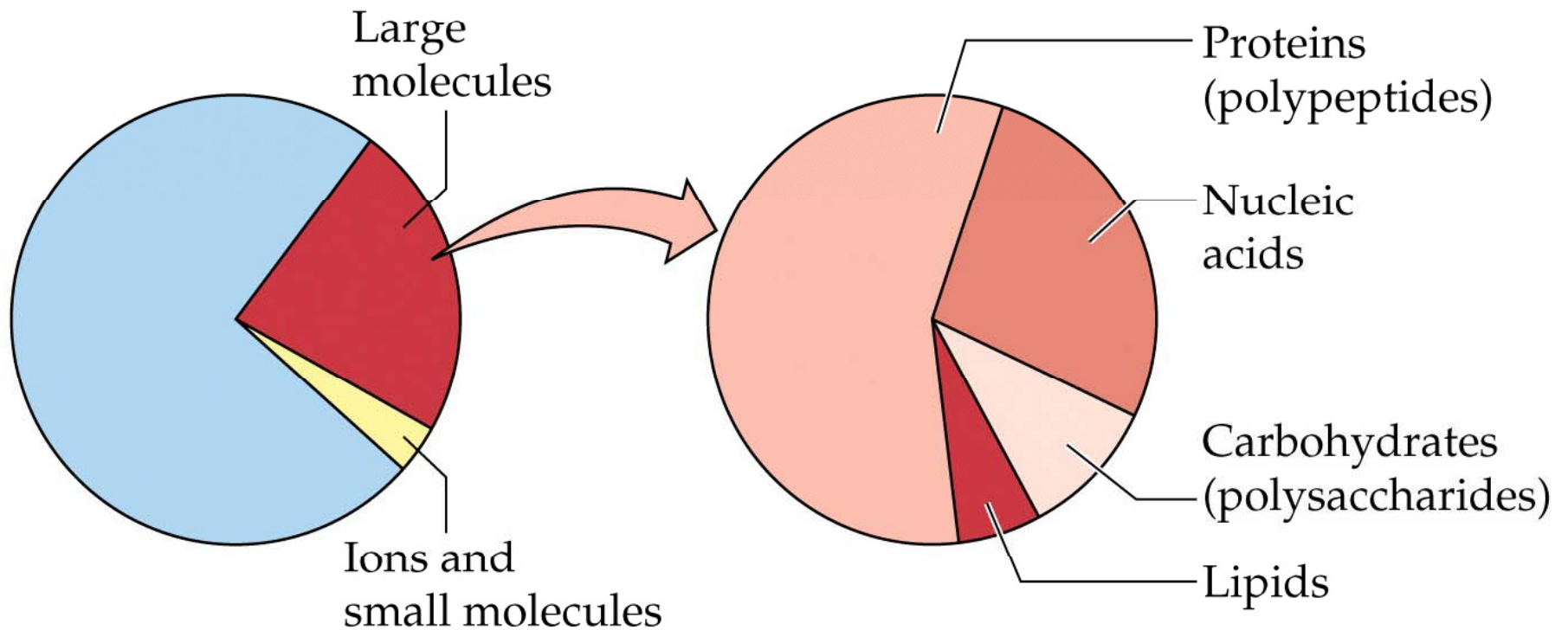


Lecture Series 2
Macromolecules: Their
Structure and Function

Reading Assignments

- Read Chapter 4
(Protein structure & Function)

Biological Substances found in Living Tissues

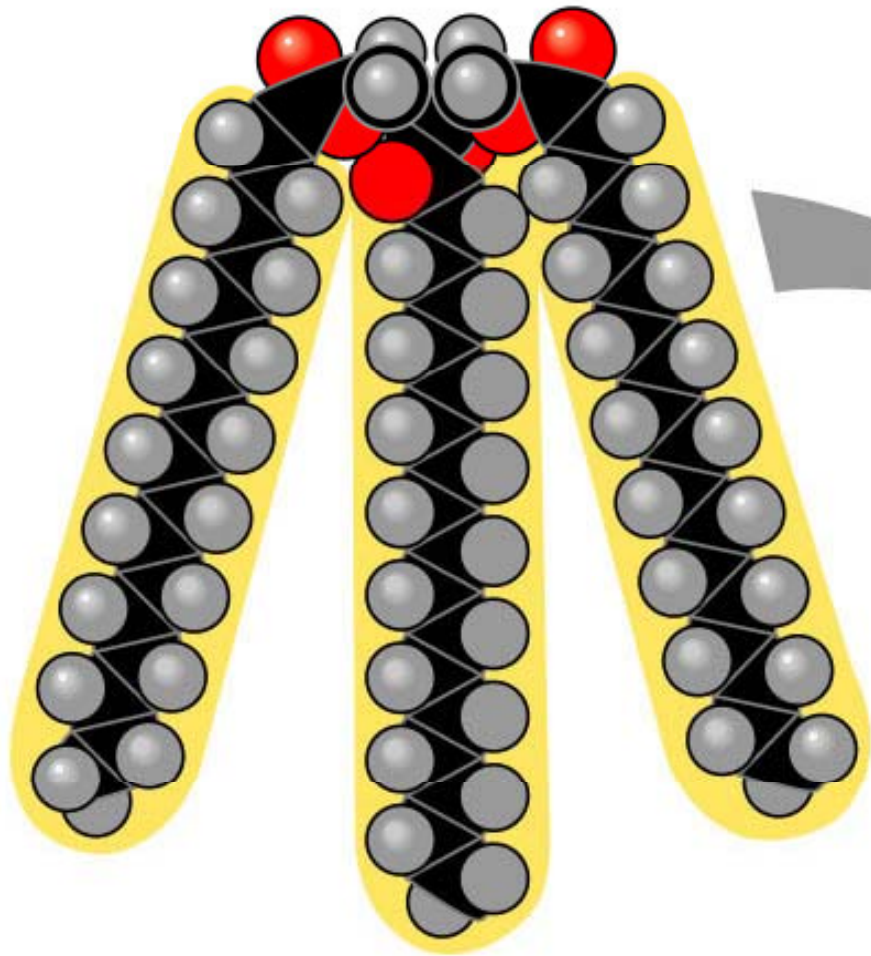


The big four in terms of macromolecules

A. Lipids: Water-Insoluble Molecules

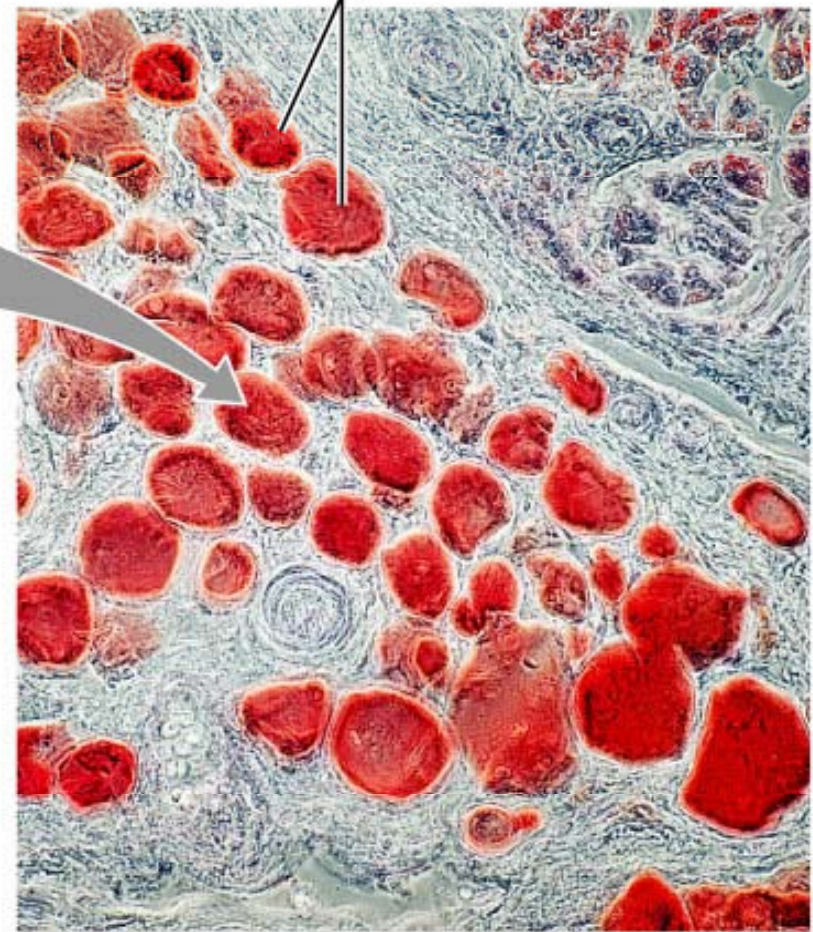
- Lipids can form large biological molecules, but these aggregations are NOT chemically polymers because individual units are not linked by covalent bonds.
- Share the common trait of being hydrophobic.

The role of hydrocarbons in fats



(a) A fat molecule

Fat droplets (stained red)



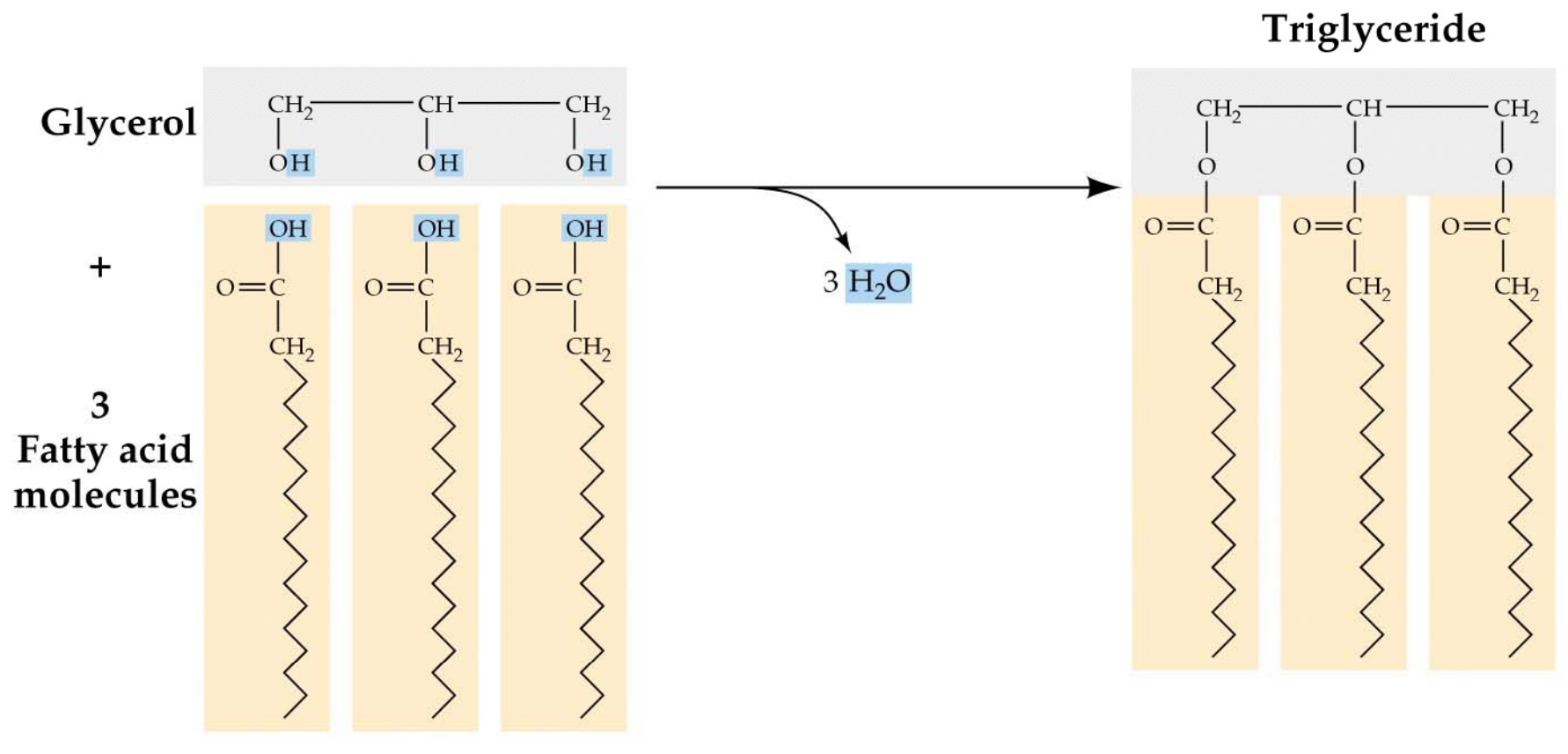
100 μm

(b) Mammalian adipose cells

A. Lipids: Water-Insoluble Molecules

- Fats and oils are composed of three fatty acids covalently bonded to a glycerol molecule by ester linkages.
- Fats and oils function to efficiently store energy.

Synthesis of a Triglyceride

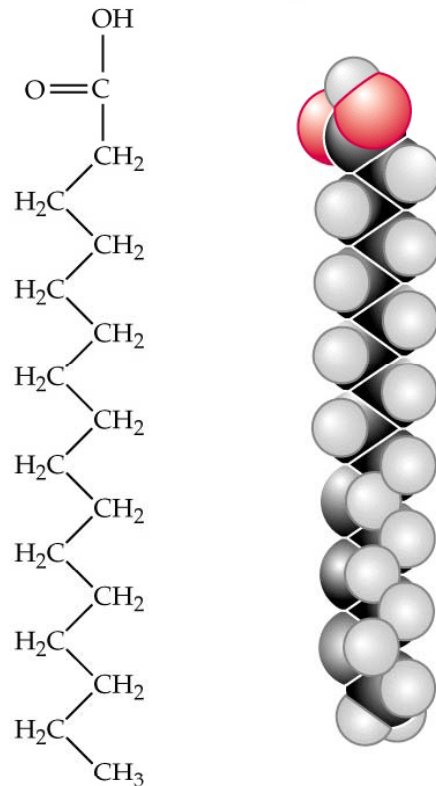


A. Lipids: Water-Insoluble Molecules

- Saturated fatty acids have a hydrocarbon chain with no double bonds. The hydrocarbon chains of unsaturated fatty acids have one or more double bonds that bend the chain, making close packing less possible.

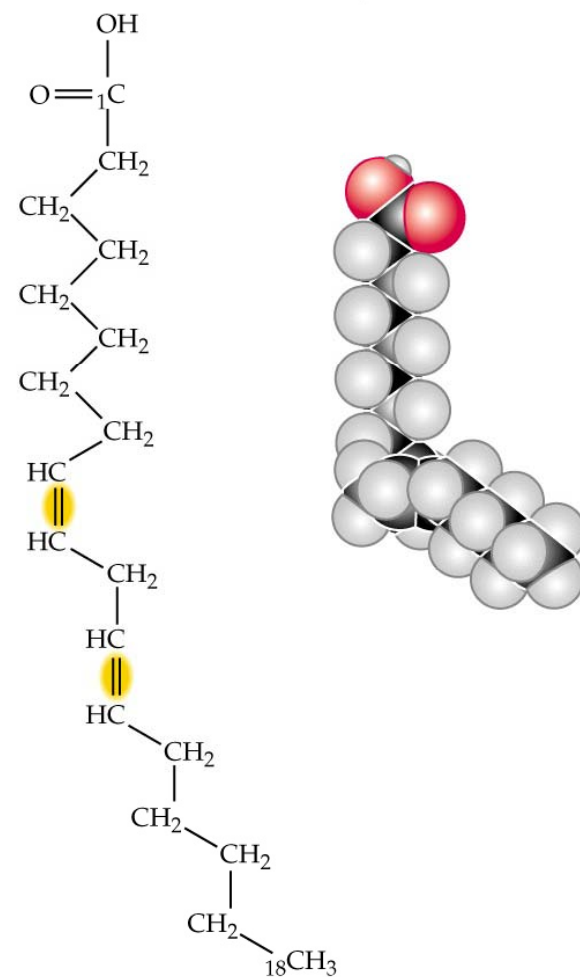
Saturated and Unsaturated Fatty Acids

(a) Saturated fatty acid



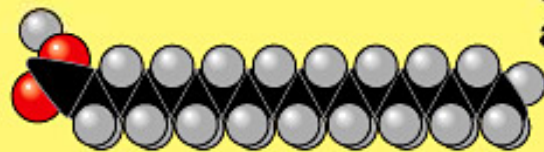
Palmitic acid

(b) Unsaturated fatty acid



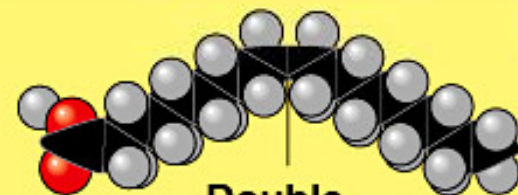
Linoleic acid

Examples of saturated and unsaturated fats and fatty acids



Stearic acid

(a) Saturated fat and fatty acid



Oleic acid

Double bond causes bending

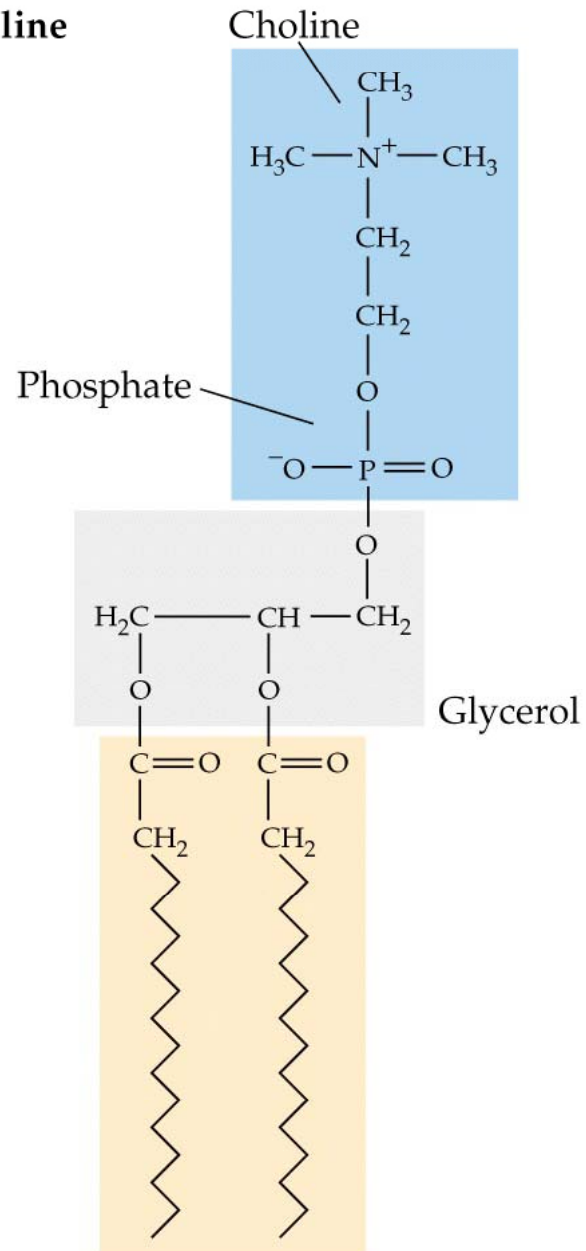
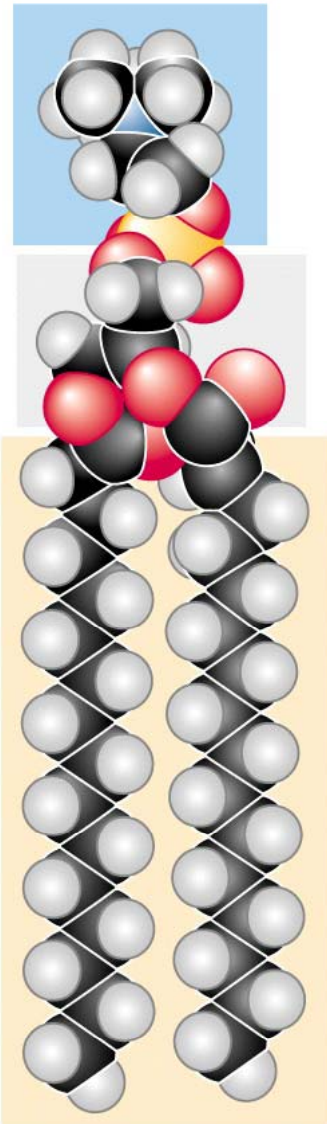
(b) Unsaturated fat and fatty acid

A. Lipids: Water-Insoluble Molecules

- Phospholipids have a hydrophobic hydrocarbon "tail" and a hydrophilic phosphate "head."
- Are considered "amphipathic"
- Phospholipids form the core of biological membranes.

Phospholipid Structure

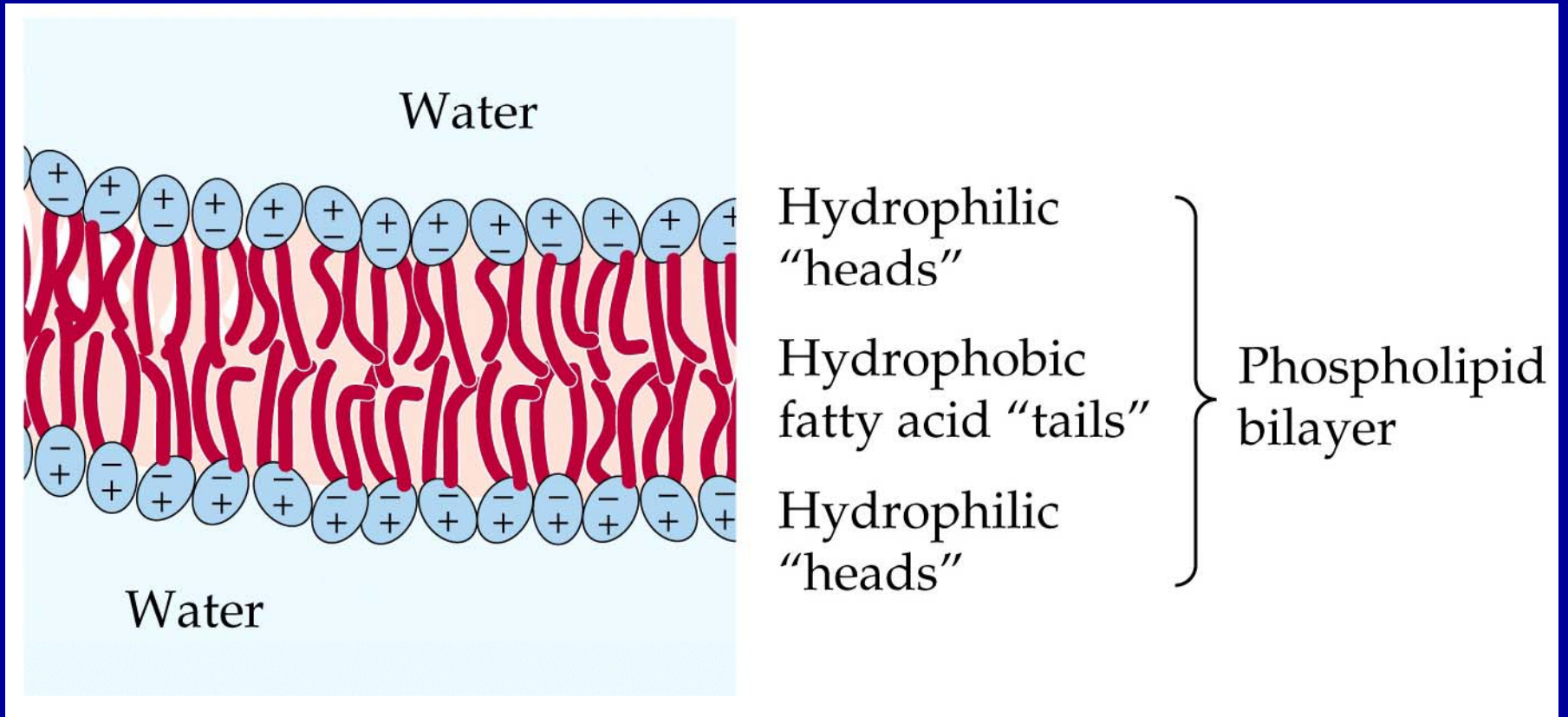
(a) Phosphatidyl choline



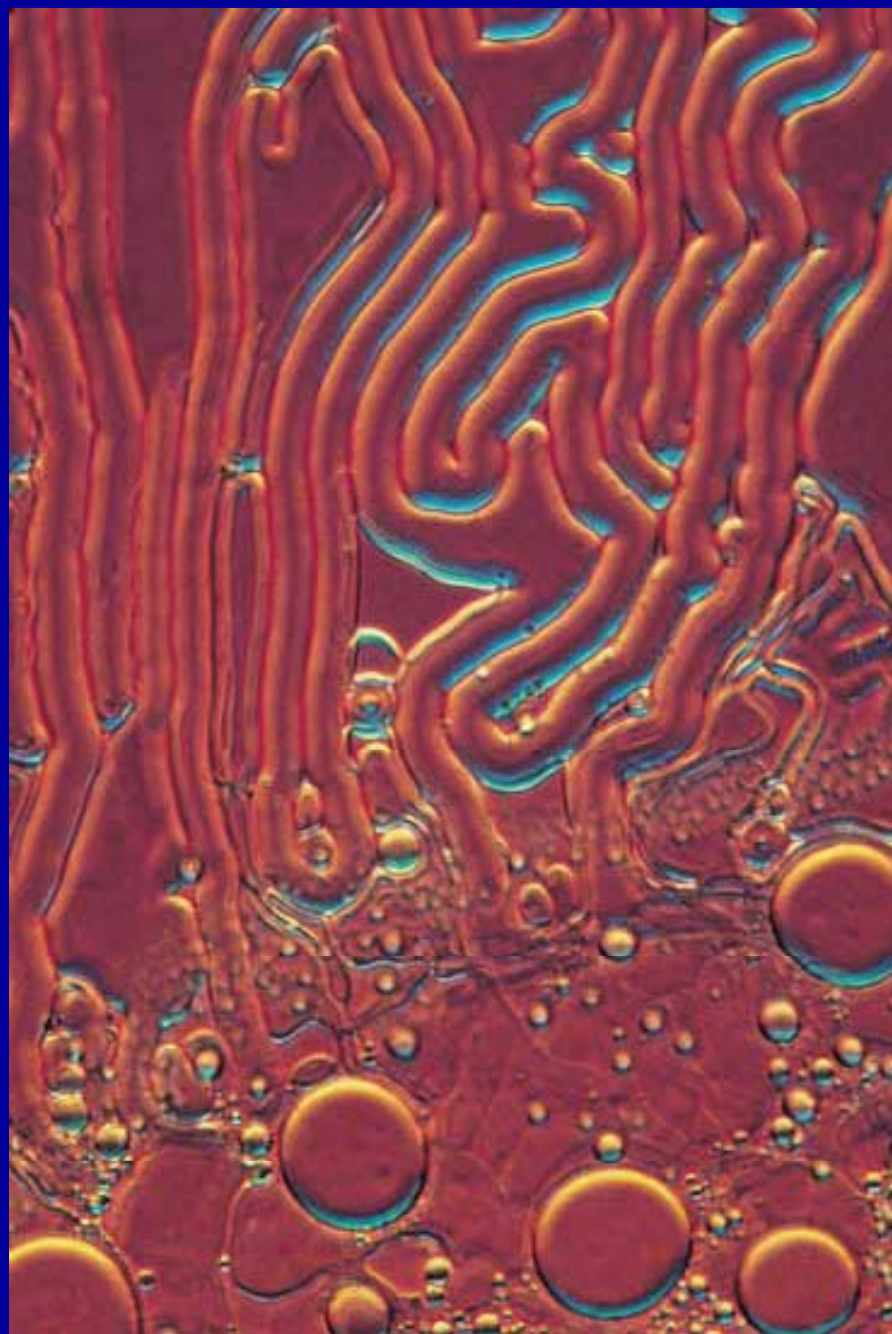
A. Lipids: Water-Insoluble Molecules

- In water, the interactions of the hydrophobic tails and hydrophilic heads generate a phospholipid bilayer two molecules thick. The head groups are directed outward, interacting with surrounding water. Tails are packed in the interior.

Phospholipids form a Bilayer



Phospholipid

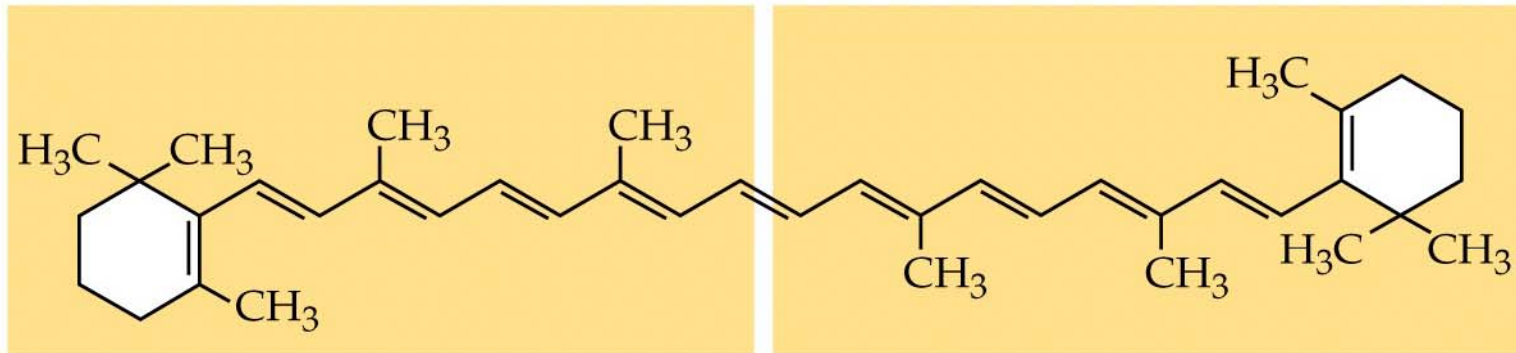


A. Lipids: Water-Insoluble Molecules

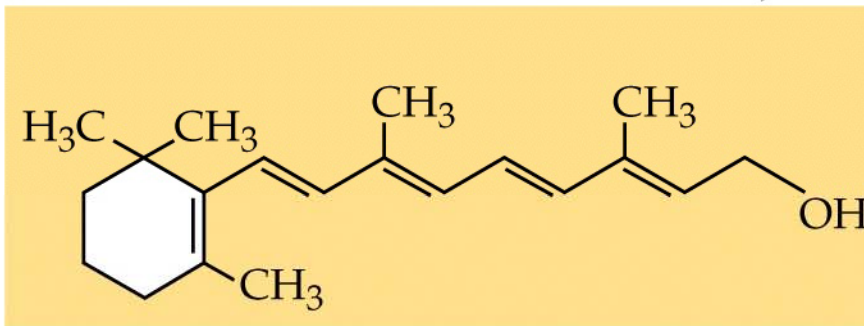
- Carotenoids trap light energy in green plants. β -Carotene can be split to form vitamin A, a lipid vitamin.

Example of an Important Lipid

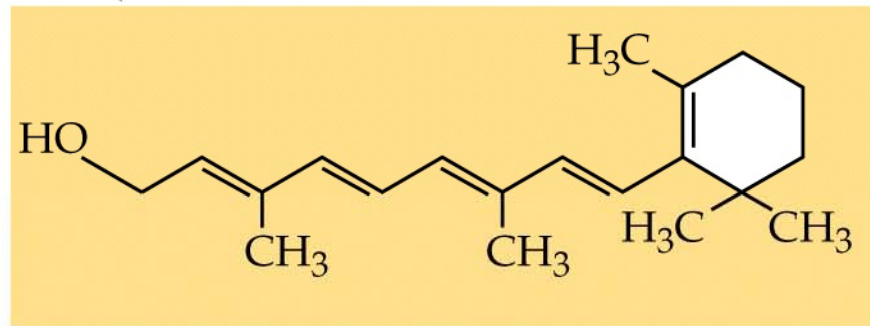
β -Carotene



Vitamin A



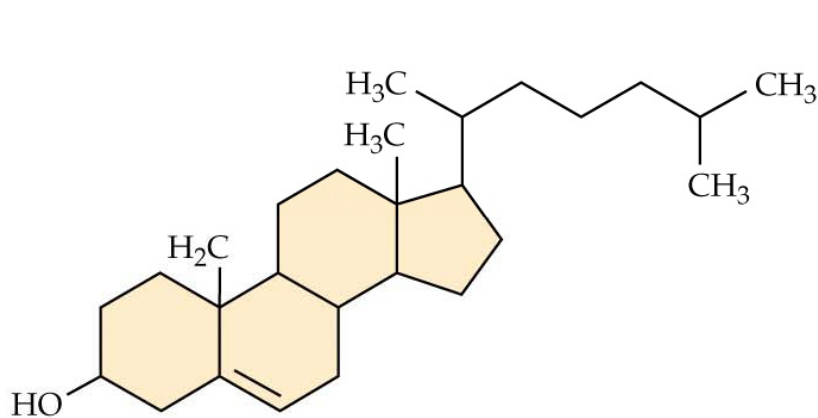
Vitamin A



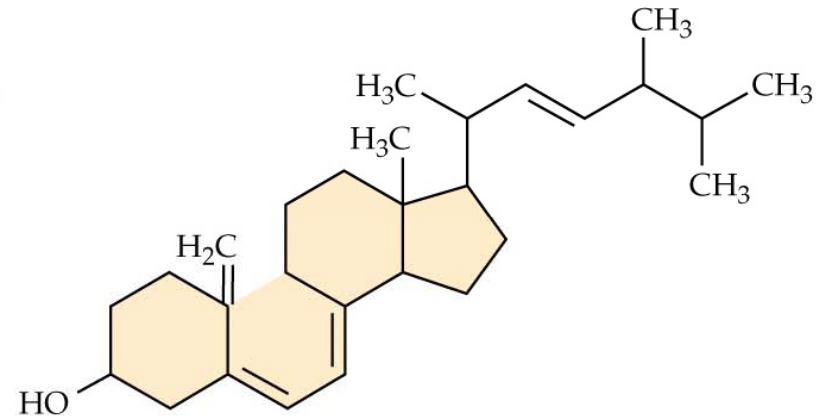
A. Lipids: Water-Insoluble Molecules

- Some lipids are steroids and function as hormones. Cholesterol is synthesized by the liver and has a role in some cell membranes, as well as in the digestion of other fats.
- Some lipids function as vitamins, required for normal functioning, must be acquired from the diet.

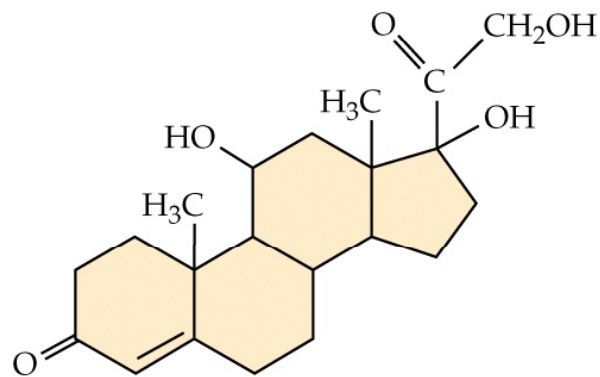
Examples of an Important Lipids that are also Steroids



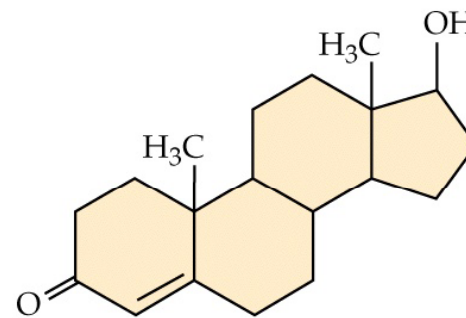
Cholesterol



Vitamin D₂



Cortisol



Testosterone

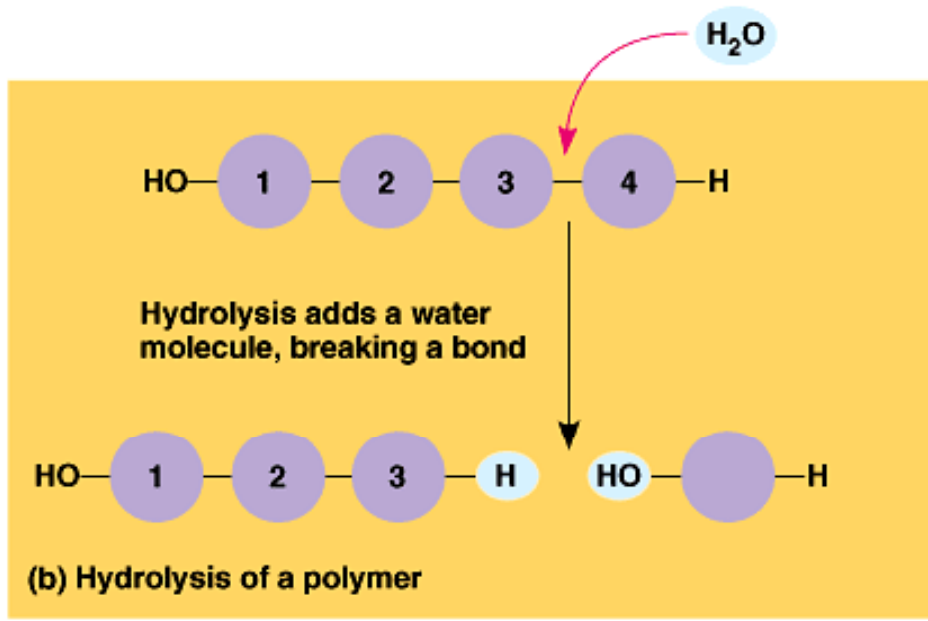
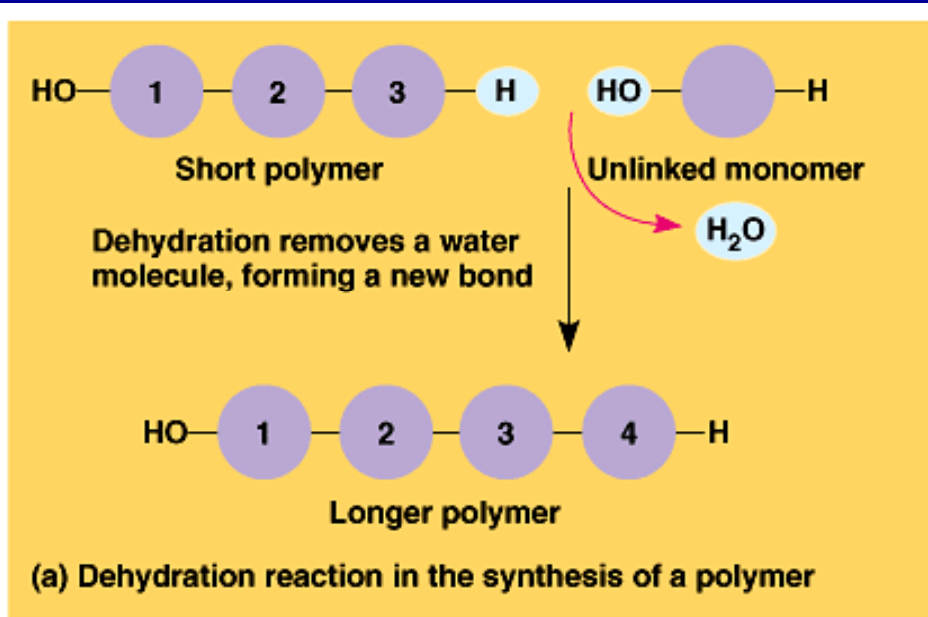
B. Macromolecules: Giant Polymers

- Macromolecules have specific three-dimensional shapes. Different functional groups give local sites on macromolecules specific properties.
- Monomers are joined by condensation reactions. Hydrolysis reactions break polymers into monomers.

3.1 *The Building Blocks of Organisms*

MONOMER	SIMPLE POLYMER	COMPLEX POLYMER
Amino acid	Peptide or oligopeptide	Polypeptide
Nucleotide	Oligonucleotide	Nucleic acid
Monosaccharide	Oligosaccharide	Polysaccharide

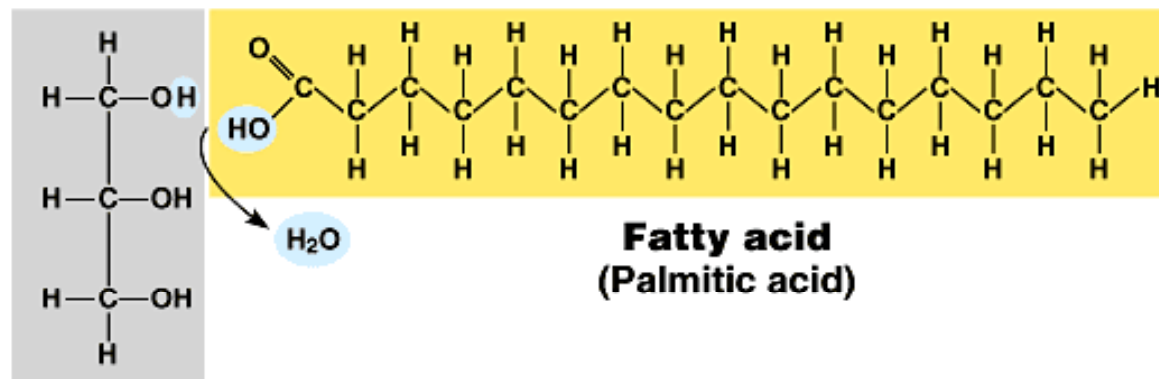
The synthesis and breakdown of polymers



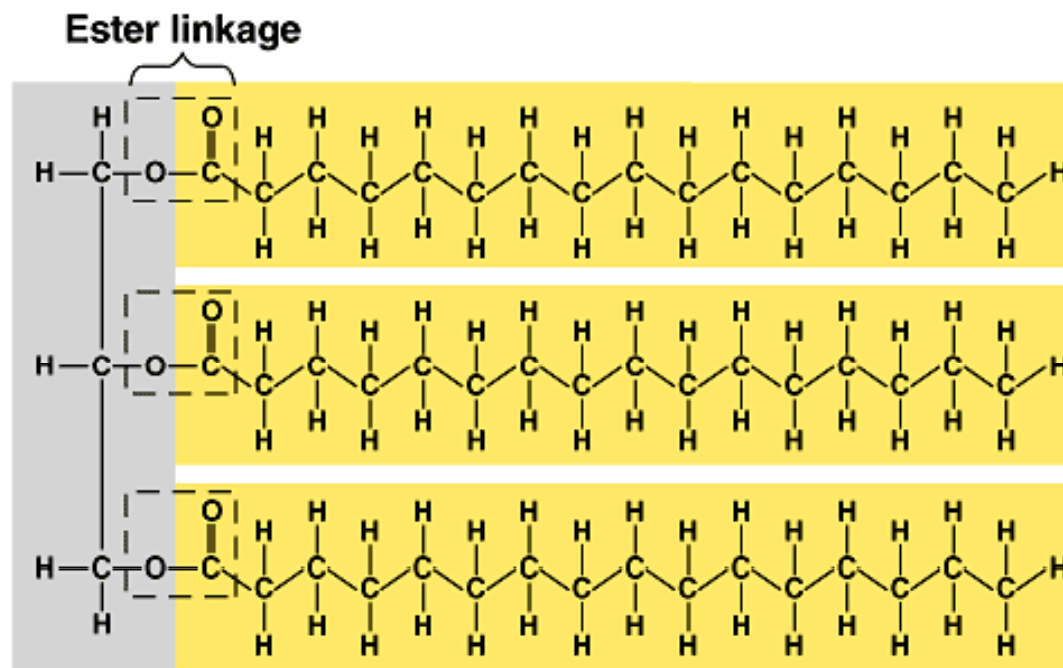
Condensation or Dehydration reactions

Hydrolysis reactions

The synthesis and structure of a fat, or triacylglycerol



Glycerol
(a) Dehydration synthesis

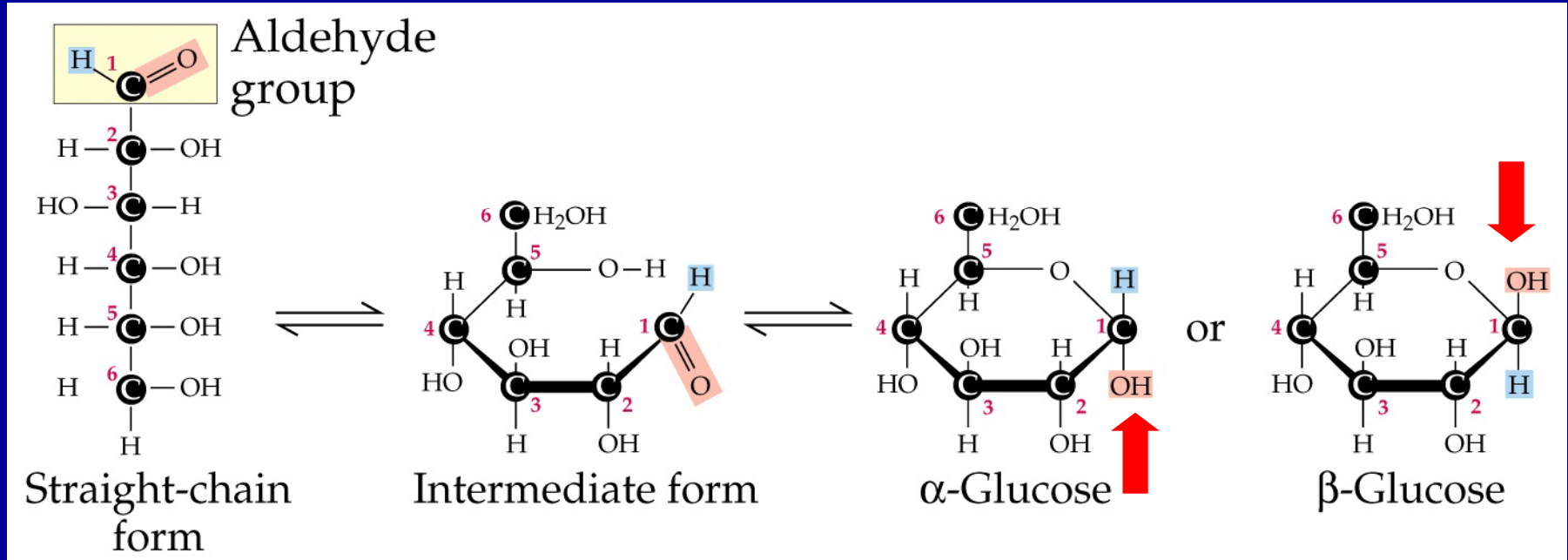


(b) Fat molecule (triacylglycerol)

C. Carbohydrates: Sugars and Sugar Polymers

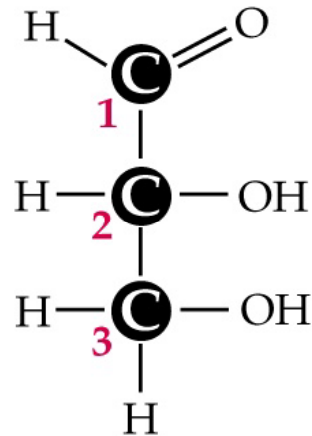
- All carbohydrates contain carbon bonded to H and OH groups. $[\text{CH}_2\text{O}]_N$
- Hexoses are monosaccharides that contain six carbon atoms.
- Monosaccharides are simple sugars.
 - ◆ Can be used for fuel.
 - ◆ Can be converted into other organic molecules.
 - ◆ Can be combined into polymers.

Various forms of Glucose

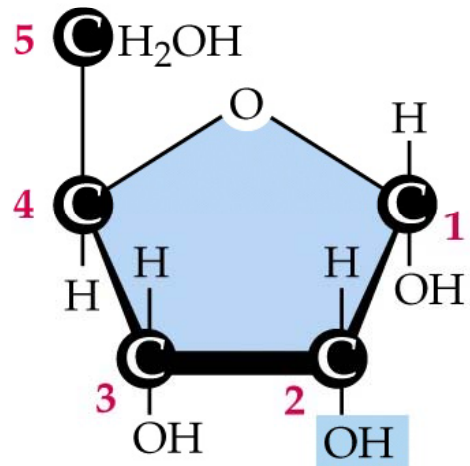


May be linear, but can form rings.

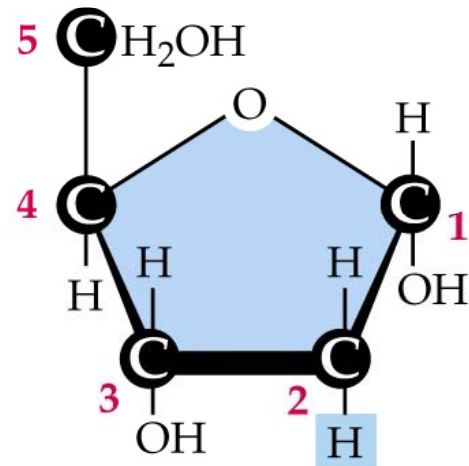
Three-carbon sugar



Five-carbon sugars

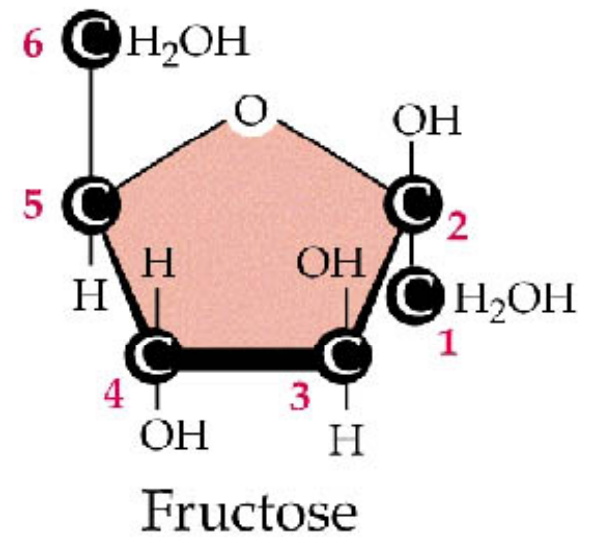
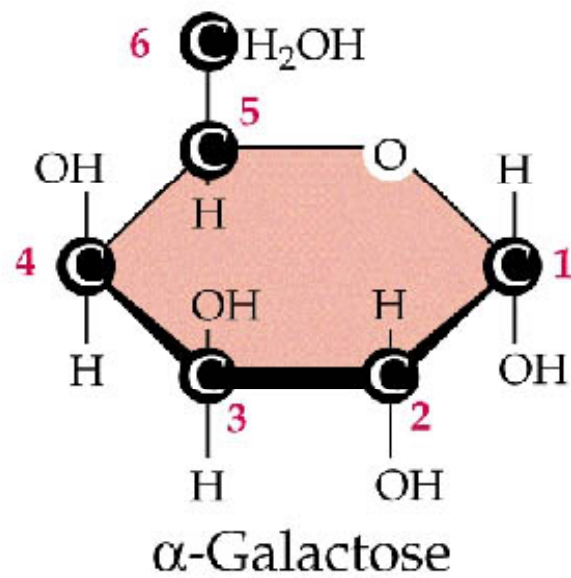
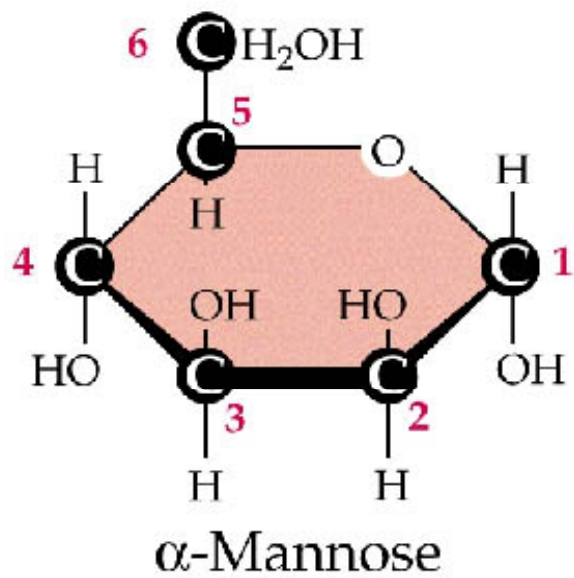


Ribose

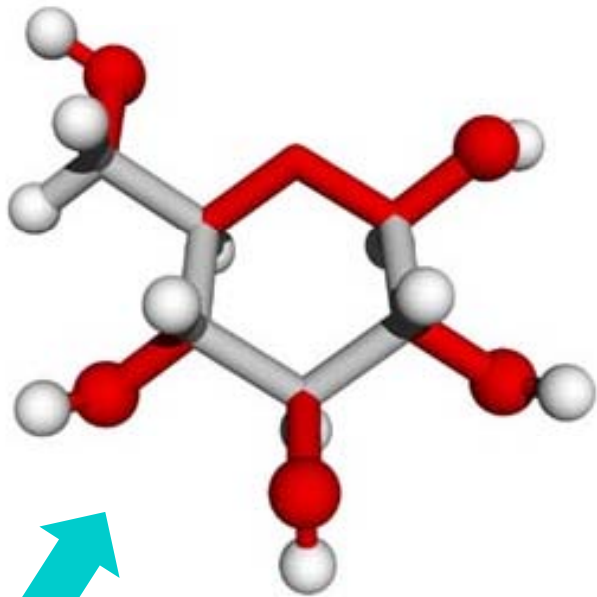


Deoxyribose

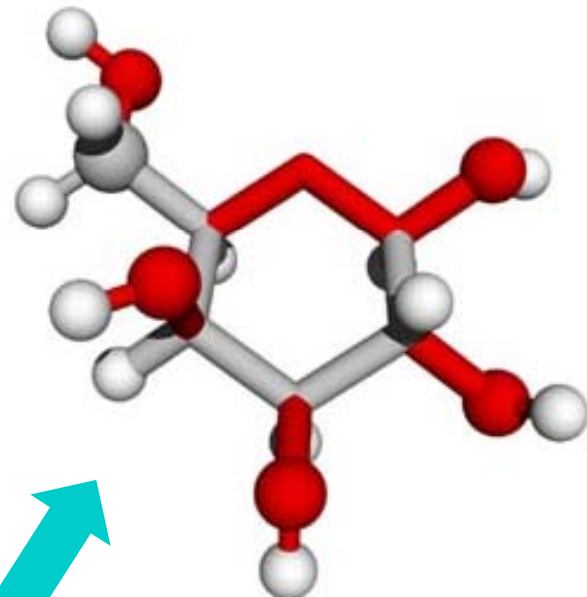
Six-carbon sugars



Hexose sugars



Glucose



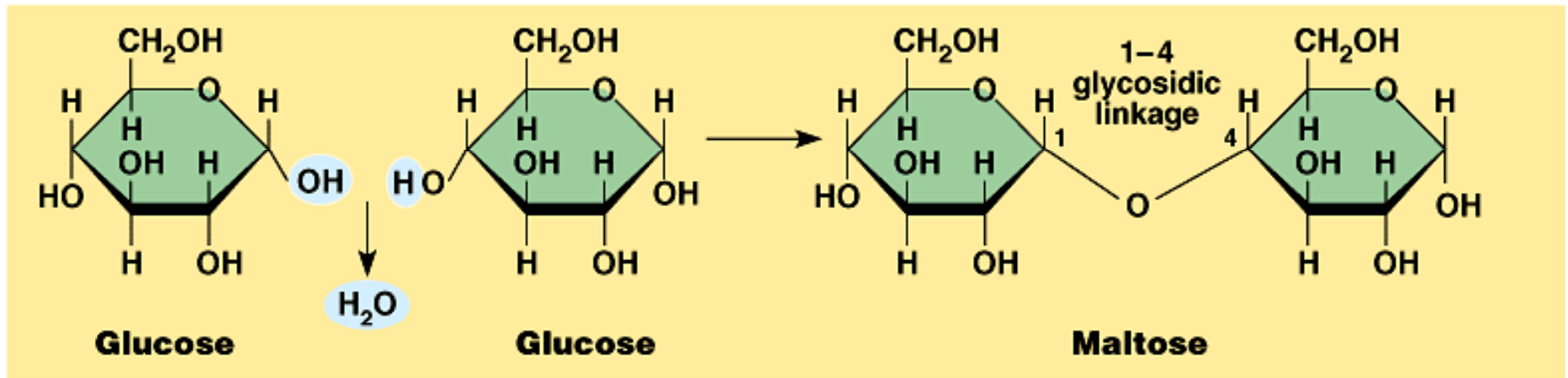
Galactose

Alpha or Beta???

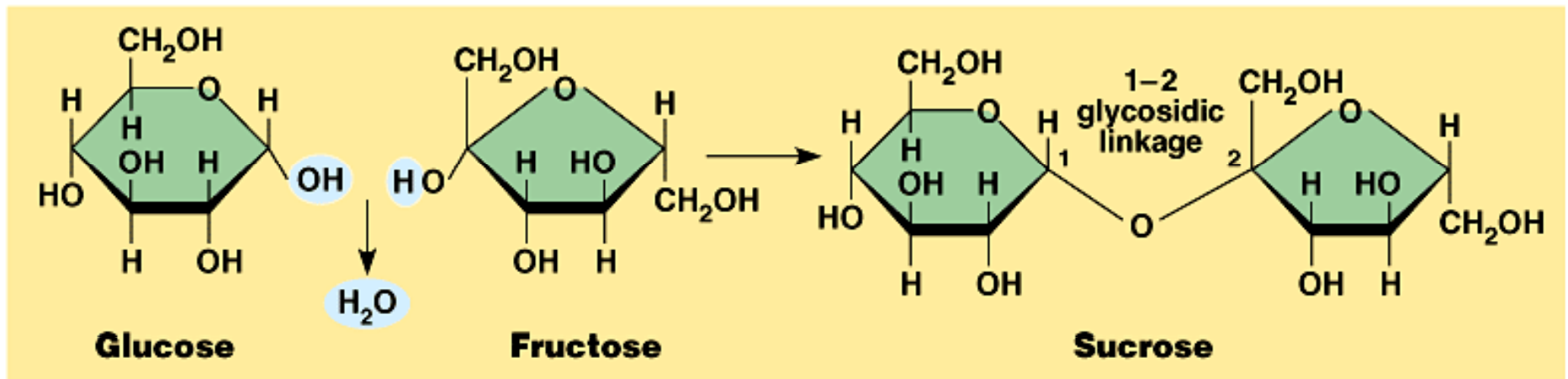
C. Carbohydrates: Sugars and Sugar Polymers

- Glycosidic linkages may have either α or β orientation in space. They covalently link monosaccharides into larger units.

Examples of disaccharide synthesis

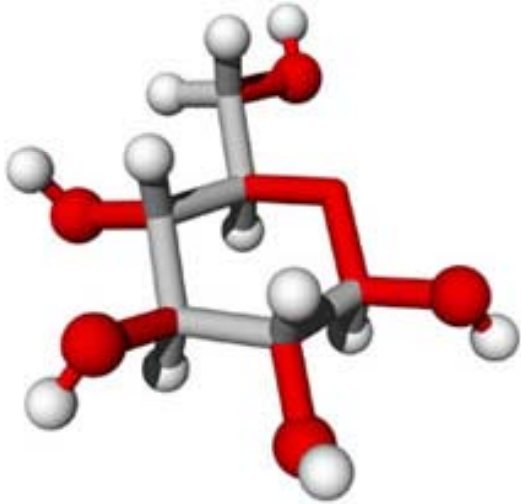


(a) Dehydration synthesis of maltose

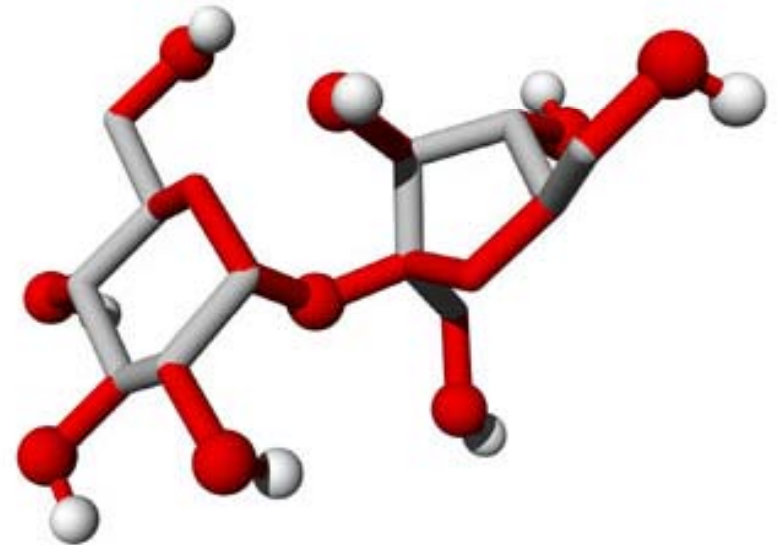


(b) Dehydration synthesis of sucrose

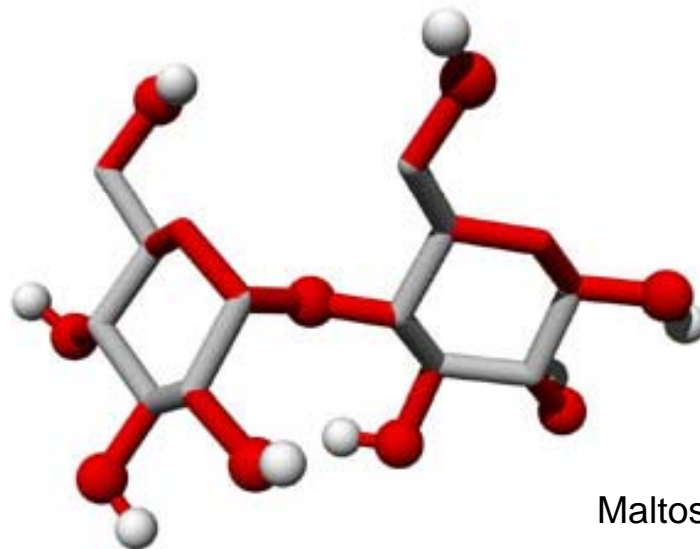
Glucose monomer and disaccharides



Glucose monomer



Sucrose



Maltose

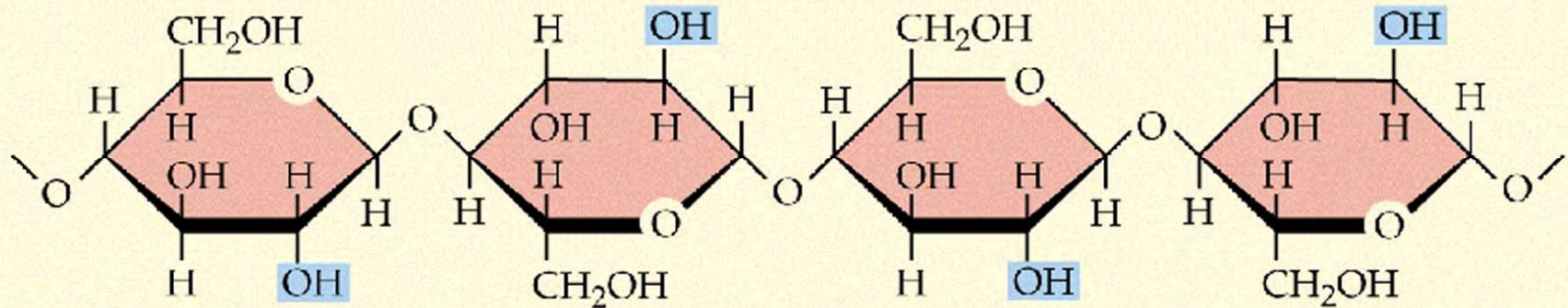
C. Carbohydrates: Sugars and Sugar Polymers

- Cellulose, a polymer, is formed by glucose units linked by β -glycosidic linkages between carbons 1 and 4.

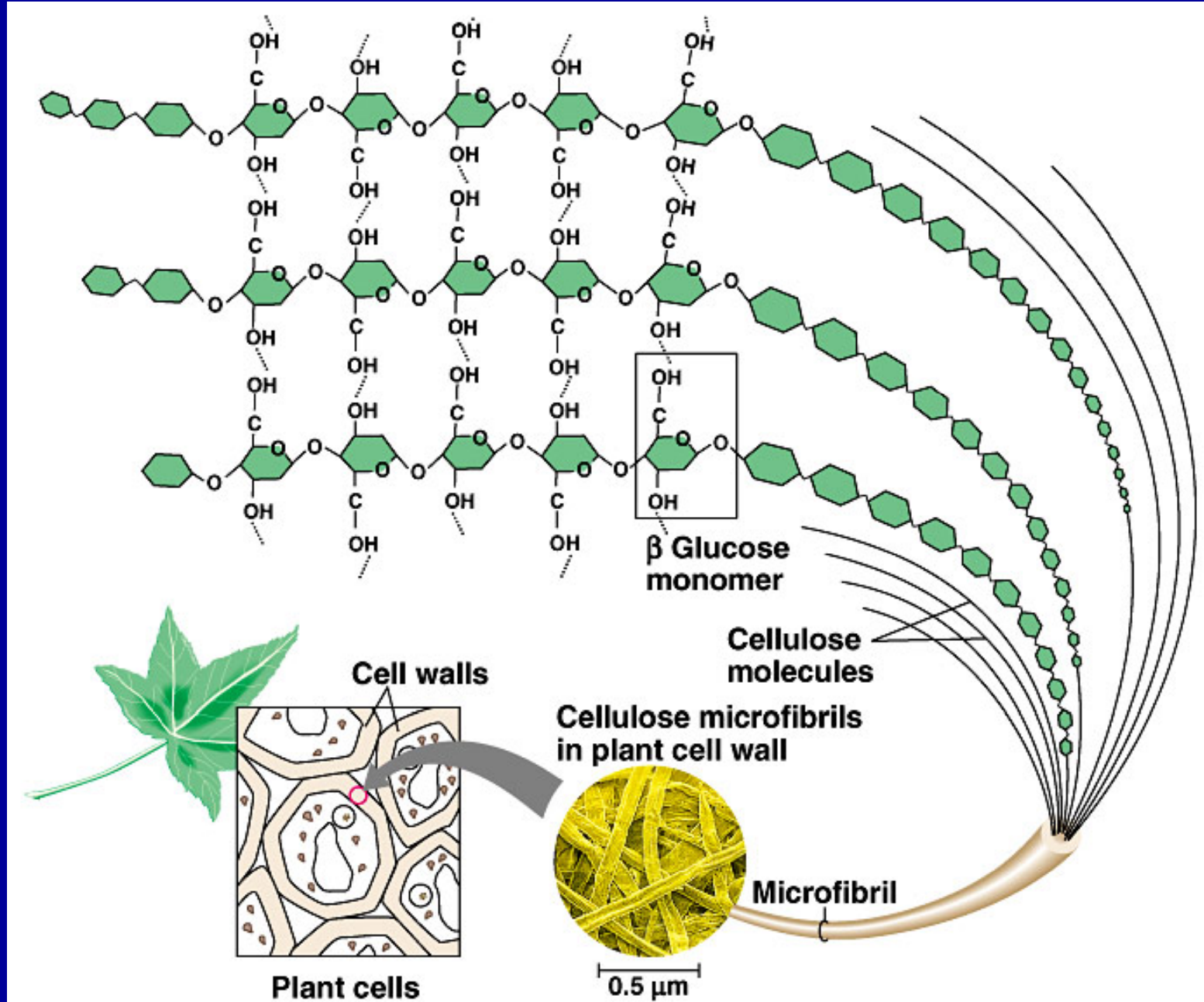
Glycosidic Linkages

(a) Molecular structure

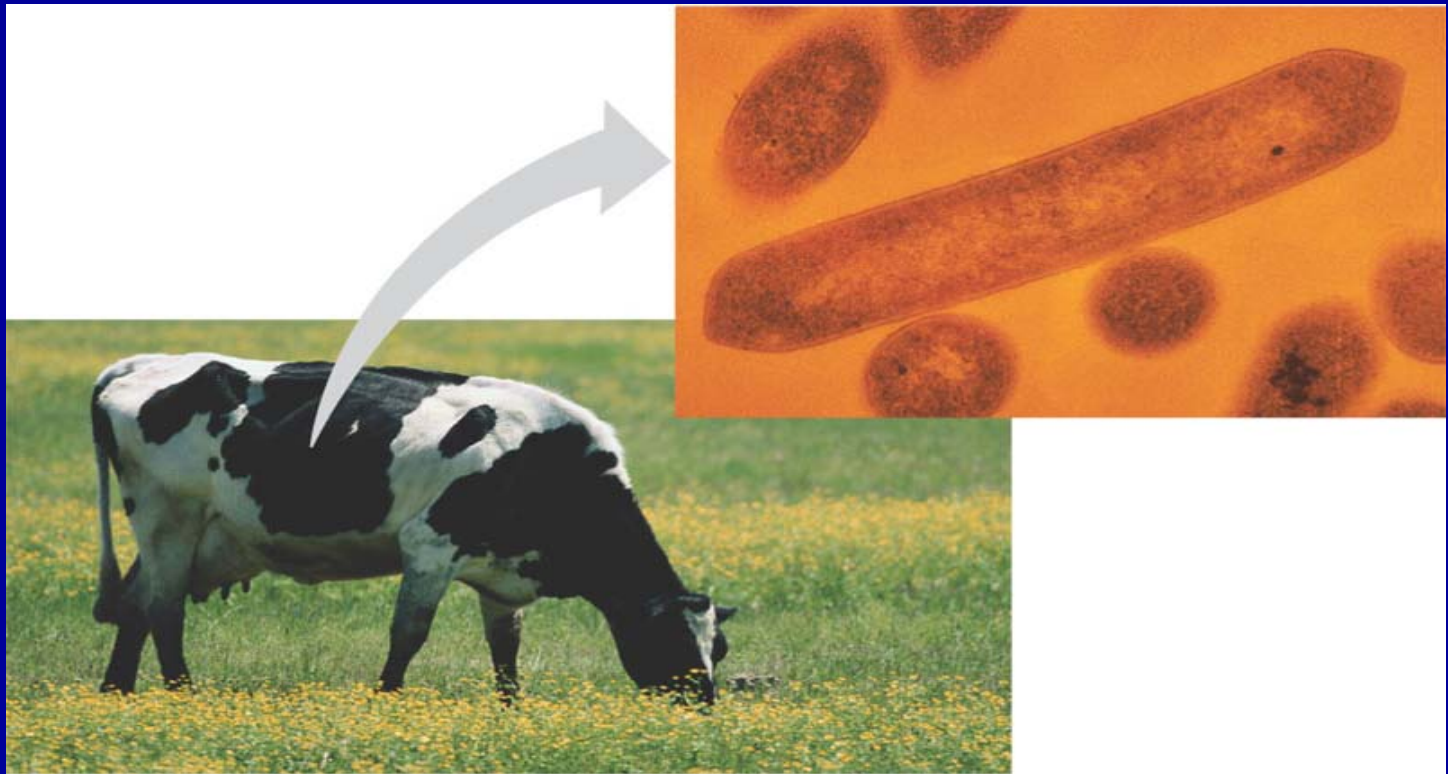
Cellulose



The arrangement of cellulose in plant cell walls



- Cellulose is difficult to digest
 - ◆ Cows have microbes in their stomachs to facilitate this process



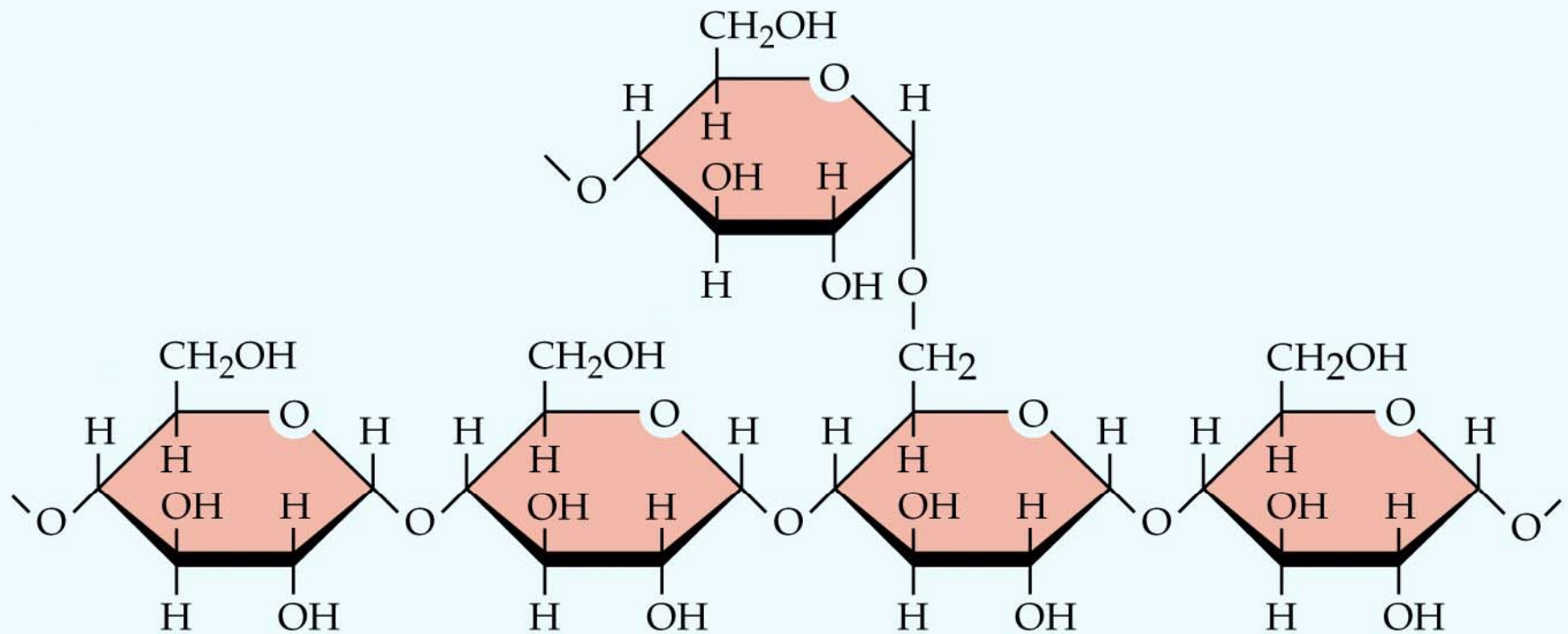
C. Carbohydrates: Sugars and Sugar Polymers

- Starches are formed by α -glycosidic linkages between carbons 1 and 4 and are distinguished by amount of branching through glycosidic bond formation at carbon 6.
- Glycogen contains α -1,4 glycosidic linkages and is highly branched.

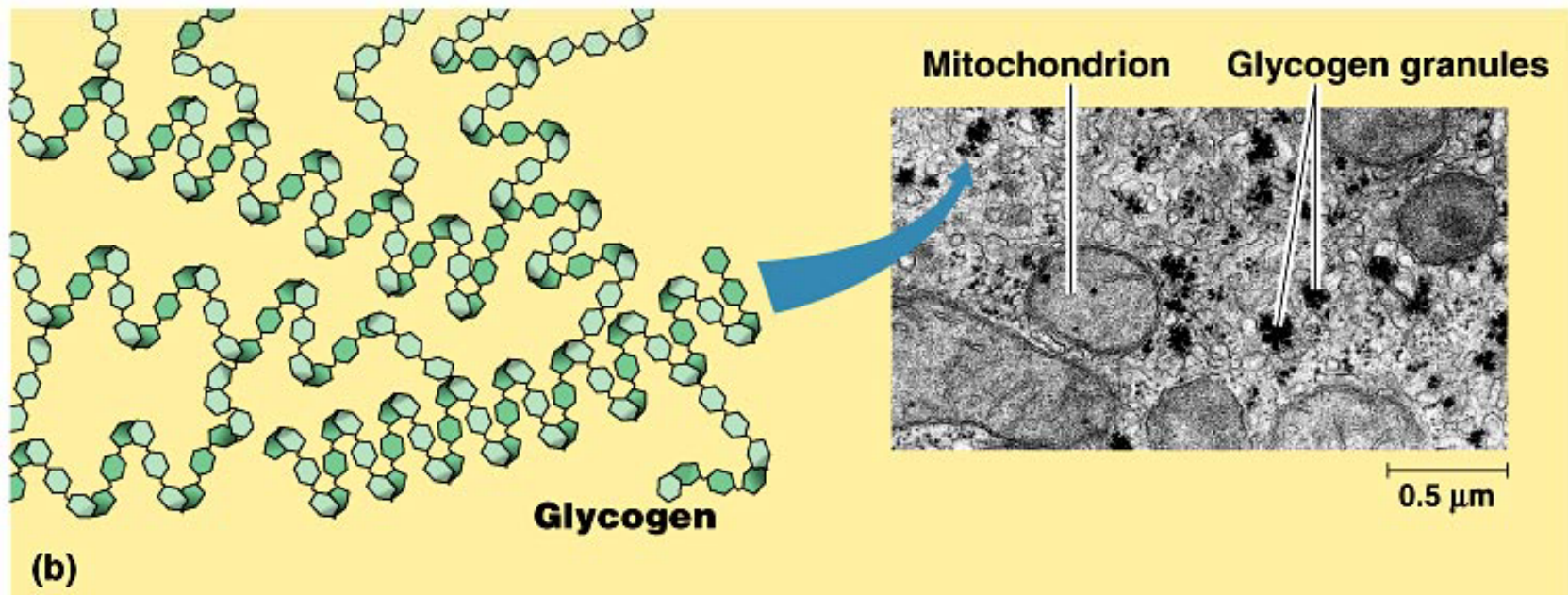
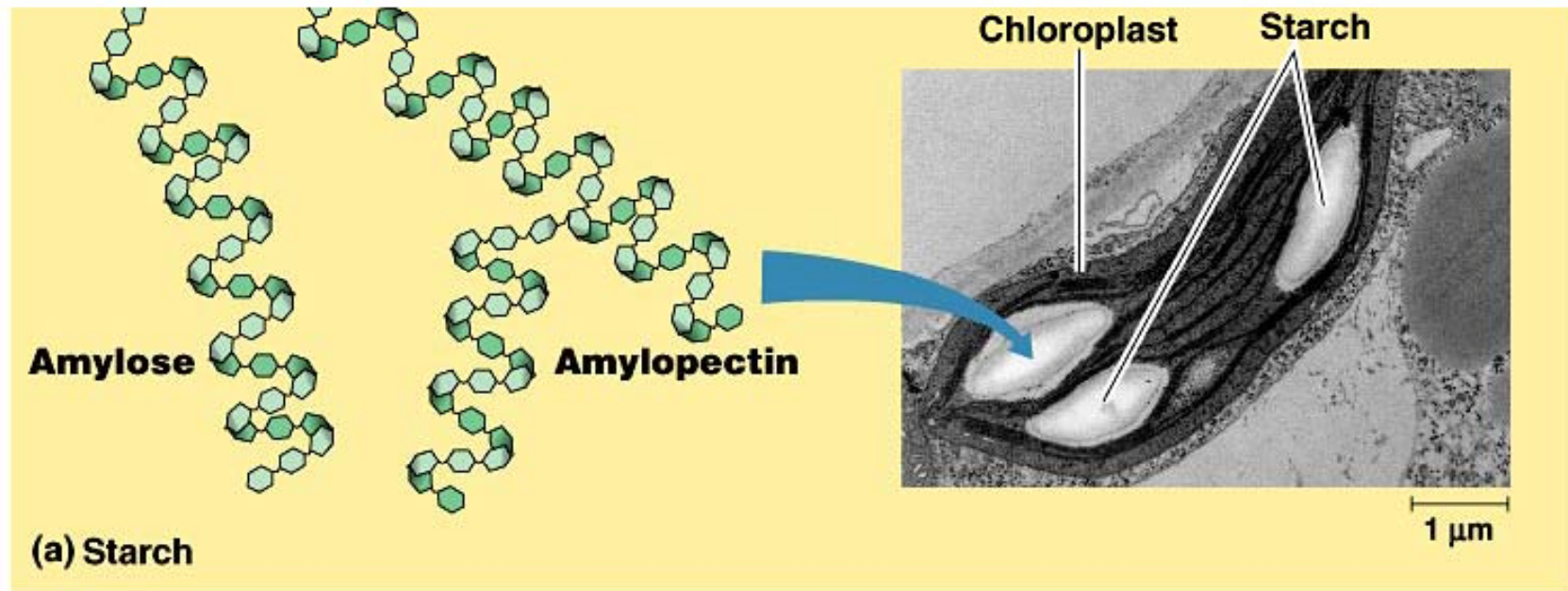
Glycosidic Linkages

(a) Molecular structure

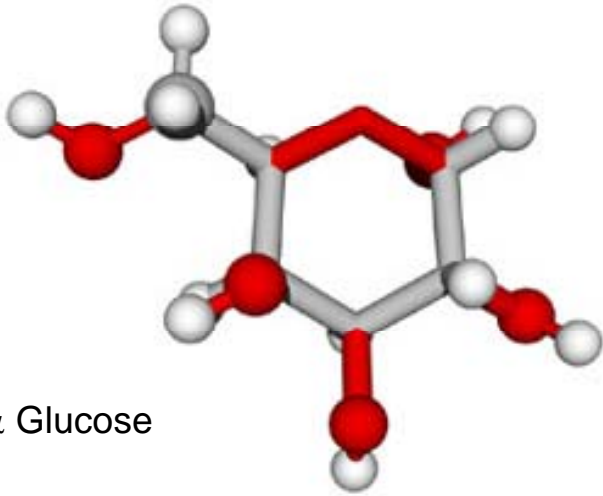
Starch and glycogen



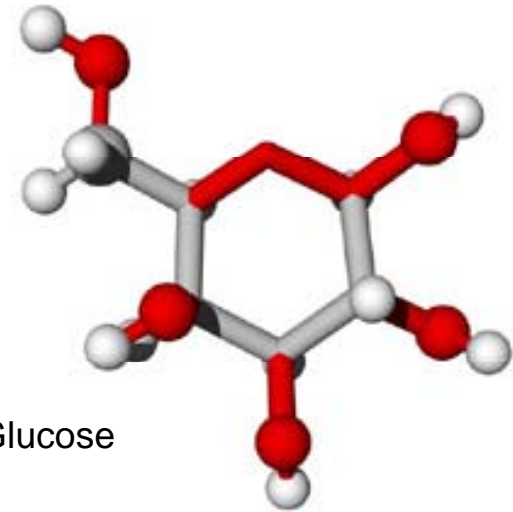
Storage polysaccharides



Starch and cellulose molecular models



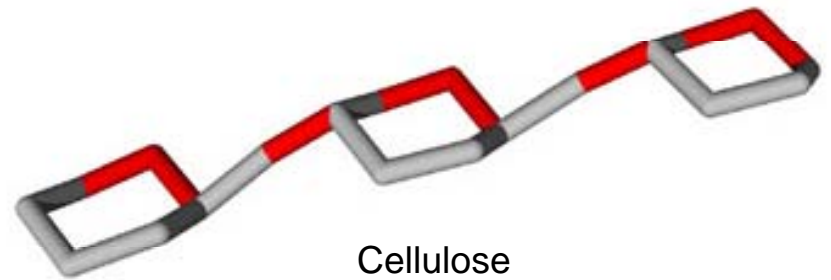
α Glucose



β Glucose



Starch

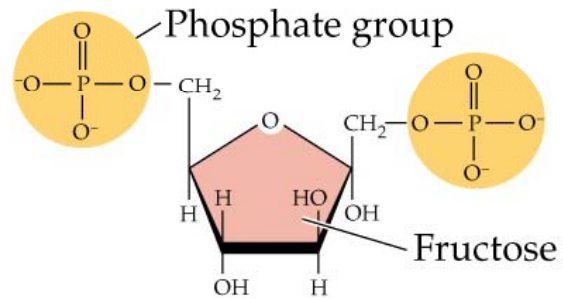


Cellulose

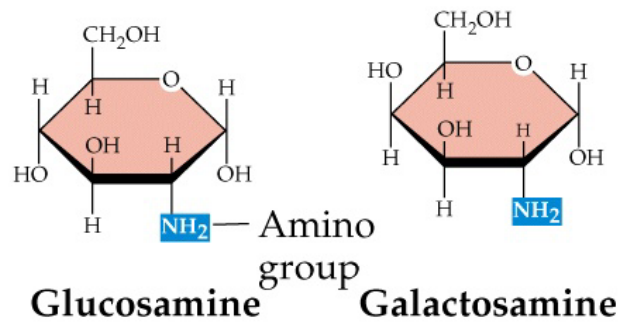
C. Carbohydrates: Sugars and Sugar Polymers

- Chemically modified monosaccharides include the sugar phosphates and amino sugars. A derivative of the amino sugar glucosamine polymerizes to form the polysaccharide chitin.

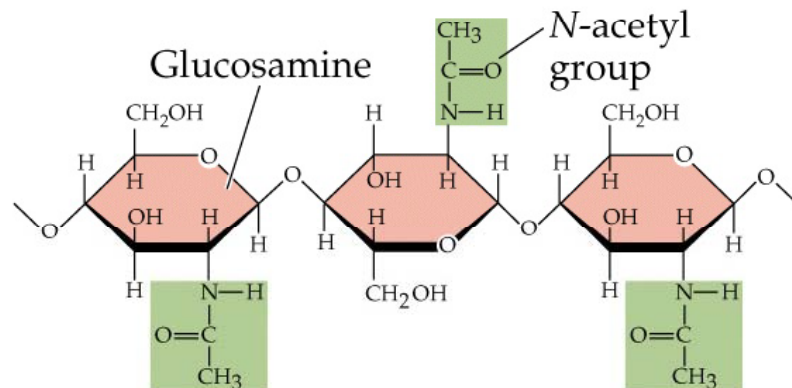
(a) Sugar phosphate



(b) Amino sugars



(c) Chitin



Modified Sugars

- Chitin, another important structural polysaccharide
 - ◆ Is found in the exoskeleton of arthropods
 - ◆ Can be used as surgical thread



Chitin forms the exoskeleton of arthropods. This cicada is molting, shedding its old exoskeleton and emerging in adult form.



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

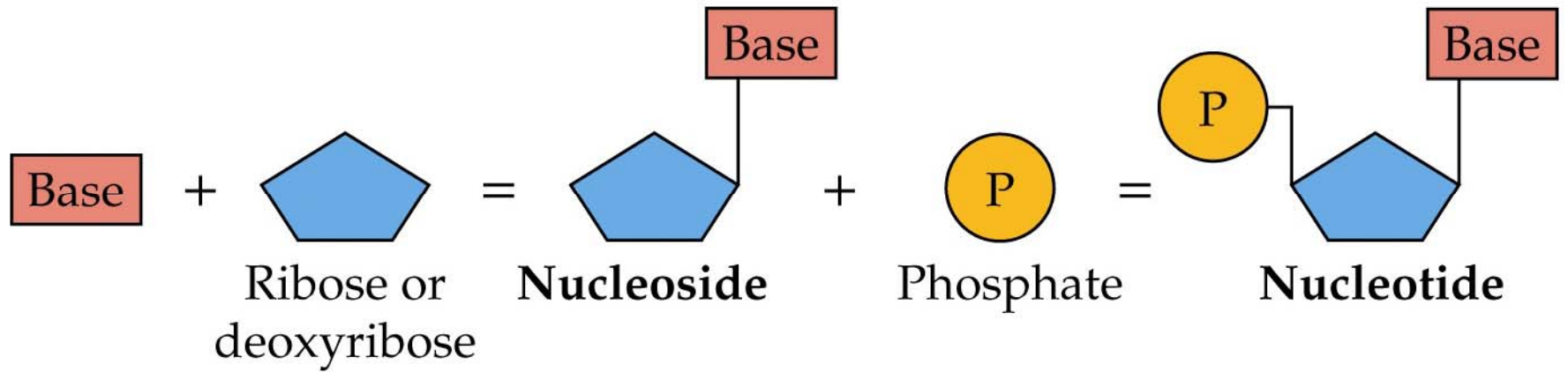
D. Nucleic Acids: Informational Macromolecules

- In cells, DNA is the hereditary material. DNA and RNA play roles in protein formation.

D. Nucleic Acids: Informational Macromolecules

- Nucleic acids are polymers of nucleotides consisting of a phosphate group, a sugar, and a nitrogen-containing base. The DNA bases are adenine, guanine, cytosine, and thymine. In RNA uracil substitutes for thymine and ribose substitutes for deoxyribose.

Nucleotides have three parts



3.3 *Distinguishing RNA from DNA*

NUCLEIC ACID	SUGAR	BASES
RNA	Ribose	Adenine Cytosine Guanine Uracil
DNA	Deoxyribose	Adenine Cytosine Guanine Thymine

D. Nucleic Acids: Informational Macromolecules

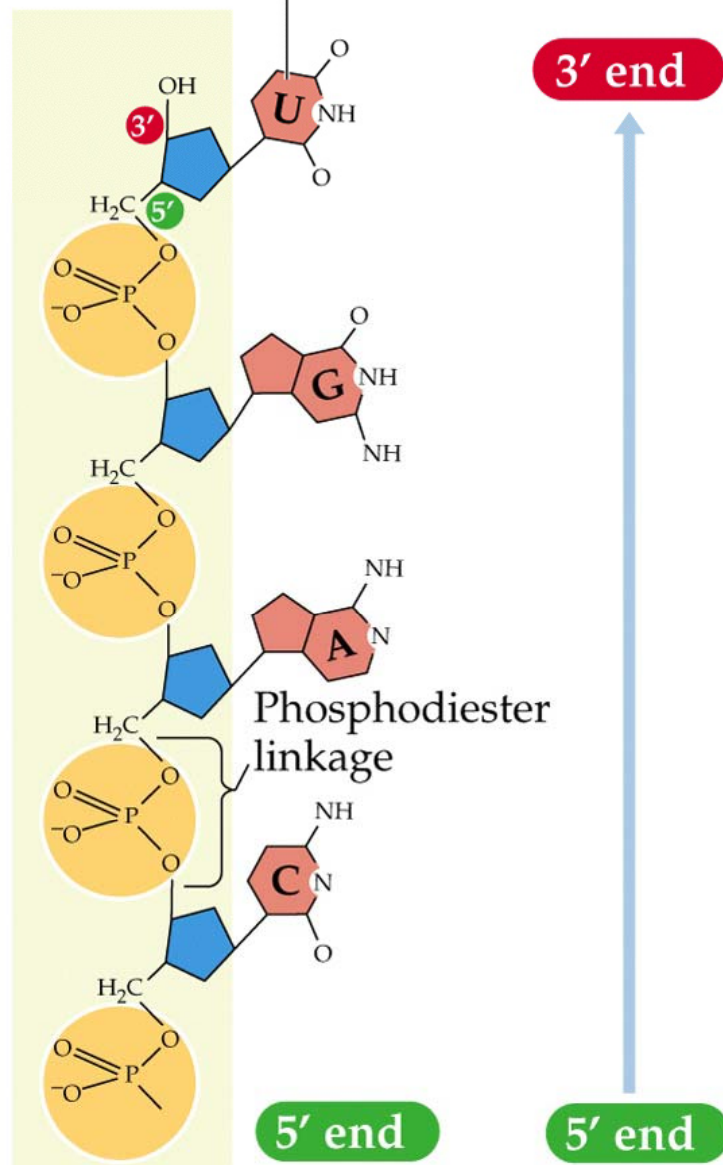
- In the nucleic acids, bases extend from a sugar–phosphate backbone using the phosphodiester linkage.
- DNA and RNA information resides in their base sequences.

D. Nucleic Acids: Informational Macromolecules

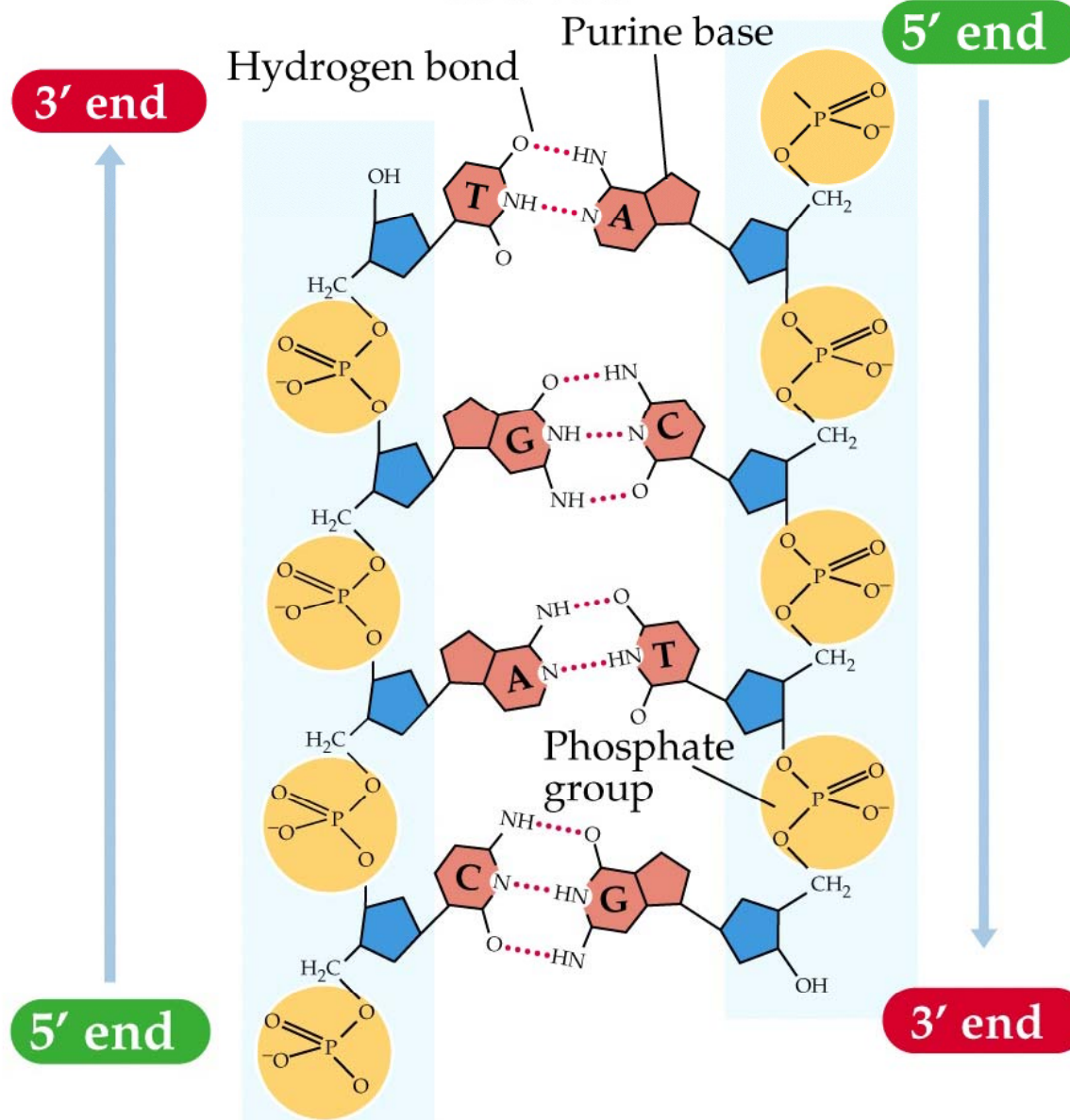
- RNA is single-stranded.
- DNA is a double-stranded helix with complementary, hydrogen-bonded base pairing between adenine and thymine and guanine and cytosine. The two strands run in opposite 5' to 3' directions.

RNA

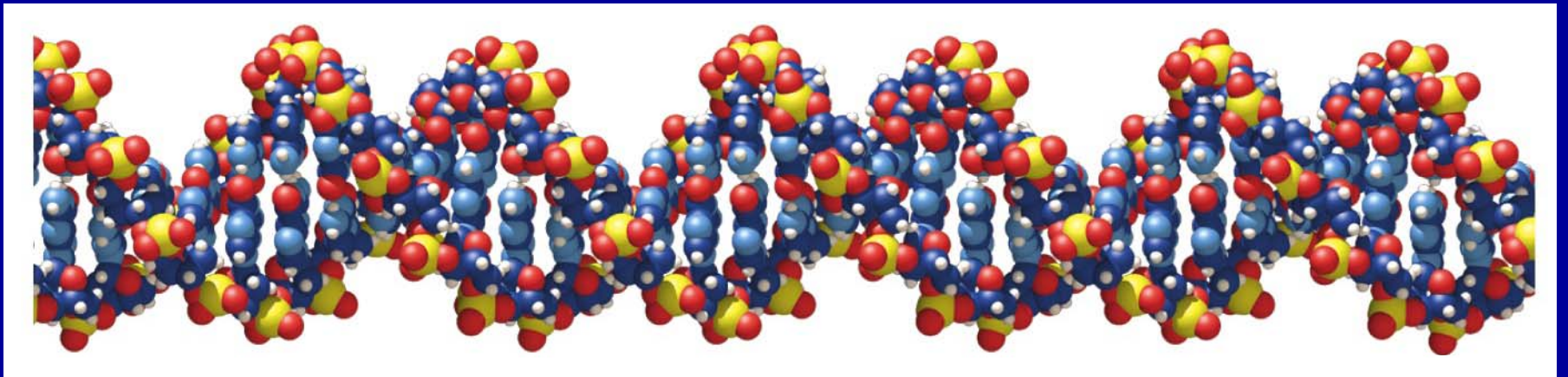
Pyrimidine base



DNA



DNA structure: The double helix



D. Nucleic Acids: Informational Macromolecules

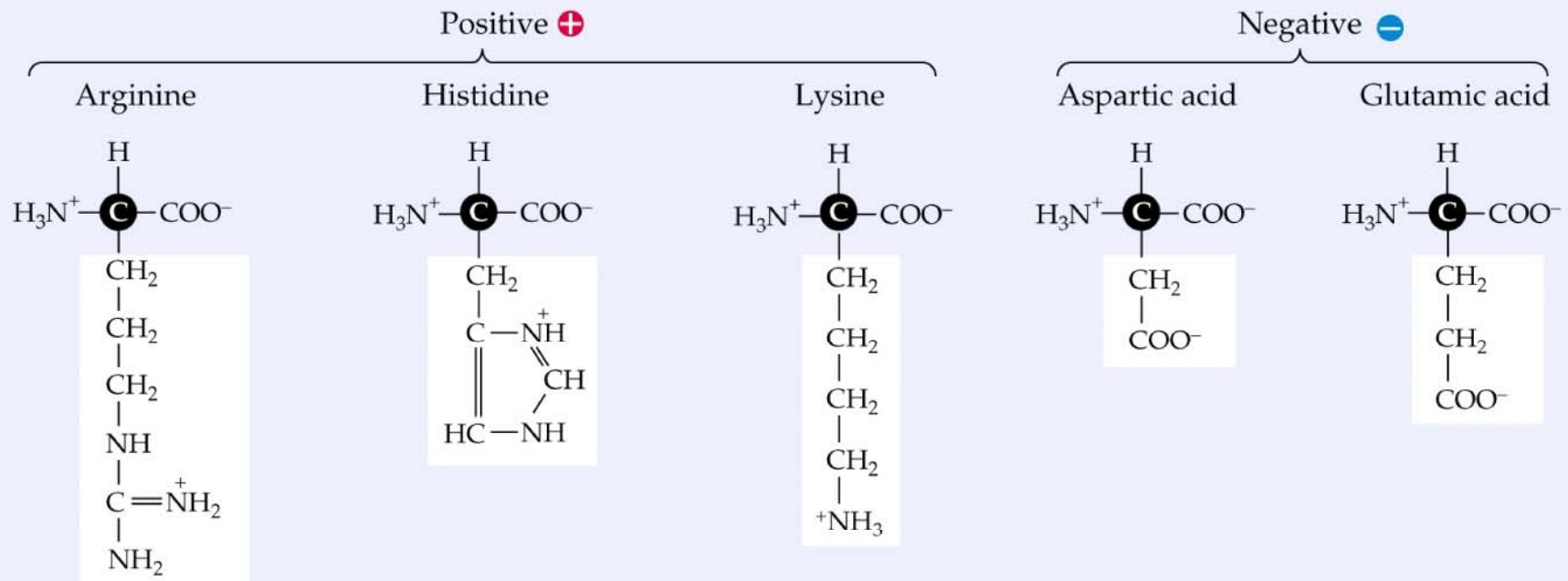
- Comparing the DNA base sequences of different living species provides information on evolutionary relatedness.
- This is called molecular phylogeny.

E. Proteins: Amazing Polymers of Amino Acids

- Functions of proteins include support, protection, catalysis, transport, defense, regulation, and movement. They sometimes require an attached prosthetic group.
- Twenty amino acids are found in proteins. Each consists of an amino group, a carboxyl group, a hydrogen, and a side chain bonded to the α carbon atom.

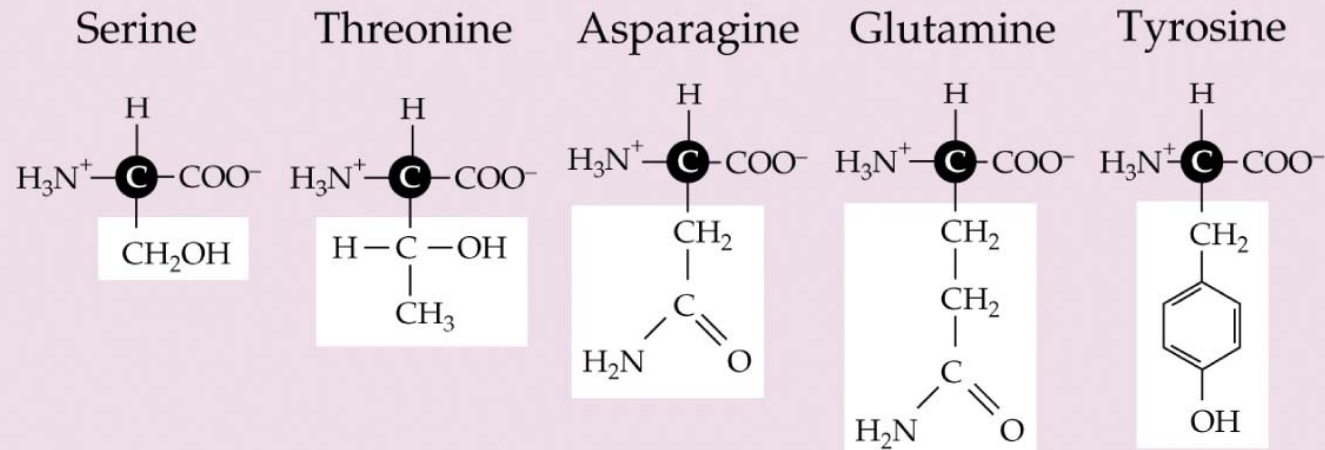
3.2 Twenty Amino Acids Found in Proteins

A. Amino acids with electrically charged side chains

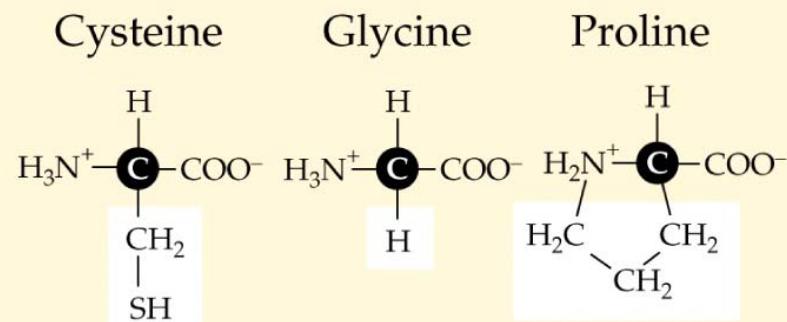


3.2 Twenty Amino Acids Found in Proteins

B. Amino acids with polar but uncharged side chains



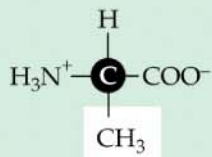
C. Special cases



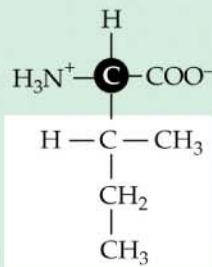
3.2 Twenty Amino Acids Found in Proteins

D. Amino acids with hydrophobic side chains

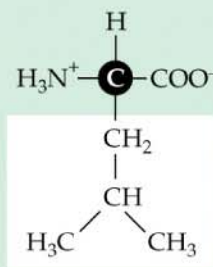
Alanine



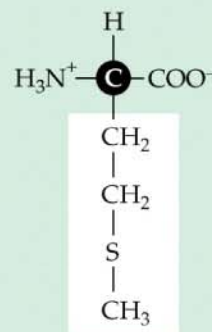
Isoleucine



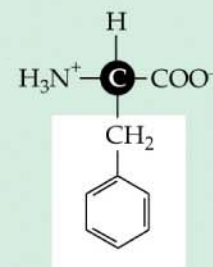
Leucine



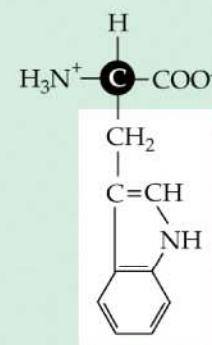
Methionine



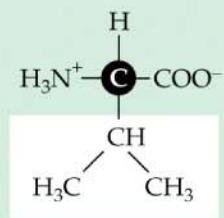
Phenylalanine



Tryptophan

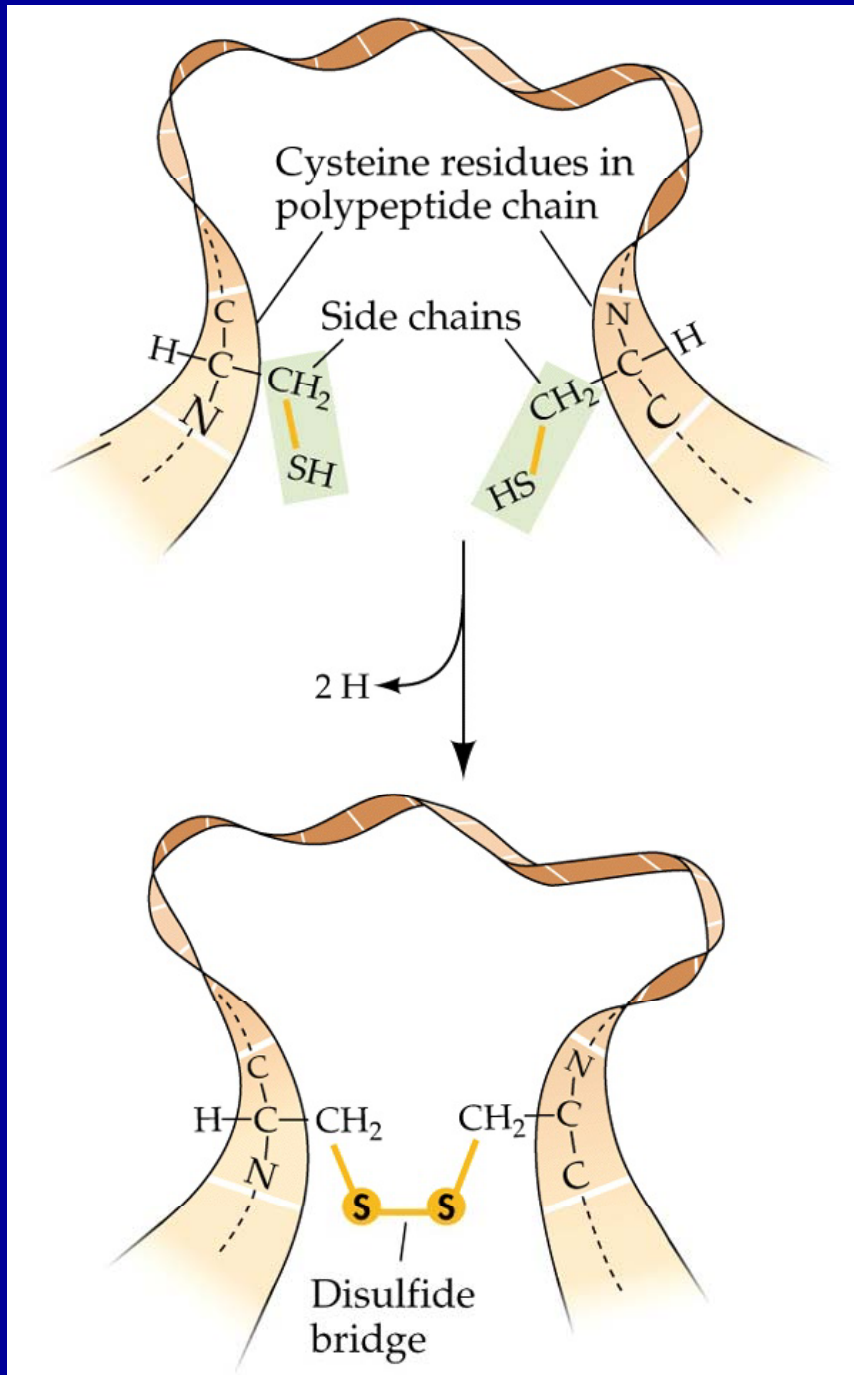


Valine



E. Proteins: Amazing Polymers of Amino Acids

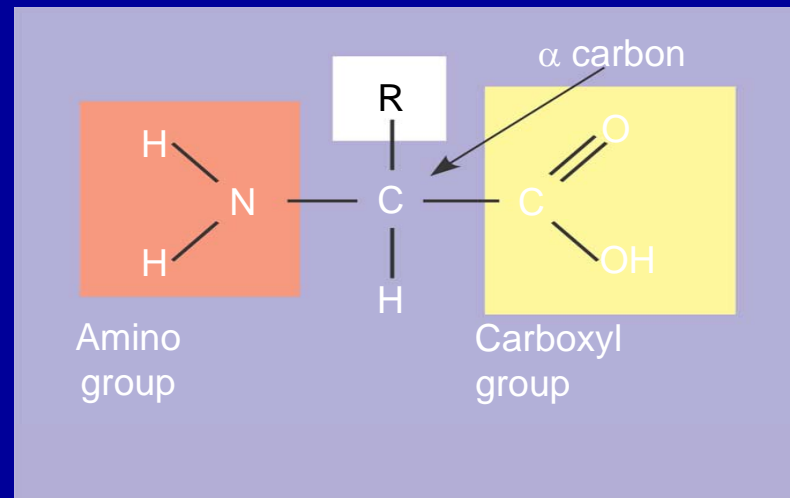
- Side chains of amino acids may be charged, polar, or hydrophobic. SH groups can form disulfide bridges.



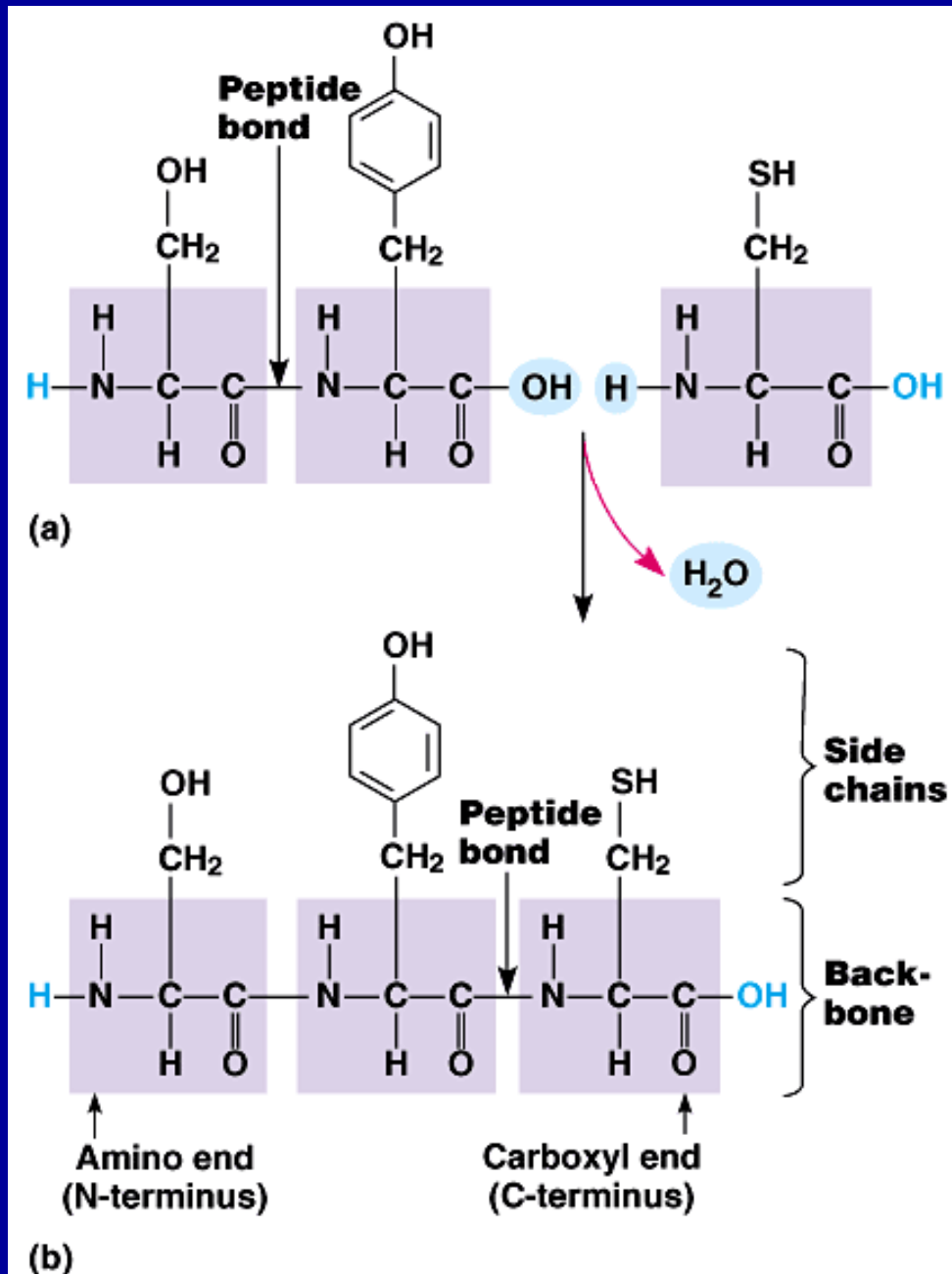
Cysteine residues can form a covalently linked disulfide bridge

E. Proteins: Amazing Polymers of Amino Acids

- Amino acids are covalently bonded together by peptide linkages.



Making a polypeptide chain



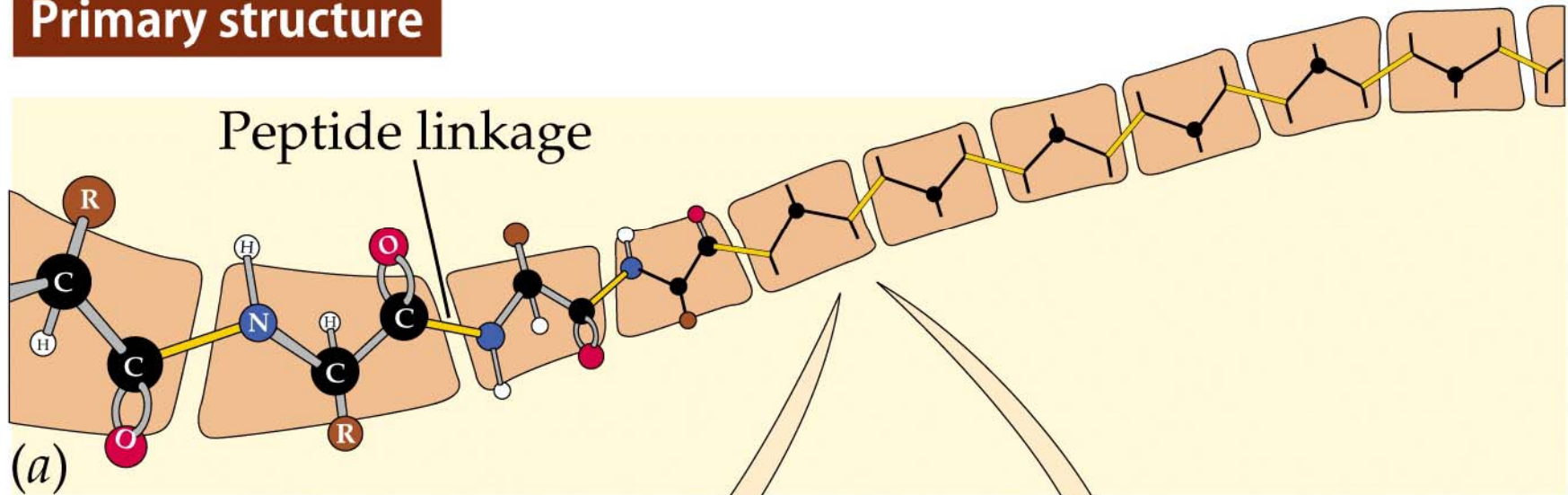
E. Proteins: Amazing Polymers of Amino Acids

- Polypeptide chains of proteins are folded into specific three-dimensional shapes. Primary, secondary, tertiary, and quaternary structures are possible.

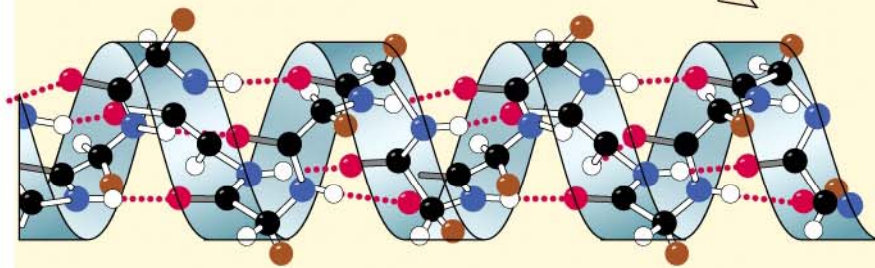
E. Proteins: Amazing Polymers of Amino Acids

- The primary structure of a protein is the sequence of amino acids bonded by peptide linkages.
- Secondary structures are maintained by hydrogen bonds between atoms of the amino acid residues.

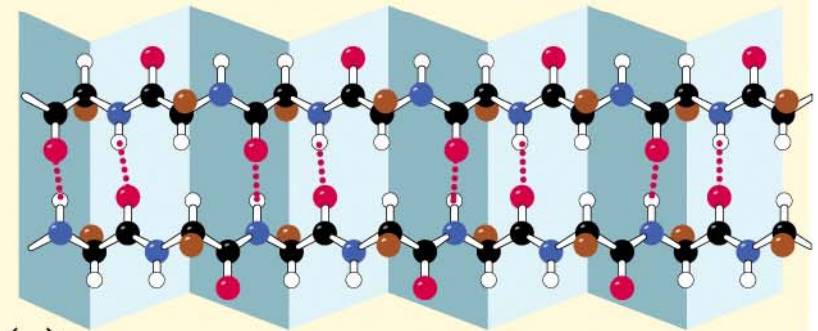
Primary structure



Secondary structure



α Helix



β Pleated sheet

Abdominal glands of the spider secrete silk fibers that form the web

The radiating strands, made of dry silk fibers maintained the shape of the web

The spiral strands (capture strands) are elastic, stretching in response to wind, rain, and the touch of insects



Spider silk: a structural protein containing β pleated sheets

E. Proteins: Amazing Polymers of Amino Acids

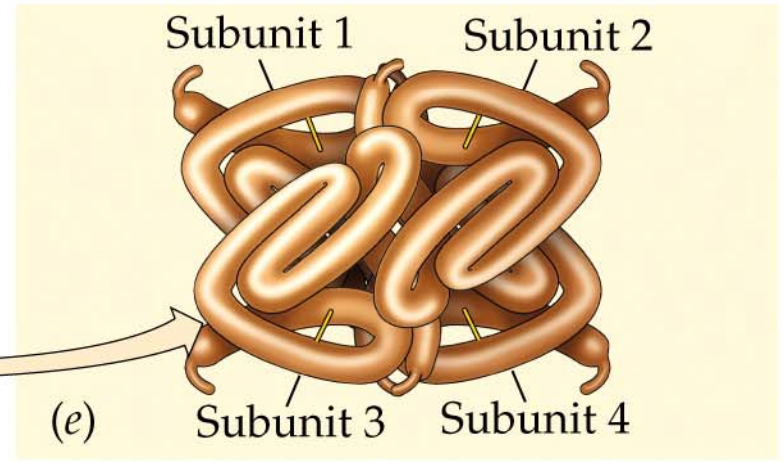
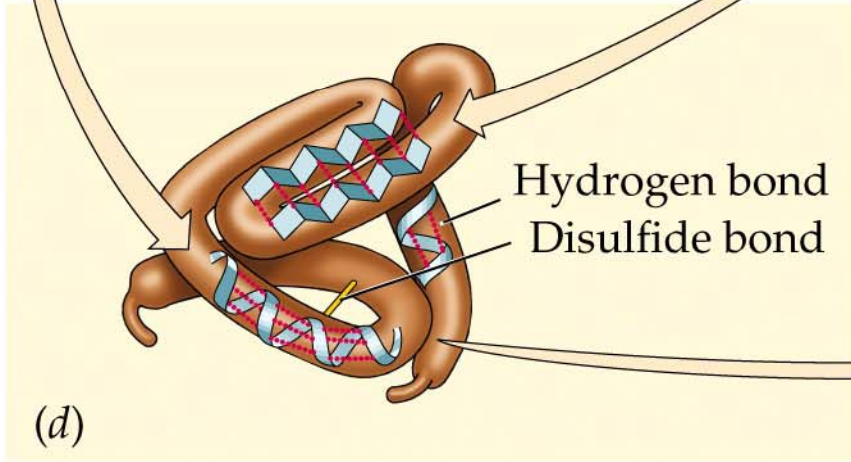
- The tertiary structure is generated by bending and folding of the polypeptide chain. This results from interactions between amino acids and R groups.
- The quaternary structure is the arrangement of polypeptides in a single functional unit consisting of more than one polypeptide subunit.

(b) α Helix

(c) β Pleated sheet

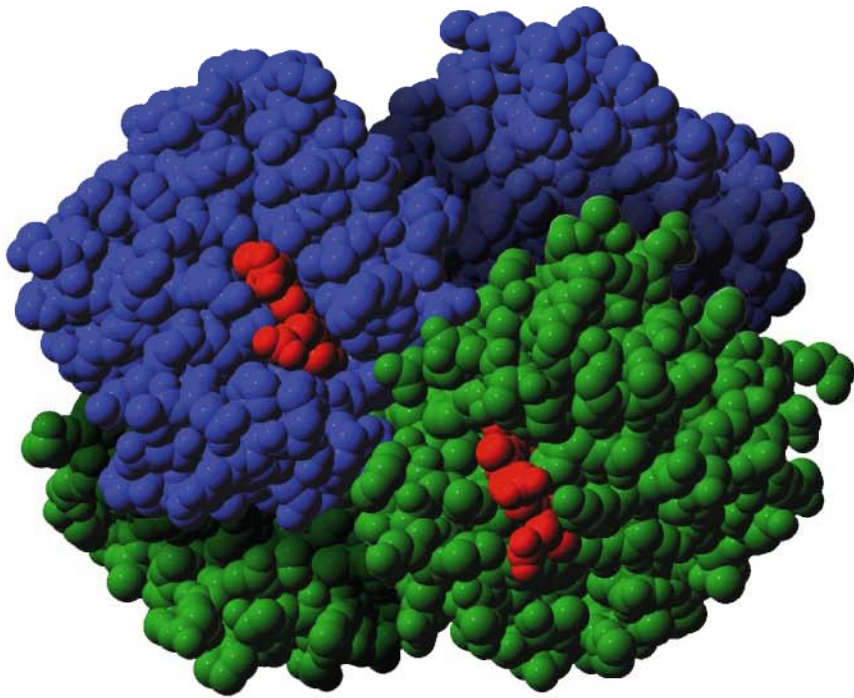
Tertiary structure

Quaternary structure

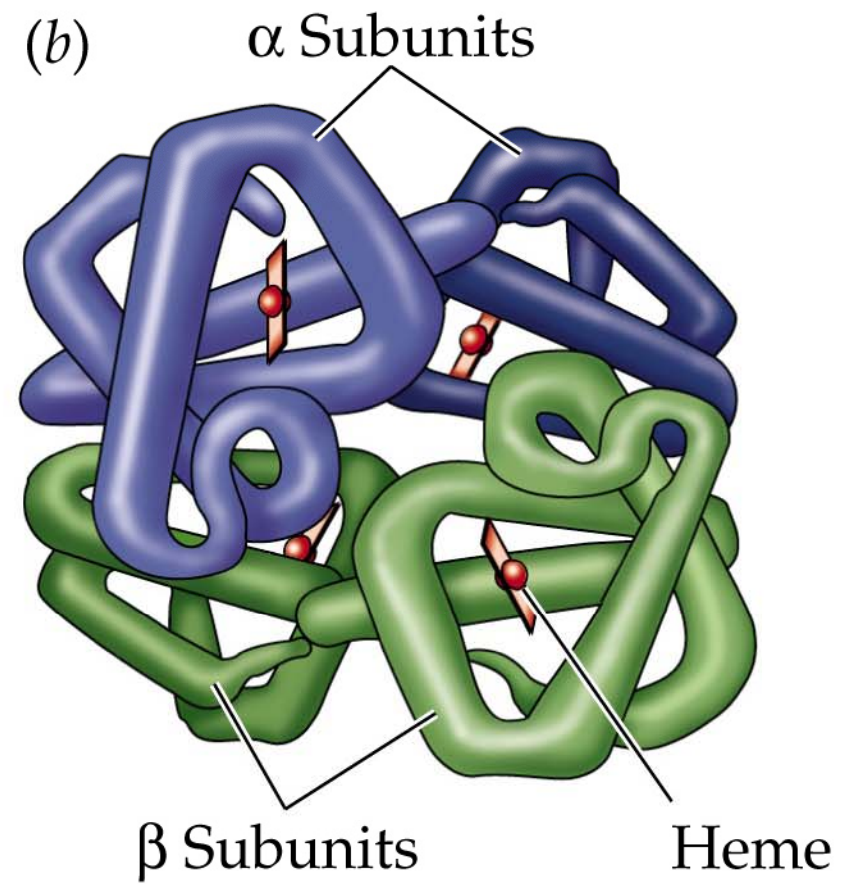


Quaternary Structure

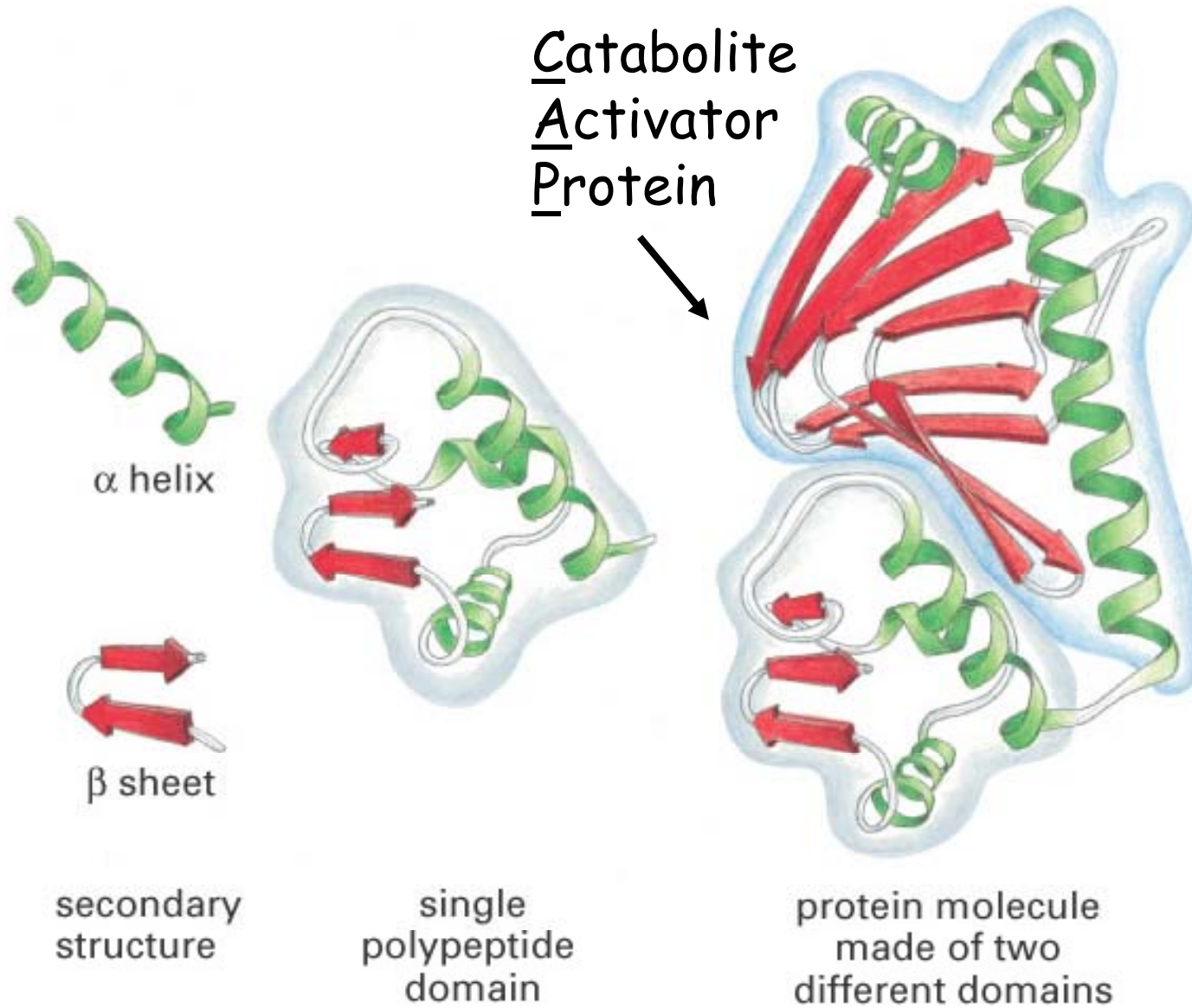
(a)



(b)

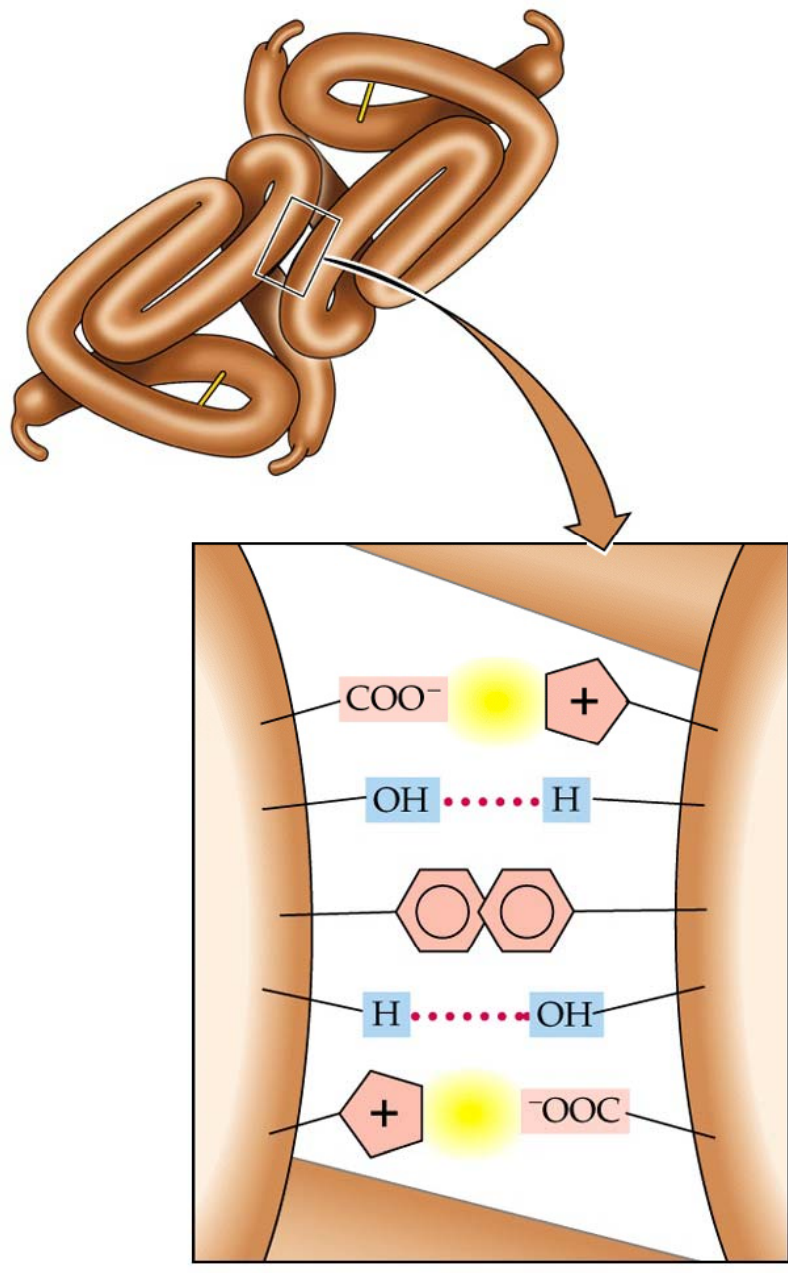


Domains

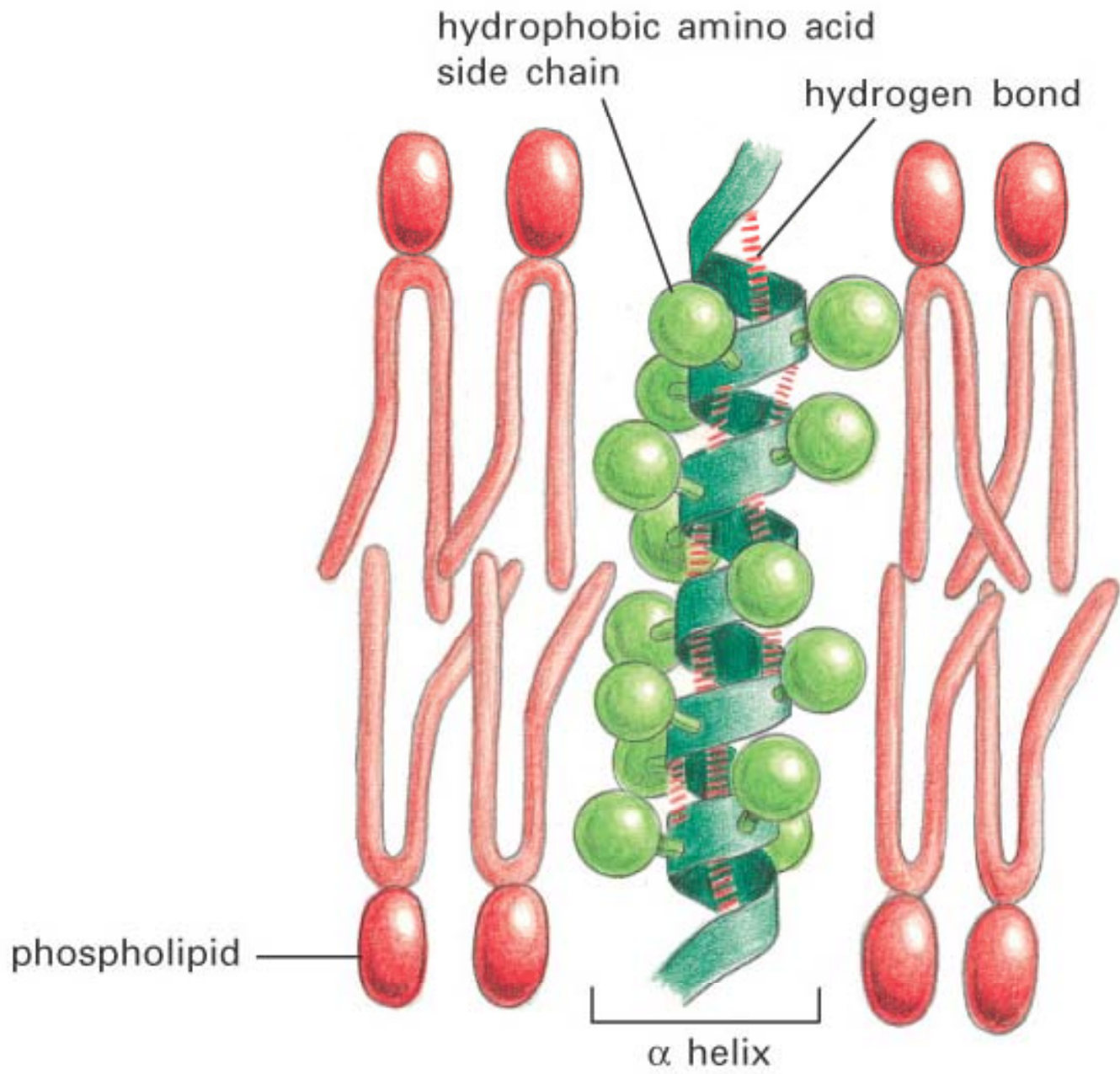


E. Proteins: Amazing Polymers of Amino Acids

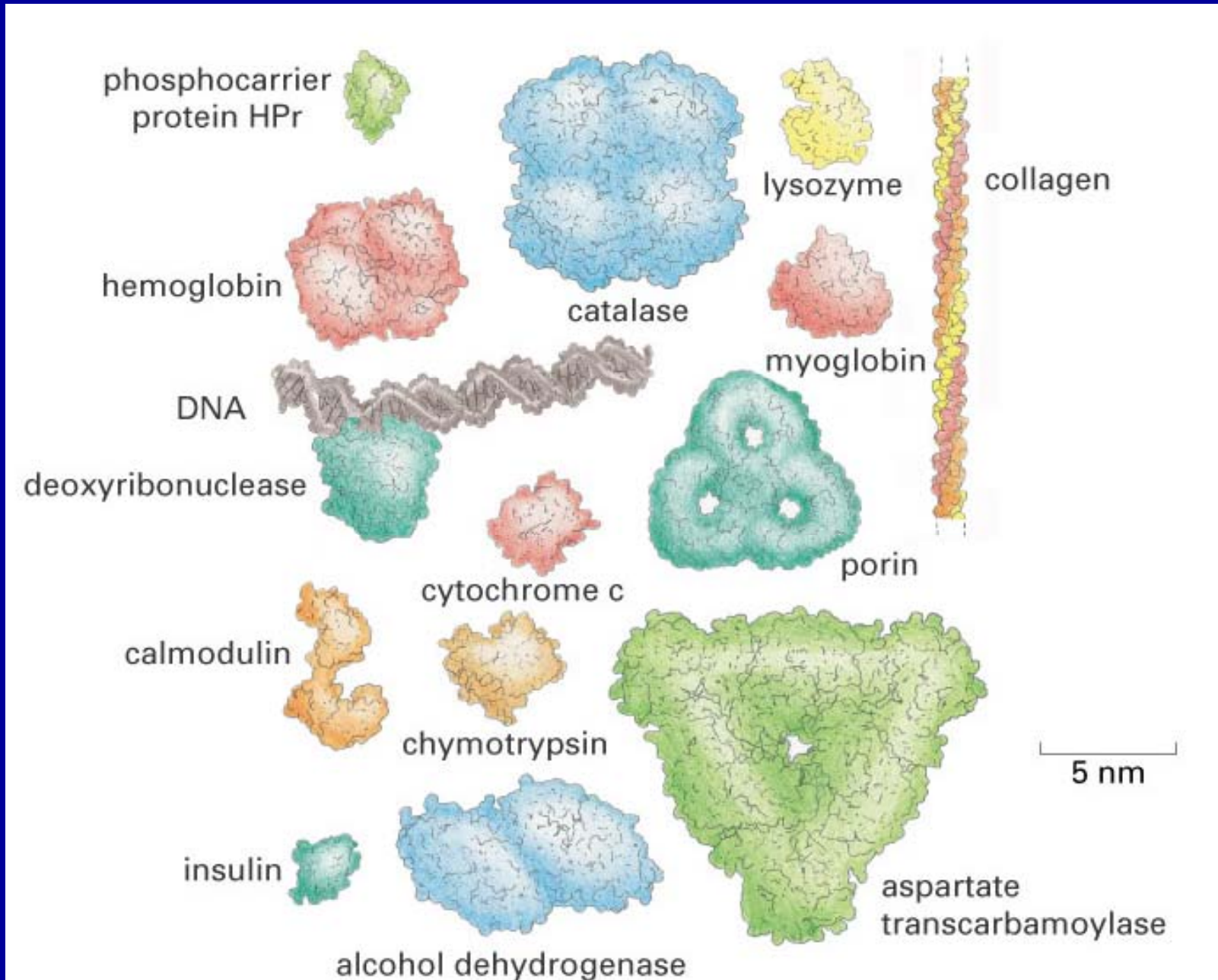
- Weak chemical interactions are important in the binding of proteins to other molecules.
- Any molecule that binds to a protein is called a ligand (e.g., antibodies to antigens).
- Proteins denatured by heat, acid, or chemicals lose tertiary and possibly secondary structure and lose biological function.



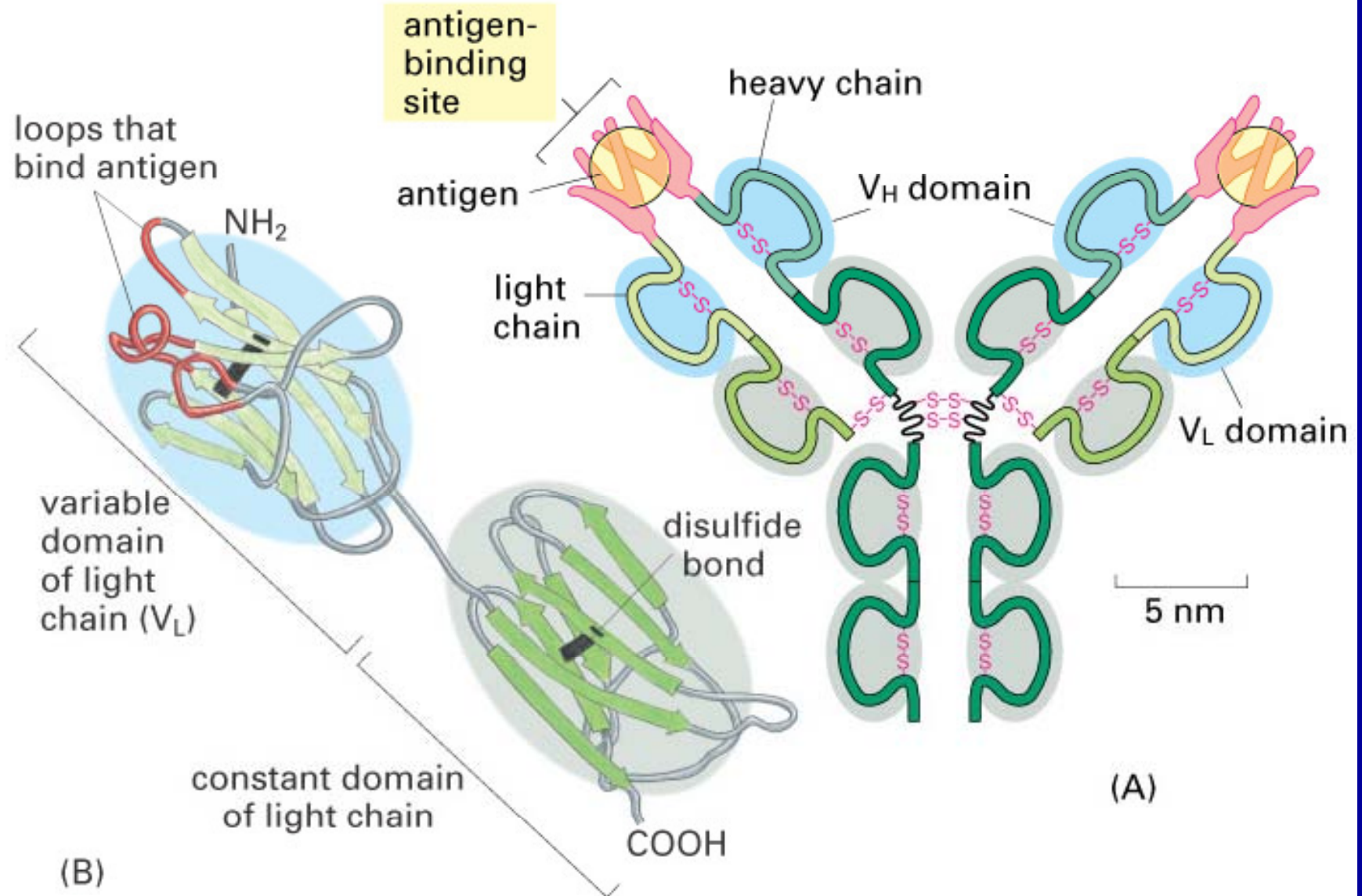
Noncovalent interactions
can occur between proteins
and other molecules



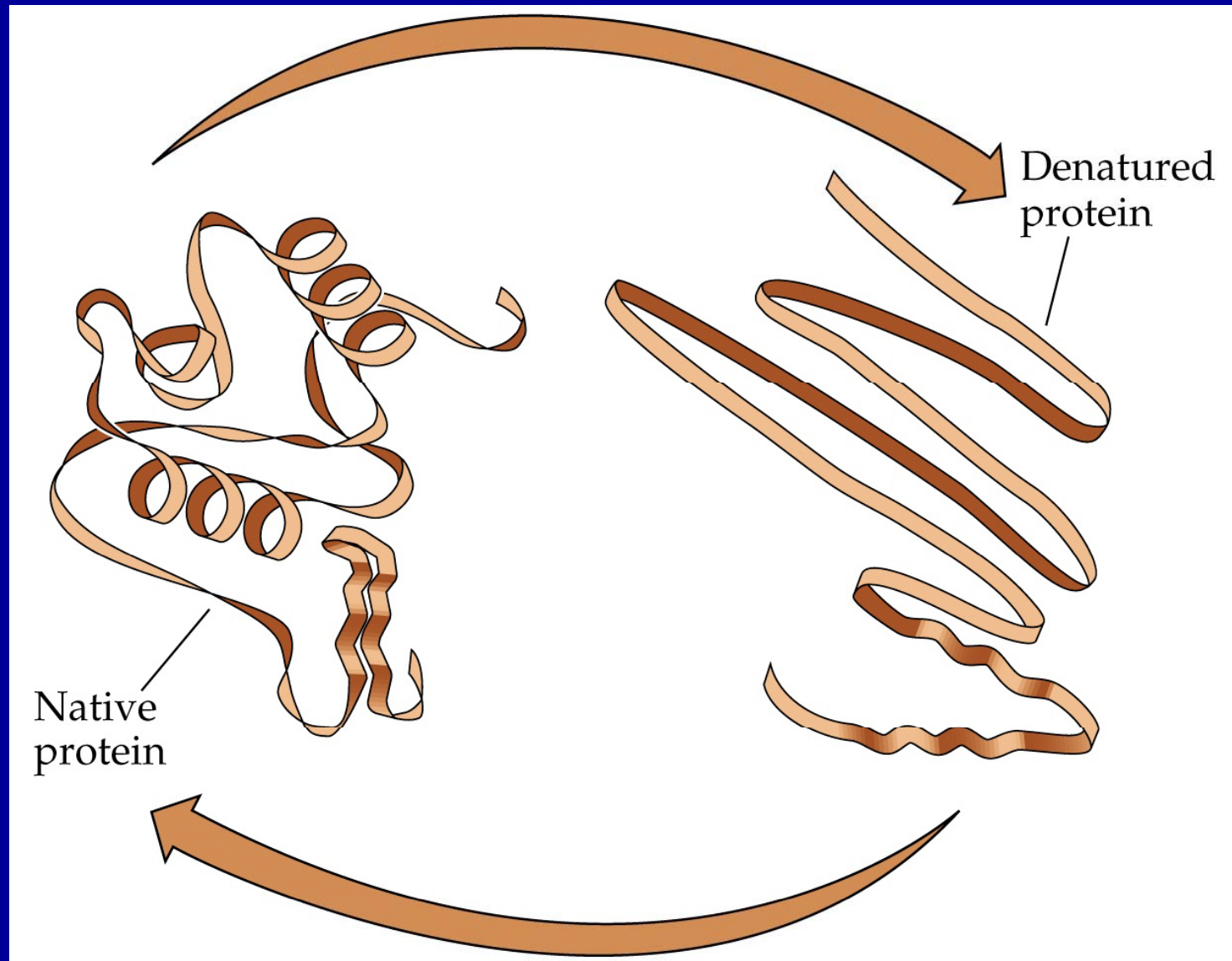
Extreme Diversity



Antibodies



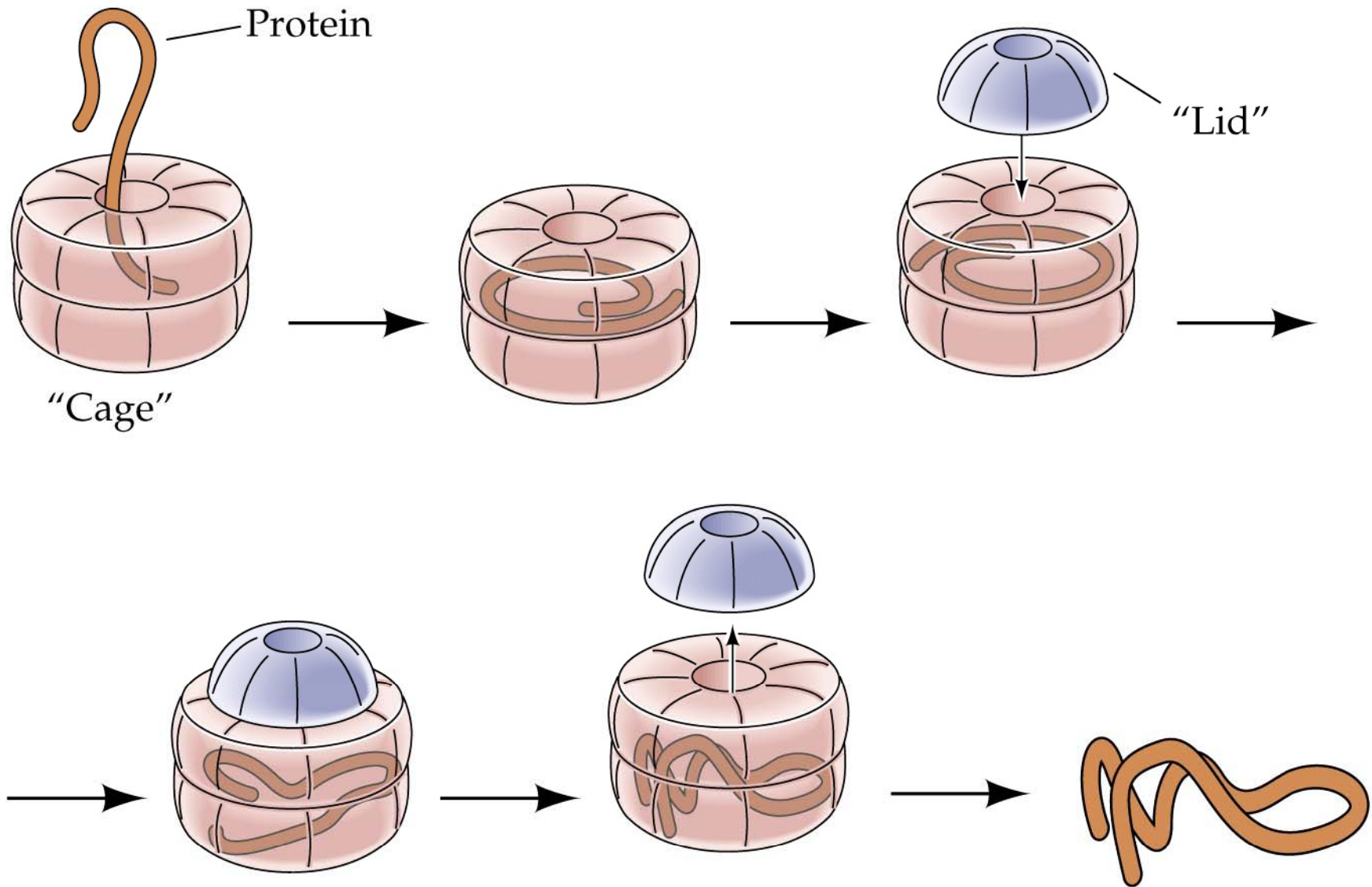
Denaturation is the loss of Tertiary Structure and Function



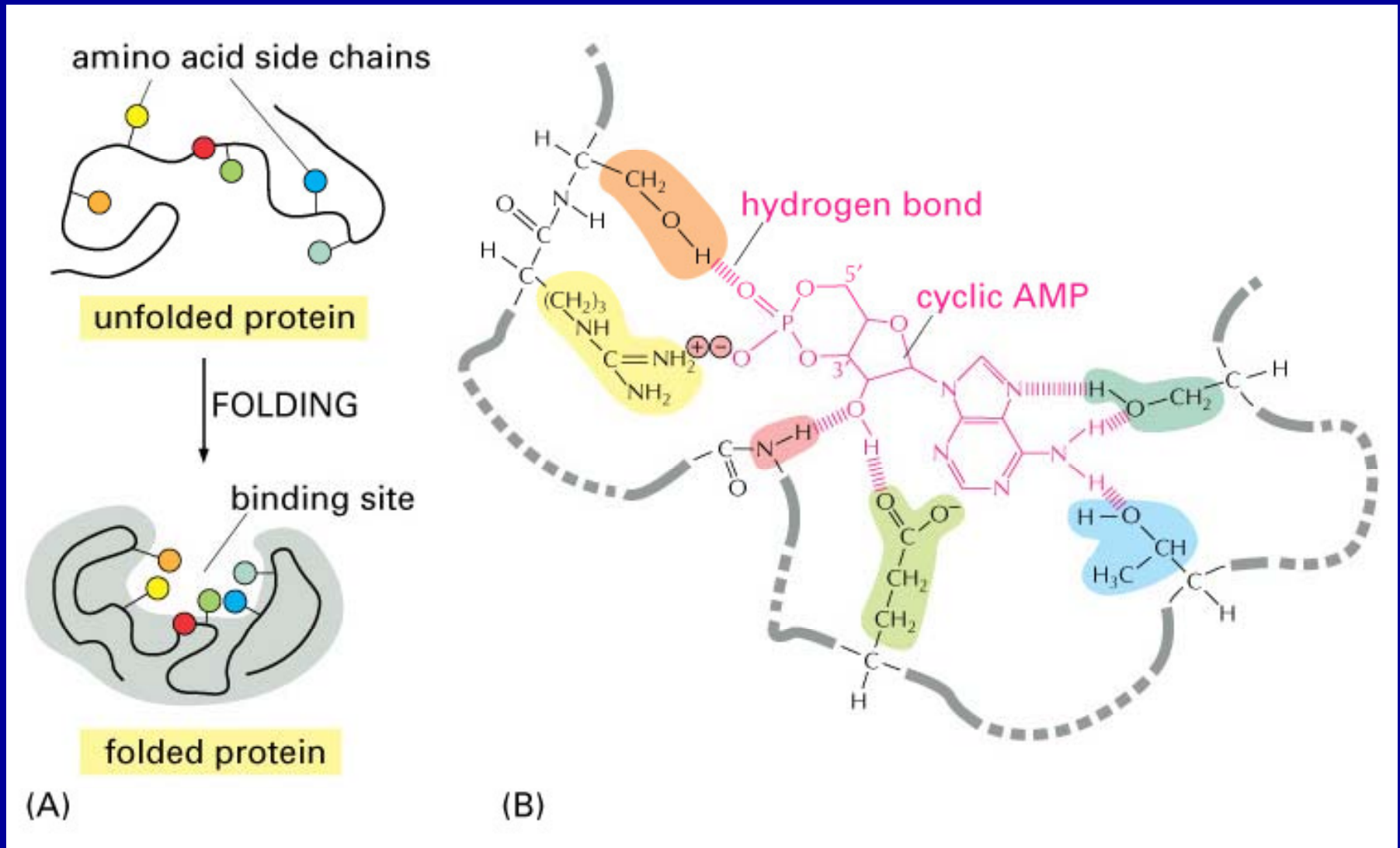
E. Proteins: Amazing Polymers of Amino Acids

- Chaperonins assist protein folding by preventing binding to inappropriate ligands.
- They also help to shape proteins with special needs regarding hydrophobic and hydrophilic interactions.

Chaperonins aid in Folding through Protection

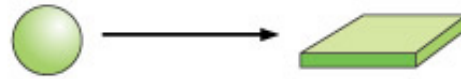


Binding to specific ligands

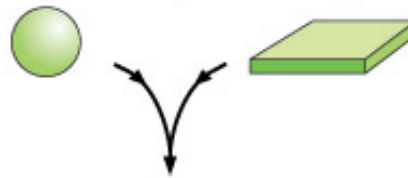


Prion diseases

(A) very rare conformational change



(B) infectious seeding of new protein aggregate



F. The Interactions with other Macromolecules

- Glycoproteins contain an oligosaccharide "label" that directs the protein to the proper cell destination. The carbohydrate groups of glycolipids are on the cell's outer surface, serving as recognition signals.
- An example of emergent properties where greater complexity is exhibited.