Bio-organic chemistry

Lecture #14

Deoxyribonucleic acids (DNA). DNA organization levels. Physiological role. Nucleotides and DNA nucleosides, their structure, chemical properties. Pyrimidine and purine bases of nucleosides and nucleotides, their tautomeric transformations.

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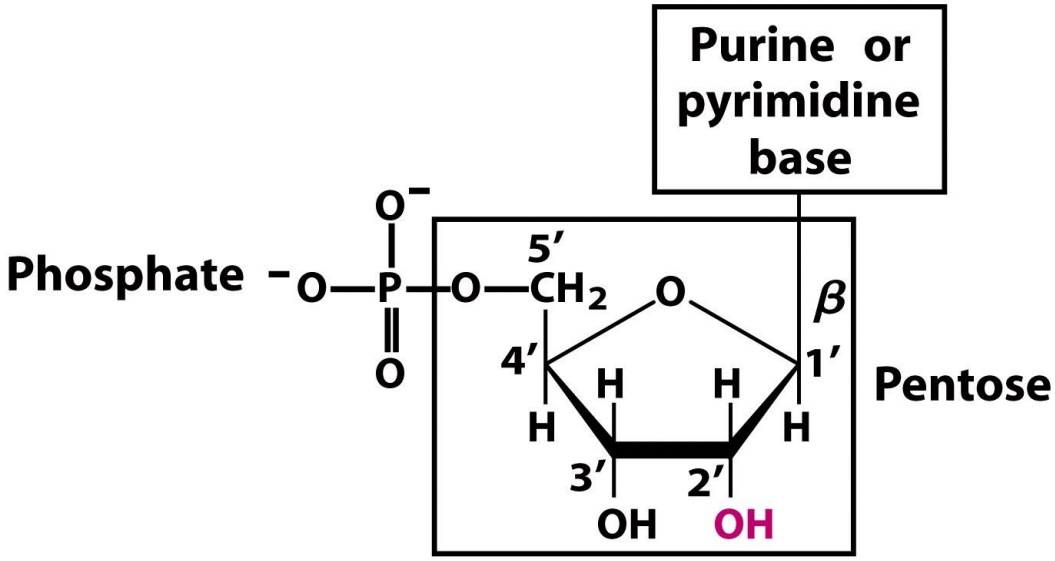
Associate Professor

Nucleotides

"Energy rich" compounds
- Chemical signals
- Enzyme co-factors

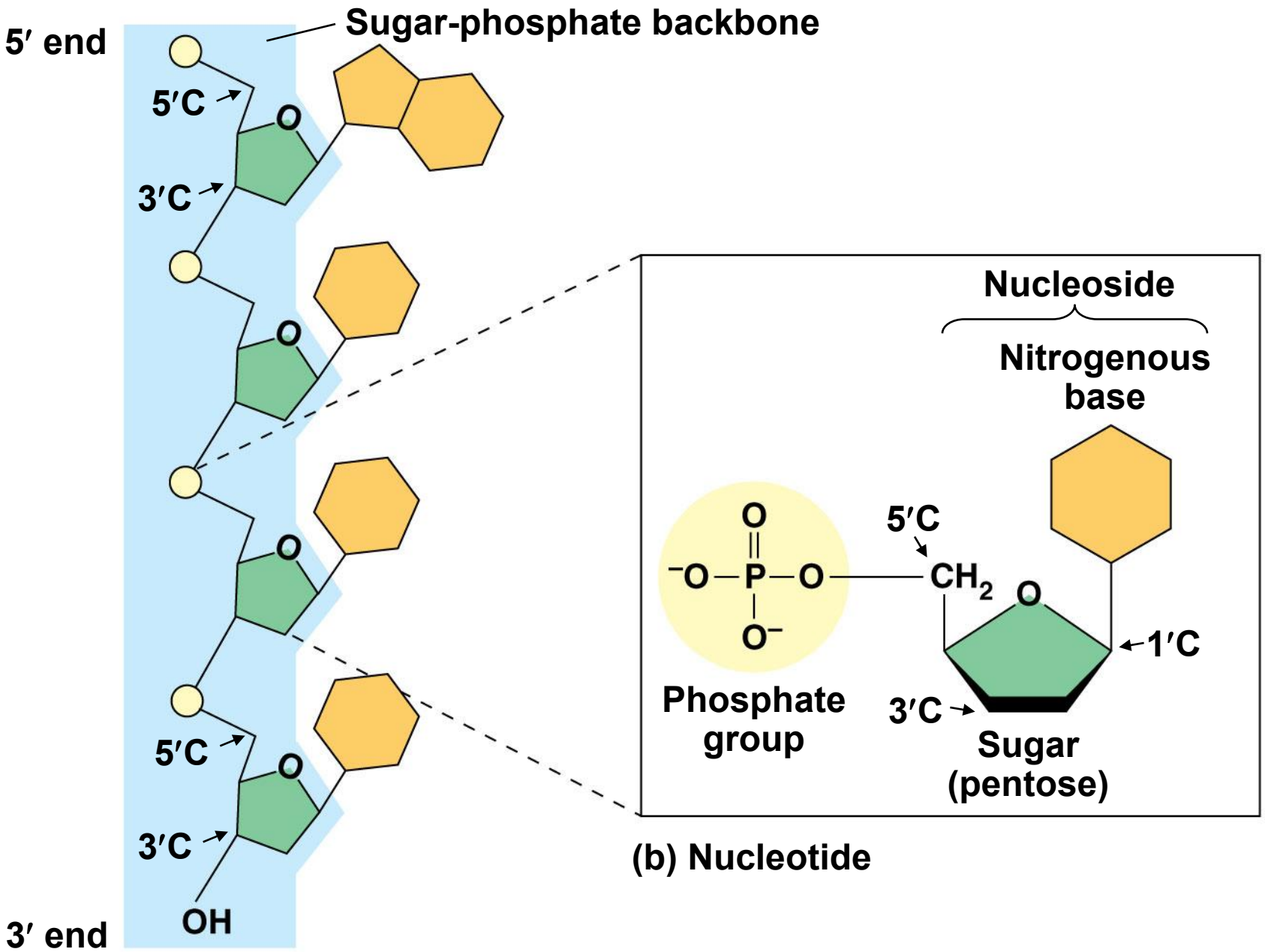
Nucleic Acids
- DNA and RNA
- Polymers of nucleotides

3 components
- Nitrogenous "base"
- Ribose (or deoxyribose)
- Phosphate



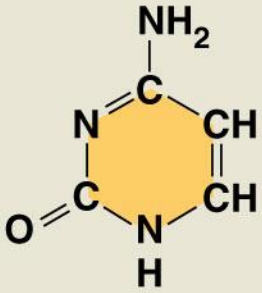
- Each nucleic acid is made of monomers called **nucleotides**

- Each nucleotide consists of a *nitrogenous base, a pentose sugar, and one or more phosphate groups*

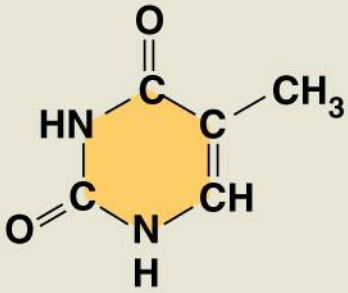


Nitrogenous bases

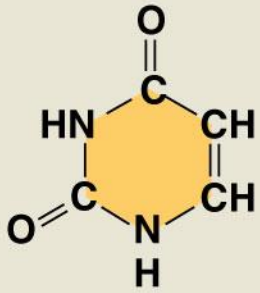
Pyrimidines



Cytosine (C)

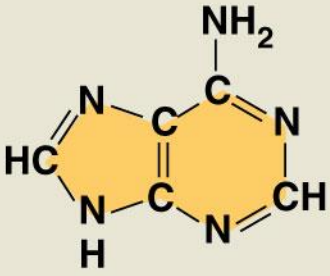


Thymine (T, in DNA)

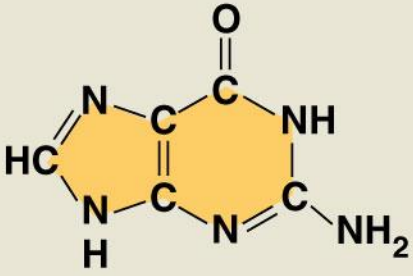


Uracil (U, in RNA)

Purines

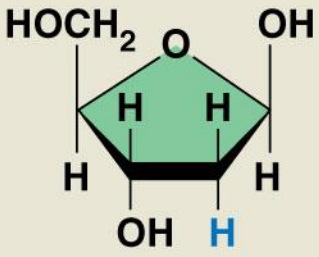


Adenine (A)

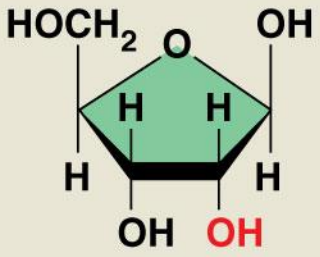


Guanine (G)

Sugars



Deoxyribose (in DNA)

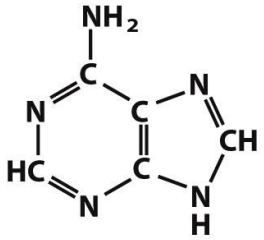


Ribose (in RNA)

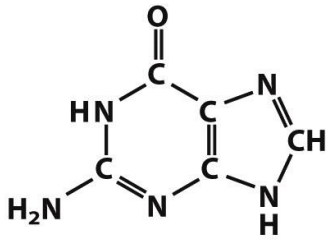
(c) Nucleoside components

"Bases"

- 2 purine bases
  - Adenine: A
  - Guanine: G



Adenine

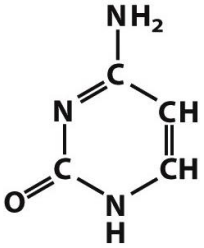


Guanine

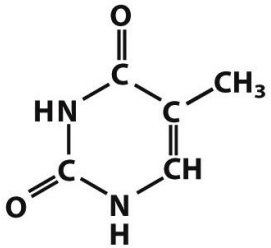
Purines

A G

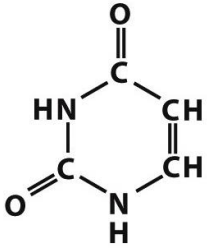
- Bases
  - Pyrimidines
  - Purines



Cytosine



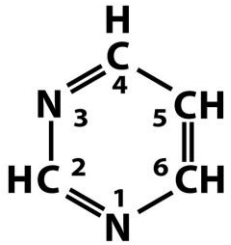
Thymine (DNA)



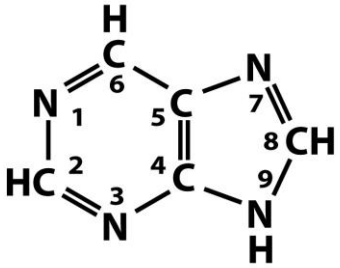
Uracil (RNA)

Pyrimidines

C T U



Pyrimidine

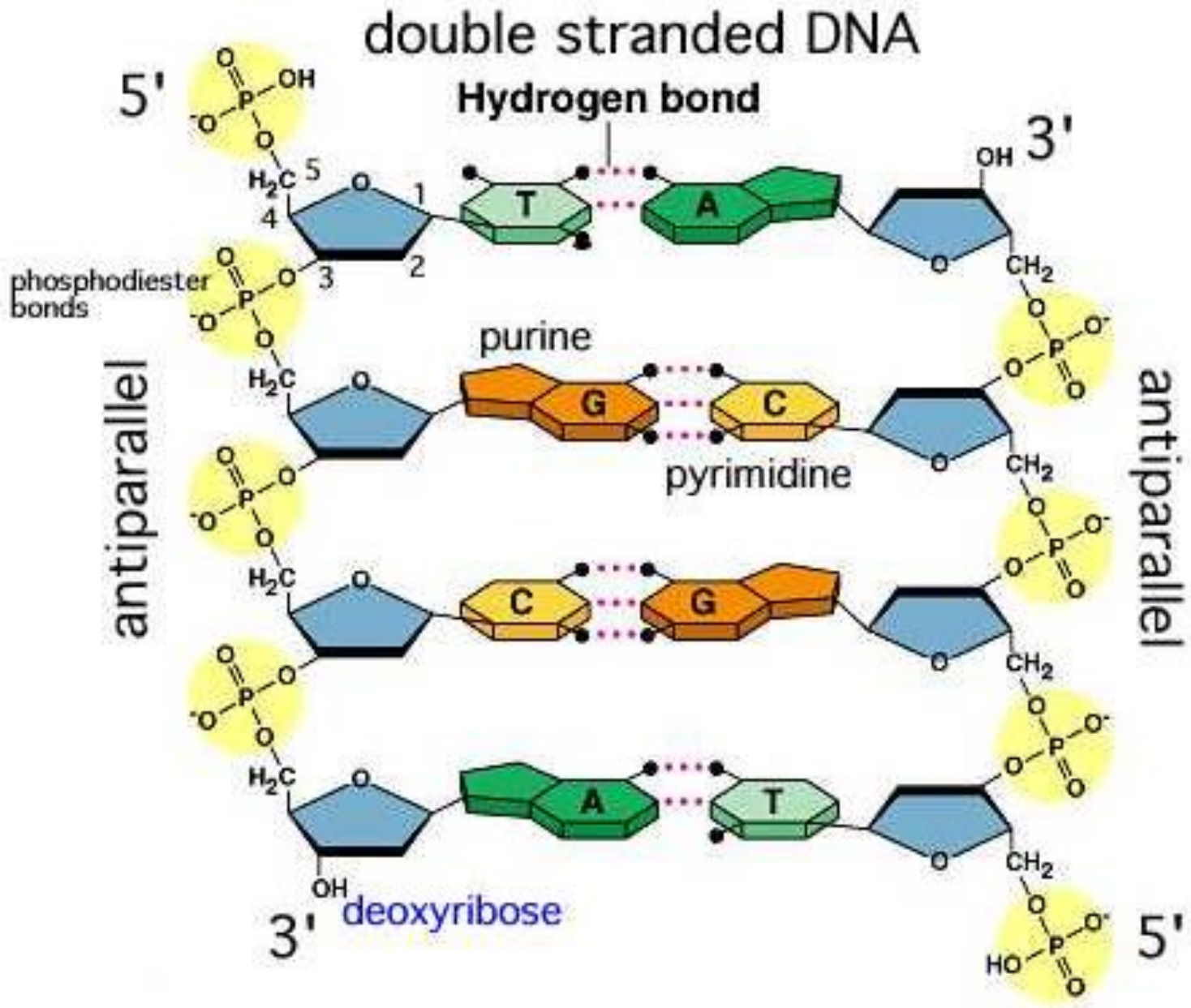


Purine

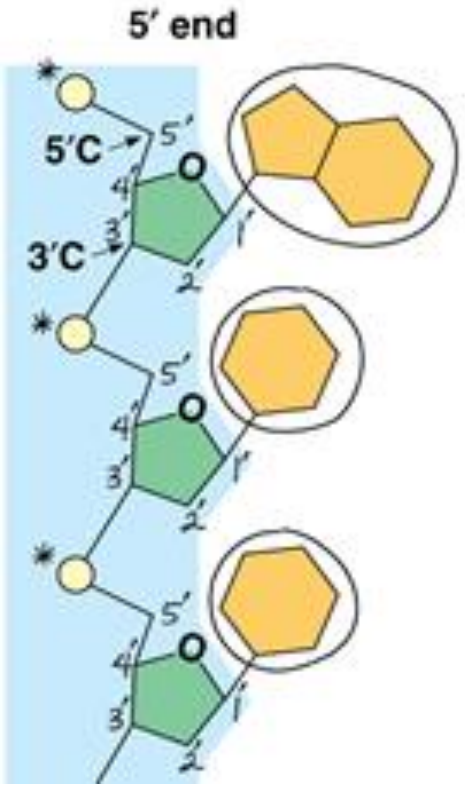
- 2 pyrimidine bases (in DNA)
  - Cytosine: C
  - Thymine: T
    - or Uracil: U

    (in RNA, instead of Thymine)

Figure 8-1b
Lehninger Principles of Biochemistry, Fifth Edition

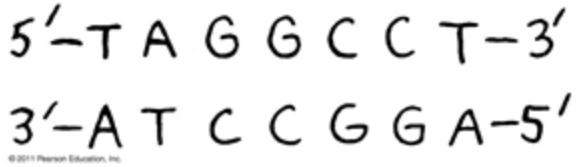

double stranded DNA
Hydrogen bond
5'
3'
phosphodiester bonds
purine
pyrimidine
antiparallel
antiparallel
T
A
G
C
C
G
A
T
3'
deoxyribose
5'

- There are two families of nitrogenous bases
  - **Pyrimidines** (cytosine, thymine, and uracil) have a single six-membered ring
  - **Purines** (adenine and guanine) have a six-membered ring fused to a five-membered ring
- In DNA, the sugar is **deoxyribose**; in RNA, the sugar is **ribose**

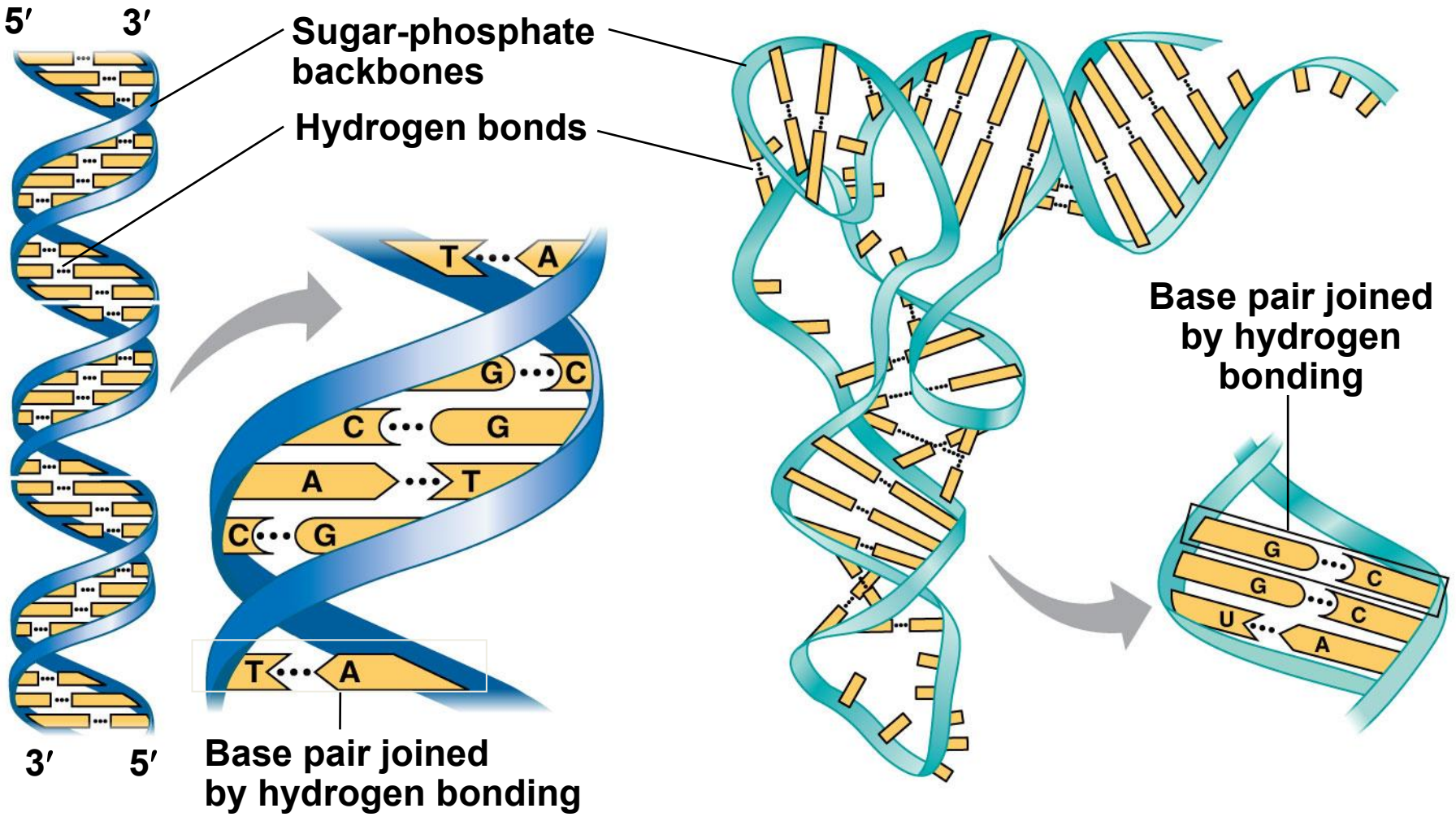


- Adjacent *nucleotides are joined by covalent bonds* that form between the —OH group on the 3′ carbon of one nucleotide and the phosphate on the 5′ carbon on the next
- These links create a backbone of sugar-phosphate units with nitrogenous bases as appendages
- The sequence of bases along a DNA or mRNA polymer is unique for each gene

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



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



- The linear sequences of nucleotides in DNA molecules are passed from parents to offspring

- Two closely related species are more similar in DNA than are more distantly related species

- Molecular biology can be used to assess evolutionary kinship

Ribose

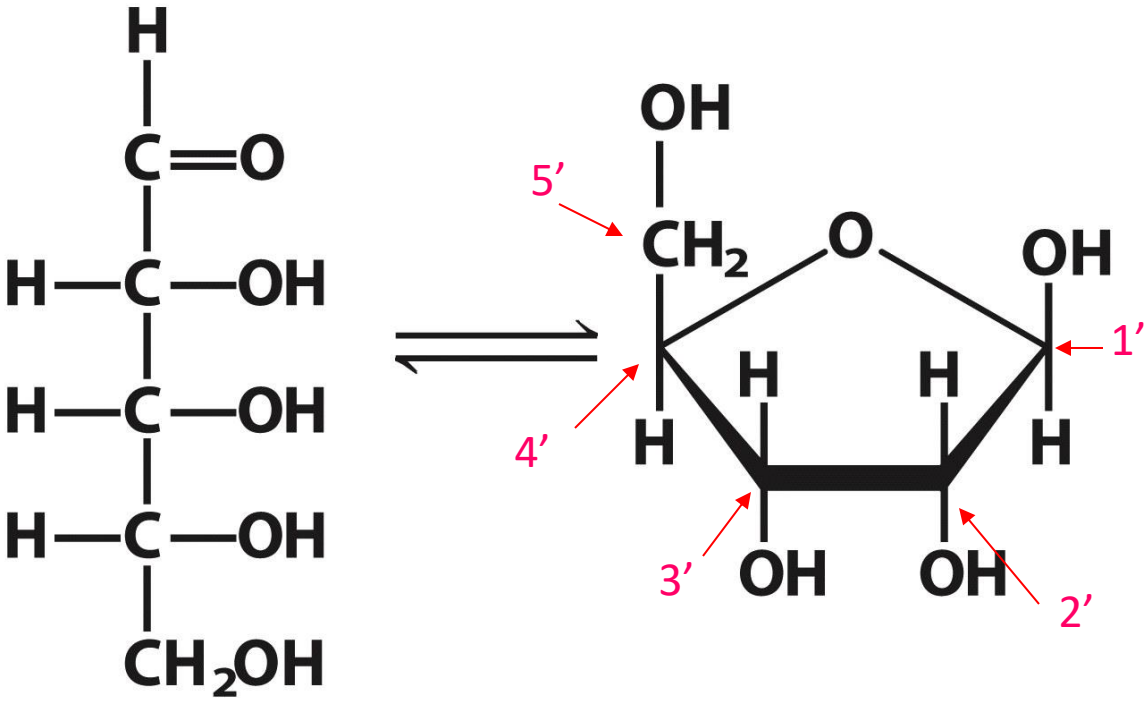
carbons numbered:

1’,2’,3’,4’,5’

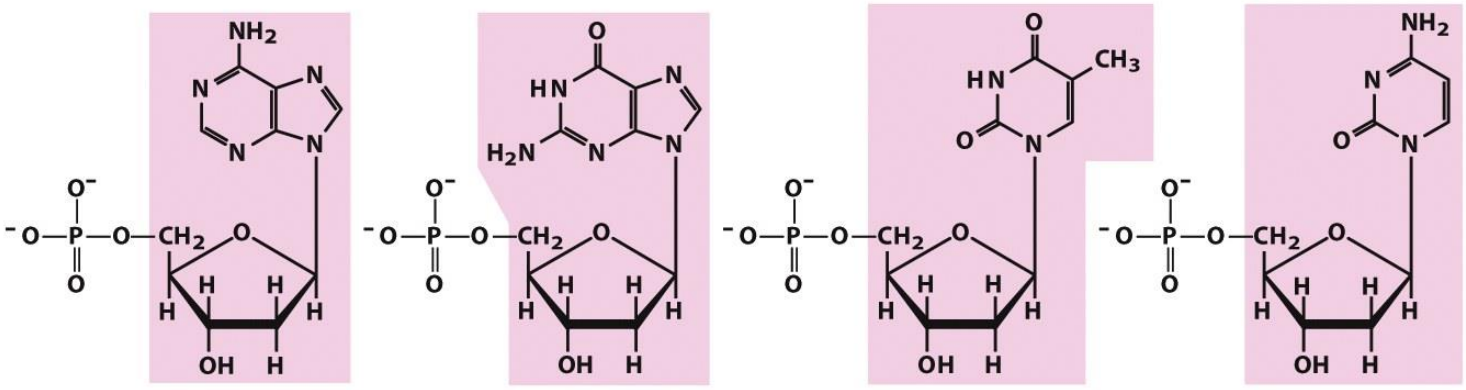
DNA:

2’ Deoxyribose

or just deoxyribose



Nucleotides



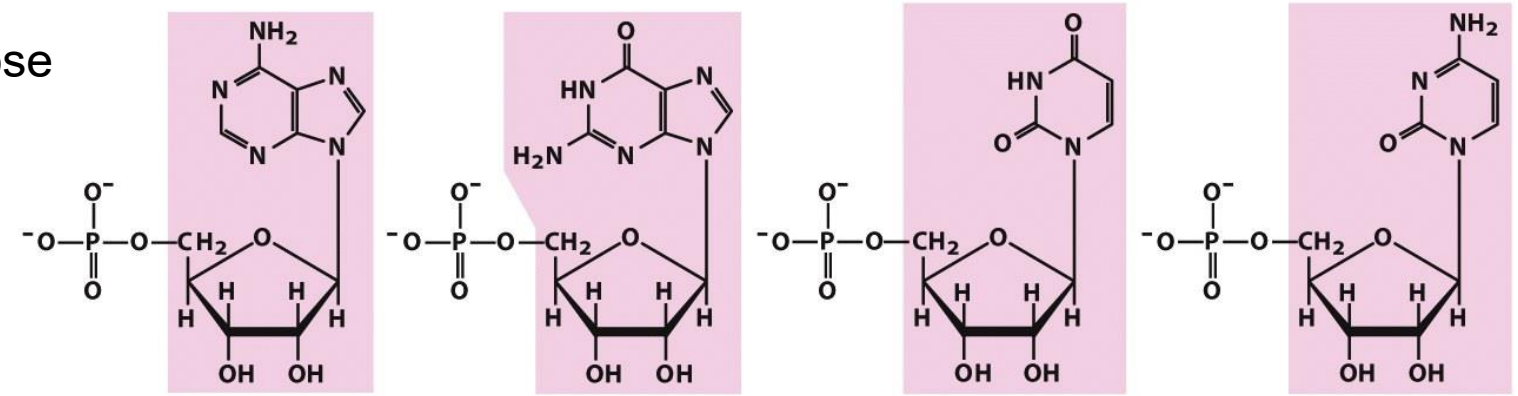
Nucleotide:	Deoxyadenylate (deoxyadenosine 5′-monophosphate)	Deoxyguanylate (deoxyguanosine 5′-monophosphate)	Deoxythymidylate (deoxythymidine 5′-monophosphate)	Deoxycytidylate (deoxycytidine 5′-monophosphate)
Symbols:	A, dA, dAMP	G, dG, dGMP	T, dT, dTMP	C, dC, dCMP
Nucleoside:	Deoxyadenosine	Deoxyguanosine	Deoxythymidine	Deoxycytidine

Deoxyribonucleotides

Summary

DNA A,C,G,T
deoxyribose

RNA A,C,G,U
ribose



Nucleotide:	Adenylate (adenosine 5′-monophosphate)	Guanylate (guanosine 5′-monophosphate)	Uridylate (uridine 5′-monophosphate)	Cytidylate (cytidine 5′-monophosphate)
Symbols:	A, AMP	G, GMP	U, UMP	C, CMP
Nucleoside:	Adenosine	Guanosine	Uridine	Cytidine

Ribonucleotides

Polymerise Nucleotides

nucleotides can be linked

- phosphates linked to 2 pentoses
- phosphodiester linkages
  - Link PO_4 at
    - 5’ end to 3’ OH of next nucleotide

- chain has POLARITY
  - –distinct ends
    - •5’ end
    - •3’ end
  - –usually “read” 5’ -> 3’

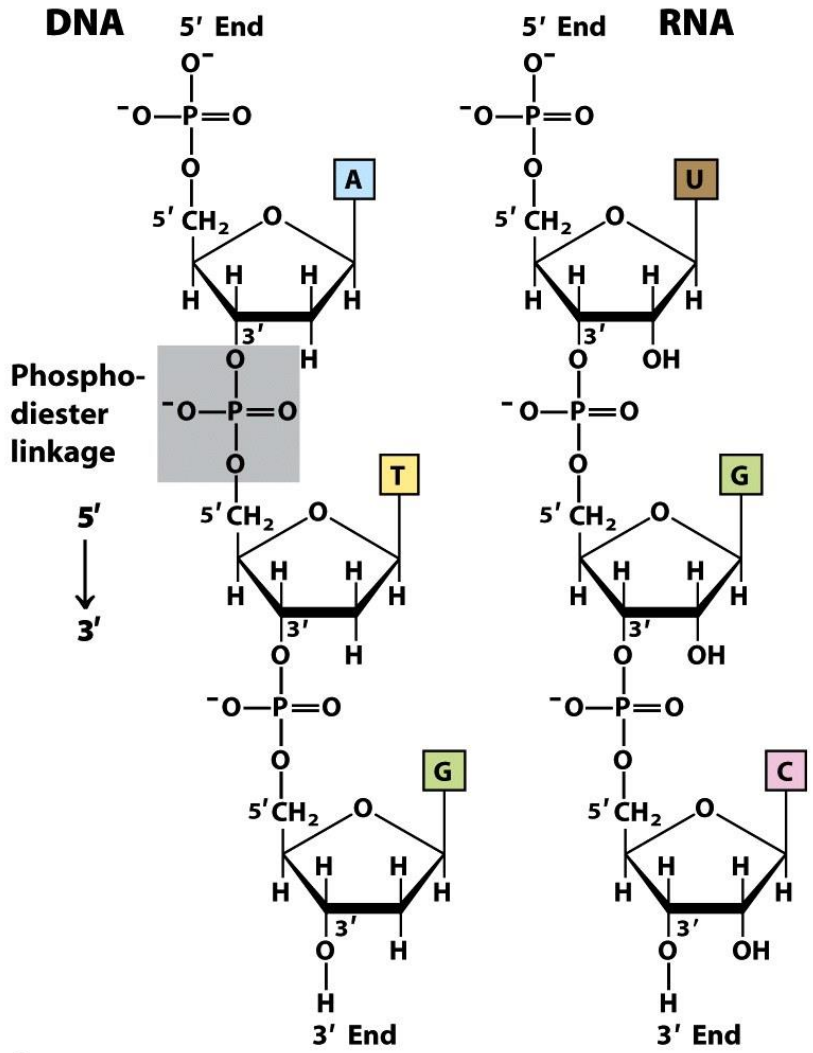


Figure 8-7
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Nucleotides as Energy Carriers

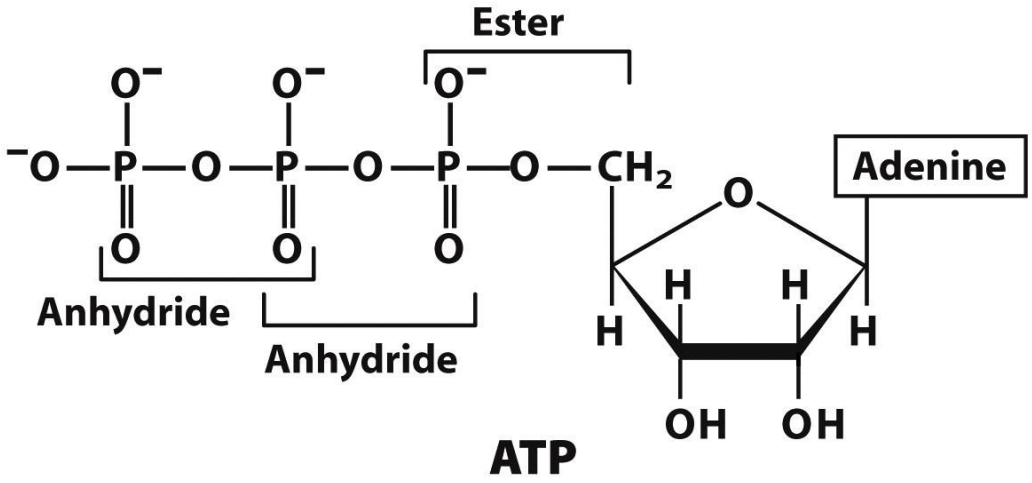
ATP

Adenosine triphosphate

ADP, AMP

Adenosine diphosphate

Adenosine monophosphate



ATP <—> ADP + PO_4

ADP <—> AMP + PO_4

- Main energy exchange reactions in cells

Structure of DNA?

The Genetic Material
Crick and Watson
Race with Linus Pauling to predict structure

Chargaff's rules:
Chemical analysis:
[A] = [T]
[G] = [C]
Constant
for each organism
over time
across all tissues

James D. Watson

Francis Crick, 1916–2004

Unnumbered 8 p277
Lehninger Principles of Biochemistry, Fifth Edition

X-Ray Diffraction

Predict

- Double helix
- 2 periodicities
  - 3.4Å
  - 34Å

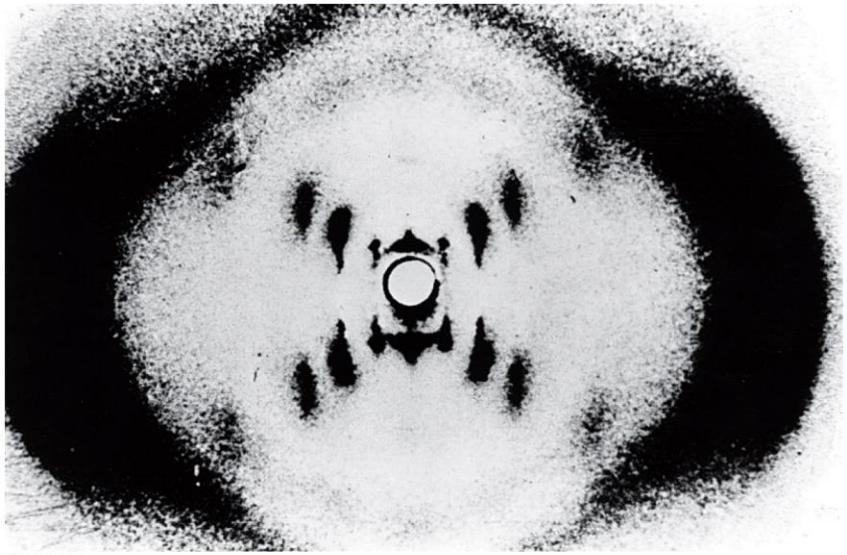


Figure 8-12
Lehninger Principles of Biochemistry, Fifth Edition

Rosalind Franklin, 1920–1958

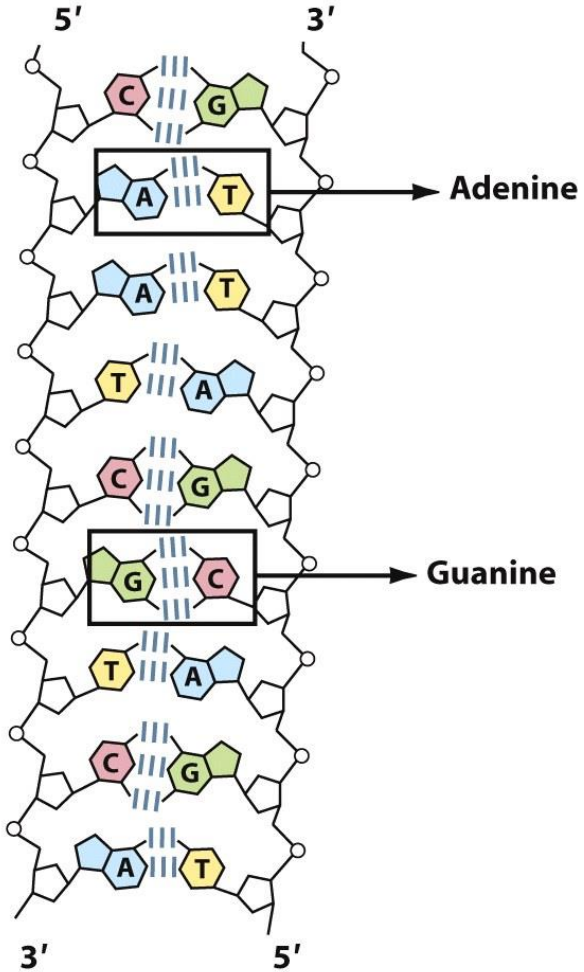
Maurice Wilkins, 1916–2004

Unnumbered 8 p278
Lehninger Principles of Biochemistry, Fifth Edition

Base Pairing

A – T basepair
2 h-bonds
G – C basepair
3 h-bonds

2 anti-parallel
DNA strands



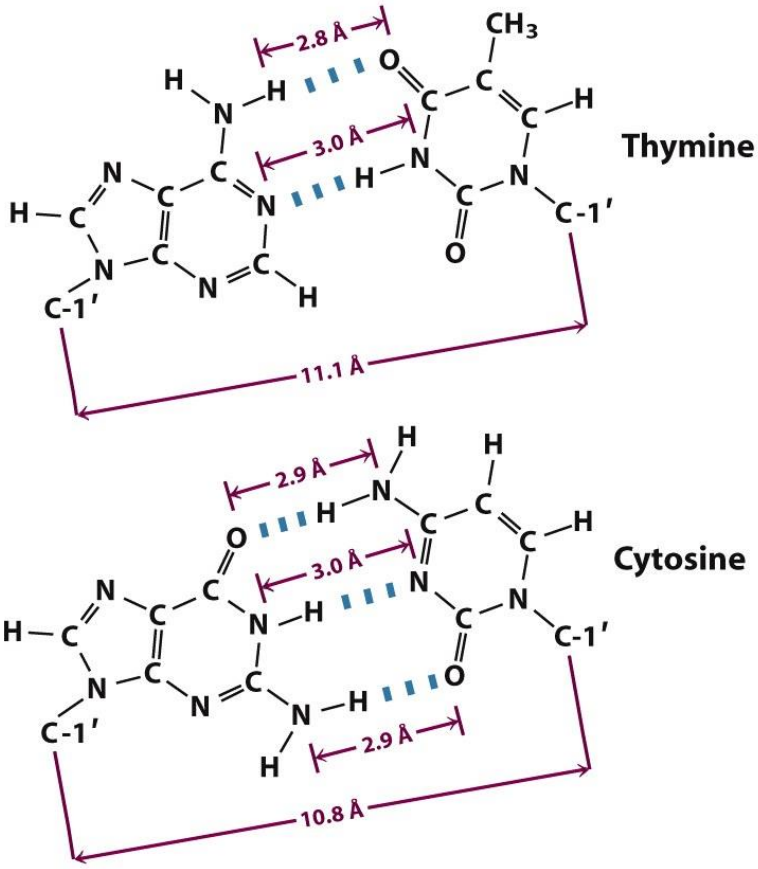


Figure 8-11
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The Double Helix

3.4Å per basepair
10 basepairs per turn
10-11 in aqueous solution
2 anti-parallel strands

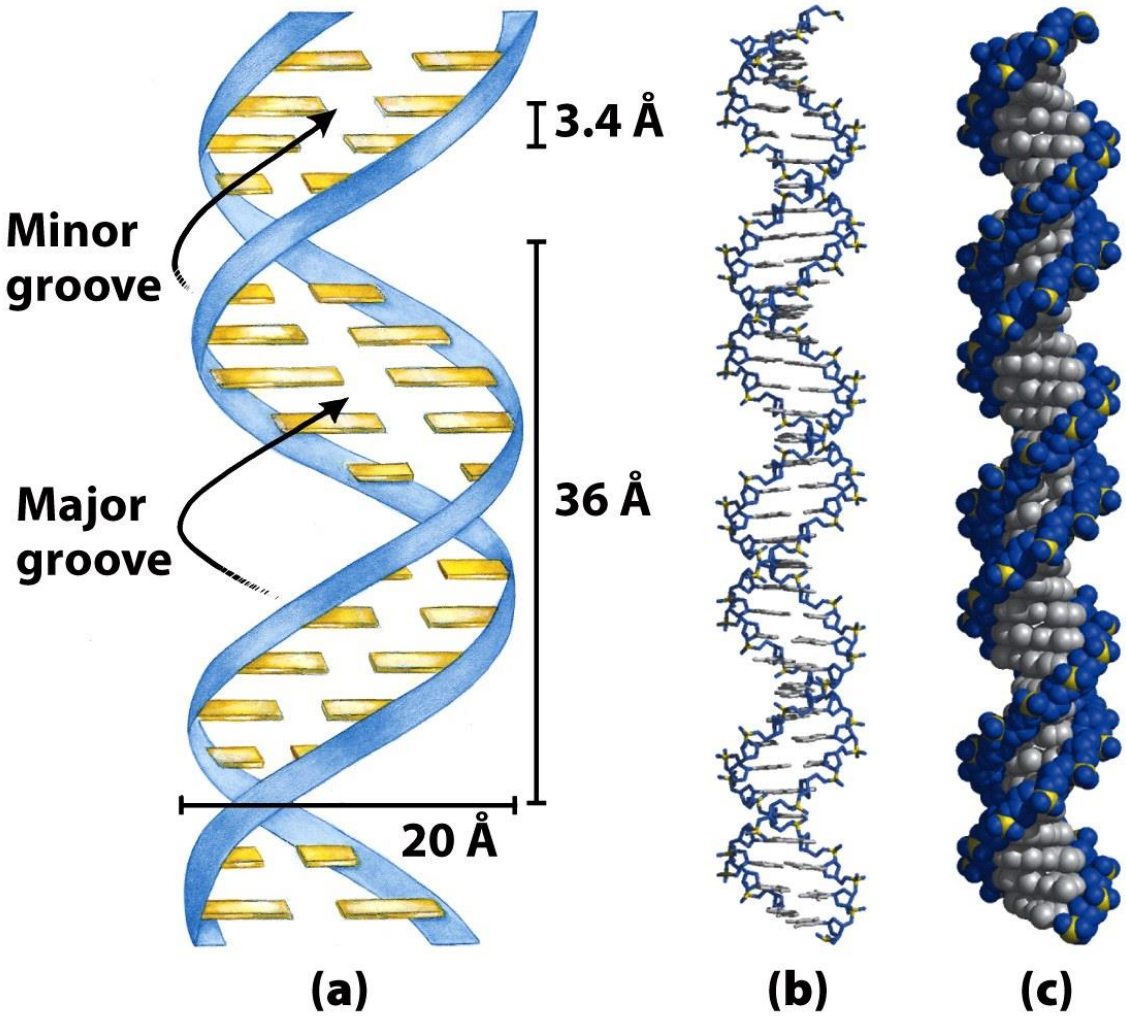

Figure 8-13
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- DNA Replication
  - By DNA Polymerase

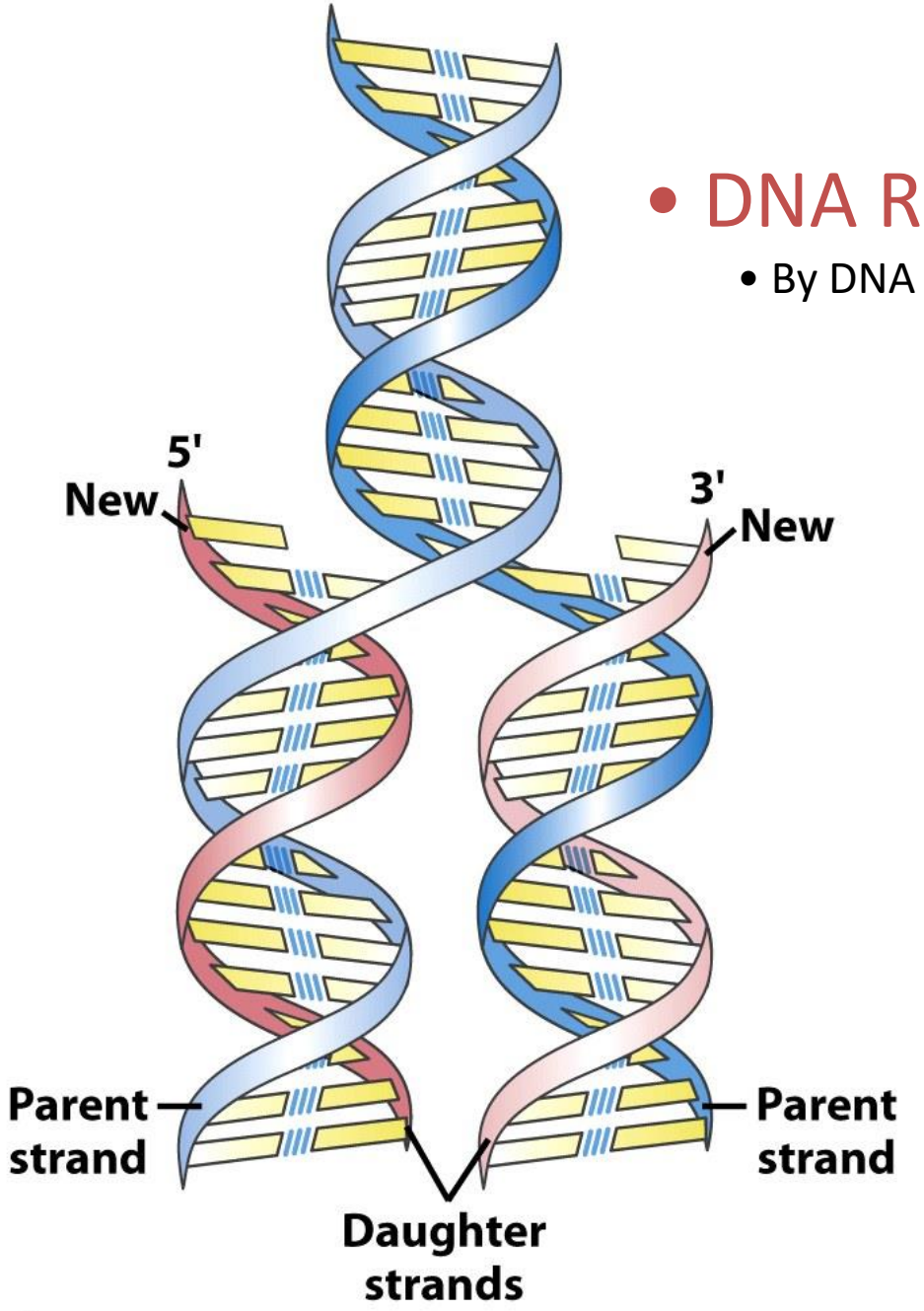

Figure 8-15
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	Monomers of components	Polymer or larger molecule	Type of linkage
Carbohydrates			
Lipids			
Proteins			
Nucleic acids			

	Monomers or Components	Polymer or larger molecule	Type of linkage
Carbohydrates	Monosaccharides	Polysaccharides	Glycosidic linkages
Lipids	Fatty acids	Triacylglycerols	Ester linkages
Proteins	Amino acids	Polypeptides	Peptide bonds
Nucleic acids	Nucleotides	Polynucleotides	Phosphodiester linkages