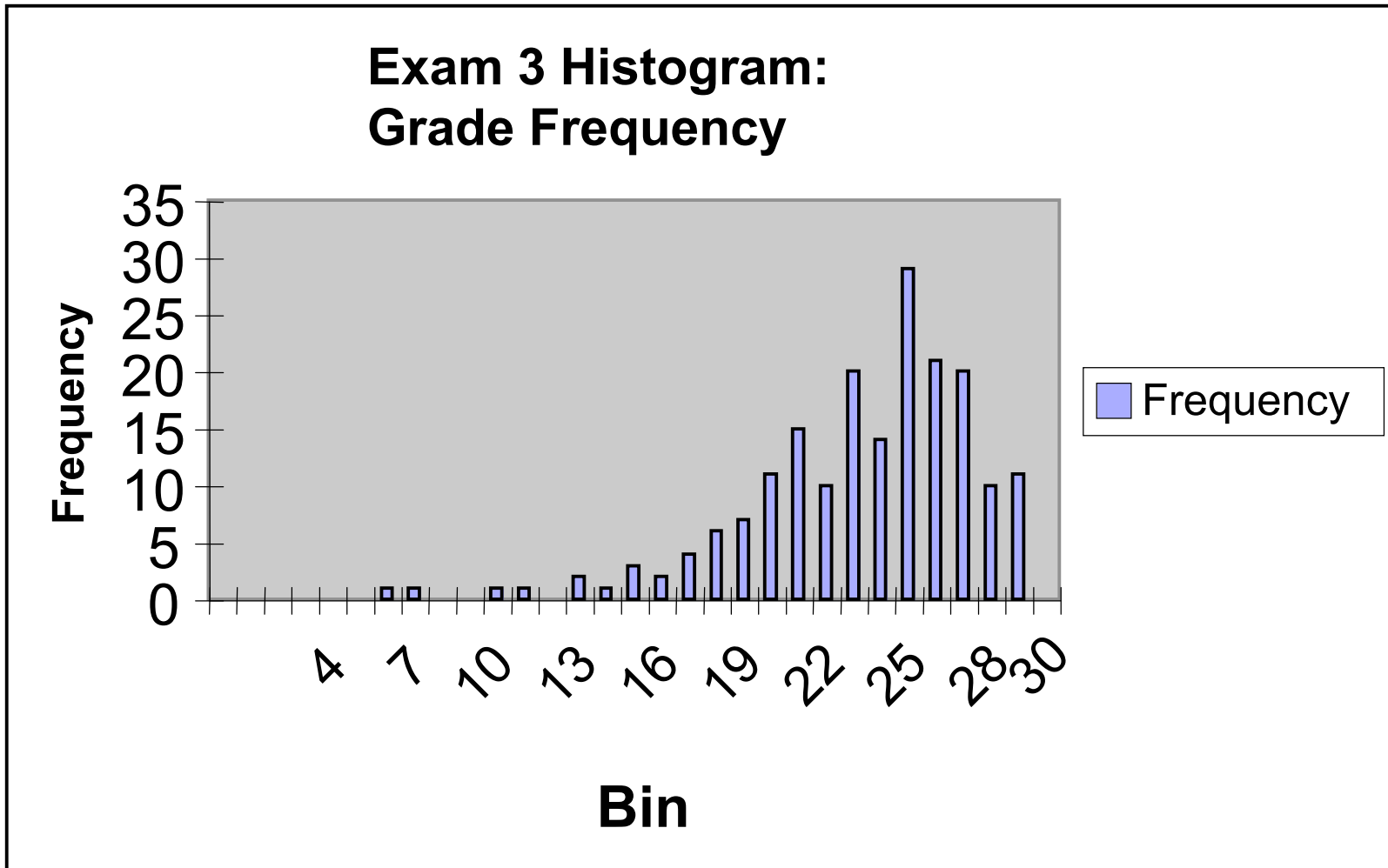


Grade distribution for Exam 3



Synthetic and Biological Polymers

Polymers: Macromolecules formed by the covalent attachment of a set of small molecules termed monomers.

Polymers are classified as:

- (1) Man-made or synthetic polymers that are synthesized in the laboratory;
- (2) Biological polymer that are found in nature.

Synthetic polymers: nylon, poly-ethylene, poly-styrene

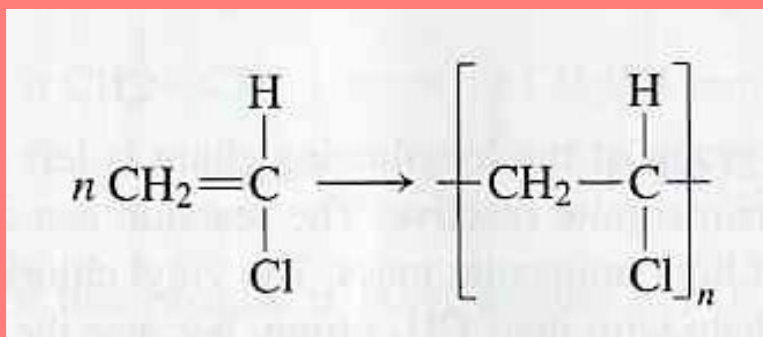
Biological polymers: DNA, proteins, carbohydrates

Methods for making polymers

Addition polymerization and condensation polymerization

Addition polymerization: monomers react to form a polymer without net loss of atoms.

Most common form: free radical chain reaction of ethylenes

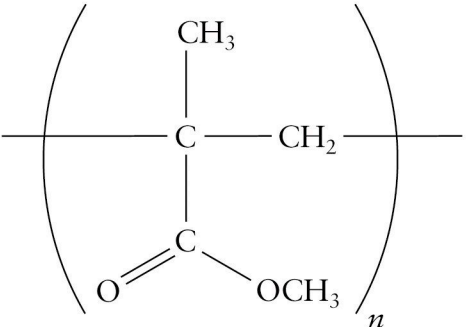


n monomers

one polymer molecule

Example of addition polymers

TABLE 19.2 Common Addition Polymers

Monomer name	Formula	Polymer formula	Common name
ethene*	$\text{CH}_2=\text{CH}_2$	$-(\text{CH}_2-\text{CH}_2)_n-$	polyethylene
vinyl chloride	$\text{CHCl}=\text{CH}_2$	$-(\text{CHCl}-\text{CH}_2)_n-$	polyvinyl chloride
styrene	$\text{CH}(\text{C}_6\text{H}_5)=\text{CH}_2$	$-(\text{CH}(\text{C}_6\text{H}_5)-\text{CH}_2)_n-$	polystyrene
acrylonitrile	$\text{CH}(\text{CN})=\text{CH}_2$	$-(\text{CH}(\text{CN})-\text{CH}_2)_n-$	Orlon, Acrilan
propene*	$\text{CH}(\text{CH}_3)=\text{CH}_2$	$-(\text{CH}(\text{CH}_3)-\text{CH}_2)_n-$	polypropylene
methyl methacrylate	$\text{CH}_3\text{OOC}(\text{CH}_3)\text{C}=\text{CH}_2$		Plexiglas, Lucite
tetrafluoroethene*	$\text{CF}_2=\text{CF}_2$	$-(\text{CF}_2-\text{CF}_2)_n-$	Teflon, PTFE [†]

*The suffix *-ene* is replaced by *-ylene* in the common names of these compounds, hence the names of the corresponding polymers.

[†]PTFE, polytetrafluoroethylene.

Free-Radical Addition Polymerization of Ethylene



200 °C
2000 atm

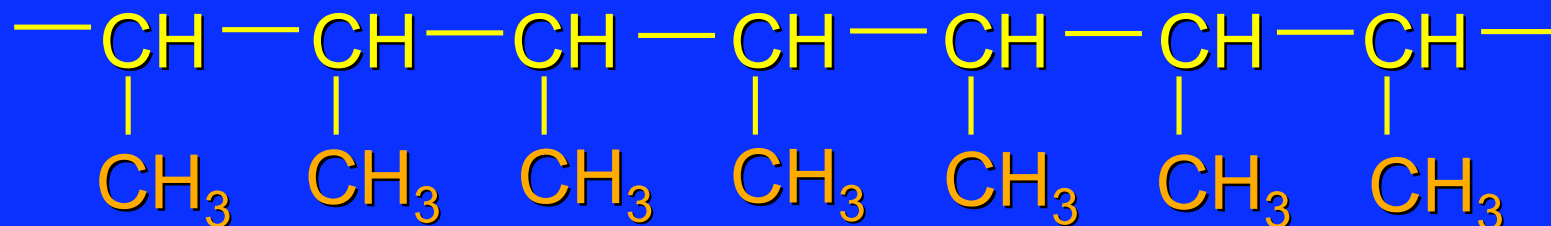
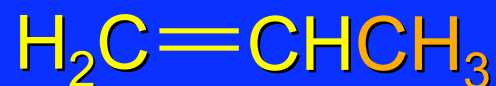


O₂
peroxides



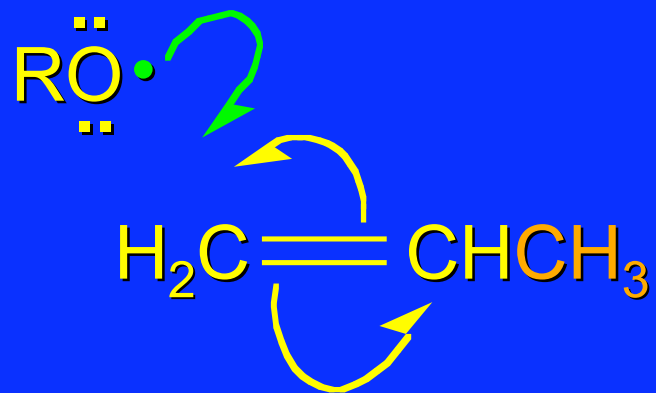
polyethylene

Free-Radical Polymerization of Propene

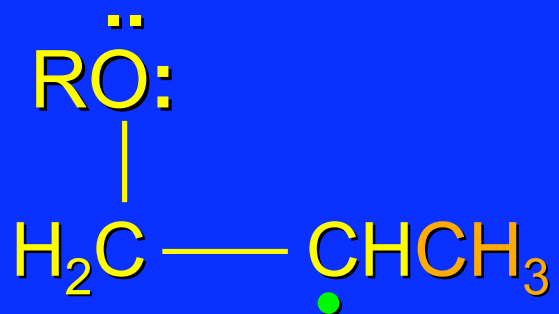


polypropylene

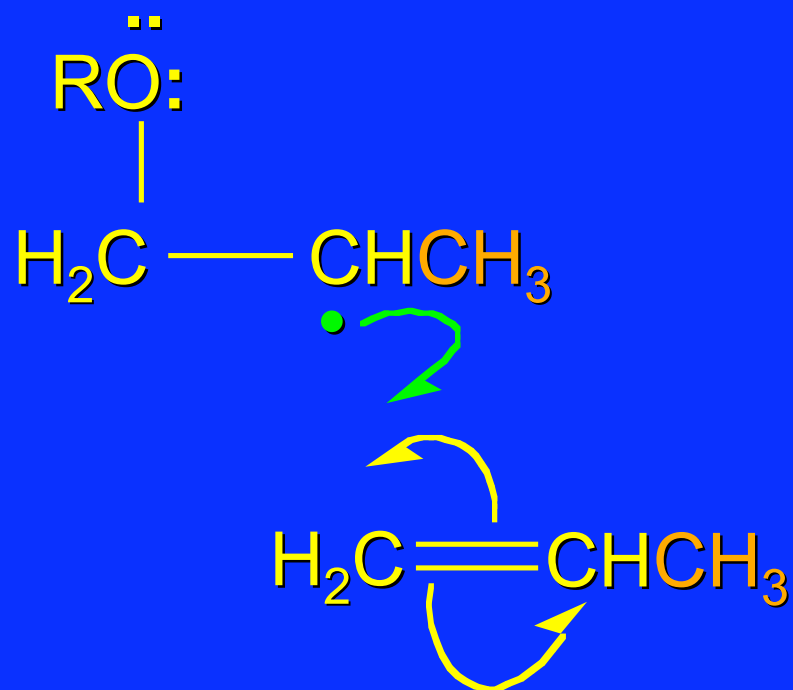
Mechanism



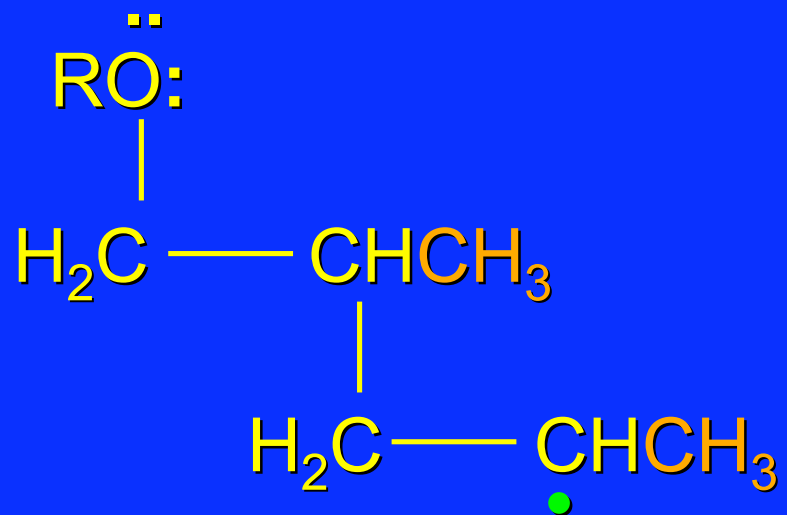
Mechanism



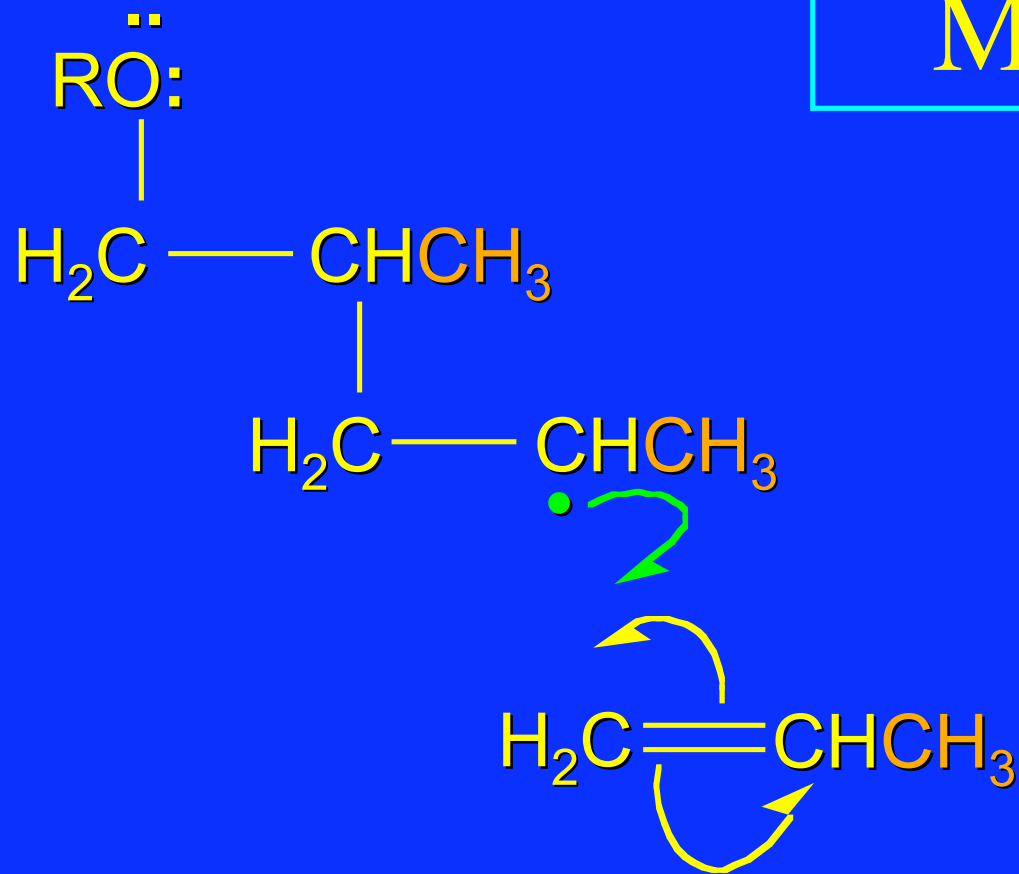
Mechanism



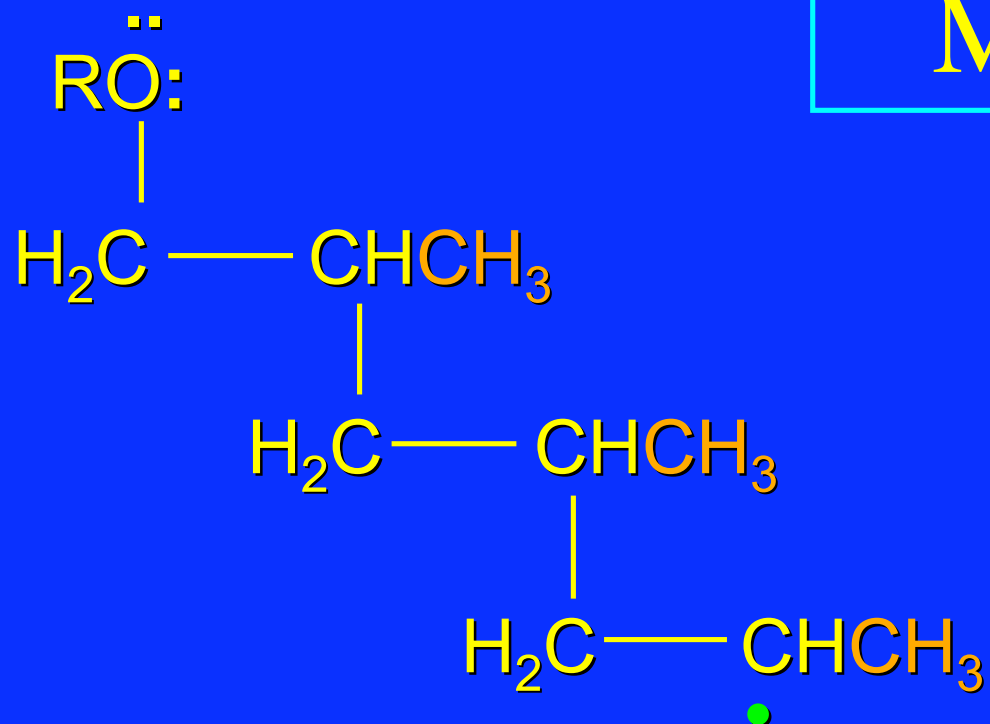
Mechanism



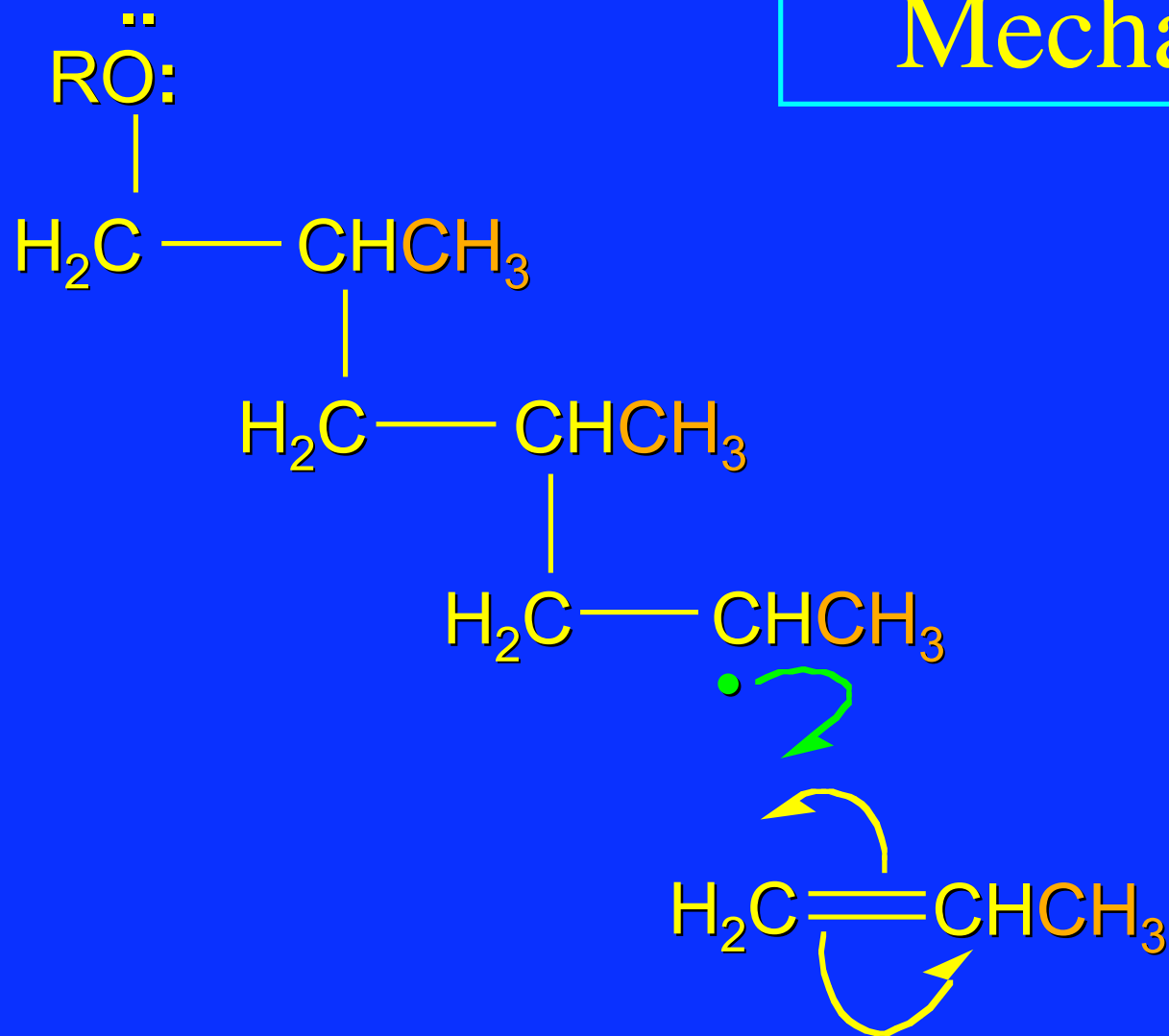
Mechanism



Mechanism



Mechanism



Likewise...

• $\text{H}_2\text{C}=\text{CHCl}$ \longrightarrow polyvinyl chloride

• $\text{H}_2\text{C}=\text{CHC}_6\text{H}_5$ \longrightarrow polystyrene

• $\text{F}_2\text{C}=\text{CF}_2$ \longrightarrow Teflon

Important constitutions for synthetic polymers



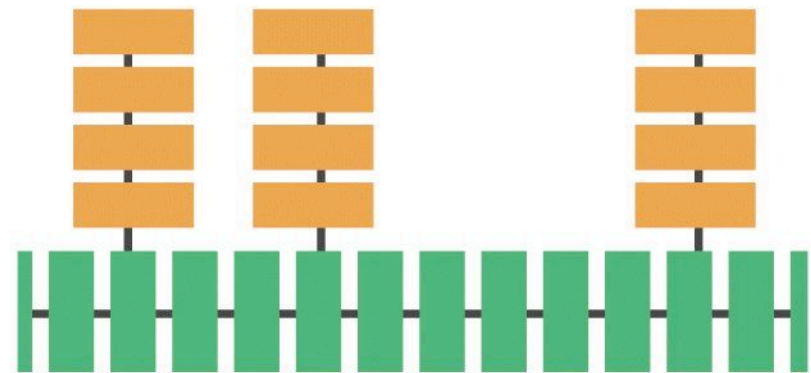
(a) Simple polymer



(b) Alternating copolymer

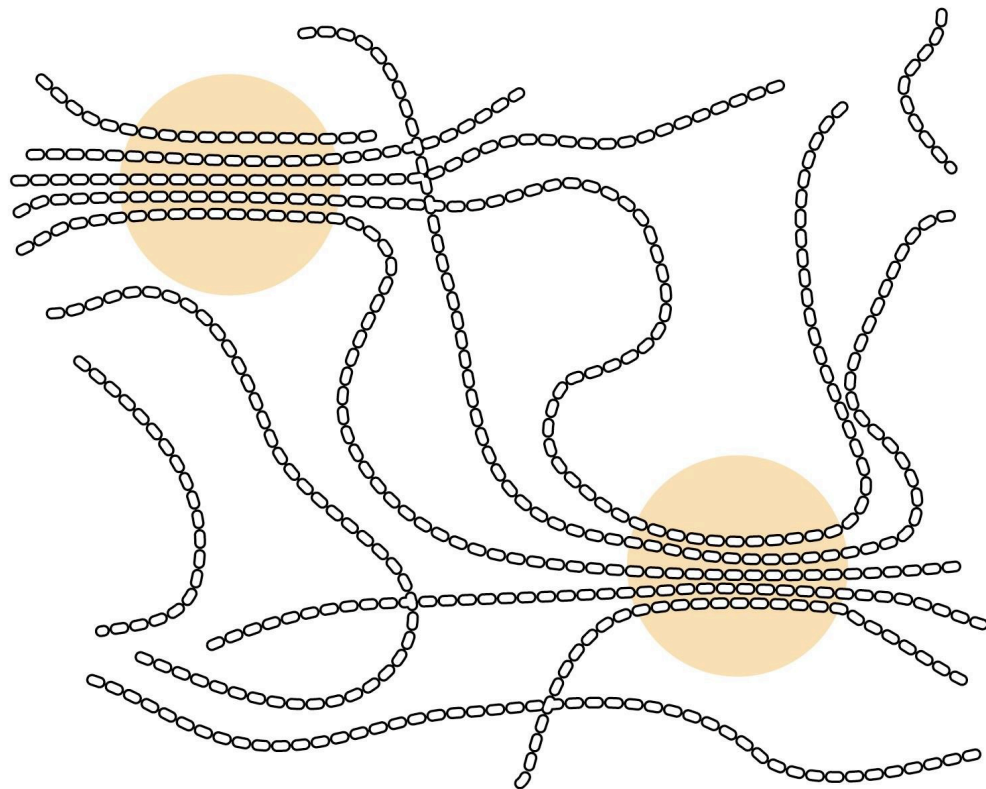


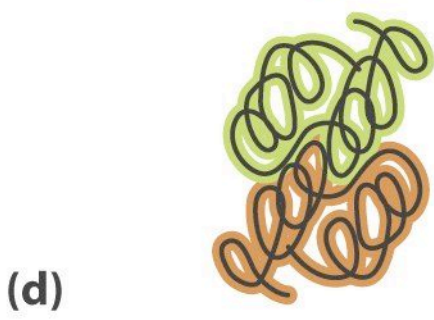
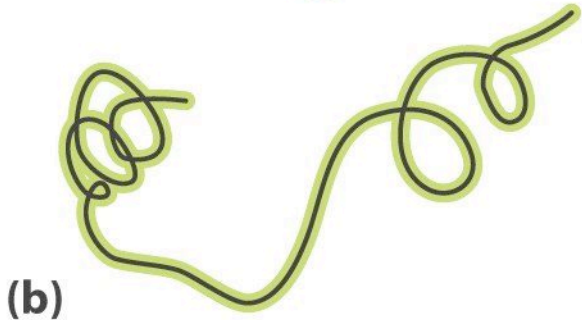
(c) Block copolymer



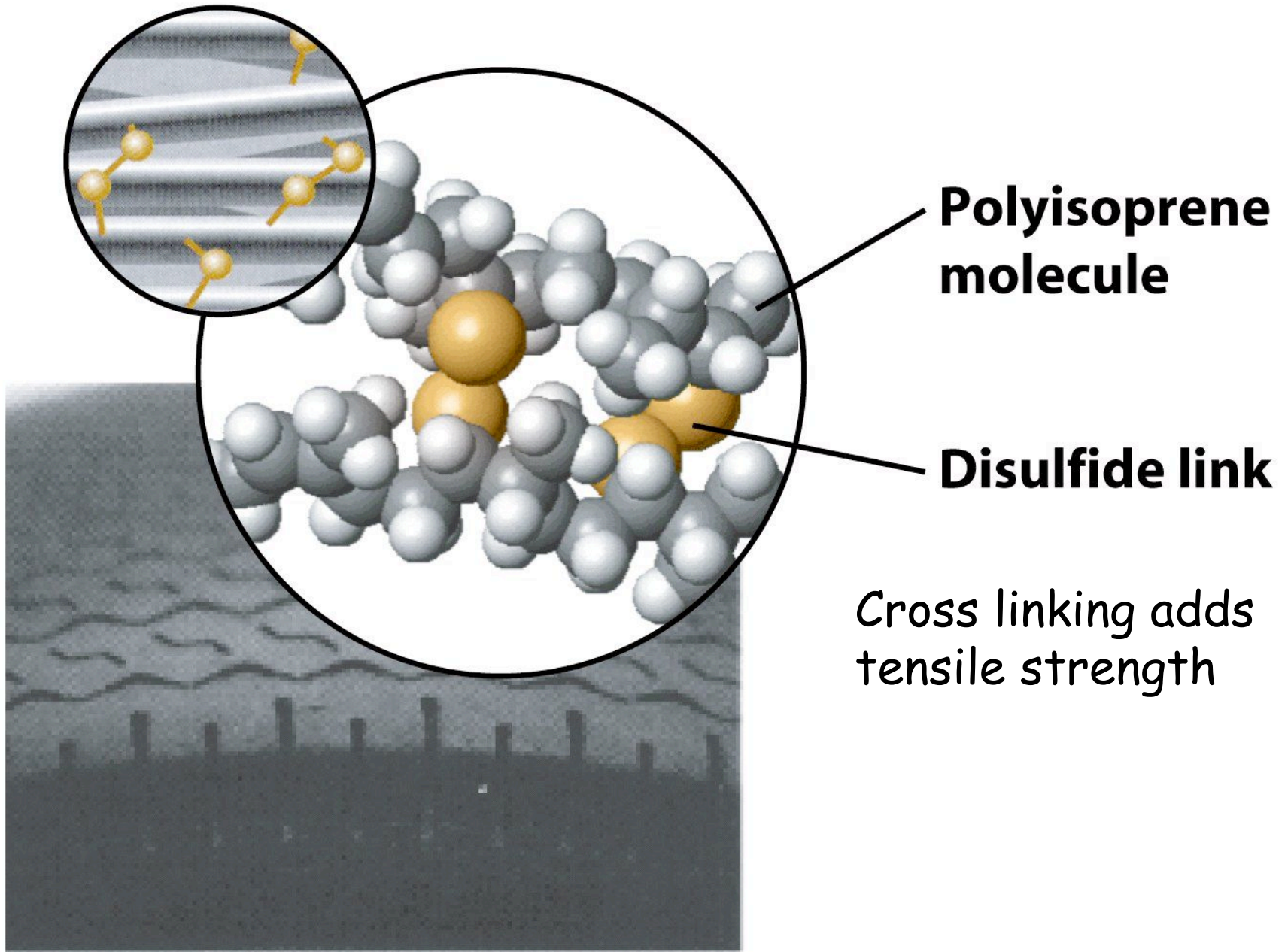
(d) Graft copolymer

Supramolecular structure of polymers





Structural
properties of
linear
polymers:
conformational
flexibility and
strength

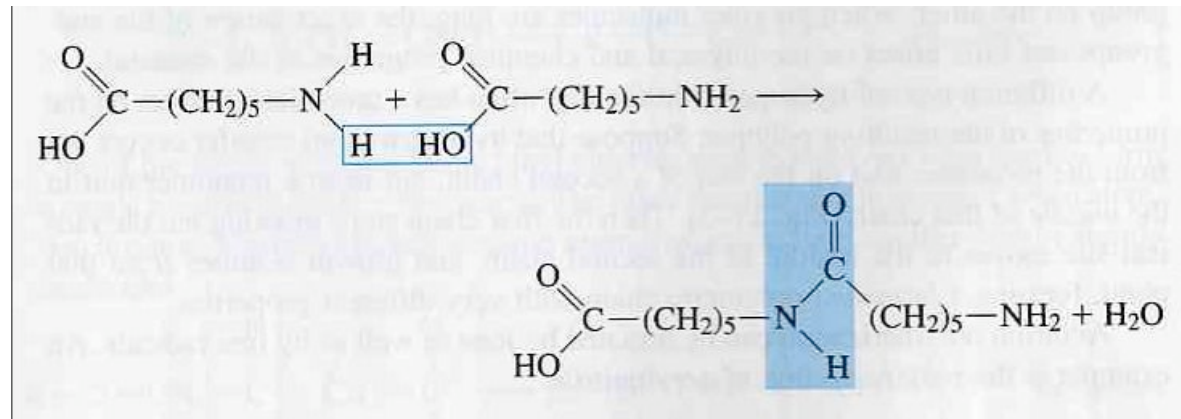


Condensation polymerization

Condensation polymerization: the polymer grows from monomers by splitting off a small molecule such as water or carbon dioxide.

Example: formation of amide links and loss of water

Monomers



First unit of polymer + H_2O

Polymers in the movies

In the 1967 movie, "The Graduate",
a smug Los Angeles businessman takes aside the
baby-faced
Dustin Hoffman and declares,

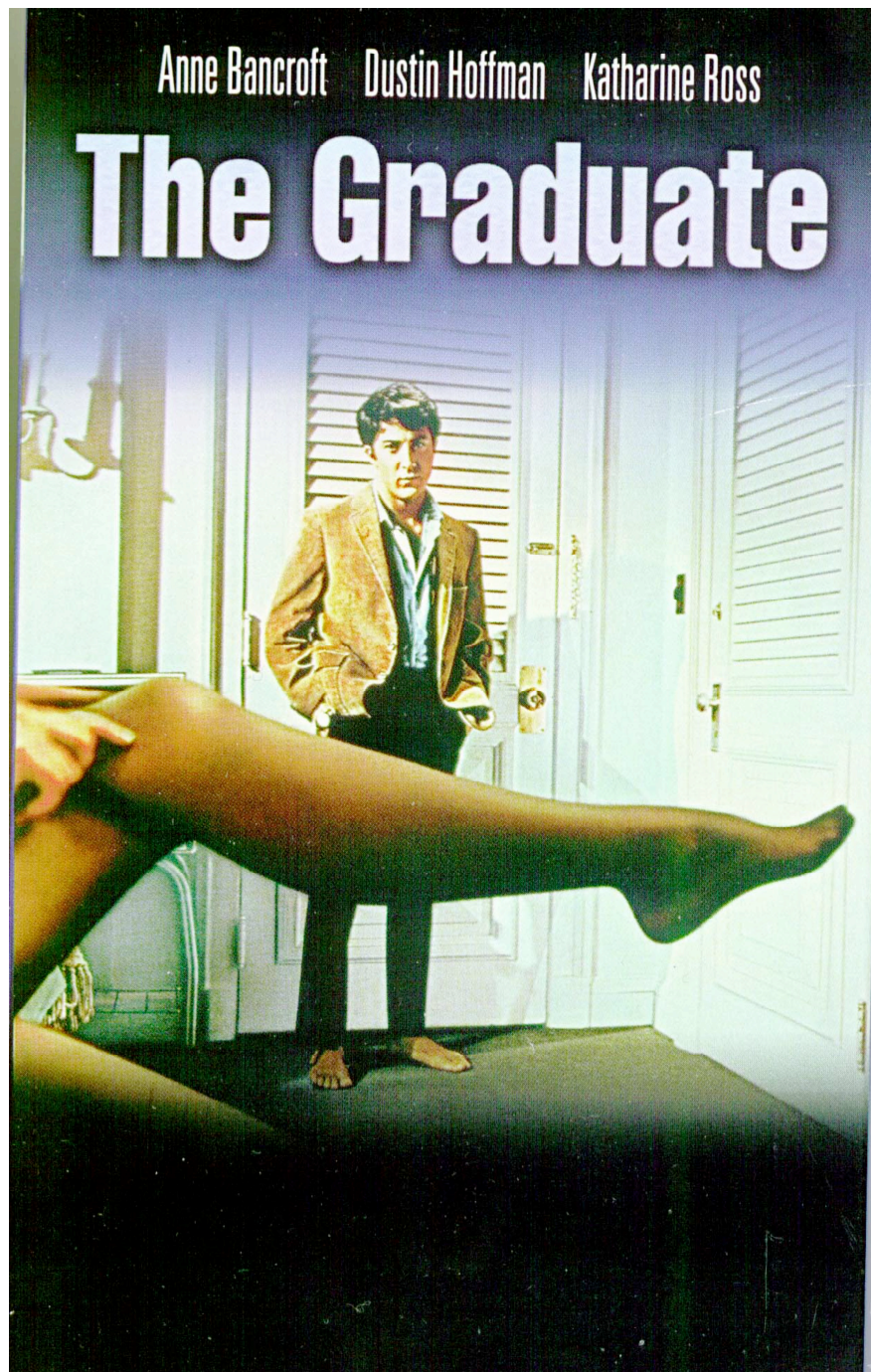
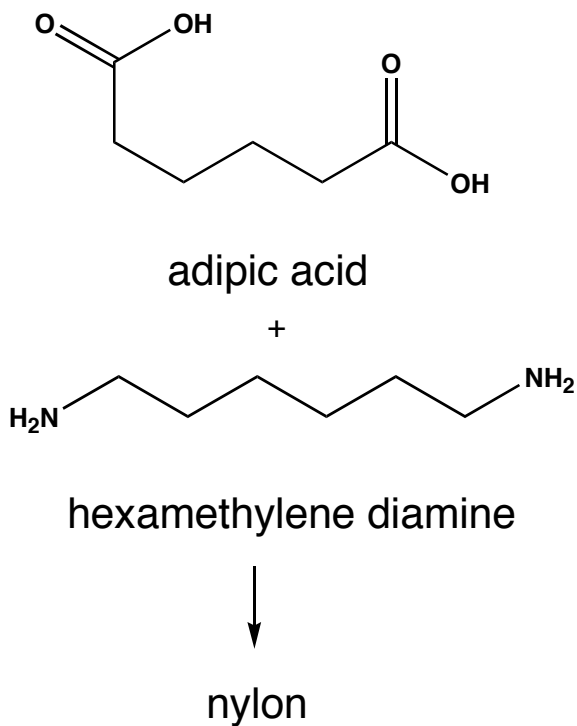
"I just want to say one word to you -- just
one word -- **'plastics.'** "

In 2005 we can replace 'plastics' with
another word: **'synthetic polymers'**

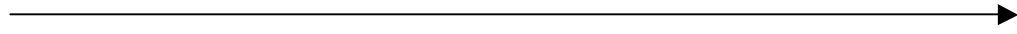
They're nylons, Benjamin.

Remember from *GChem*?

Nylon is a condensation polymer made of the monomers adipic acid and hexamethylene diamine.

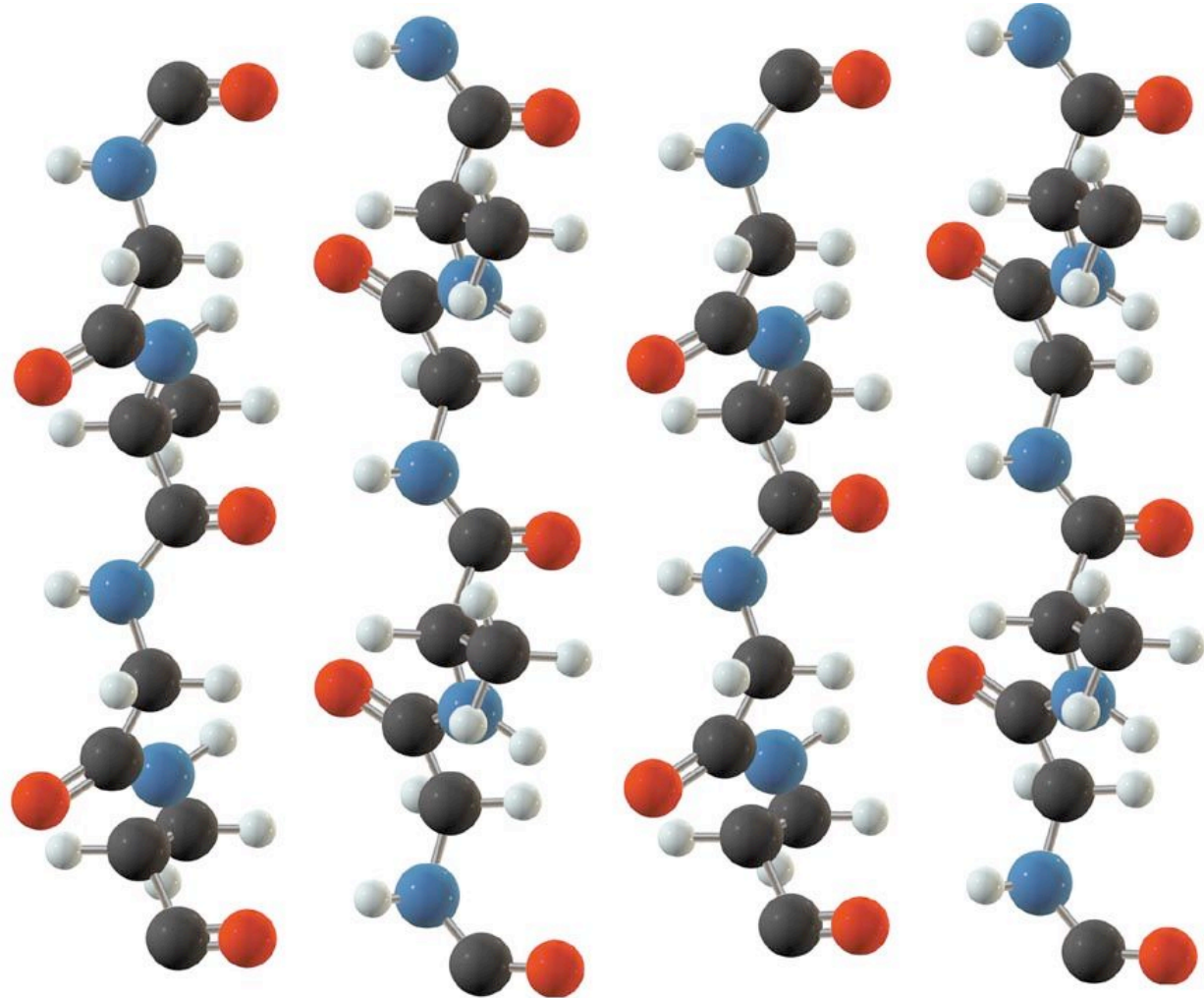


Hydrogen bonds between chains



Supramolecular
Structure of
nylon

Intermolecular
hydrogen bonds
give nylon
enormous tensile
strength



Biopolymers

Nucleic acid polymers (DNA, RNA)

Amino acids polymers (Proteins)

Sugar polymers (Carbohydrates)

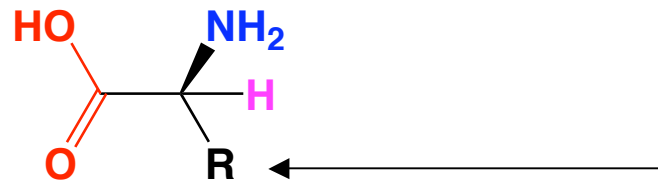
Genetic information for the cell: DNA

Structural strength and catalysis: Proteins

Energy source: Carbohydrates

Proteins: amino acid monomers

The basic structure of an amino acid monomer



The difference between amino acids is the R group

TABLE 27.1 α -Amino Acids Found in Proteins

Name	Abbreviation	Structural formula*
Amino acids with nonpolar side chains		
Glycine	Gly (G)	$\text{H}-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Alanine	Ala (A)	$\text{H}_3\text{C}-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Valine [†]	Val (V)	$(\text{CH}_3)_2\text{CH}-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Leucine [†]	Leu (L)	$(\text{CH}_3)_2\text{CHCH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Isoleucine [†]	Ile (I)	$\text{CH}_3\text{CH}_2\overset{\text{CH}_3}{\text{C}}-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Methionine [†]	Met (M)	$\text{CH}_3\text{SCH}_2\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Proline	Pro (P)	$\begin{array}{c} \text{H}_2\text{C} \\ \\ \text{H}_2\text{C}-\overset{\text{NH}_2^+}{\text{C}} \\ \\ \text{H}_2\text{C}-\text{CHCO}_2^- \end{array}$
Phenylalanine [†]	Phe (F)	$\text{C}_6\text{H}_5-\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Tryptophan [†]	Trp (W)	$\text{C}_8\text{H}_7\text{N}-\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Amino acids with polar but nonionized side chains		
Asparagine	Asn (N)	$\text{H}_2\text{NC}(=\text{O})\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$

*All amino acids are shown in the form present in greatest concentration at pH 7.

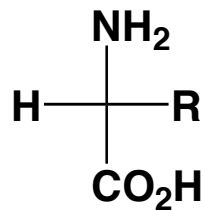
[†]An essential amino acid, which must be present in the diet of animals to ensure normal growth.**TABLE 27.1** α -Amino Acids Found in Proteins (*Continued*)

Name	Abbreviation	Structural formula*
Amino acids with polar but nonionized side chains		
Glutamine	Gln (Q)	$\text{H}_2\text{NC}(=\text{O})\text{CH}_2\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Serine	Ser (S)	$\text{HOCH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Threonine [†]	Thr (T)	$\text{CH}_3\overset{\text{OH}}{\text{C}}\text{H}-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Tyrosine	Tyr (Y)	$\text{HO}-\text{C}_6\text{H}_4-\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Cysteine	Cys (C)	$\text{HSCH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Amino acids with acidic side chains		
Aspartic acid	Asp (D)	$-\text{OC}(=\text{O})\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Glutamic acid	Glu (E)	$-\text{OC}(=\text{O})\text{CH}_2\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Amino acids with basic side chains		
Lysine [†]	Lys (K)	$\text{H}_3\overset{+}{\text{N}}\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Arginine [†]	Arg (R)	$\text{H}_2\text{N}^+=\text{CNHCH}_2\text{CH}_2\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$
Histidine [†]	His (H)	$\text{C}_5\text{H}_4\text{N}_2-\text{CH}_2-\overset{\text{NH}_3^+}{\text{C}}-\text{CHCO}_2^-$

Proteins: condensation polymers

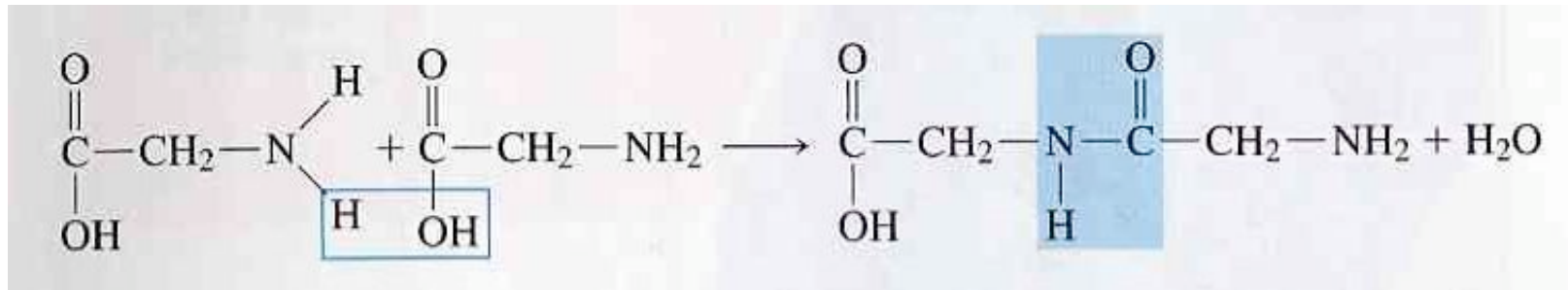
Formed by condensation polymerization of amino acids

Monomers: 20 essential amino acids



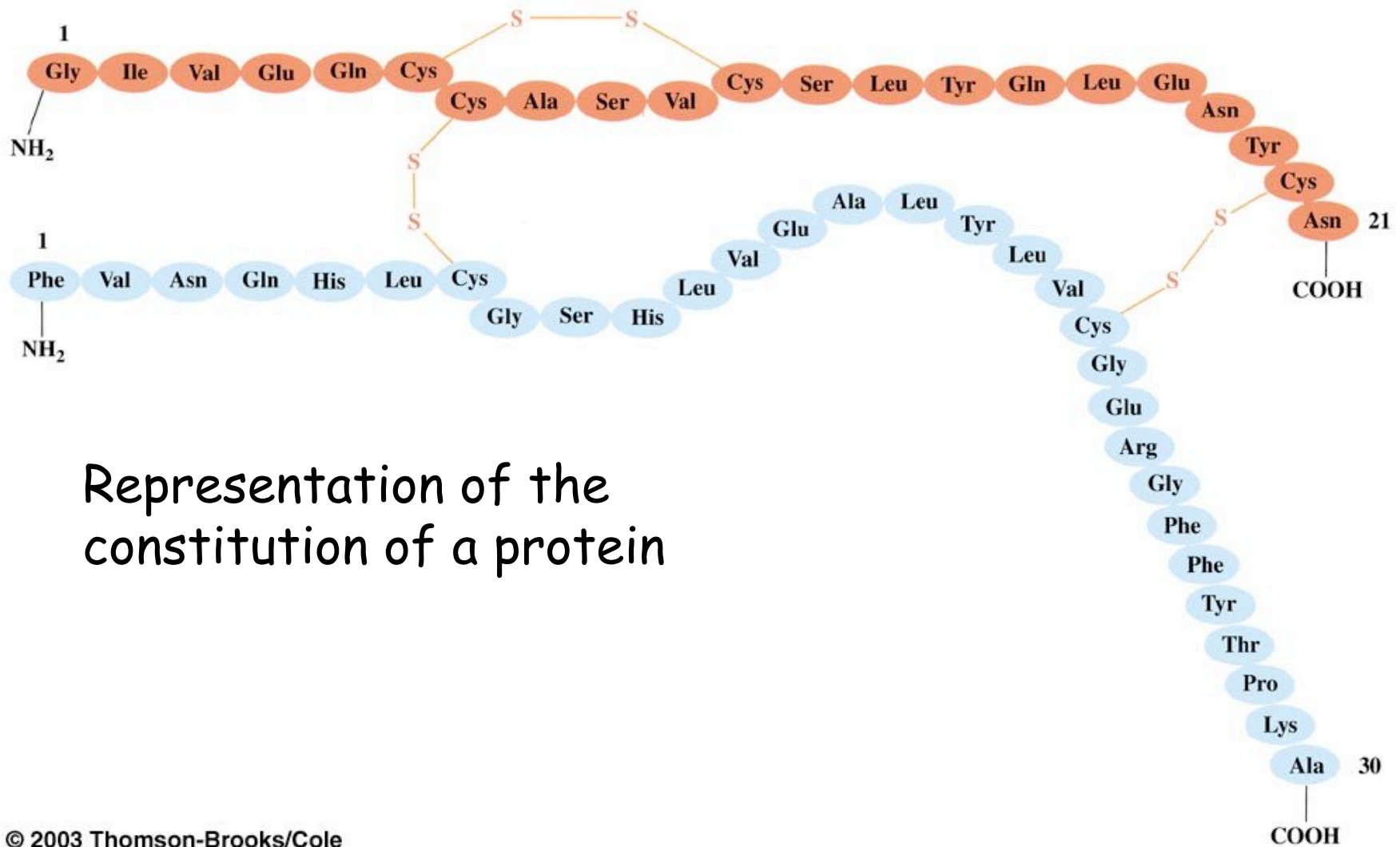
General structure of an amino acid

R is the only variable group



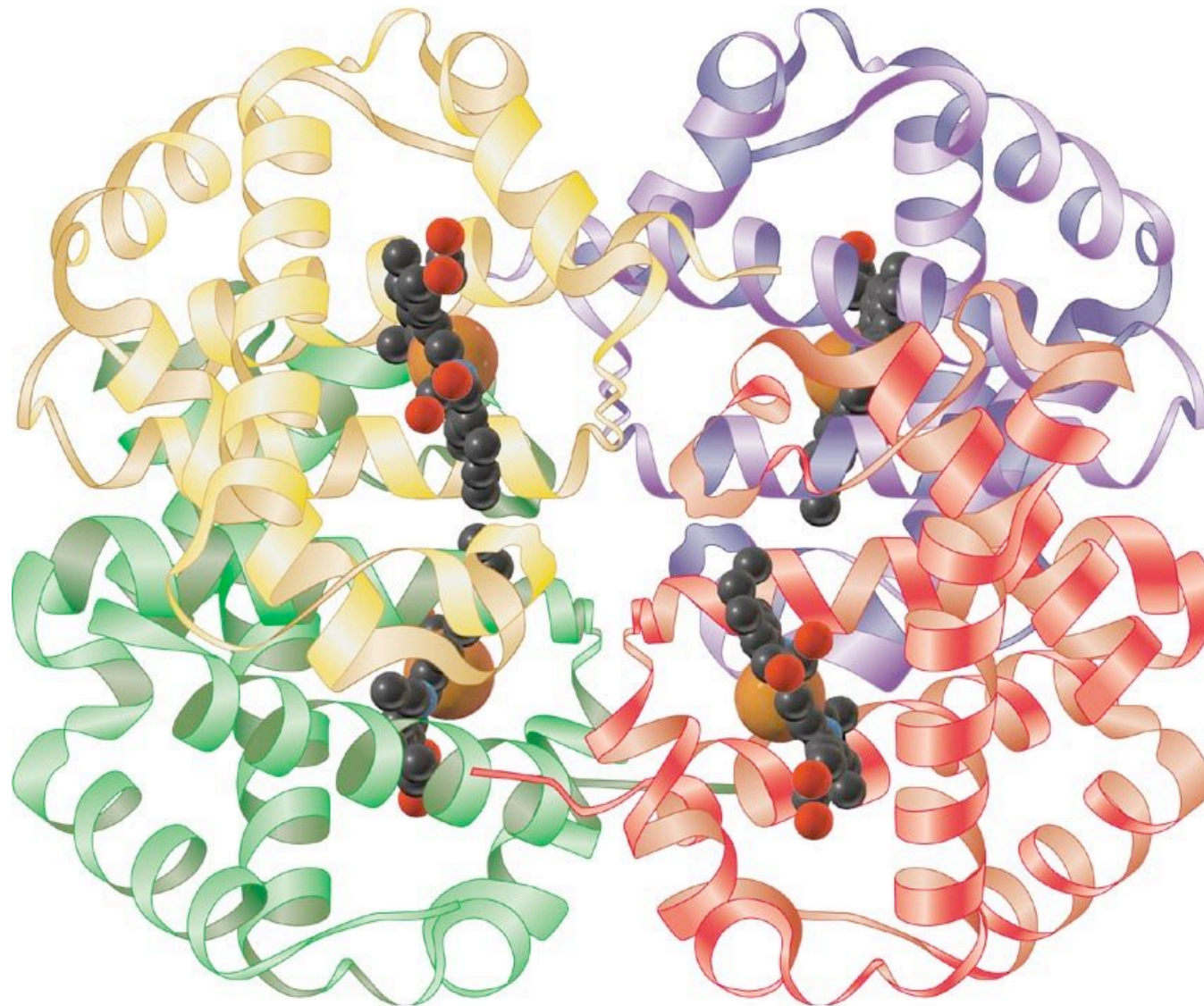
Glycine (R = H) + Glycine

First step toward poly(glycine)



Representation of the
constitution of a protein

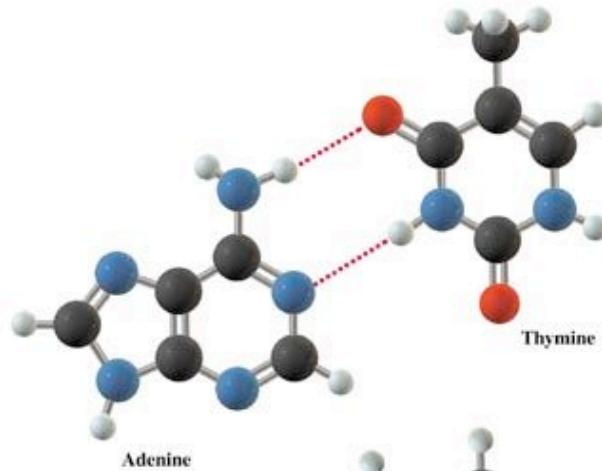
Three D representation of the structure of a protein



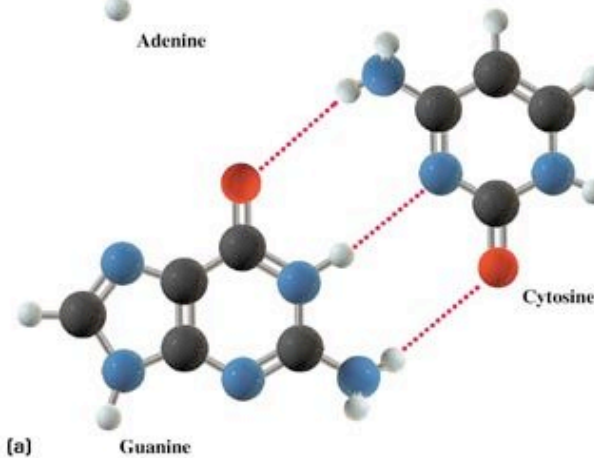
DNA

The monomers:

Adenine (A)



Thymine (T)

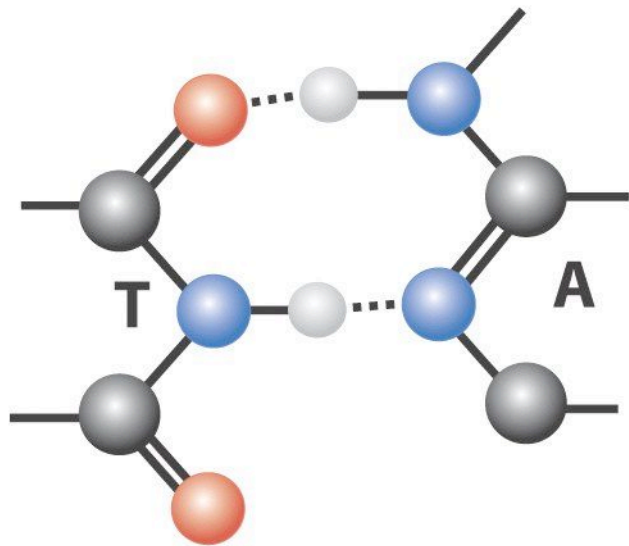


Cytosine (C)

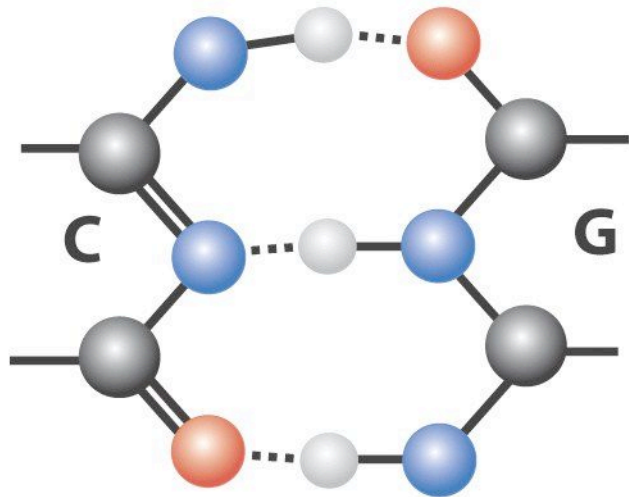
Guanine (G)

Phosphate-
Sugar (backbone) of
DNA



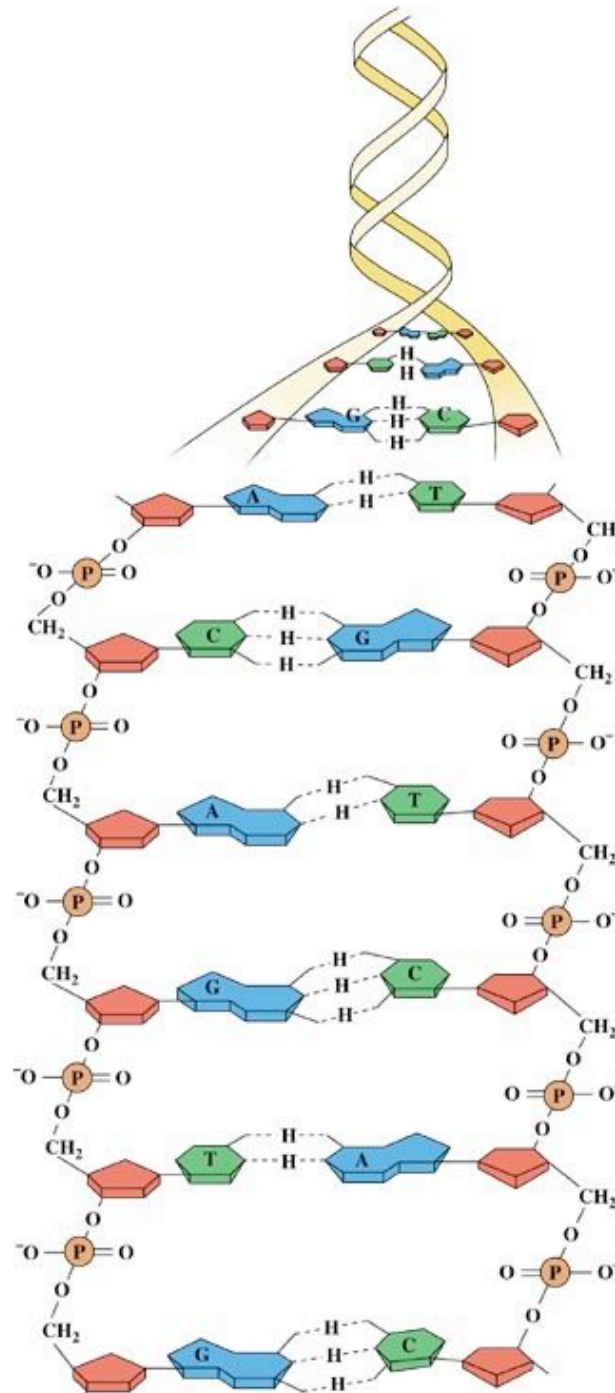


Base pairs

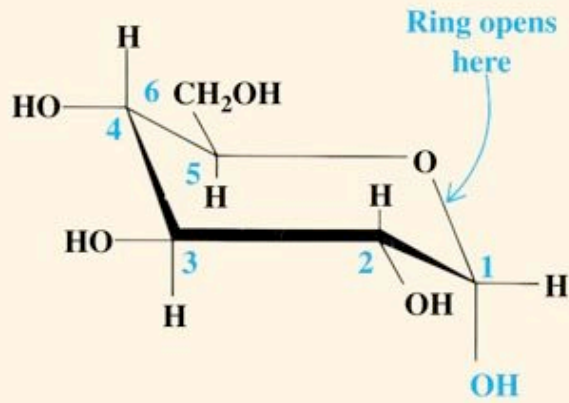


Phosphate-sugar backbone holds the DNA macromolecule together

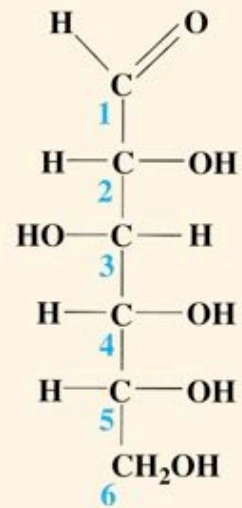
One strand
unwinds to
duplicate its
complement via a
polymerization of
the monomers
C, G, A and T



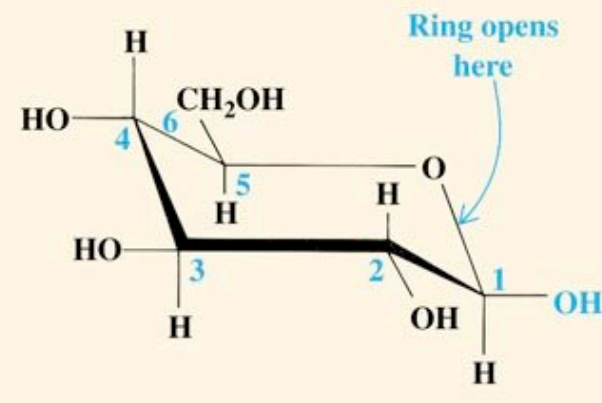
Carbohydrates



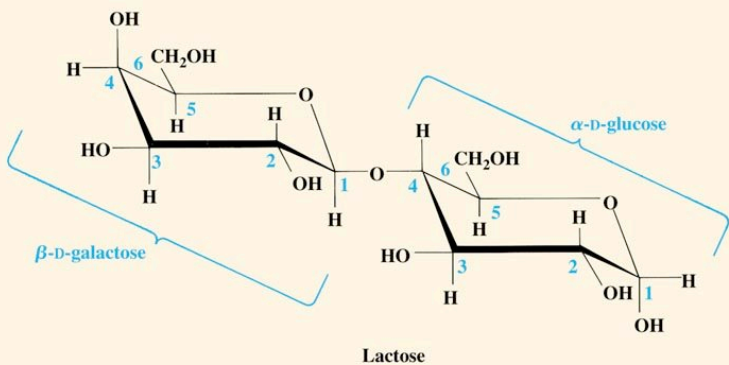
(a) α -D-glucose



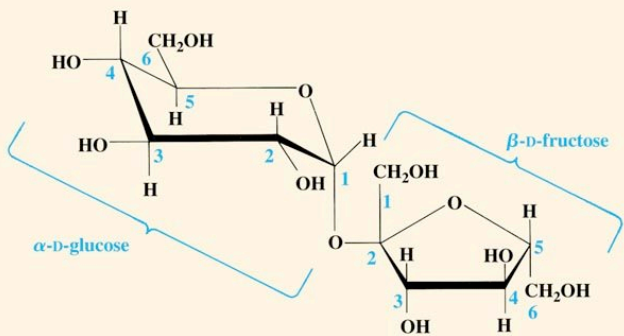
(b) Open-chain
D-glucose



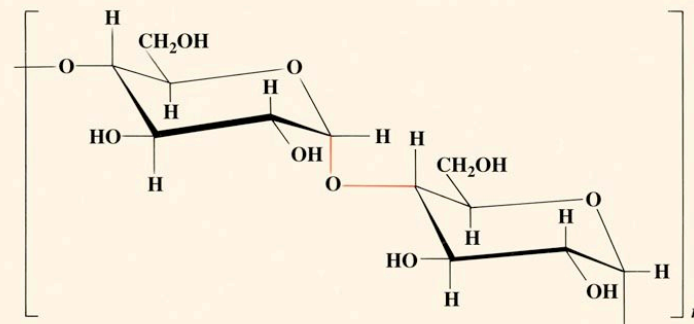
(c) β -D-glucose



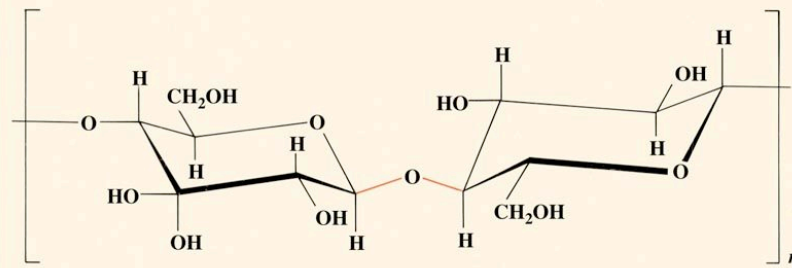
Lactose



Sucrose



(a) Starch



(b) Cellulose