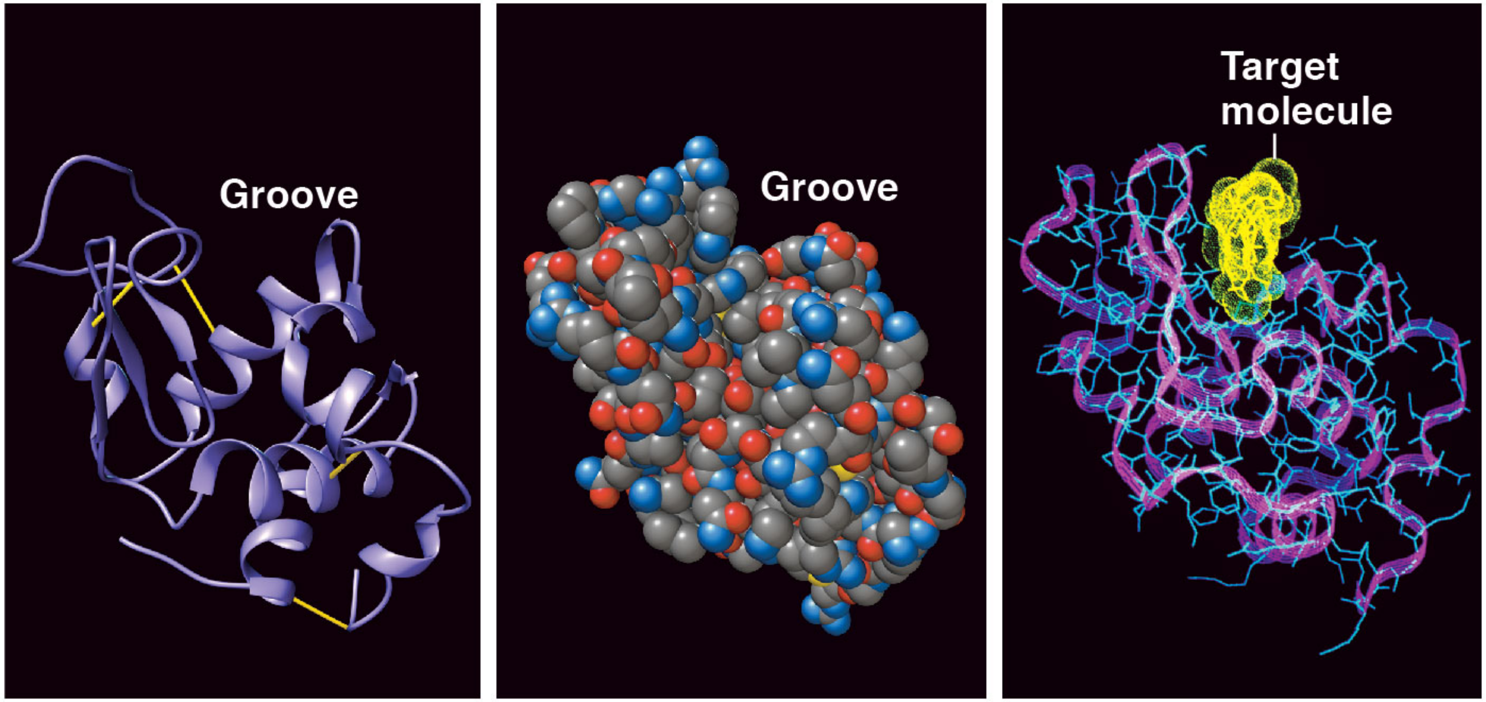


(a) A ribbon model (b) A space-filling model (c) A wireframe model

Ch. 3b: The Structure and Function of Macromolecules

You Must Know

- The role of **dehydration synthesis** in the formation of organic compounds and **hydrolysis** in the digestion of organic compounds.
- How the sequence and subcomponents of the four groups of organic compounds determine their properties.
- The cellular functions of carbs, lipids, proteins, and nucleic acids.
- How changes in these organic molecules would affect their function.

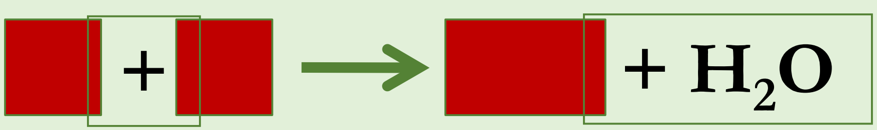
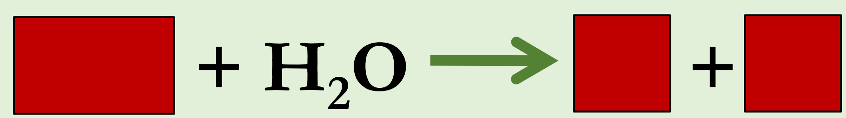
You Must Know

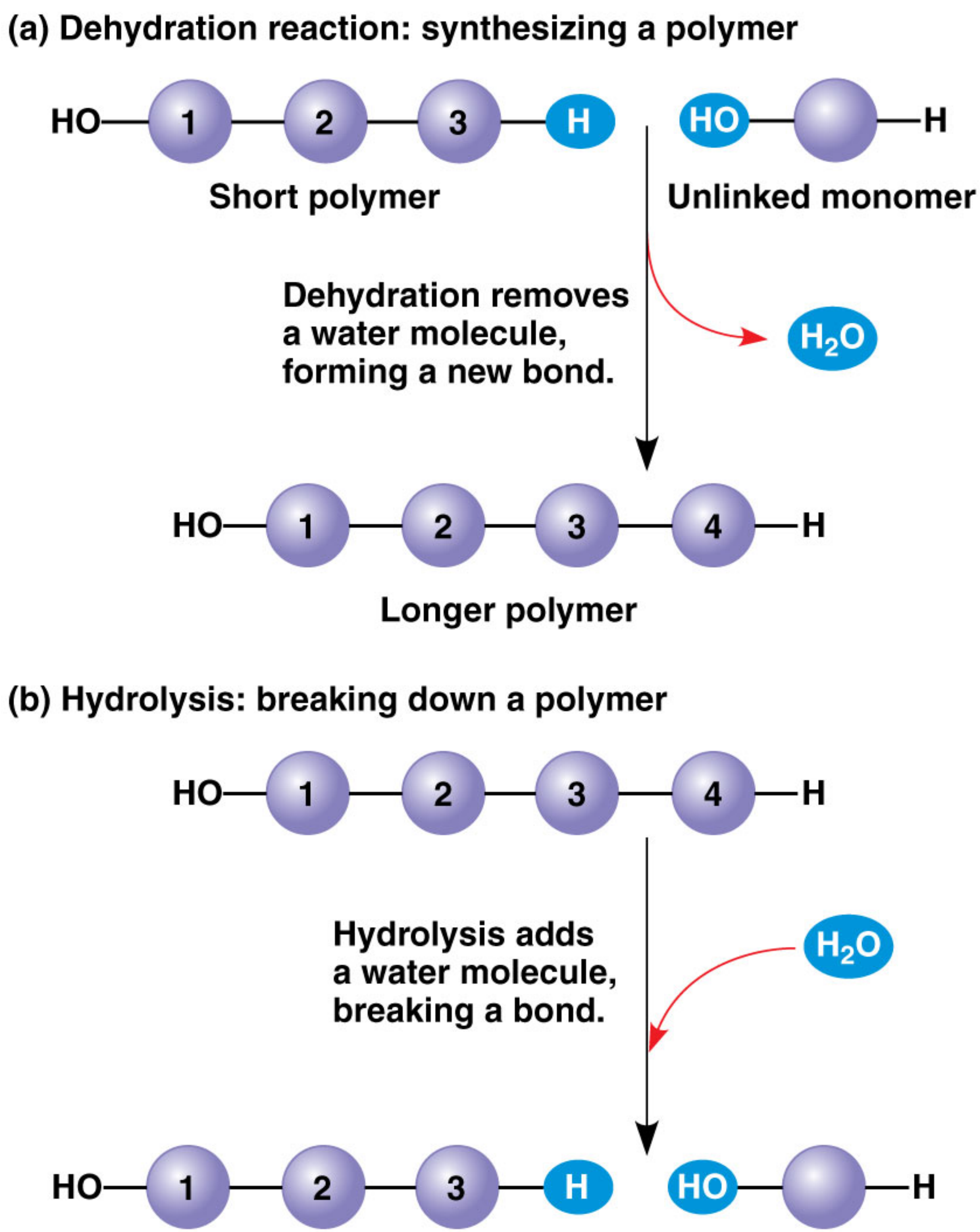
- The 4 structural levels of proteins and how changes at any levels can affect the activity of the protein.
- How proteins reach their final shape (**conformation**), the **denaturing** impact that heat and pH can have on protein structure, and how these changes may affect the organism.
- Directionality influences structure and function of polymers, such as nucleic acids (5' and 3' ends) and proteins (amino and carboxyl ends).

Monomers	Polymers	Macromolecules
•Small organic •Used for building blocks of polymers •Connects with condensation reaction (dehydration synthesis)	•Long molecules of monomers •With many identical or similar blocks linked by covalent bonds	•Giant molecules •2 or more polymers bonded together

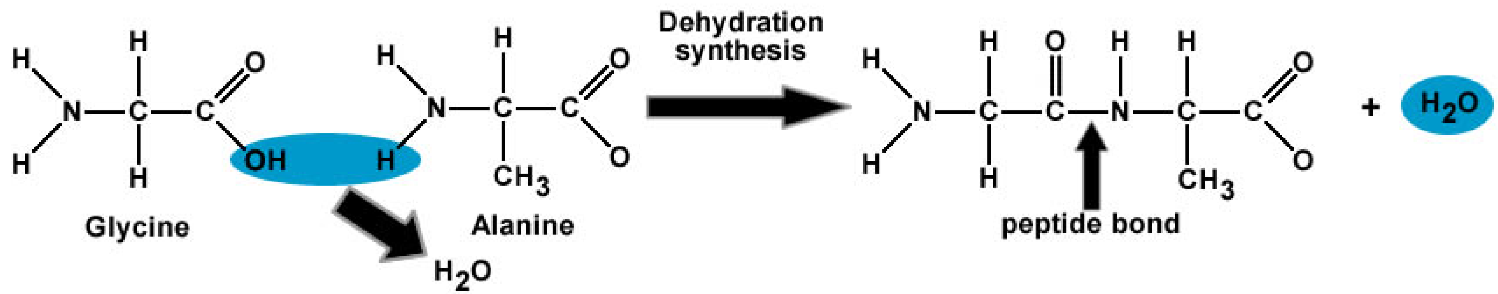
ie. amino acid → peptide → polypeptide → protein

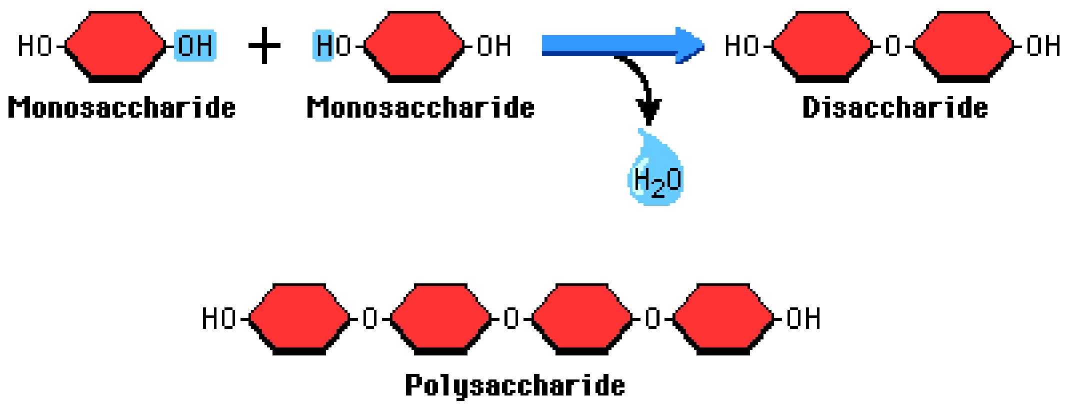
smaller → larger

Dehydration Synthesis (Condensation Reaction)	Hydrolysis
Make polymers	Breakdown polymers
Monomers → Polymers	Polymers → Monomers
A + B → AB	AB → A + B
	

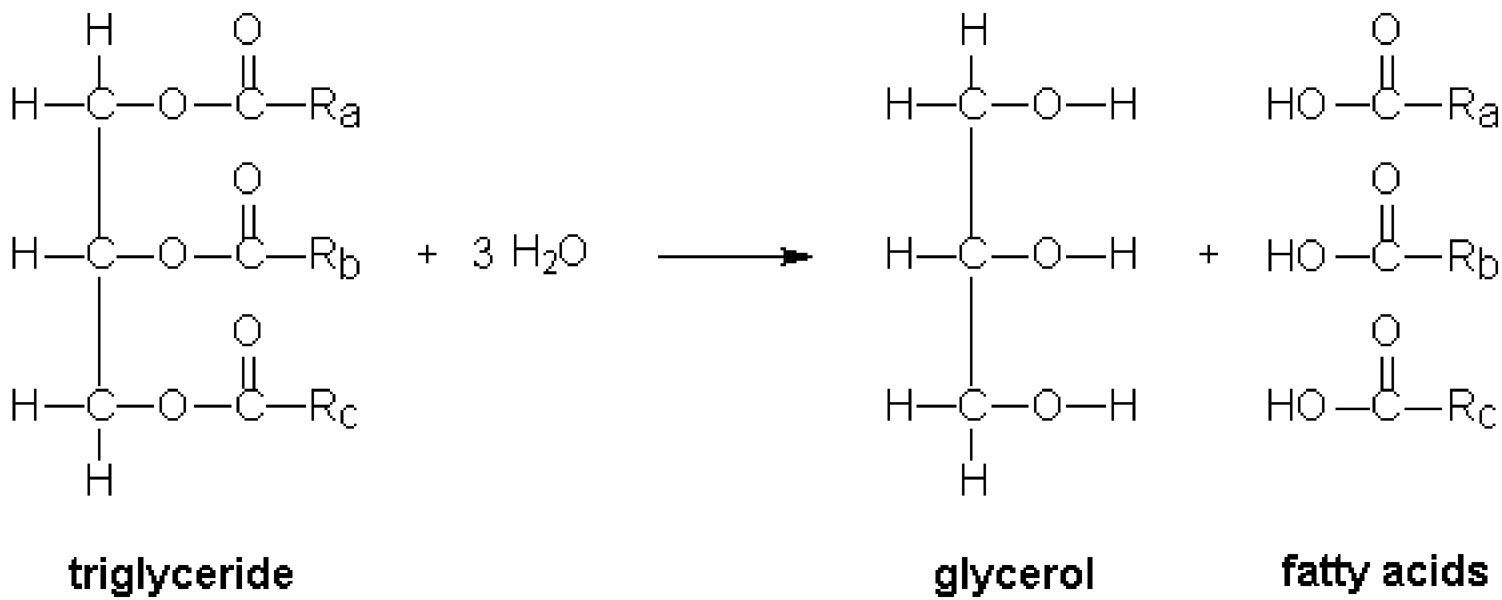

(a) Dehydration reaction: synthesizing a polymer
HO 1 2 3 H
HO H
Short polymer
Unlinked monomer
Dehydration removes a water molecule, forming a new bond.
H_2O
HO 1 2 3 4 H
Longer polymer
(b) Hydrolysis: breaking down a polymer
HO 1 2 3 4 H
Hydrolysis adds a water molecule, breaking a bond.
H_2O
HO 1 2 3 H
HO H

Dehydration Synthesis

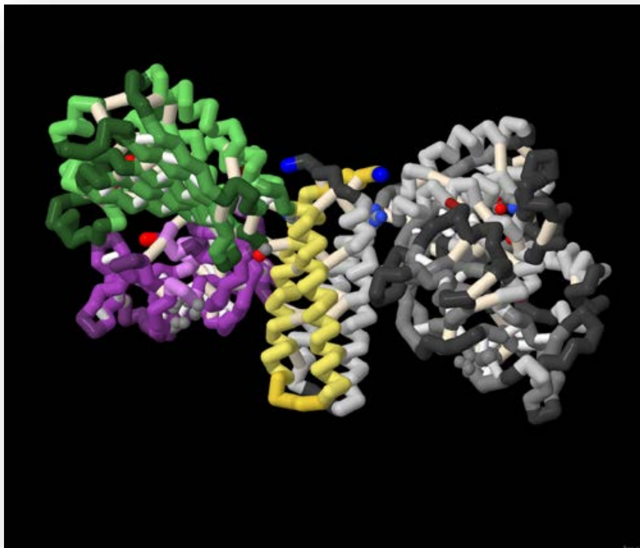


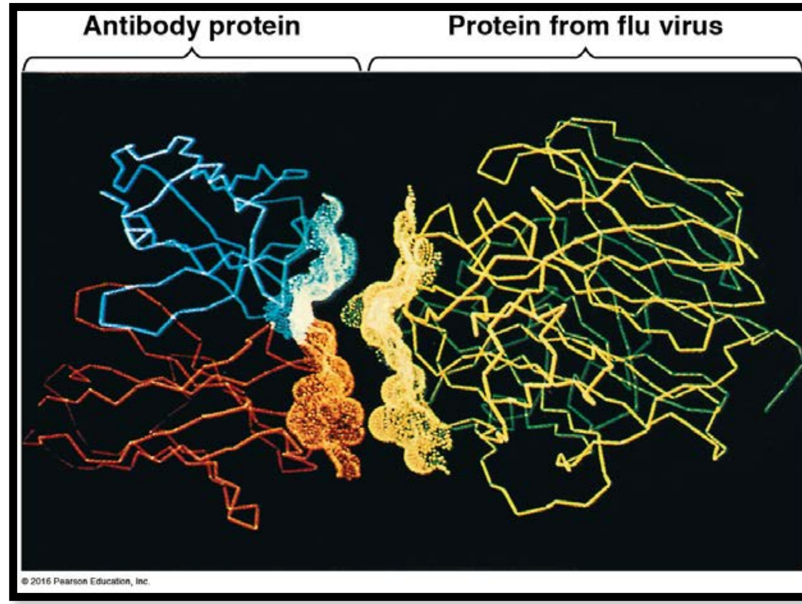


Hydrolysis



Proteomics: Analysis of proteins and sequences



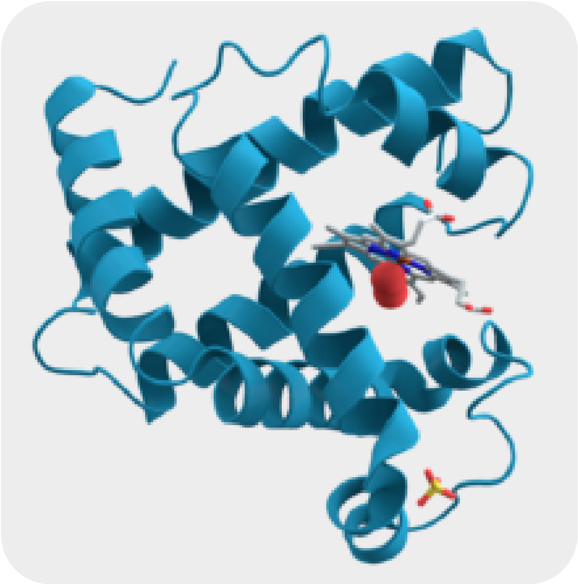


Species	Alignment of Amino Acid Sequences of β-globin					
Human	1	VHLTPEEKSA	VTALWGKVNV	DEVGGEALGR	LLVVYPWTQR	FFESFGDLST
Monkey	1	VHLTPEEKNA	VTTLWGKVNV	DEVGGEALGR	LLLVYPWTQR	FFESFGDLSS
Gibbon	1	VHLTPEEKSA	VTALWGKVNV	DEVGGEALGR	LLVVYPWTQR	FFESFGDLST
Human	51	PDAVMGNPKV	KAHGKKVLGA	FSDGLAHLDN	LKGTFATLSE	LHCDKLHVDP
Monkey	51	PDAVMGNPKV	KAHGKKVLGA	FSDGLNHLDN	LKGTFAQLSE	LHCDKLHVDP
Gibbon	51	PDAVMGNPKV	KAHGKKVLGA	FSDGLAHLDN	LKGTFAQLSE	LHCDKLHVDP
Human	101	ENFRLLGNVL	VCVLAHHFGK	EFTPPVQAAY	QKVVAGVANA	LAHKYH
Monkey	101	ENFKLLGNVL	VCVLAHHFGK	EFTPQVQAAY	QKVVAGVANA	LAHKYH
Gibbon	101	ENFRLLGNVL	VCVLAHHFGK	EFTPQVQAAY	QKVVAGVANA	LAHKYH

Data from Human: http://www.ncbi.nlm.nih.gov/protein/AAA21113.1; rhesus monkey: http://www.ncbi.nlm.nih.gov/ protein/122634; gibbon: http://www.ncbi.nlm.nih.gov/protein/122616

I. Proteins

- "Proteios" = first or primary
- 50% dry weight of cells
- Contains: C, H, O, N, S



Myoglobin protein

Protein Functions + examples

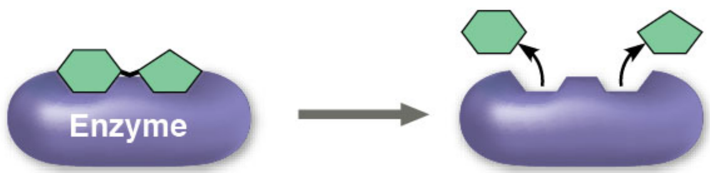
- Enzymes (lactase)
- Defense (antibodies)
- Storage (milk protein = casein)
- Transport (hemoglobin)
- Hormones (insulin)
- Receptors
- Movement (motor proteins)
- Structure (keratin)

Overview of protein functions

Enzymatic proteins

Function: Selective acceleration of chemical reactions

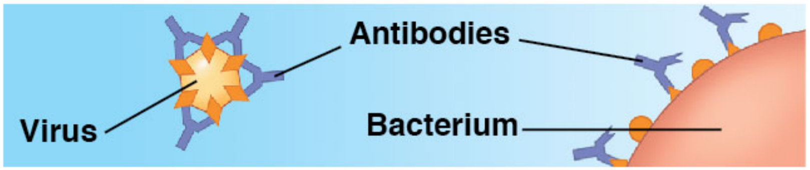
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.



Defensive proteins

Function: Protection against disease

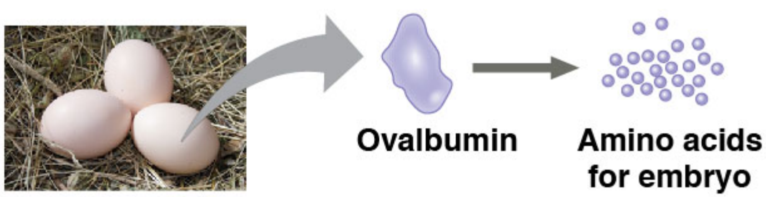
Example: Antibodies inactivate and help destroy viruses and bacteria.



Storage proteins

Function: Storage of amino acids

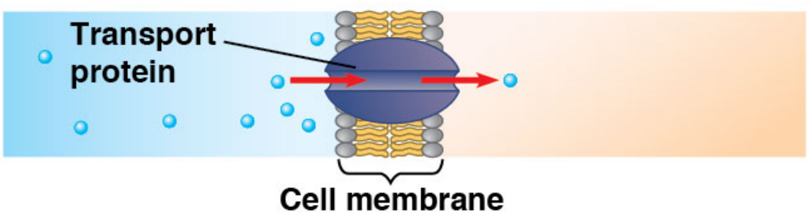
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.



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.

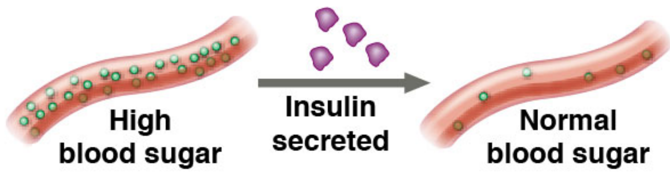


Overview of protein functions

Hormonal proteins

Function: Coordination of an organism's activities

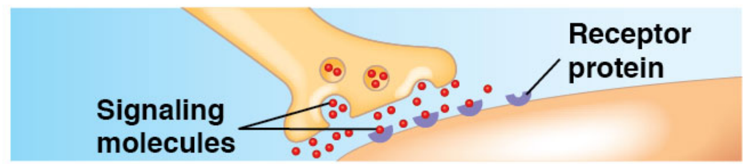
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.



Receptor proteins

Function: Response of cell to chemical stimuli

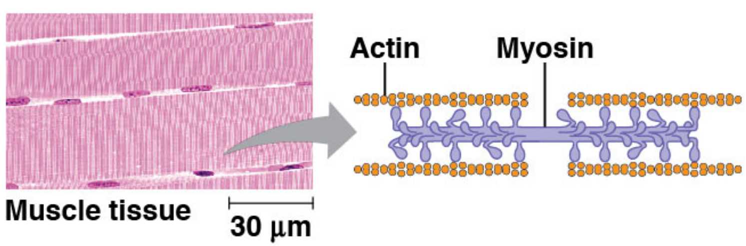
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



Contractile and motor proteins

Function: Movement

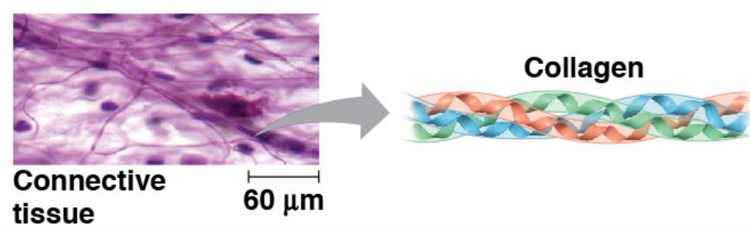
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.



Structural proteins

Function: Support

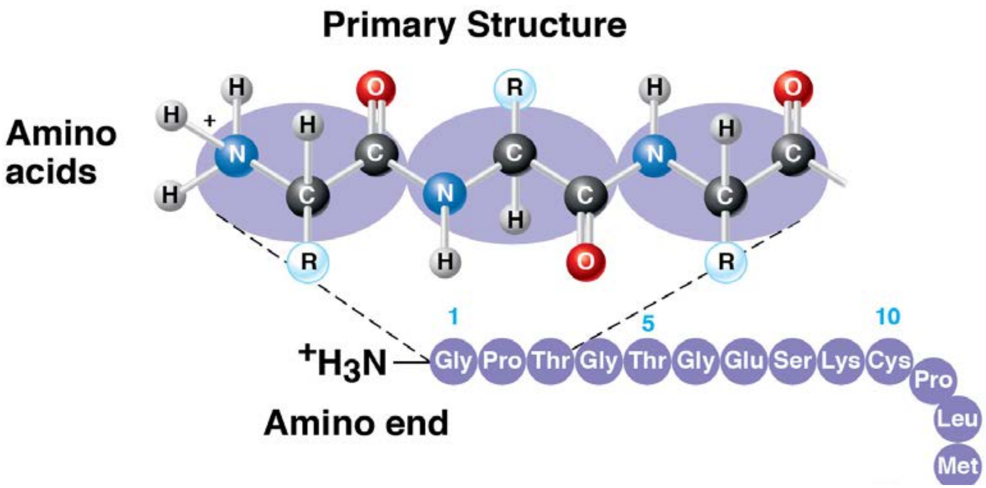
Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.

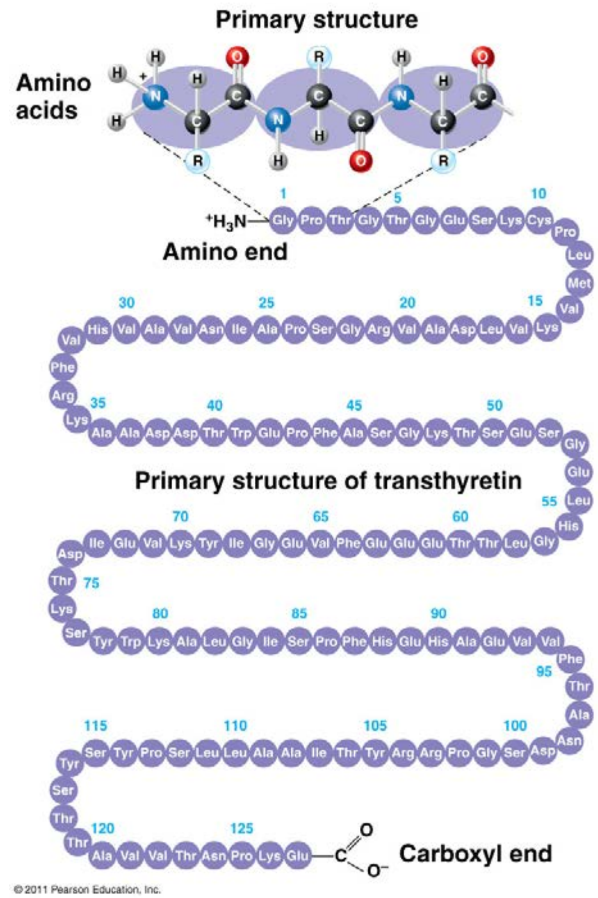


Four Levels of Protein Structure

Primary

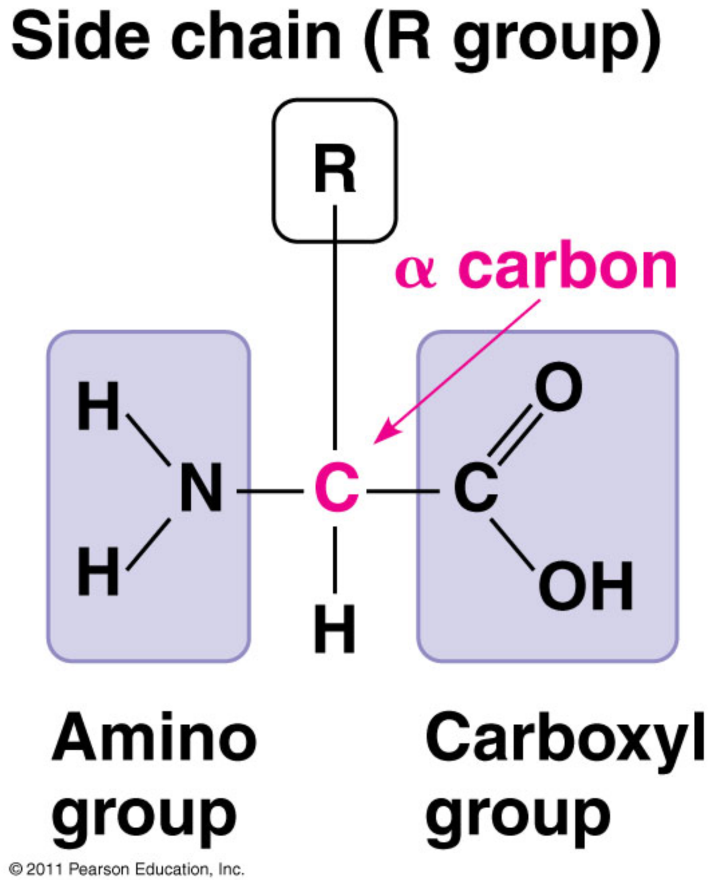
- *Linear sequence amino acids*
- 20 different aa’s
- **peptide bonds** link aa’s

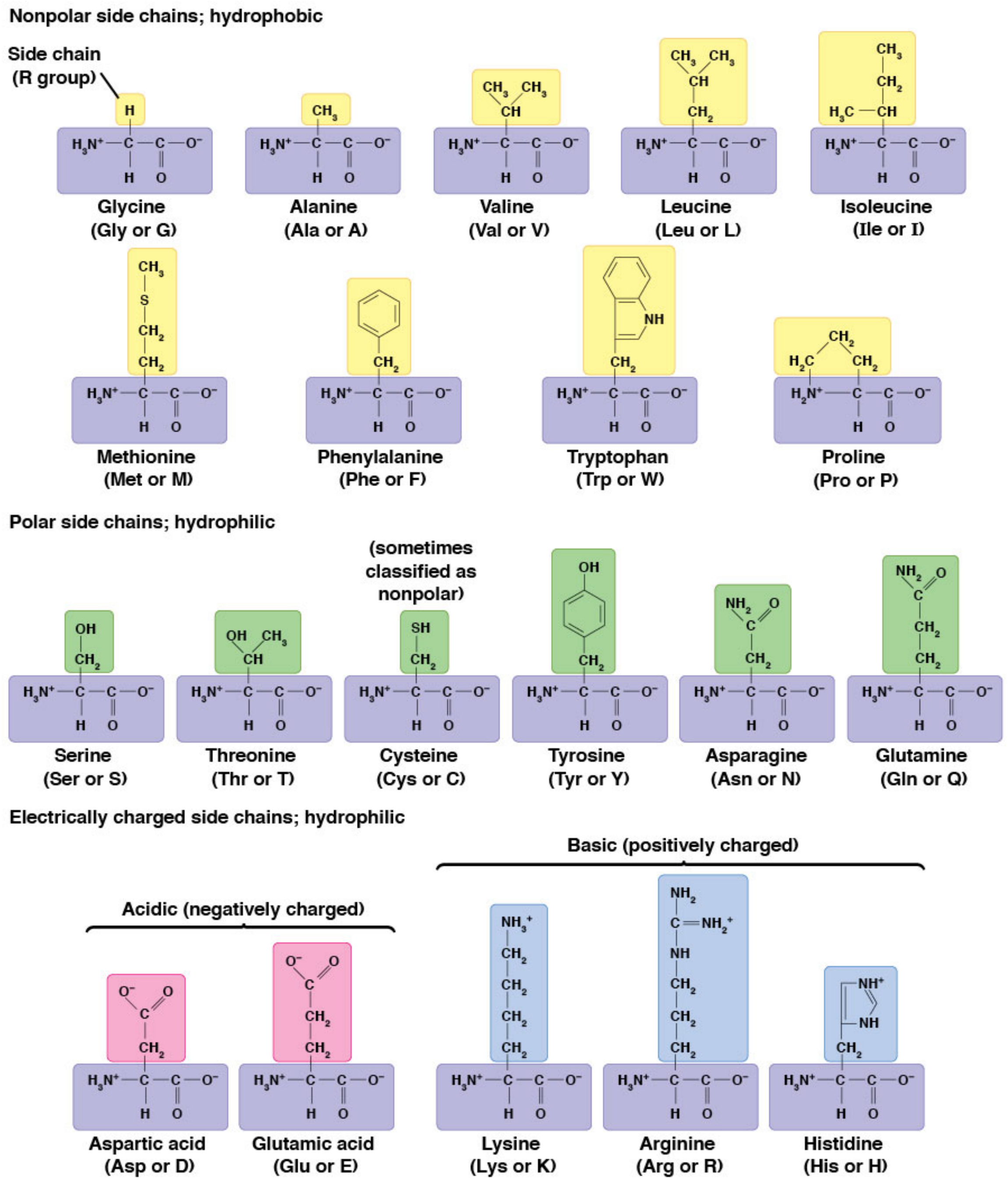


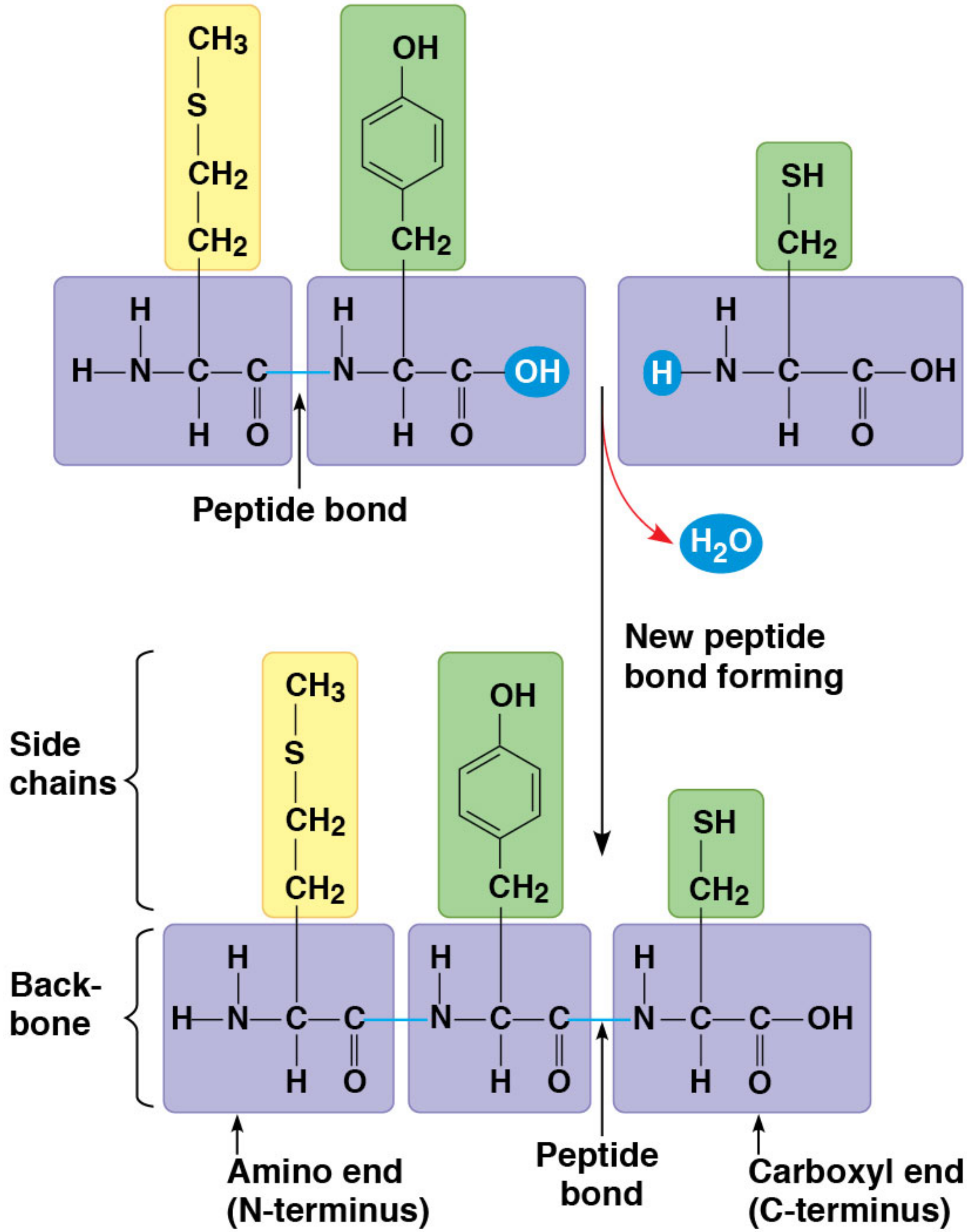


Amino Acid

- **R group** = side chains
- <u>Properties</u>:
  - hydrophobic
  - hydrophilic
  - ionic (acids & bases)
- "amino" : $-NH_2$
- "acid" : $-COOH$



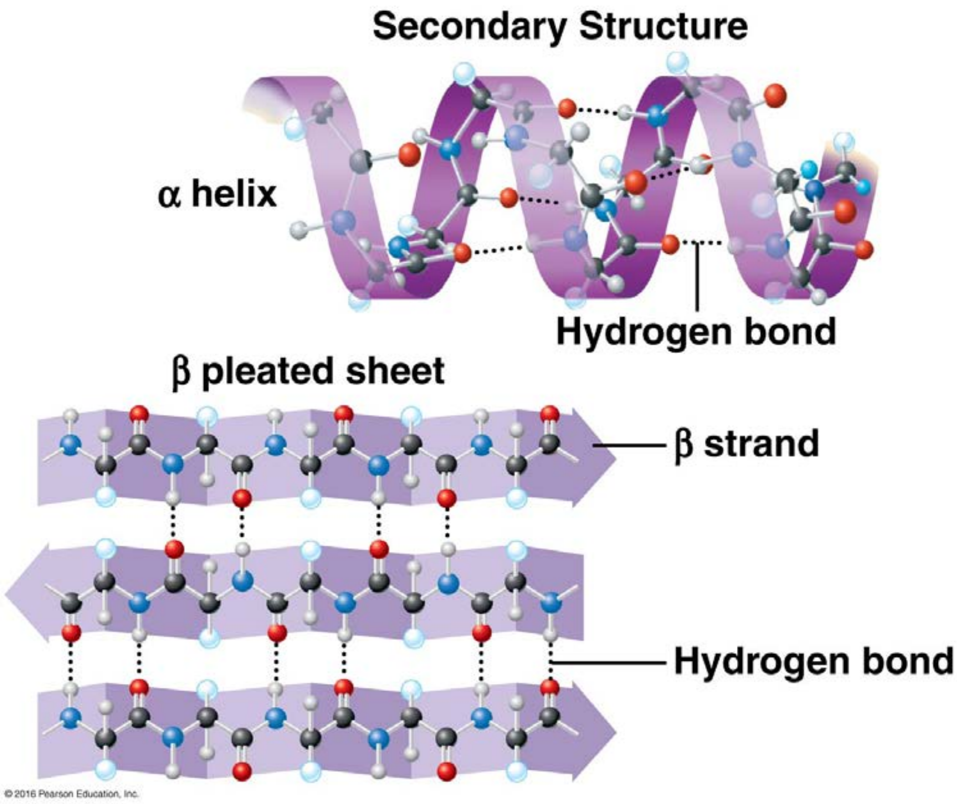

Nonpolar side chains; hydrophobic
Side chain (R group)
Glycine (Gly or G)
Alanine (Ala or A)
Valine (Val or V)
Leucine (Leu or L)
Isoleucine (Ile or I)
Methionine (Met or M)
Phenylalanine (Phe or F)
Tryptophan (Trp or W)
Proline (Pro or P)
Polar side chains; hydrophilic
(sometimes classified as nonpolar)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


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

Four Levels of Protein Structure

Secondary

- Gains 3-D shape (folds, coils)
- *Due to H-bonding*
- Alpha (α) helix, Beta (β) pleated sheet



Basic Principles of Protein Folding

A. Hydrophobic aa's buried in interior of protein (hydrophobic interactions)

B. Hydrophilic aa's exposed on surface of protein (hydrogen bonds)

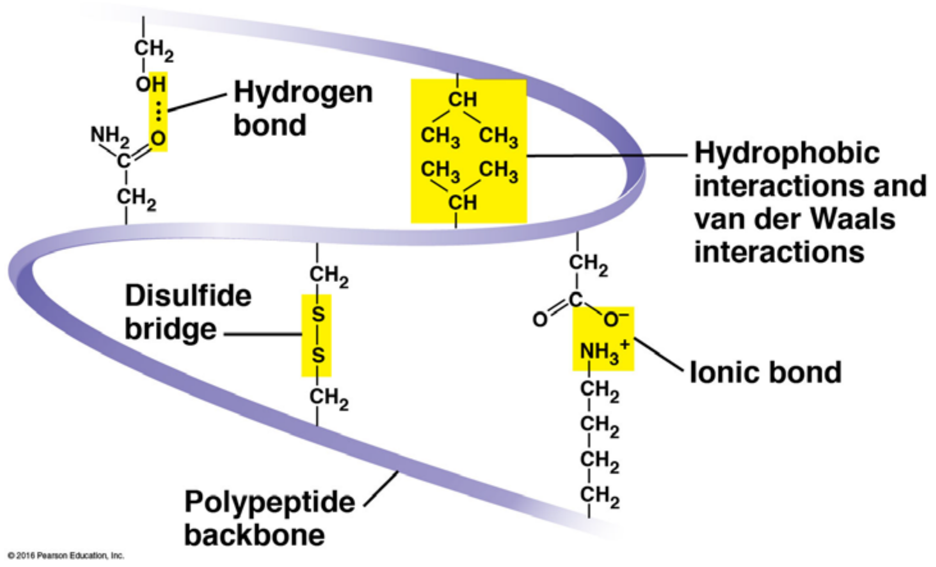
C. Acidic + Basic aa's form salt bridges (ionic bonds).

D. Cysteines can form disulfide bonds.

Four Levels of Protein Structure

Tertiary

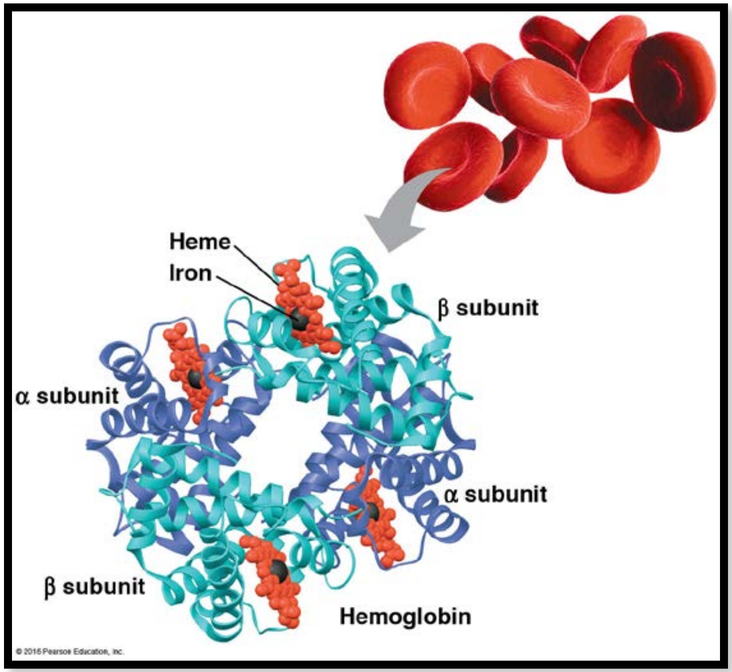
- Protein folds up on itself further
- Bonding between **side chains** (R groups) of amino acids
- H bonds, ionic bonds, disulfide bridges, hydrophobic interactions, van der Waals interactions
- 3D globular shape

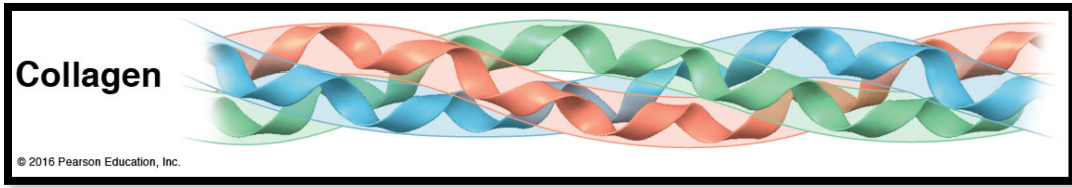


Four Levels of Protein Structure

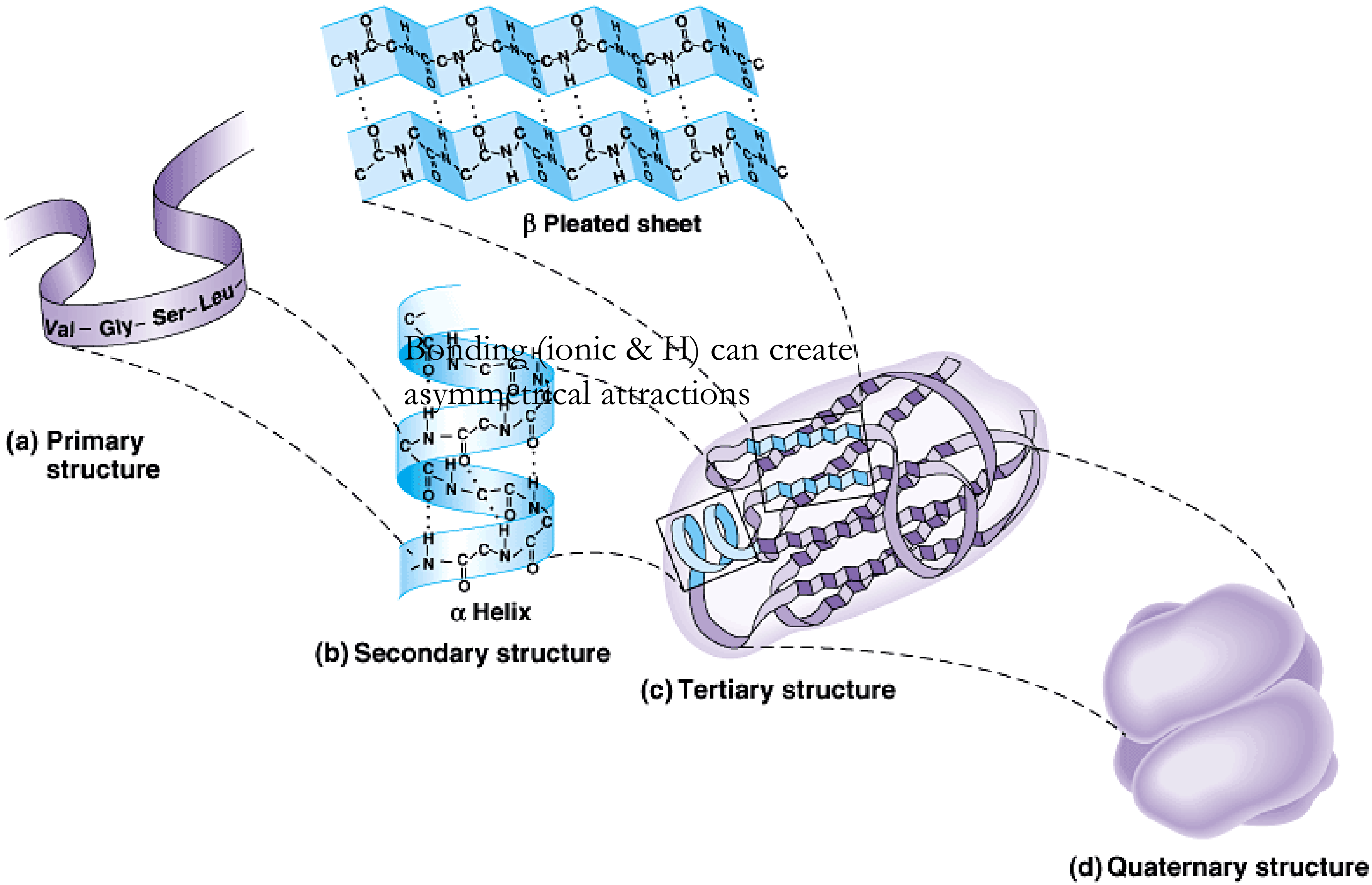
Quaternary

- **2+ polypeptides** bond together → Ex. Hemoglobin



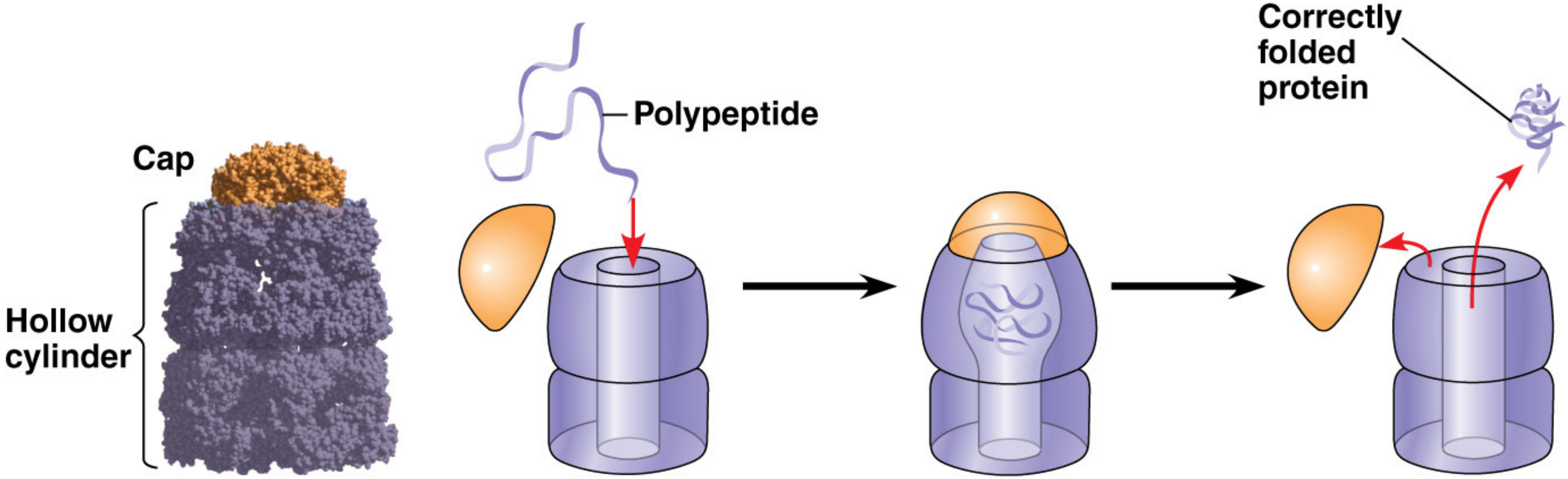


amino acids → polypeptides → protein



Bonding (ionic & H) can create asymmetrical attractions

<u>Chaperonins</u> assist in proper folding of proteins



Steps of Chaperonin Action:

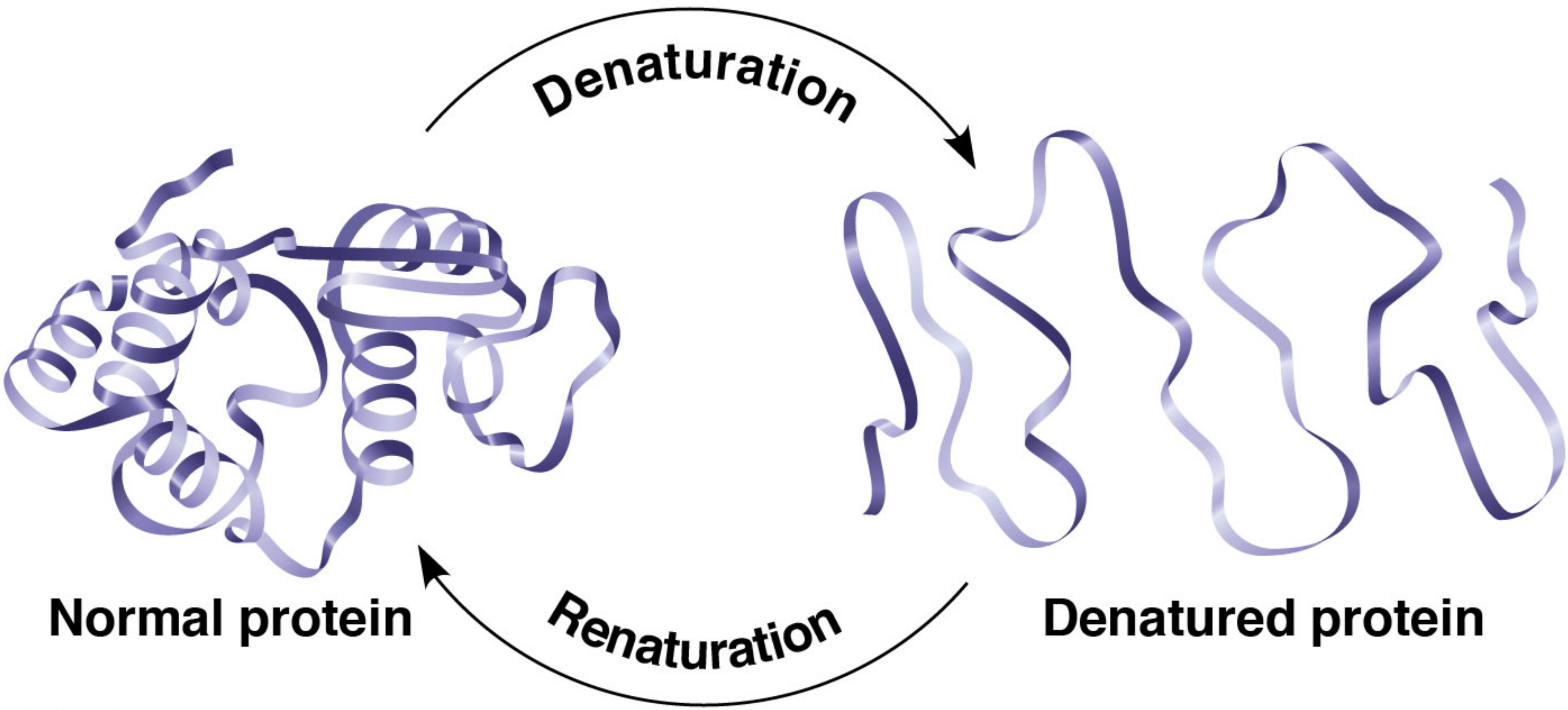
1. An unfolded polypeptide enters the cylinder from one end.
2. The cap attaches, causing the cylinder to change shape in such a way that it creates a hydrophilic environment for the folding of the polypeptide.
3. The cap comes off, and the properly folded protein is released.

Protein Structure & Folding:

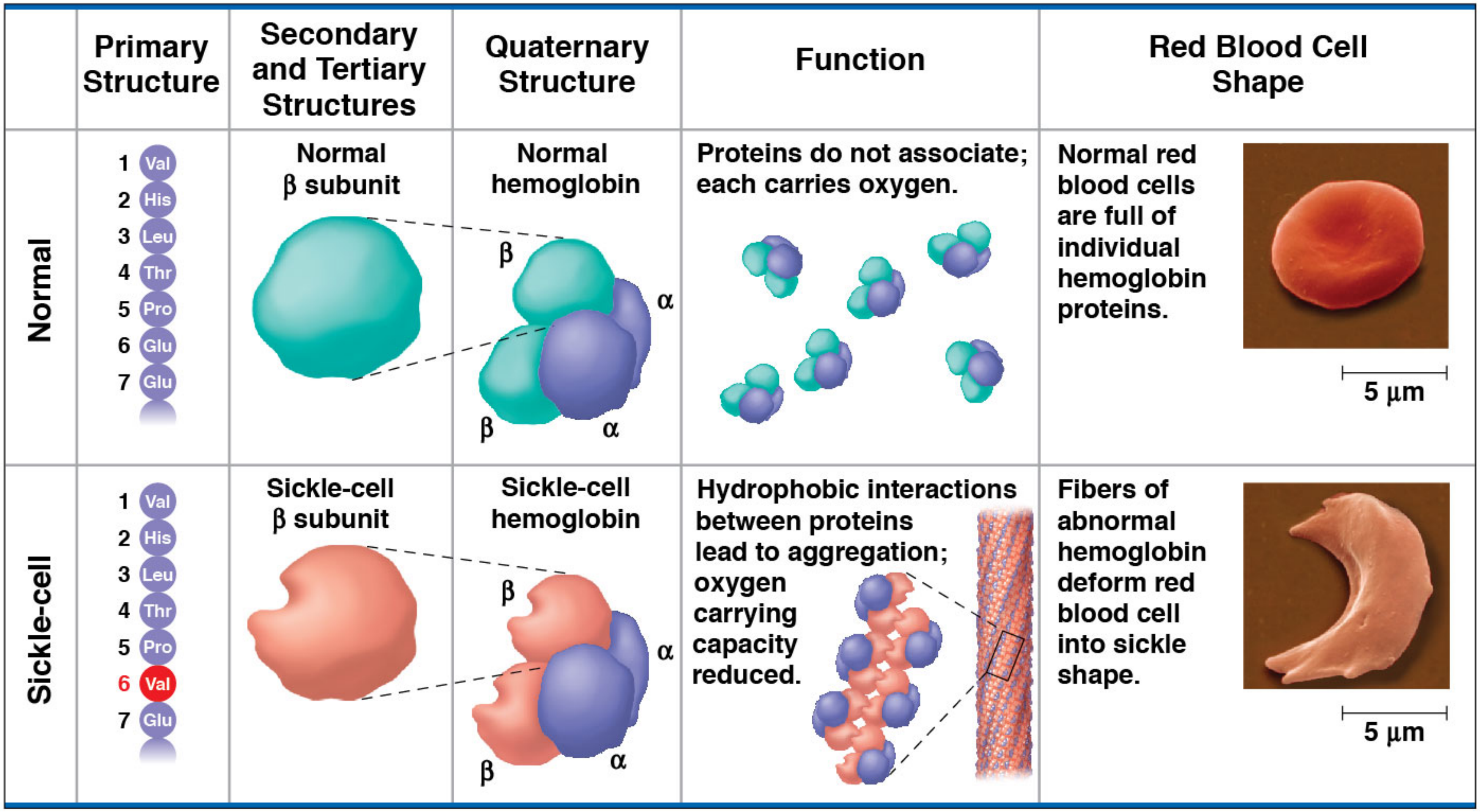
https://www.youtube.com/watch?v=z6OTR0oX3_E

- Protein **structure and function** are sensitive to chemical and physical conditions

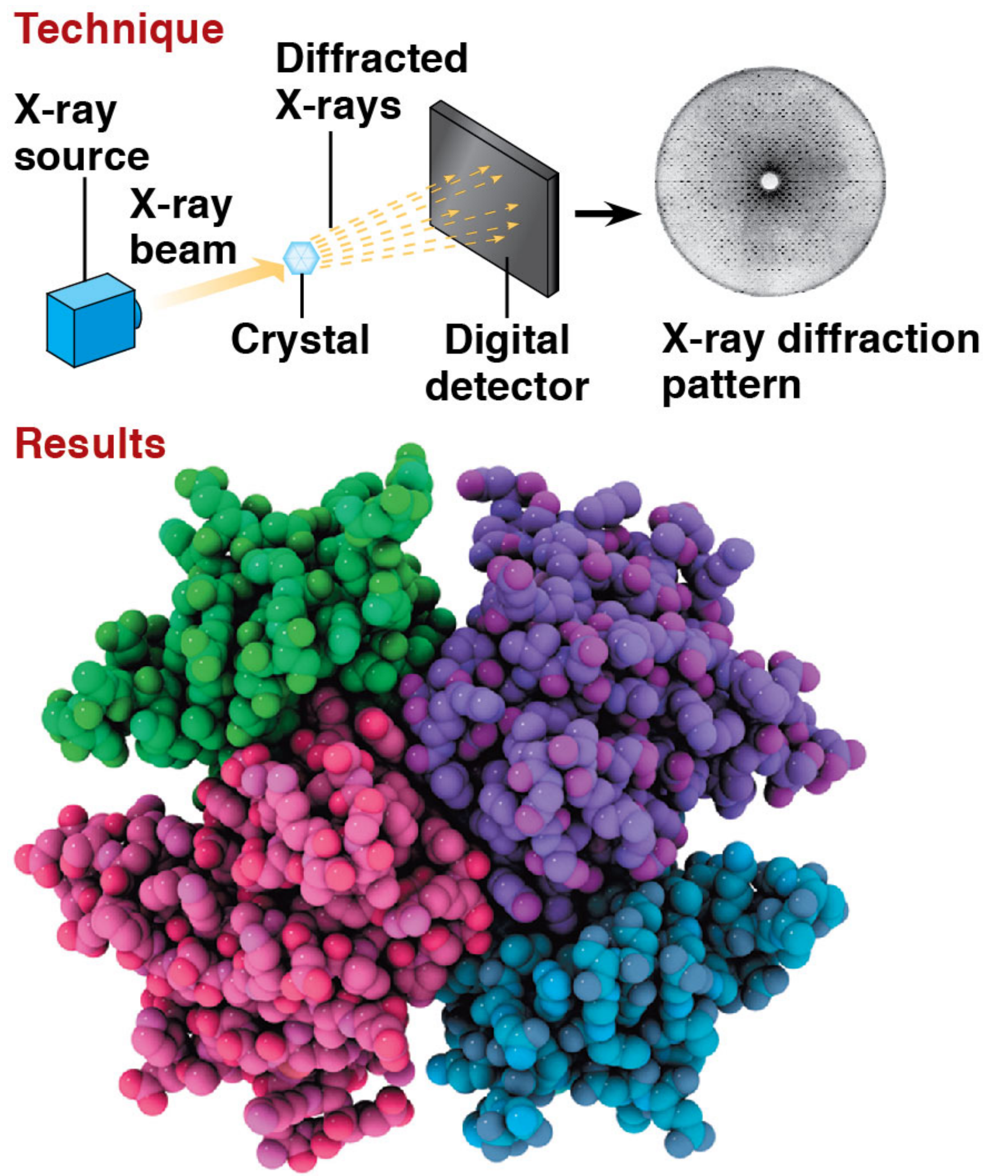
- Unfolds or **denatures** if **pH** and/or **temperature** are not optimal



A change in structure = A change in function



X-ray crystallography used to determine the 3-D structure of proteins



Genomics: Analysis of genes and genomes

II. Nucleic Acids

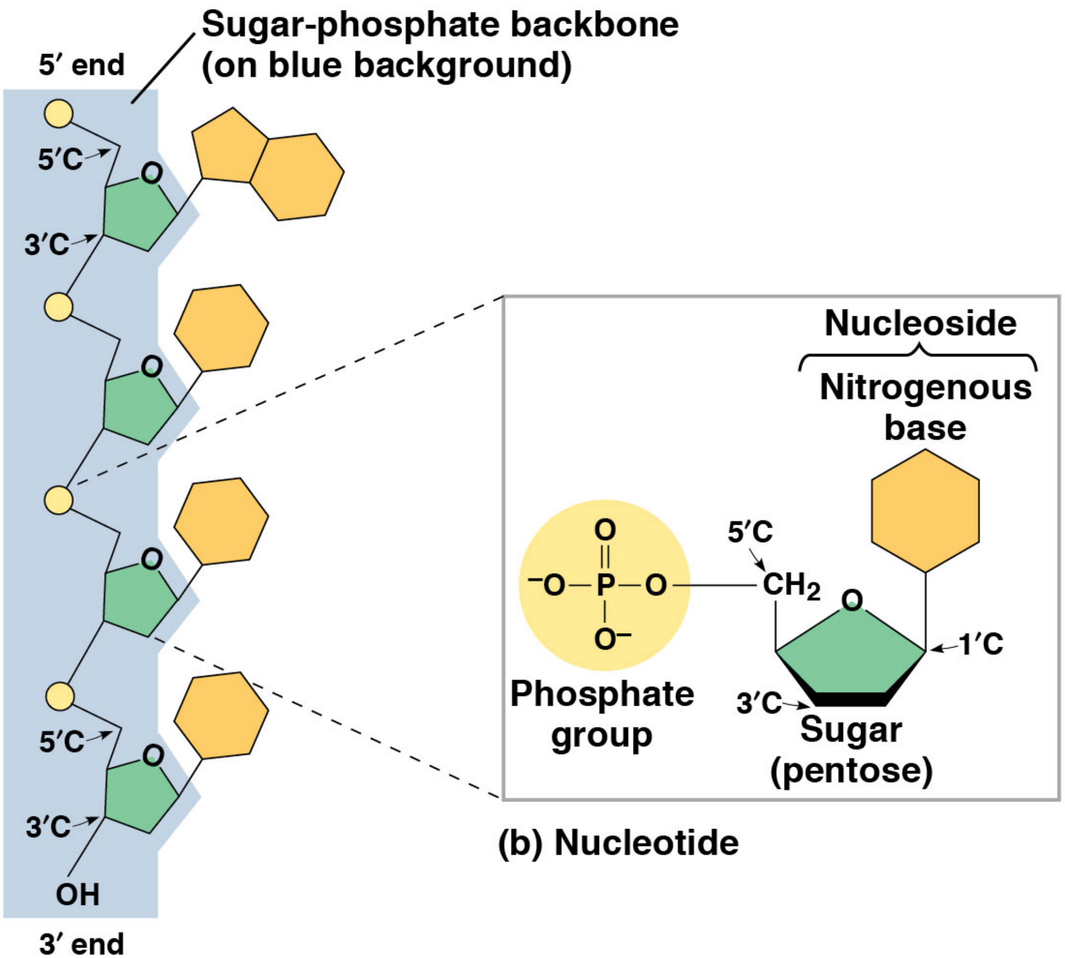
- Function: store hereditary info

DNA	RNA
• Double-stranded helix • N-bases: A, G, C, *Thymine* • Stores hereditary info • Longer/larger • Sugar: deoxyribose	• Single-stranded • N-bases: A, G, C, *Uracil* • Carry info from DNA to ribosomes • tRNA, rRNA, mRNA, RNAi • Sugar: ribose

- **Nucleic acids** are *polymers* of **nucleotides**

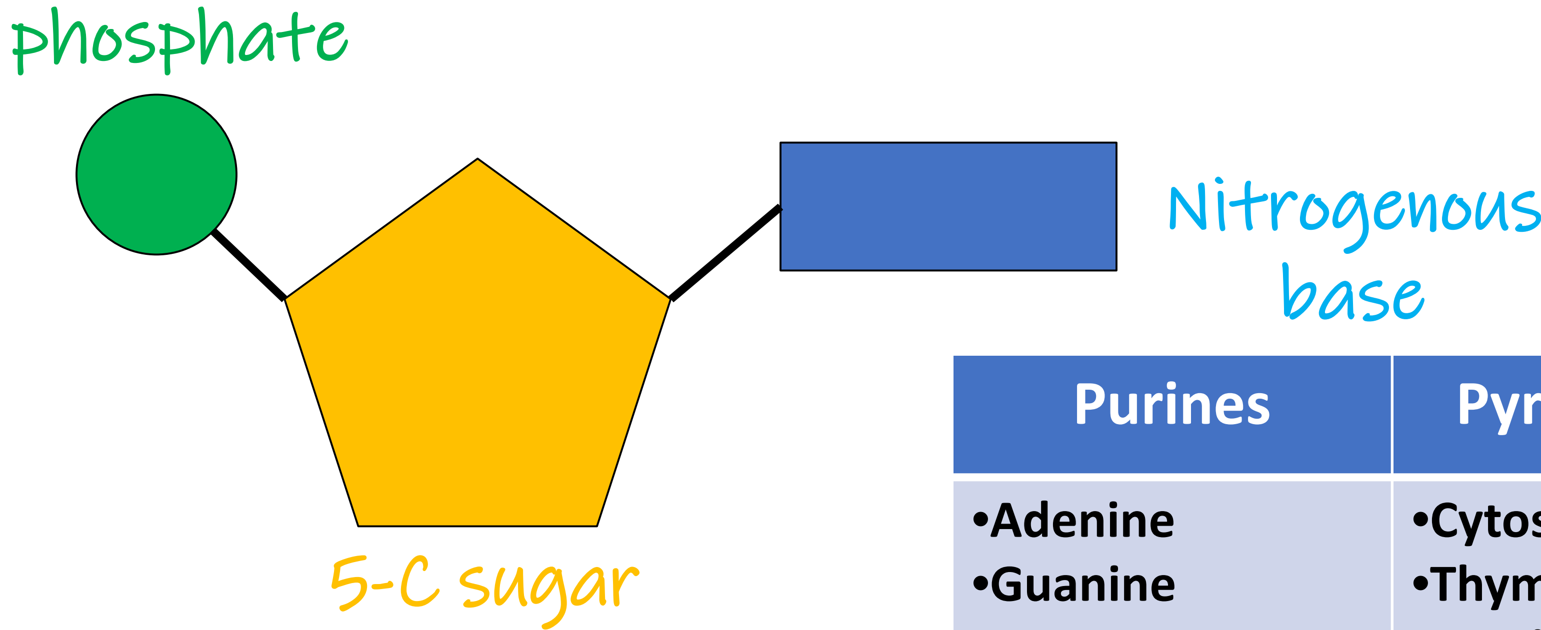
A nucleotide monomer has ***3 parts***:

- Sugar
- Phosphate
- Nitrogen Base



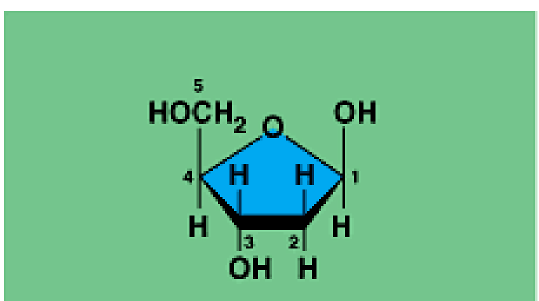
(a) Polynucleotide, or nucleic acid

Nucleotide Structure

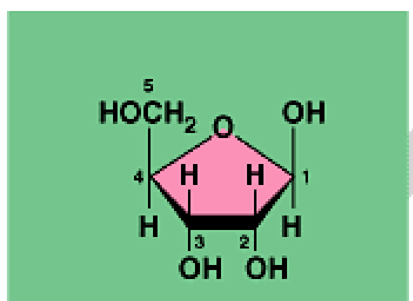


A – T
G – C

Purines	Pyrimidines
•Adenine •Guanine	•Cytosine •Thymine (DNA) •Uracil (RNA)
•Double ring	•Single ring

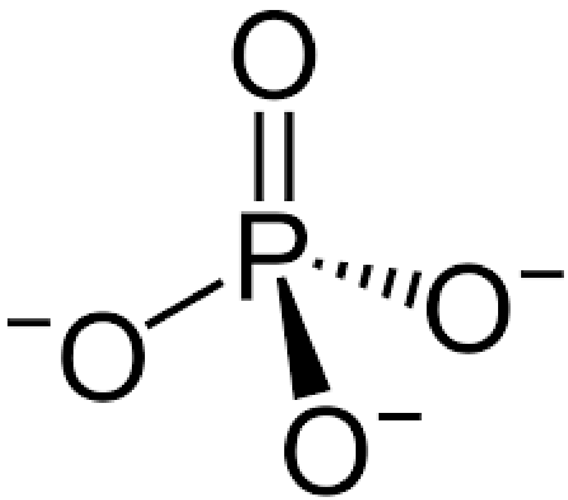


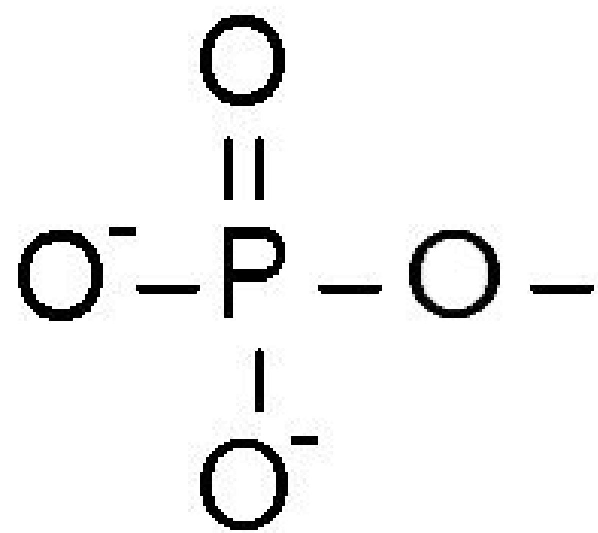
Deoxyribose (in DNA)



Ribose (in RNA)

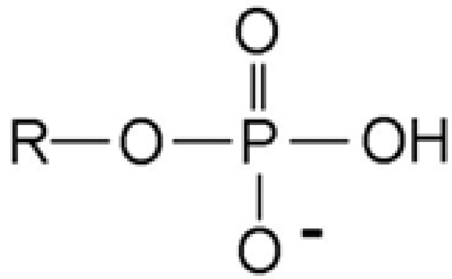
Phosphate group:



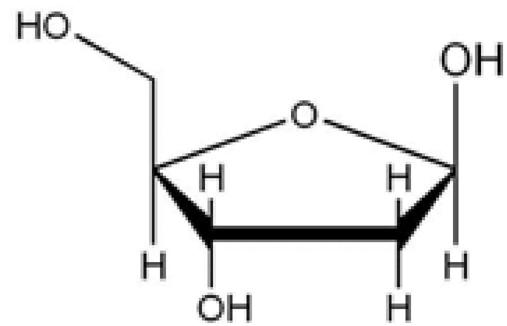


Deoxyribonucleotides:

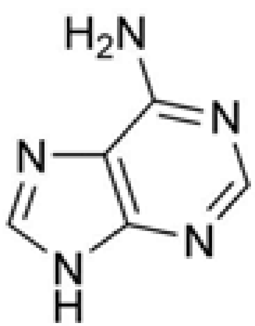
Phosphate group



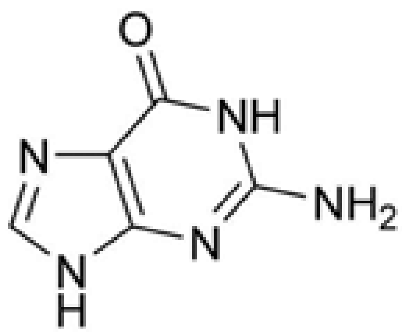
Deoxyribose



Purines

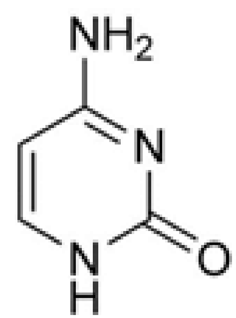


Adenine

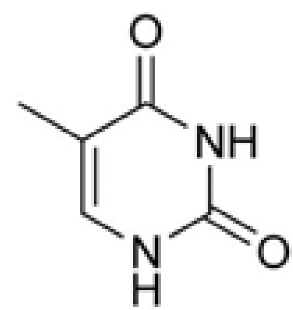


Guanine

Pyrimidines

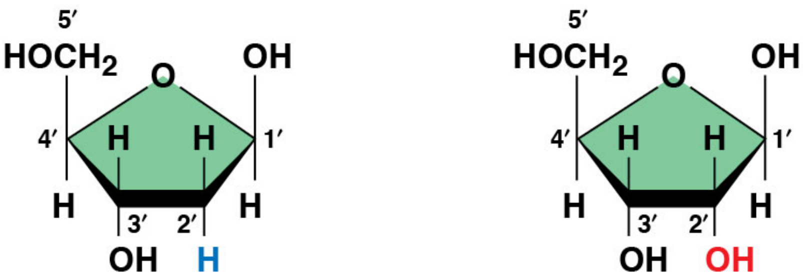


Cytosine



Thymine

SUGARS

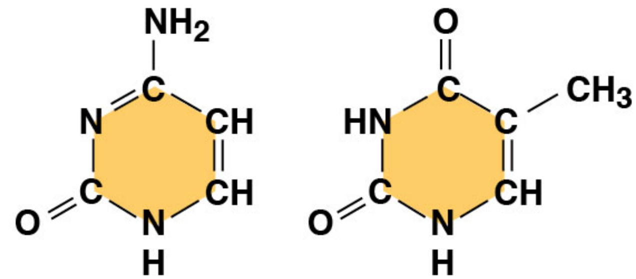


Deoxyribose (in DNA) — **Ribose (in RNA)**

(c) Nucleoside components

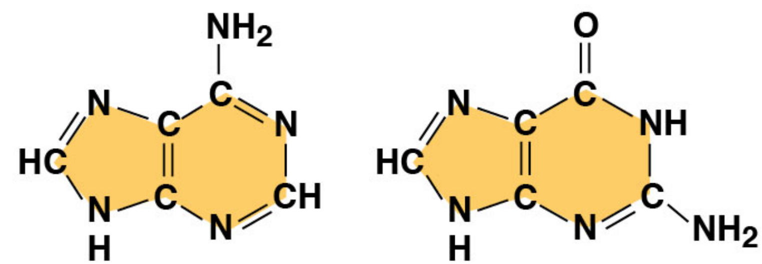
NITROGENOUS BASES

Pyrimidines



Cytosine (C) — **Thymine (T, in DNA)** — **Uracil (U, in RNA)**

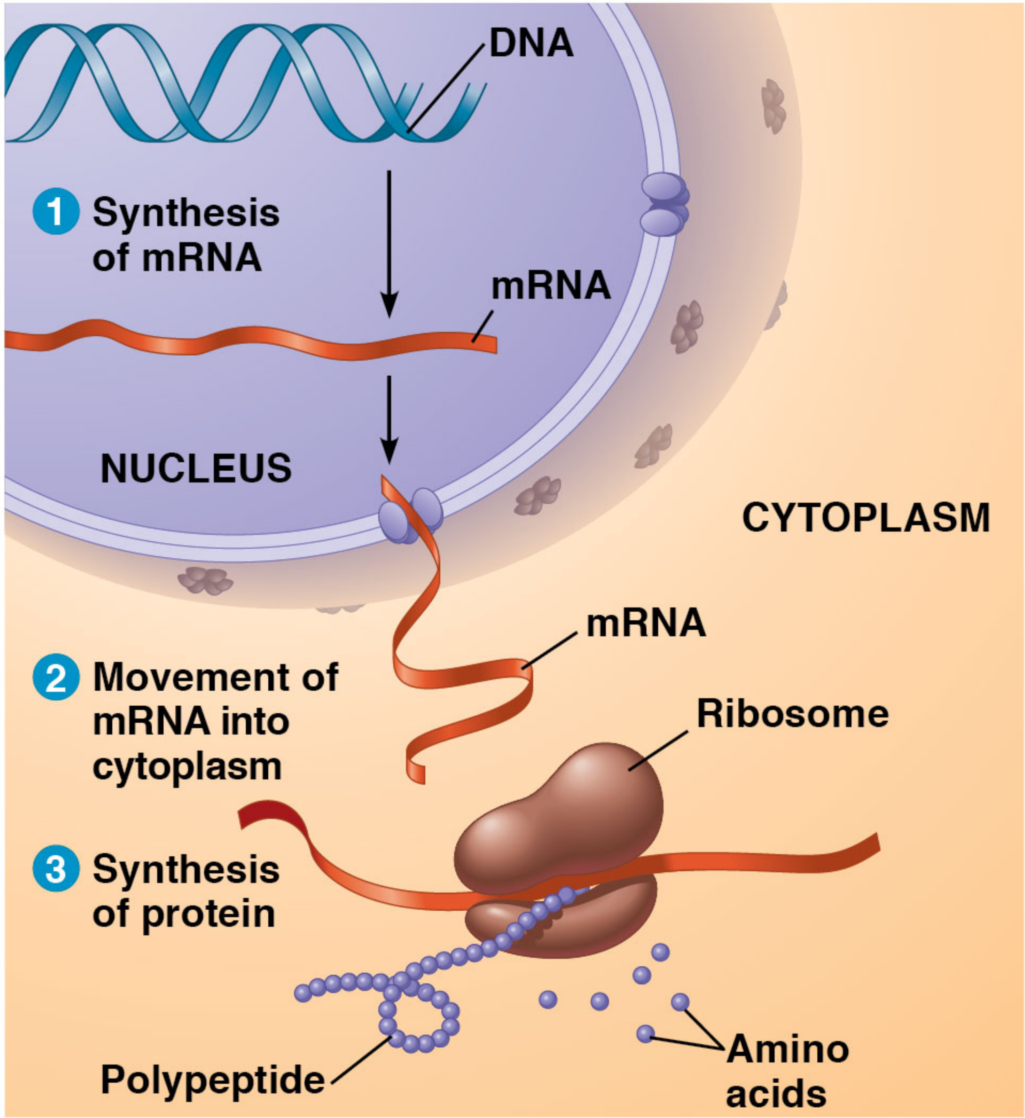
Purines



Adenine (A) — **Guanine (G)**

(c) Nucleoside components

Information flow in a cell:
DNA → RNA → protein

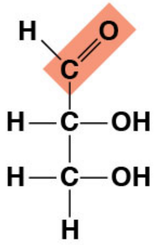


III. Carbohydrates

- **Fuel** and **building material**
- Include simple sugars (fructose) and polymers (starch)
- Ratio of 1 carbon: 2 hydrogen: 1 oxygen or CH_2O (empirical formula)
- monosaccharide → disaccharide → polysaccharide
- **Monosaccharides** = monomers (eg. glucose, ribose)
- **Polysaccharides:**
  - Storage (plants-starch, animals-glycogen)
  - Structure (plant-cellulose, arthropod-chitin)

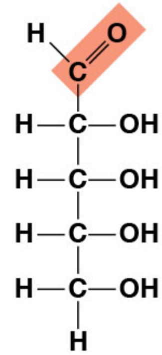
} Differ in position & orientation of glycosidic linkage

Triose: three-carbon sugar ($C_3H_6O_3$)



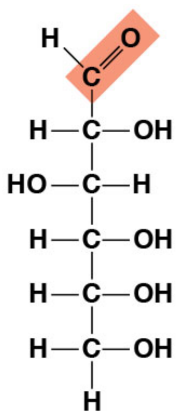
Glyceraldehyde
An initial breakdown product of glucose in cells

Pentose: five-carbon sugar ($C_5H_{10}O_5$)

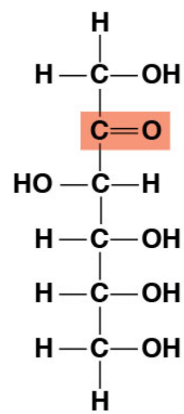


Ribose
A component of RNA

Hexoses: six-carbon sugars ($C_6H_{12}O_6$)



Glucose

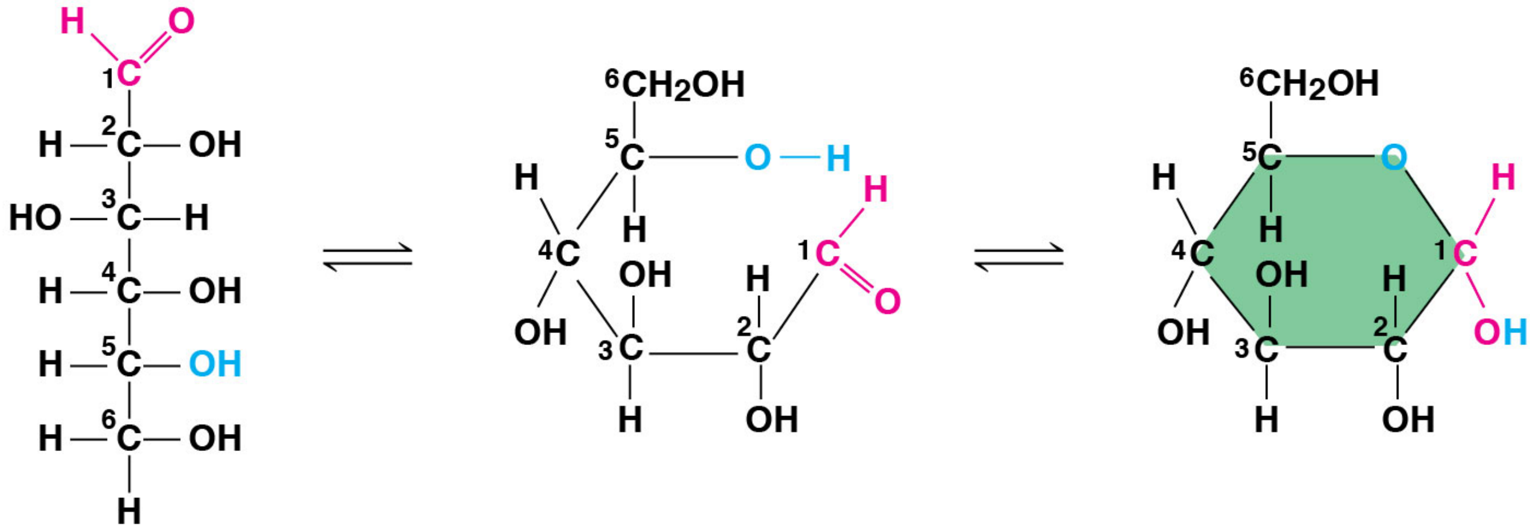


Fructose

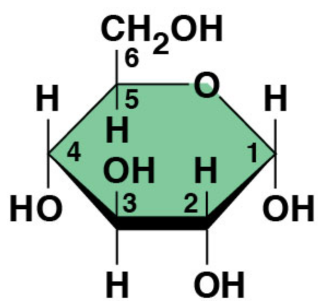
Energy sources for organisms

The structure and classification of some monosaccharides

Linear and ring forms of glucose

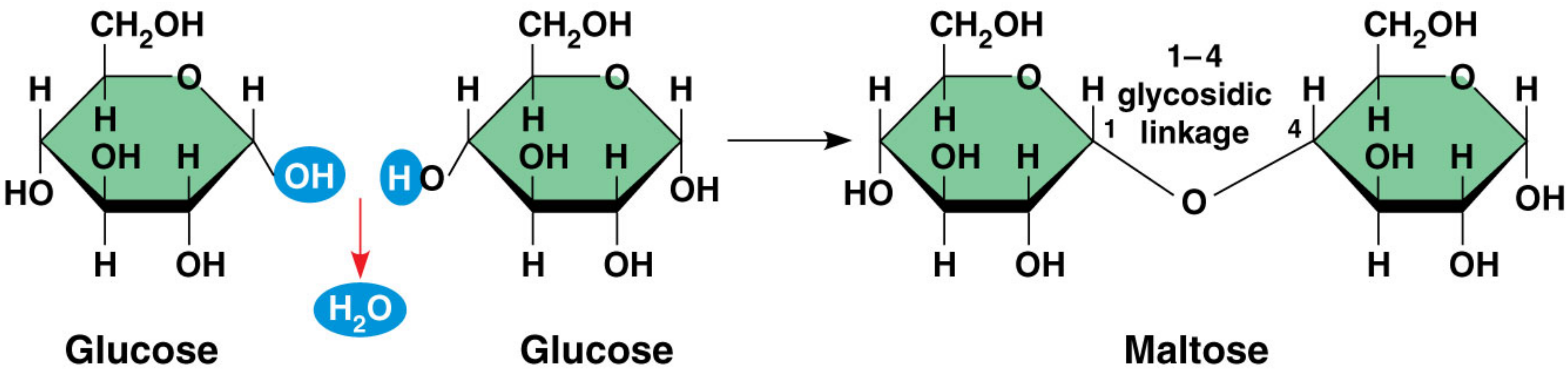


(a) Linear and ring forms

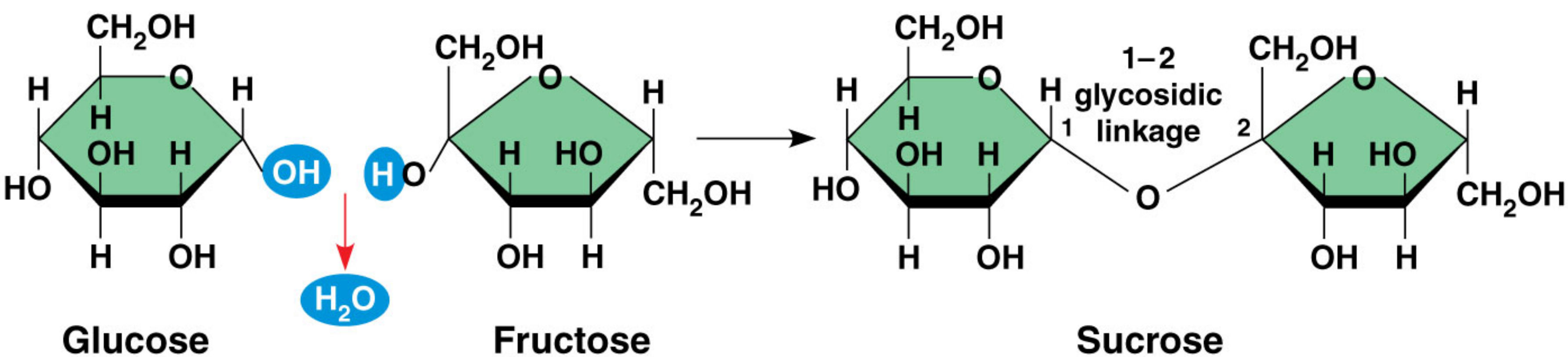


(b) Abbreviated ring structure

Carbohydrate synthesis



(a) Dehydration reaction in the synthesis of maltose

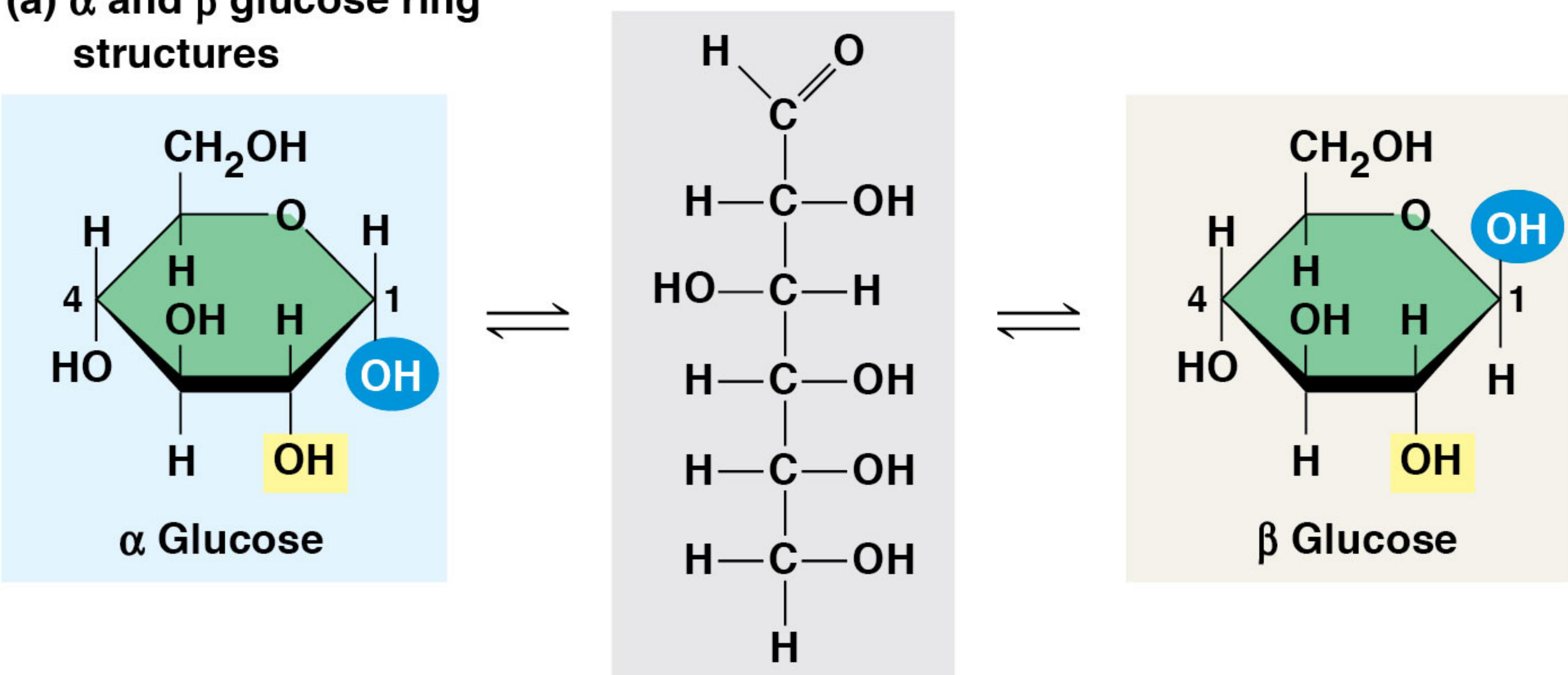


(b) Dehydration reaction in the synthesis of sucrose

Cellulose vs. Starch

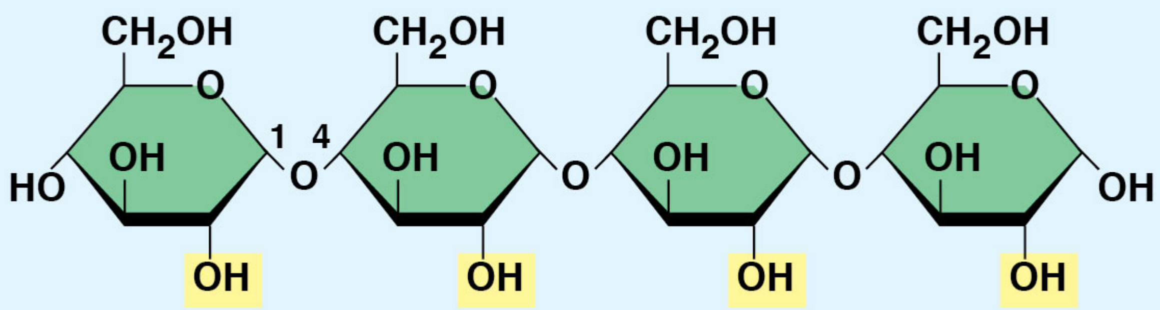
- Two Forms of Glucose: α glucose and β glucose

(a) α and β glucose ring structures

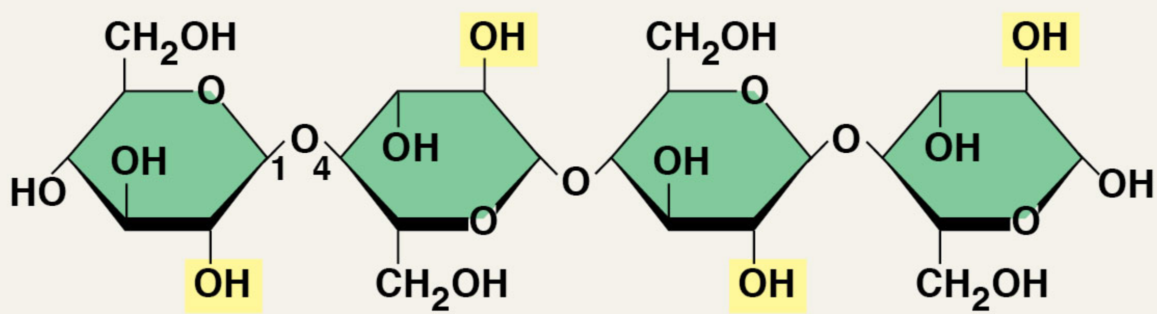


Cellulose vs. Starch

- Starch = **α** glucose monomers
- Cellulose = **β** glucose monomers

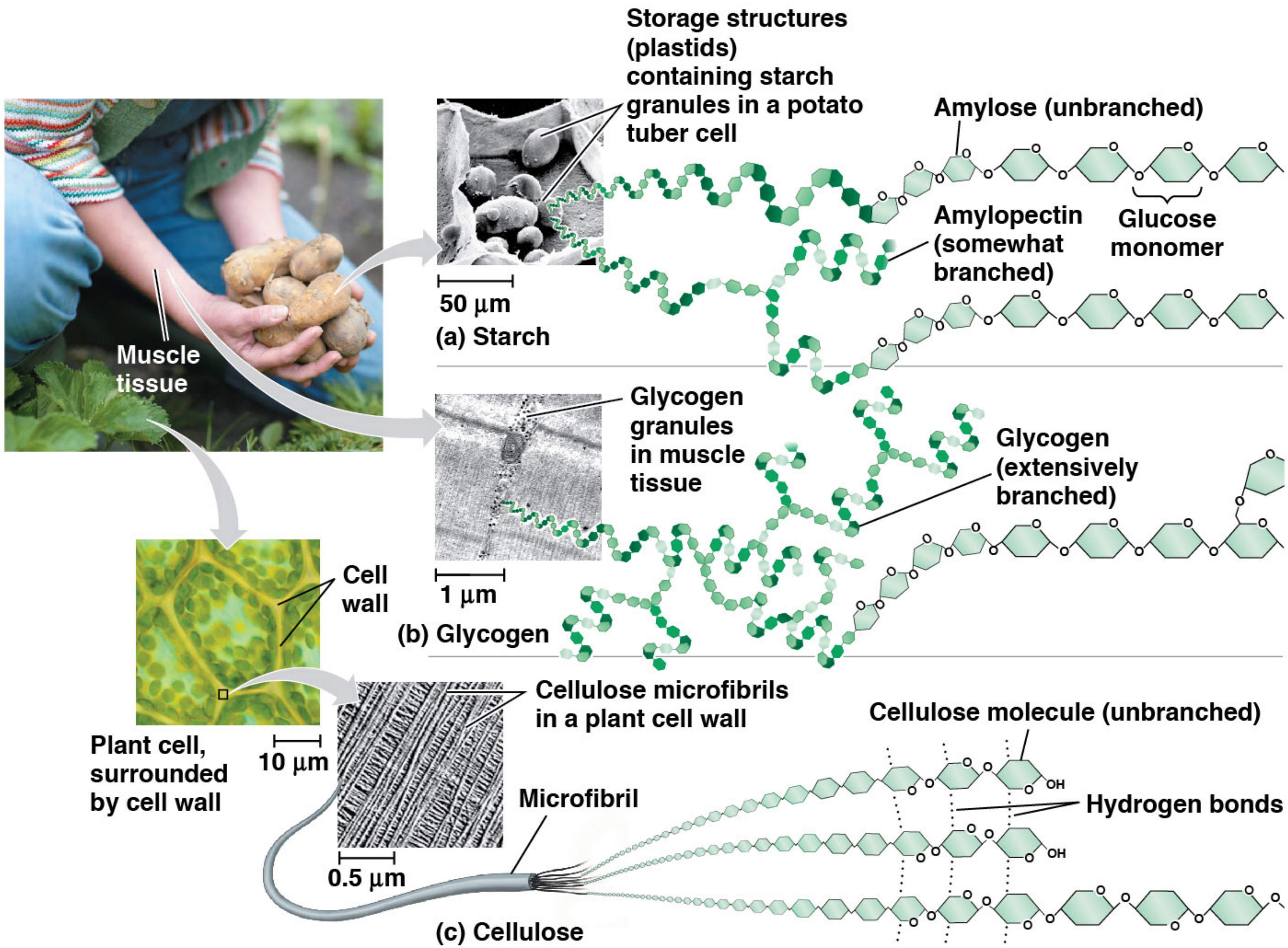


(b) Starch: 1–4 linkage of α glucose monomers

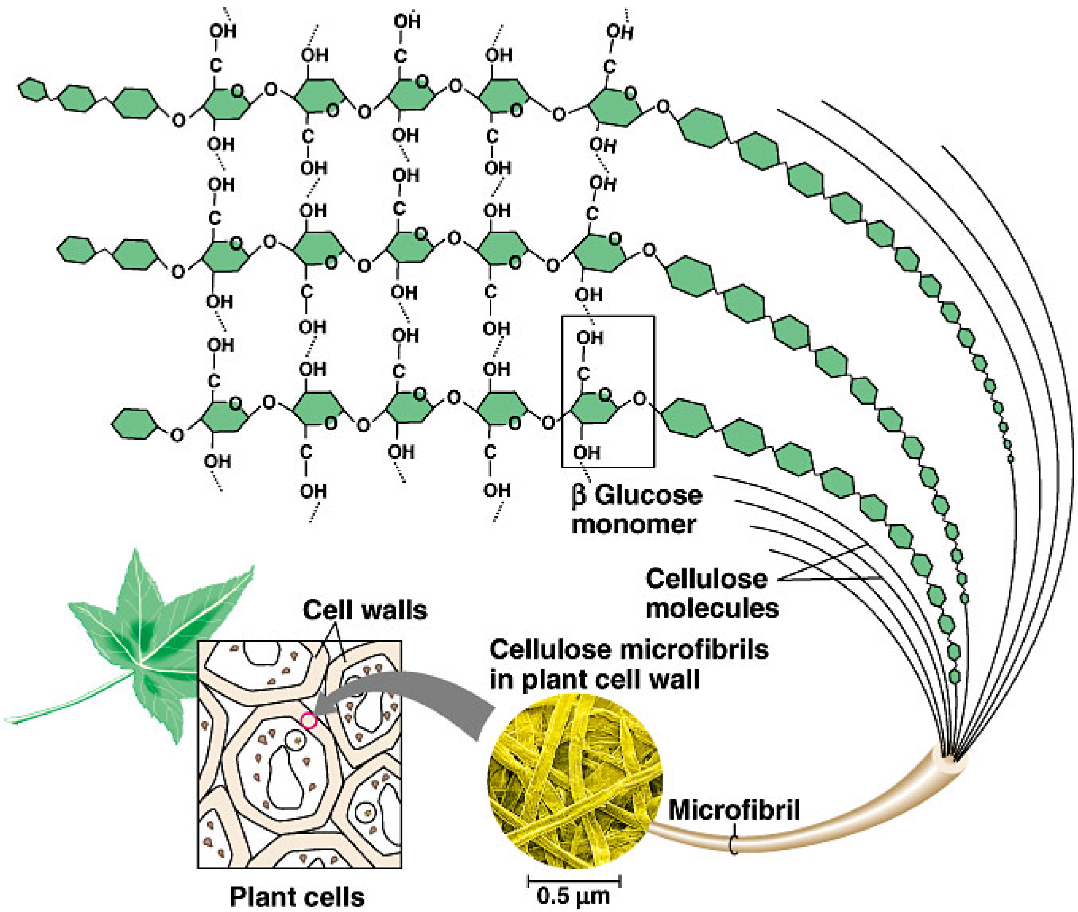


(c) Cellulose: 1–4 linkage of β glucose monomers

Storage polysaccharides: Starch (plants) and Glycogen (animals)



Structural polysaccharides: Cellulose & Chitin (exoskeleton)



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

IV. Lipids

A. **Fats (triglycerides)**

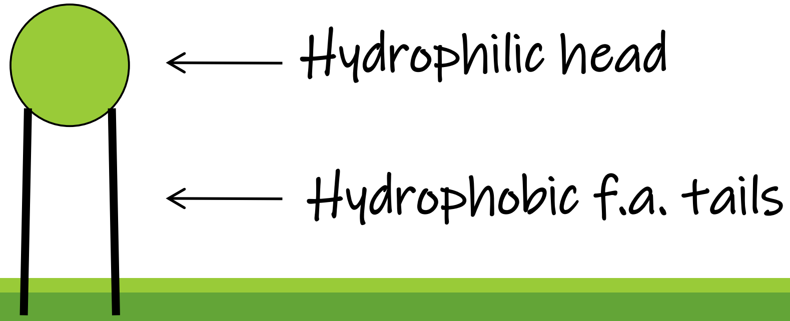
- Store energy/insulate against heat loss/protect internal organs
- Glycerol + 3 Fatty Acids
- Saturated, unsaturated, polyunsaturated

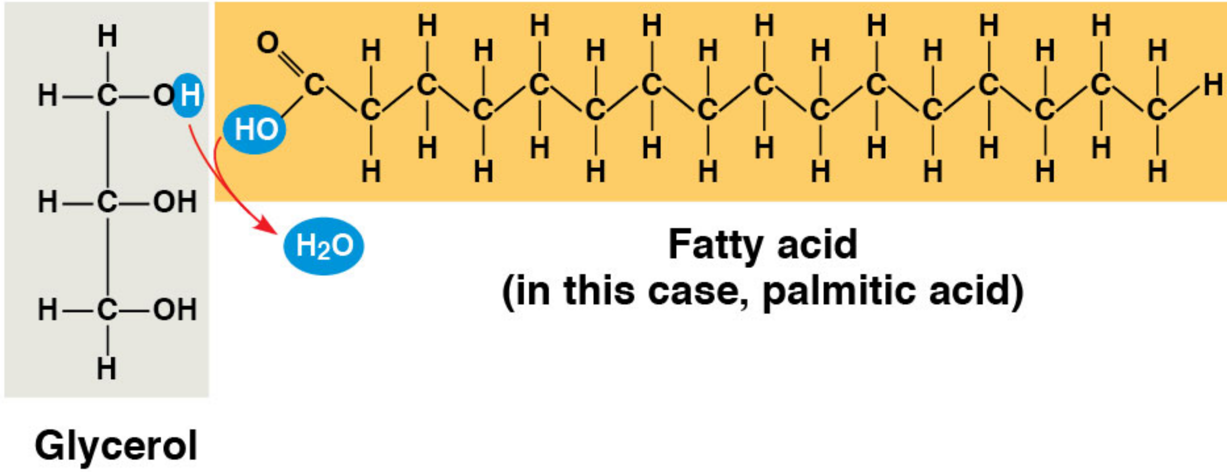
B. **Steroids**: cholesterol

- Component of cell membranes
- Precursor of other molecules like hormones

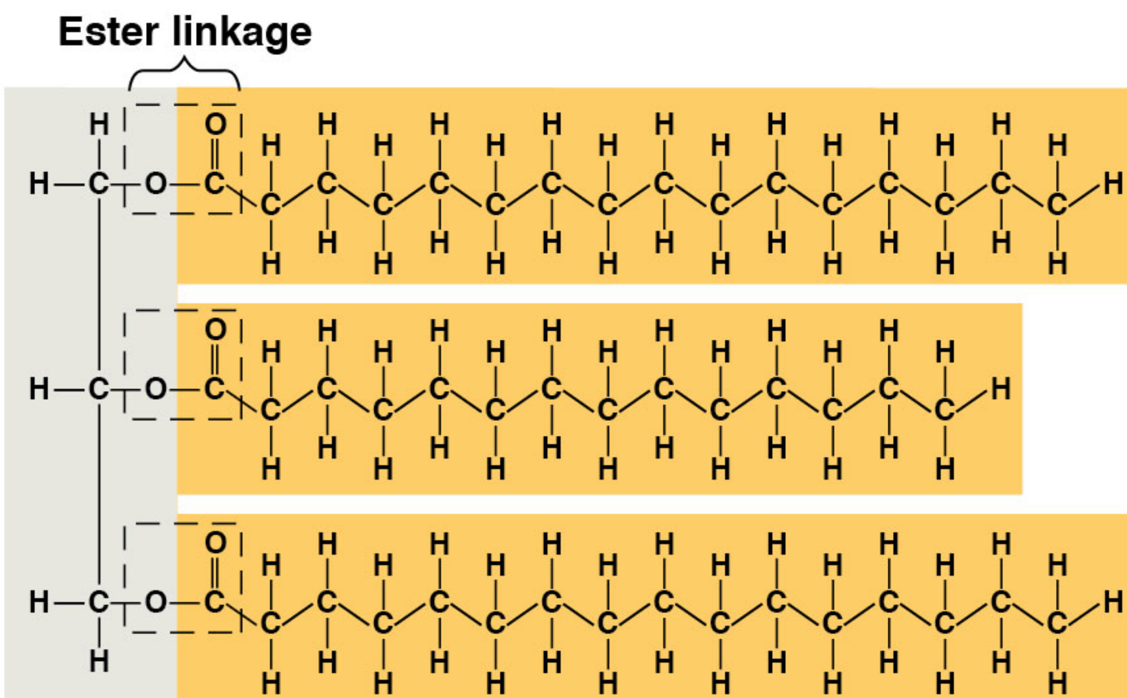
C. **Phospholipids:** lipid bilayer of cell membrane

- hydrophilic (polar head
- hydrophobic tails

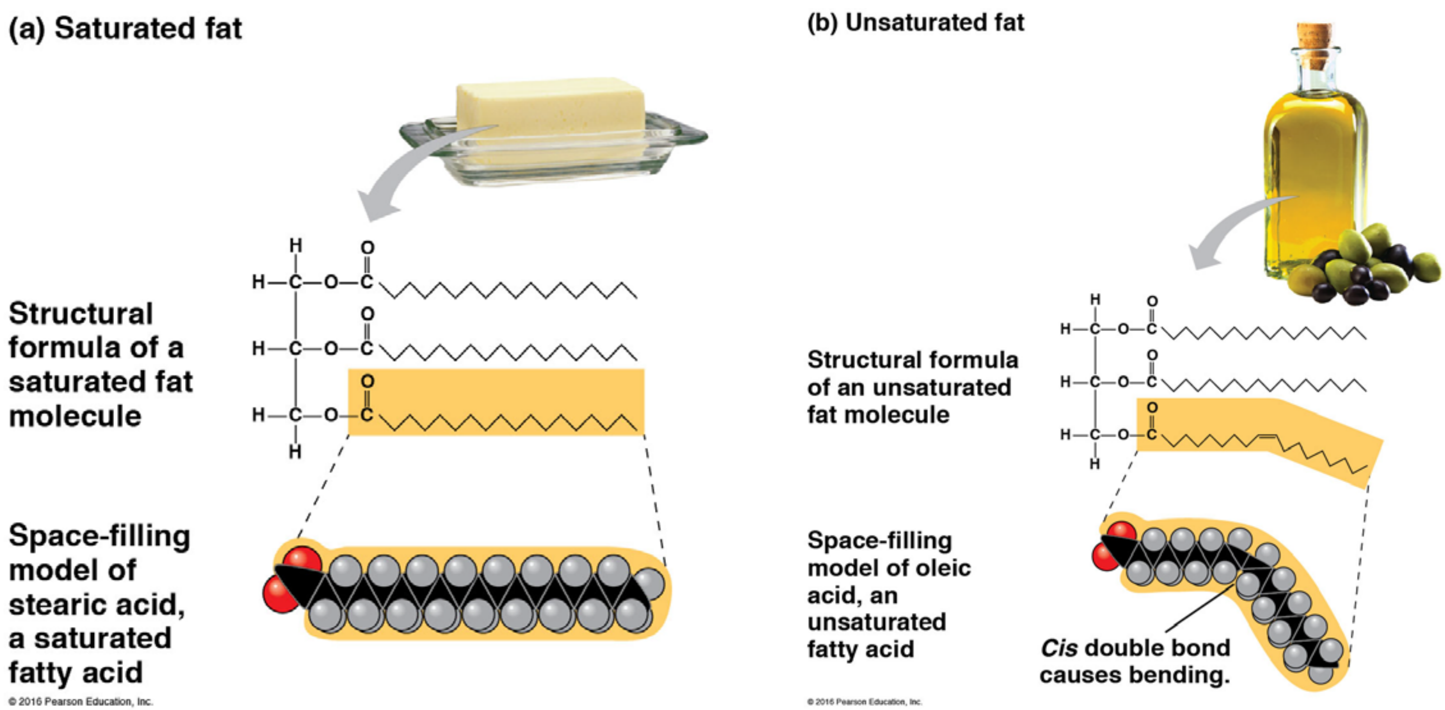




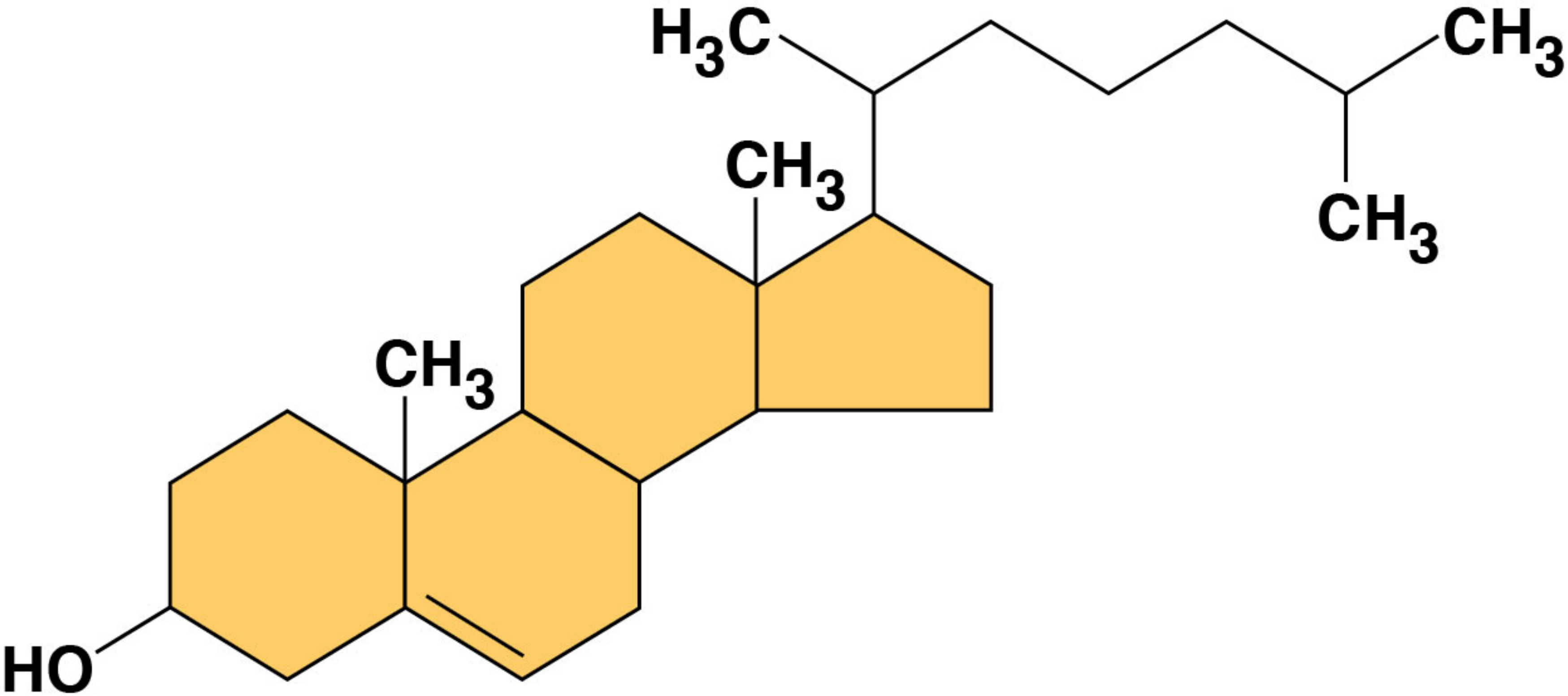
(a) One of three dehydration reactions in the synthesis of a fat



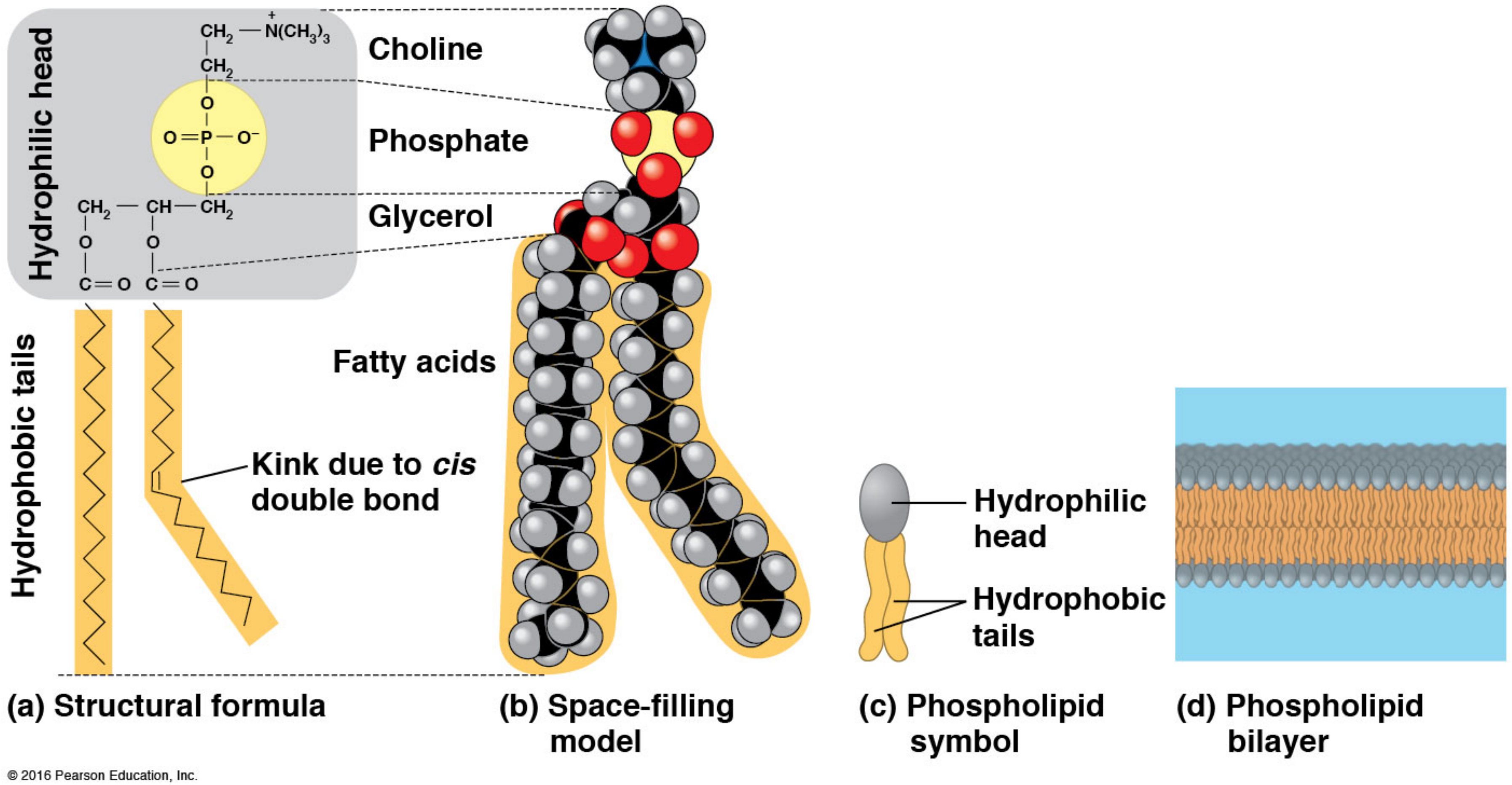
(b) Fat molecule (triacylglycerol)



Saturated	Unsaturated	Polyunsaturated
"saturated" with H	Have some C=C, result in kinks	
In animals	In plants	
Solid at room temp.	Liquid at room temp.	
Eg. butter, lard	Eg. corn oil, olive oil	

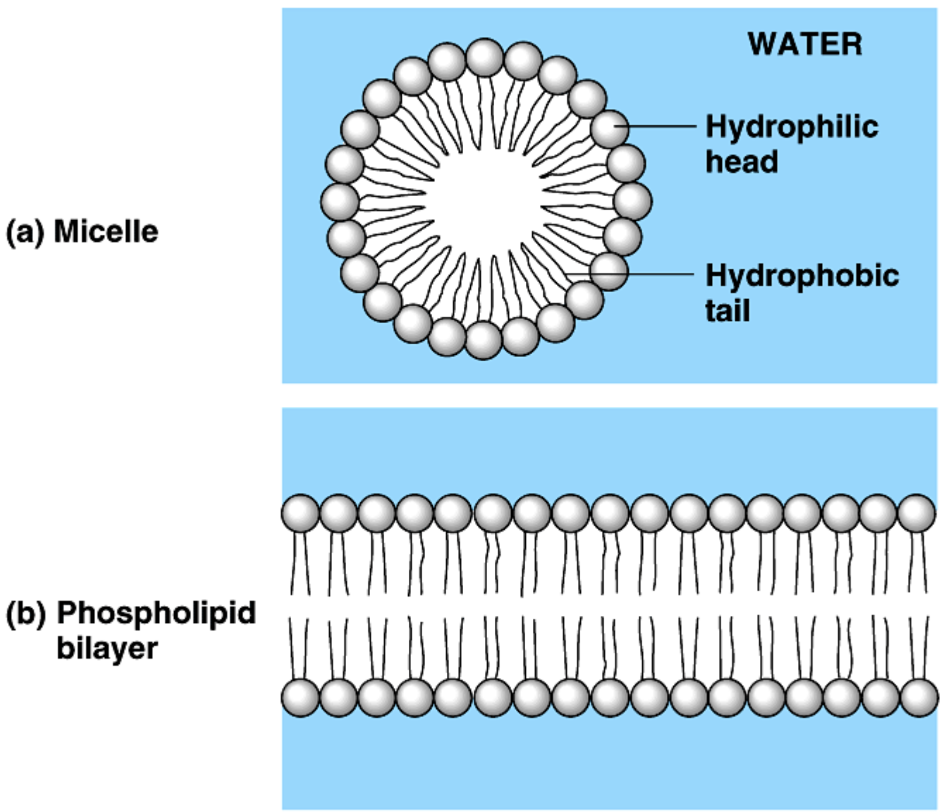


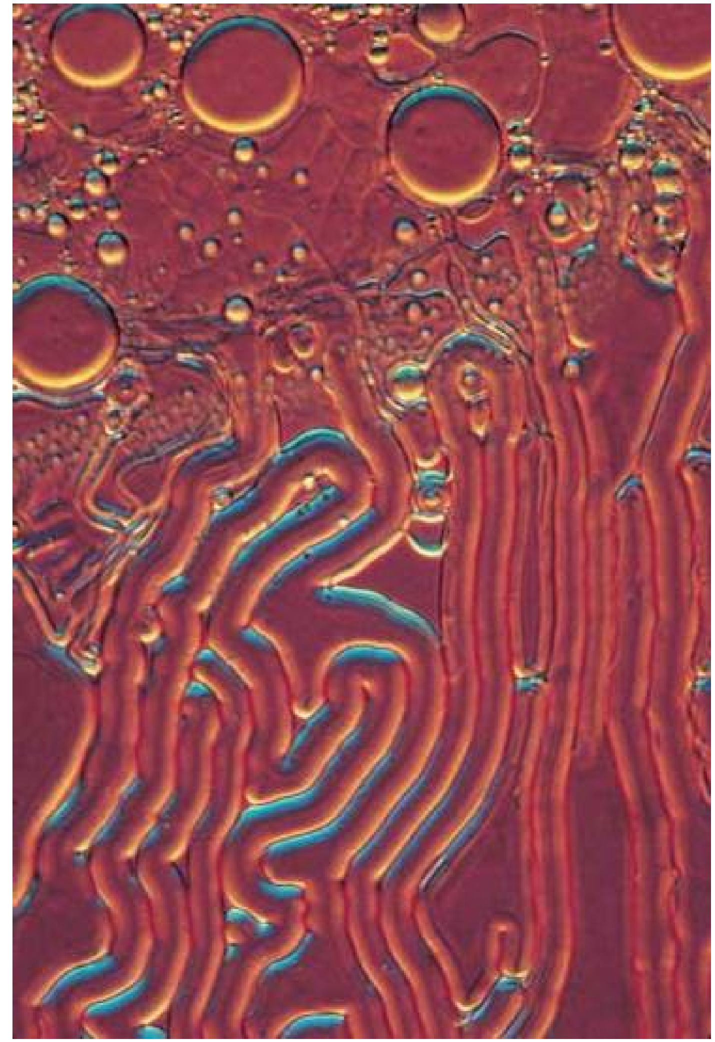
Cholesterol, a steroid

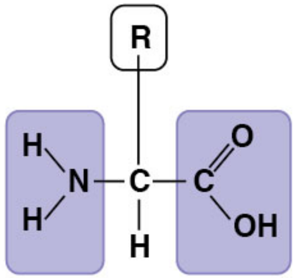


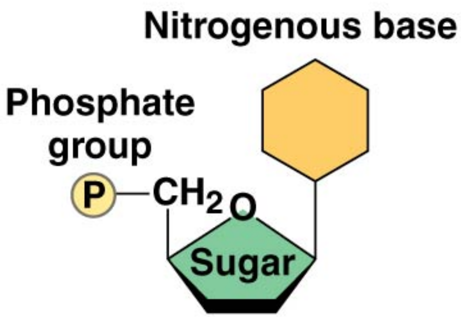
The structure of a phospholipid

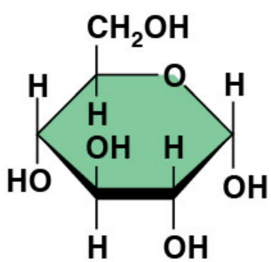
Hydrophobic/hydrophilic interactions make a **phospholipid bilayer**

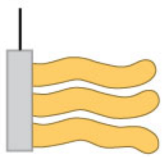
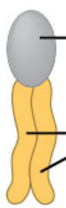
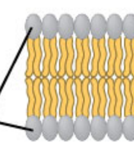
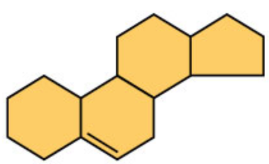




Components	Examples	Functions
 Amino acid monomer (20 types)	• Enzymes • Structural proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Defensive proteins	• Catalyze chemical reactions • Provide structural support • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Protect against disease

Components	Examples	Functions
 Nucleotide monomer	DNA:  • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded	Stores hereditary information
	RNA:  • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded	Various functions in gene expression, including carrying instructions from DNA to ribosomes

Components	Examples	Functions
 **Monosaccharide monomer**	**Monosaccharides: glucose, fructose**	**Fuel; carbon sources that can be converted to other molecules or combined into polymers**
	Disaccharides: lactose, sucrose	
	Polysaccharides: • **Cellulose (plants)** • **Starch (plants)** • **Glycogen (animals)** • **Chitin (animals and fungi)**	• **Strengthens plant cell walls** • **Stores glucose for energy** • **Stores glucose for energy** • **Strengthens exoskeletons and fungal cell walls**

Components	Examples	Functions
	Triacylglycerols (fats or oils): glycerol + three fatty acids	Important energy source 
	Phospholipids: glycerol + phosphate group + two fatty acids	Lipid bilayers of membranes 
	Steroids: four fused rings with attached chemical groups	• Component of cell membranes (cholesterol) • Signaling molecules that travel through the body (hormones)