النادي الطبي

تَنوير

BIOLOGY

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وَقُل رَبِّ زِدْنِي عِلْمًا

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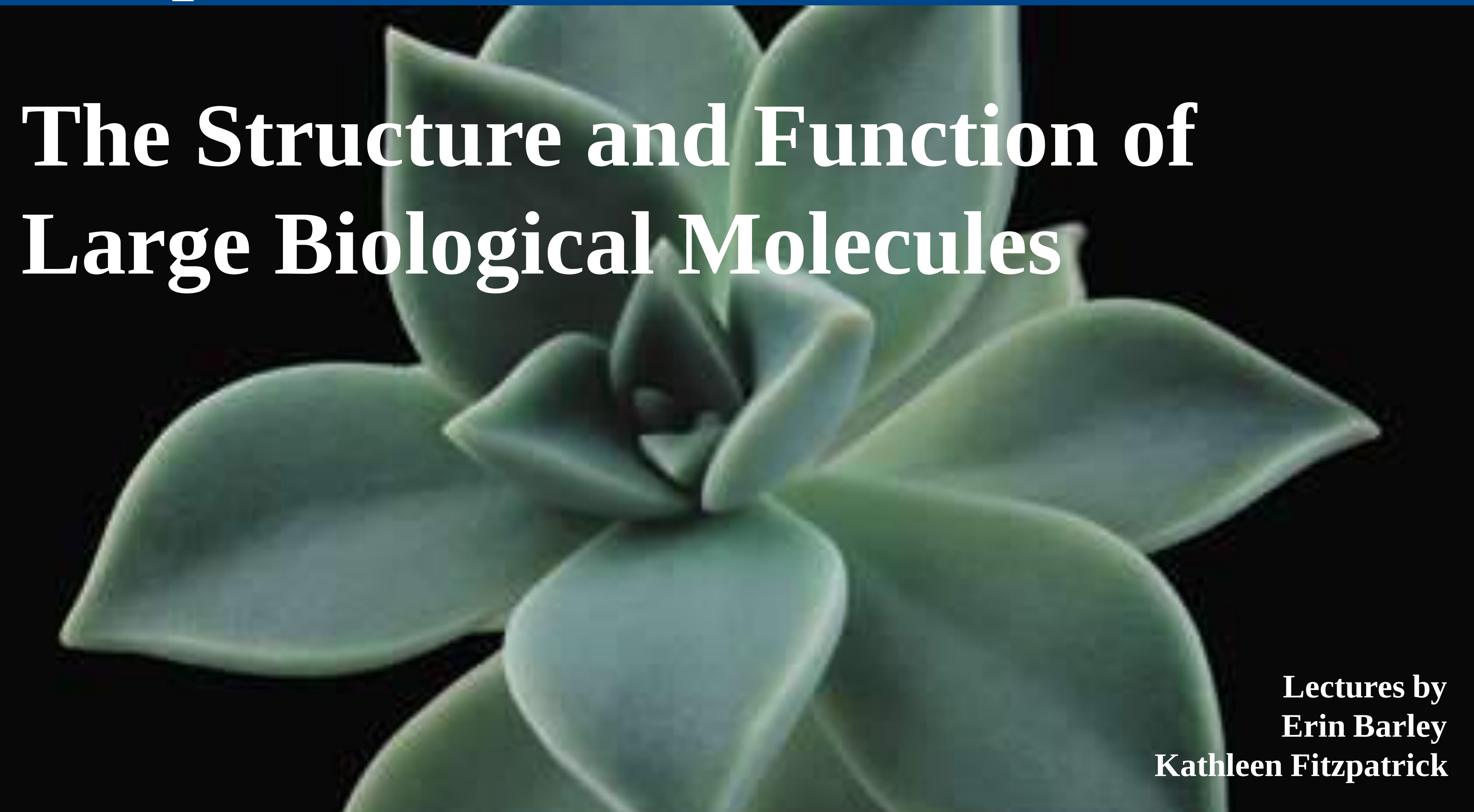
Chapter 5



The Structure and Function of Large Biological Molecules

Lectures by
Erin Barley
Kathleen Fitzpatrick

Overview: The 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 composed of thousands of covalently connected atoms
- Molecular structure and function are inseparable

Notes:

- Atoms → molecule → organelle → cell → Tissue → organ → system → organism

molecules

Micro:
- smaller and less needed

like: vitamins

Macro:
- Larger and more needed

like: proteins, lipids, carbohydrets, and nucleic acids

- mono, uni : أحادي
- di, bi : ثنائي
- Tri : ثلاثي
- Tetra: رباعي
- Penta: خماسي
- hexa: سداسي
- hepta: سباعي
- Octa: ثماني

Figure 5.1

Concept 5.1: Macromolecules are polymers, built from monomers

- A **polymer** is a long molecule consisting of many similar building blocks
- These small building-block molecules are called **monomers**
- Three of the four classes of life's organic molecules are polymers
  - Carbohydrates
  - Proteins
  - Nucleic acids

* lipids aren't considered real polymers

Polymers are made from monomers

by ← synthesis and breakdown → by

dehydration → H_2O ← hydrolysis

- Isomers: same molecular formula but different structural formula

- lysis : تحلل

chemical bonds:

1) Hydrophobic bond (كارهة للماء (رابطة ضعيفة جداً
2) Ionic bond ايونية
3) Hydrogen bond هيدروجينية
4) Covalent bond تساهمية
   - polar
     X - - - Y
     electrons closer to one side
   - non polar
     X - - - Y
     electrons in the middle

The Synthesis and Breakdown of 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

Figure 5.2a

(a) Dehydration reaction: synthesizing a polymer

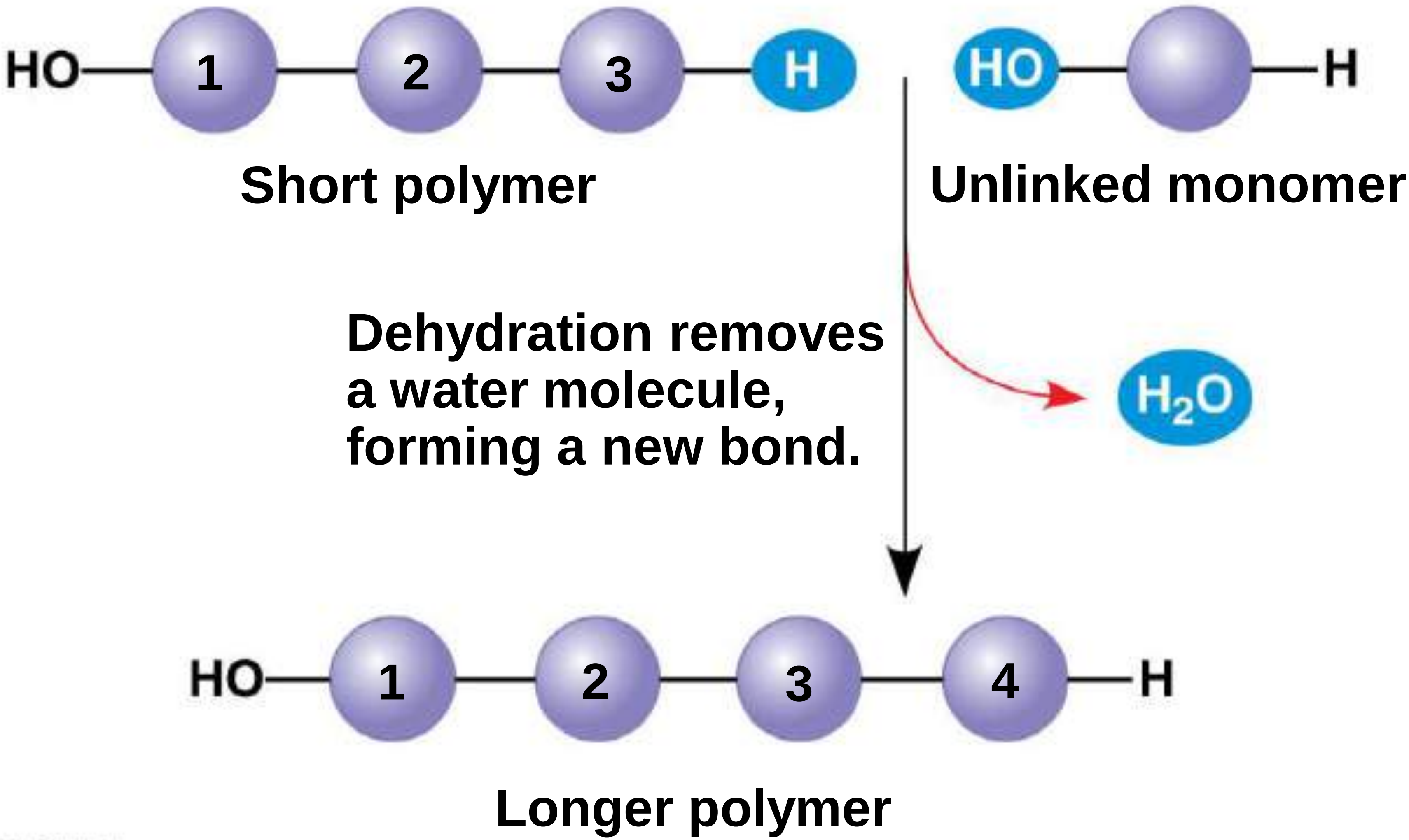
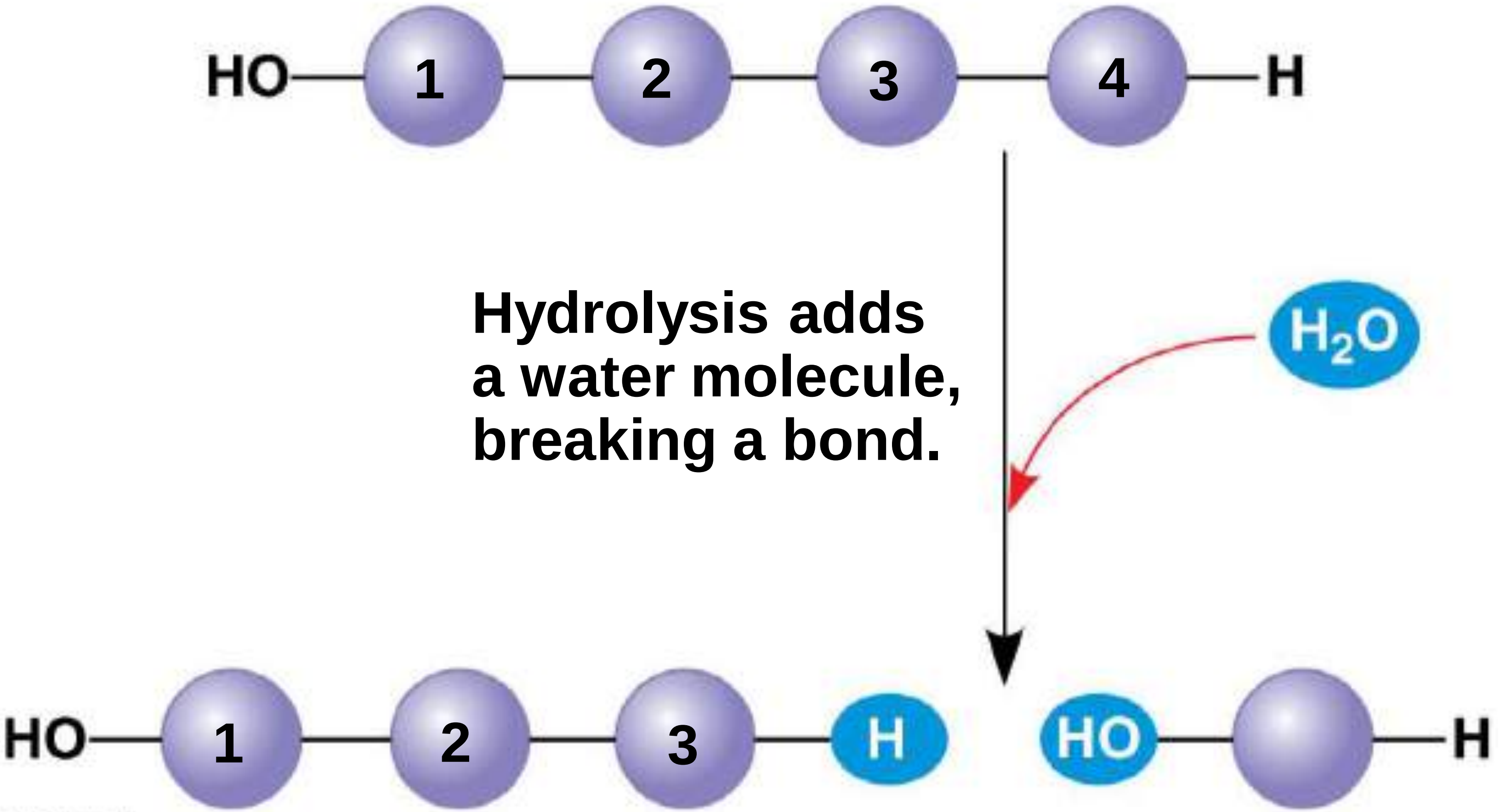


Figure 5.2b

(b) Hydrolysis: breaking down a polymer



The Diversity of Polymers

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

Concept 5.2: Carbohydrates serve as fuel and building material

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

Sugars

- **Monosaccharides** have molecular formulas that are usually multiples of CH_2O ← قاعدة عامة
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- Monosaccharides are classified by
  - The location of the carbonyl group (C=O) (as aldose [if C=O on the end] or ketose) → if C=O in the middle
  - The number of carbons in the carbon skeleton
  - Fuctional groups
  - Rings
  - Isomers

Figure 5.3

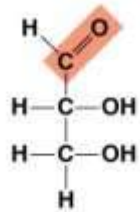
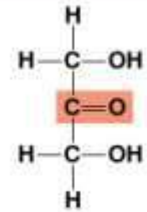
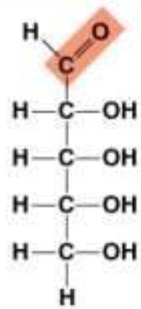
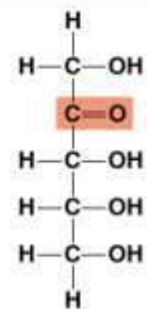
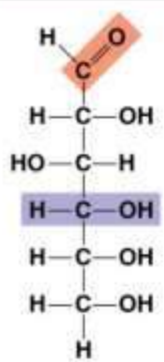
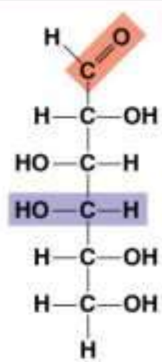
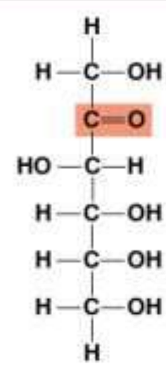
Aldoses (Aldehyde Sugars)	Ketoses (Ketone Sugars)
Trioses: 3-carbon sugars ($C_3H_6O_3$)	
 Glyceraldehyde	 Dihydroxyacetone
Pentoses: 5-carbon sugars ($C_5H_{10}O_5$)	
 Ribose	 Ribulose
Hexoses: 6-carbon sugars ($C_6H_{12}O_6$)	
 Glucose  Galactose	 Fructose

Figure 5.3a

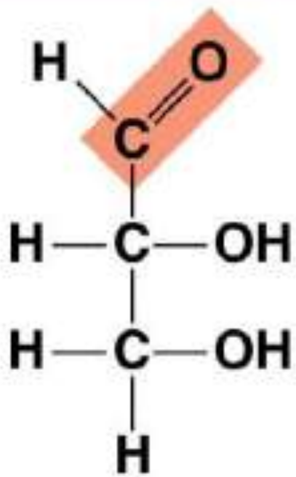
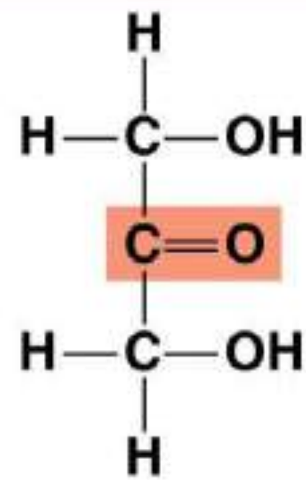
Aldose (Aldehyde Sugar)	Ketose (Ketone Sugar)
Trioses: 3-carbon sugars ($C_3H_6O_3$)	
	
Glyceraldehyde	Dihydroxyacetone

Figure 5.3b

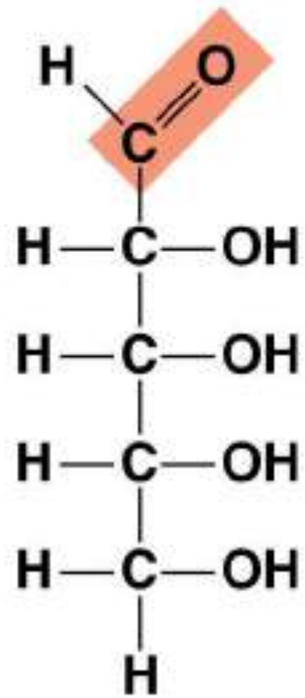
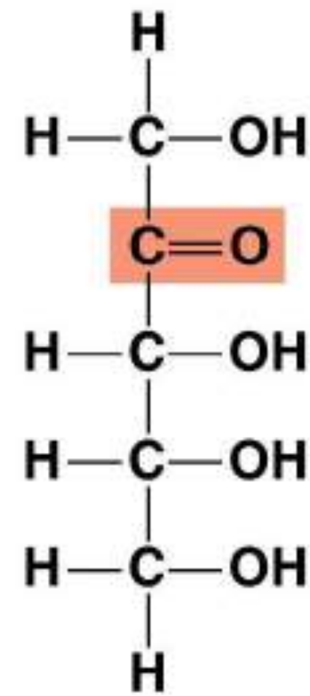
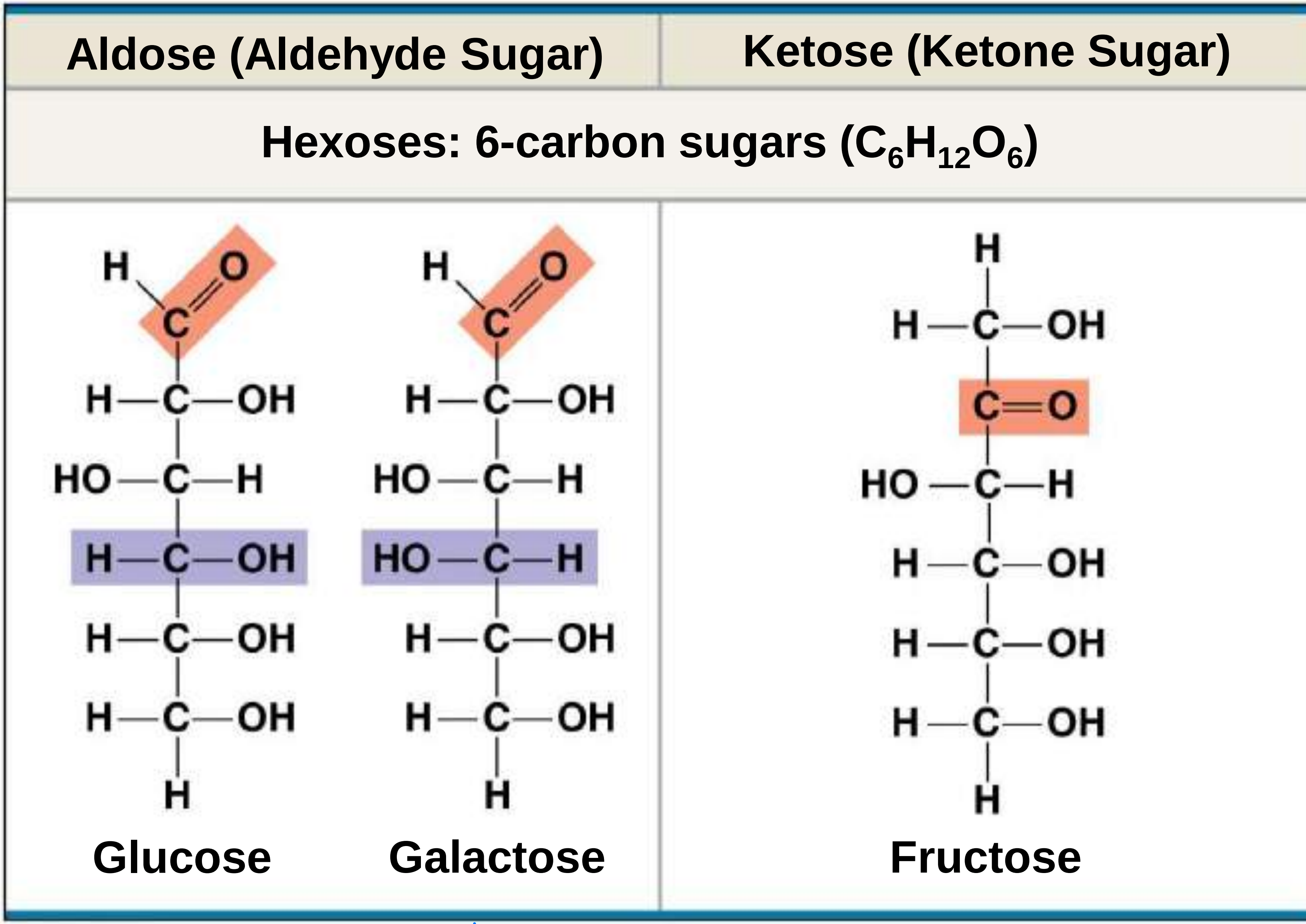
Aldose (Aldehyde Sugar)	Ketose (Ketone Sugar)
Pentoses: 5-carbon sugars ($C_5H_{10}O_5$)	
	
Ribose	Ribulose

Figure 5.3c



بلش العد من الكربونيل

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

molecular formula: صيغة جزيئية → $C_6H_{12}O_6$

structural formula: صيغة بنائية →

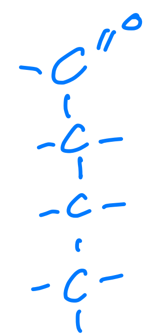
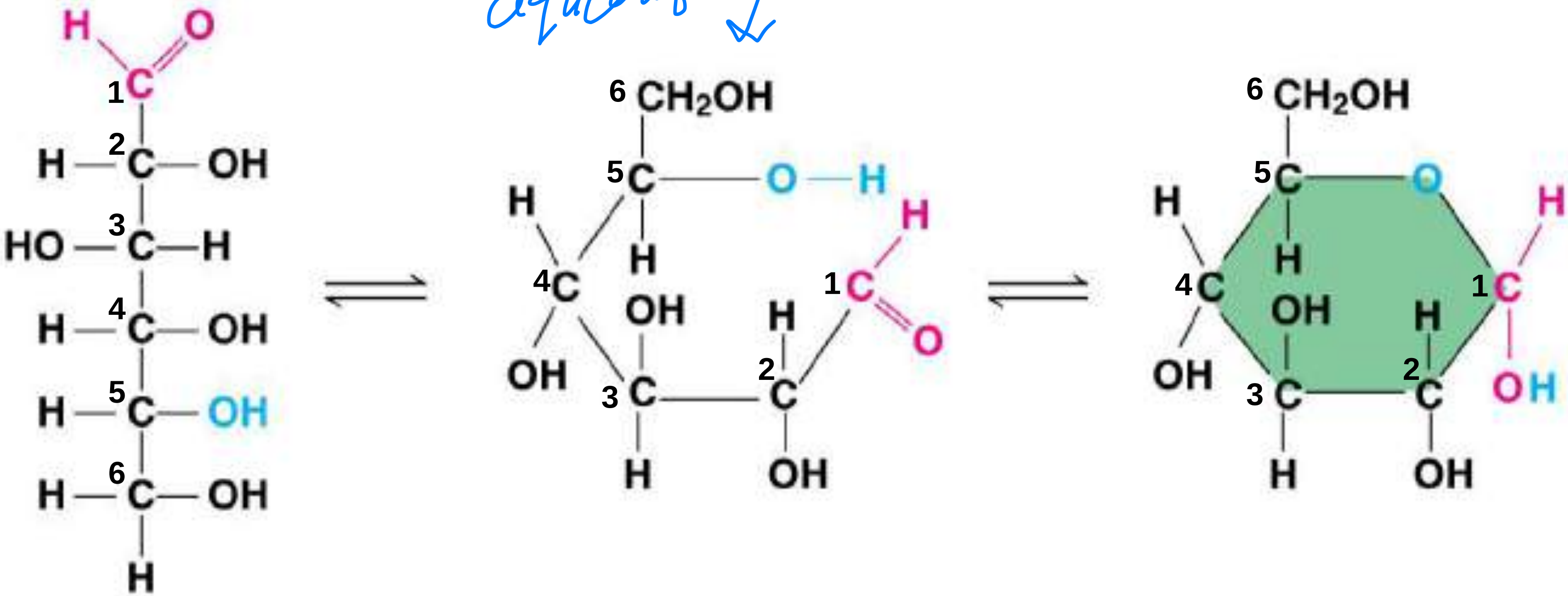
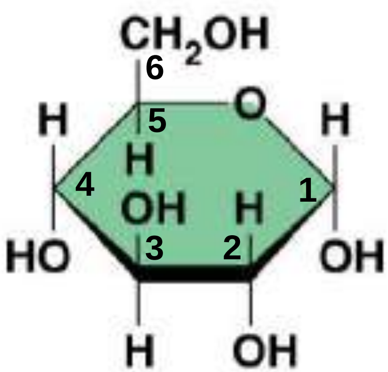


Figure 5.4

aqueous



(a) Linear and ring forms

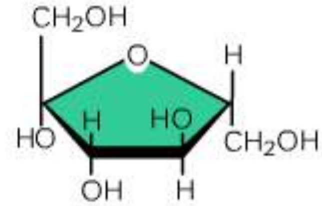


(b) Abbreviated ring structure

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

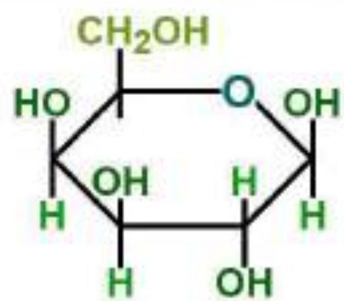
رابطة تساهمية غلايكوسيدية

Glucose



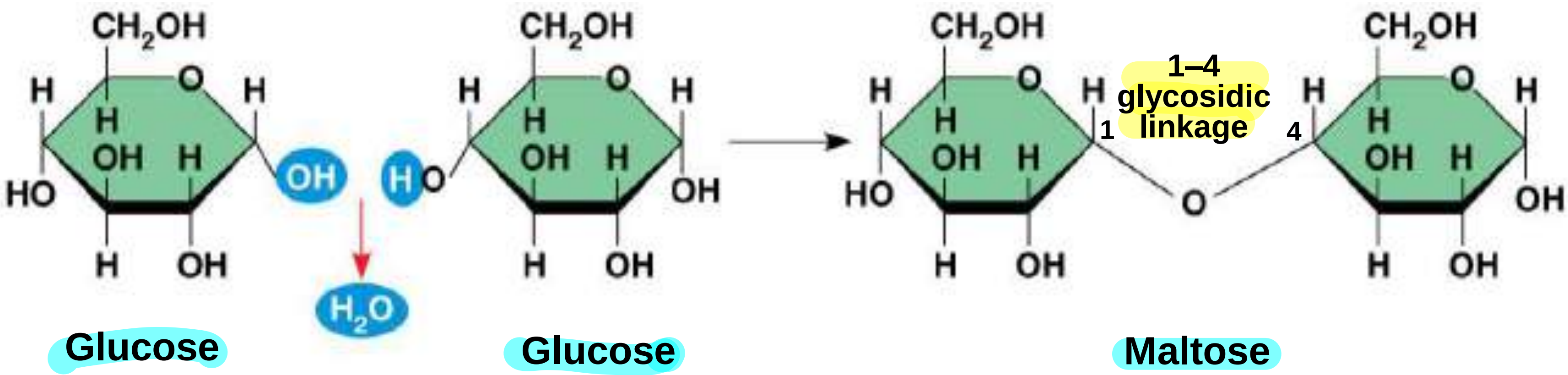
Fructose

Structure of Galactose

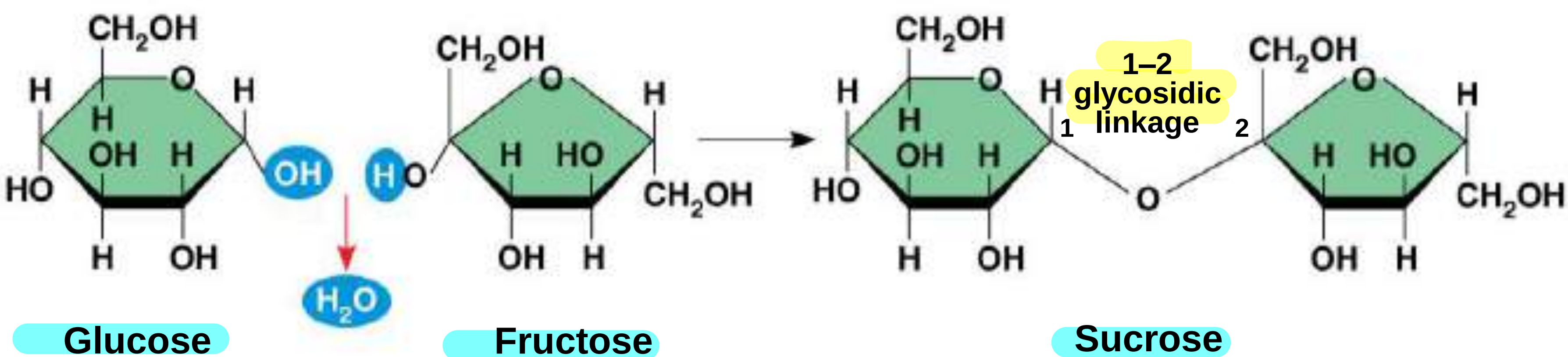


Animation: Disaccharide
Right-click slide / select “Play”

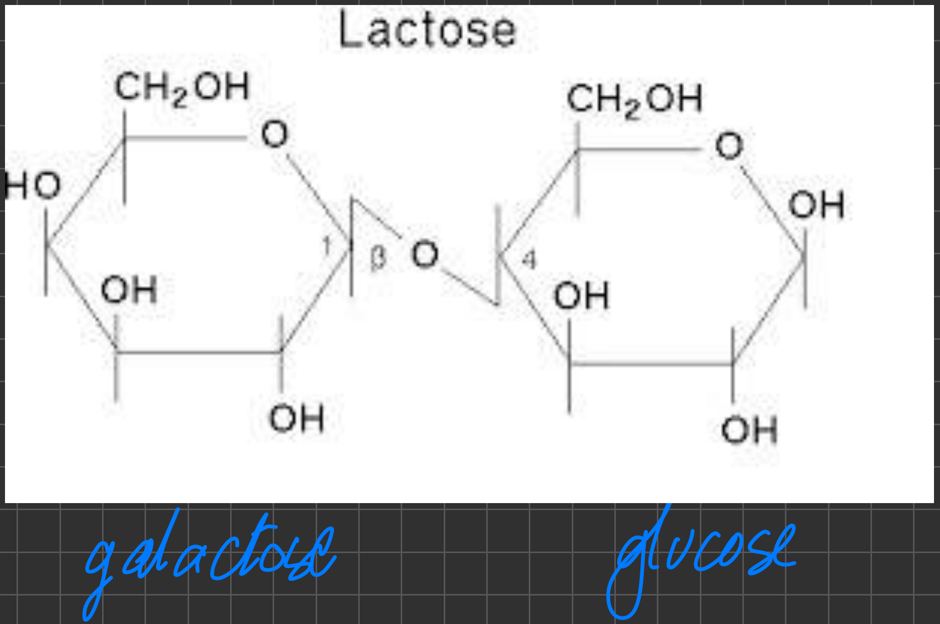
Figure 5.5



(a) Dehydration reaction in the synthesis of maltose



(b) Dehydration reaction in the synthesis of sucrose


Lactose
CH2OH
O
HO
OH
OH
1
β
O
4
CH2OH
O
OH
OH
OH
galactose
glucose

Polysaccharides : three monosaccharides and more

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

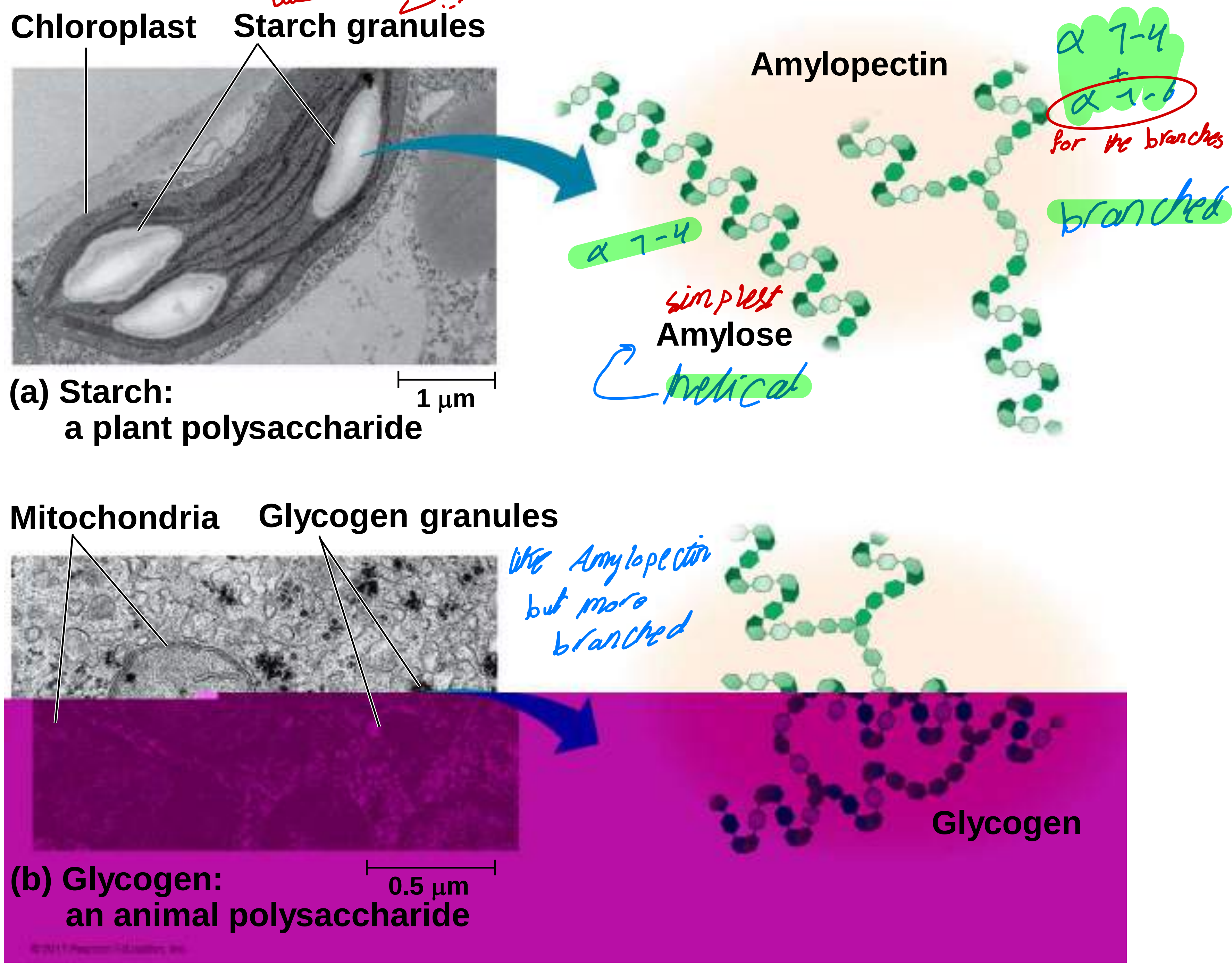
Polysaccharides by function

- structural
  - chitin
  - cellulose (plants' walls)
- storage
  - starch (plants)
    - Polymers of glucose
  - glycogen (animals)

Storage Polysaccharides

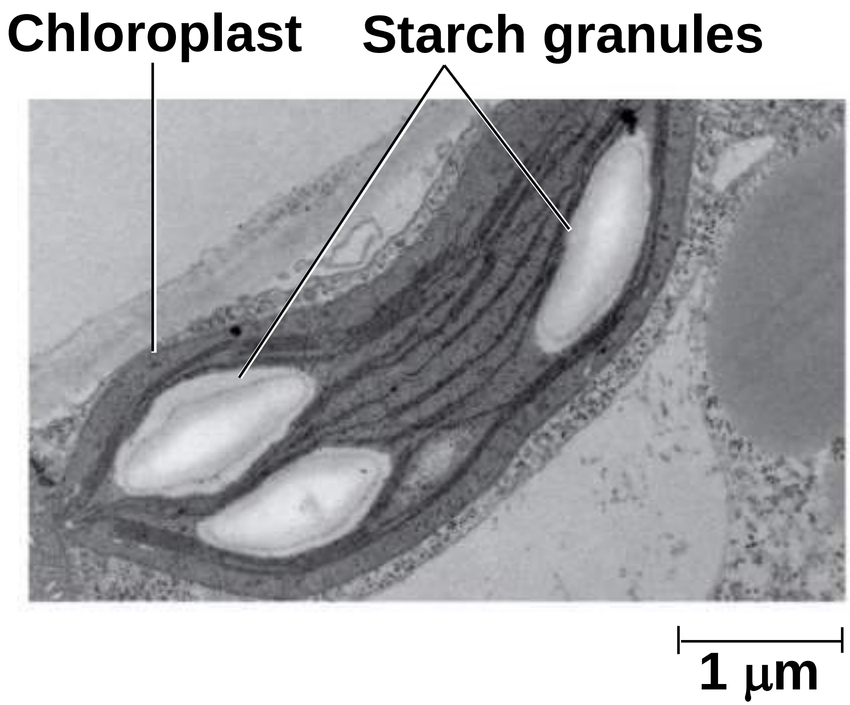
- **Starch**, a storage polysaccharide of plants, consists entirely of glucose monomers
- Plants store surplus starch as granules within chloroplasts and other plastids
- The simplest form of starch is amylose

Figure 5.6



Chloroplast
Starch granules
حبيبات النشا
Amylopectin
α 1-4 + α 1-6
for the branches
branched
α 1-4
simplest
Amylose
helical
1 μm
(a) Starch: a plant polysaccharide
Mitochondria
Glycogen granules
like Amylopectin but more branched
Glycogen
0.5 μm
(b) Glycogen: an animal polysaccharide

Figure 5.6a



also from glucose

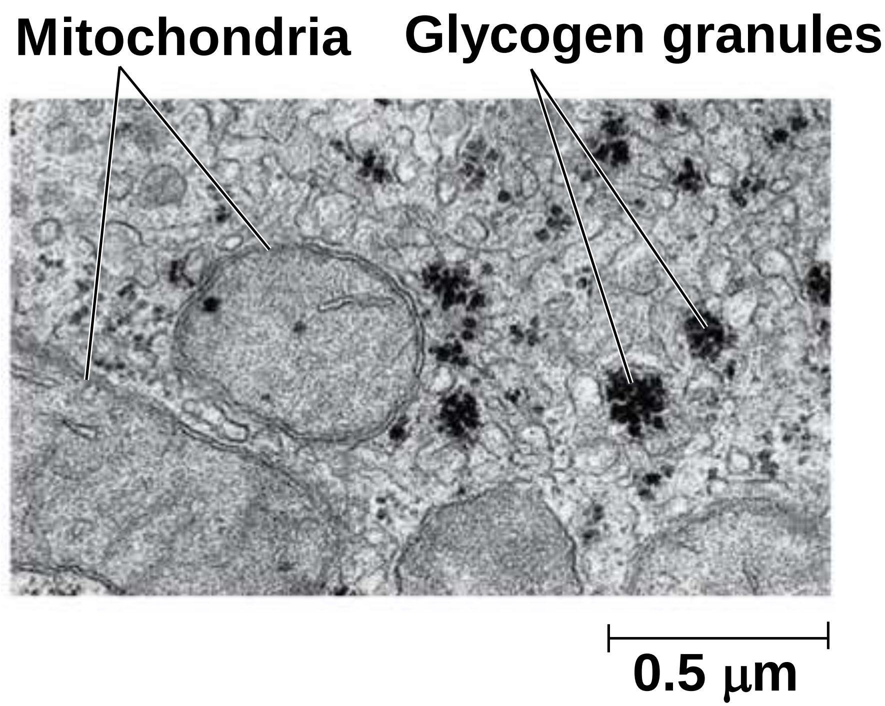
B

- **Glycogen** is a storage polysaccharide in animals
- Humans and other vertebrates store glycogen mainly in liver and muscle cells

stored for 24 H

if not used it turns to fat

Figure 5.6b



Structural Polysaccharides

- 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
- The difference is based on two ring forms for glucose: alpha (α) and beta (β)

Figure 5.7

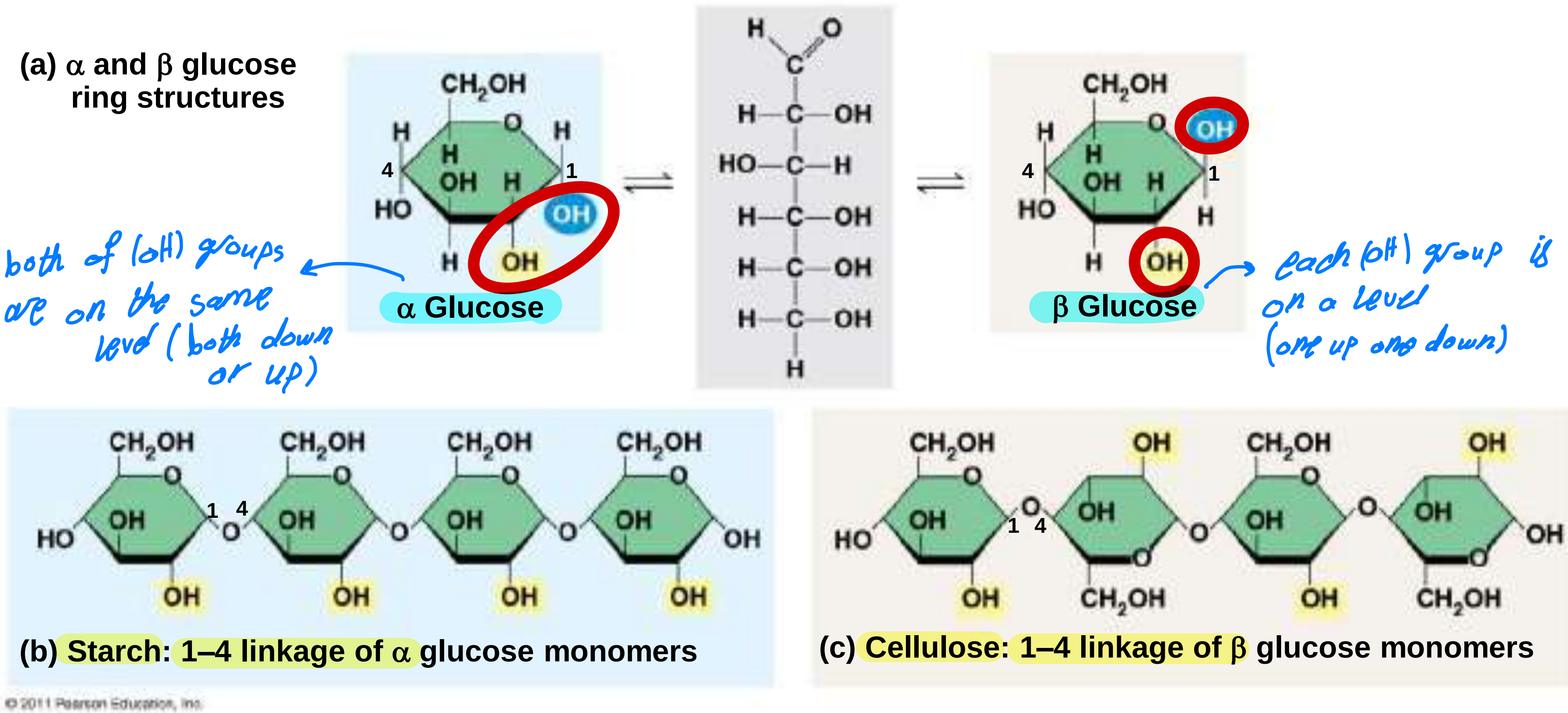
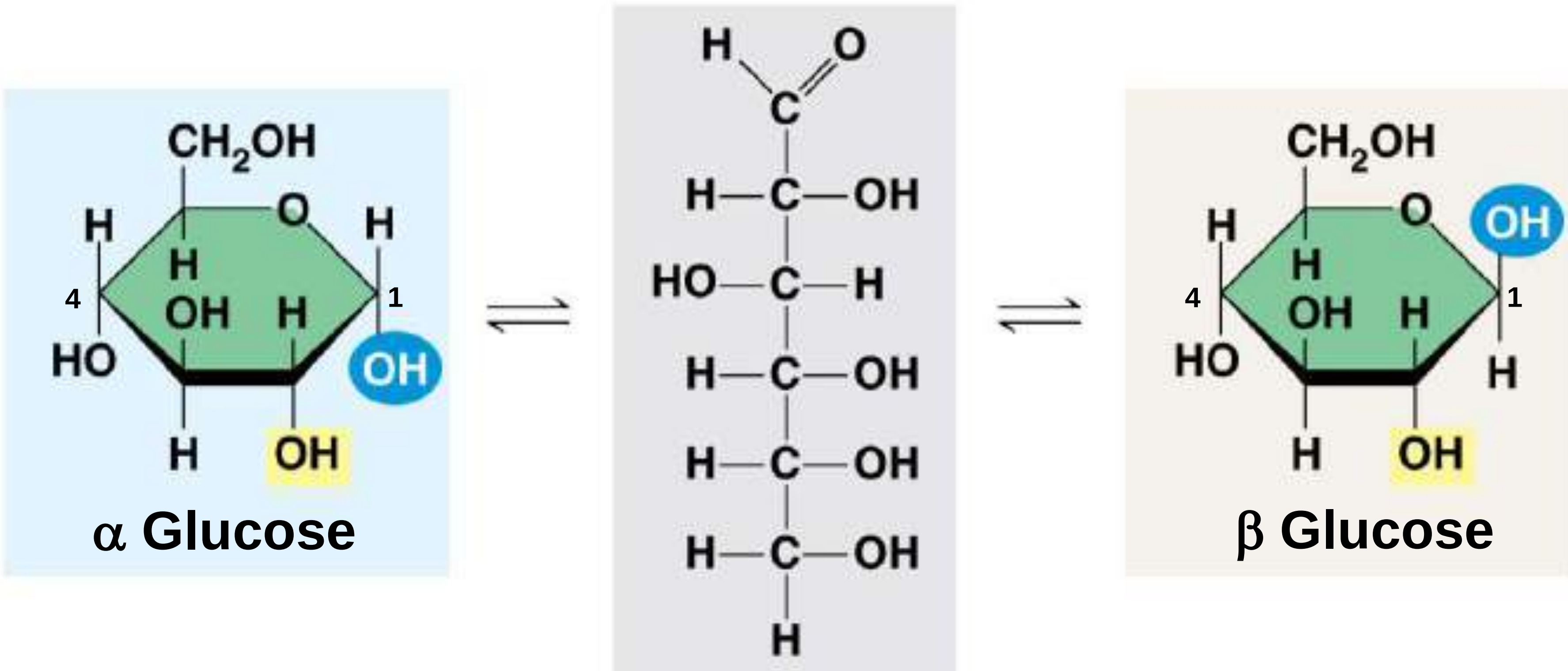
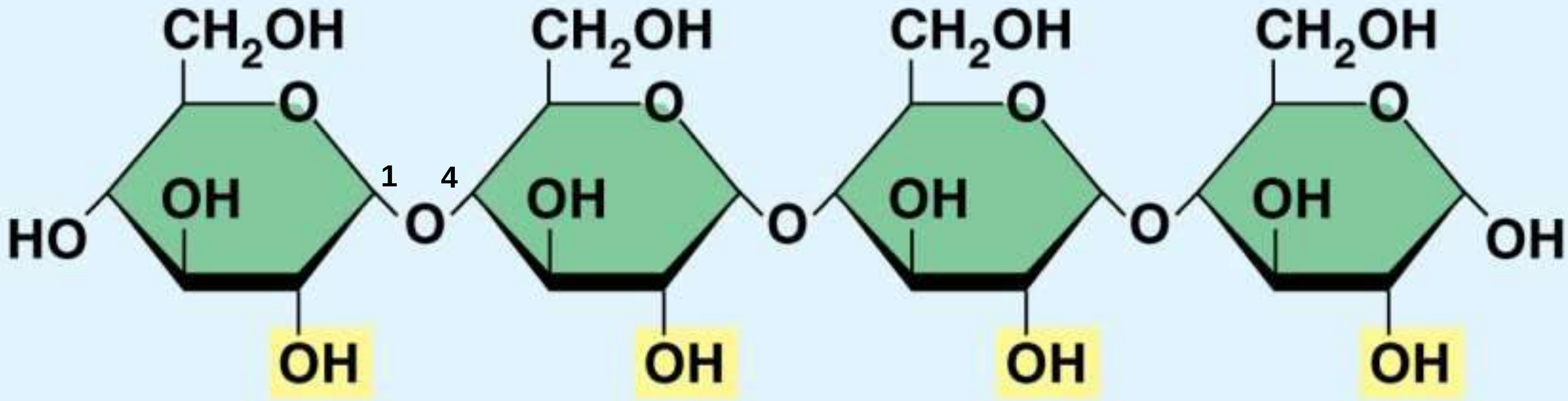

(a) α and β glucose ring structures
α Glucose
β Glucose
both of (OH) groups are on the same level (both down or up)
each (OH) group is on a level (one up one down)
(b) Starch: 1–4 linkage of α glucose monomers
(c) Cellulose: 1–4 linkage of β glucose monomers
© 2011 Pearson Education, Inc.

Figure 5.7a

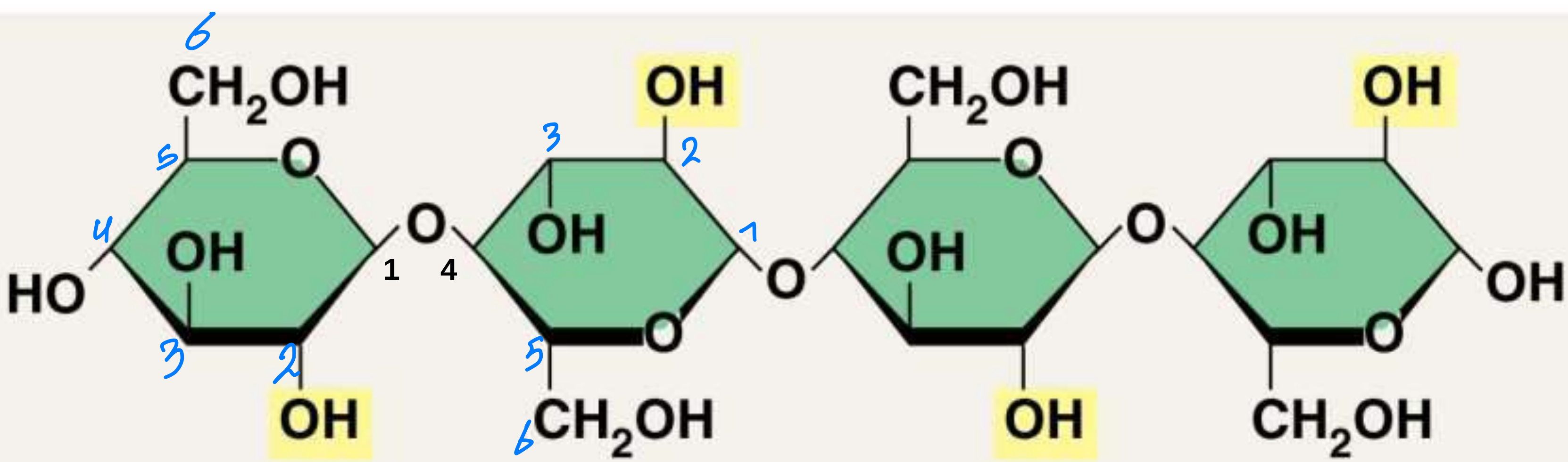


(a) α and β glucose ring structures

Figure 5.7b



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



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

- Polymers with α glucose are helical
- Polymers with β glucose are straight
- In straight structures, H atoms on one strand can bond with OH groups on other strands
- Parallel cellulose molecules held together this way are grouped into microfibrils, which form strong building materials for plants

Figure 5.8

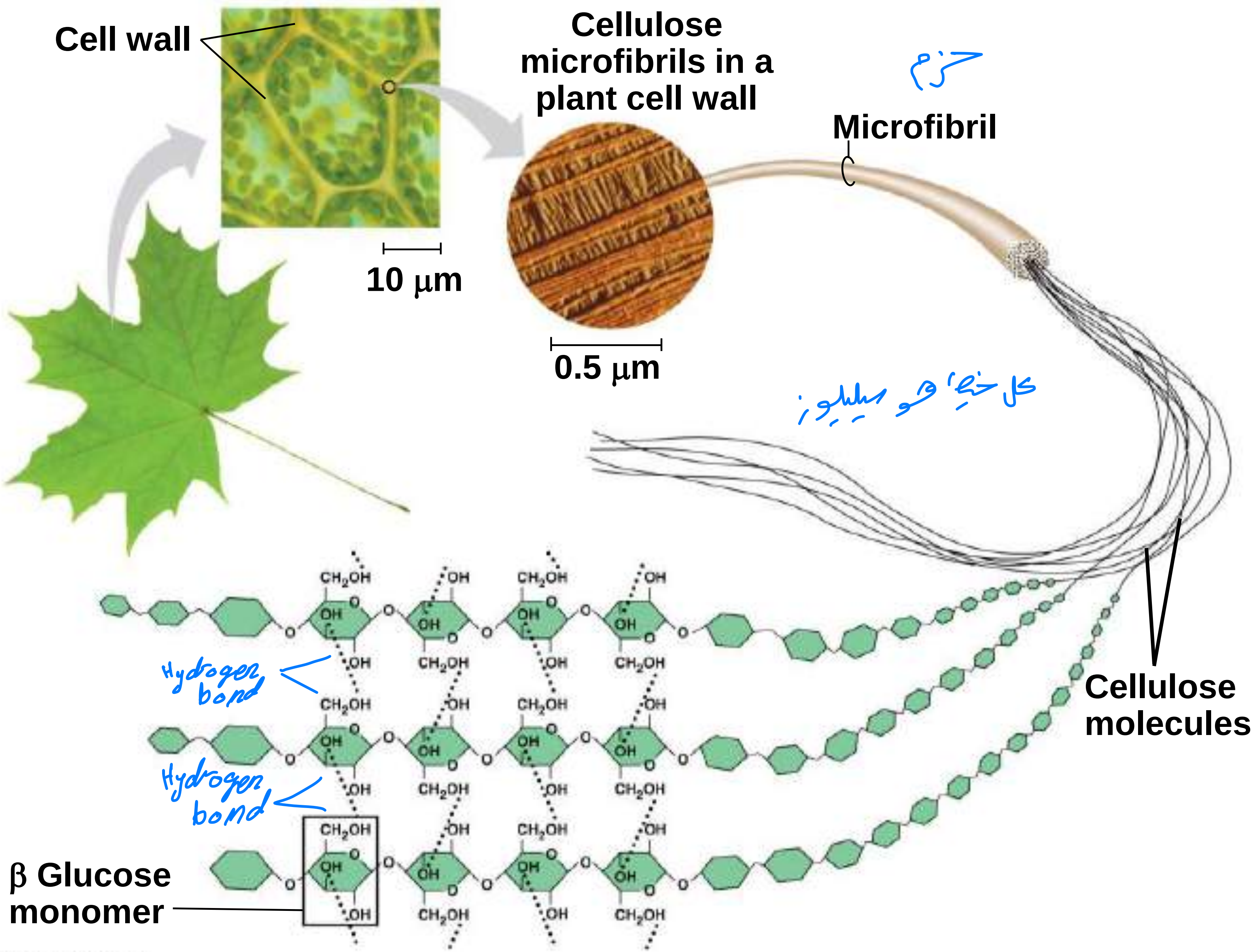

Cell wall
10 µm
Cellulose microfibrils in a plant cell wall
0.5 µm
Microfibril
حزم
كل خيط هو سيليلوز
Cellulose molecules
Hydrogen bond
Hydrogen bond
β Glucose monomer

Figure 5.8a

Figure 5.8b

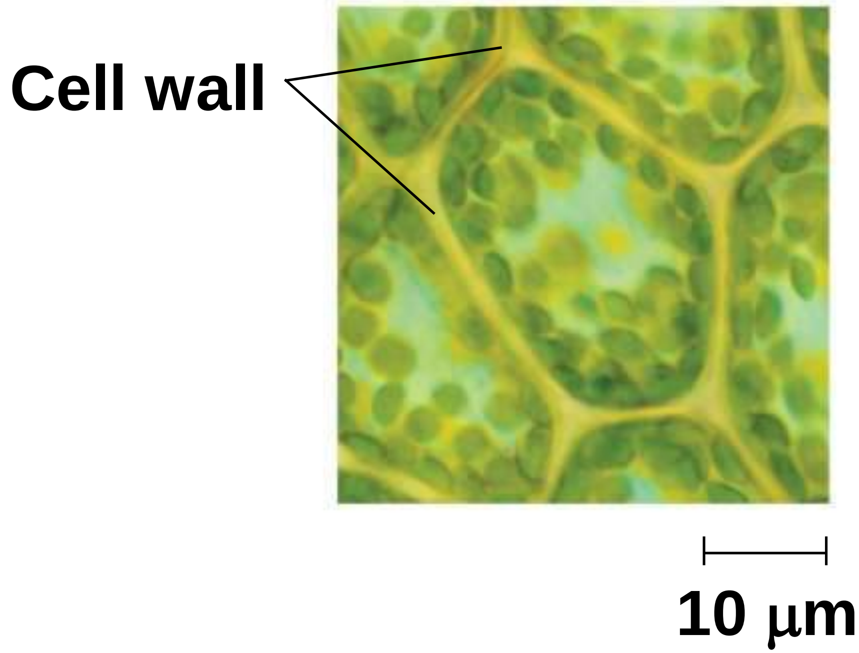


Figure 5.8c

Cellulose microfibrils in a plant cell wall

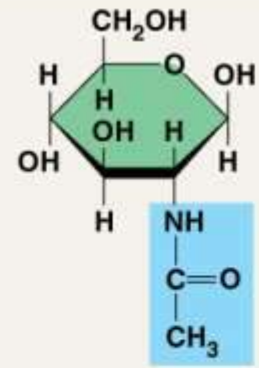
0.5 μm

- Enzymes that digest starch by hydrolyzing α linkages can't hydrolyze β linkages in cellulose
- 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

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

Figure 5.9

gets rid of it by molting



The structure of the chitin monomer

Chitin forms the exoskeleton of arthropods.

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

Figure 5.9a

▲ **Chitin forms the exoskeleton of arthropods.**

Figure 5.9b

▲ Chitin is used to make a strong and flexible surgical thread that decomposes after the wound or incision heals.

يتحلل

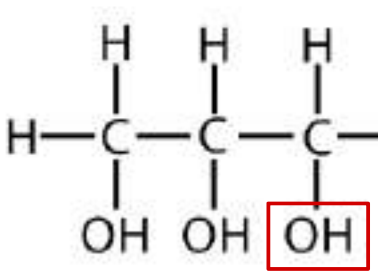
Concept 5.3: Lipids are a diverse group of hydrophobic molecules

- **Lipids** are the one class of large biological molecules that do not form polymers
- The unifying feature of lipids is having little or no affinity for water
- Lipids are hydrophobic because they consist mostly of hydrocarbons, which form nonpolar covalent bonds
- The most biologically important lipids are fats, phospholipids, and steroids

Fats

- **Fats** are constructed from two types of smaller molecules: glycerol and fatty acids
- 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

Glycerol:



Hydroxyl group

Fatty acid:

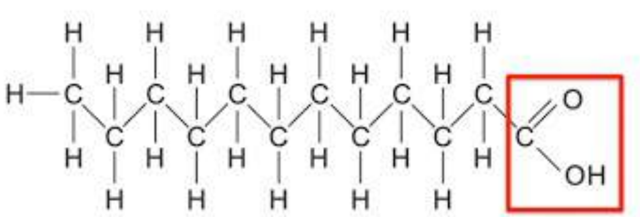
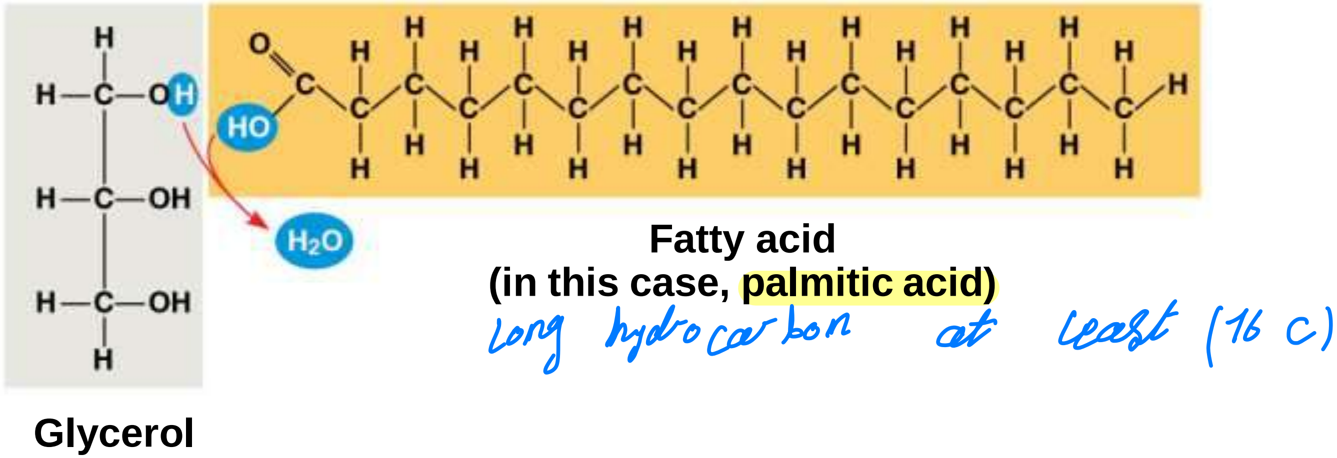
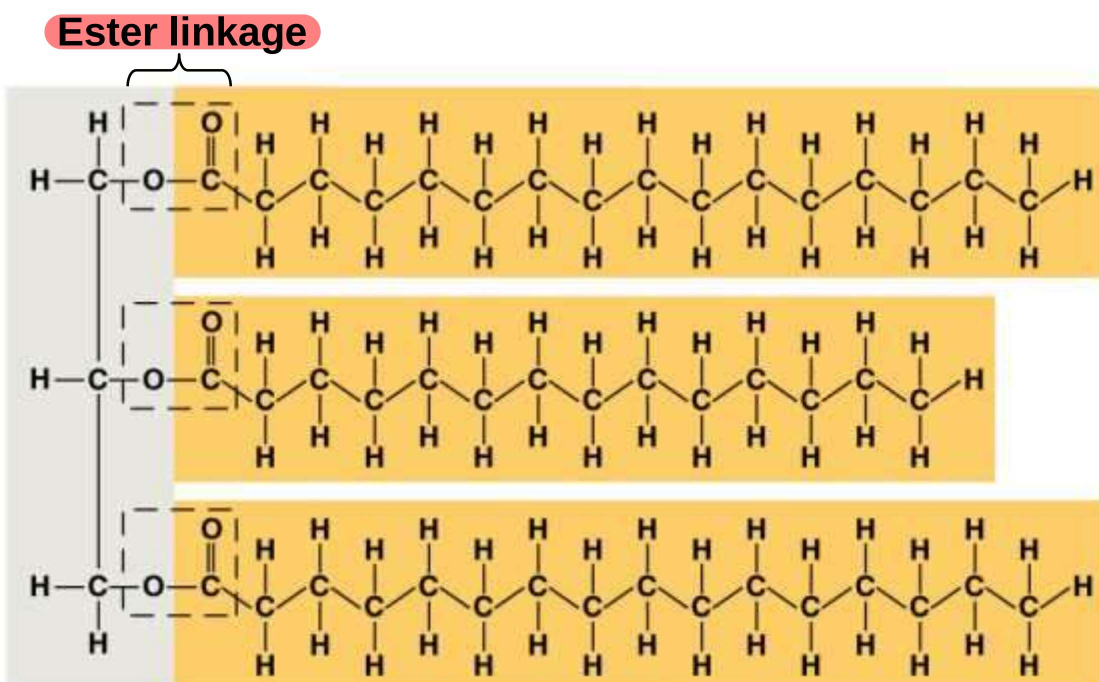


Figure 5.10

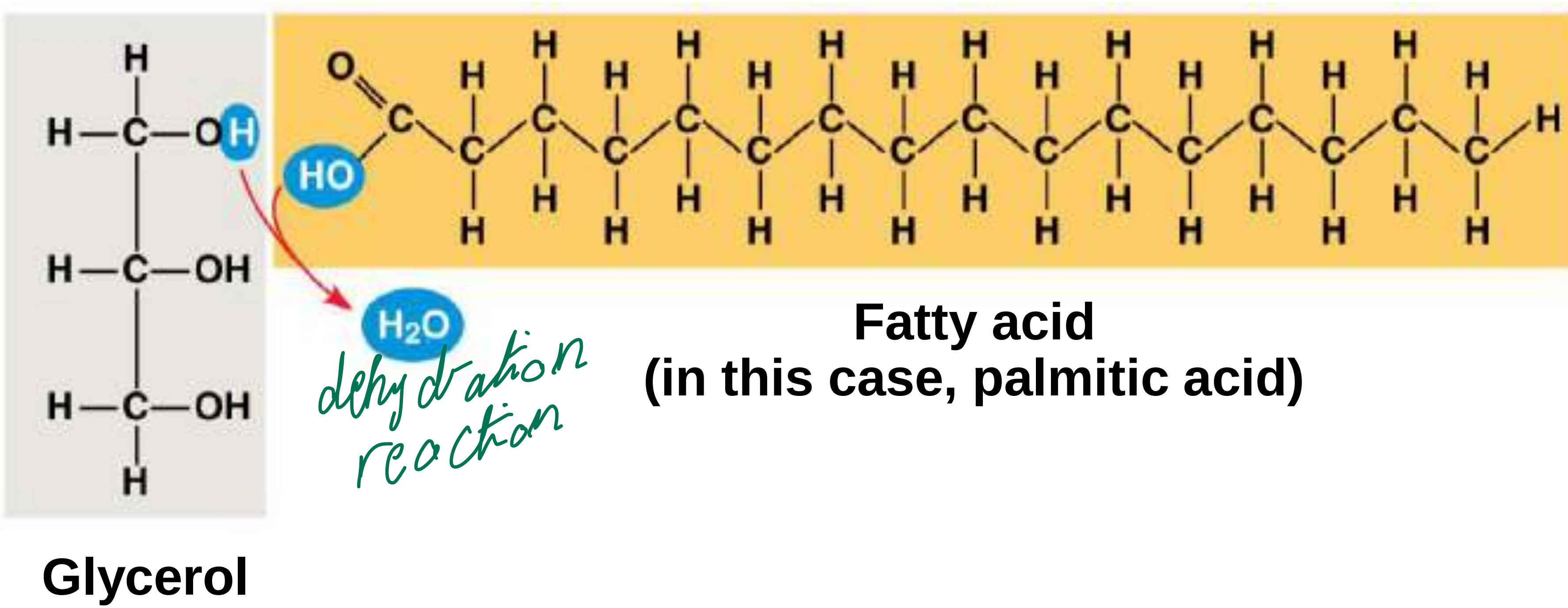


(a) One of three dehydration reactions in the synthesis of a fat



(b) Fat molecule (triacylglycerol)

Figure 5.10a



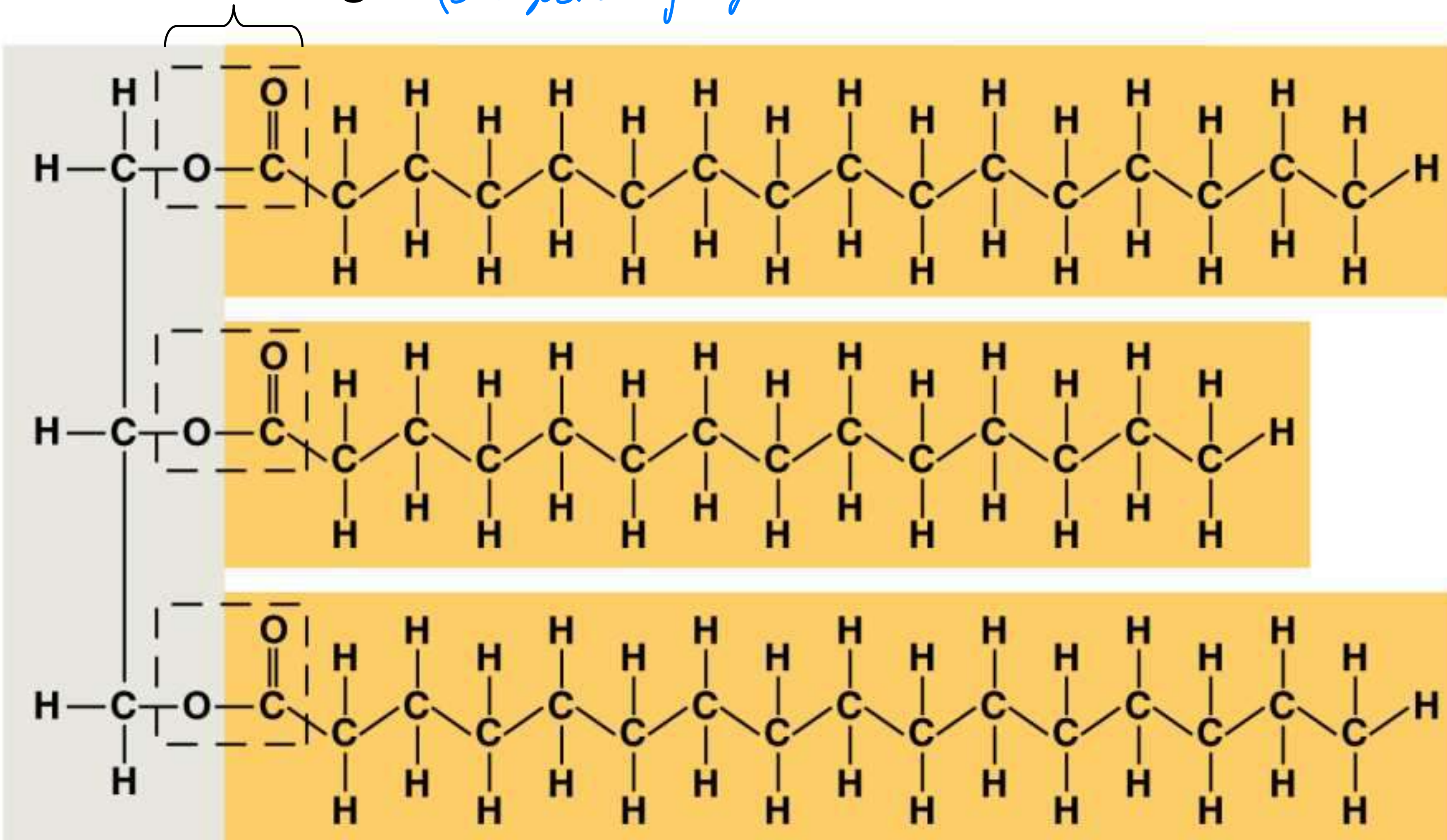
(a) One of three dehydration reactions in the synthesis of a fat

- Fats separate from water because water molecules form hydrogen bonds with 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

Figure 5.10b

(H) from glycerol
(OH) from fatty acid

Ester linkage



(b) Fat molecule (triacylglycerol)

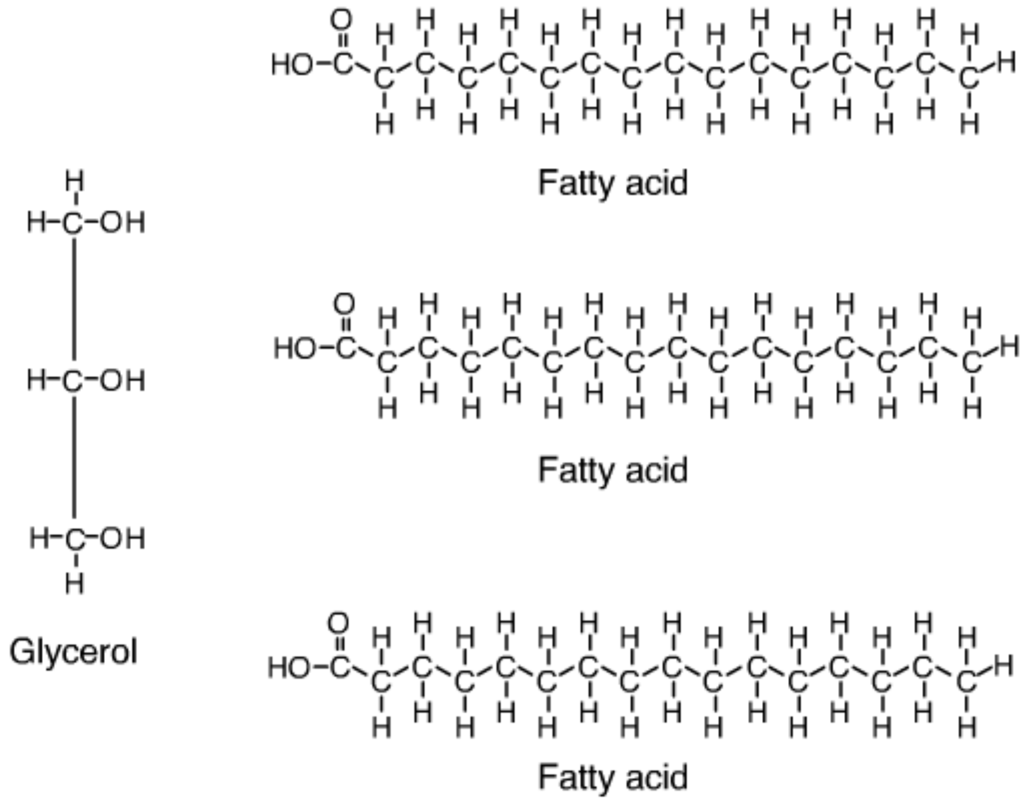
- Fatty acids vary in length (number of carbons) and in the number and locations of double bonds

حموض دهنية مشبعة

- **Saturated fatty acids** have the maximum number of hydrogen atoms possible and no double bonds

حموض دهنية غير مشبعة

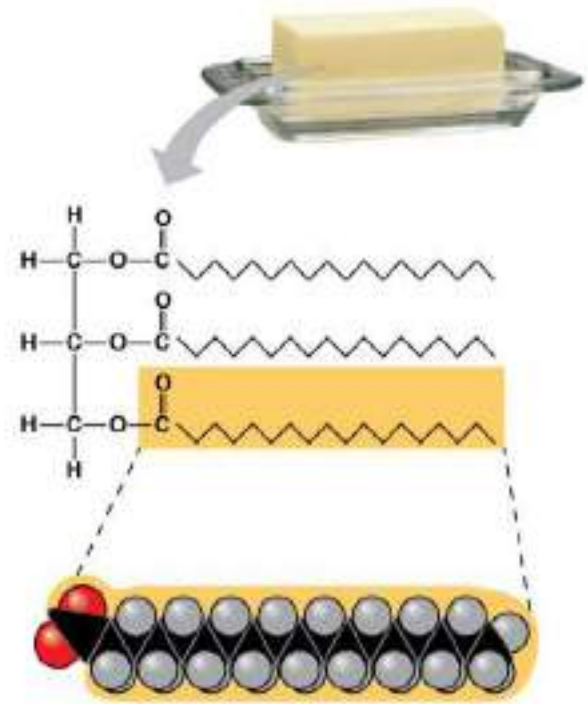
- **Unsaturated fatty acids** have one or more double bonds



Animation: Fats
Right-click slide / select "Play"

Figure 5.11

(a) Saturated fat

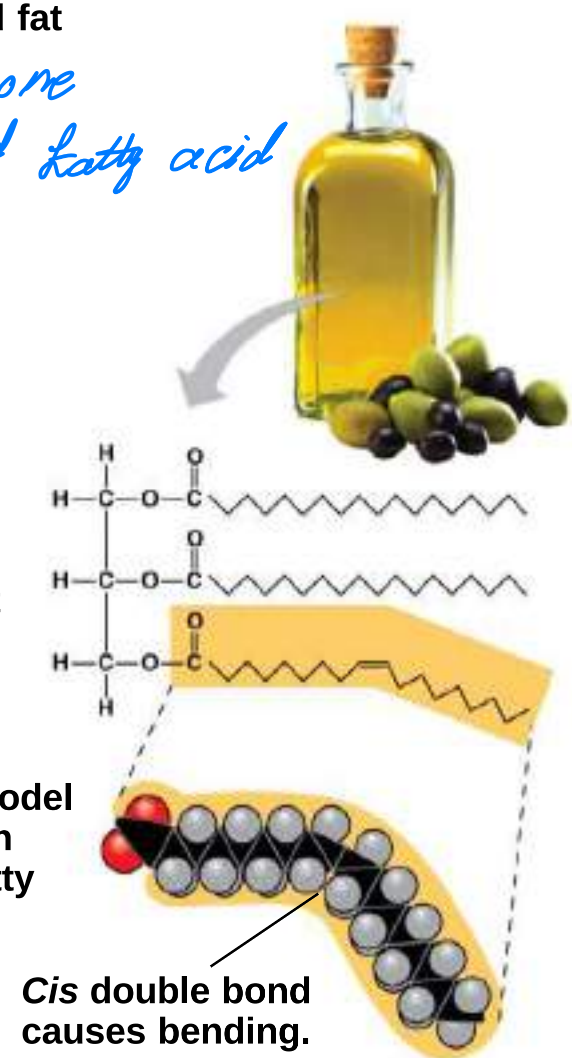


Structural formula of a saturated fat molecule

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

(b) Unsaturated fat

at least one unsaturated fatty acid

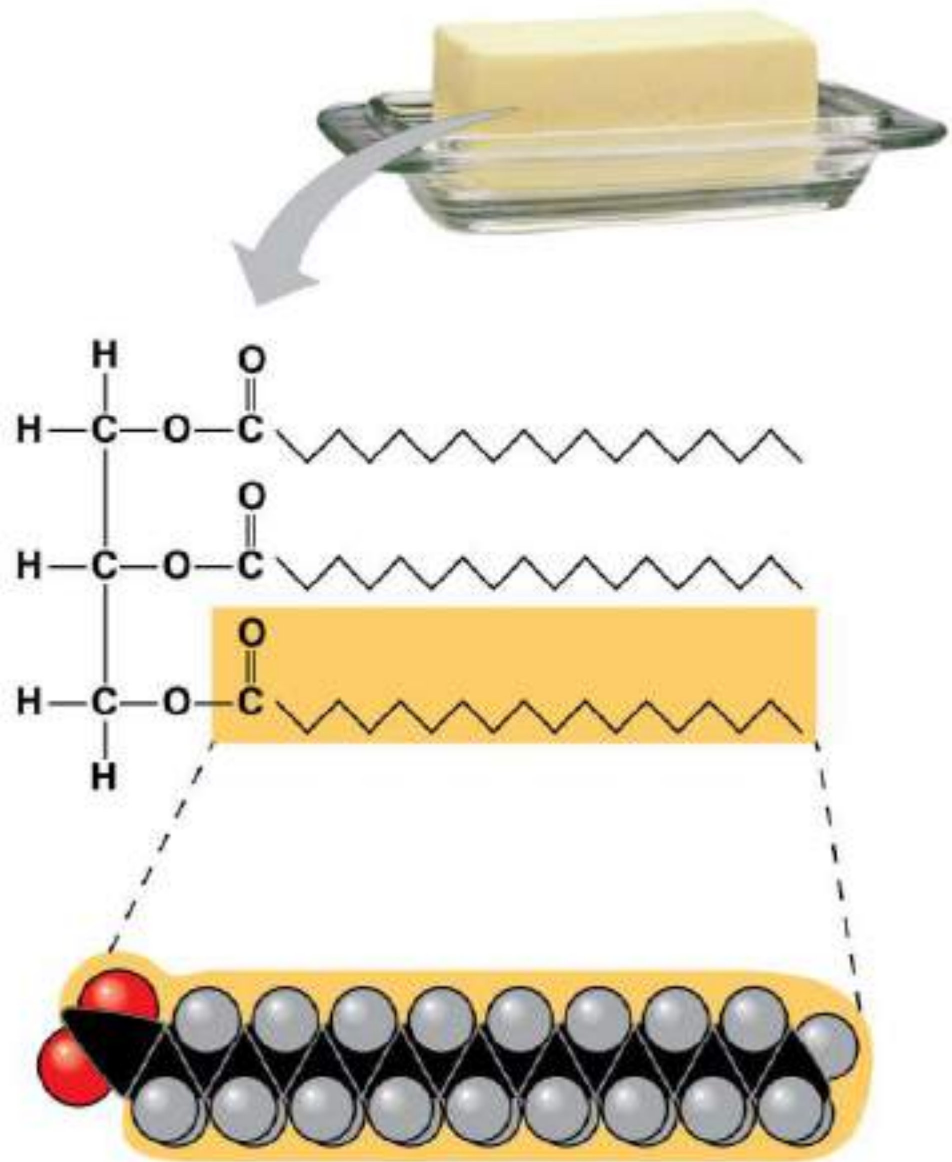


Structural formula of an unsaturated fat molecule

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

Figure 5.11a

(a) Saturated fat

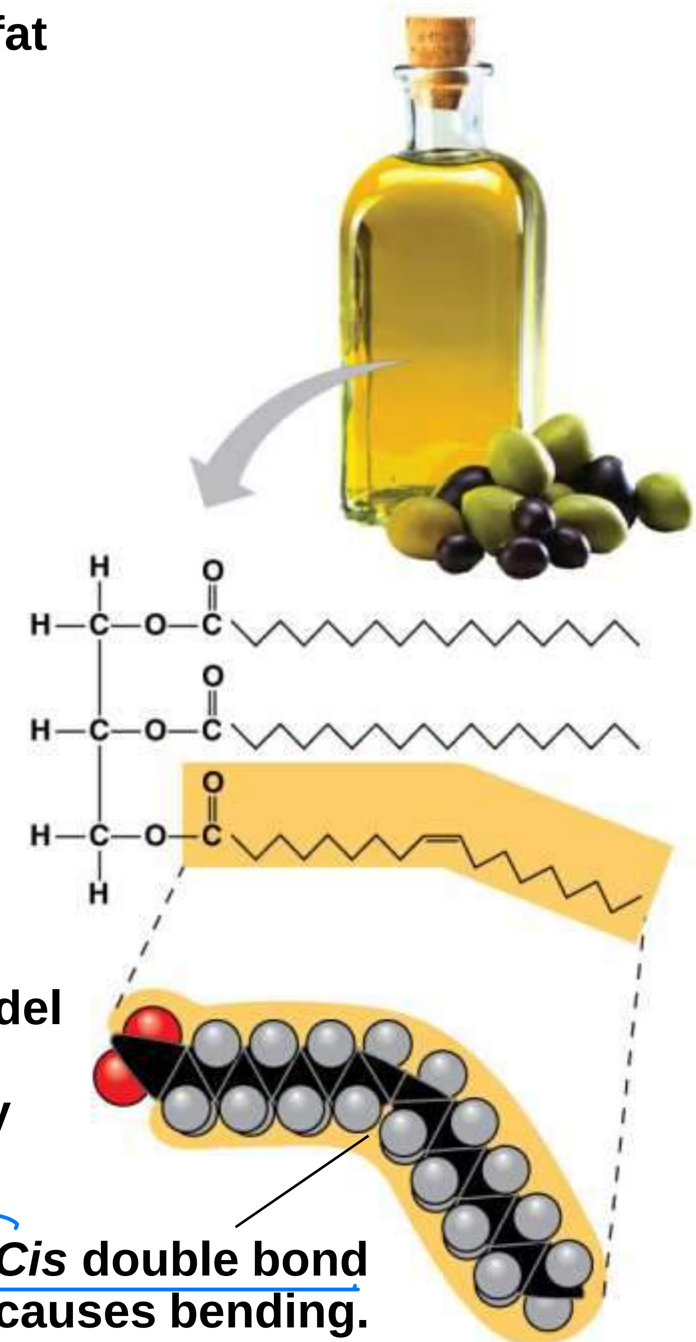


Structural formula of a saturated fat molecule

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

Figure 5.11b

(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.

naturally formed

- 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

- 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

Lipids

- Fats
- Phospholipids
- Steroids

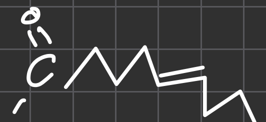
fatty acids + glycerol → Fats

glycerol → three carbon alcohol + 3 hydroxyl groups (-OH)

fatty acids:

- saturated (maximum hydrogen atoms, all single bonds)

- unsaturated (one or more double bonds)



Saturated / unsaturated fats → depends on the fatty acids kind

created by 3 dehydration reactions

- Saturated fats → solid in room temprature like animal fats
- Unsaturated fats → Liquid in room temprature like plants oils and fish oils

saturated fats ← hydrogenation ← unsaturated fats (called trans fats)

hydrogenation → to convert unsaturated fats to saturated fats by adding hydrogen

too much saturated fats --contributes--> cardiovascular diseas

trans fats --contributes more--> cardiovascular diseas

- Certain unsaturated fatty acids are not synthesized in the human body
- These must be supplied in the diet
- These essential fatty acids include the omega-3 fatty acids, required for normal growth, and thought to provide protection against cardiovascular disease

- The major function of fats is energy storage
- Humans and other mammals (ثدييات) store their fat in adipose cells (خلايا دهنية)
- Adipose tissue also cushions vital organs and insulates the body

الأنسجة الدهنية تحمي الأعضاء الحيوية و تعزل الجسم

Phospholipids

- 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

phosphate group

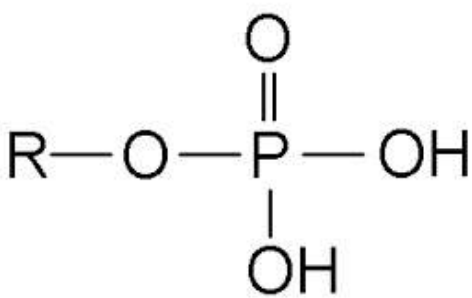
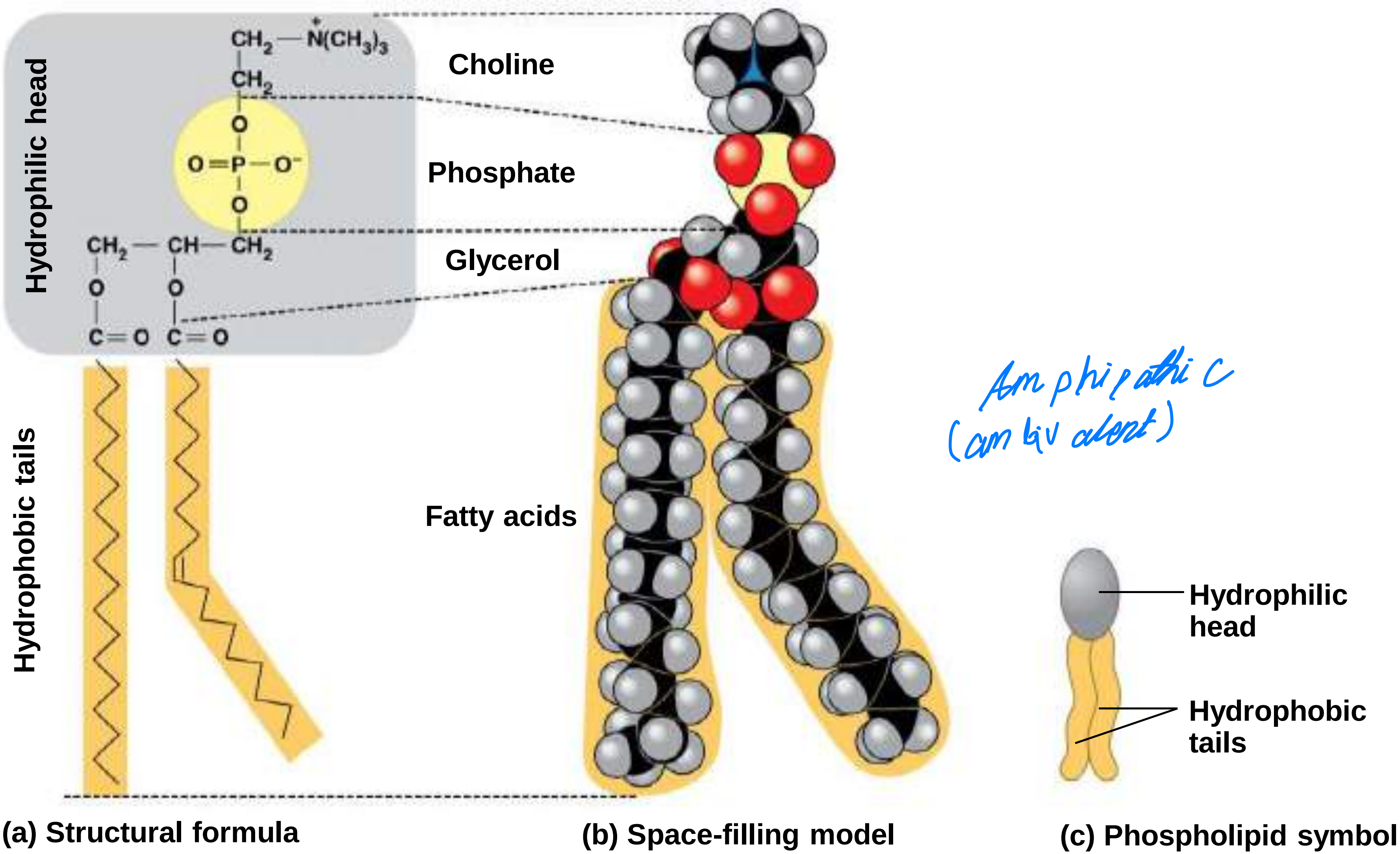
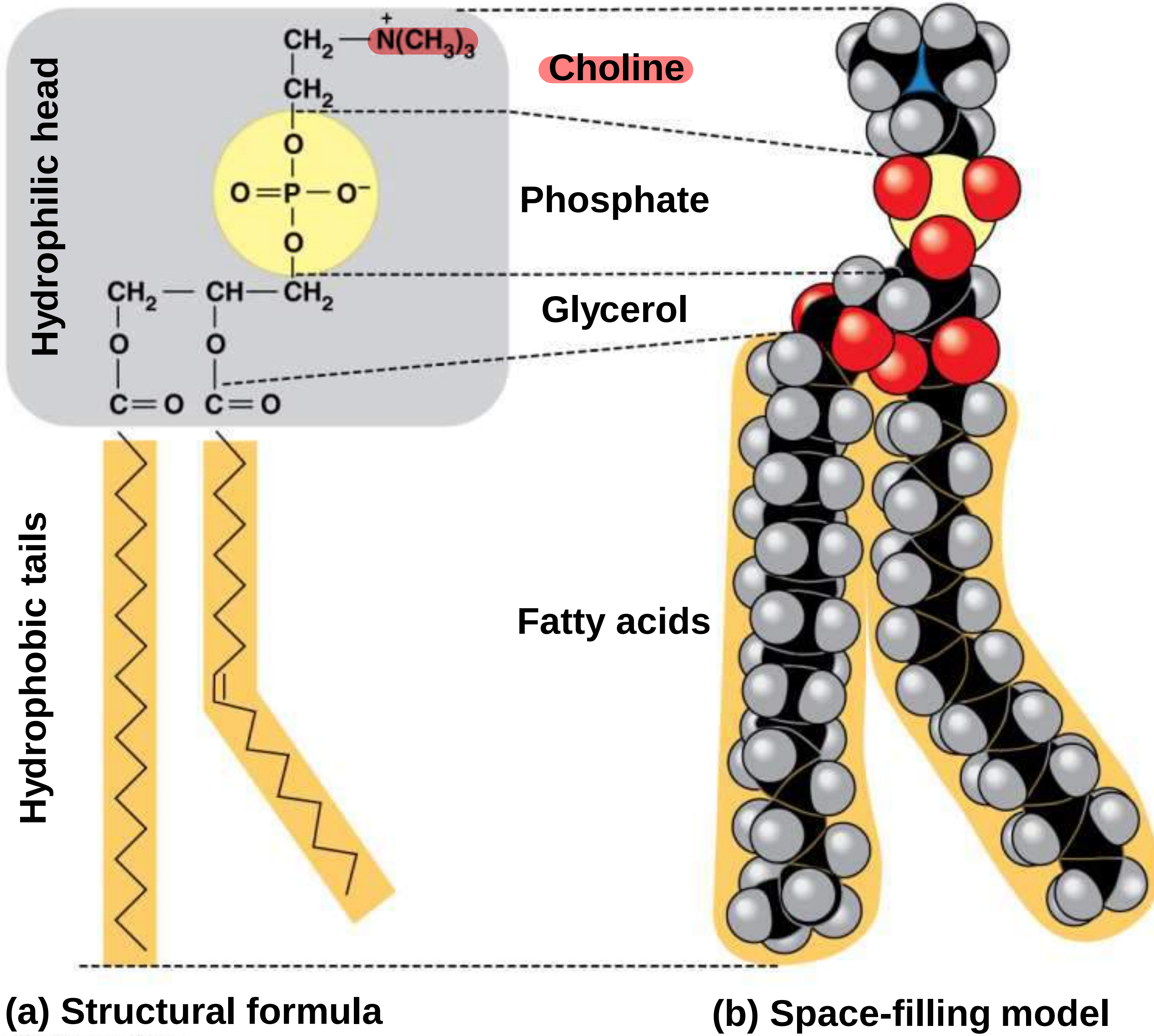


Figure 5.12



Amphipathic
(ambivalent)

Figure 5.12a

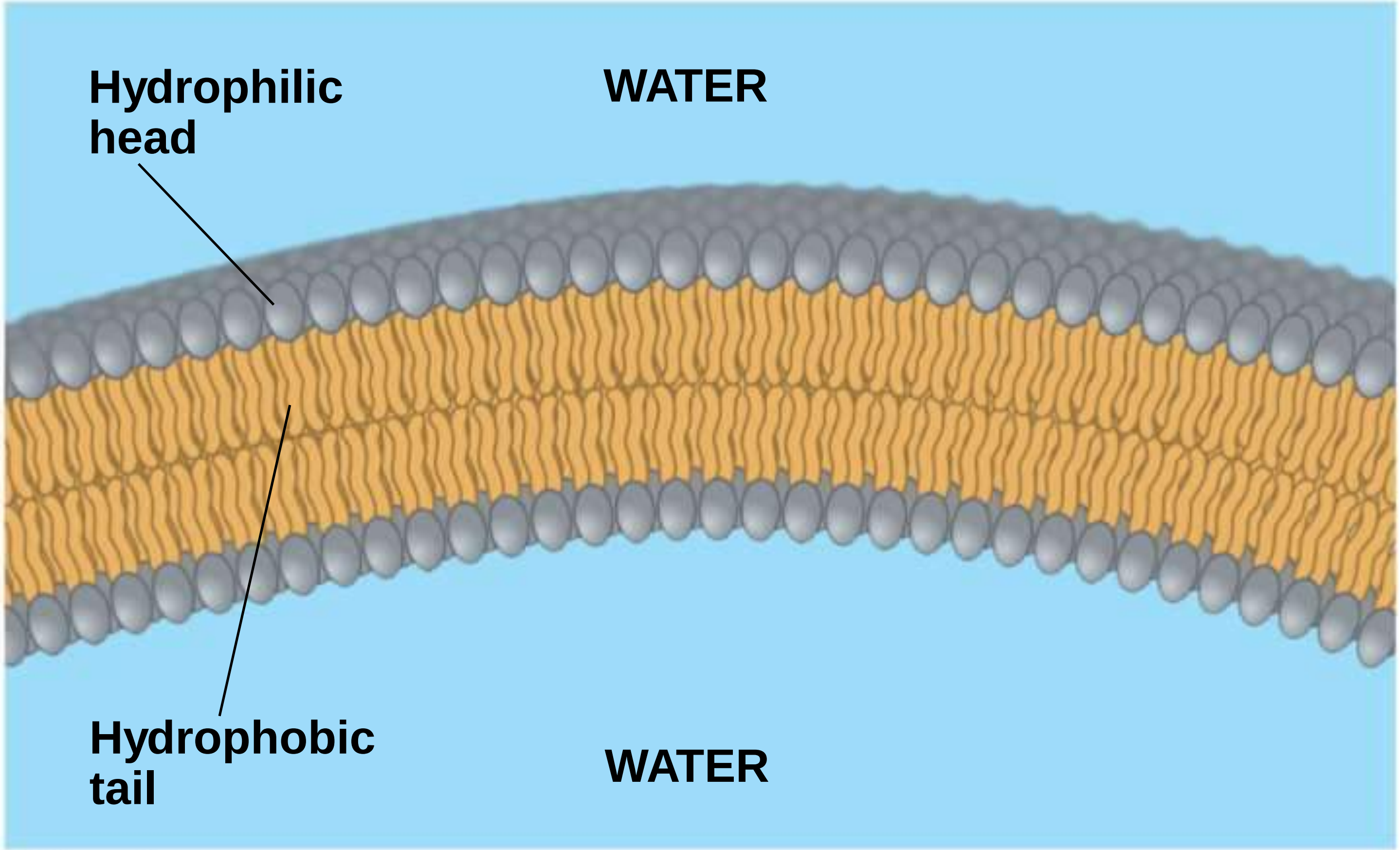


Hydrophilic head
Hydrophobic tails
CH2 — N(CH3)3 +
CH2
O
O=P—O−
O
CH2 — CH — CH2
O
O
C=O C=O
Choline
Phosphate
Glycerol
Fatty acids
(a) Structural formula
(b) Space-filling model

طبقة ثنائية

- When phospholipids are added to water, they self-assemble into a bilayer, with the hydrophobic tails pointing toward the interior
- The structure of phospholipids results in a bilayer arrangement found in cell membranes أغشية
- Phospholipids are the major component of all cell membranes

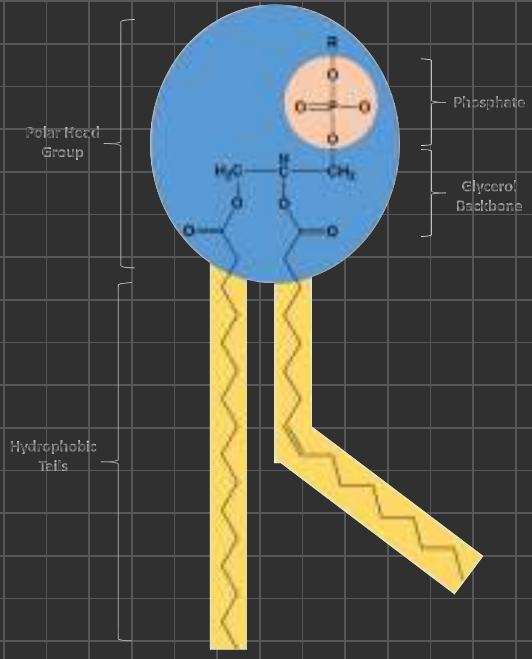
Figure 5.13



Phospholipids

1 glycerol + 1 phosphate group + 2 fatty acids

Hydrophilic head — Hydrophobic tails



The phospholipids are amphipathic (ambivalent)

when phospholipids are in water they self-assemble into a bilayer :

The hydrophobic tails face toward the interior

The hydrophilic heads face the water side

phospholipids are the major component of cell membranes

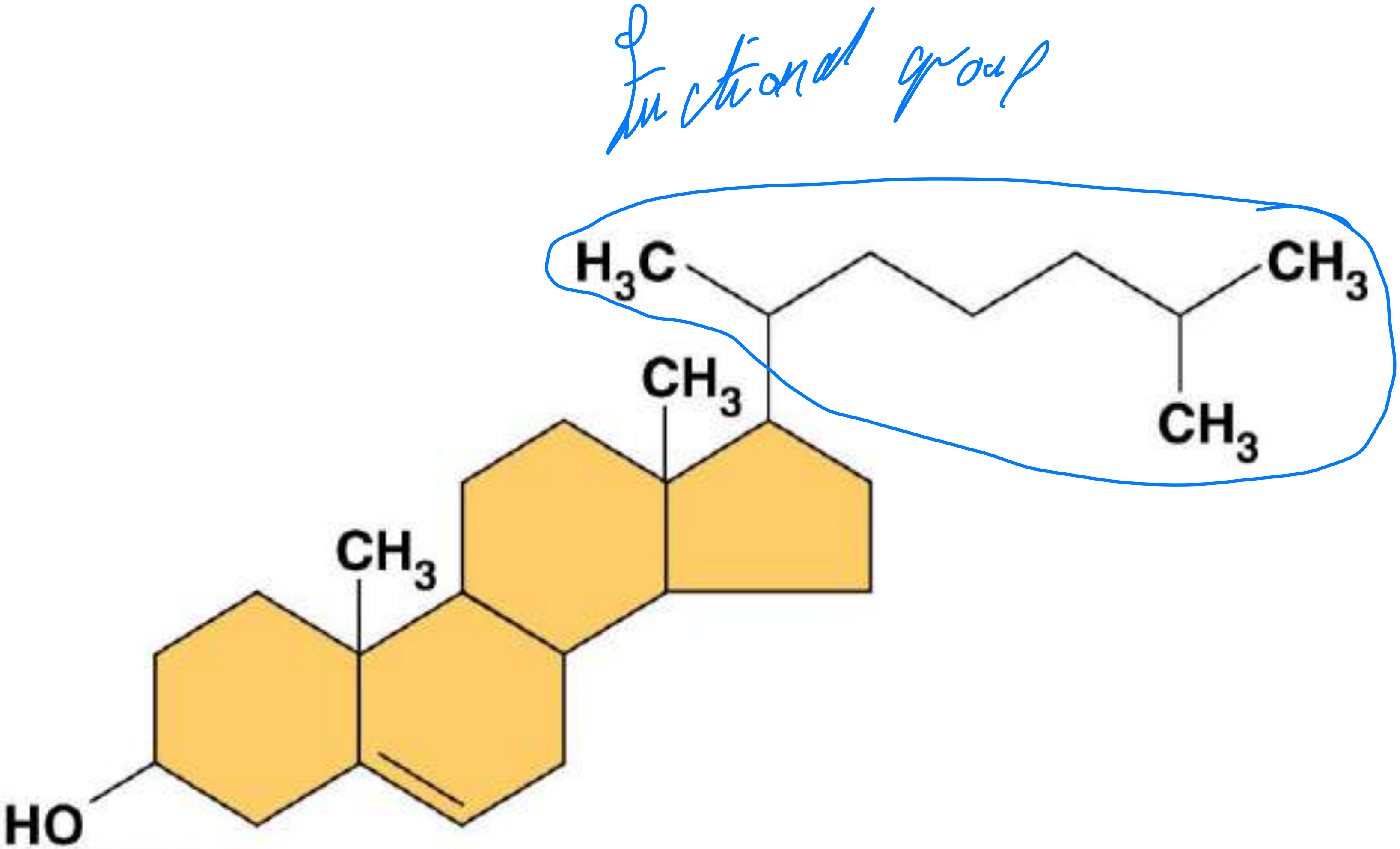
Steroids

- **Steroids** are lipids characterized by a carbon skeleton consisting of four fused rings
- **Cholesterol**, an important steroid, is a component in animal cell membranes
- Although cholesterol is essential in animals, high levels in the blood may contribute to cardiovascular disease

3 hex rings
1 penta ring

the steroids change depending on the functional group connected with the 4th carbon ring

Figure 5.14



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

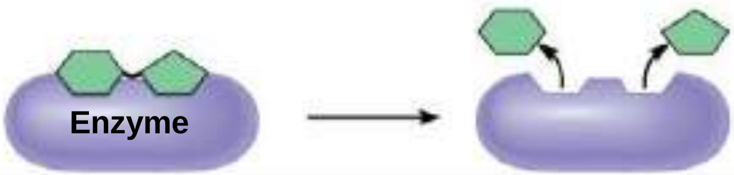
- Proteins account for more than 50% of the dry mass of most cells
- Protein functions include structural support, storage, transport, cellular communications, movement, and defense against foreign substances

Figure 5.15-a

Enzymatic proteins

Function: Selective acceleration of chemical reactions

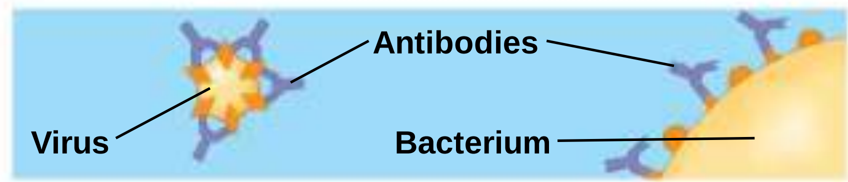
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.



Defensive proteins

Function: Protection against disease

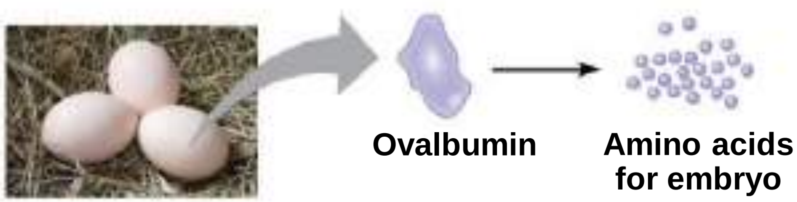
Example: Antibodies inactivate and help destroy viruses and bacteria.



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 cell membranes.

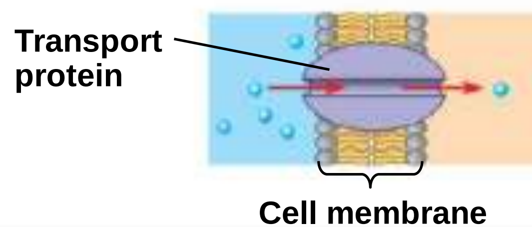


Figure 5.15-b

Hormonal proteins

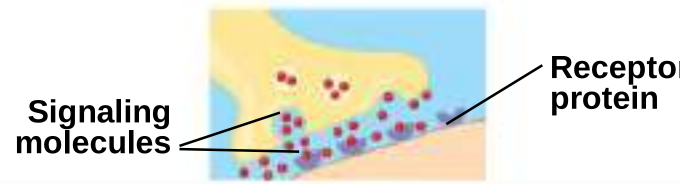
Function: Coordination of an organism's activities

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

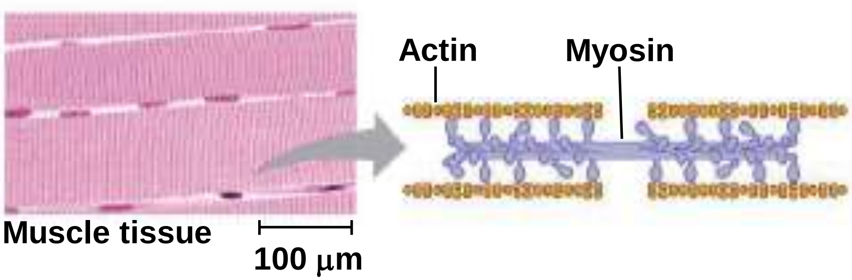
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



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.



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.

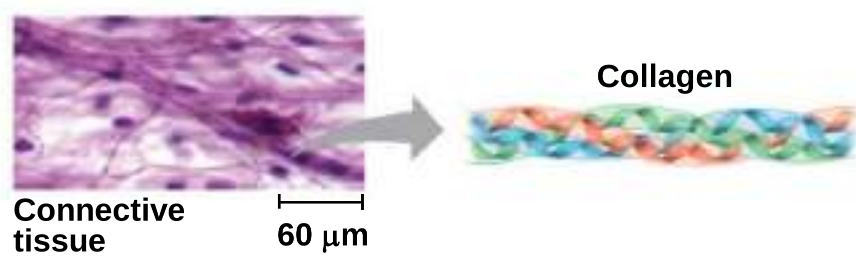


Figure 5.15a

Enzymatic proteins

Function: Selective acceleration of chemical reactions

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

Figure 5.15b

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.

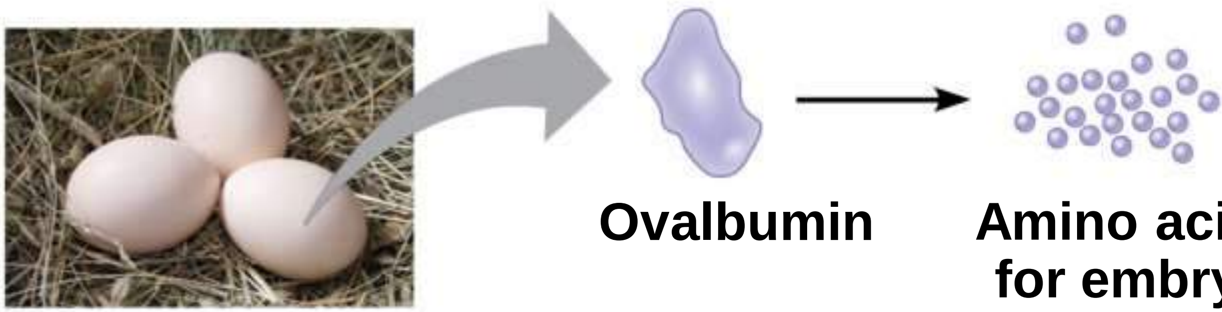


Figure 5.15c

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 5.15d

الانقباض

Contractile and motor proteins

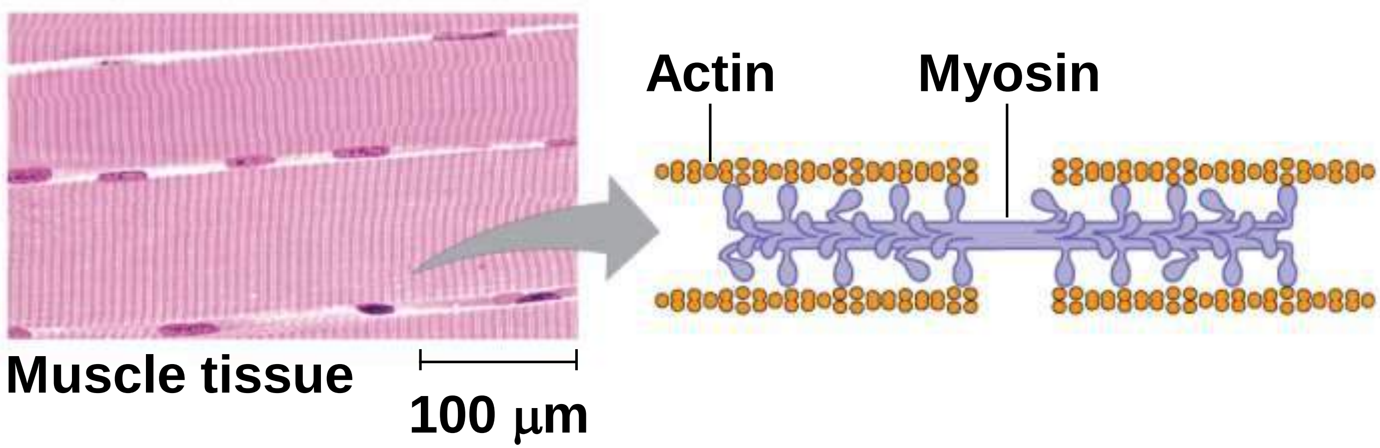
Function: Movement

الاهداب الاسواط

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

تموجات

انقباض



Muscle tissue

Figure 5.15e

Defensive proteins

Function: Protection against disease

Example: Antibodies inactivate and help destroy viruses and bacteria.

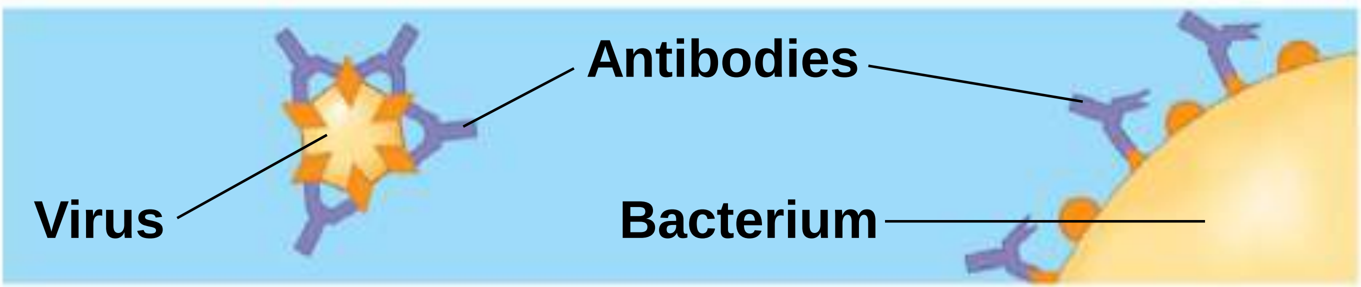


Figure 5.15f

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 cell membranes.

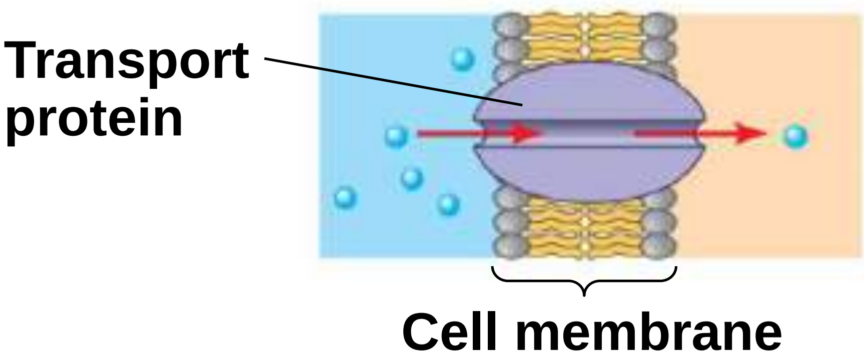
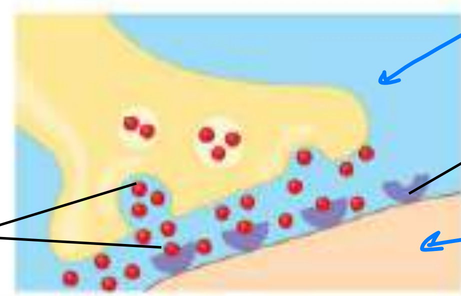


Figure 5.15g

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.**



Signaling molecules

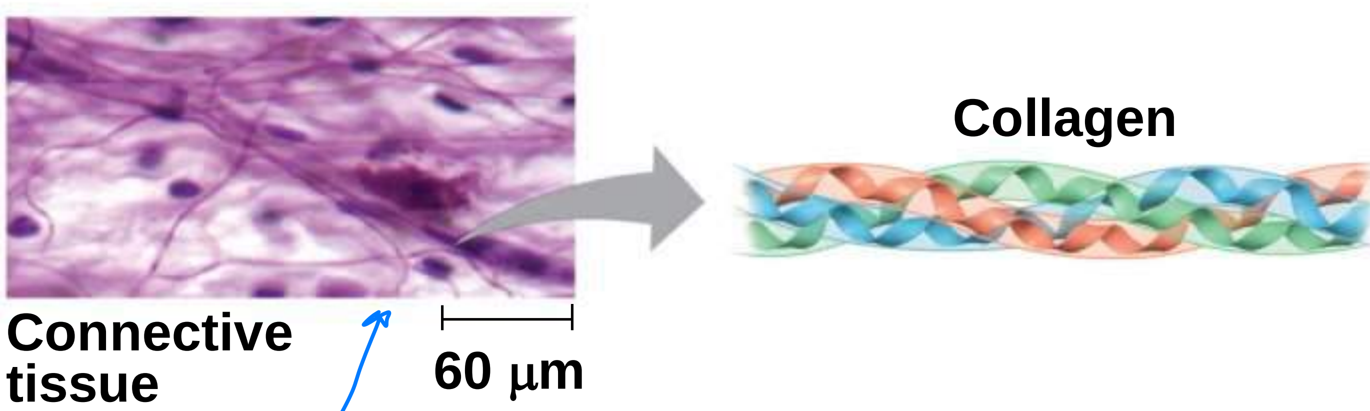
Receptor protein

Figure 5.15h

Structural proteins

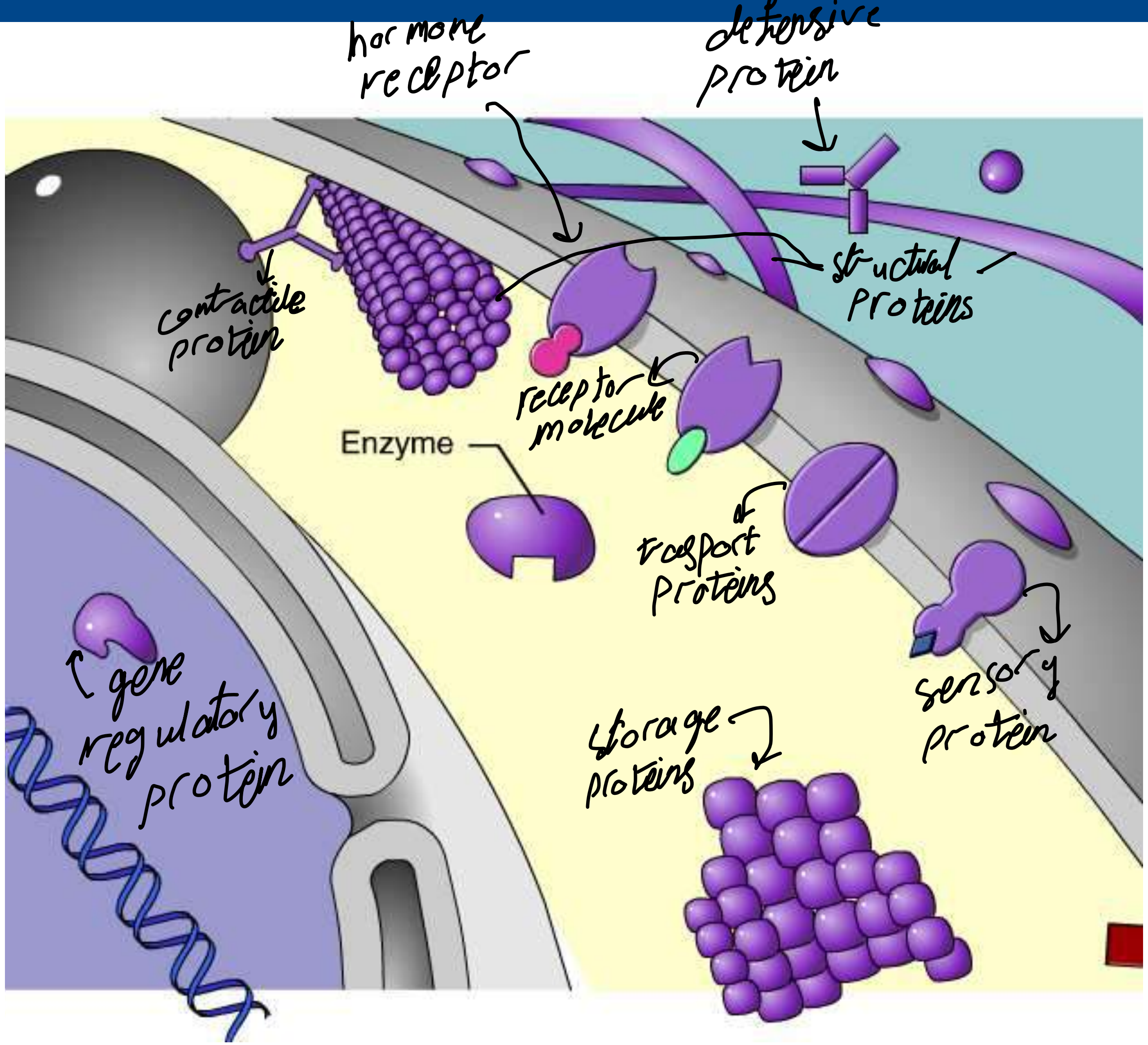
Function: Support

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.



the thin one is elastin

- **Enzymes** are a type of protein that acts as a **catalyst** to speed up chemical reactions
- Enzymes can perform their functions repeatedly, functioning as workhorses that carry out the processes of life



Animation: Enzymes

Right-click slide / select “Play”

Polypeptides

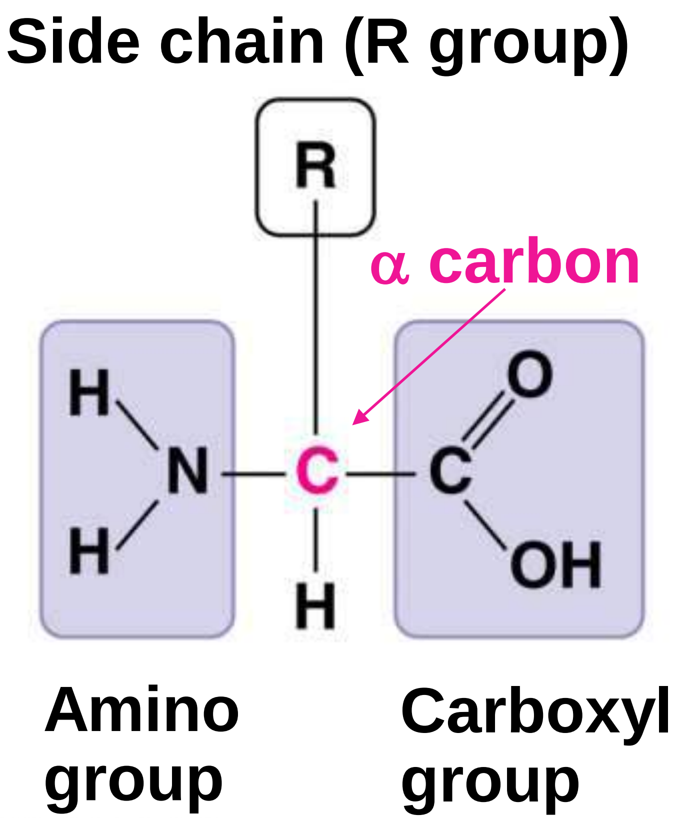
- **Polypeptides** are unbranched polymers built from the same set of 20 amino acids
- A **protein** is a biologically functional molecule that consists of one or more polypeptides

polypeptides on themselfs don't have any function

Amino Acid Monomers

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

Figure 5.UN01

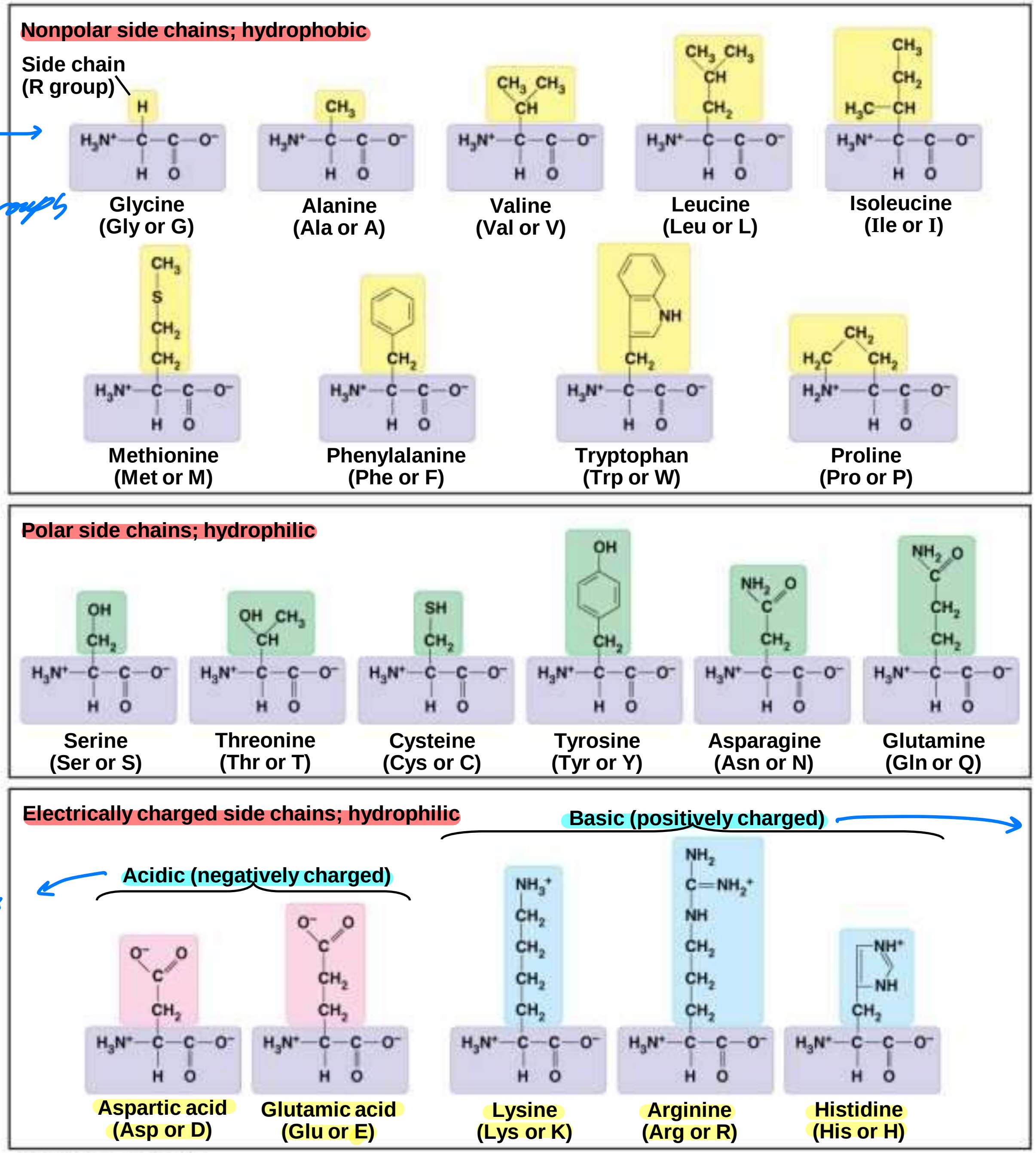


the human body can't build all amino acids

20 a.a

- 11 a.a — can build
- 9 a.a — can't build (essential a.a)

Figure 5.16



the only a.a with 2 similar groups

extra COO^-

extra NH

Figure 5.16a

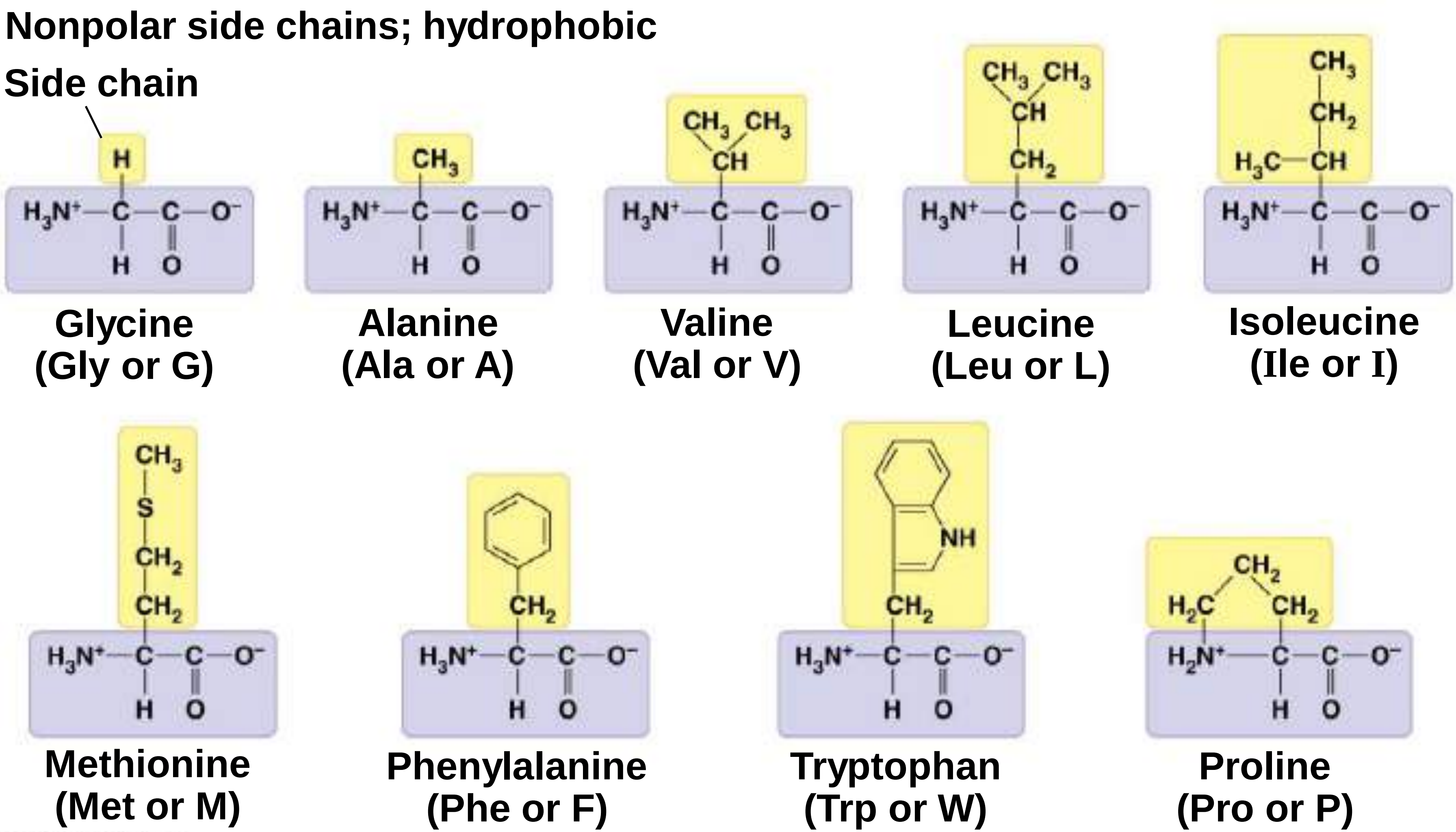
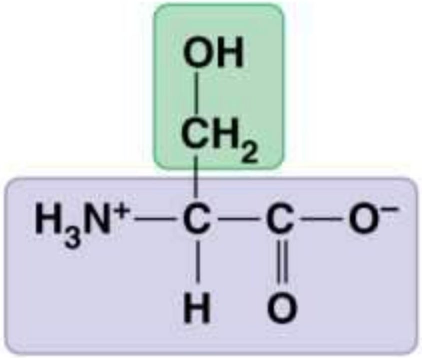
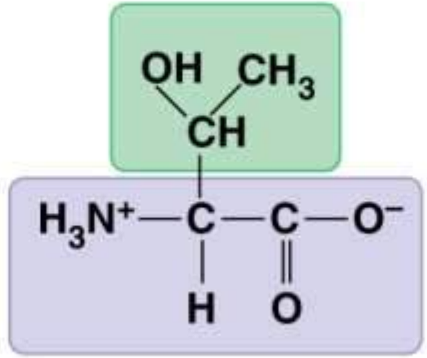

Nonpolar side chains; hydrophobic
Side chain
Glycine
(Gly or G)
Alanine
(Ala or A)
Valine
(Val or V)
Leucine
(Leu or L)
Isoleucine
(Ile or I)
Methionine
(Met or M)
Phenylalanine
(Phe or F)
Tryptophan
(Trp or W)
Proline
(Pro or P)

Figure 5.16b

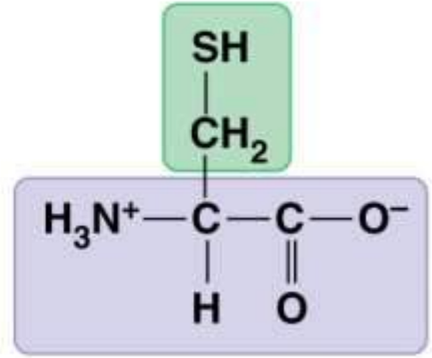
Polar side chains; hydrophilic



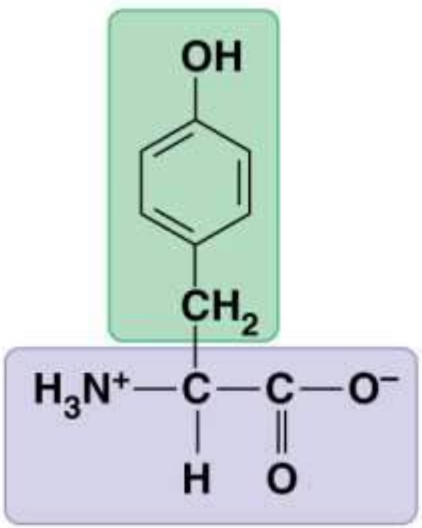
Serine
(Ser or S)



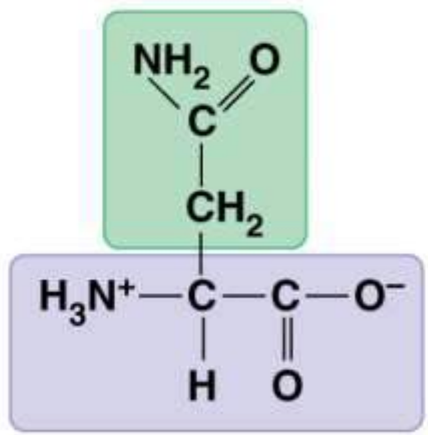
Threonine
(Thr or T)



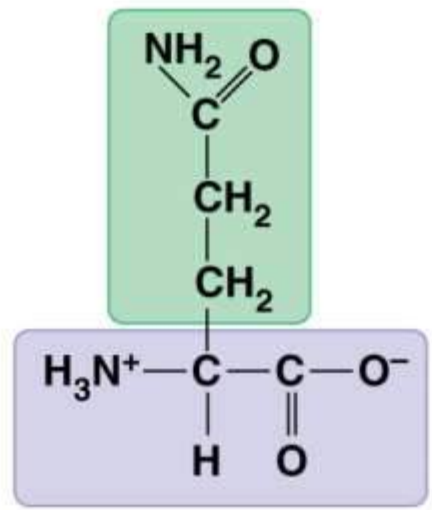
Cysteine
(Cys or C)



Tyrosine
(Tyr or Y)



Asparagine
(Asn or N)



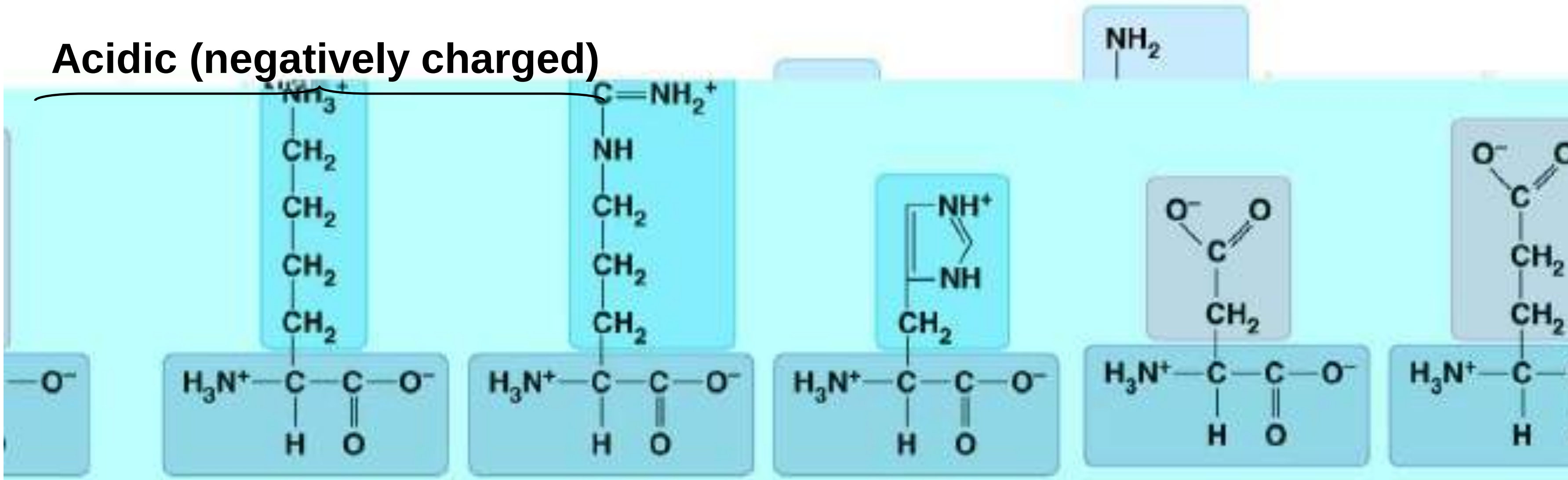
Glutamine
(Gln or Q)

Figure 5.16c

Electrically charged side chains; hydrophilic

Basic (positively charged)

Acidic (negatively charged)



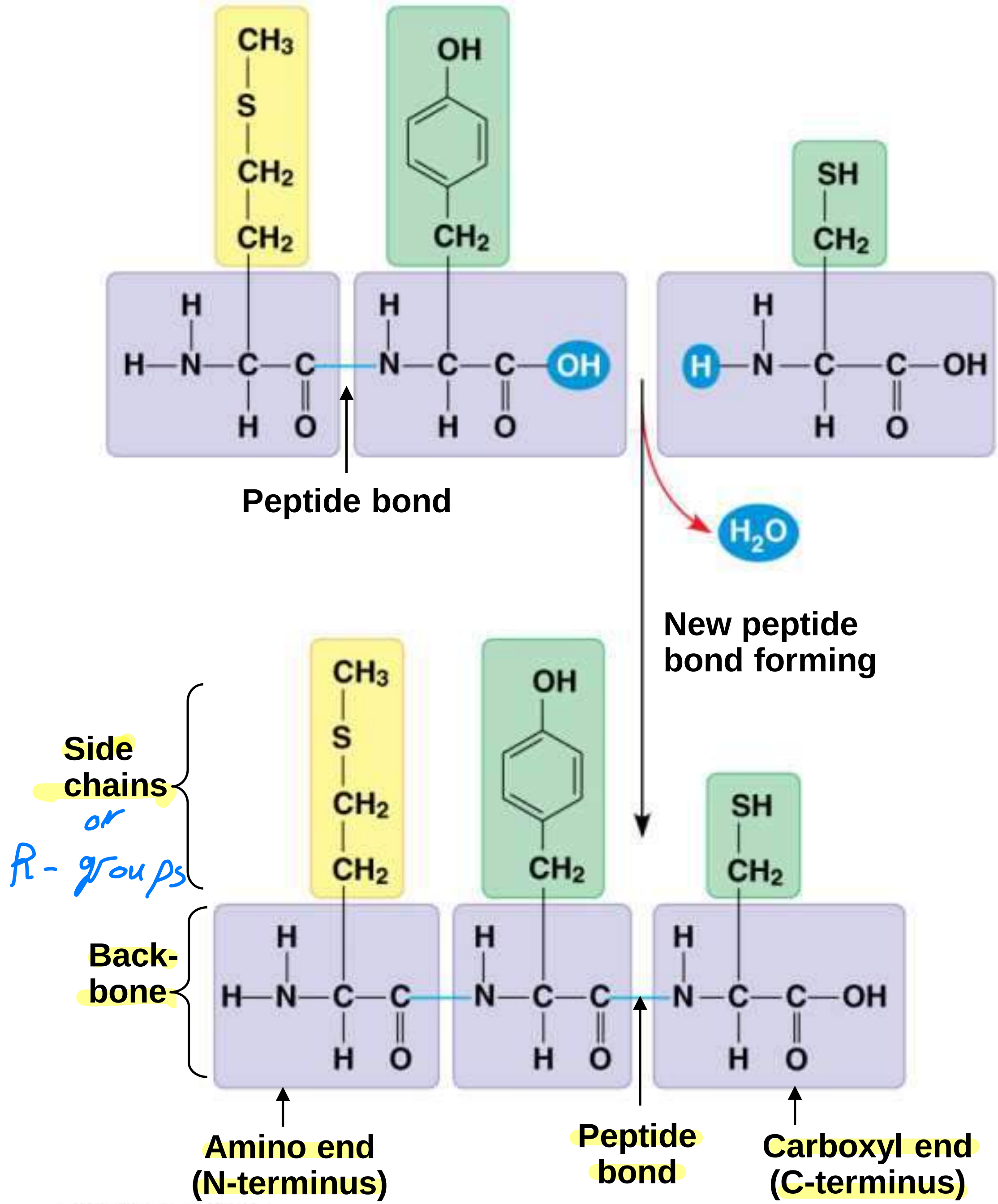
Aspartic acid (Asp or D) | **Glutamic acid (Glu or E)** | **Lysine (Lys or K)** | **Arginine (Arg or R)** | **Histidine (His or H)**

Amino Acid Polymers

- Amino acids are linked by **peptide bonds**
- A polypeptide is a polymer of amino acids
- Polypeptides range in length from a few to more than a thousand monomers
- Each polypeptide has a unique linear sequence of amino acids, with a carboxyl end (C-terminus) and an amino end (N-terminus)

Figure 5.17

dehydration reaction



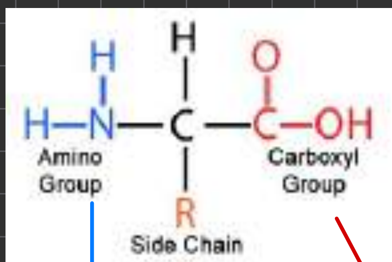
Amino acid → Polypeptide → protein
(20 a.a in total)

depending on the side Chain (R)

Hydrophobic
(non polar side chains)

Hydrophilic

- Polar side chains
- Electrically charged
  - (Acidic) Negatively charged
    - Aspartic acid (Asp / D)
    - Glutamic acid (Glu / E)
  - (Basic) positively charged
    - Lysine (Lys / K)
    - Arginine (Arg / R)
    - Histidine (His / H)



Amino end (N-terminus)

Carboxyl end (C-terminus)

- Amino acids are linked by peptide bonds

Polypeptide → protein

↓

a polymer of amino acids

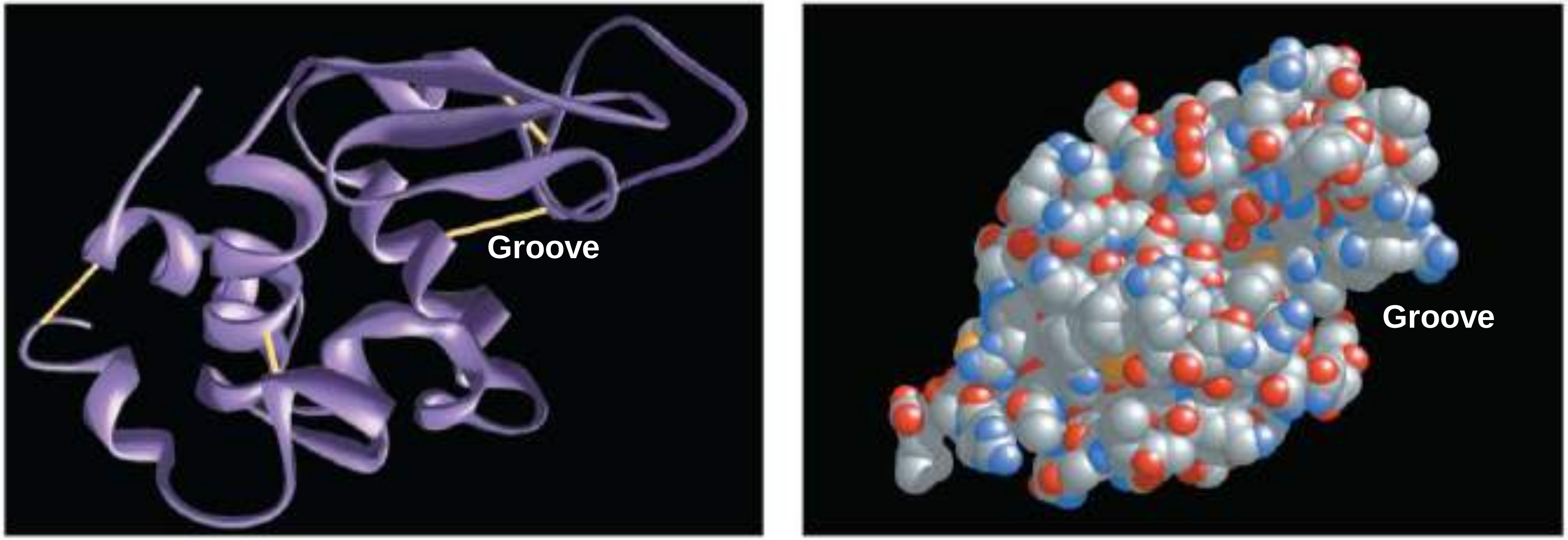
consists of few to thousands of a.a

it doesn't have a function in the basic form unless it has been twisted, folded, coiled in a unique shape.

Protein Structure and Function

- A functional protein consists of one or more polypeptides precisely twisted, folded, and coiled into a unique shape

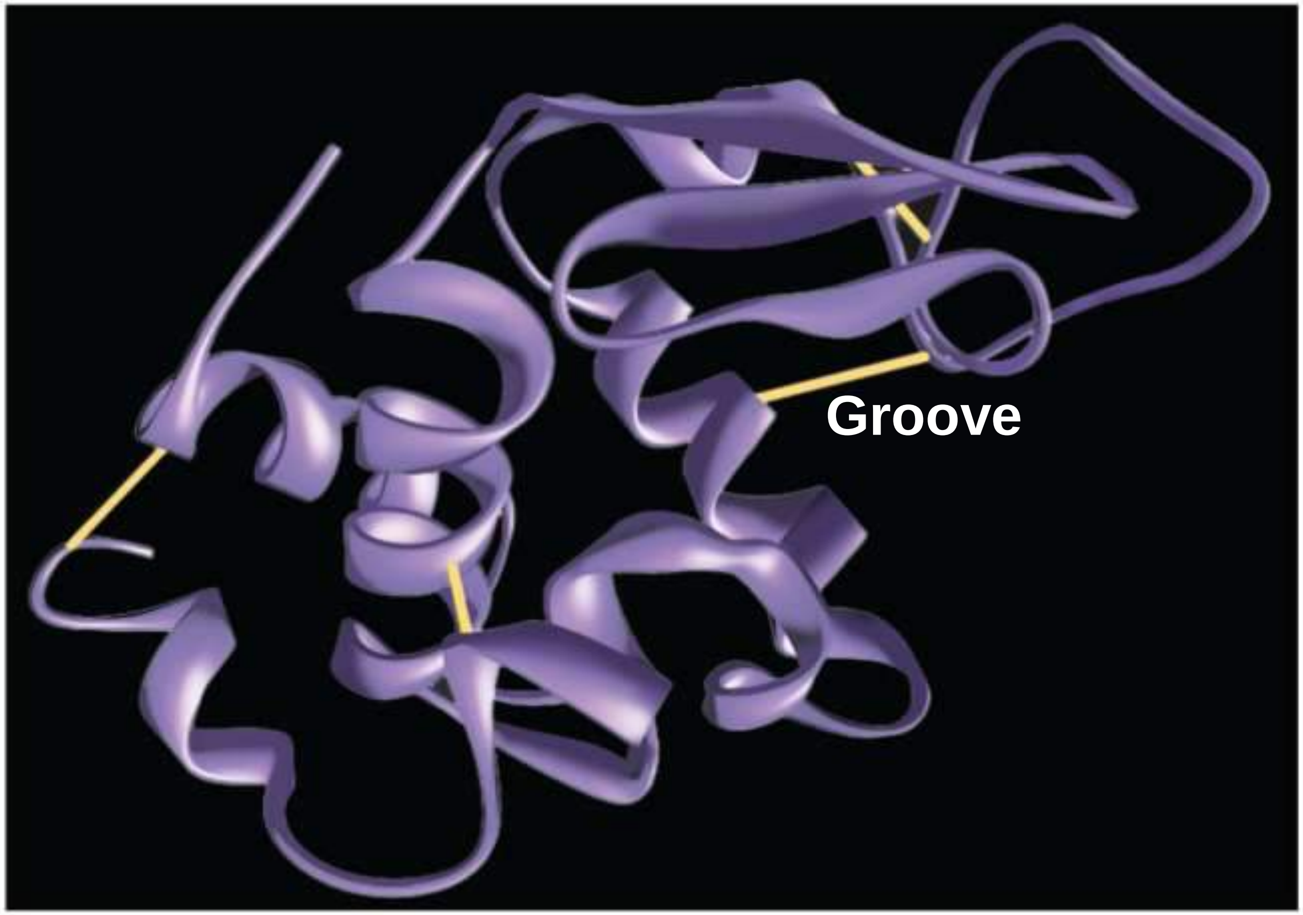
Figure 5.18



(a) A ribbon model

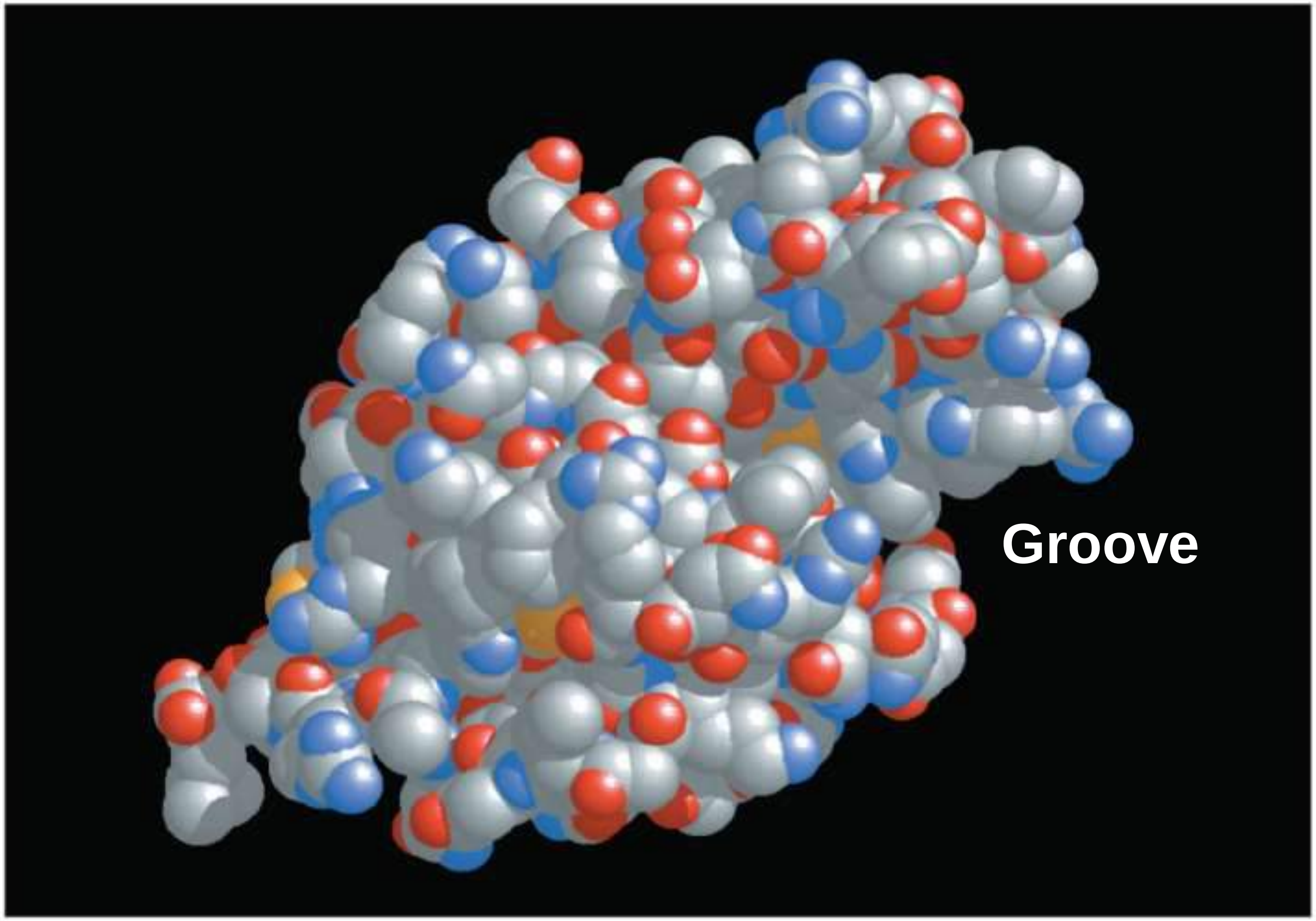
(b) A space-filling model

Figure 5.18a



(a) A ribbon model

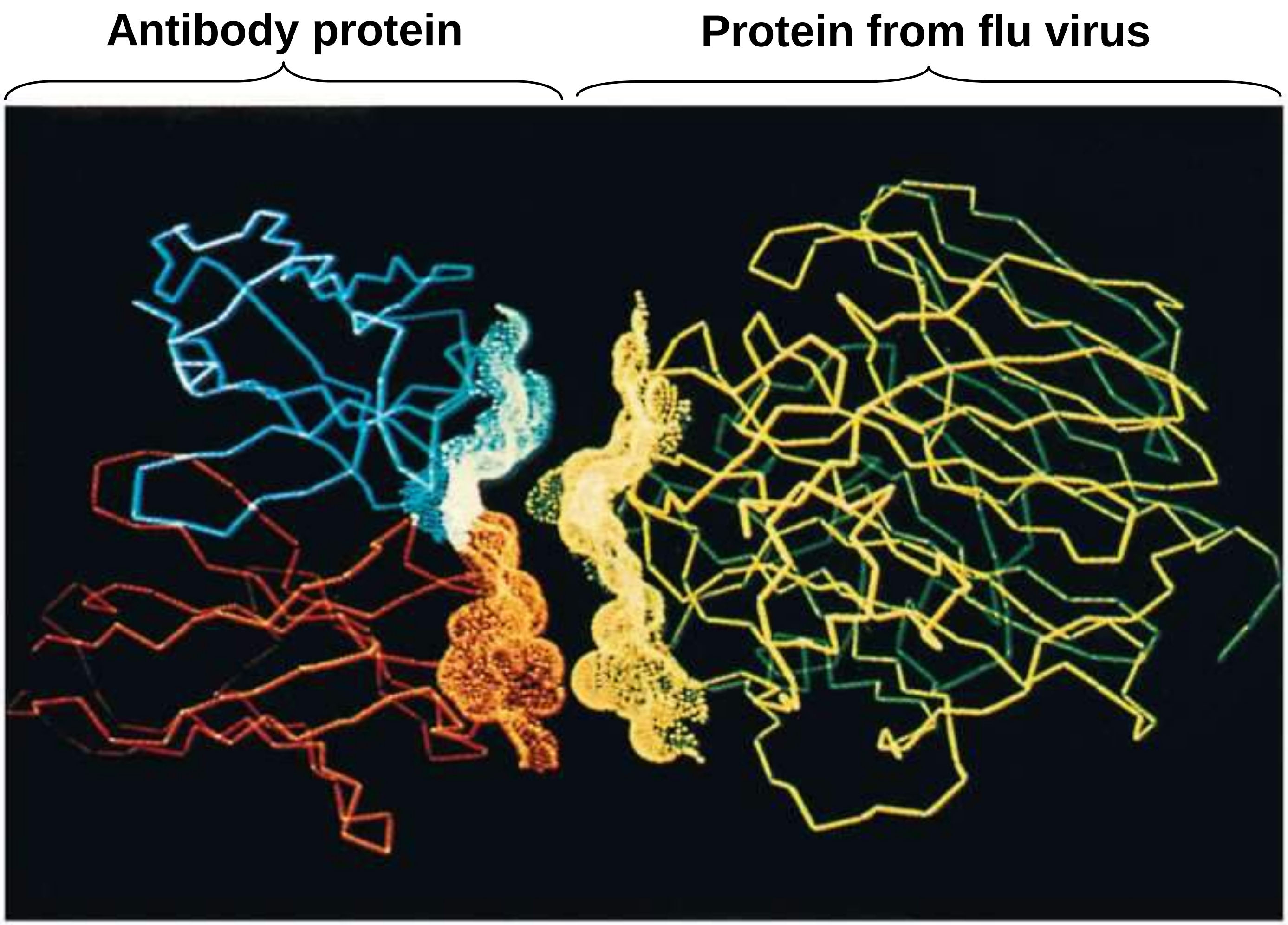
Figure 5.18b



(b) A space-filling model

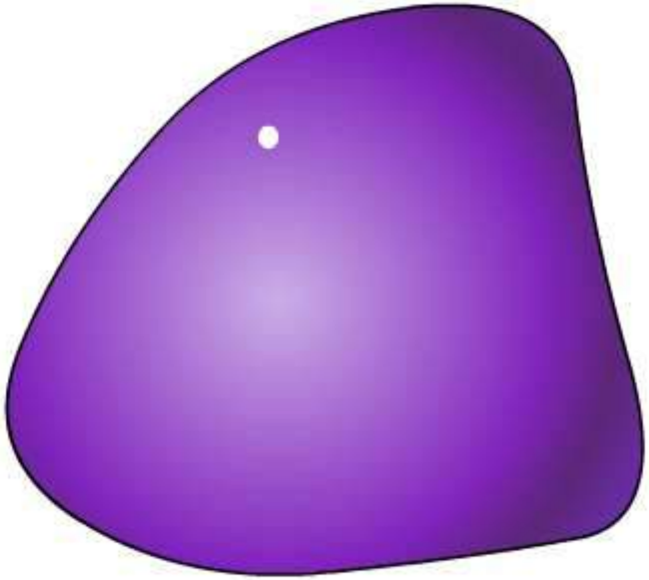
- The sequence of amino acids determines a protein’s three-dimensional structure
- A protein’s structure determines its function

Figure 5.19



Four 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

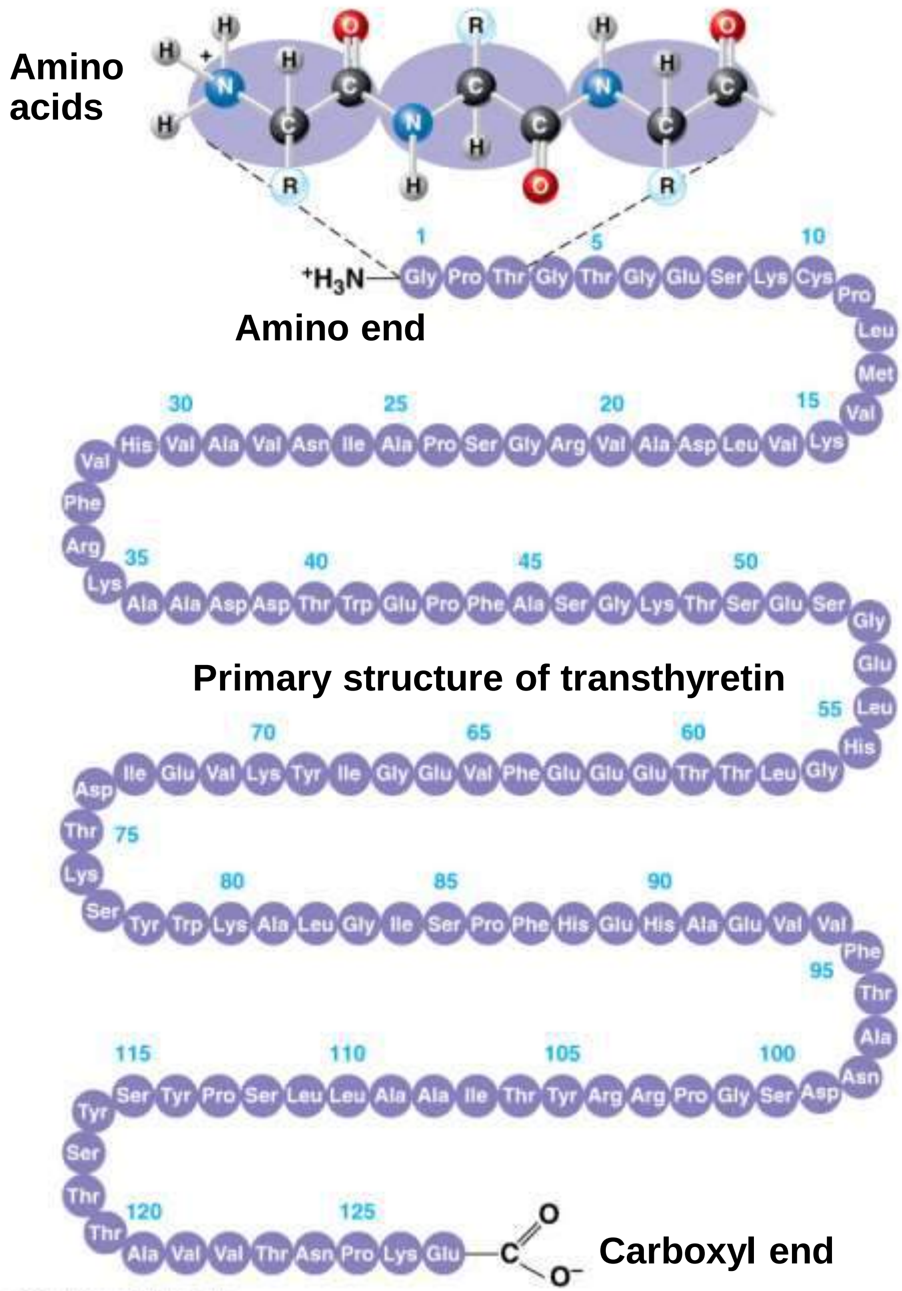


Animation: Protein Structure Introduction

Right-click slide / select “Play”

Figure 5.20a

Primary structure

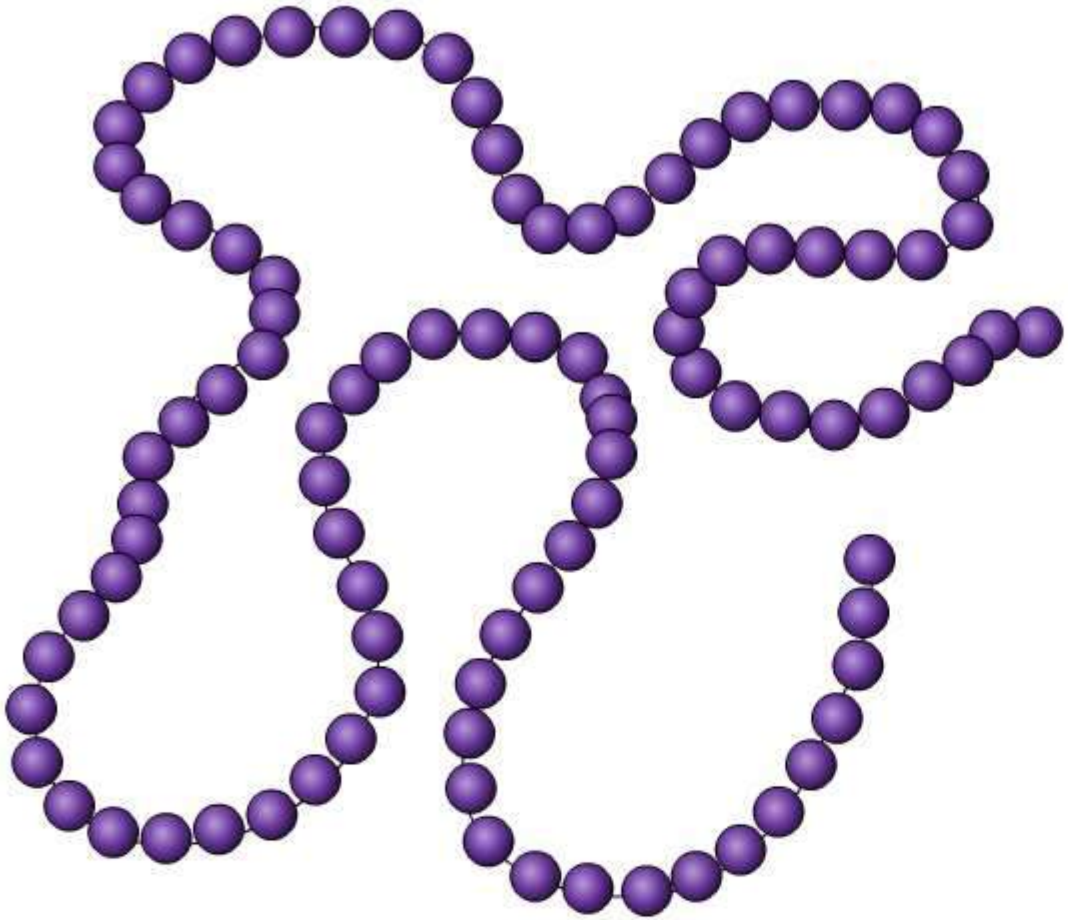


the most important

- **Primary structure**, the sequence of amino acids in a protein, is like the order of letters in a long word

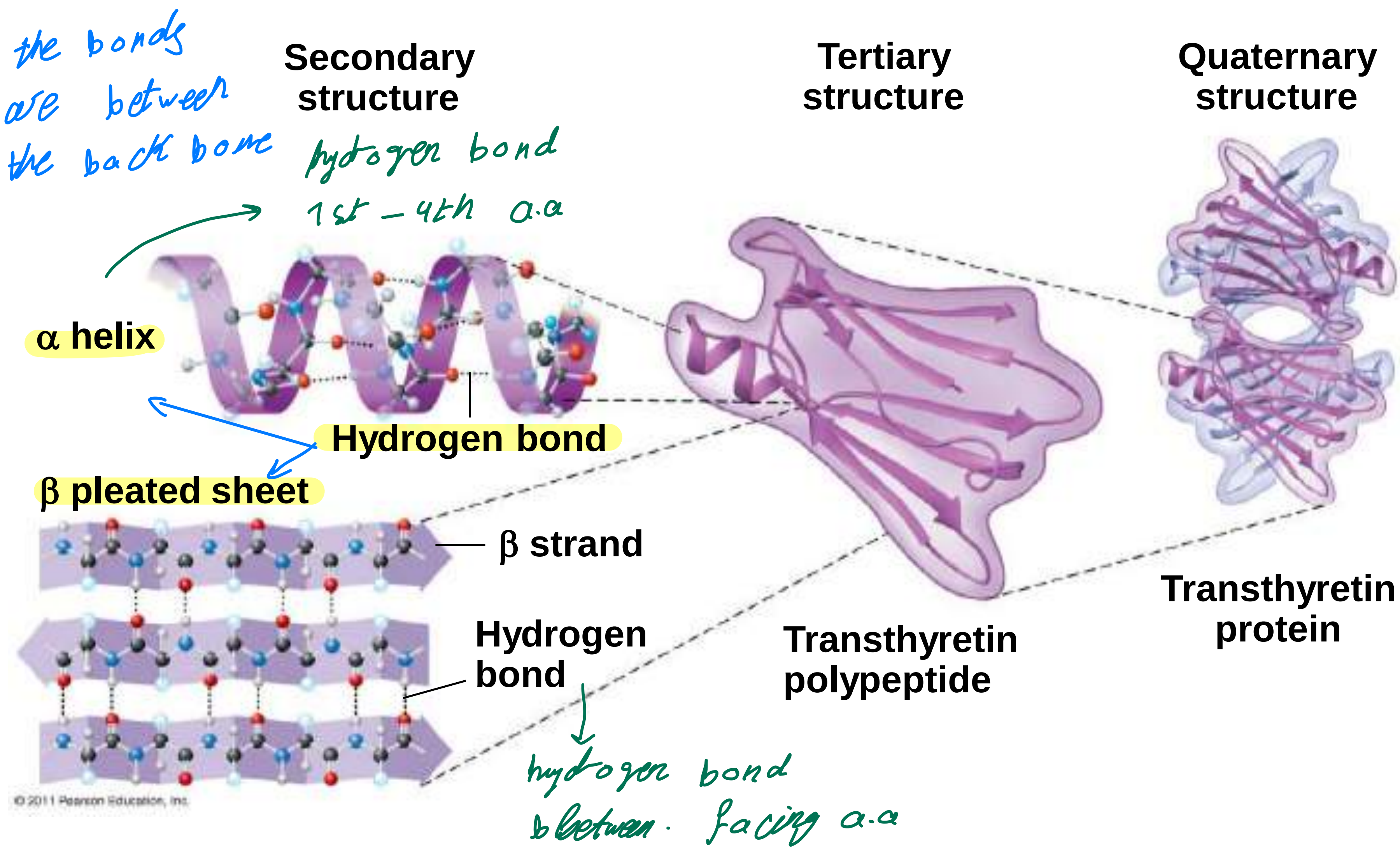
متوارث

- Primary structure is determined by inherited genetic information



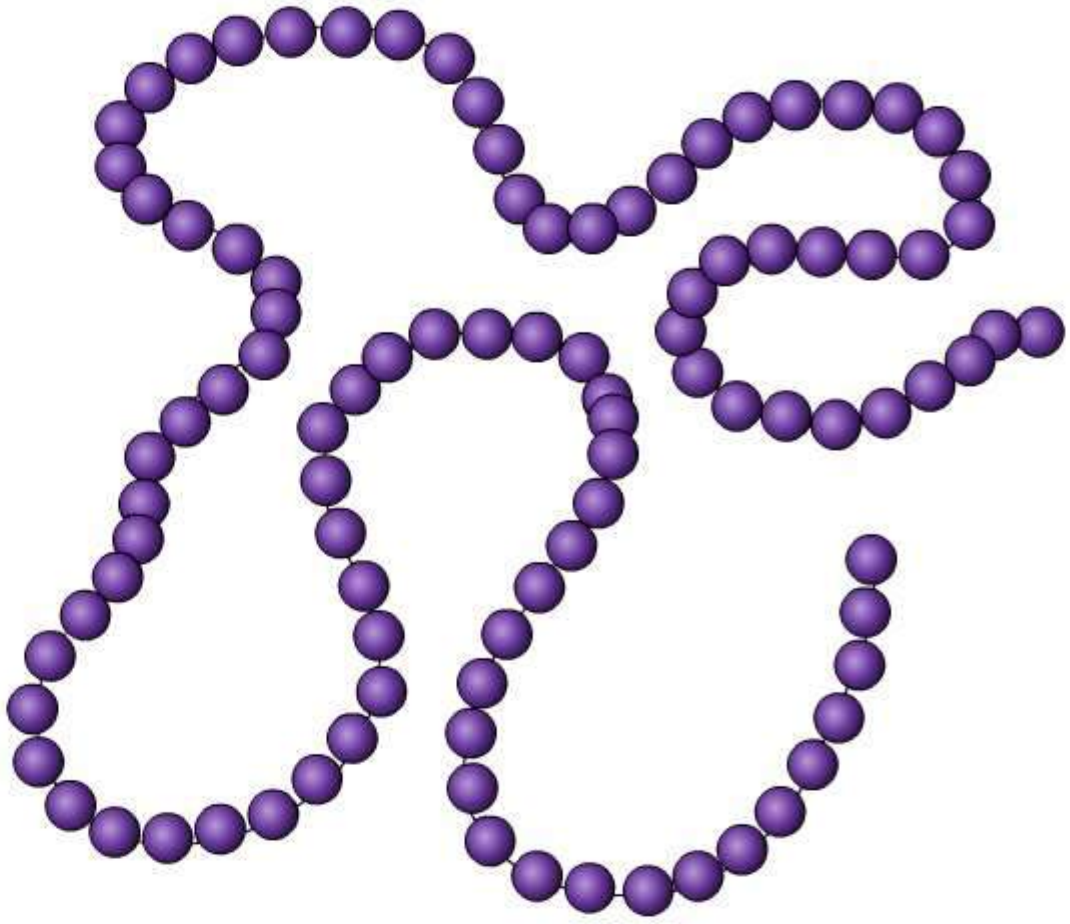
Animation: Primary Protein Structure
Right-click slide / select “Play”

Figure 5.20b


Secondary structure
Tertiary structure
Quaternary structure
α helix
Hydrogen bond
β pleated sheet
β strand
Hydrogen bond
Transthyretin polypeptide
Transthyretin protein
© 2011 Pearson Education, Inc.
the bonds are between the back bone
hydrogen bond 1st – 4th a.a
hydrogen bond between facing a.a

still not functional

- 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**



Animation: Secondary Protein Structure

Right-click slide / select "Play"

Figure 5.20c

Secondary structure

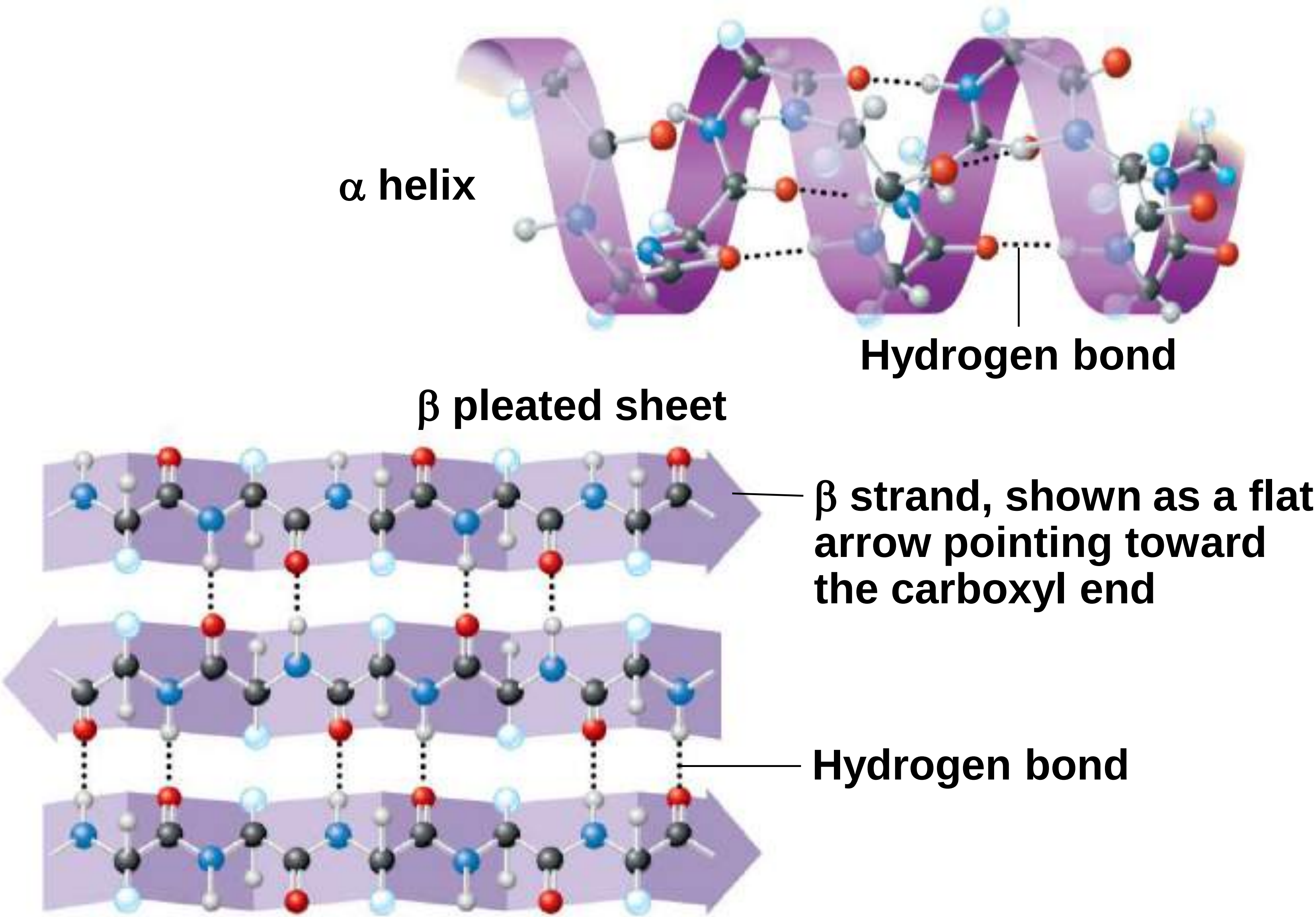


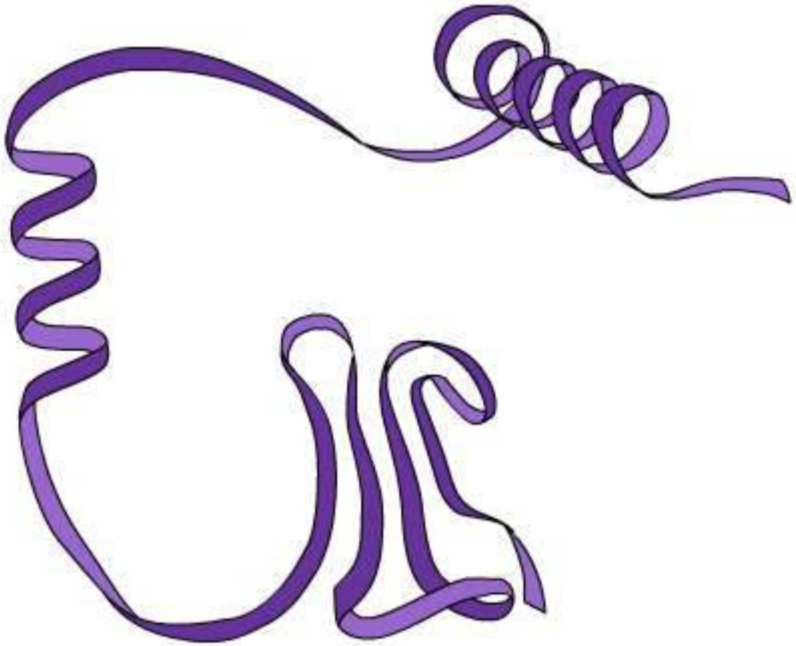
Figure 5.20d

functional (Native protein)

1 Polypeptide

- **Tertiary structure** is determined by interactions between R groups, rather than interactions between backbone constituents
- These interactions between R groups include hydrogen bonds, ionic bonds, **hydrophobic interactions**, and van der Waals interactions
- Strong covalent bonds called **disulfide bridges** may reinforce the protein's structure

between Two (S) atoms

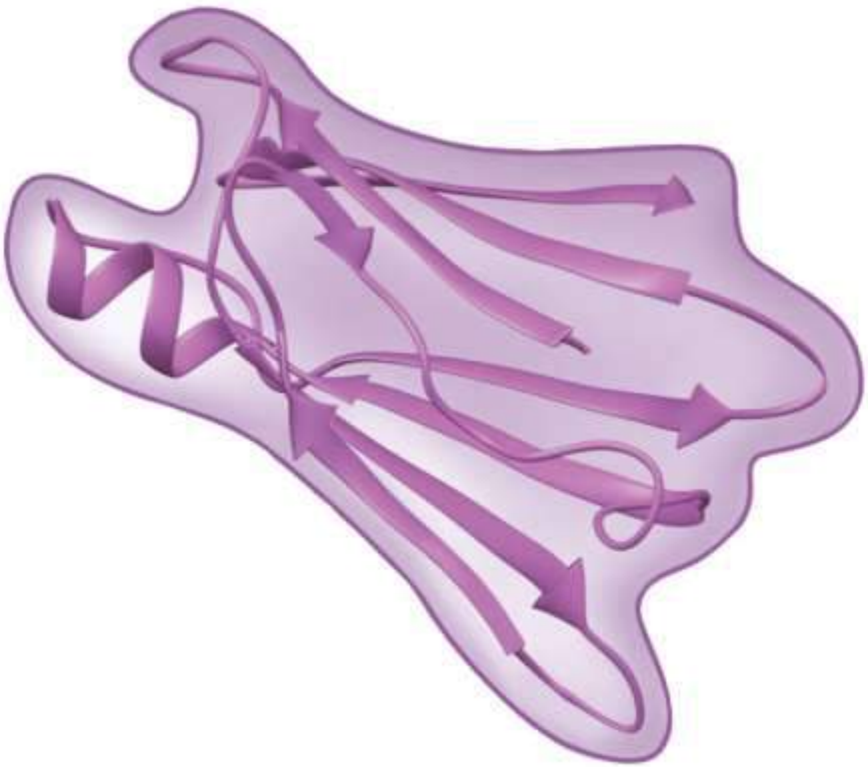


Animation: Tertiary Protein Structure

Right-click slide / select “Play”

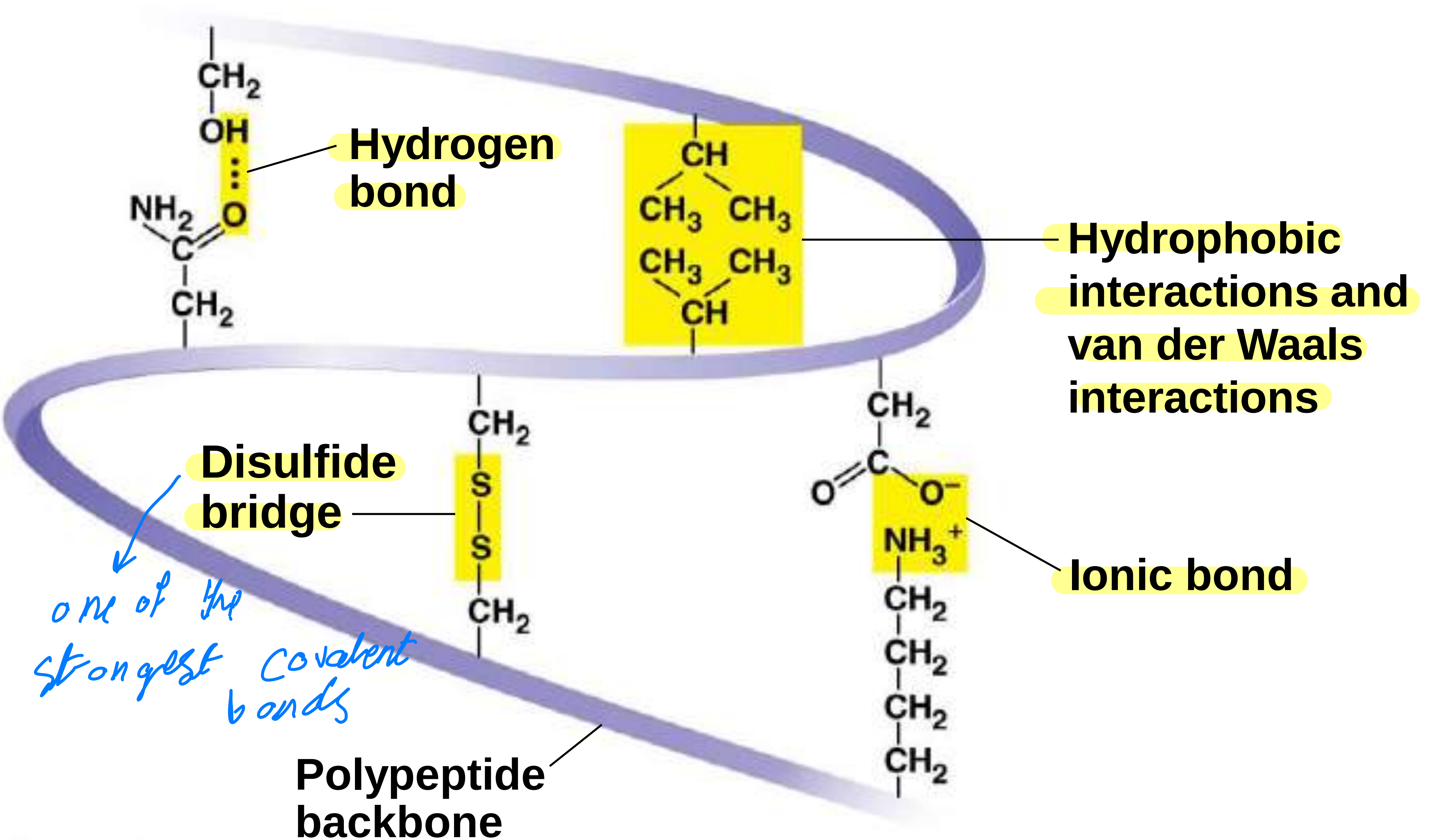
Figure 5.20e

Tertiary structure



Transthyretin polypeptide

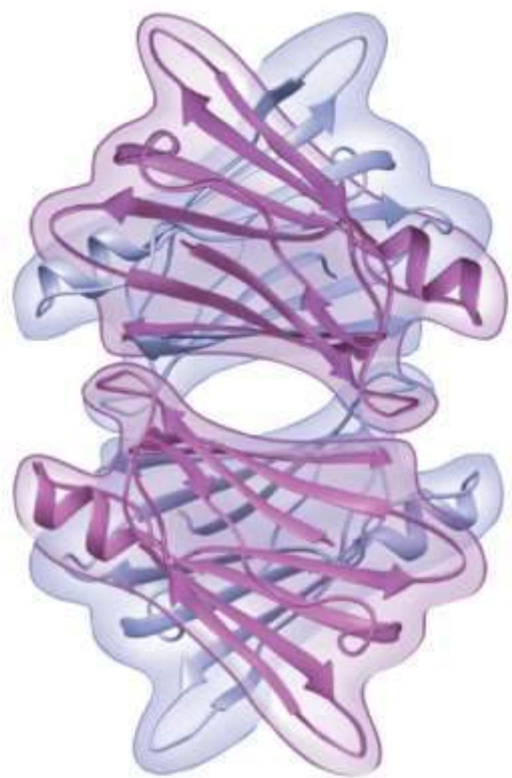
Figure 5.20f



Hydrogen bond
Hydrophobic interactions and van der Waals interactions
Disulfide bridge
Ionic bond
Polypeptide backbone
CH2
OH
O
NH2
C
CH
CH3
S
O−
NH3+
one of the strongest covalent bonds

Figure 5.20g

Quaternary structure



Transthyretin protein (four identical polypeptides)

Figure 5.20h

Collagen

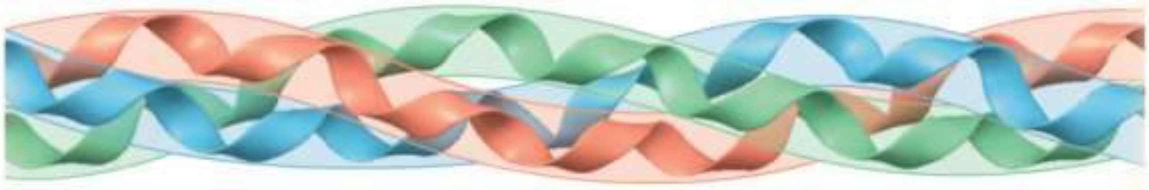
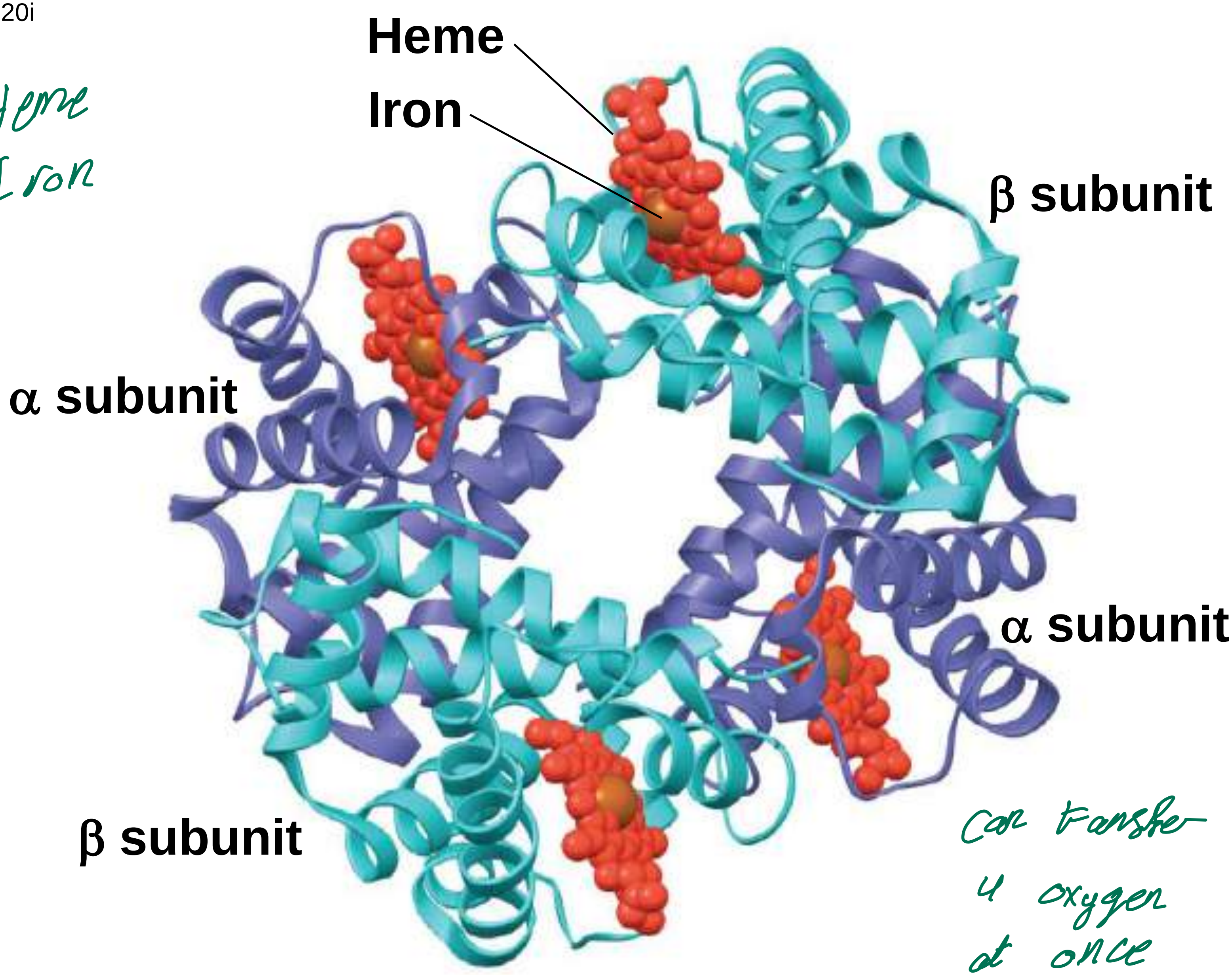


Figure 5.20i

4 Heme
4 Iron

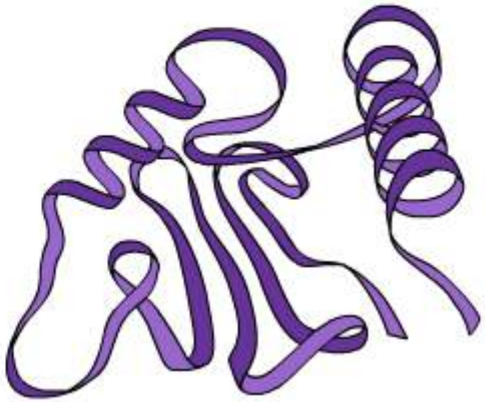


can transfer
4 oxygen
at once

Hemoglobin

Figure 5.20j

- **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 alpha and two beta chains

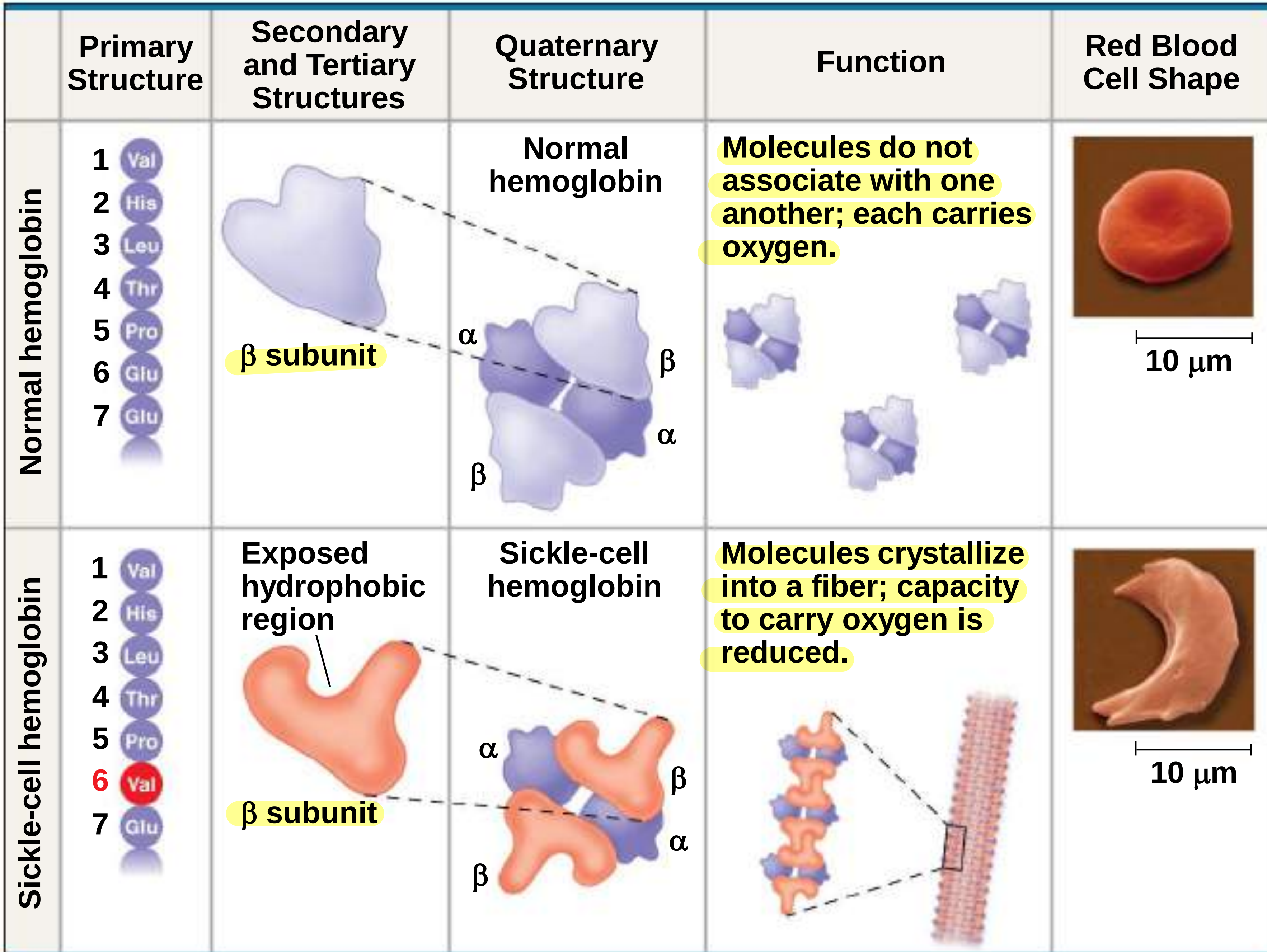


Animation: Quaternary Protein Structure
Right-click slide / select “Play”

Sickle-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

Figure 5.21



Primary Structure
Secondary and Tertiary Structures
Quaternary Structure
Function
Red Blood Cell Shape
Normal hemoglobin
1 Val
2 His
3 Leu
4 Thr
5 Pro
6 Glu
7 Glu
β subunit
Normal hemoglobin
α
β
α
β
Molecules do not associate with one another; each carries oxygen.
10 µm
Sickle-cell hemoglobin
1 Val
2 His
3 Leu
4 Thr
5 Pro
6 Val
7 Glu
Exposed hydrophobic region
β subunit
Sickle-cell hemoglobin
α
β
α
β
Molecules crystallize into a fiber; capacity to carry oxygen is reduced.
10 µm

Figure 5.21a

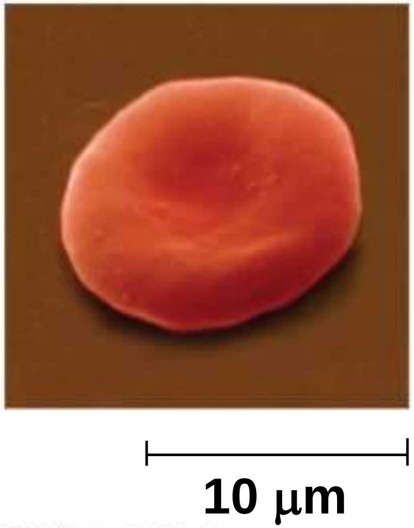


Figure 5.21b

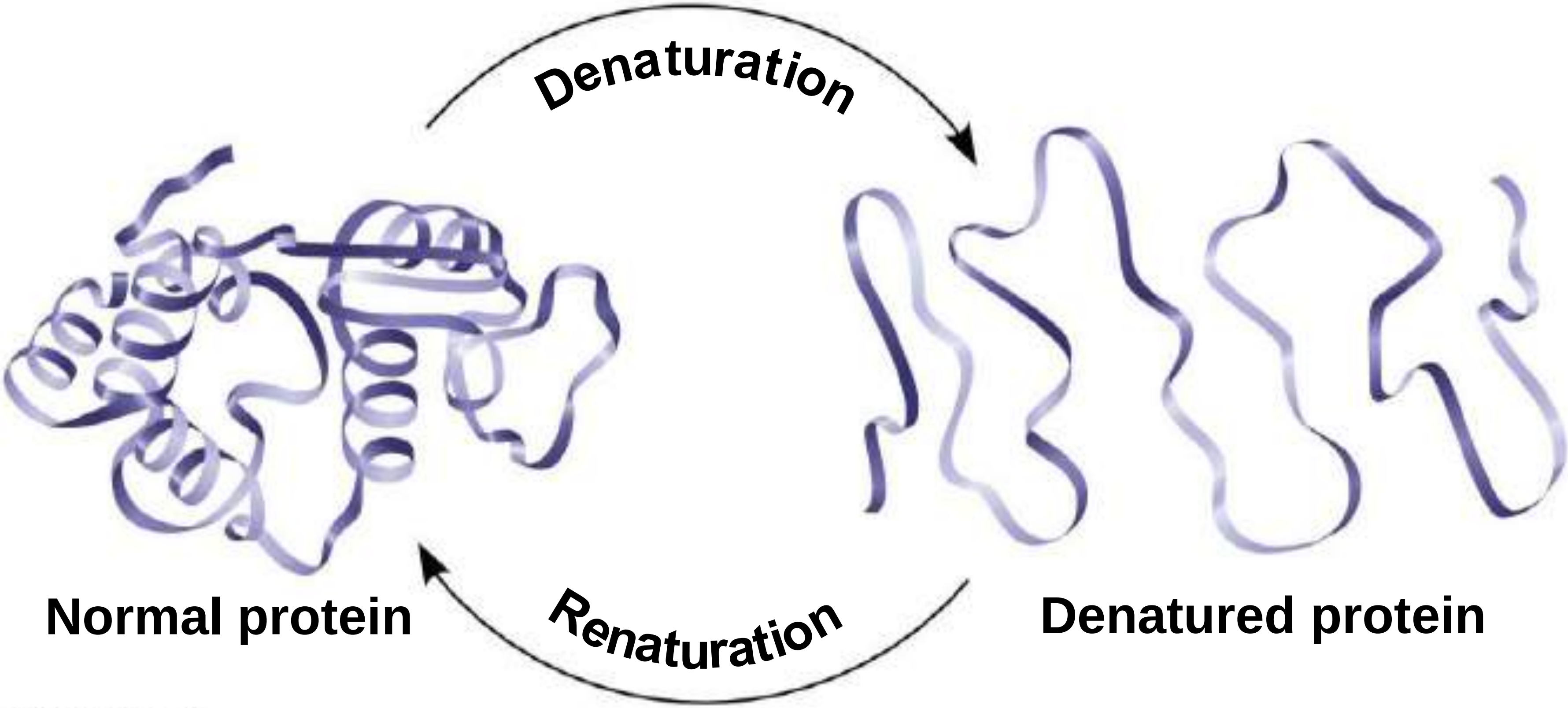
What Determines Protein Structure?

- 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** → تحصل بسبب تأثير الحرارة
- A denatured protein is biologically inactive

irreversable inside the cell

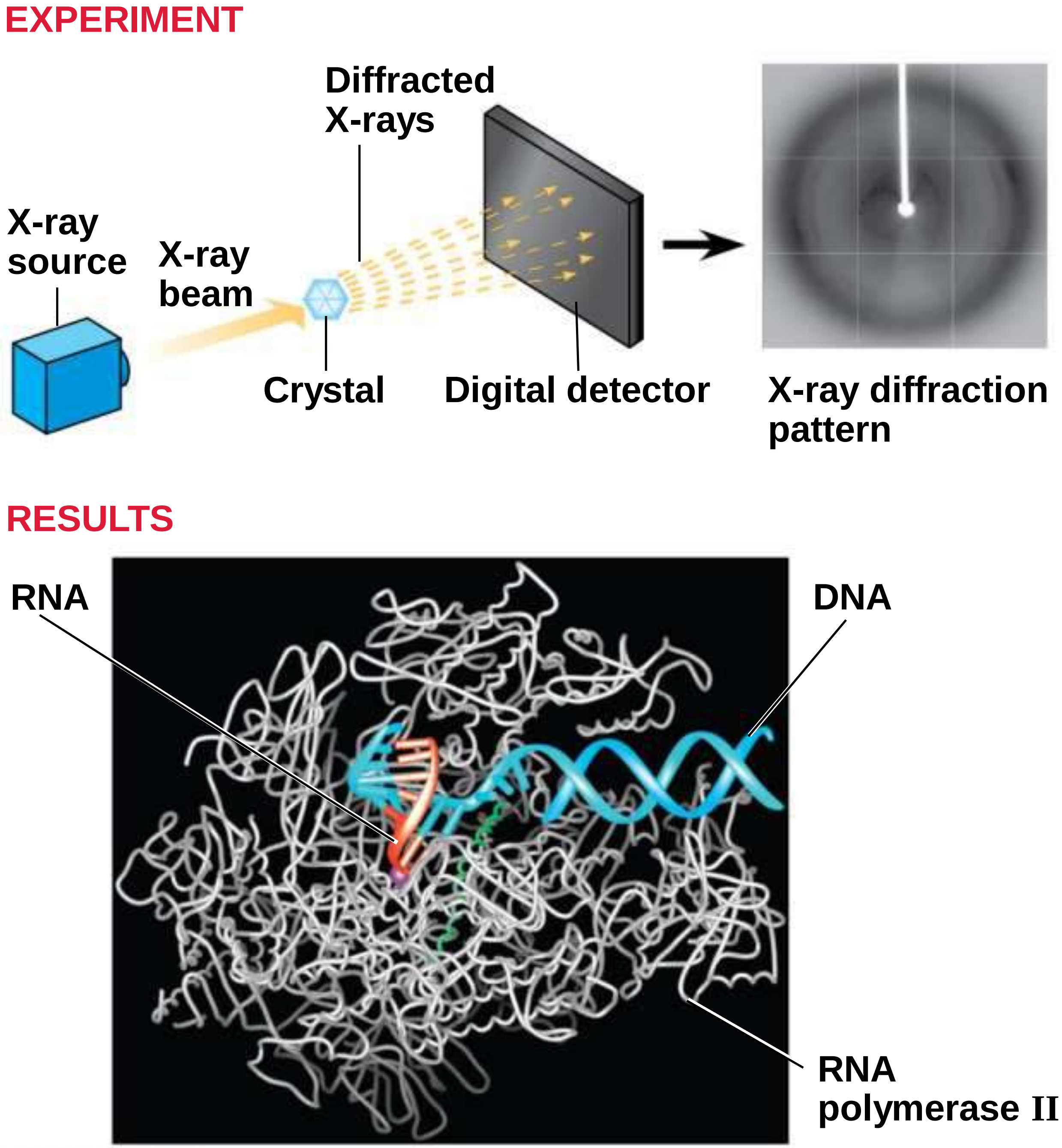
- can be reversed outside the cell and in a soluble state

Figure 5.22


Denaturation
Renaturation
Normal protein
Denatured protein

- 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 uses computer programs to predict protein structure from amino acid sequences

Figure 5.24



EXPERIMENT
Diffracted X-rays
X-ray source
X-ray beam
Crystal
Digital detector
X-ray diffraction pattern
RESULTS
RNA
DNA
RNA polymerase II

Figure 5.24a

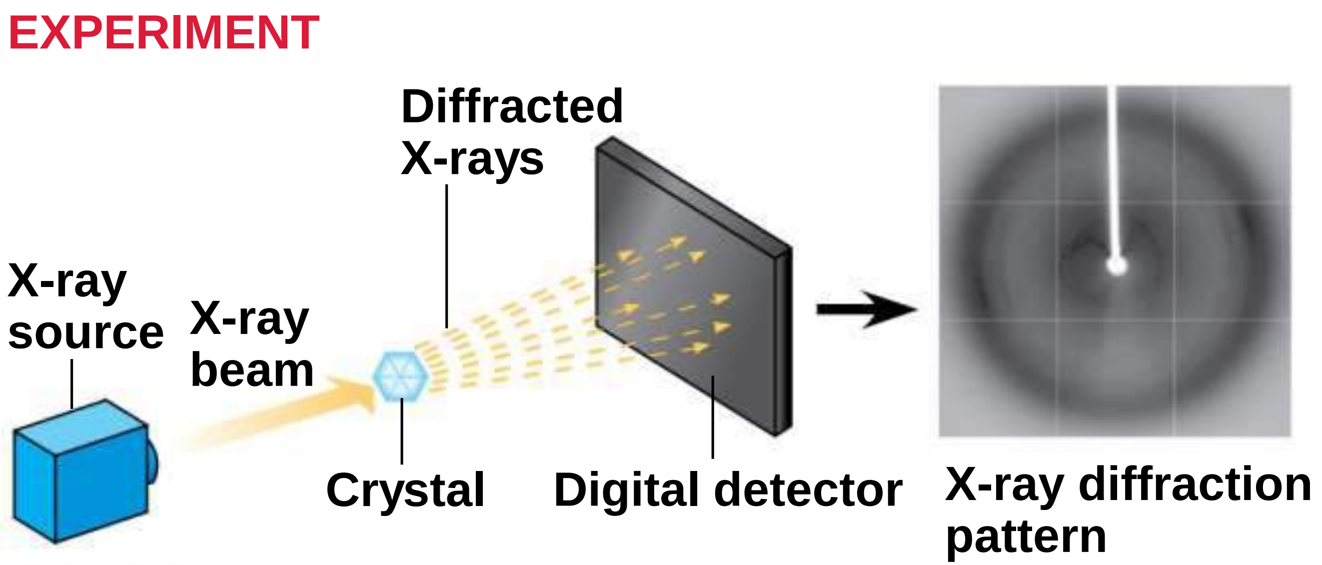
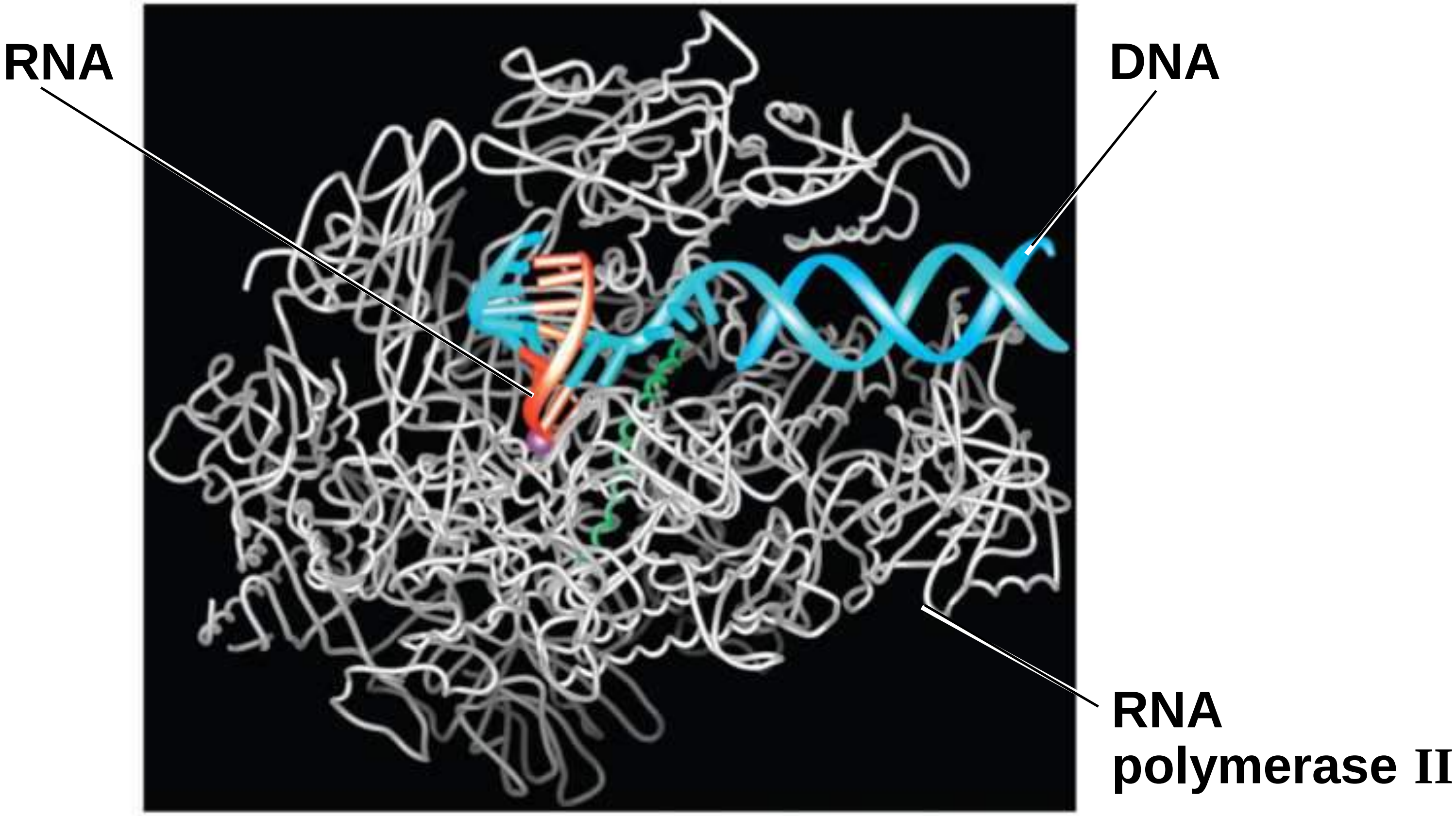

EXPERIMENT
Diffracted X-rays
X-ray source
X-ray beam
Crystal
Digital detector
X-ray diffraction pattern

Figure 5.24b

RESULTS



protein structure

- **single polypeptide**
  - **Primary (non functional)**
    - the most important structure and it determines the protein
    - linear (no folds, twists)
    - has peptide bonds between a.a
  - **secondary**
    - has hydrogen bond in the backbone
    - has two shapes
      - **α-helix** → hydrogen bonds between a a.a and the 4th a.a after it
      - **β-pleated sheet** → hydrogen bonds between a a.a and the one facing it
  - **tertiary (functional)**
    - interaction between side chains (R groups)
      1) hydrogen bonds
      2) Ionic bonds
      3) hydrophobic interactions (van der Waals interactions)
      4) disulfide bridges (strong covalent bond S–S)
- **two or more polypeptide** → Quaternary

Quaternary structure (functional)

has more than one polypeptide

same bonds between R groups as the tertiary structure

Ex:

- 3 Polypeptide → collagen: fibrous protein the 3 polypeptides are coiled like a rope
- 4 Polypeptide
  - → identical polypeptides: Transthyretin
  - → different polypeptides: Hemoglobin: 2 α subunits and 2 β subunits

Concept 5.5: Nucleic acids store, transmit, and help express hereditary information

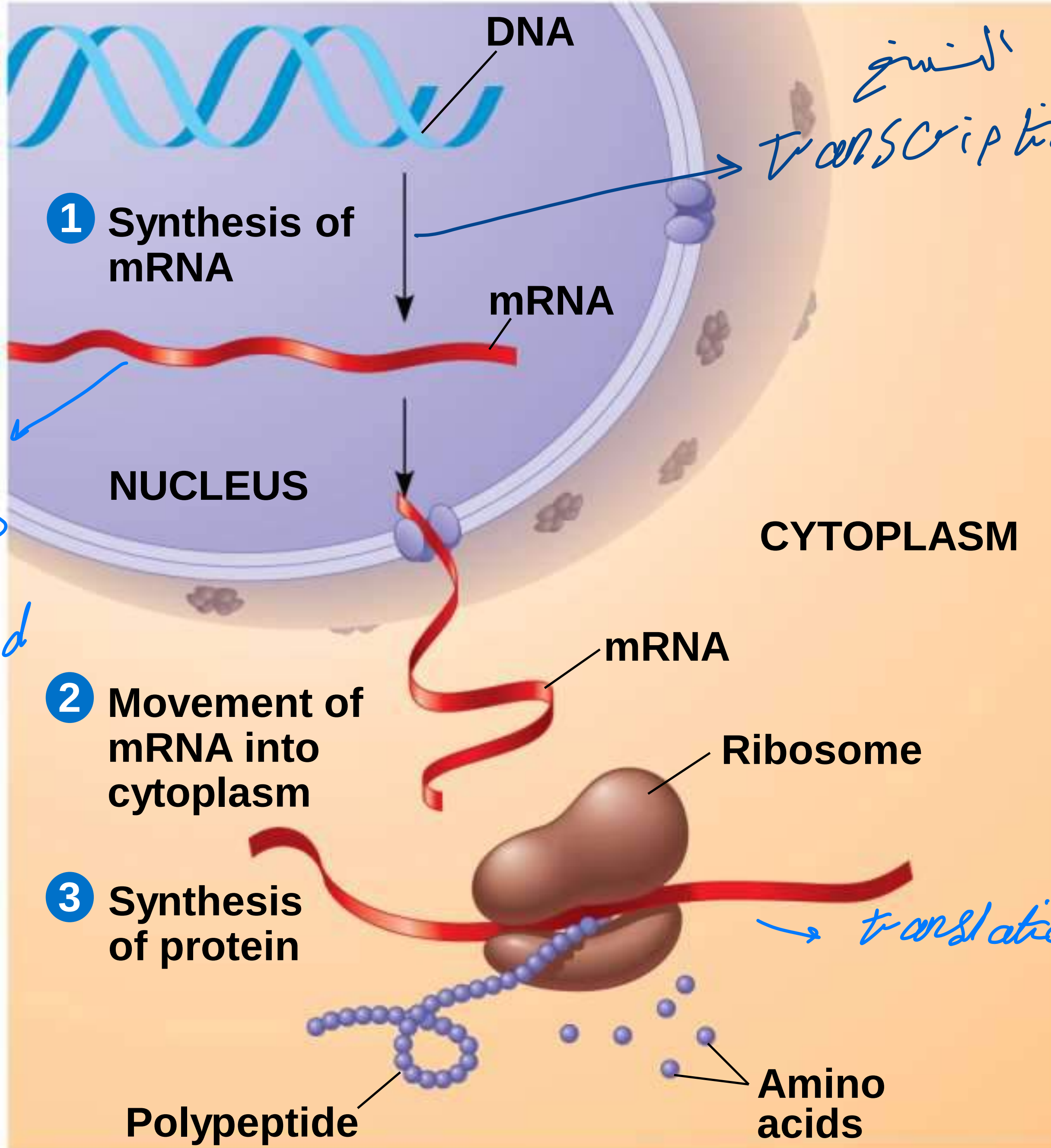
- The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a **gene**
- Genes are made of DNA, a **nucleic acid** made of monomers called nucleotides

the result of translating a gene is always a protein

The 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
- Protein synthesis occurs on ribosomes

Figure 5.25-3



double strands (double helix)

can leave the nucleus because its single strand

النسخ

transcription

translation

The 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

Figure 5.26

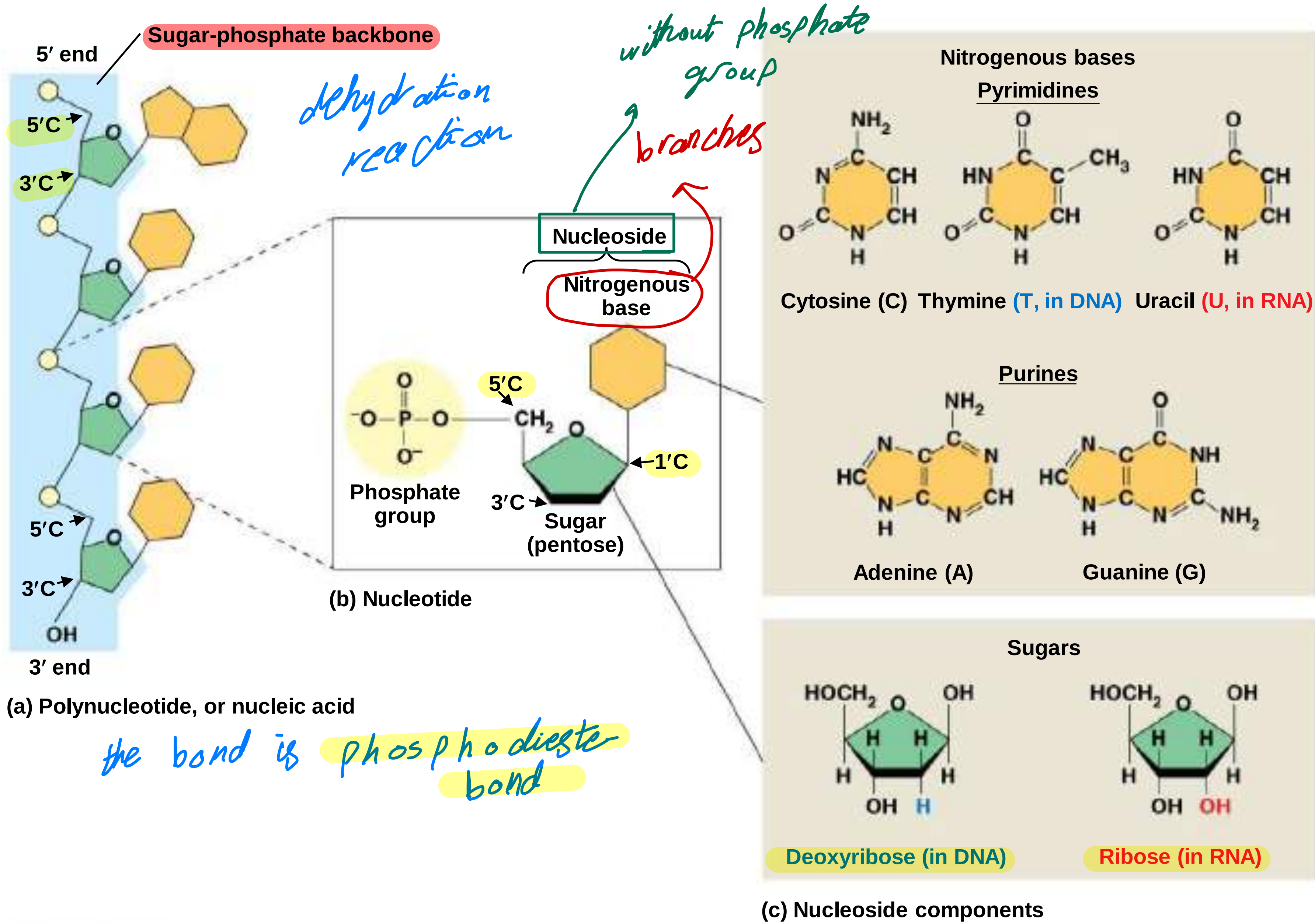
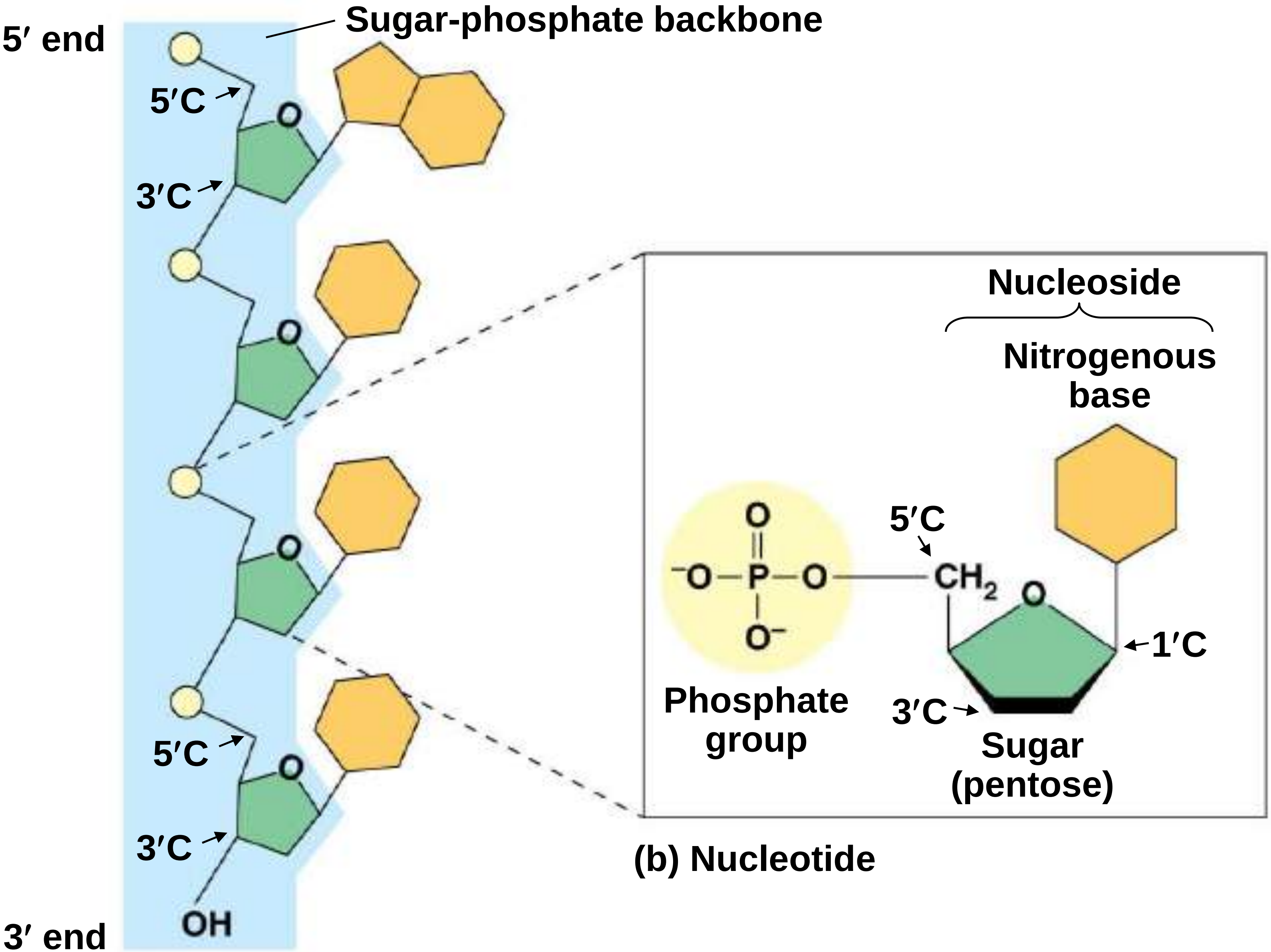
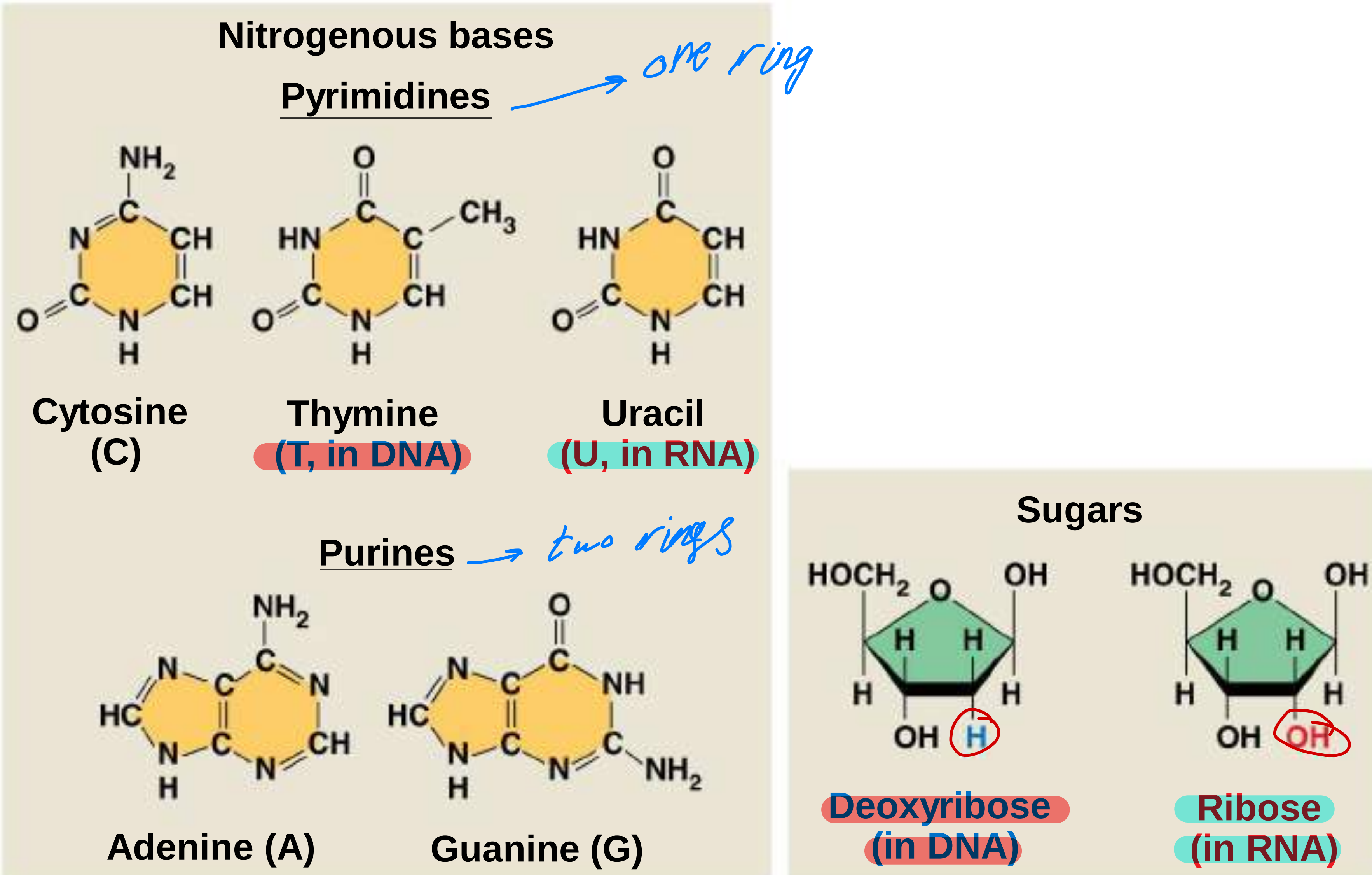

Sugar-phosphate backbone
5′ end
5′C
3′C
5′C
3′C
OH
3′ end
(a) Polynucleotide, or nucleic acid
dehydration reaction
without phosphate group
branches
Nucleoside
Nitrogenous base
5′C
O
⁻O–P–O
O⁻
CH2
O
1′C
3′C
Phosphate group
Sugar (pentose)
(b) Nucleotide
Nitrogenous bases
Pyrimidines
Cytosine (C)
Thymine (T, in DNA)
Uracil (U, in RNA)
Purines
Adenine (A)
Guanine (G)
Sugars
HOCH2
OH
Deoxyribose (in DNA)
Ribose (in RNA)
(c) Nucleoside components
the bond is phosphodiester bond

Figure 5.26ab



(a) Polynucleotide, or nucleic acid

Figure 5.26c



(c) Nucleoside components

- 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

Nucleotide Polymers

- Nucleotide polymers are linked together to build a polynucleotide
- Adjacent nucleotides are joined by covalent bonds that form between the —OH group on the 3′ carbon of one nucleotide and the phosphate on the 5′ carbon on the next
- 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

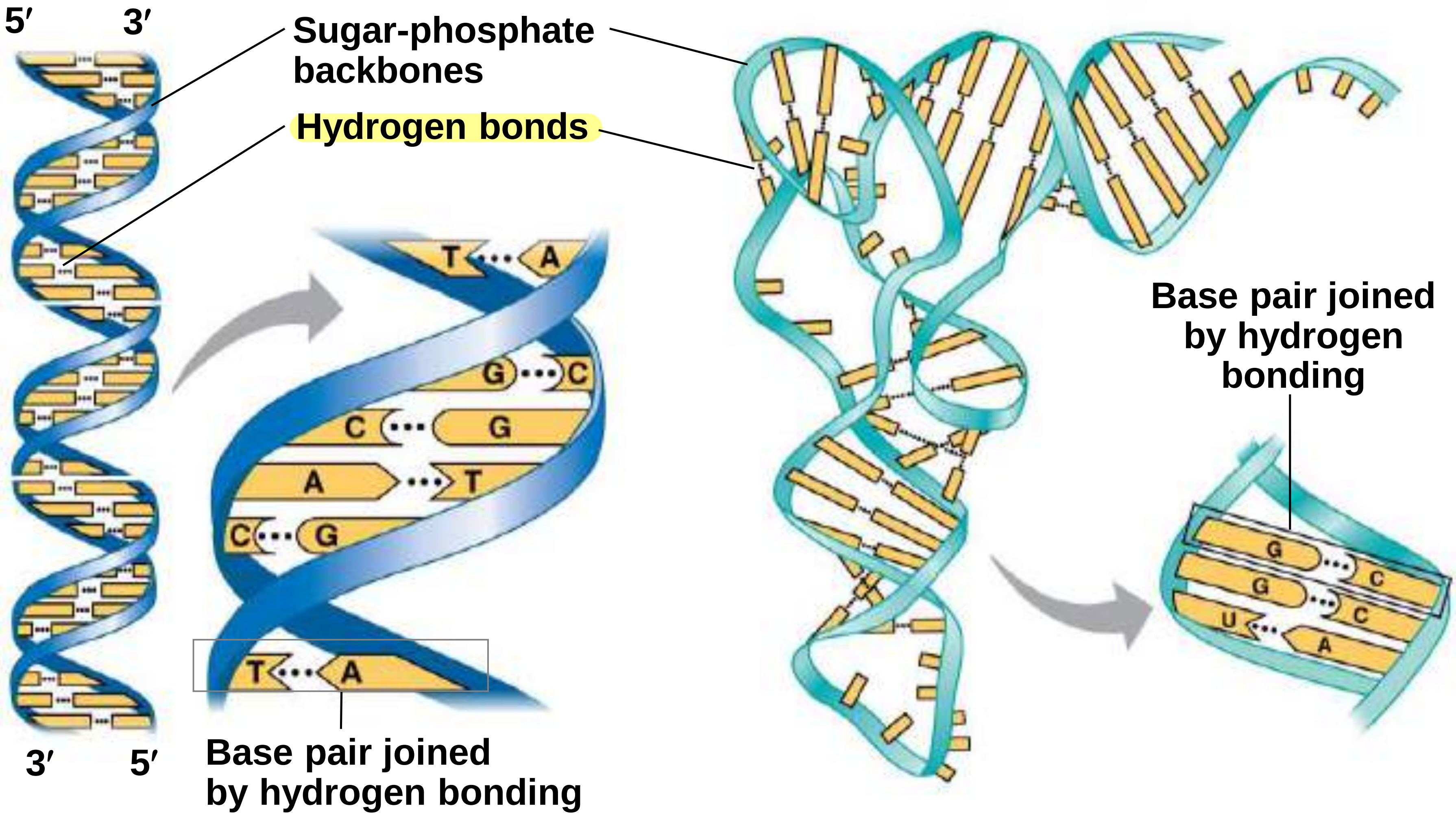
The Structures of DNA and RNA Molecules

- RNA molecules usually exist as single polypeptide chains
- DNA molecules have two polynucleotides spiraling around an imaginary axis, forming a **double helix**
- In the DNA double helix, the two backbones run in opposite $5' \rightarrow 3'$ directions from each other, an arrangement referred to as **antiparallel**
- One DNA molecule includes many genes

charagaff → %A = %T
%G = %C

- The nitrogenous bases in DNA pair up and form hydrogen bonds: adenine (A) always with thymine (T), and guanine (G) always with cytosine (C)
- Called complementary base pairing
- Complementary pairing can also occur between two RNA molecules or between parts of the same molecule
- In RNA, thymine is replaced by uracil (U) so A and U pair

Figure 5.27



(a) DNA

(b) Transfer RNA

A = T

G ≡ C

Nucleic acids

[Pentose sugar + Nitrogenous base + Phosphate group]

(Nucleoside = Pentose sugar + Nitrogenous base)

	DNA (Deoxyribonucleic acid) منقوص الأكسجين	RNA (Ribnucleic acid)
Sugar	Deoxyribose	Ribose
Nitrogenous bases	Adenine (A) Thymine (T) Guanine (G) Cytosine (C)	Adenine Uracil (U) Guanine Cytosine
Shape	double helix two polynucleotides spiraling around (in the opposite direction of each other) antiparallel	single strand one polynucleotide

Connection of monomers (nucleotides)

covalent bonds between the hydroxyl group (–OH) on the 3'C and the phosphate group on the 5'C in the next nucleotide

creating a backbone of sugar–phosphate units and the nitrogenous bases as branches

Nitrogenous bases

Purines → 2 rings

- Adenine
- Guanine

1 ring ← Pyrimidines

- Cytosine
- Thymine
- Uracil

Guanine – Cytosine: 3 hydrogen bonds

Adenine – Thymine, Uracil: 2 hydrogen bonds

Watson and crick are the scientists who discovered the structure of DNA

Charagaff

→ %A = %T, %U

→ %G = %C

Ex: In DNA there is 20% A what is the percentage of the other nitrogenous bases?

Answer: %A = %T

%T = 20%

%A + %T = 40%

→ 100% − 40% = %G + %C

60% = %G + %C

30% = %G

30% = %C

The Theme of Emergent Properties in the Chemistry of Life: *A Review*

- Higher levels of organization result in the emergence of new properties
- Organization is the key to the chemistry of life