

# Nucleic acids

- Nucleotide =
  - nitrogenous base
  - pentose sugar
  - Phosphate
- Nucleoside =
  - nitrogenous base
  - pentose sugar

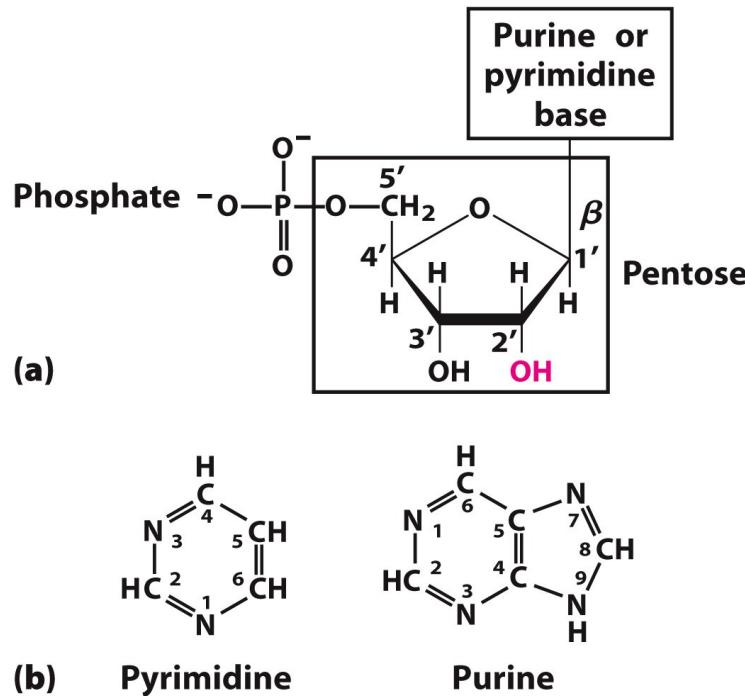


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# Building Blocks

- Carbon AND nitrogen atoms on the nitrogenous base are numbered in cyclic format.
- Carbons of the pentose are designated N' to alleviate confusion.

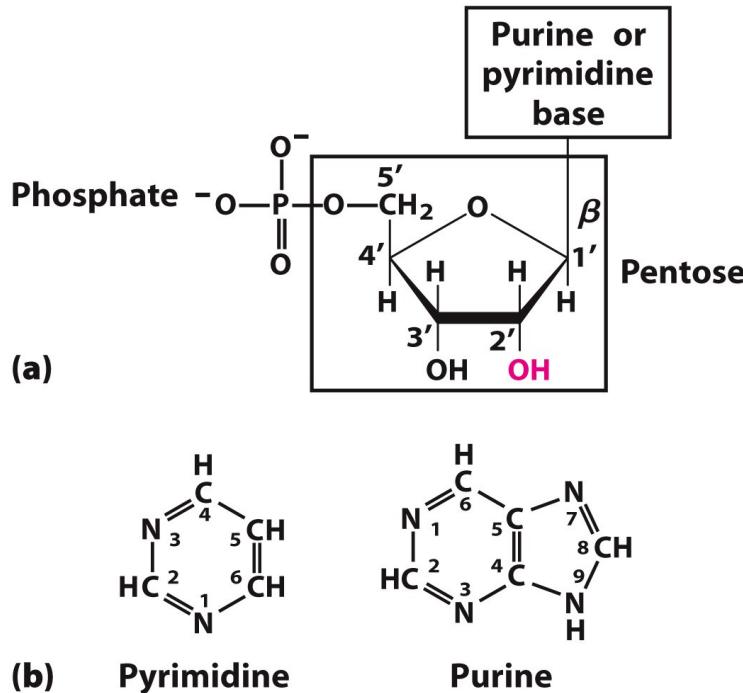
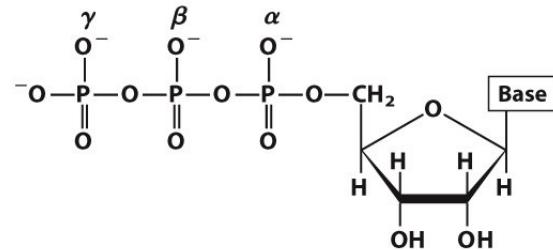


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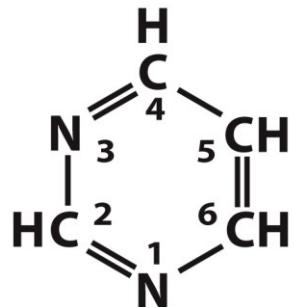
# Building Blocks

- Negatively charged at neutral pH
- Typically attached to 5' position
  - Nucleic acids are built using the 5'-triphosphates version of the nucleotide.
    - ATP, GTP, TTP, CTP
  - Two of the three phosphates used for building nucleic acids form a leaving group, and completed nucleic acids contain one phosphate moiety per nucleotide.

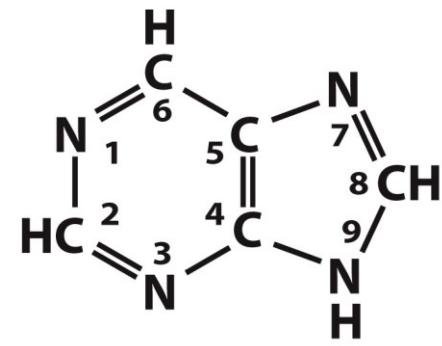


# Nitrogenous Bases

- Derivatives of pyrimidine or purine
- Nitrogen-containing heteroaromatic molecules
- Planar or almost planar structures
- Absorb UV light around 250-270 nm



Pyrimidine



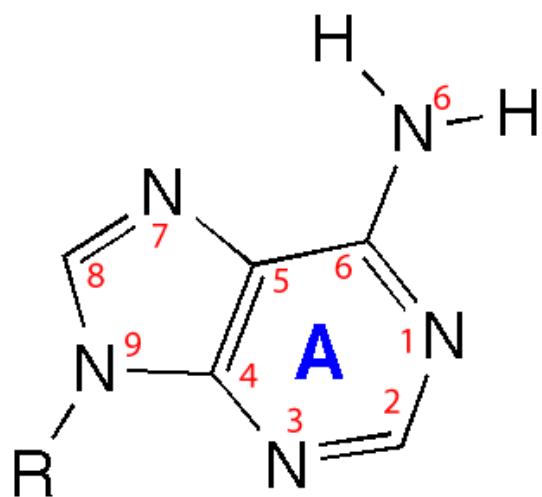
Purine

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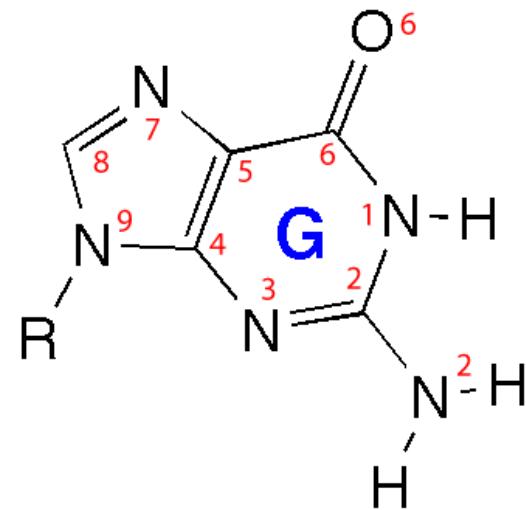
# Nucleobases

- Cytosine, adenine, and guanine are found in both DNA and RNA.
- Thymine is found only in DNA.
- Uracil is found only in RNA.
- All are good H-bond donors and acceptors.
- Neutral molecules at pH 7

## Purines

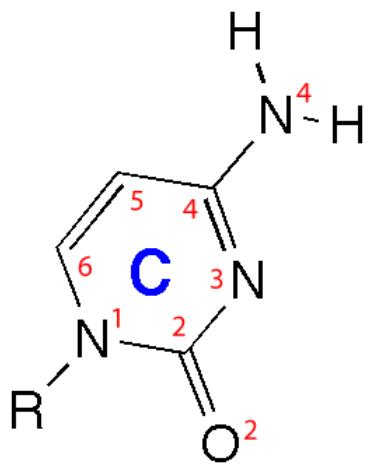


Adenine

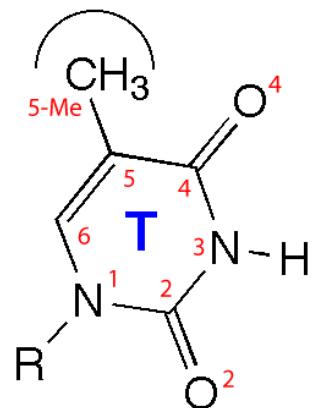


Guanine

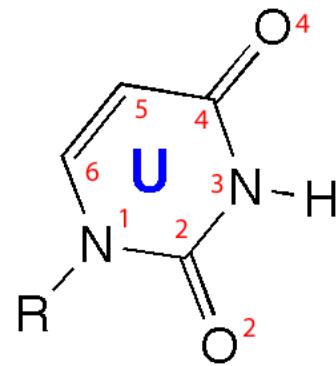
## Pyrimidines



Cytosine



Thymine  
(DNA)



Uracil  
(RNA)

# Nomenclature: Deoxyribonucleotides

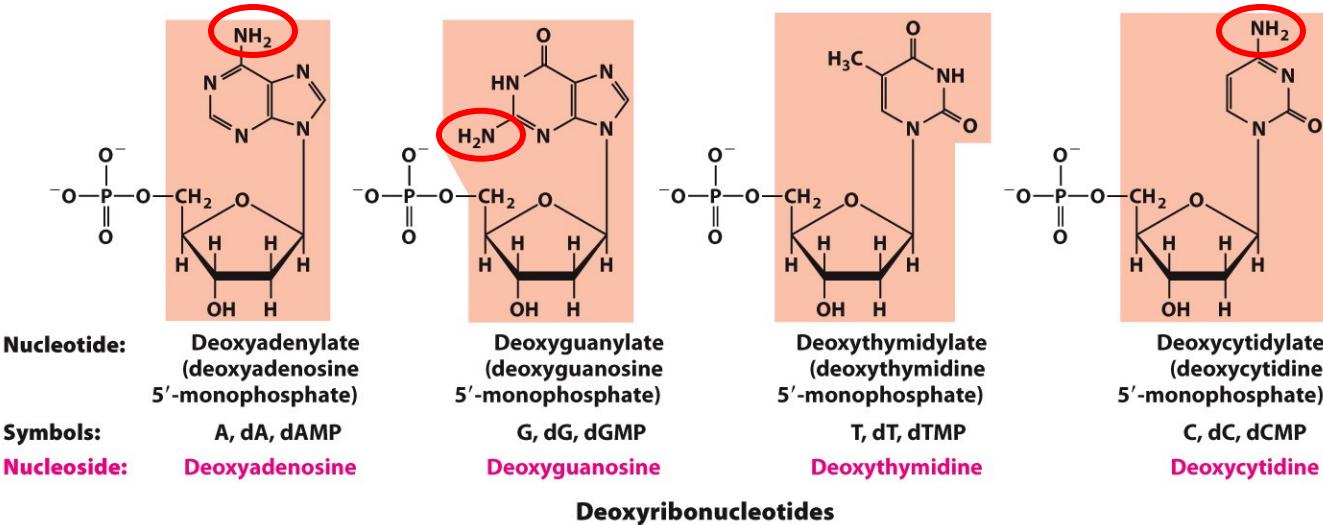


Figure 8-4a

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# Nomenclature: Ribonucleotides

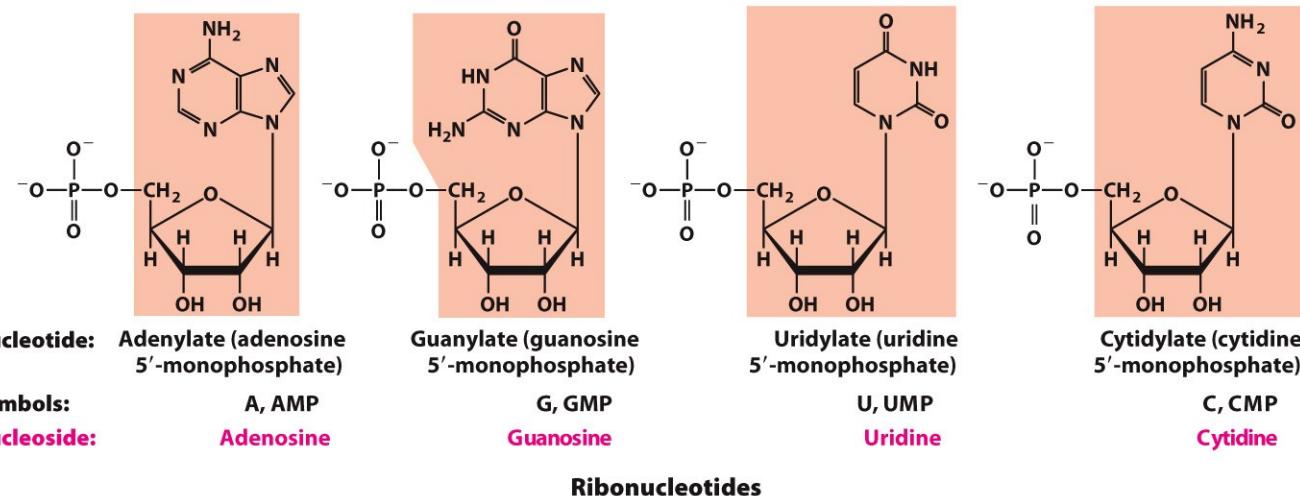


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# Nomenclature

TABLE 8-1 Nucleotide and Nucleic Acid Nomenclature

Base	Nucleoside	Nucleotide	Nucleic acid
<b>Purines</b>			
Adenine	Adenosine Deoxyadenosine	Adenylate Deoxyadenylate	RNA DNA
Guanine	Guanosine Deoxyguanosine	Guanylate Deoxyguanylate	RNA DNA
<b>Pyrimidines</b>			
Cytosine	Cytidine Deoxycytidine	Cytidylate Deoxycytidylate	RNA DNA
Thymine	Thymidine or deoxythymidine	Thymidylate or deoxythymidylate	DNA
Uracil	Uridine	Uridylate	RNA
Note: "Nucleoside" and "nucleotide" are generic terms that include both ribo- and deoxyribo- forms. Also, ribonucleosides and ribonucleotides are here designated simply as nucleosides and nucleotides (e.g., riboadenosine as adenosine), and deoxyribonucleosides and deoxyribonucleotides as deoxynucleosides and deoxynucleotides (e.g., deoxyriboadenosine as deoxyadenosine). Both forms of naming are acceptable, but the shortened names are more commonly used. Thymine is an exception; "ribothymidine" is used to describe its unusual occurrence in RNA.			

# Polynucleotides

- Covalent bonds are formed via **phosphodiester** linkages.
  - negatively charged backbone

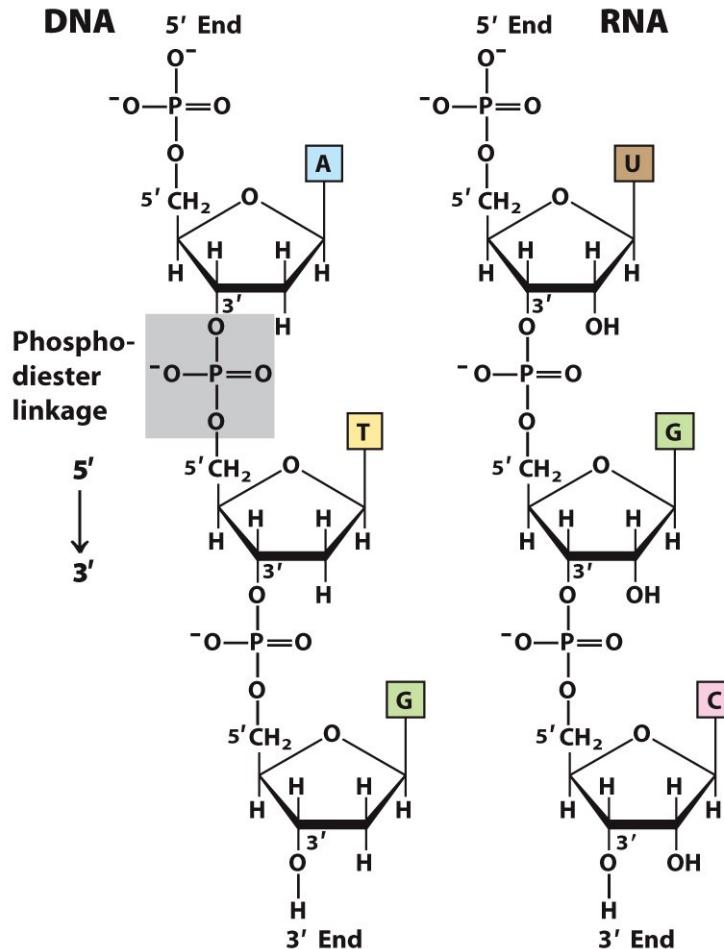


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# Polynucleotides

- DNA backbone is in a deep kinetic trap.
  - DNA from mammoths?
  - Hydrolysis accelerated by enzymes (DNase)
- RNA backbone is labile
  - In water, RNA lasts for a few years.
  - In cells, mRNA is degraded in a few hours.

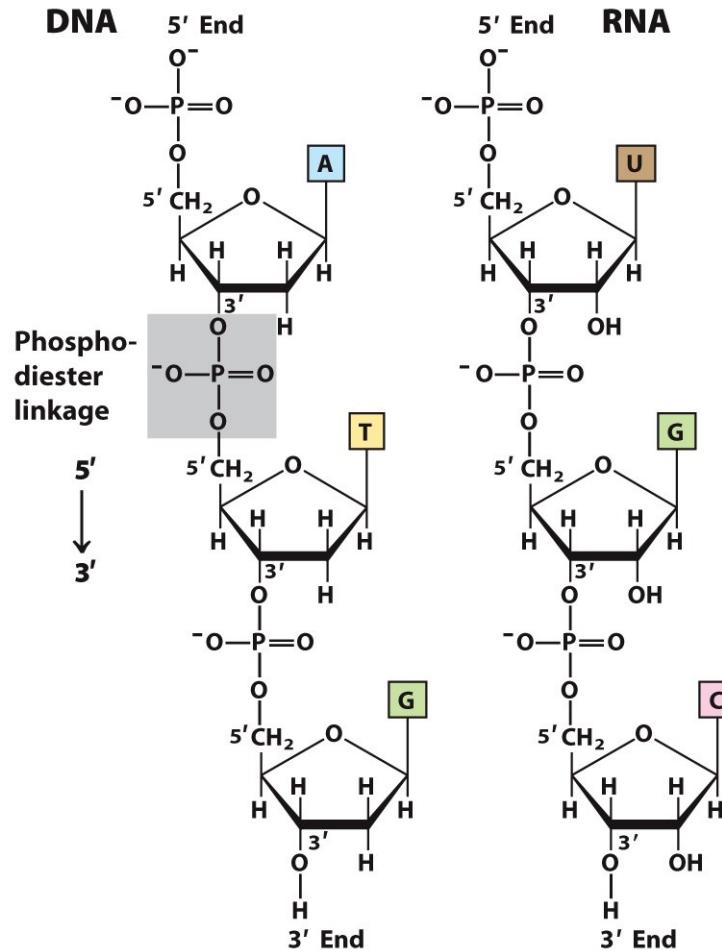


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# Polynucleotides

- Linear polymers
  - no branching or cross-links
- Directionality
  - The 5' end is different from the 3' end.
  - We read the sequence from 5' to 3'

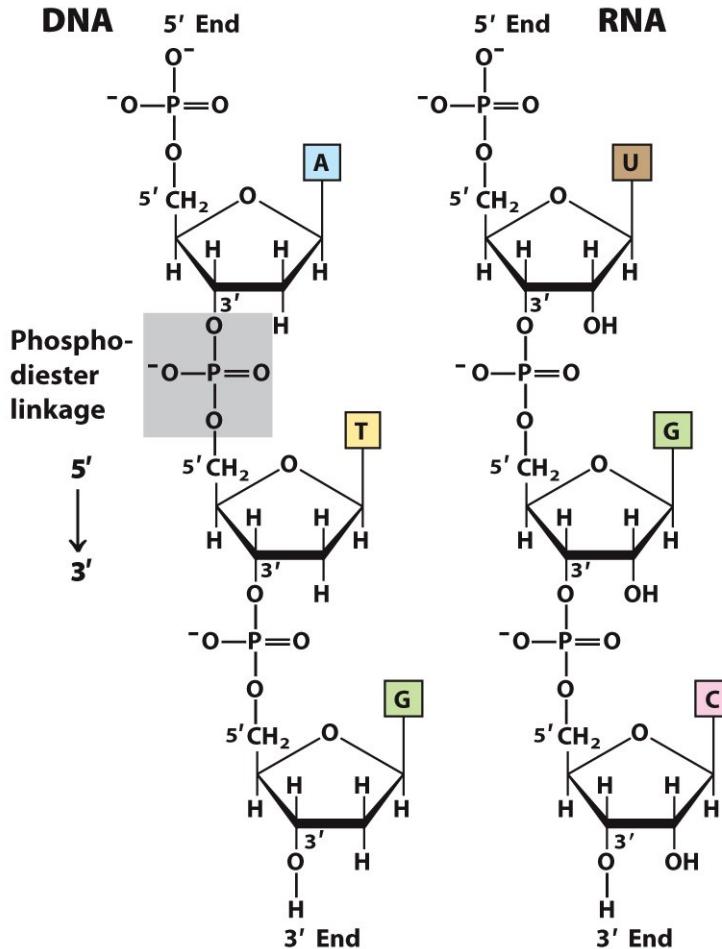


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# AT and GC Base Pairs

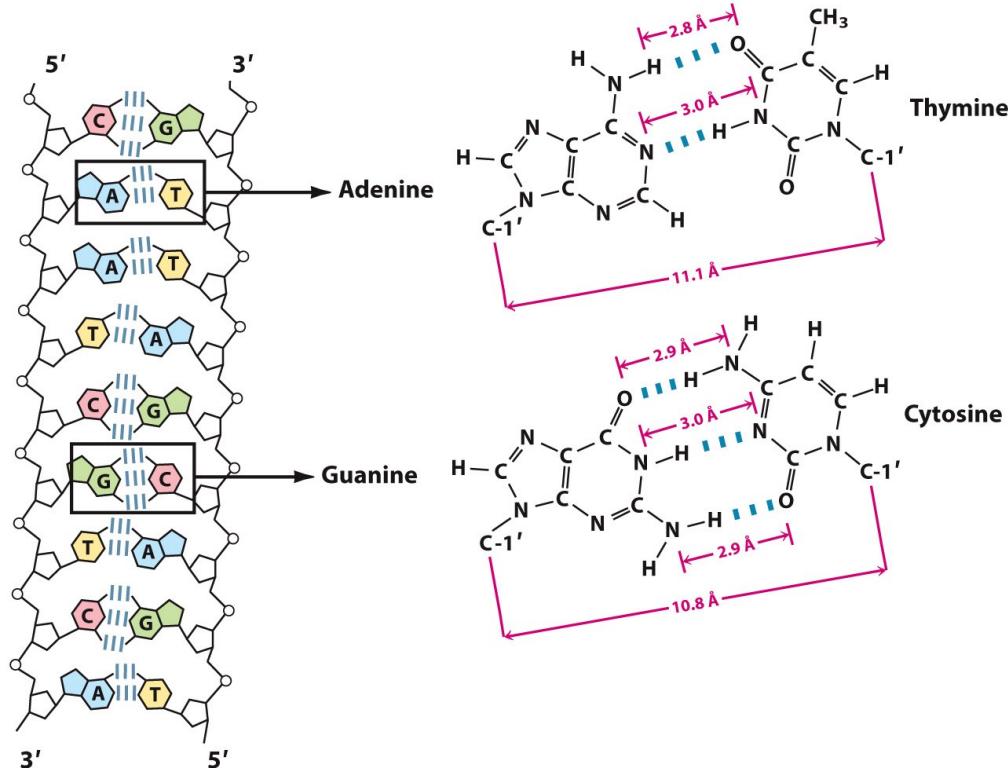
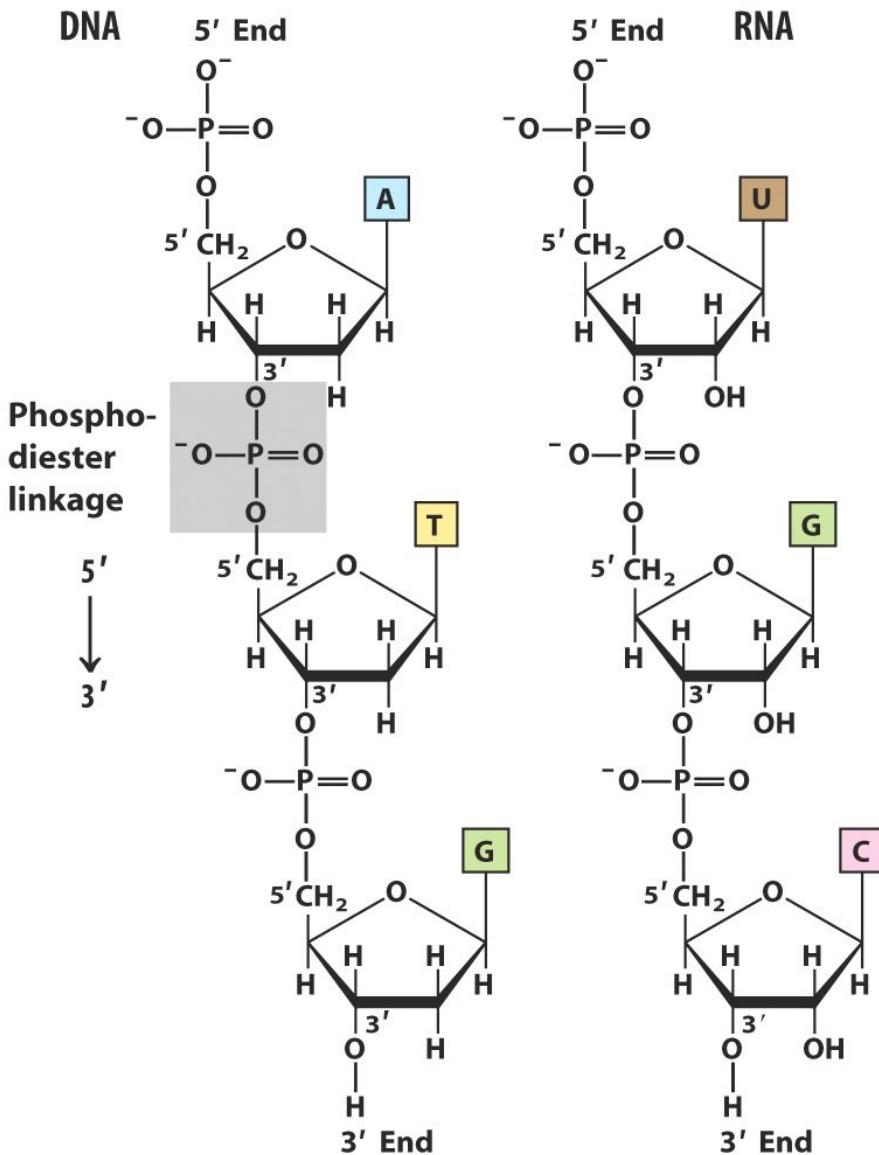


Figure 8-11

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# Nucleic acid structure



- Nucleic acids also known as **polynucleotides** are chains of nucleotides whose **phosphate bridge** the 3' and 5' positions of neighboring ribose units, known as **phosphodiester bond**.
- Each nucleotide residue is named after the base.
- 5'end and 3' end of the nucleic acid.
- by convention, DNA & RNA strand has direction from 5' to 3'. (5'-ATG-3').
- Nucleic acid contains information in the form of its sequence of residues.
- Negatively charged at physiological pH.

# Watson-Crick Model of B-DNA

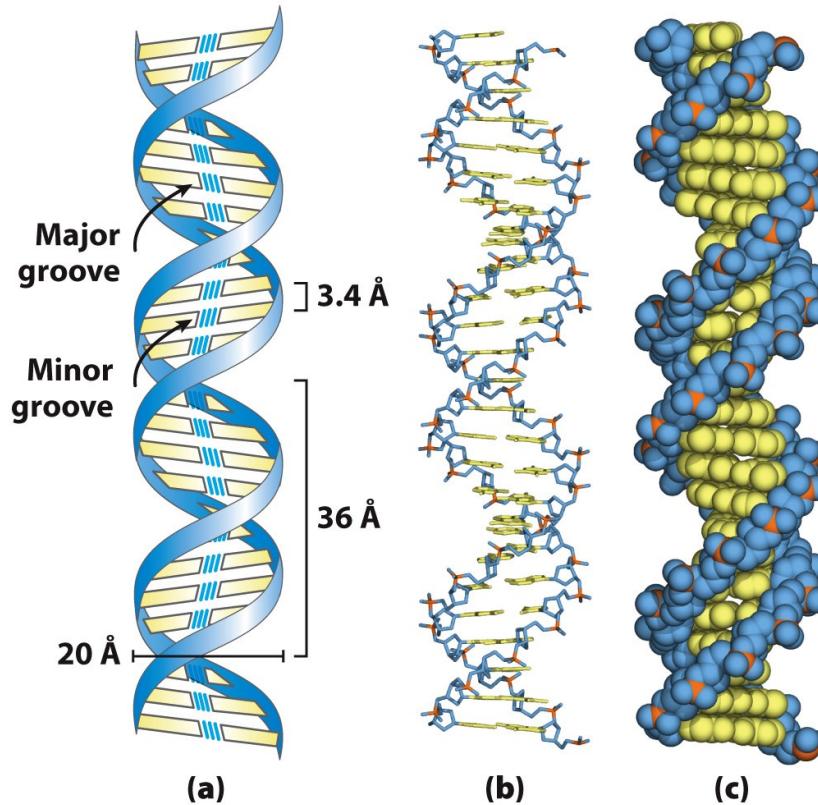


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Is this helix right- or left-handed?

# 1953 Watson-Crick structure of DNA

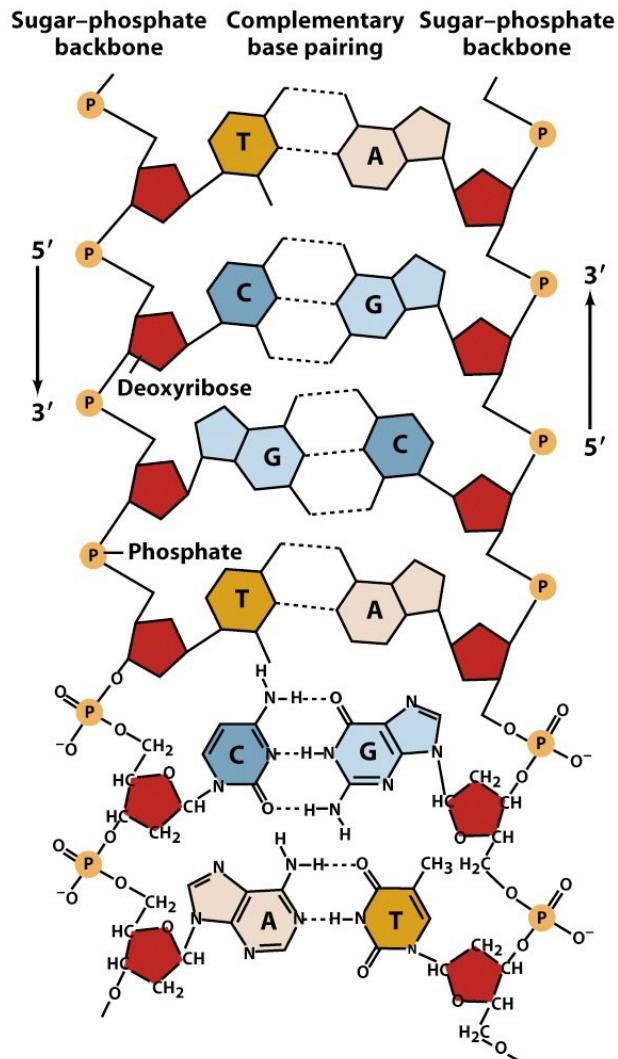


Figure 3-8 Fundamentals of Biochemistry, 2/e  
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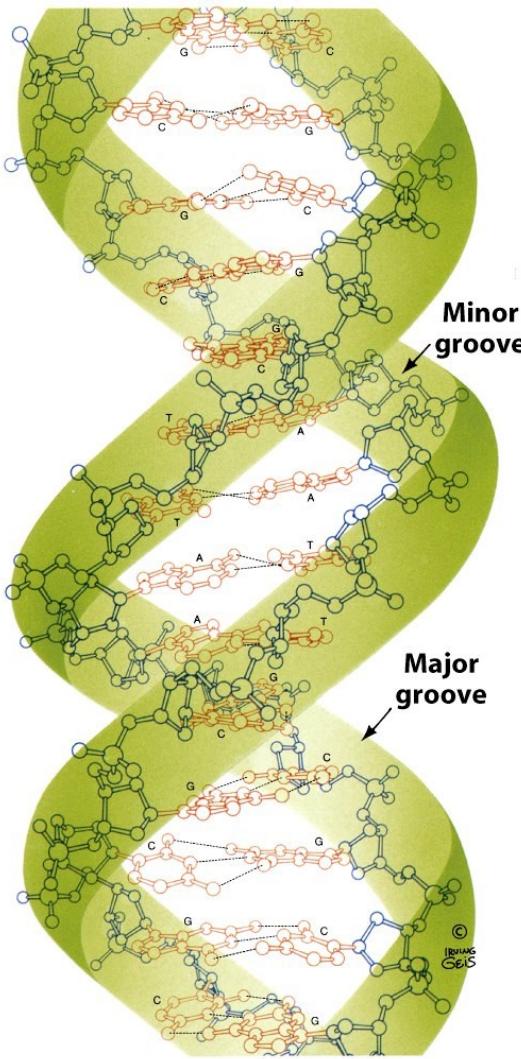
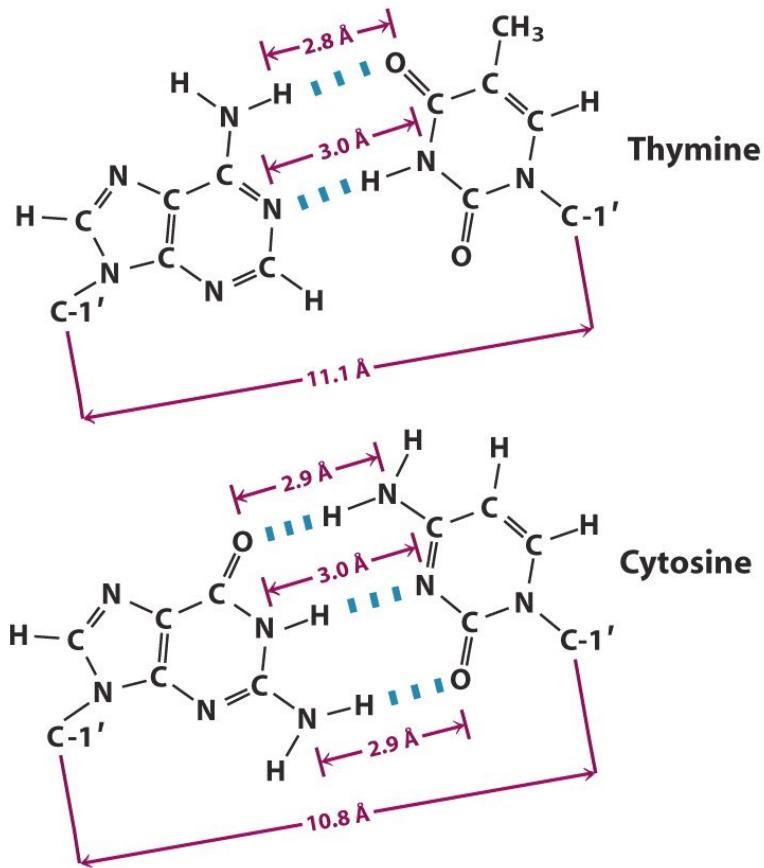
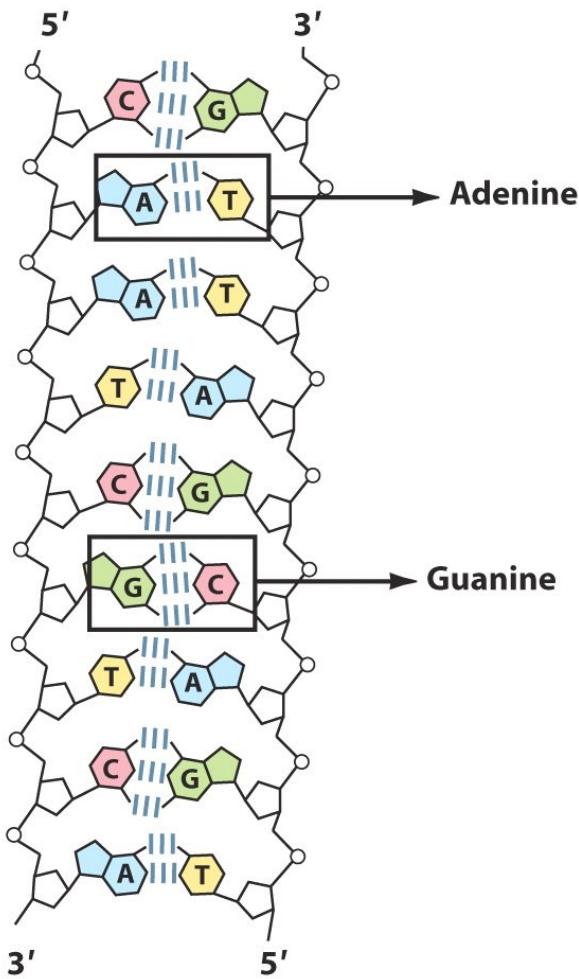


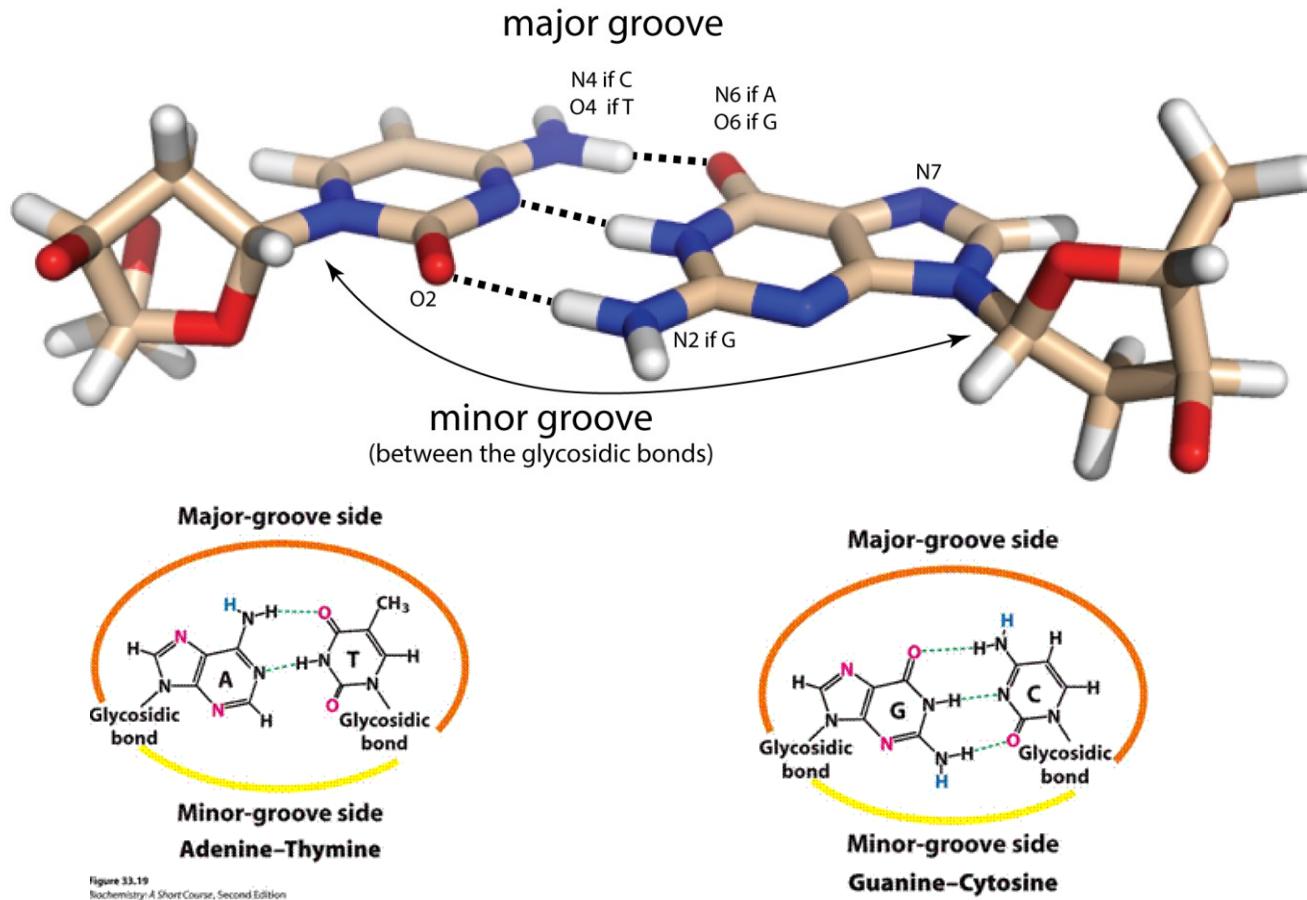
Figure 3-6 Fundamentals of Biochemistry, 2/e

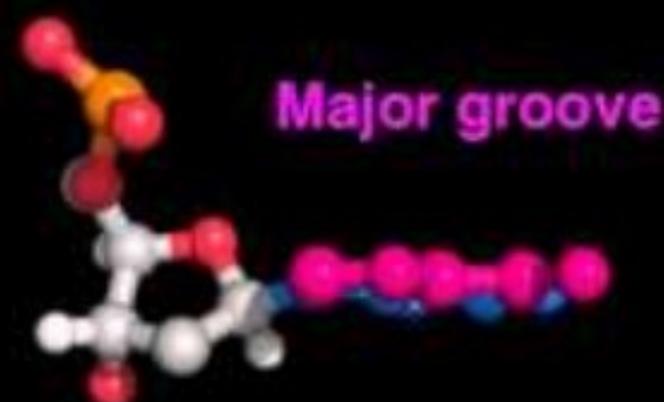
1. Two polynucleotide chains wind around a common axis to form a **double helix**.
2. Two strands of DNA are **anti-parallel** but each forms a **right-handed helix**.
3. The **bases point inward** and pair through **hydrogen bonds**.
4. Complementary base pairings are **A pairs with T** and **G pairs with C**.
5. The surface of the double helix contains two grooves of unequal width: the **major and minor grooves**.

# Hydrogen bonds in DNA base pairing



# Major and minor groove

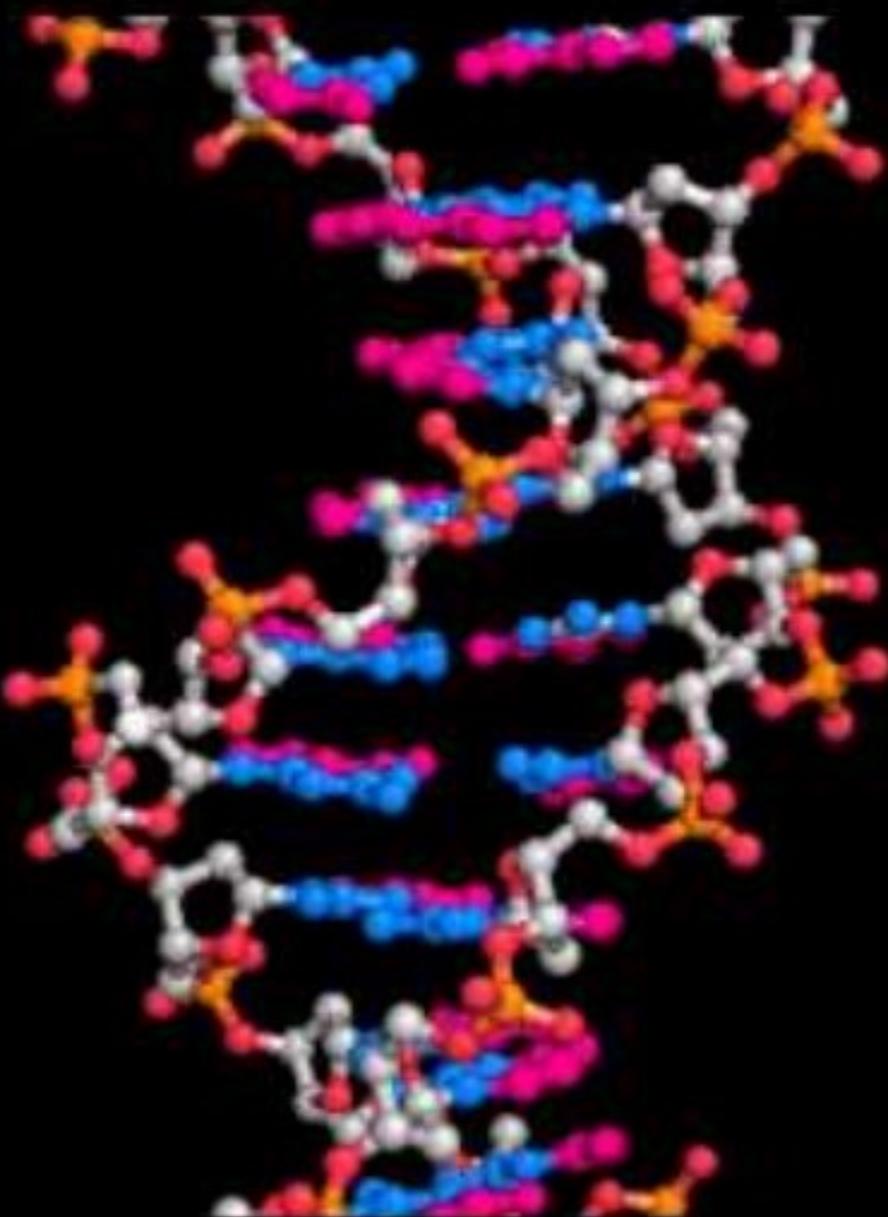




Major groove



Minor groove



# Single stranded nucleic acids

Single stranded DNA is rare.

RNA primarily occurs as single strands, which usually form compact structures rather than loose extended chains.

Base pairing often occurs intramolecularly, forming **stem-loop** structures.

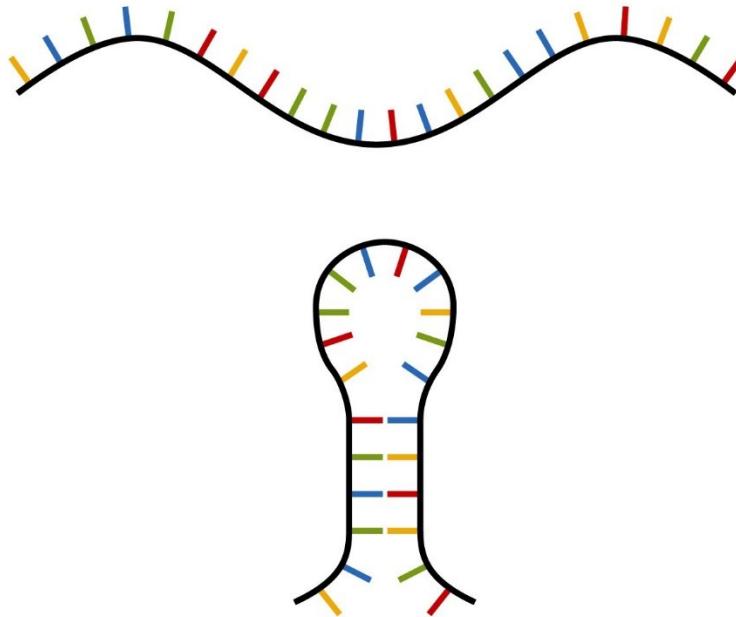


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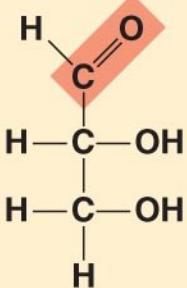
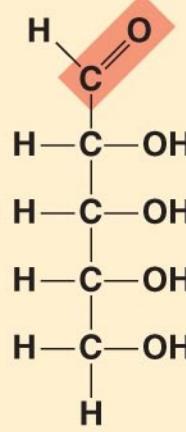
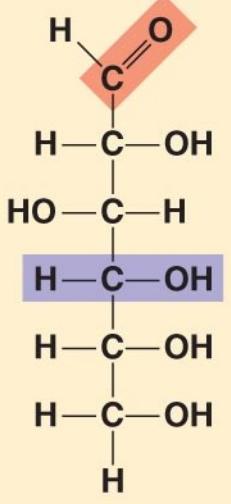
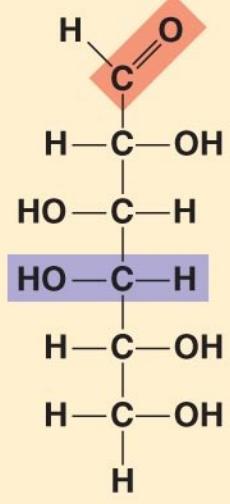
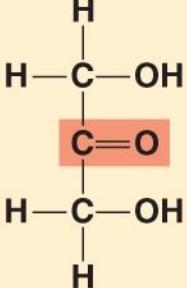
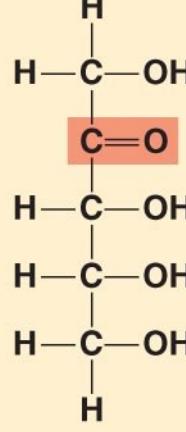
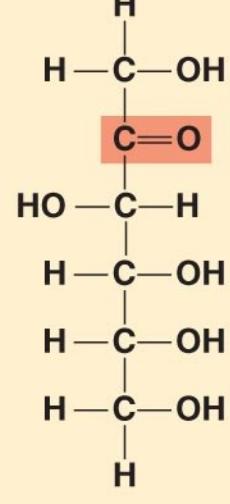
# Carbohydrates

# 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

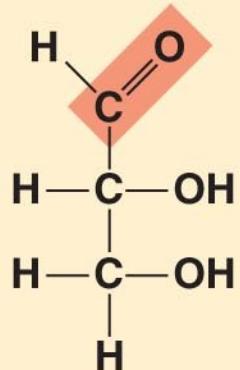
# Sugars

- Monosaccharides have molecular formulas that are usually multiples of  $\text{CH}_2\text{O}$
- Glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) is the most common monosaccharide
- Monosaccharides are classified by
  - The location of the carbonyl group (as aldose or ketose)
  - The number of carbons in the carbon skeleton

	Trioses ( $C_3H_6O_3$ )	Pentoses ( $C_5H_{10}O_5$ )	Hexoses ( $C_6H_{12}O_6$ )	
Aldoses	 <p>Glyceraldehyde</p>	 <p>Ribose</p>	 <p>Glucose</p>	 <p>Galactose</p>
Ketoses	 <p>Dihydroxyacetone</p>	 <p>Ribulose</p>	 <p>Fructose</p>	

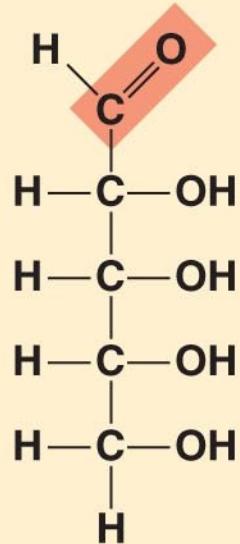
Aldoses

Trioses ( $C_3H_6O_3$ )



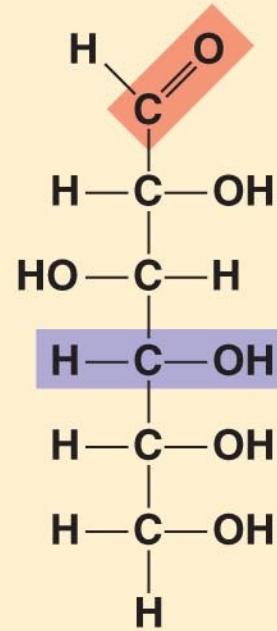
Glyceraldehyde

Pentoses ( $C_5H_{10}O_5$ )

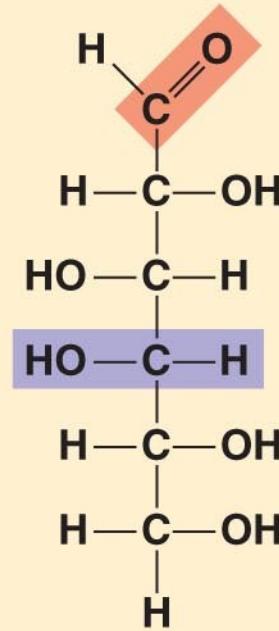


Ribose

Hexoses ( $C_6H_{12}O_6$ )

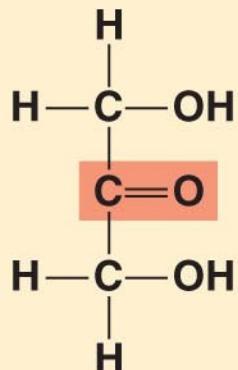


Glucose

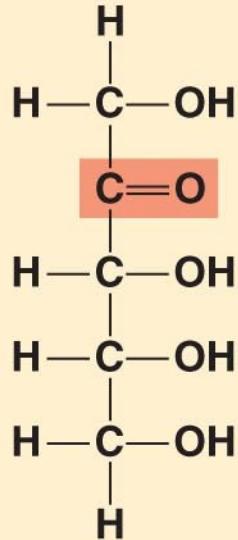


Galactose

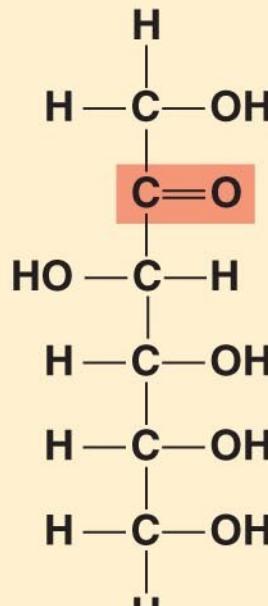
**Trioses ( $C_3H_6O_3$ )**



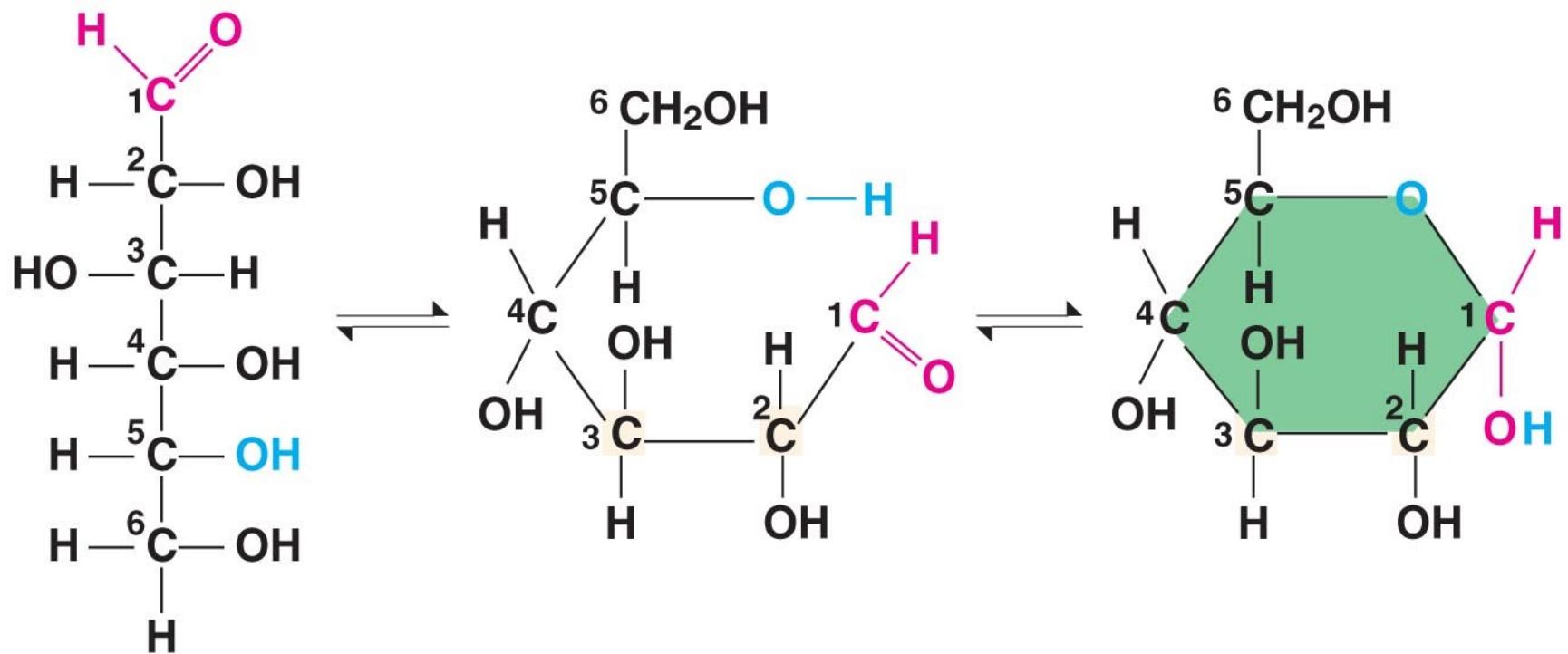
**Pentoses ( $C_5H_{10}O_5$ )**



**Hexoses ( $C_6H_{12}O_6$ )**

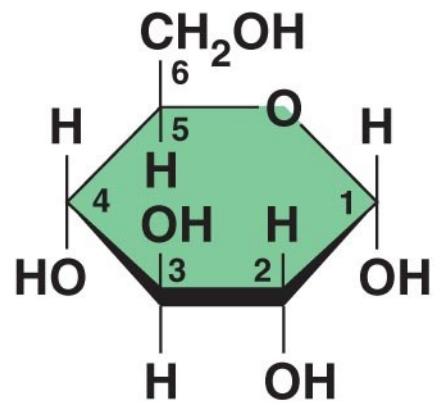


- Though often drawn as linear skeletons, in aqueous solutions many sugars form rings
- Monosaccharides serve as a major fuel for cells and as raw material for building molecules



## (a) Linear and ring forms

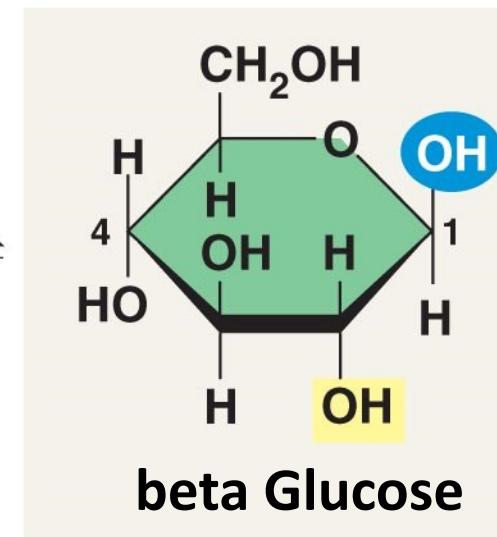
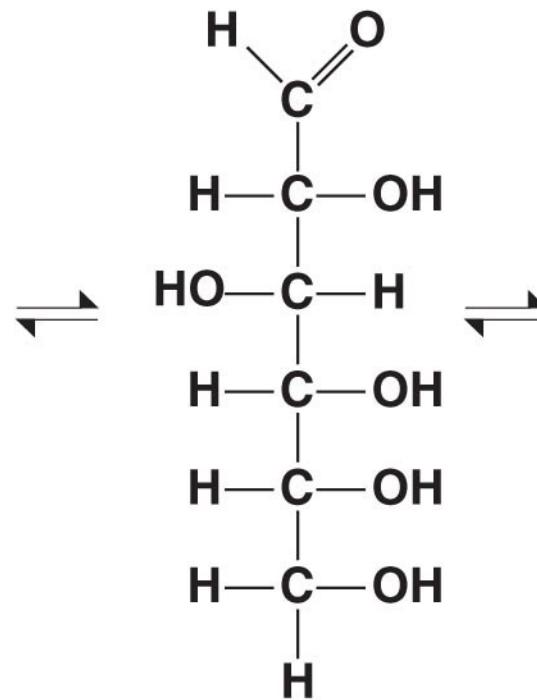
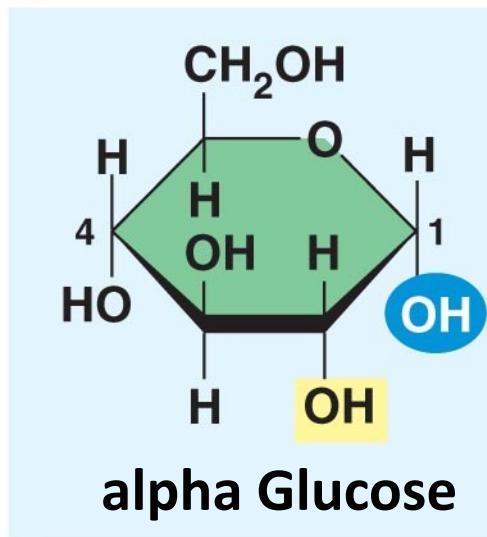
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## (b) Abbreviated ring structure

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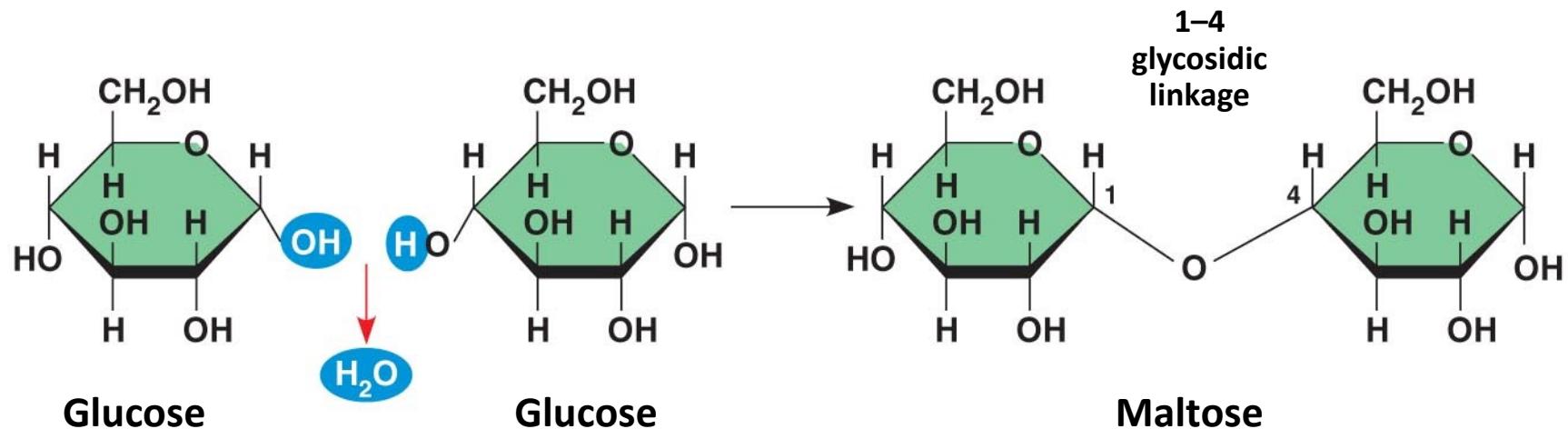
Fig. 5-7a



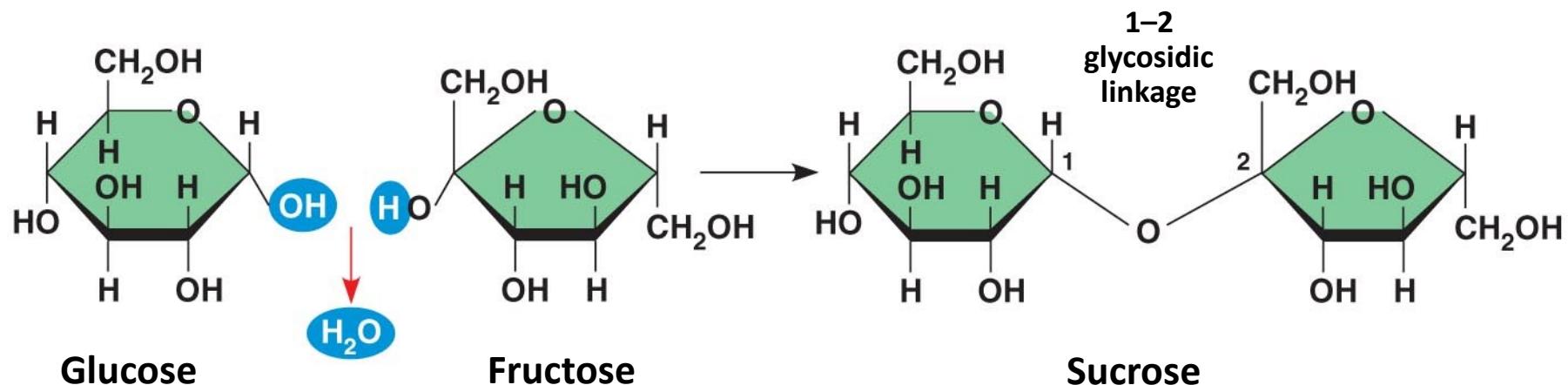
### (a) alpha and beta glucose ring structures

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



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



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

# Polysaccharides

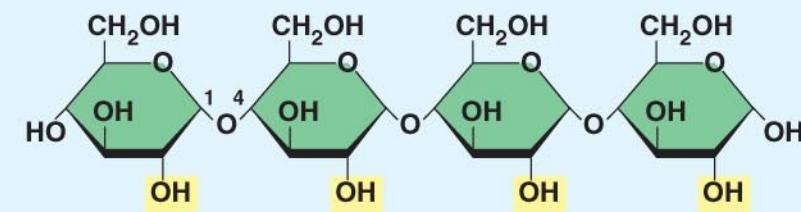
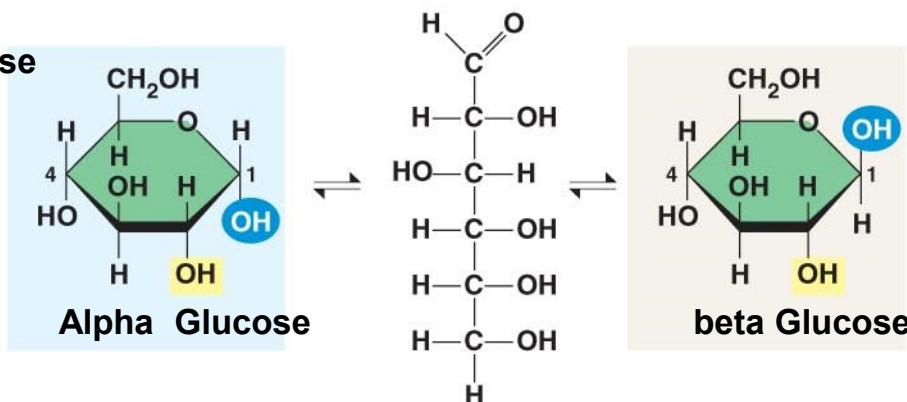
- **Polysaccharides**, the polymers of sugars, have storage and structural roles
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages

# *Storage Polysaccharides*

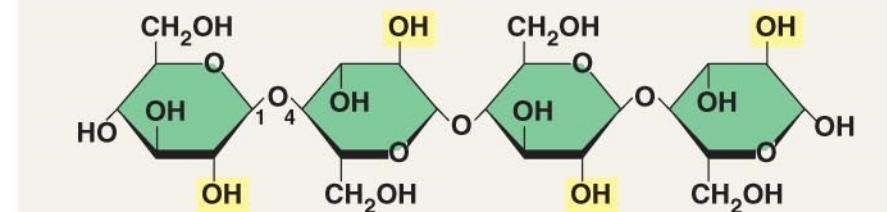
- **Starch**, a storage polysaccharide of plants, consists entirely of glucose monomers
- Plants store surplus starch as granules within chloroplasts and other plastids

Fig. 5-7

(a) alpha and beta glucose ring structures

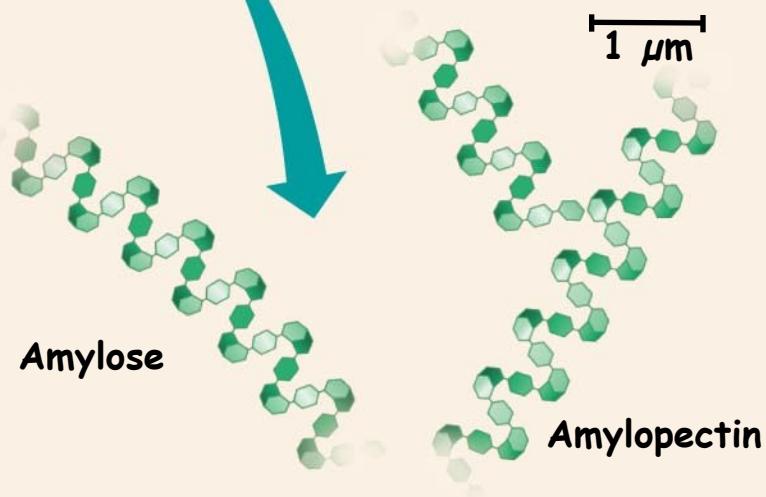
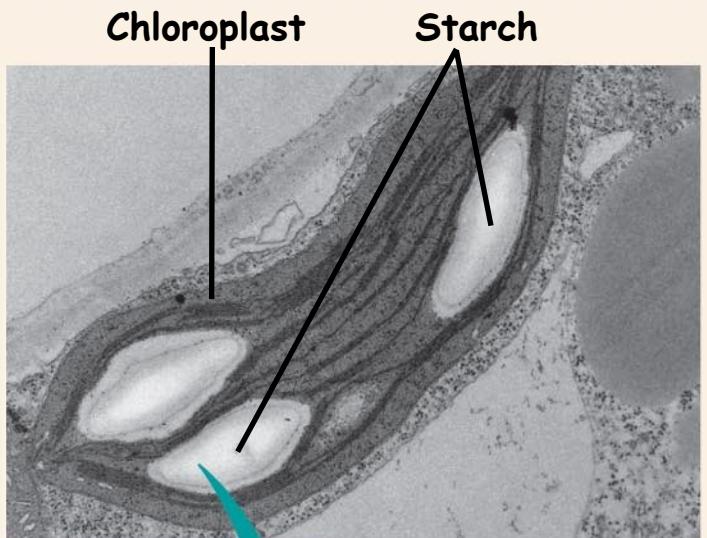


(b) Starch: 1–4 linkage of alpha glucose monomers

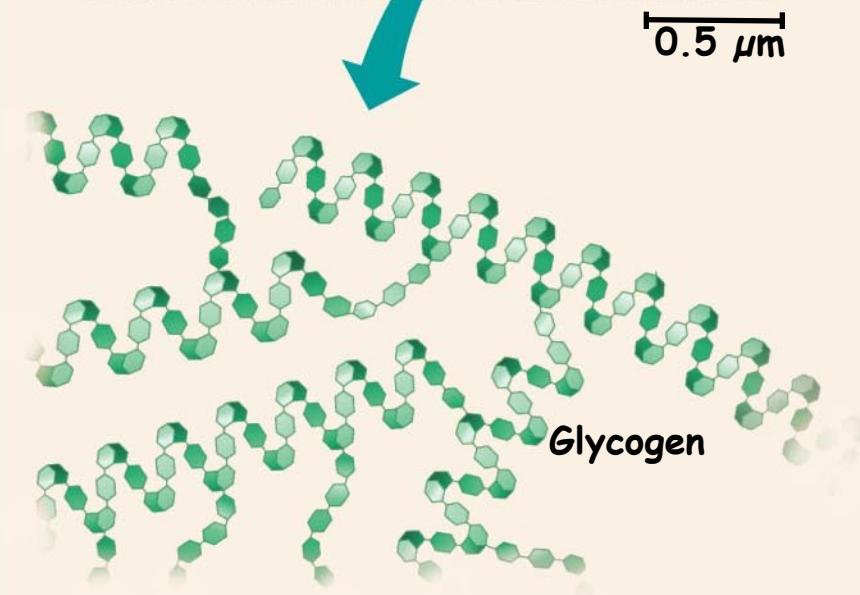
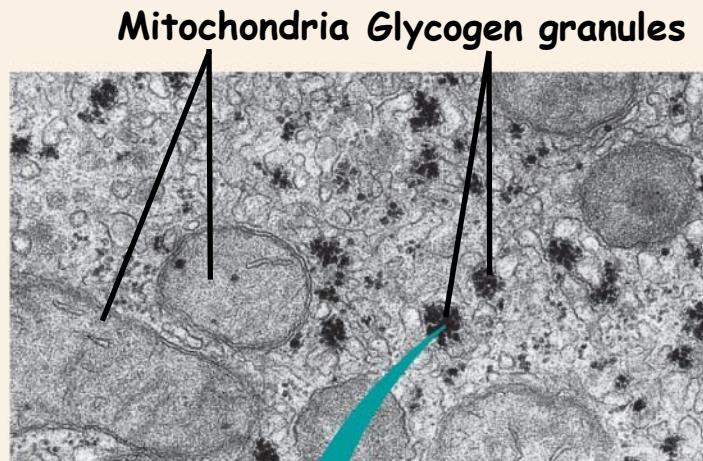


(b) Cellulose: 1–4 linkage of beta glucose monomers

- Polymers with  $\alpha$  glucose are helical
- Polymers with  $\beta$  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



**(a) Starch: a plant polysaccharide**

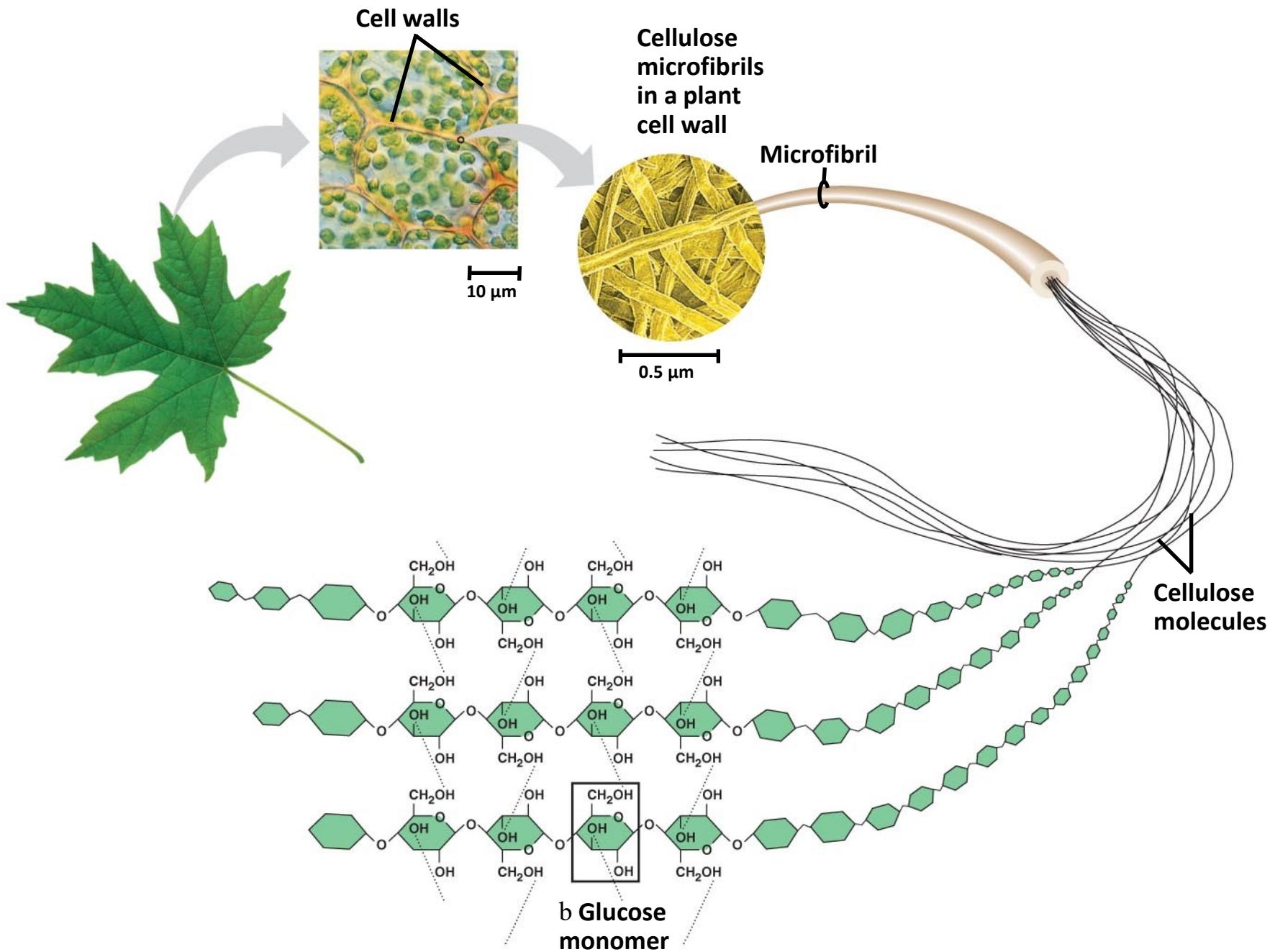


**(b) Glycogen: an animal polysaccharide**

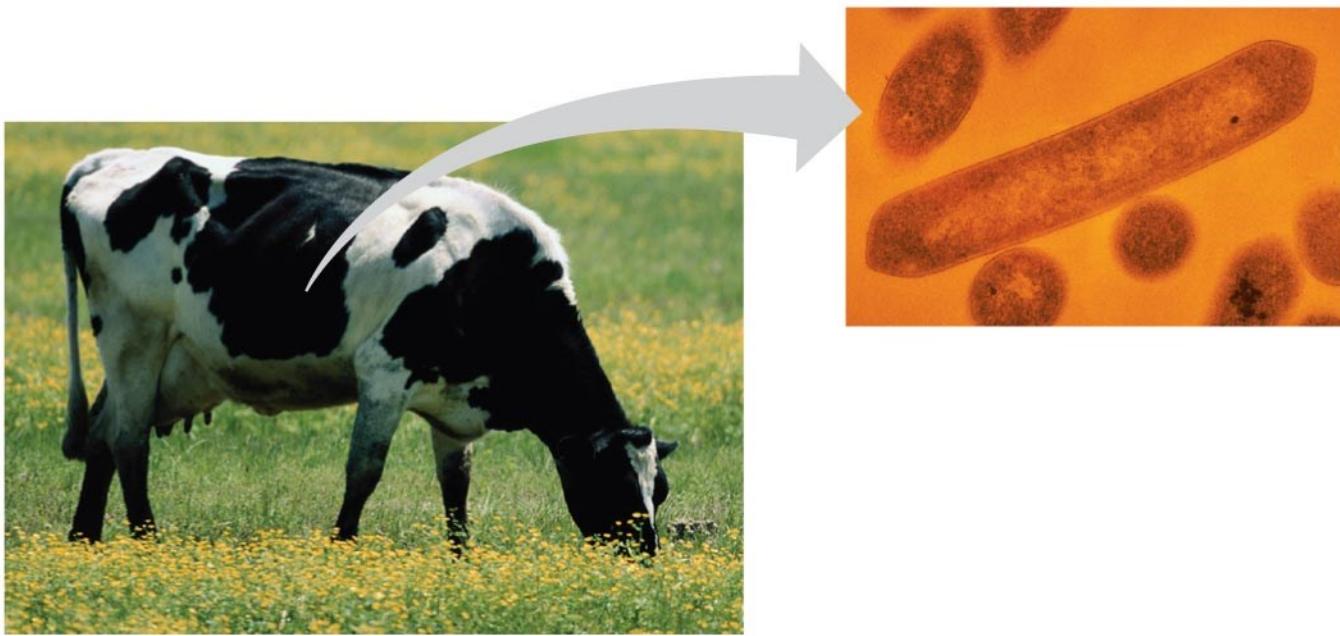
- **Glycogen** is a storage polysaccharide in animals
- Humans and other vertebrates store glycogen mainly in liver and muscle cells

# 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 ( $\alpha$ ) and beta ( $\beta$ )



- Enzymes that digest starch by hydrolyzing  $\alpha$  linkages can't hydrolyze  $\beta$  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



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