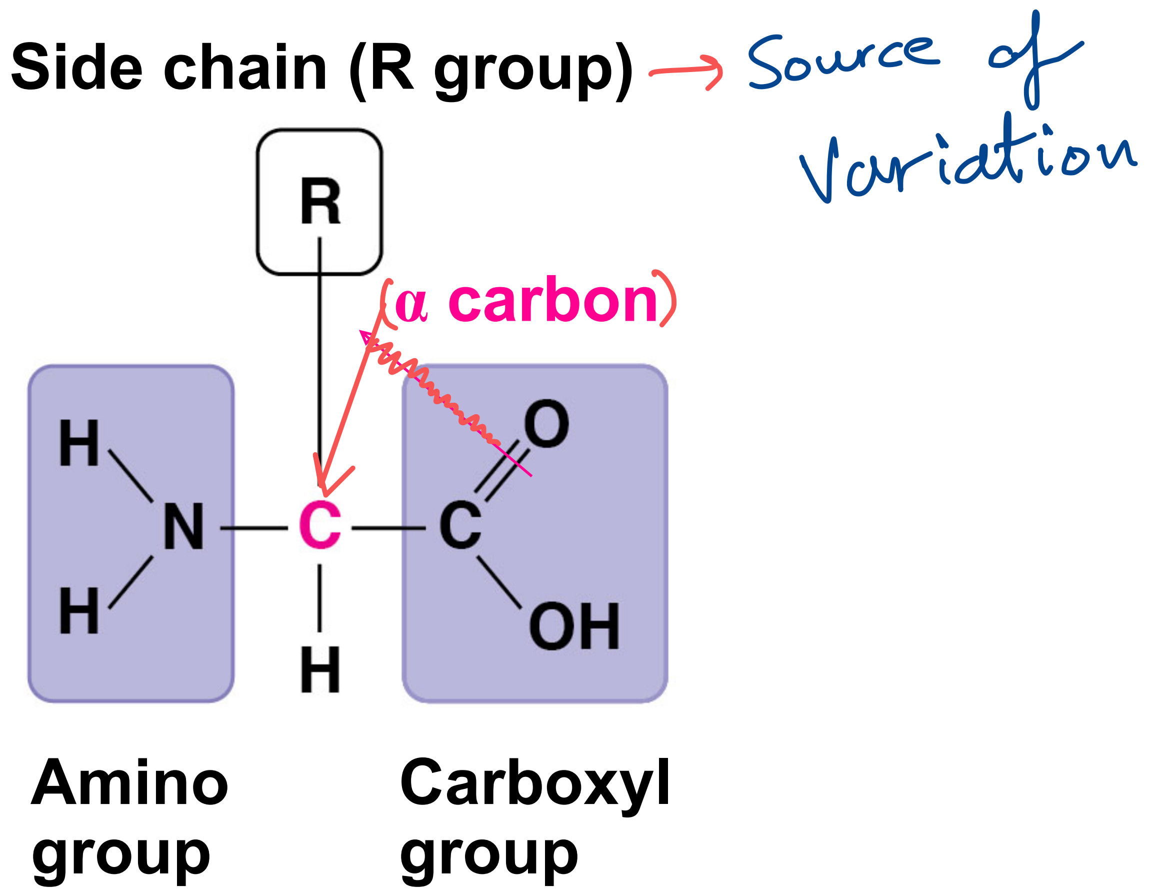
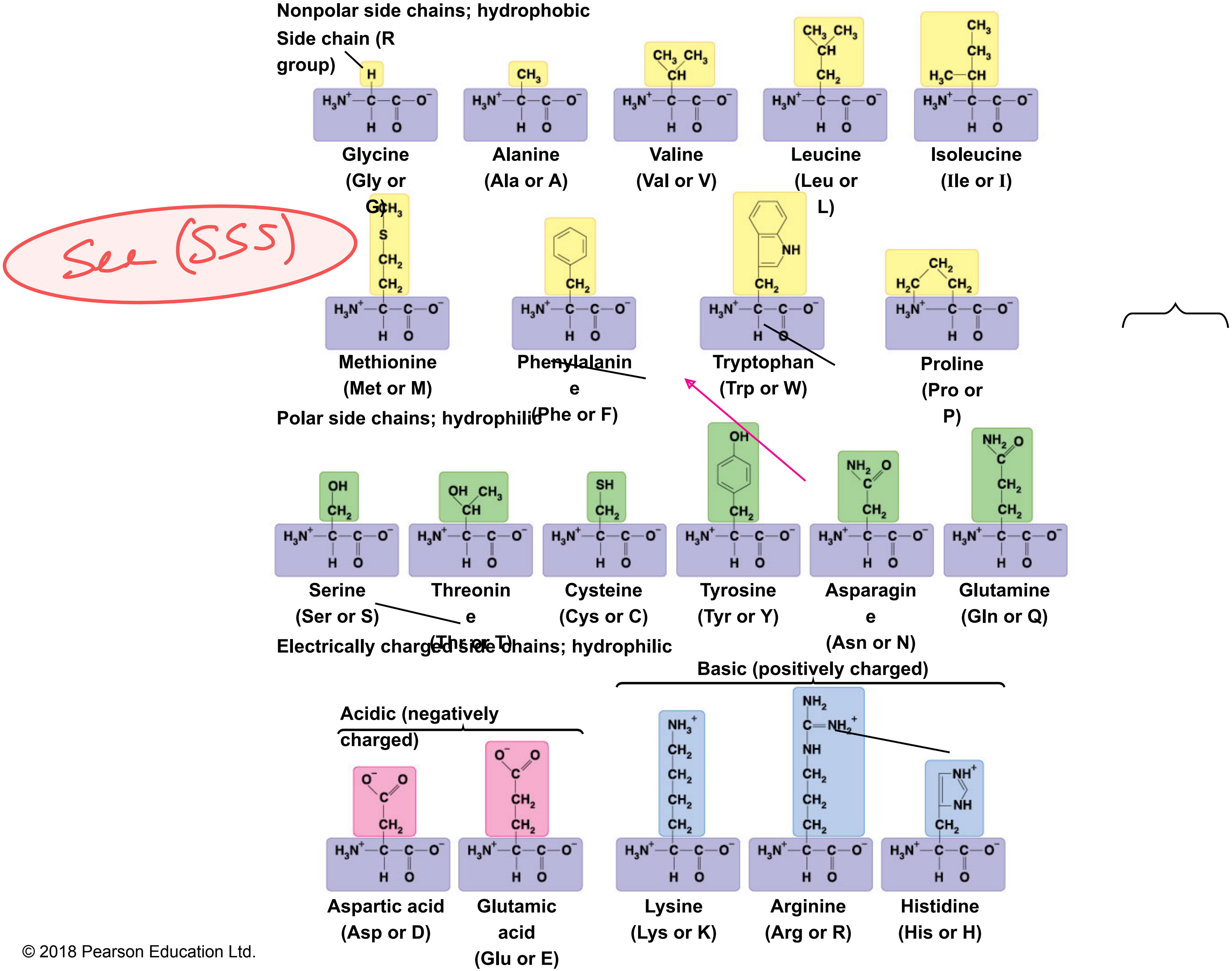


Figure 5.14



Nonpolar side chains; hydrophobic
Side chain (R group)
Glycine (Gly or G)
Alanine (Ala or A)
Valine (Val or V)
Leucine (Leu or L)
Isoleucine (Ile or I)
Methionine (Met or M)
Phenylalanine (Phe or F)
Tryptophan (Trp or W)
Proline (Pro or P)
Polar side chains; hydrophilic
Serine (Ser or S)
Threonine (Thr or T)
Cysteine (Cys or C)
Tyrosine (Tyr or Y)
Asparagine (Asn or N)
Glutamine (Gln or Q)
Electrically charged side chains; hydrophilic
Acidic (negatively charged)
Basic (positively charged)
Aspartic acid (Asp or D)
Glutamic acid (Glu or E)
Lysine (Lys or K)
Arginine (Arg or R)
Histidine (His or H)
See (SSS)

Figure 5.14a

9

## Nonpolar side chains; hydrophobic

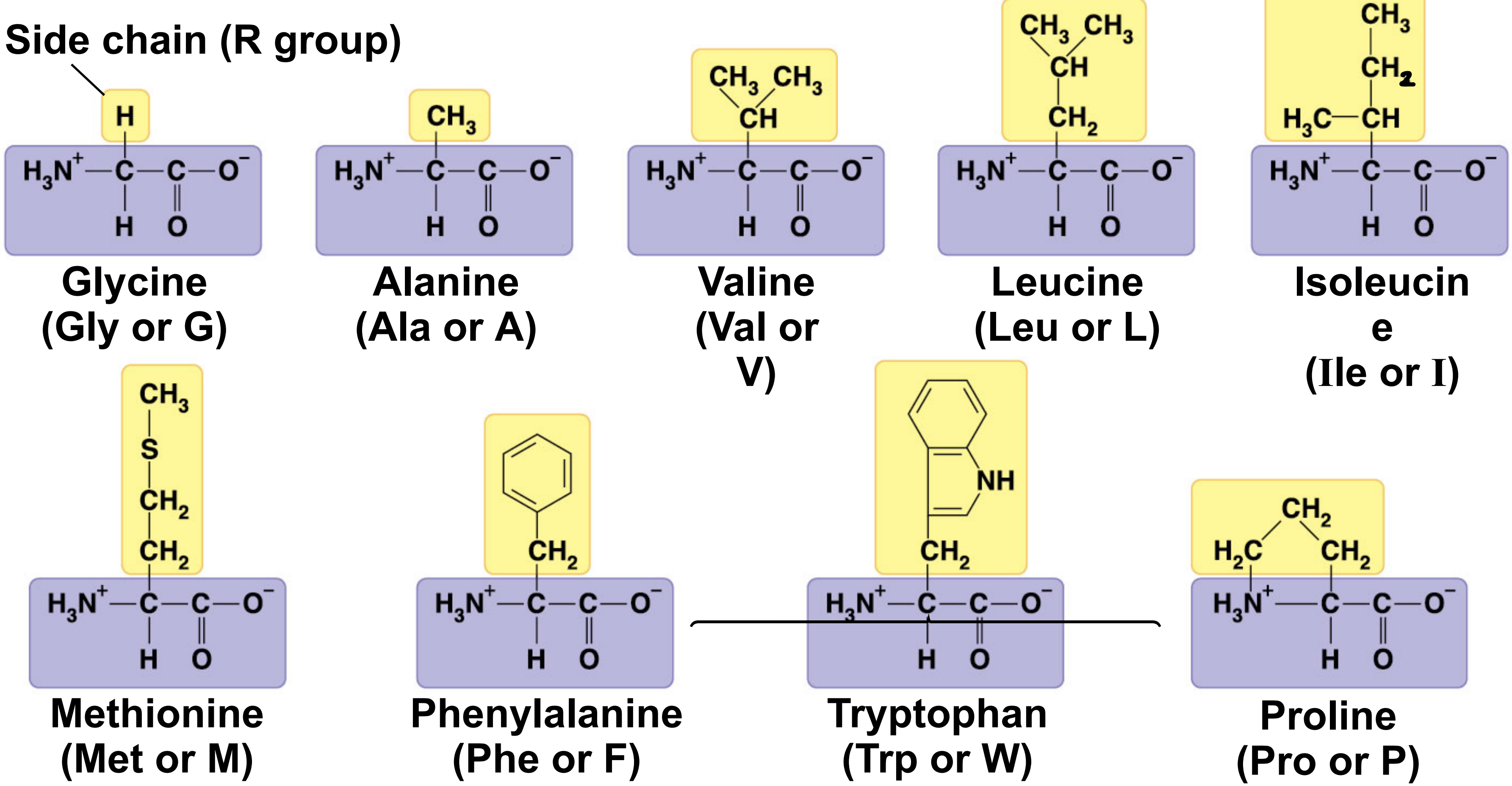
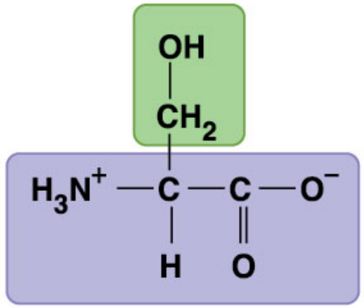


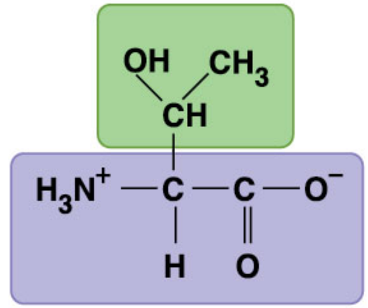
Figure 5.14b

## Polar side chains; hydrophilic

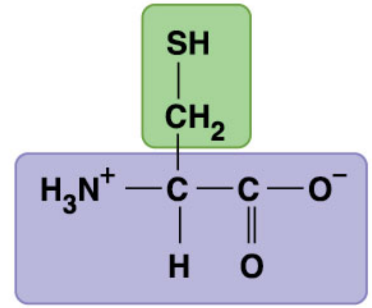
6



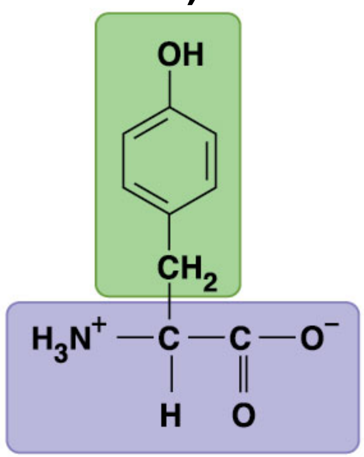
**Serine (Ser or S)**



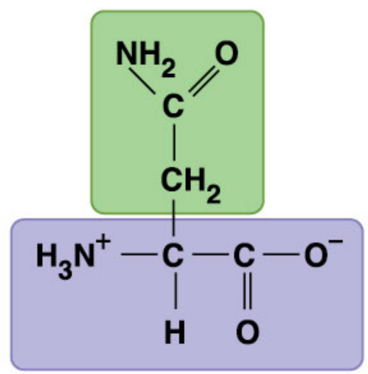
**Threonine (Thr or T)**



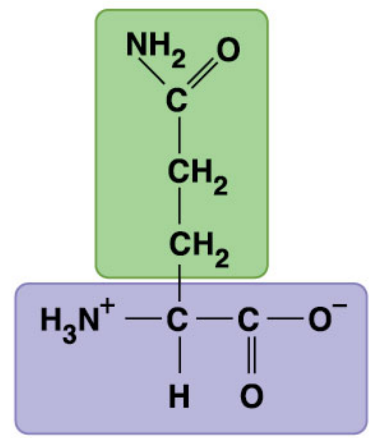
**Cysteine (Cys or C)**



**Tyrosine (Tyr or Y)**

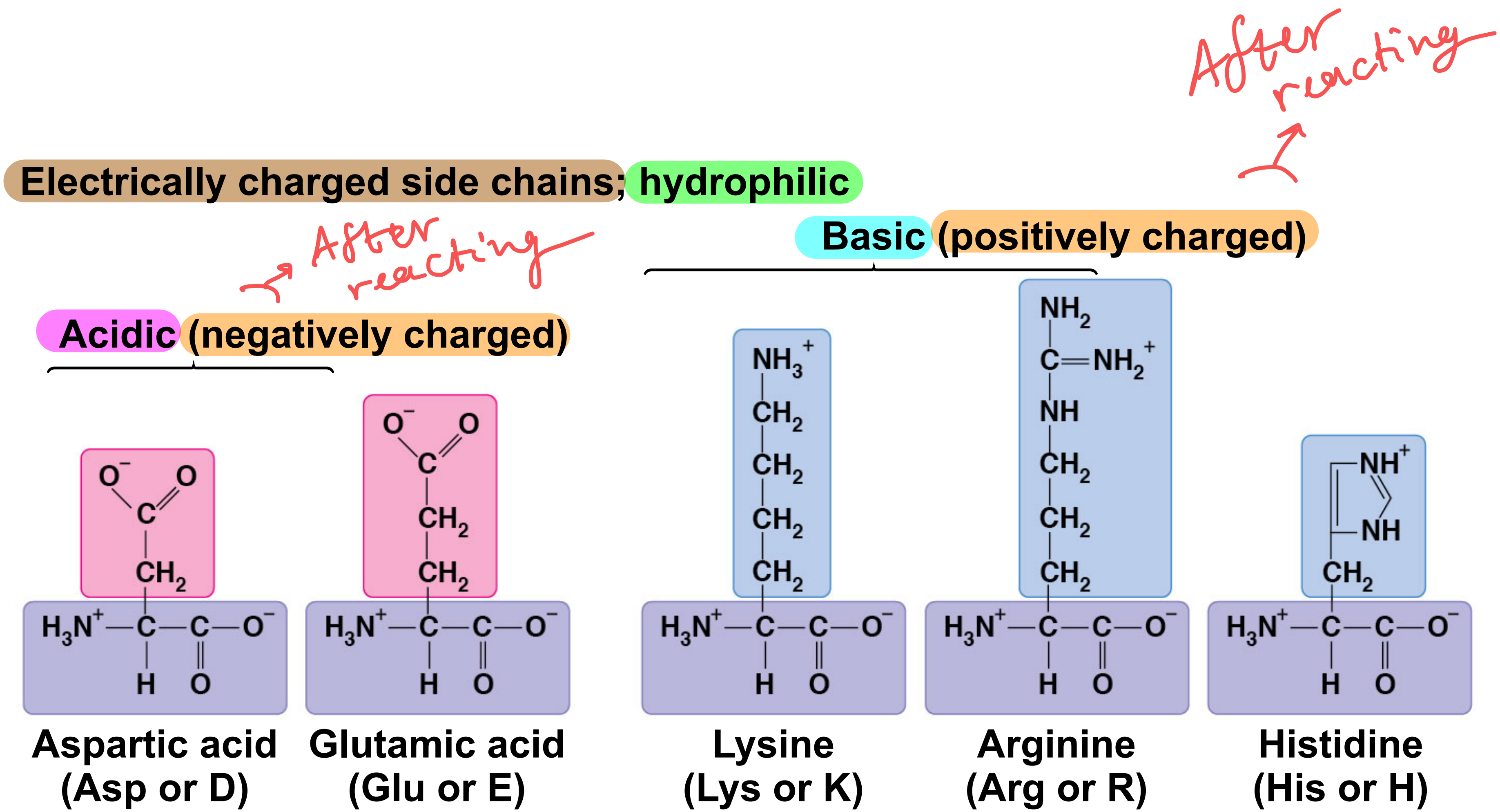


**Asparagine (Asn or N)**



**Glutamine (Gln or Q)**

Figure 5.14c



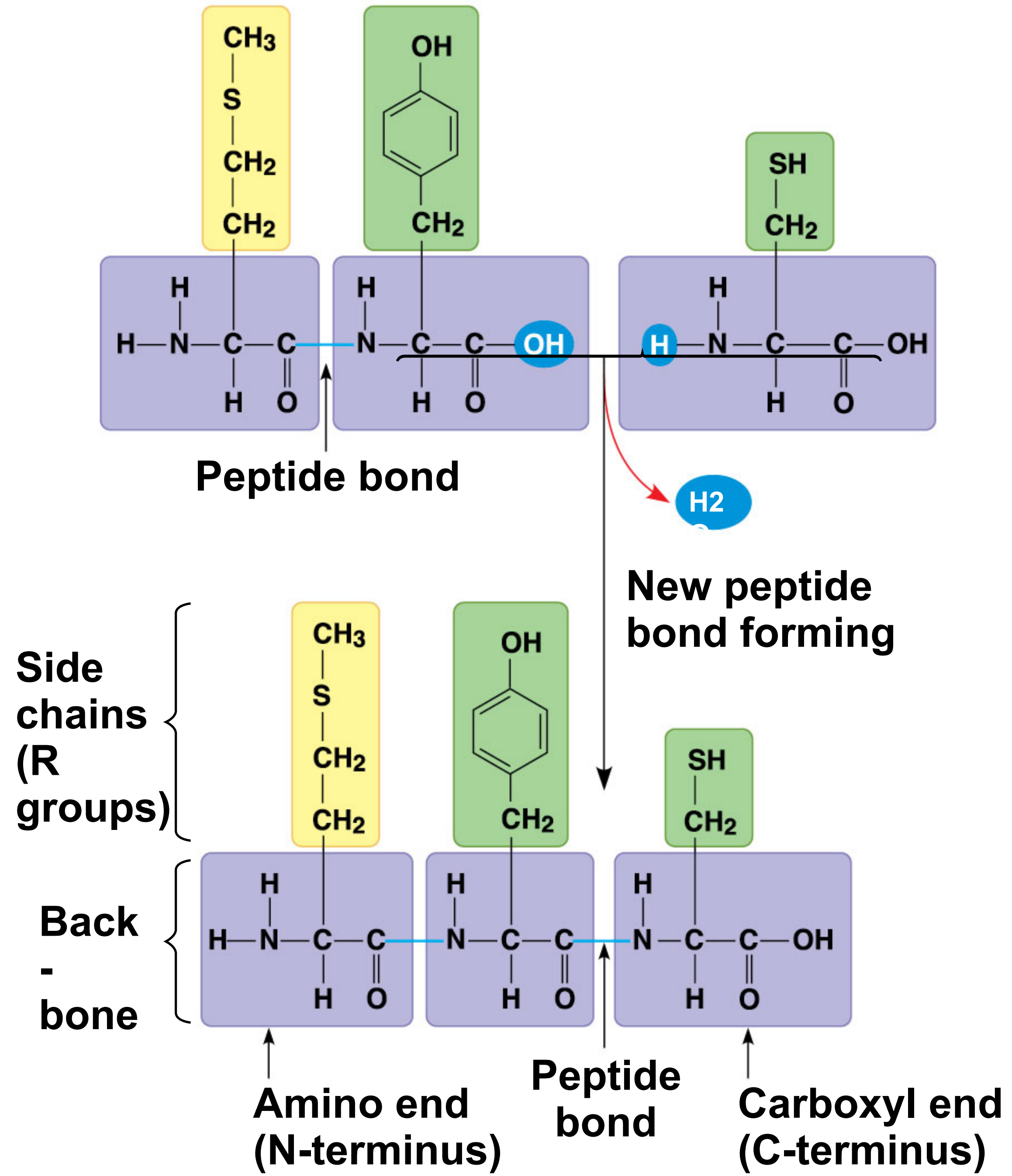

2

3

# olypeptides (Amino Acid Polymers)

- Amino acids are linked by covalent bonds called **peptide bonds** → Carboxyl – Amino linkage
- A polypeptide is a polymer of amino acids
- Polypeptides range in length from a few to more than 1,000 monomers
- Each polypeptide has a unique linear sequence of amino acids, with a carboxyl end (C-terminus) and an amino end (N-terminus)
- Amino acids vary in water solubility according to the R group.

Figure 5.15



Peptide bond
H2
New peptide bond forming
Side chains (R groups)
Back - bone
Amino end (N-terminus)
Peptide bond
Carboxyl end (C-terminus)

Figure 5.15a

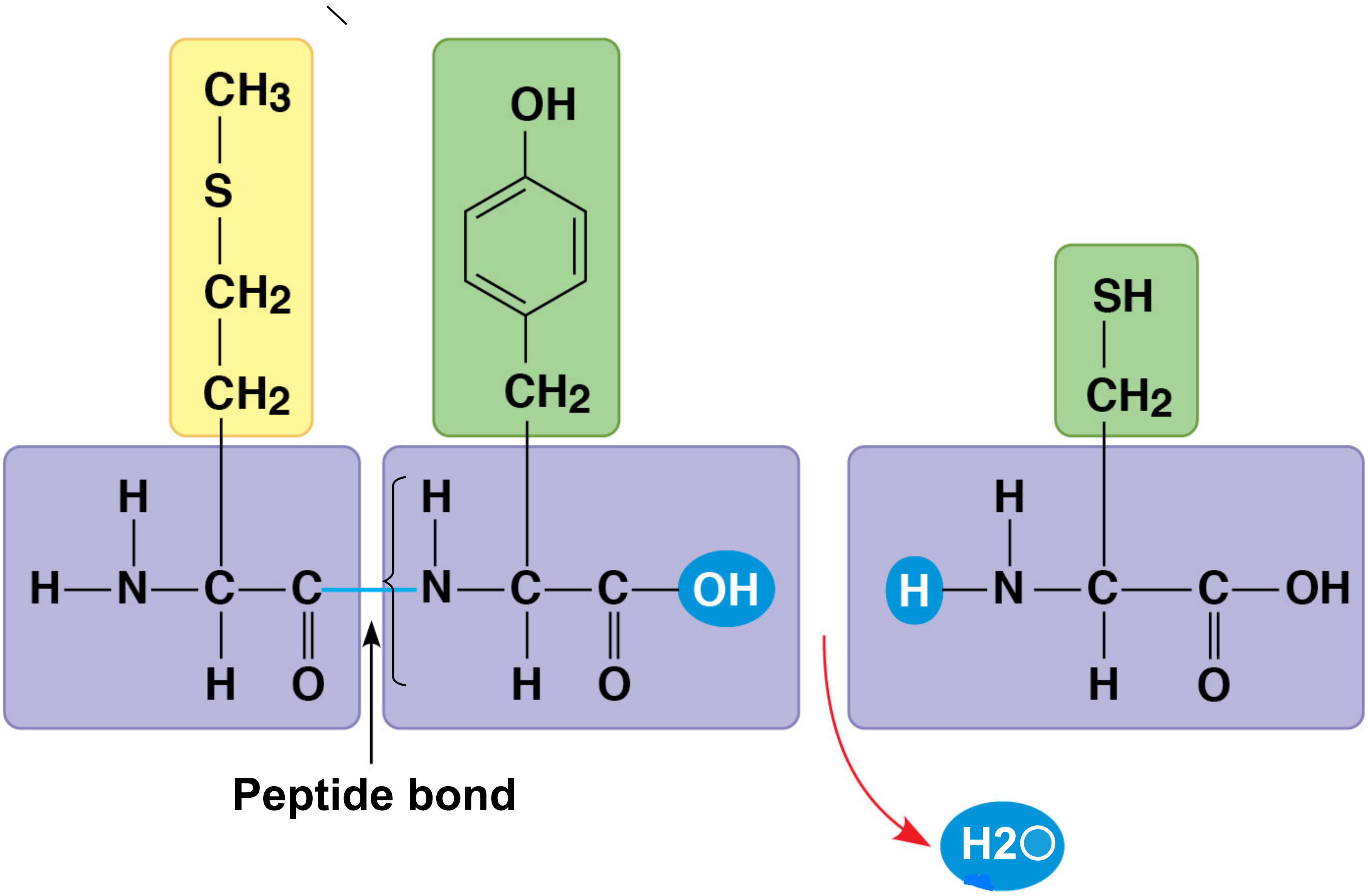
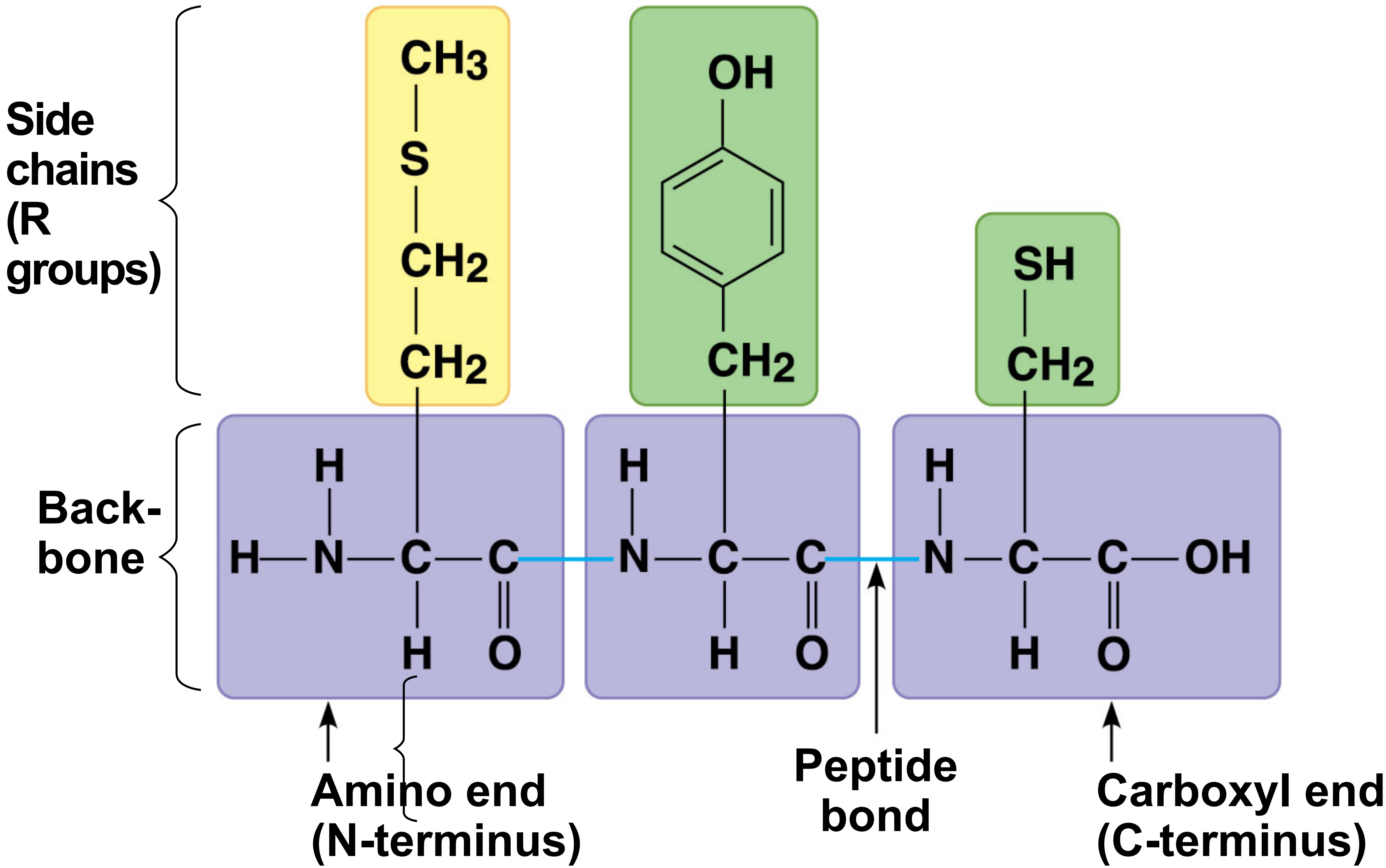

CH3
S
CH2
CH2
OH
CH2
SH
CH2
H
H—N—C—C
H O
H
N—C—C—OH
H O
H
H—N—C—C—OH
H O
Peptide bond
H2O

Figure 5.15b



Side chains (R groups)
Back-bone
CH3
S
CH2
CH2
OH
CH2
SH
CH2
H
H—N—C—C
H O
H
N—C—C
H O
H
N—C—C—OH
H O
Amino end (N-terminus)
Peptide bond
Carboxyl end (C-terminus)

# rotein Structure and Function

- The specific activities of proteins result from their intricate three-dimensional architecture
- A functional protein consists of one or more polypeptides precisely twisted, folded, and coiled into a unique shape

Figure 5.16

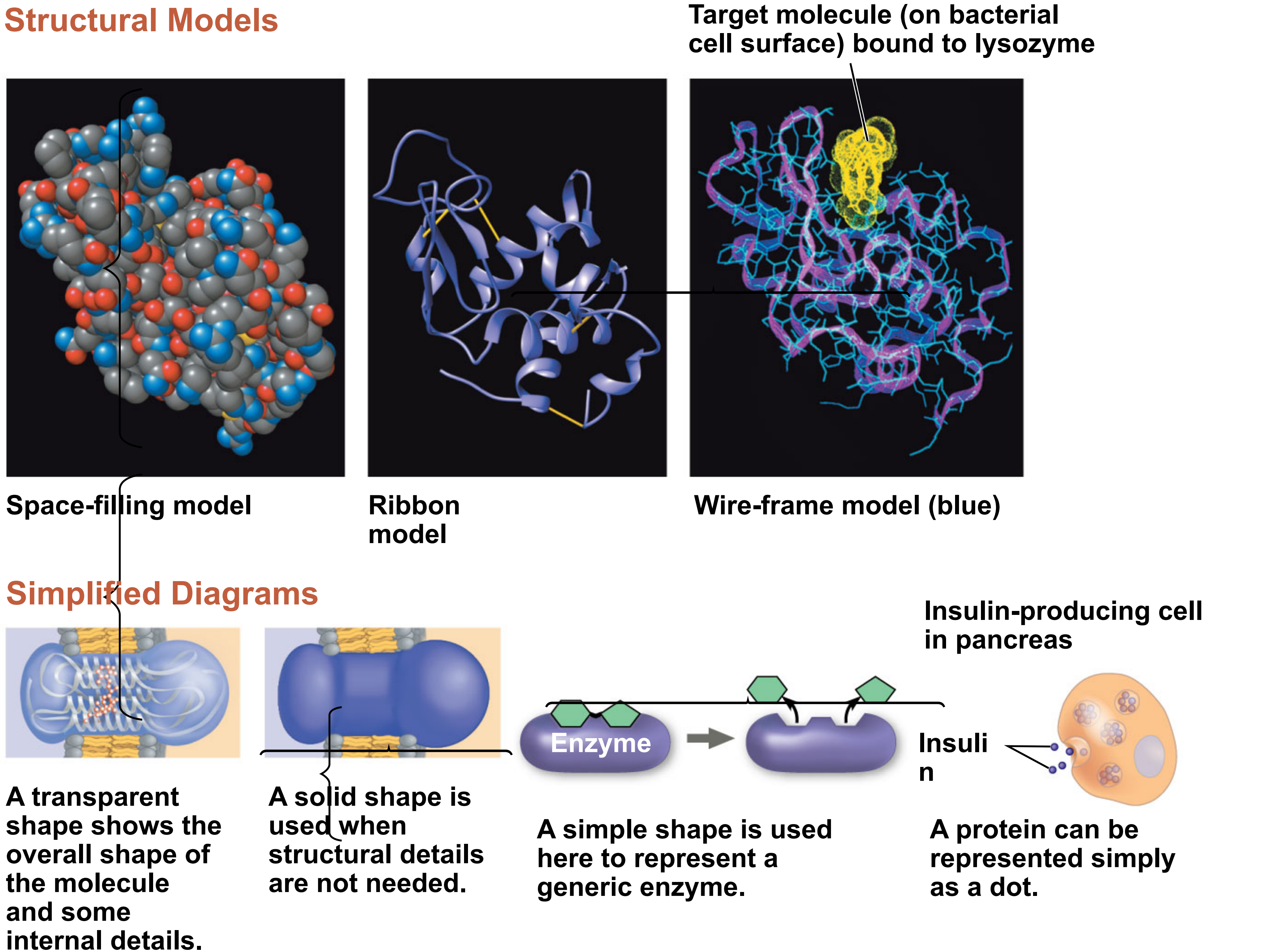

Structural Models
Target molecule (on bacterial cell surface) bound to lysozyme
Space-filling model
Ribbon model
Wire-frame model (blue)
Simplified Diagrams
Insulin-producing cell in pancreas
Enzyme
Insuli n
A transparent shape shows the overall shape of the molecule and some internal details.
A solid shape is used when structural details are not needed.
A simple shape is used here to represent a generic enzyme.
A protein can be represented simply as a dot.

Figure 5.16a

## Structural Models

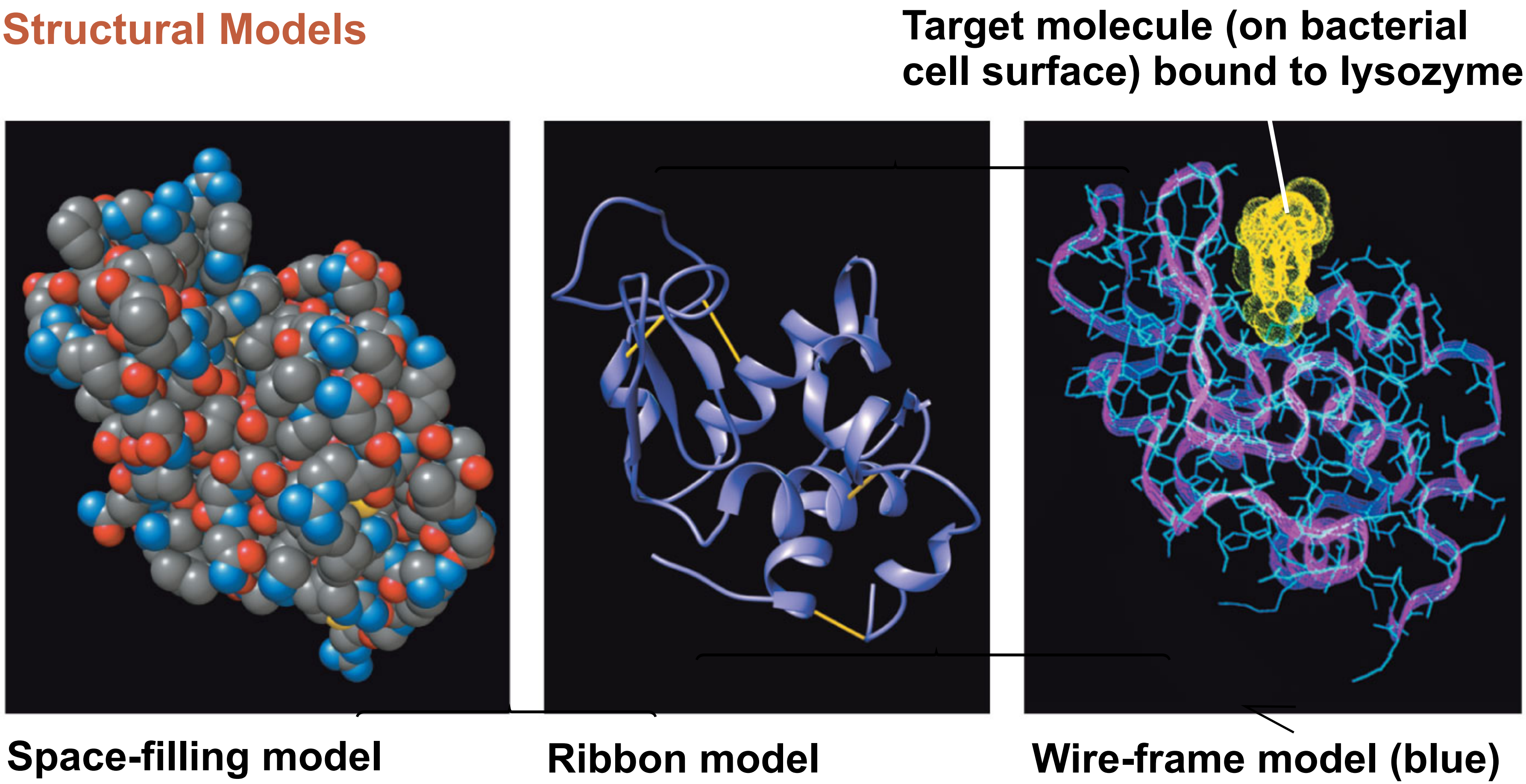
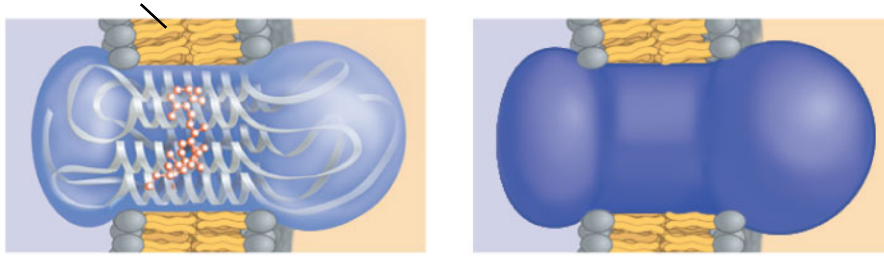


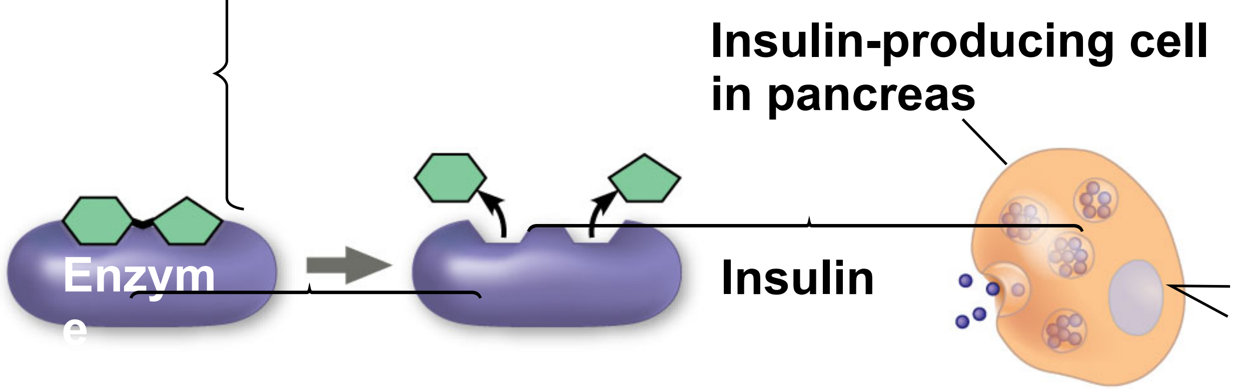
Figure 5.16b

## Simplified Diagrams



A transparent shape shows the overall shape of the molecule and some internal details.

A solid shape is used when structural details are not needed.

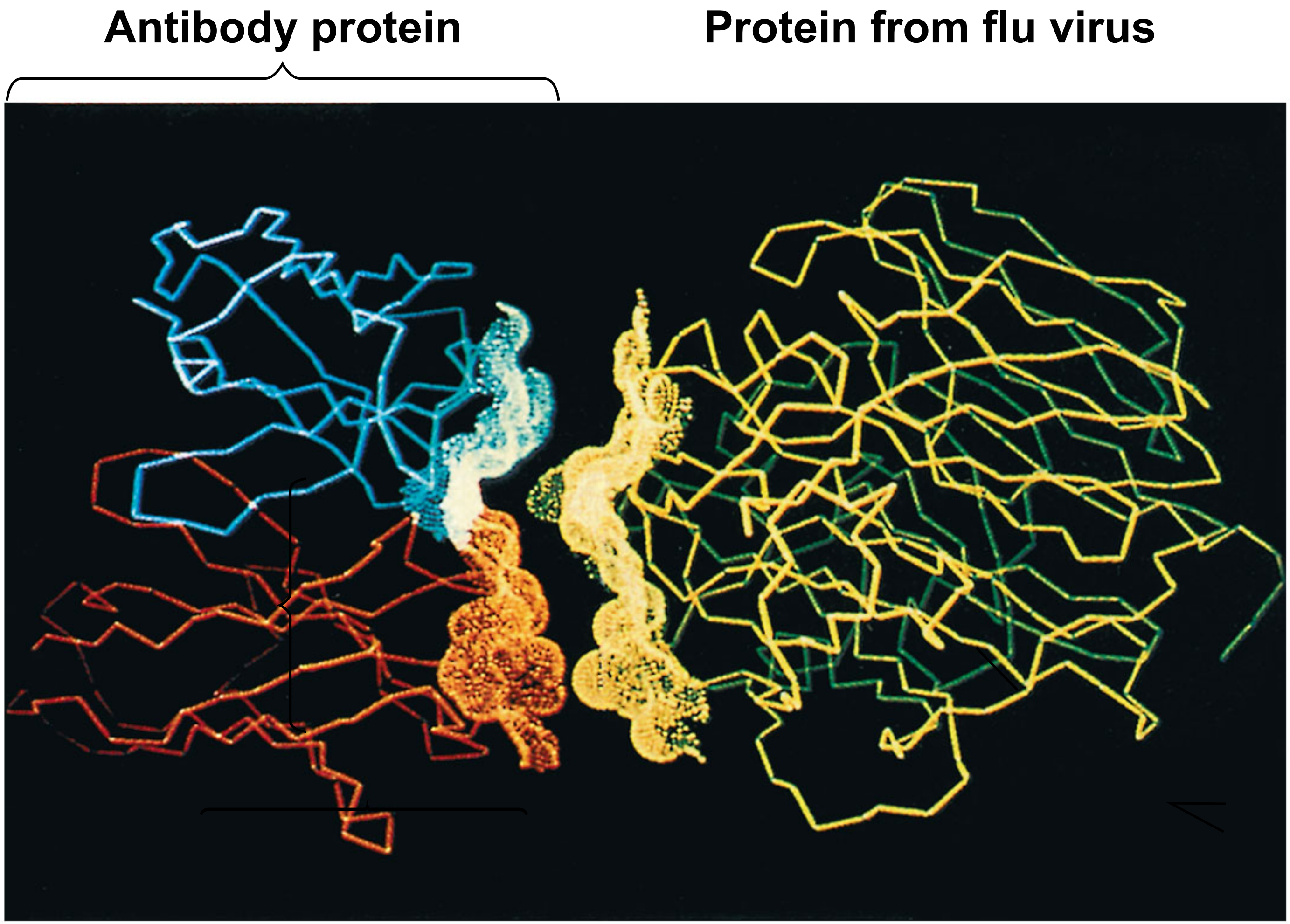



A simple shape is used here to represent a generic enzyme.

A protein can be represented simply as a dot.

- The sequence of amino acids determines a protein's three-dimensional structure
- A protein's structure determines how it works
- The function of a protein usually depends on its ability to recognize and bind to some other molecule

Figure 5.17

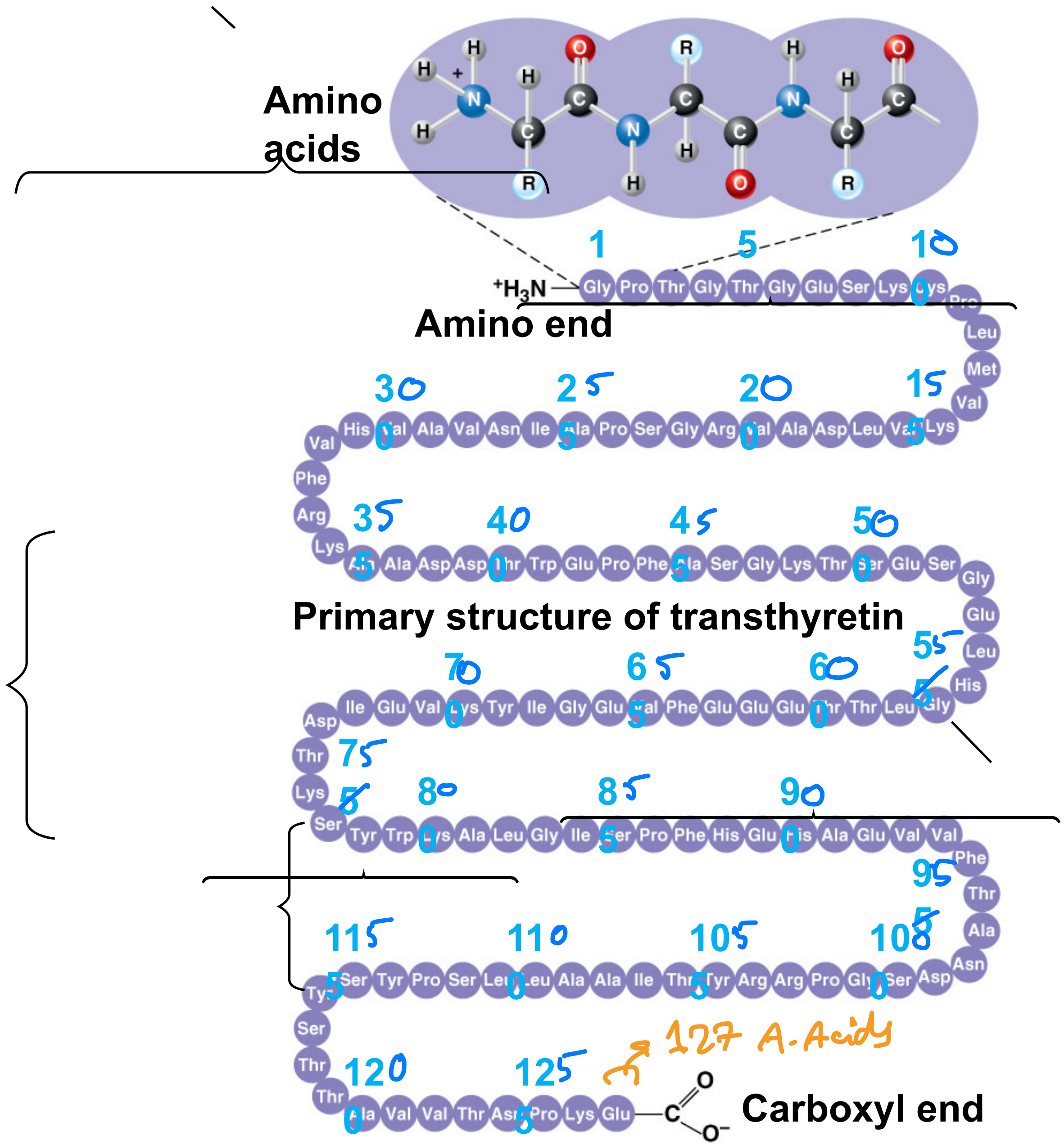


# our Levels of Protein Structure

- The primary structure of a protein is its unique sequence of amino acids
- Secondary structure, found in most proteins, consists of coils and folds in the polypeptide chain
- Tertiary structure is determined by interactions among various side chains (R groups)
- Quaternary structure results when a protein consists of multiple polypeptide chains

Figure 5.18a

# Primary Structure

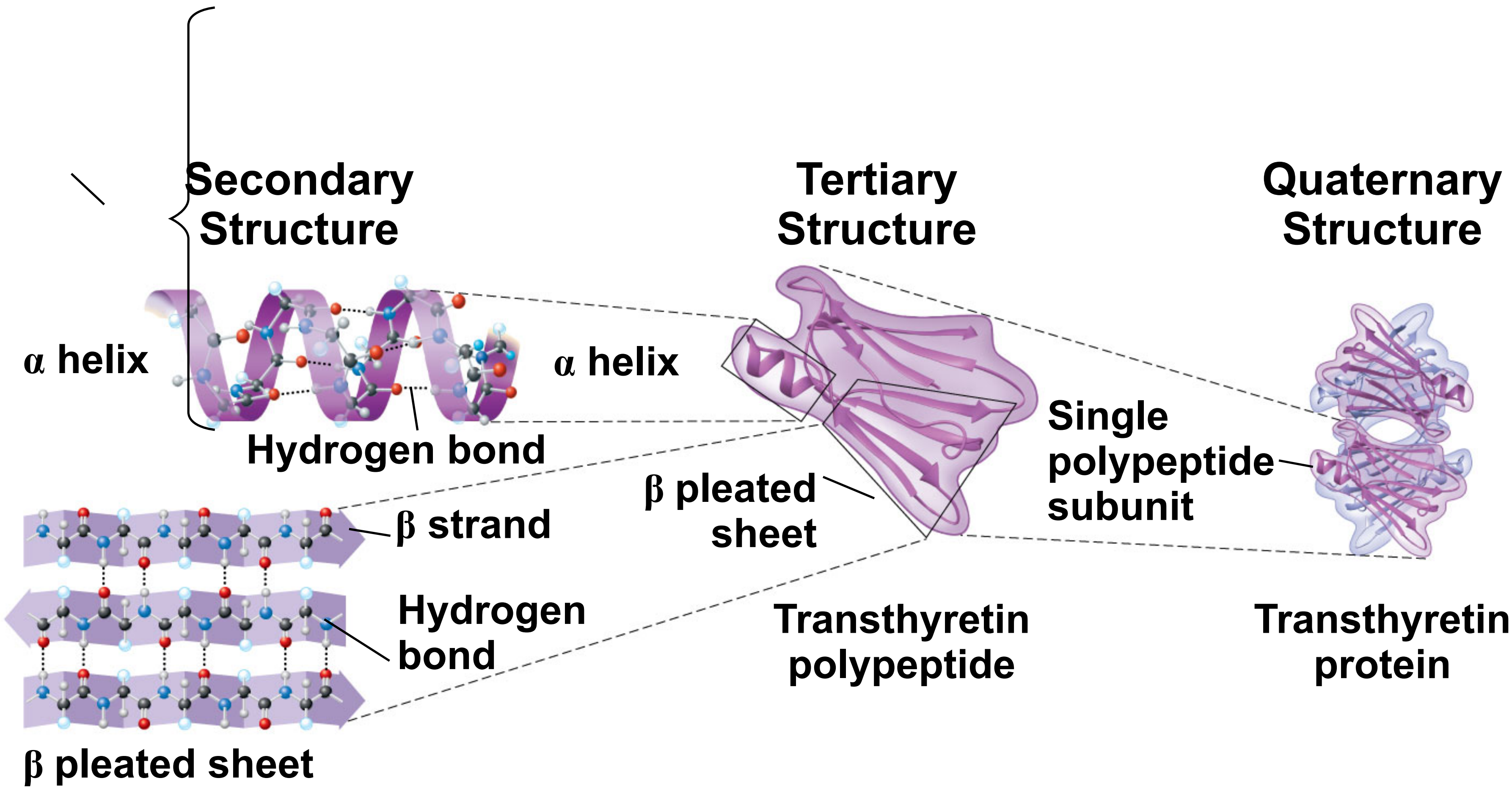



⊗ Transthyretin:
4 polypeptide chains

127 A. Acids per chain

tranfers Vitamin A & one of thyroid hormones

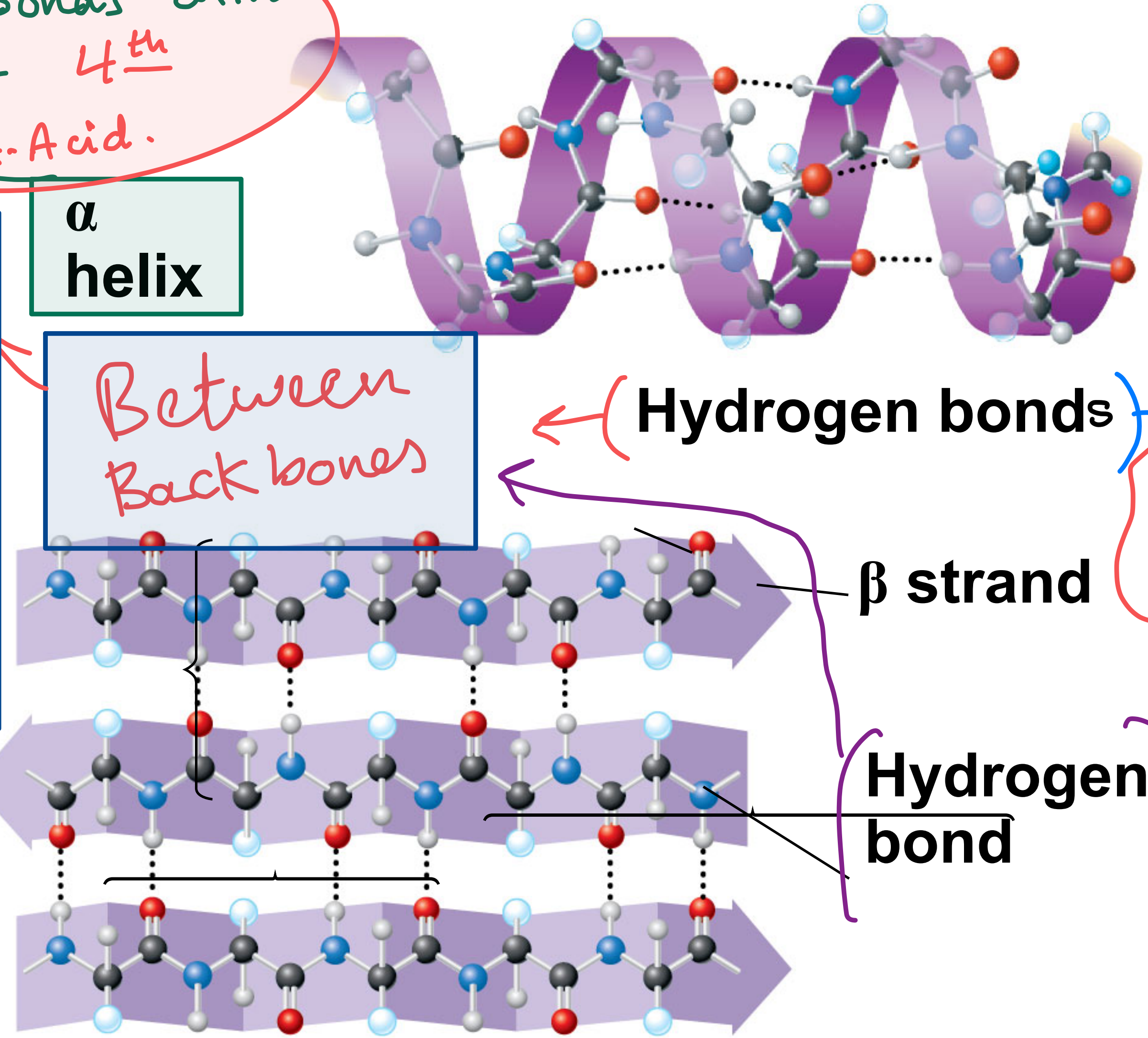
Figure 5.18b



Secondary Structure
Tertiary Structure
Quaternary Structure
α helix
α helix
Hydrogen bond
β strand
Hydrogen bond
β pleated sheet
β pleated sheet
Single polypeptide subunit
Transthyretin polypeptide
Transthyretin protein

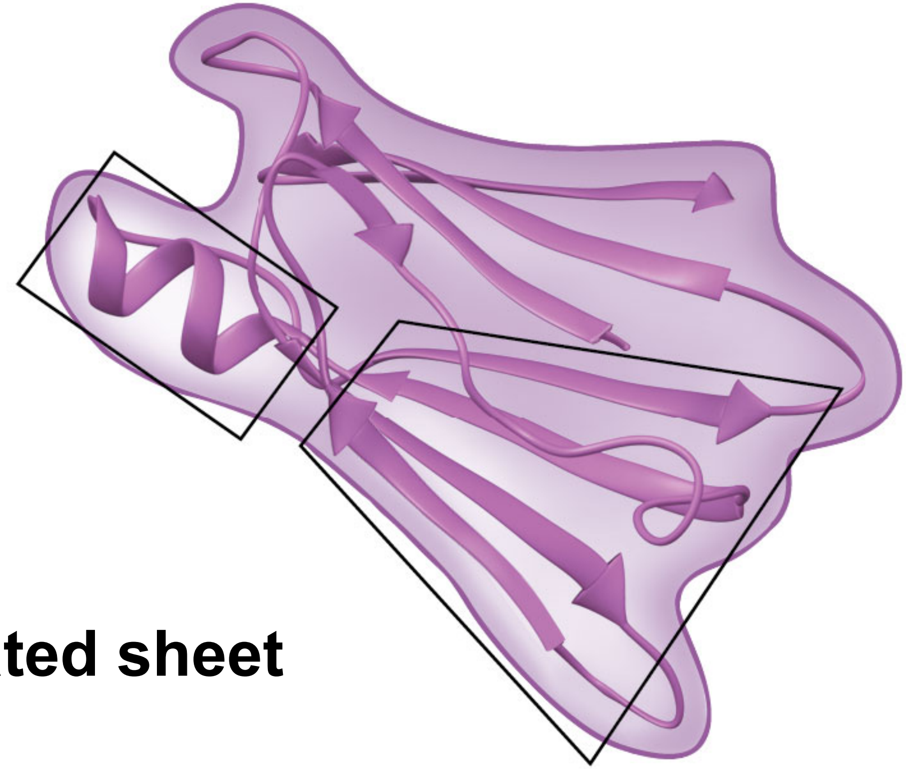
Figure 5.18ba

# Secondary Structure




β pleated sheet

# Tertiary Structure




Transthyretin polypeptide

Figure 5.18bc

## Quaternary Structure

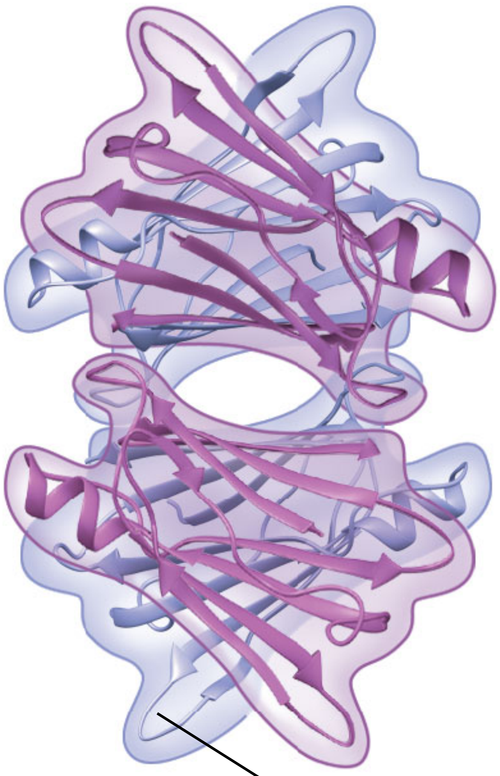


Figure 5.18c

+ (mainly)

⊕ Roughly :

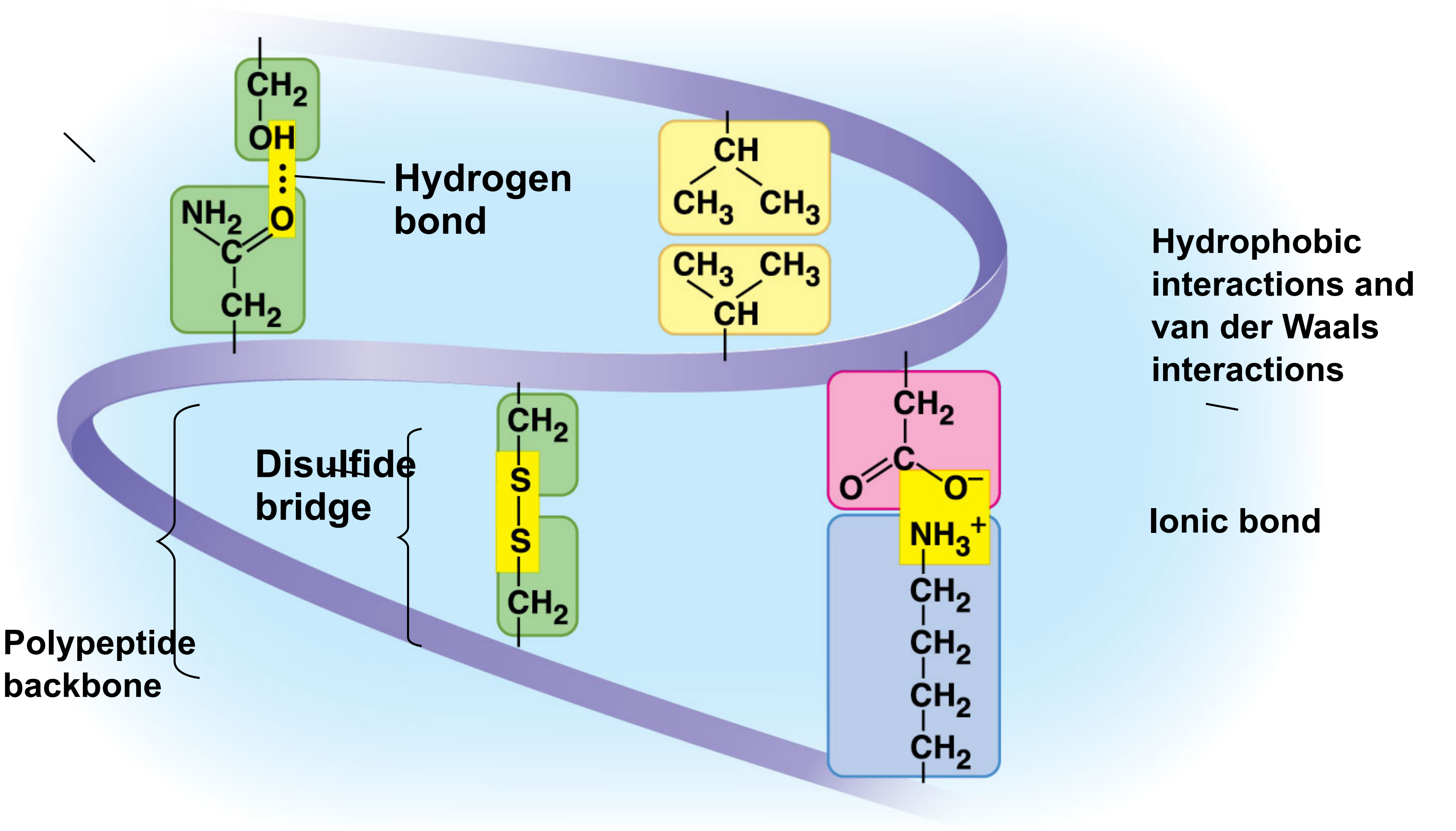
Globular Proteins : many β p. sheets

Fibrous Proteins : many α Helices

⊕ α - keratin (protein of hair) has many α-Helices

So do silk-protein & other structural Proteins.

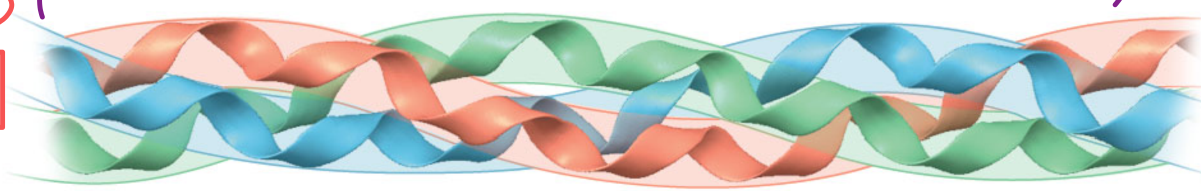
Figure 5.18d



$CH_2$
OH
Hydrogen bond
$NH_2$
C
O
$CH_2$
CH
$CH_3$ $CH_3$
$CH_3$ $CH_3$
CH
Hydrophobic interactions and van der Waals interactions
Disulfide bridge
$CH_2$
S
S
$CH_2$
$CH_2$
C
O
$O^-$
$NH_3^+$
$CH_2$
$CH_2$
$CH_2$
$CH_2$
Ionic bond
Polypeptide backbone

Figure 5.18e

3 identical P. peptides



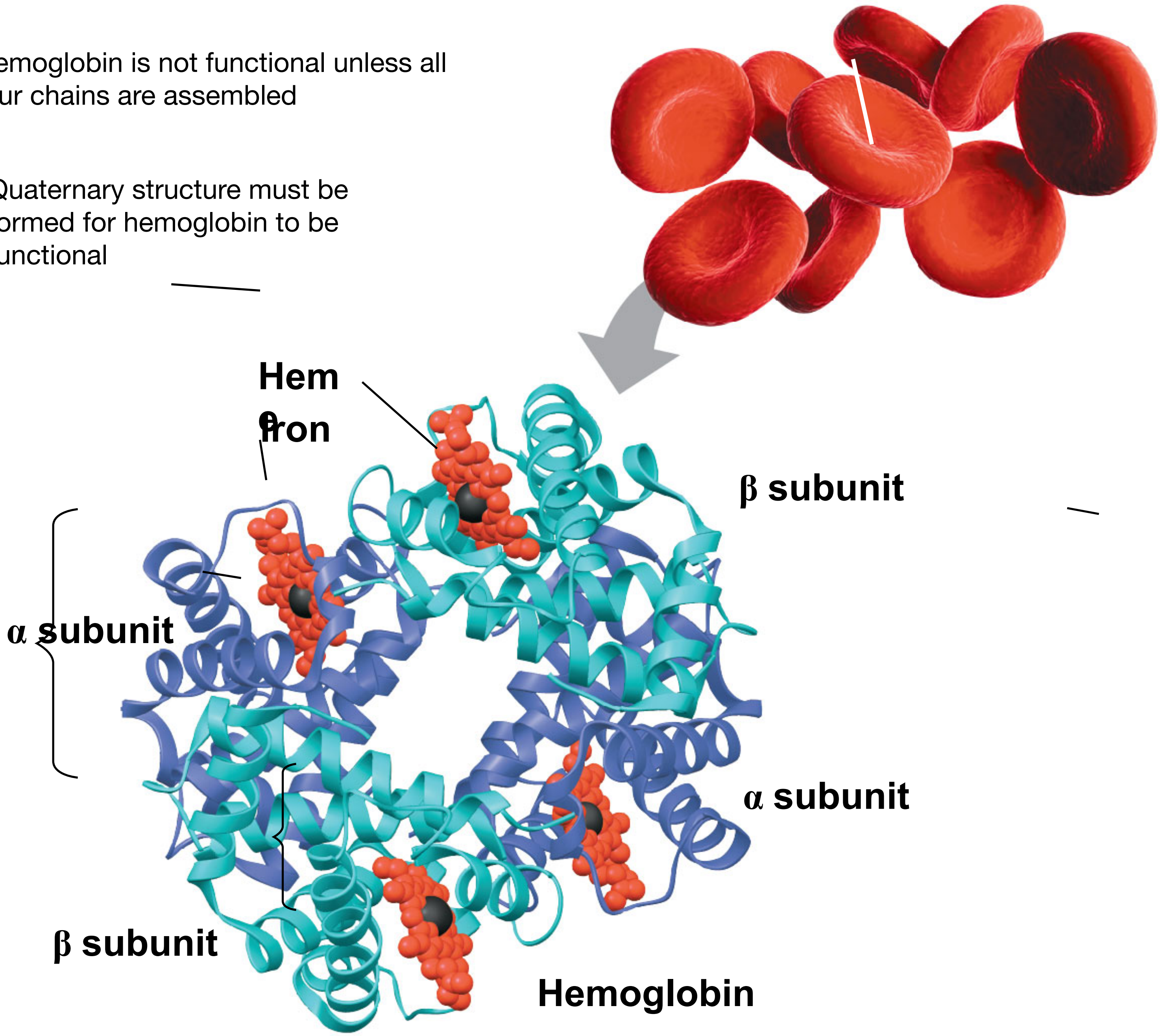
**Collagen**

⊛ Accounts to 40% of Proteins in Human Bodies.

Figure 5.18f

Hemoglobin is not functional unless all four chains are assembled

Quaternary structure must be formed for hemoglobin to be functional



- The **primary structure** of a protein is its sequence of amino acids
- Primary structure is like the order of letters in a long word
- Primary structure is determined by inherited genetic information

- The coils and folds of **secondary structure** result from hydrogen bonds between repeating constituents of the polypeptide backbone
- Typical secondary structures are a coil called an **α helix** and a folded structure called a **β pleated sheet**

- **Tertiary structure**, the overall shape of a polypeptide, results from interactions between R groups, rather than interactions between backbone constituents
- These interactions include hydrogen bonds (1), ionic bonds (2), **hydrophobic interactions** (3), and van der Waals interactions (4) (*)
- Strong covalent bonds called **disulfide bridges** may reinforce the protein's structure

(*) H. Phobic interaction as a name is misleading; when water exclude non-polar R chains they cluster when they come close together, V der W's work.

- **Quaternary structure** results when two or more polypeptide chains form one macromolecule
- Collagen is a fibrous protein consisting of three polypeptides coiled like a rope
- Hemoglobin is a globular protein consisting of four polypeptides: two α and two β subunits

# ickle-Cell Disease: A Change in Primary Structure

- A slight change in primary structure can affect a protein's structure and ability to function
- **Sickle-cell disease**, an inherited blood disorder, results from a single amino acid substitution in the protein hemoglobin
- The abnormal hemoglobin molecules cause the red blood cells to aggregate into chains and to deform into a sickle shape

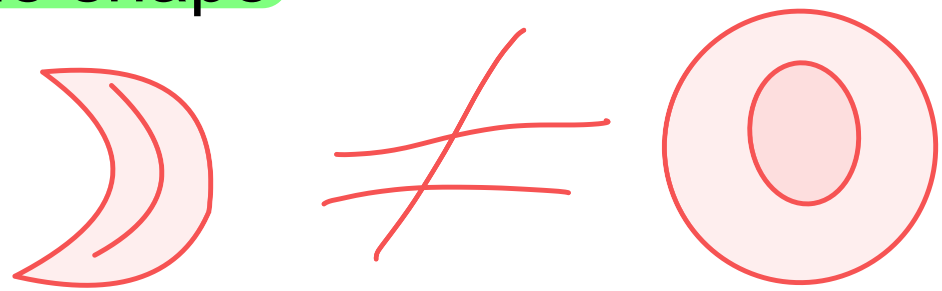
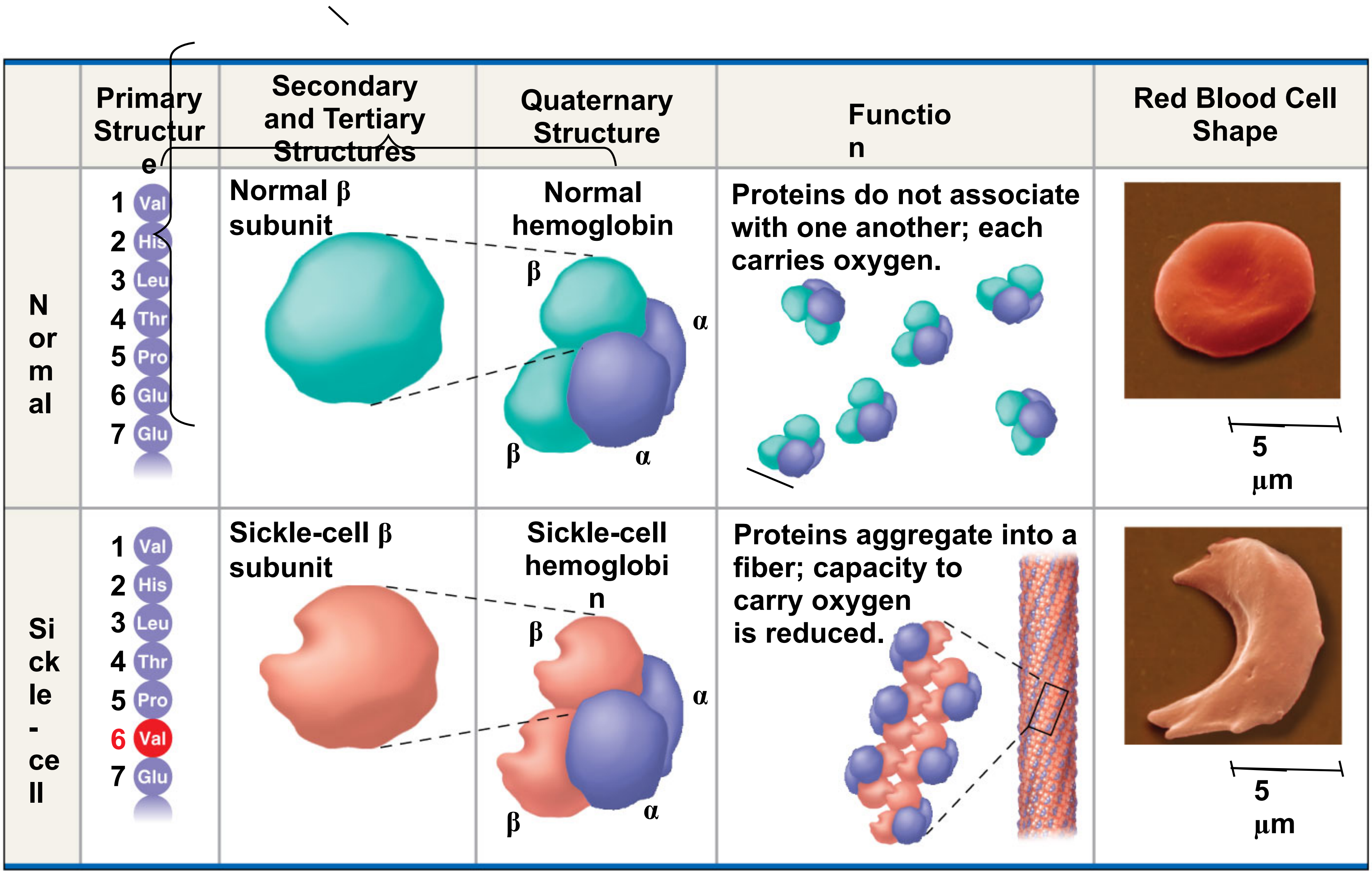
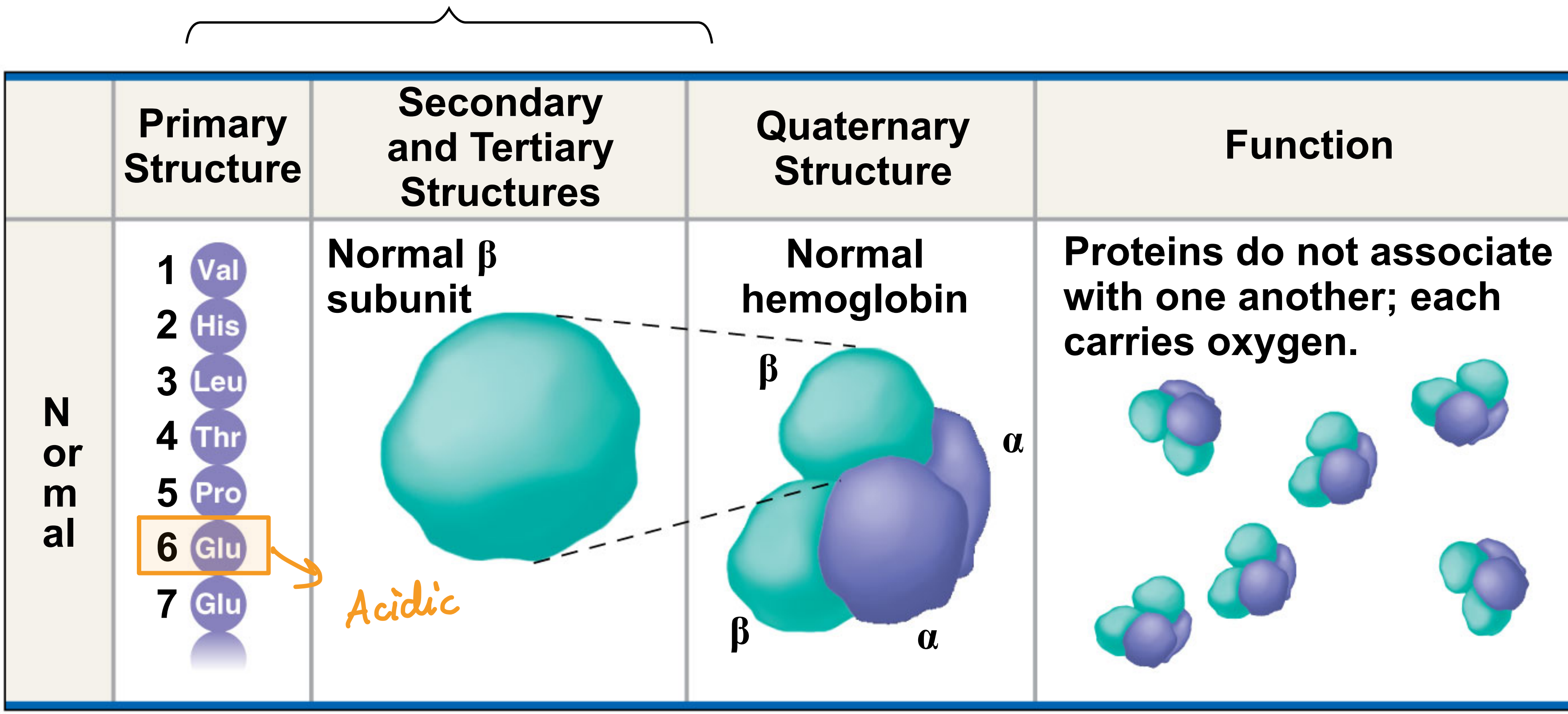


Figure 5.19




see(SSS)

Figure 5.19a




Quaternary structures remain seperated from one another to maximize gas transportation and work properly.

Figure 5.19aa

Normal Red-Blood Cell.

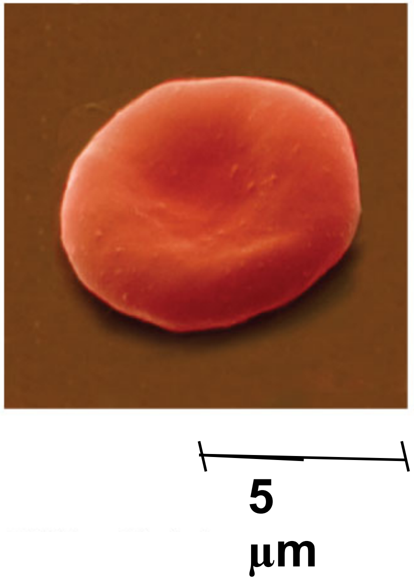
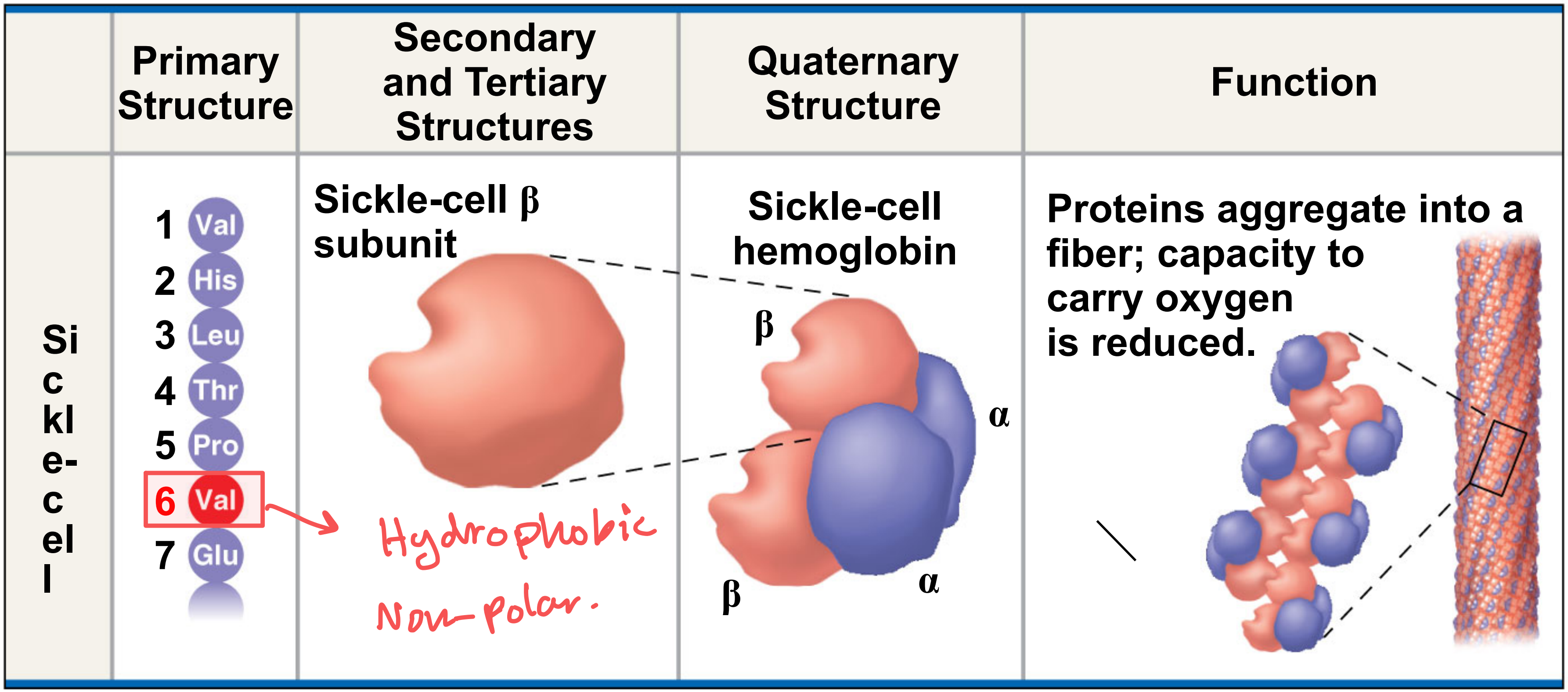


Figure 5.19b



Primary Structure
Secondary and Tertiary Structures
Quaternary Structure
Function
Si
c
kl
e-
c
el
l
1 Val
2 His
3 Leu
4 Thr
5 Pro
6 Val
7 Glu
Sickle-cell β subunit
Hydrophobic
Non-polar.
Sickle-cell hemoglobin
β
α
β
α
Proteins aggregate into a fiber; capacity to carry oxygen is reduced.

Figure 5.19ba

Abnormal Sickle-cell.

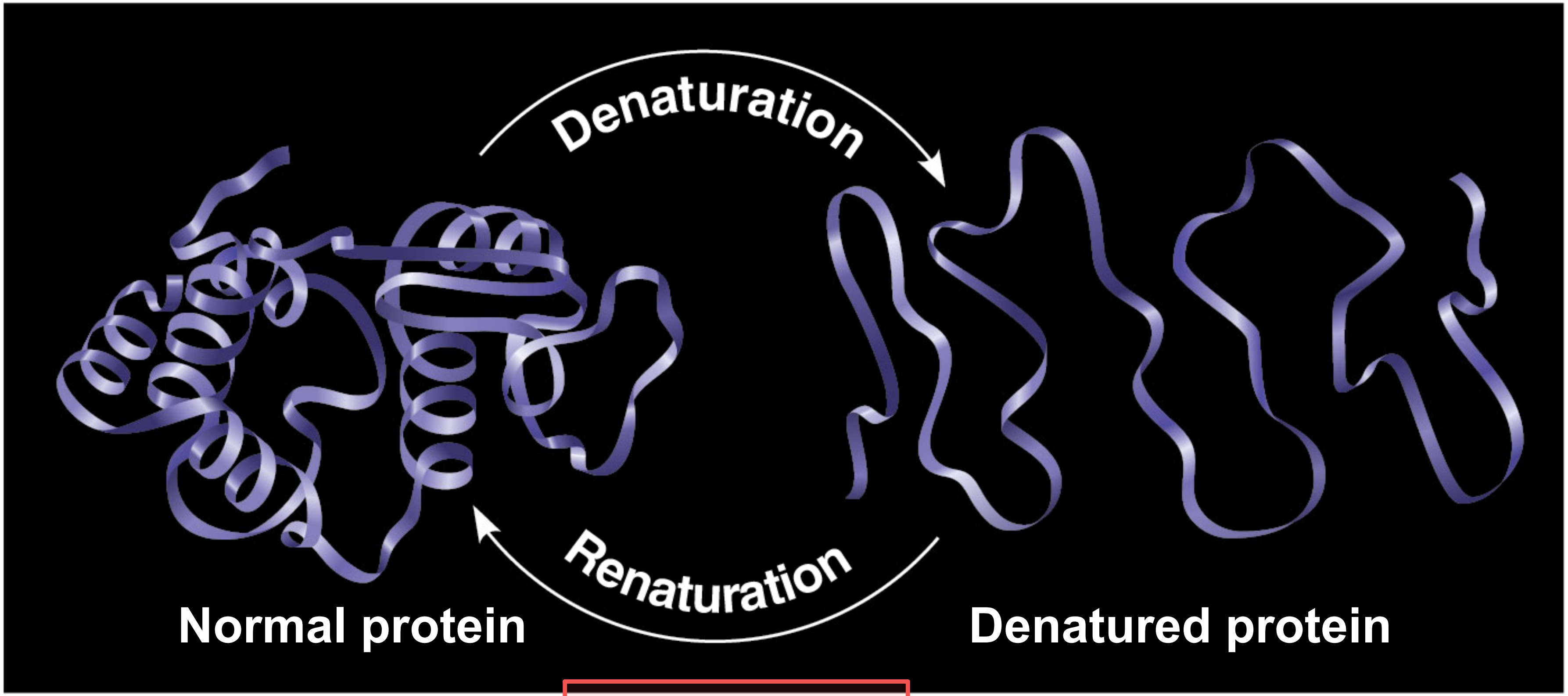
5 µm

# /hat Determines Protein Structure?

- In addition to primary structure, physical and chemical conditions can affect structure
- Alterations in pH, salt concentration, temperature, or other environmental factors can cause a protein to unravel
- This loss of a protein's native structure is called **denaturation** (*)
- A denatured protein is biologically inactive

(*) Denaturation may occur if proteins are place in a non-polar solvent → they refold so the non-polar [hydrophobic parts] face the outside (solvent).

Figure 5.20




Renaturation is not always possible

it depends on conditions and other factors.

# rotein Folding in the Cell

- It is hard to predict a protein's structure from its primary structure
- Most proteins probably go through several stages on their way to a stable structure
- Diseases such as Alzheimer's (1), Parkinson's (2), and mad cow (3) disease are associated with misfolded proteins

+ { cystic fibrosis (4) }

- Scientists use **X-ray crystallography** to determine a protein's structure
- Another method is nuclear magnetic resonance (NMR) spectroscopy, which does not require protein crystallization
- Bioinformatics is another approach to prediction of protein structure from amino acid sequences

⊕ Intrinsically disordered Proteins ⊛

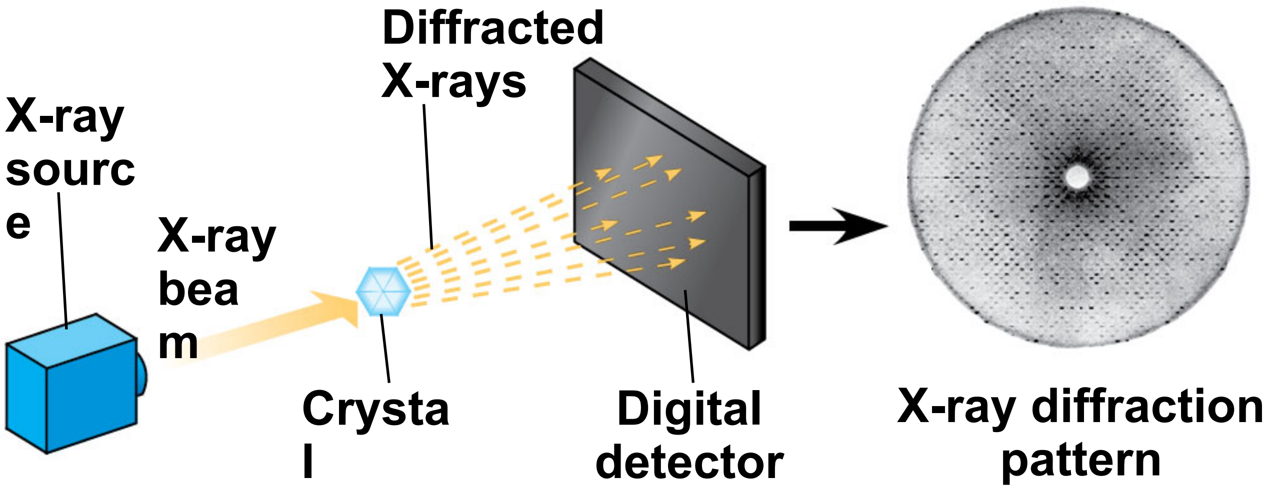
account for (20–30)% of mammalian Proteins

⊛ don't have a specific 3-D structure

→ Variability helps with variable functions.

Figure 5.21

## Technique




## Results

## oncept 5.5: Nucleic acids store,[1] transmit,[2] and help express hereditary information[3]

- The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a **gene**
- Genes consist of DNA, a **nucleic acid** made of monomers called nucleotides

⊕ each chromosome (non-duplicated) contains

[1] DNA molecule

# he Roles of Nucleic Acids

- There are two types of nucleic acids
  - **Deoxyribonucleic acid (DNA)**
  - **Ribonucleic acid (RNA)**
- DNA provides directions for its own replication
- DNA directs synthesis of messenger RNA (mRNA) and, through mRNA, controls protein synthesis
- This process is called **gene expression**

DNA → RNA → Proteins

which carries most of the Biological functions.

Figure 5.22_1

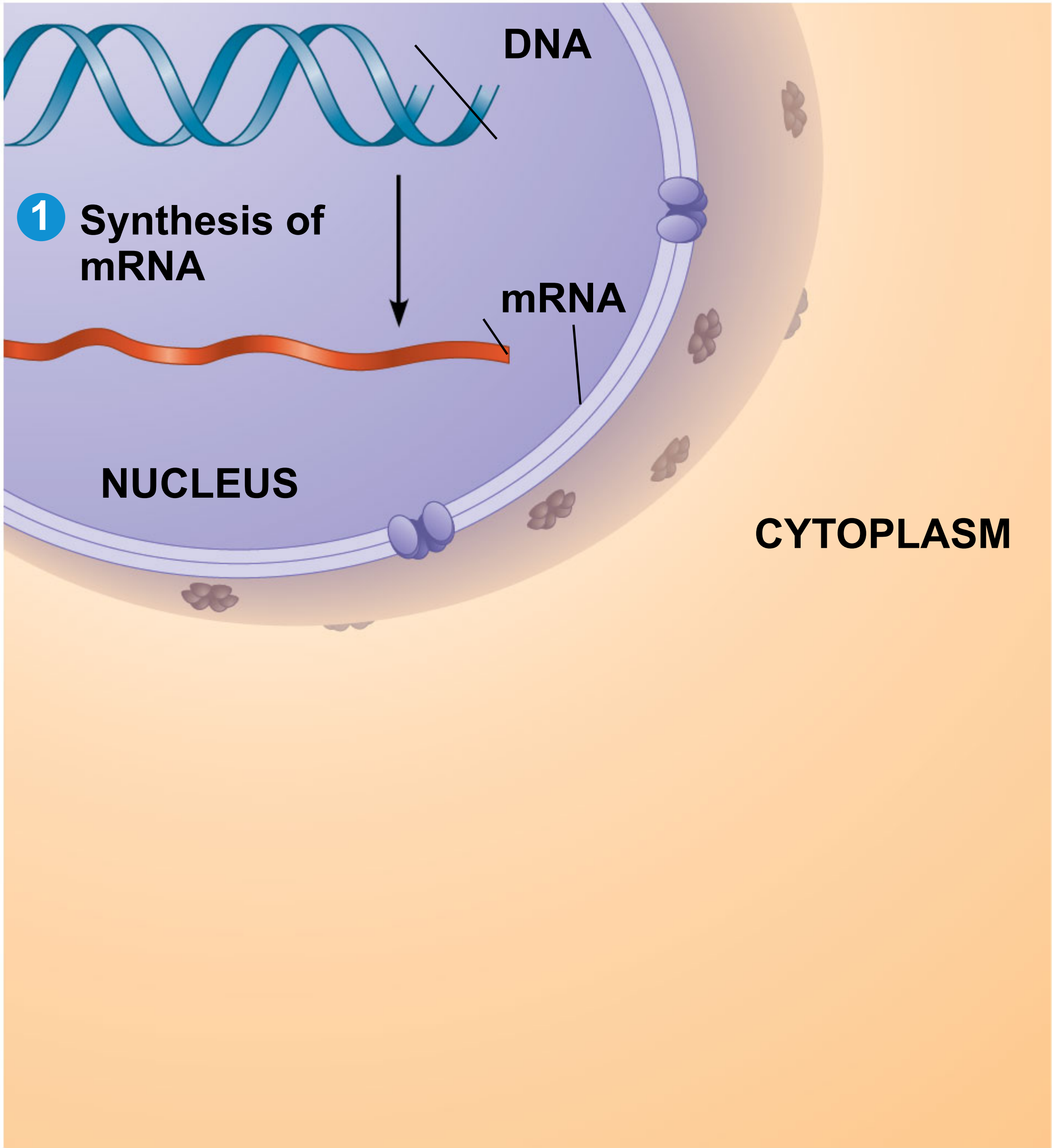


Figure 5.22_2

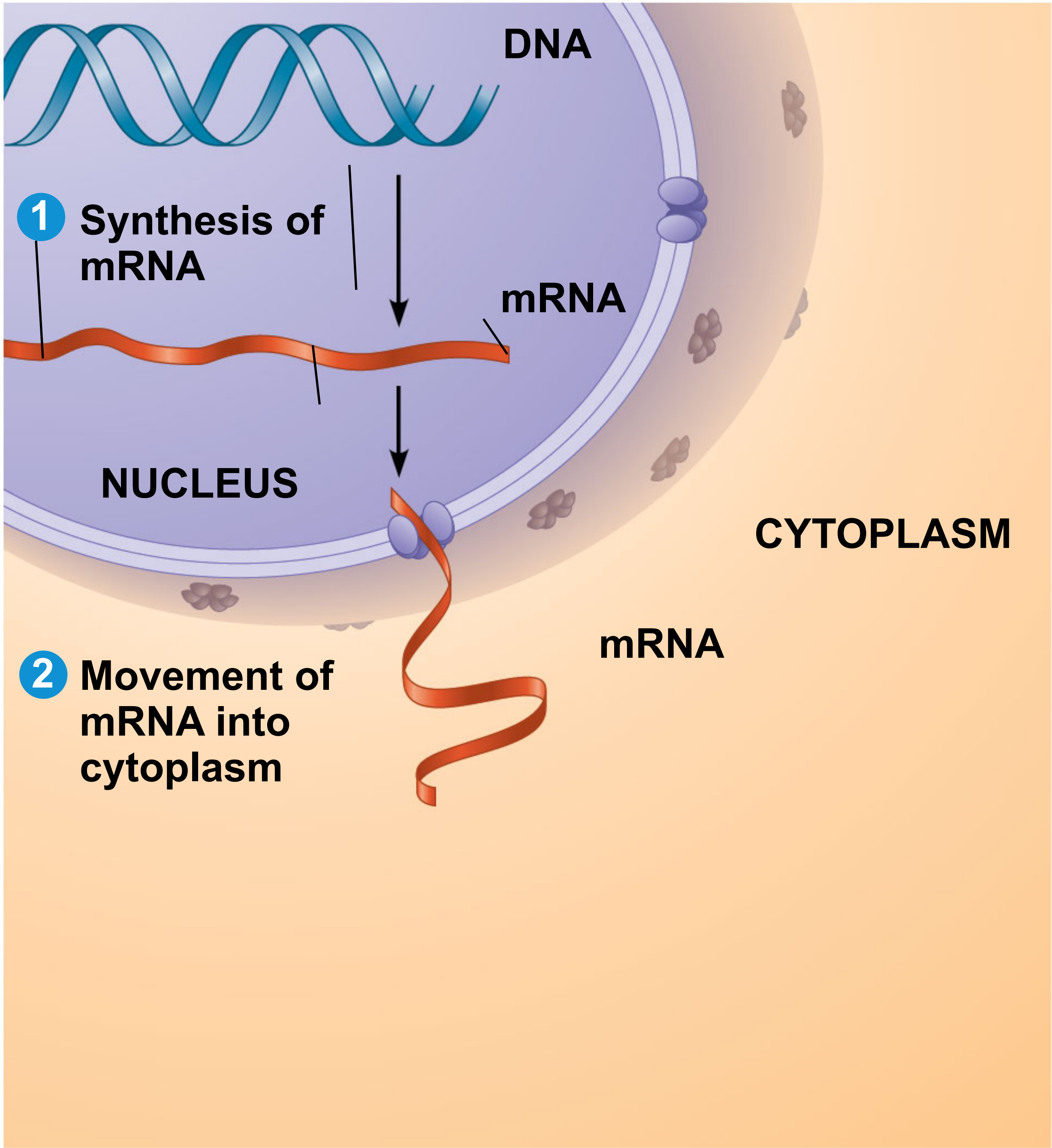
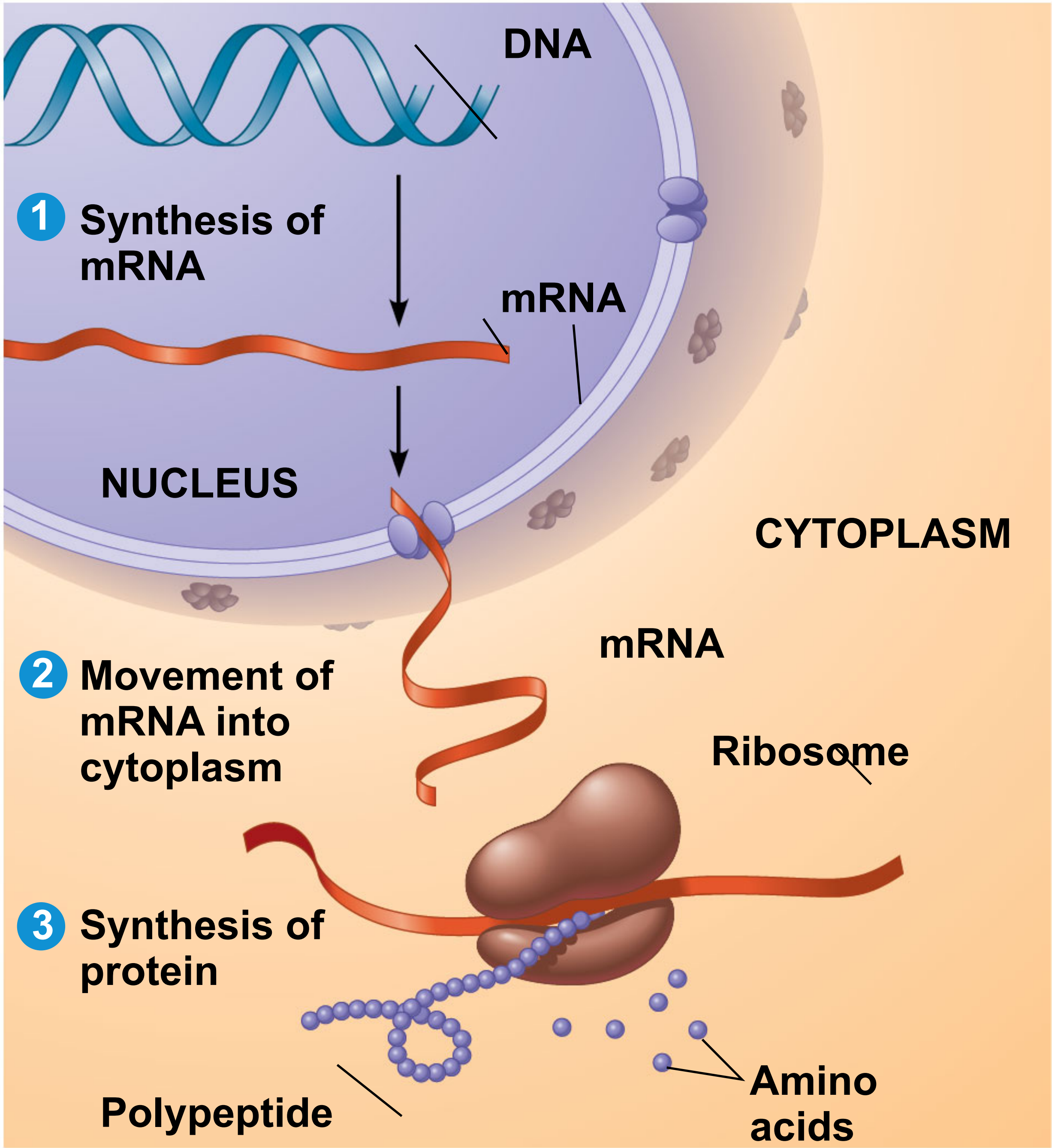

DNA
1 Synthesis of mRNA
mRNA
NUCLEUS
CYTOPLASM
mRNA
2 Movement of mRNA into cytoplasm

Figure 5.22_3



DNA
1 Synthesis of mRNA
mRNA
mRNA
NUCLEUS
CYTOPLASM
mRNA
2 Movement of mRNA into cytoplasm
Ribosome
3 Synthesis of protein
Polypeptide
Amino acids

- Each gene along a DNA molecule directs synthesis of a messenger RNA (mRNA)
- The mRNA molecule interacts with the cell's protein-synthesizing machinery to direct production of a polypeptide
- The flow of genetic information can be summarized as DNA → RNA → protein

# he Components of Nucleic Acids

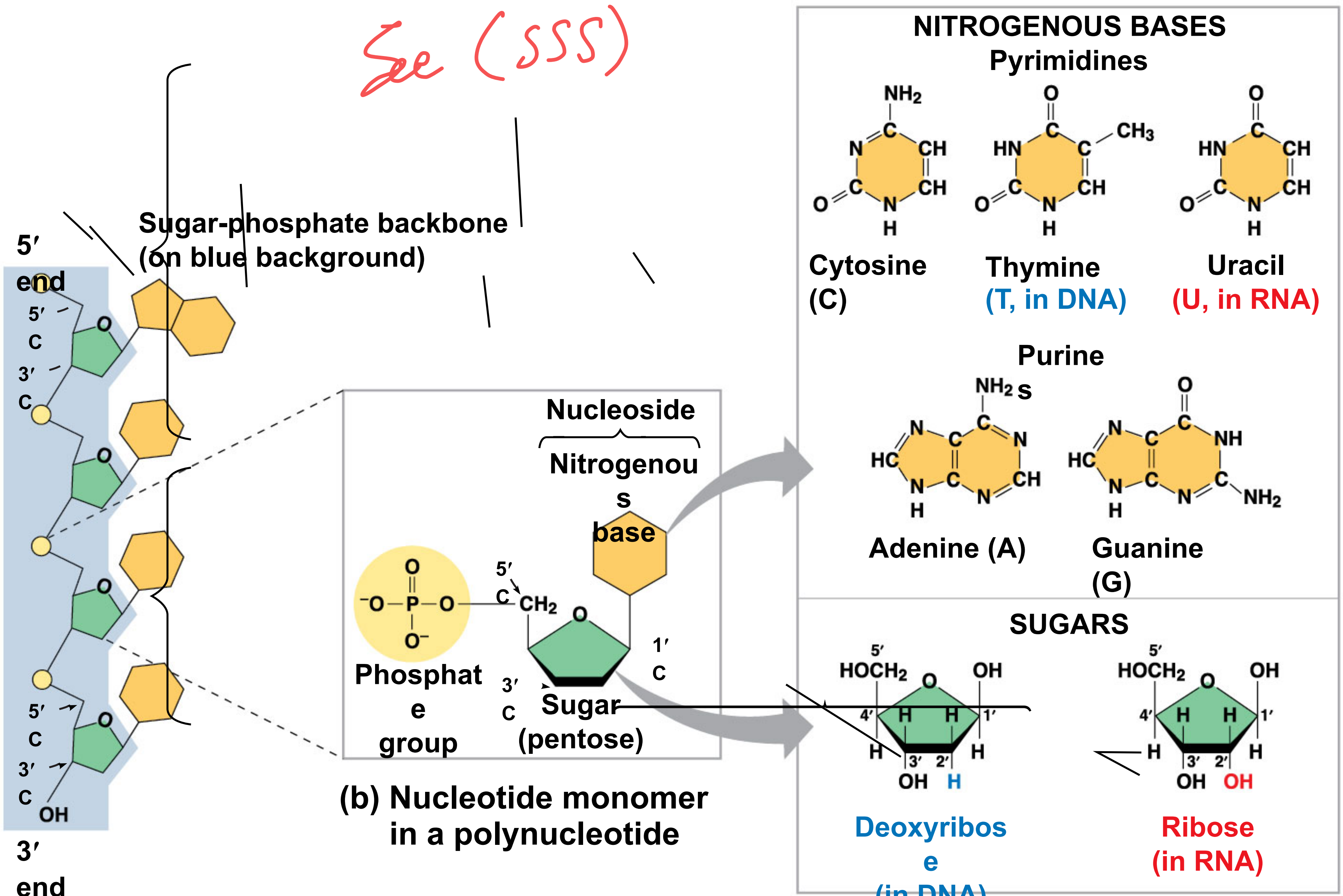
- Nucleic acids are polymers called **polynucleotides**
- Each polynucleotide is made of monomers called **nucleotides**
- Each nucleotide consists of a nitrogenous base, a pentose sugar, and one or more phosphate groups
- The portion of a nucleotide without the phosphate group is called a nucleoside

- Nucleoside = nitrogenous base + sugar
- There are two families of nitrogenous bases
  - **Pyrimidines** (cytosine, thymine, and uracil) have a single six-membered ring
  - **Purines** (adenine and guanine) have a six-membered ring fused to a five-membered ring
- In DNA, the sugar is **deoxyribose**; in RNA, the sugar is **ribose**
- Nucleotide = nucleoside + phosphate group

(1, 2, 3) groups.

most common

Figure 5.23

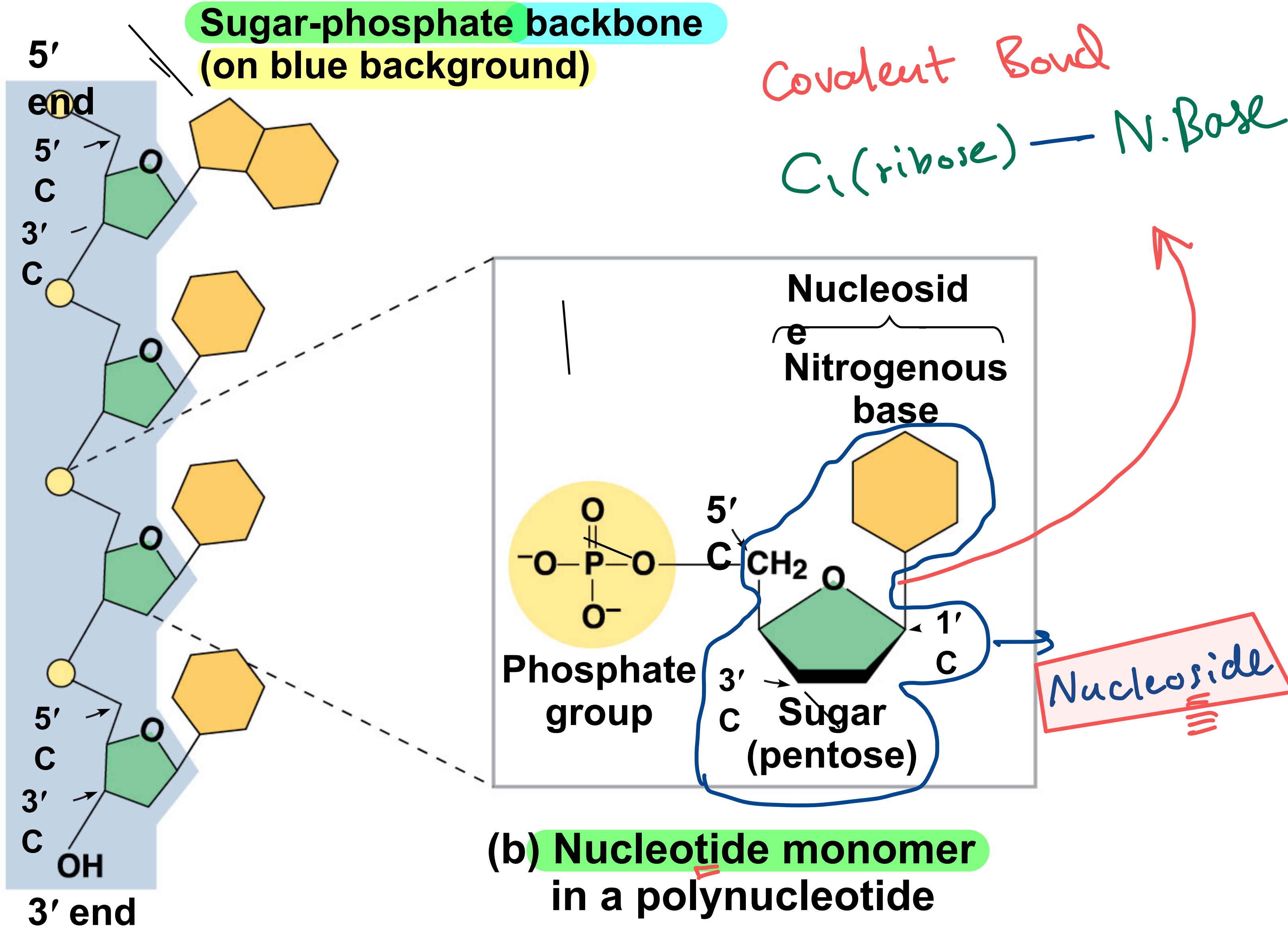



(a) Polynucleotide, or nucleic acid

(b) Nucleotide monomer in a polynucleotide

(c) Nucleoside components

Figure 5.23a



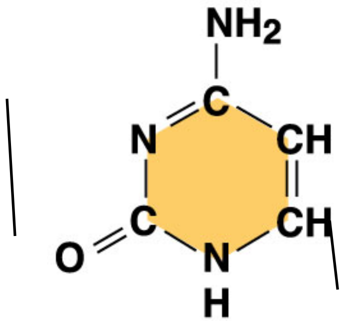

(b) Nucleotide monomer in a polynucleotide

(a) Polynucleotide, or nucleic acid

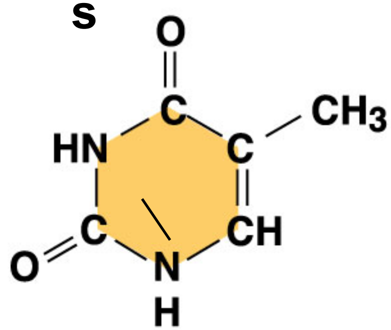
Figure 5.23b

# NITROGENOUS BASES

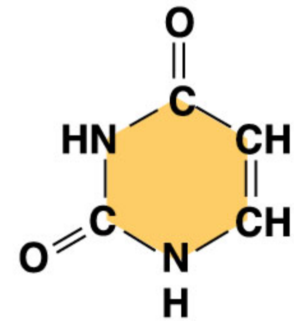
## Pyrimidines




Cytosine (C)

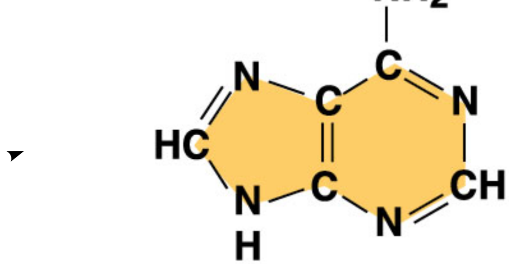



Thymine
(T, in DNA)

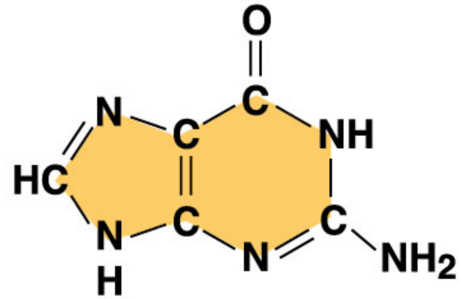



Uracil
(U, in RNA)

## Purines



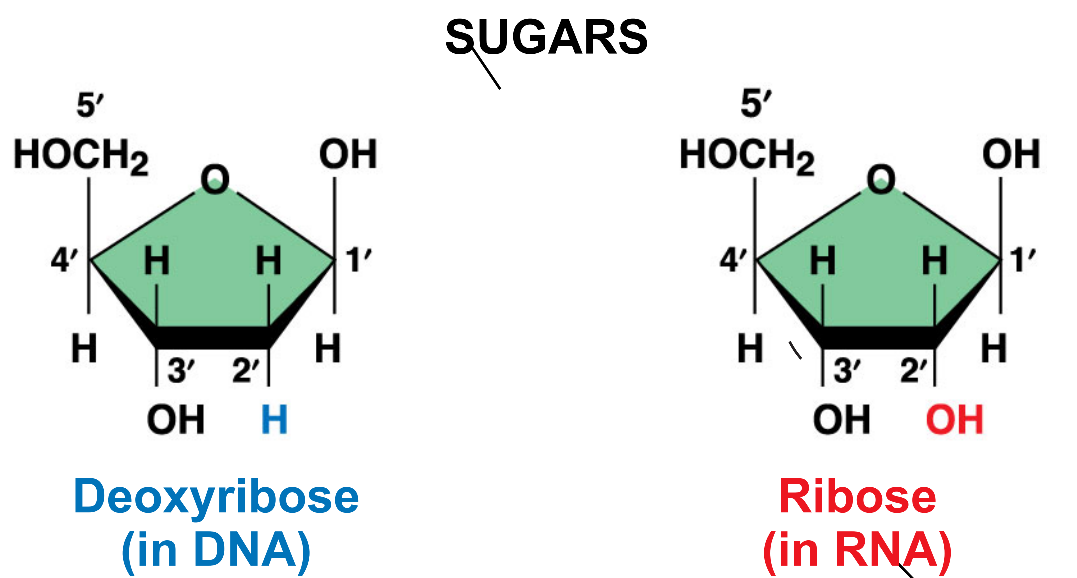

Adenine (A)




Guanine (G)

## (c) Nucleoside components

Figure 5.23c




**(c) Nucleoside components**

C2′ ⇒ determines the type of Ribose.

C3′ ⇒ OH links with P-group from another nucleotide

C5′ ⇒ OH links with P-group from the same nucleotide.

# ucleotide Polymers

- Nucleotides are linked together by a phosphodiester linkage to build a polynucleotide
- A phosphodiester linkage consists of a phosphate group that links the sugars of two nucleotides
- These links create a backbone of sugar-phosphate units with nitrogenous bases as appendages
- The sequence of bases along a DNA or mRNA polymer is unique for each gene

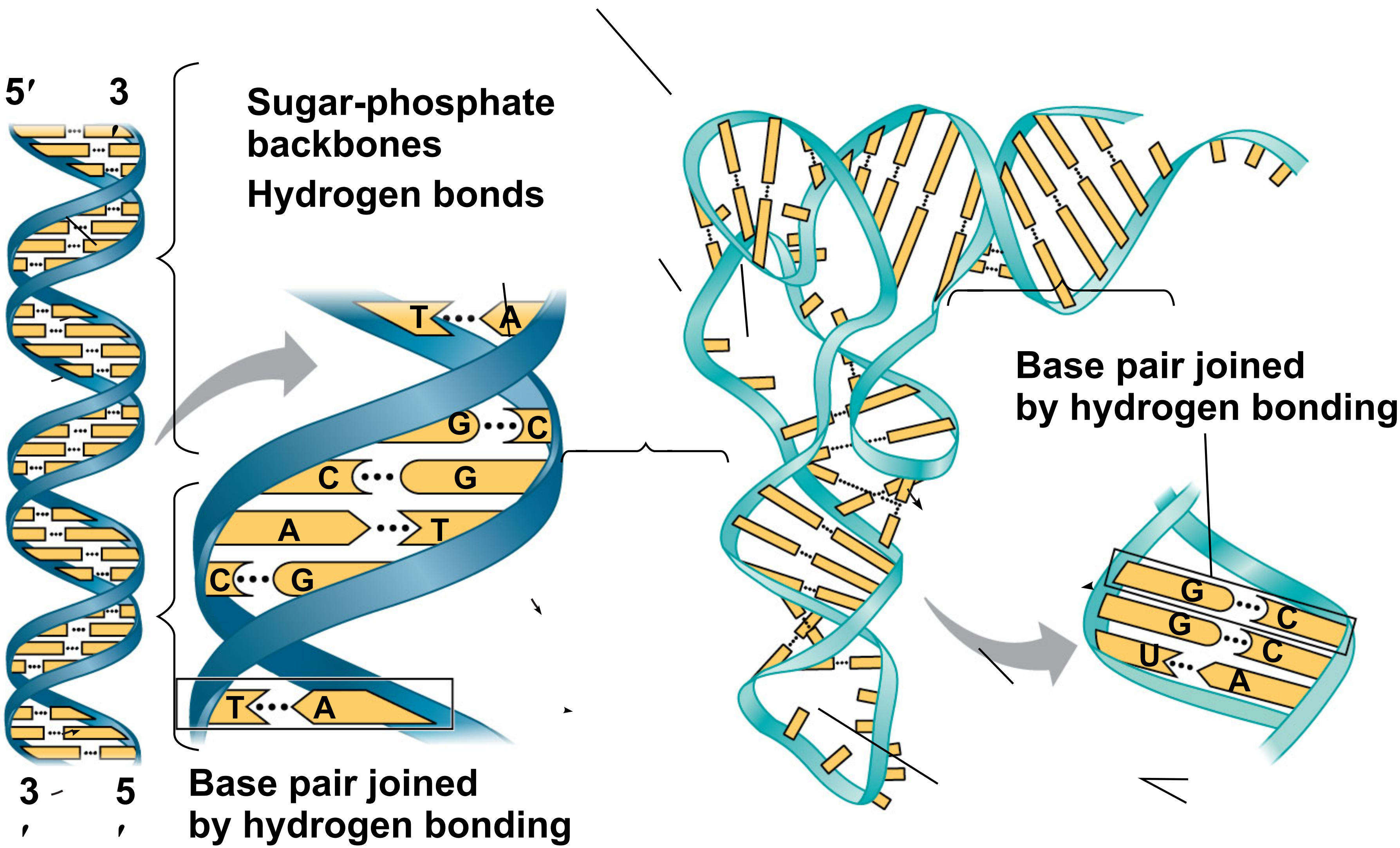
# he Structures of DNA and RNA Molecules

- DNA molecules have two polynucleotides spiraling around an imaginary axis, forming a **double helix**
- The backbones run in opposite 5′ → 3′ directions from each other, an arrangement referred to as **antiparallel**
- One DNA molecule includes many genes

- Only certain bases in DNA pair up and form hydrogen bonds: adenine (A) always with thymine (T), and guanine (G) always with cytosine (C)
- This is called complementary base pairing
- This feature of DNA structure makes it possible to generate two identical copies of each DNA molecule in a cell preparing to divide

- RNA, in contrast to DNA, is single-stranded
- Complementary pairing can also occur between two RNA molecules (1) or between parts of the same molecule (2)
- In RNA, thymine is replaced by uracil (U), so A and U pair
- While DNA always exists as a double helix, RNA molecules are more variable in form

Figure 5.24




(a) DNA (b) Transfer RNA