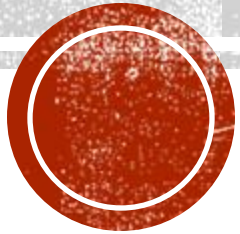
DNA AND RNA STRUCTURES

Benilda Ramos-Butron



OBJECTIVES:

- Describe the DNA and RNA molecules
- Recount the history of the elucidation of the structure of the DNA
- Enumerate enzymes and their functions in DNA replication
- Discuss the step-by-step process of DNA replication

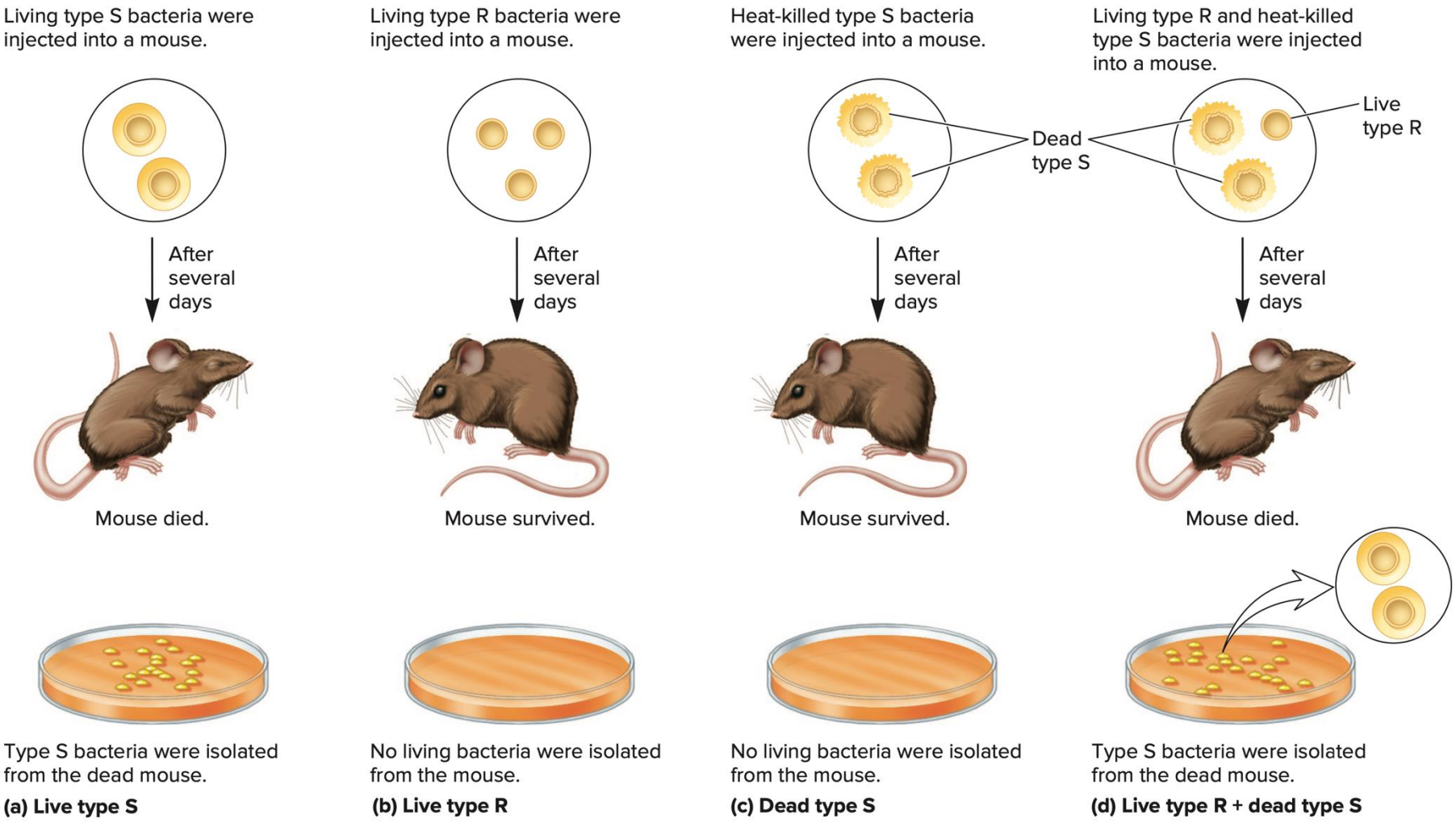
4 CRITERIA OF THE GENETIC MATERIAL

1. Information.
2. Transmission.
3. Replication
4. Variation

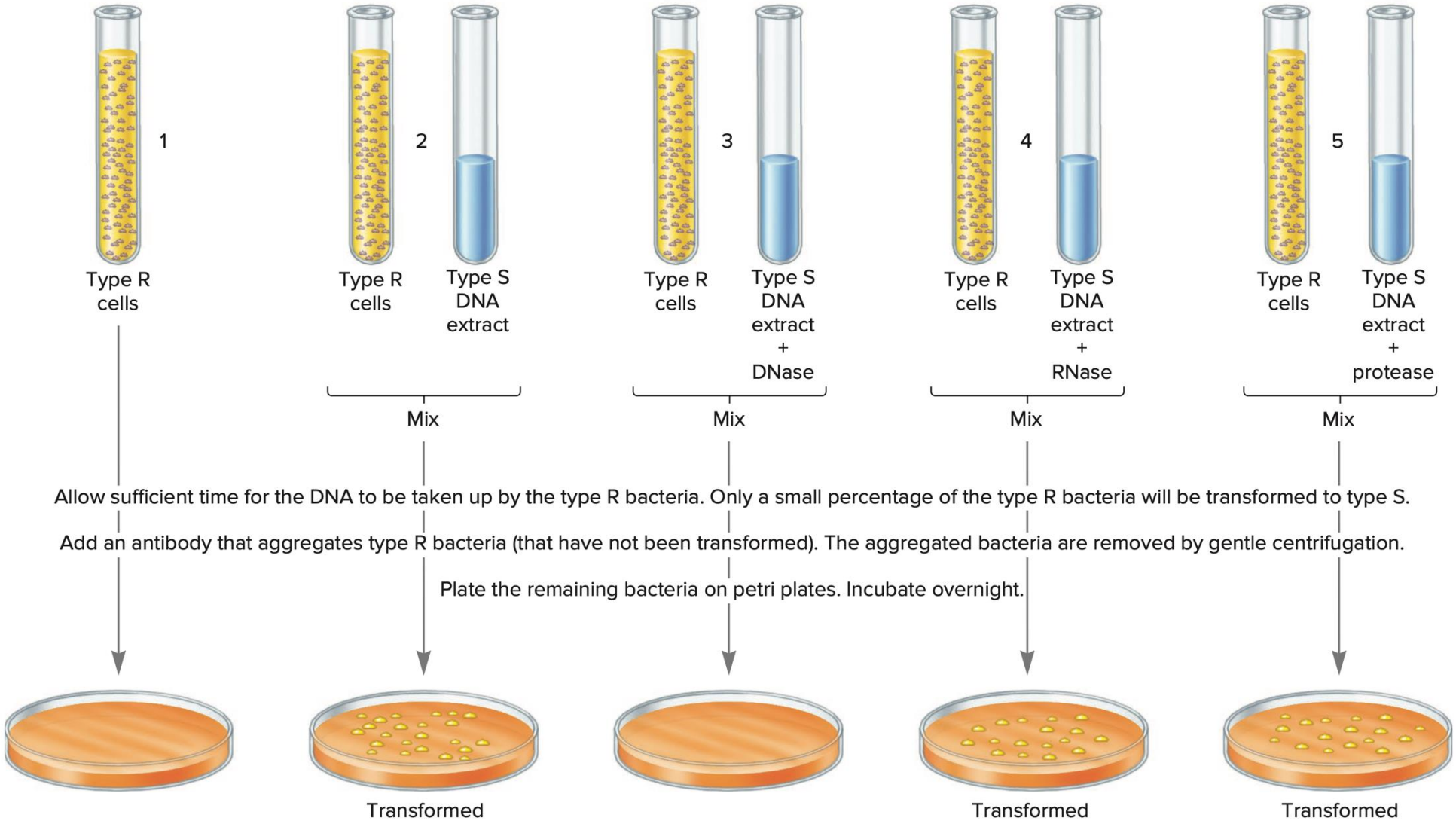
HISTORY

- **1880**, August Weismann and Carl Nageli floated the idea that a chemical substance within a living cell is responsible for the transmission of traits from parents to offsprings
- **1902-1903**, **Chromosomal Theory of Inheritance**, primarily proposed by Walter Sutton and Theodor Boveri, states that genes are located on chromosomes, and the behavior of chromosomes during meiosis explains Mendel's laws of inheritance

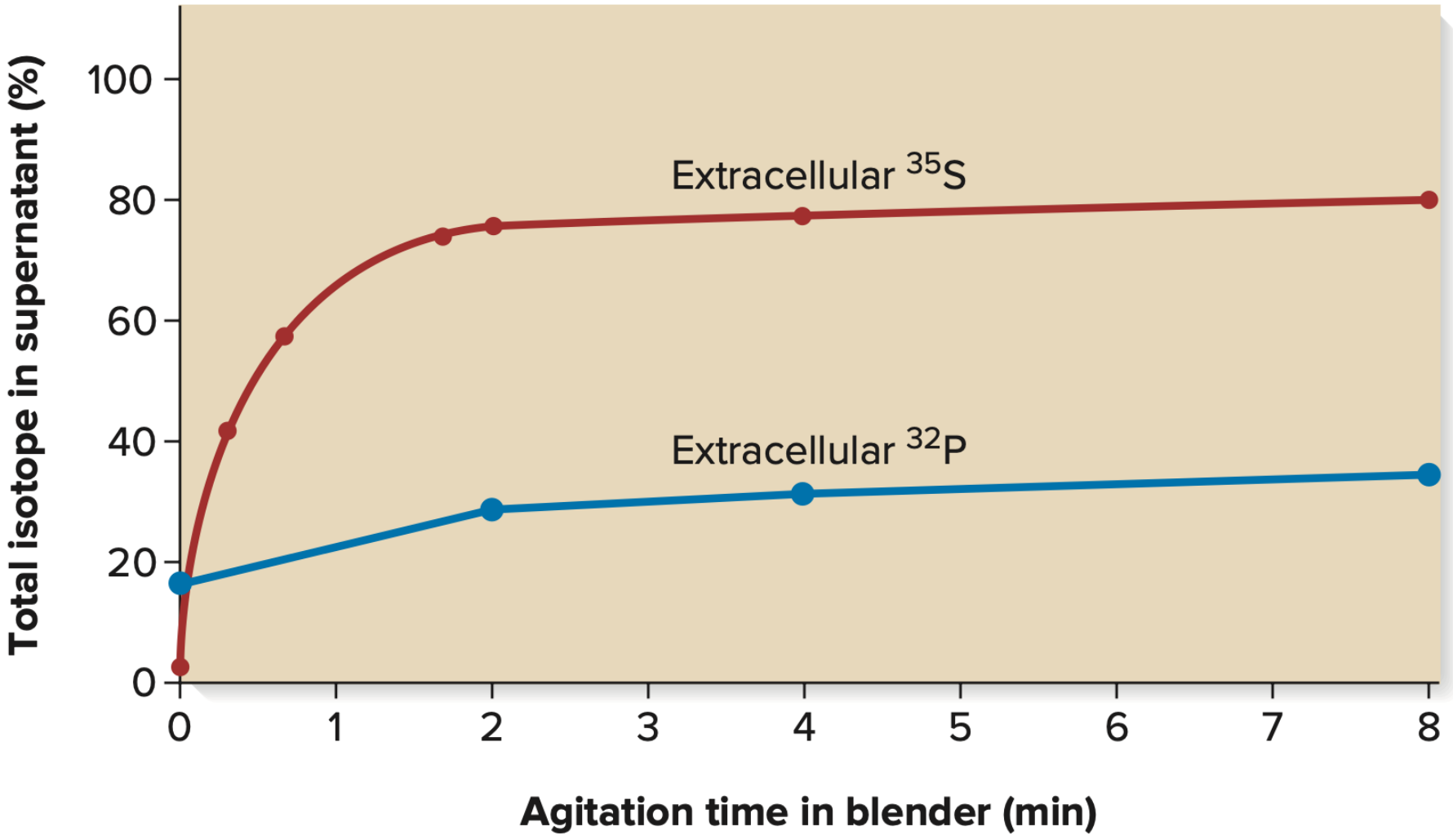
FREDERICK GRIFFITH EXPERIMENT ON GENETIC TRANSFORMATION IN S. PNEUMONIAE



AVERY, MACLEOD, AND MCCARTY EXPERIMENT



ALFRED HERSHEY AND MARTHA CHASE



80%
Blending removes 80% of ^{35}S from *E. coli* cells.

35%
Most of the ^{32}P (65%) remains with intact *E. coli* cells.

OVERVIEW OF THE DNA AND RNA STRUCTURE

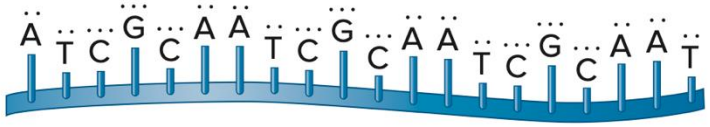
OVERVIEW OF THE DNA AND RNA STRUCTURE

- Nucleic acid – coined by Friedrich Miescher (1869)
- First referred to as "*nuclein*"
- It was determined that they are acidic molecules, which means they release hydrogen ions (H+) in solution and have a net negative charge at neutral pH
- Final term used: **nucleic acid**

4 LEVELS OF NUCLEIC ACID COMPLEXITY

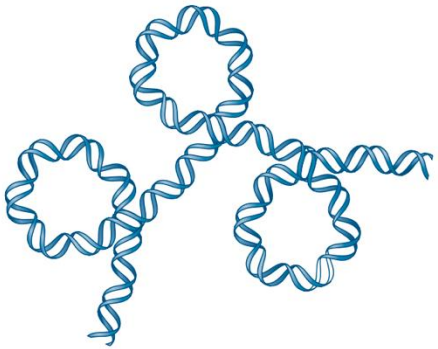
1. **Nucleotides** form the repeating structural unit of nucleic acids.
2. Nucleotides are linked together in a linear manner to form a **strand** of DNA or RNA.
3. Two strands of DNA (or sometimes strands of RNA) interact with each other to form a **double helix**.
4. The three-dimensional structure of DNA results from the folding and bending of the double helix.

Nucleotides



Single strand

Double helix

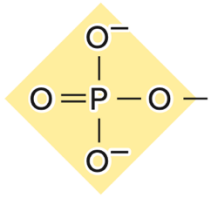


Three-dimensional structure

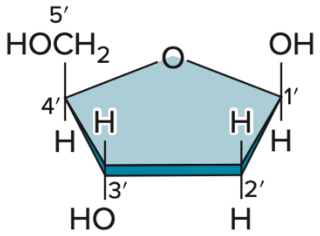
NUCLEOTIDE STRUCTURE

What are the components of a nucleotide?

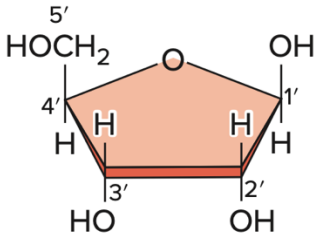
Phosphate group



Sugars



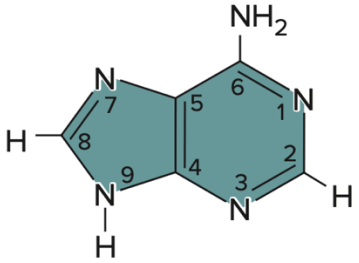
D-Deoxyribose (in DNA)



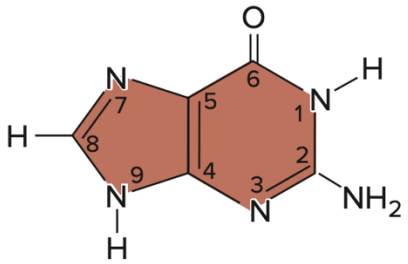
D-Ribose (in RNA)

Bases

Purines (double ring)

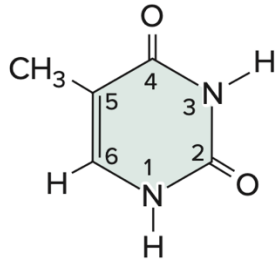


Adenine (A)

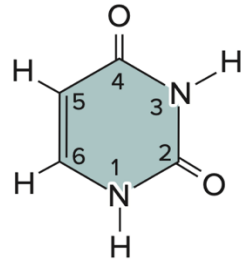


Guanine (G)

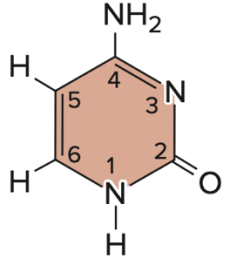
Pyrimidines (single ring)



Thymine (T) (in DNA)

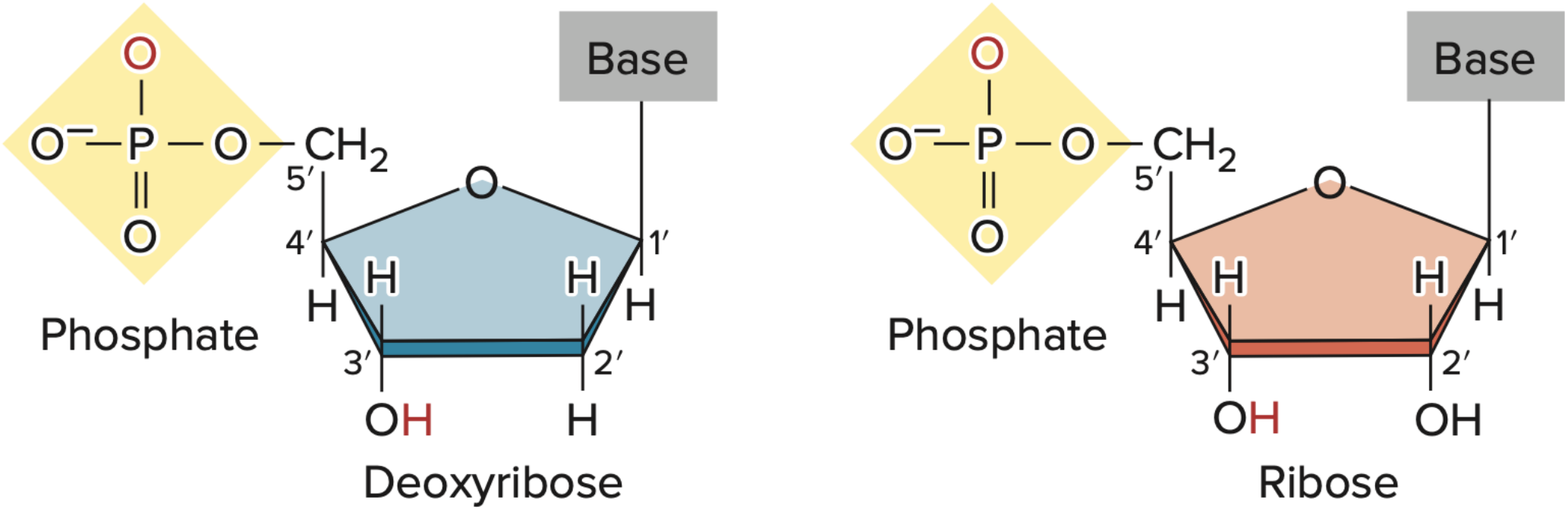


Uracil (U) (in RNA)



Cytosine (C)

Describe the nucleotide.

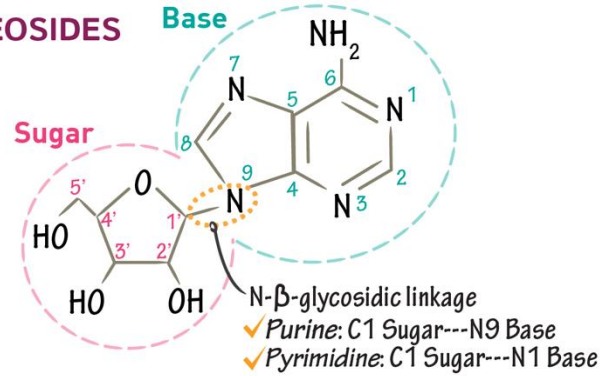


(a) Repeating unit of deoxyribonucleic acid (DNA)

(b) Repeating unit of ribonucleic acid (RNA)

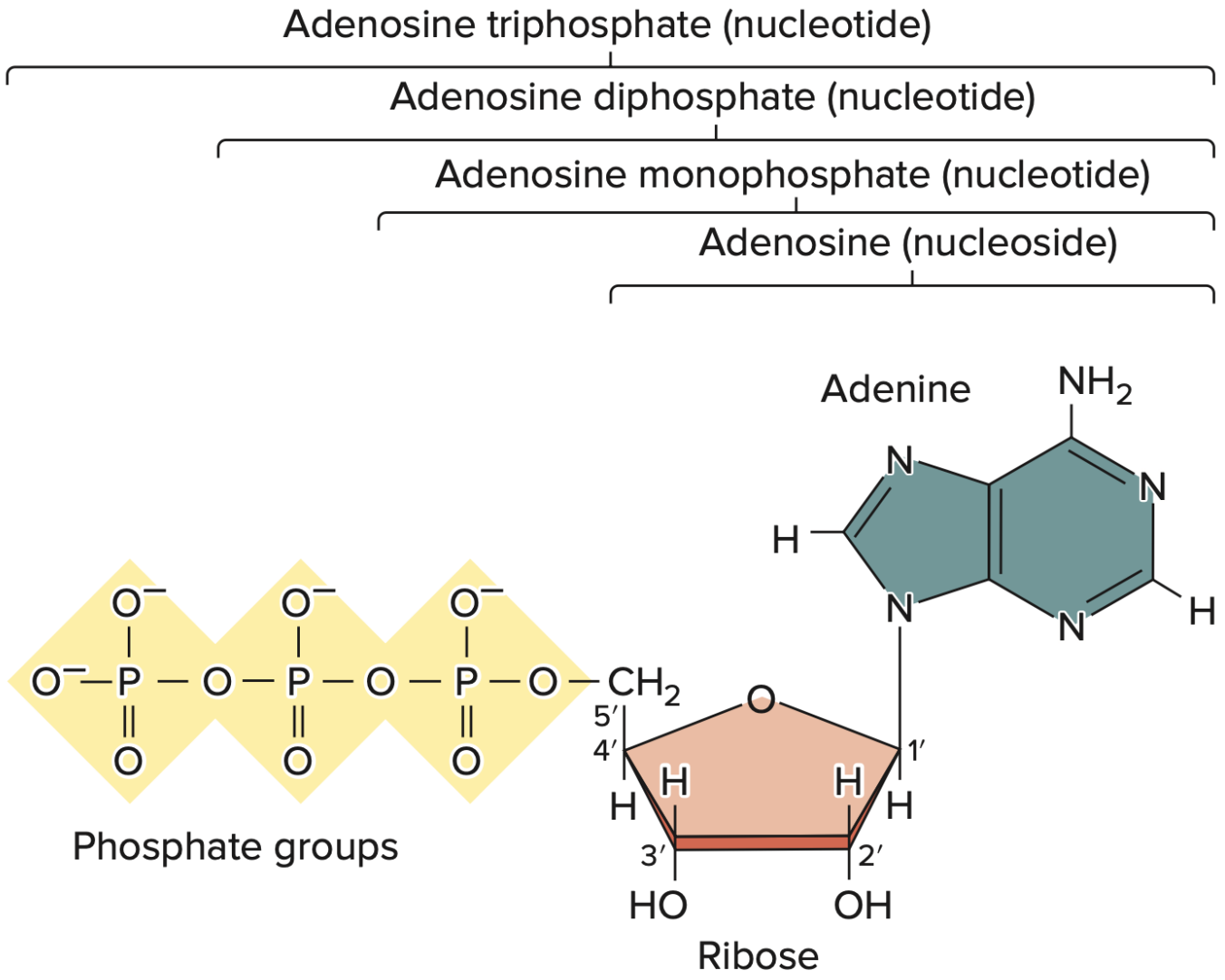
What if phosphate molecule is removed from the nucleotide?

NUCLEOSIDES



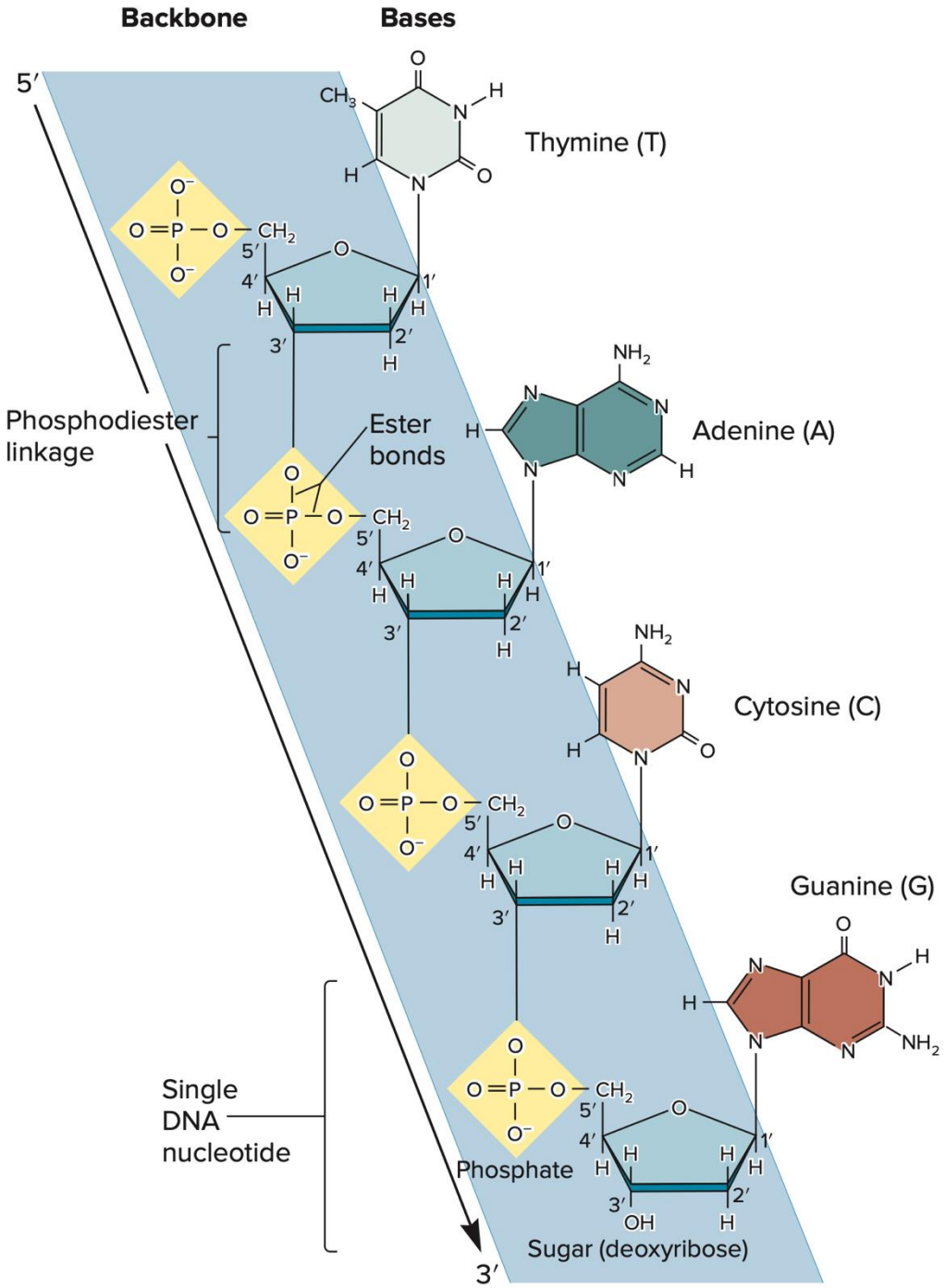
Base	Ribonucleoside	Deoxyribonucleoside
Adenine	Adenosine	Deoxyadenosine
Cytosine	Cytidine	Deoxycytidine
Guanine	Guanosine	Deoxyguanosine
Uracil	Uridine	Deoxyuridine
Hypoxanthine	Inosine	(does not occur)
Thymine	Ribothymidine (rare)	Deoxythymidine Thymidine

NUCLEOSIDE TO NUCLEOTIDE



STRUCTURE OF A DNA STRAND

Describe the structure of a strand of DNA shown here.



STRUCTURAL FEATURES

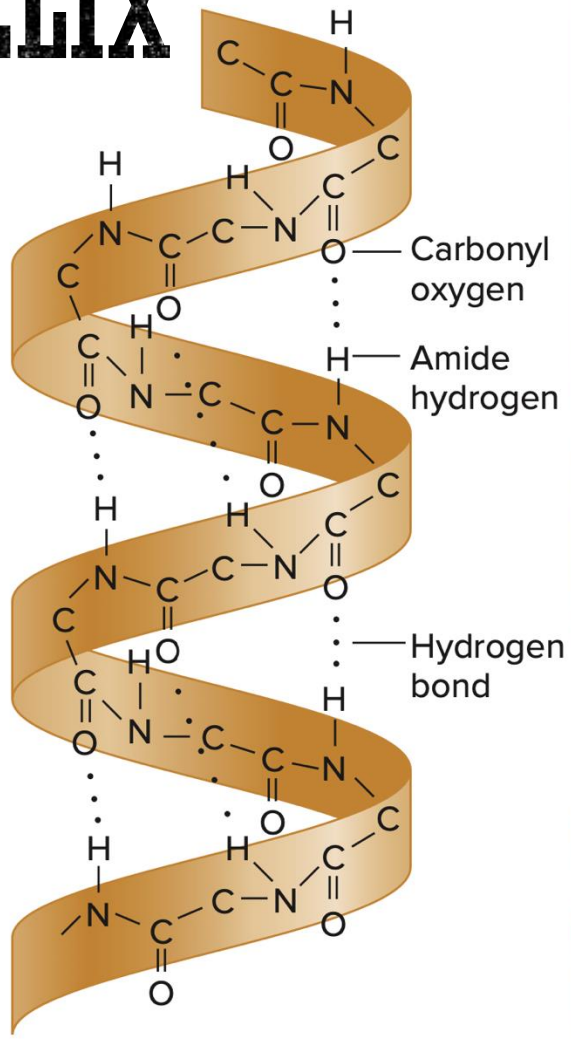
1. A phosphate group connects two sugar molecules via two ester bonds called a **phosphodiester linkage**.
2. The phosphates and sugar molecules form the backbone of the strand. The backbone is negatively charged due to the negative charge on each phosphate.
3. The bases project from the backbone.
4. A phosphodiester linkage involves attachment of a phosphate to the 3′ carbon in one nucleotide and to the 5′ carbon in the next nucleotide.

DISCOVERY OF THE DOUBLE HELIX

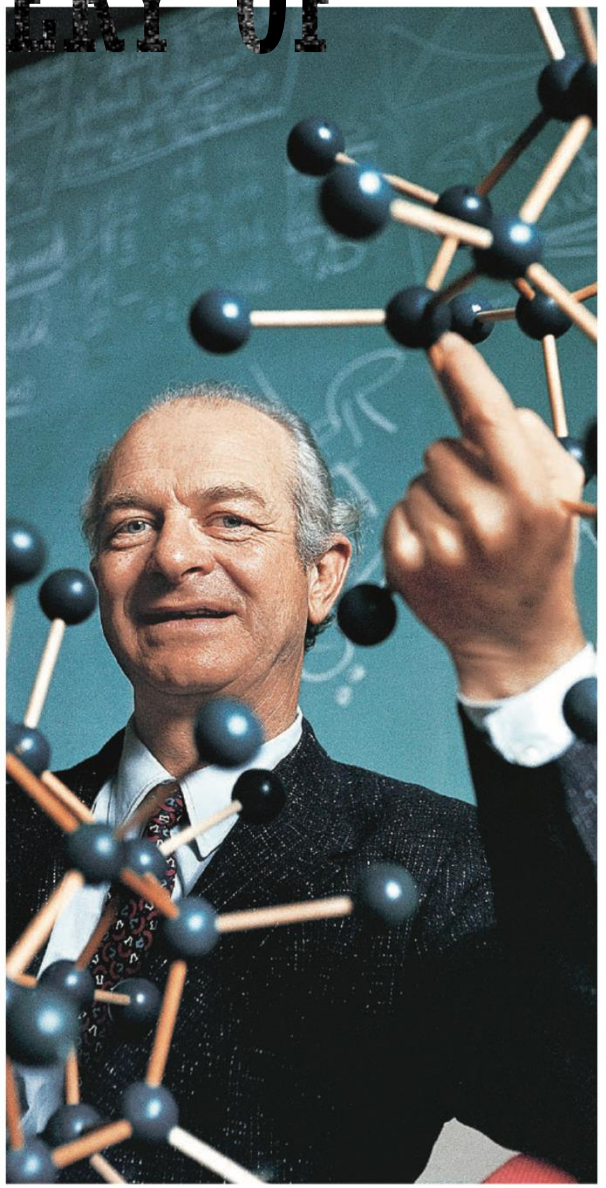
https://www.youtube.com/watch?v=JjO6n85wq8A&t=81s

EVENTS LEADING TO THE DISCOVERY OF THE DNA DOUBLE HELIX

1. Model building started by Linus Pauling



(a) An α helix in a protein

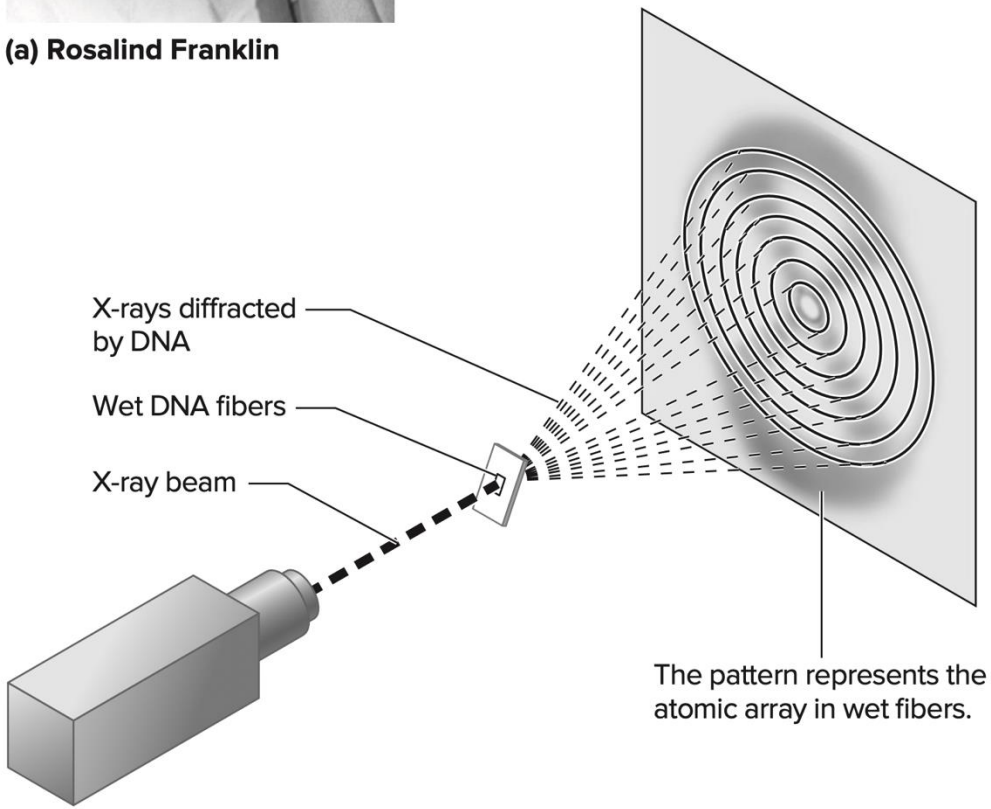


(b) Linus Pauling

EVENTS LEADING TO THE DISCOVERY OF THE DNA DOUBLE HELIX

(a) Rosalind Franklin

1. Model building started by Linus Pauling
2. Use of X-ray diffraction



(b) X-ray diffraction of wet DNA fibers

Suggested several features of DNA:

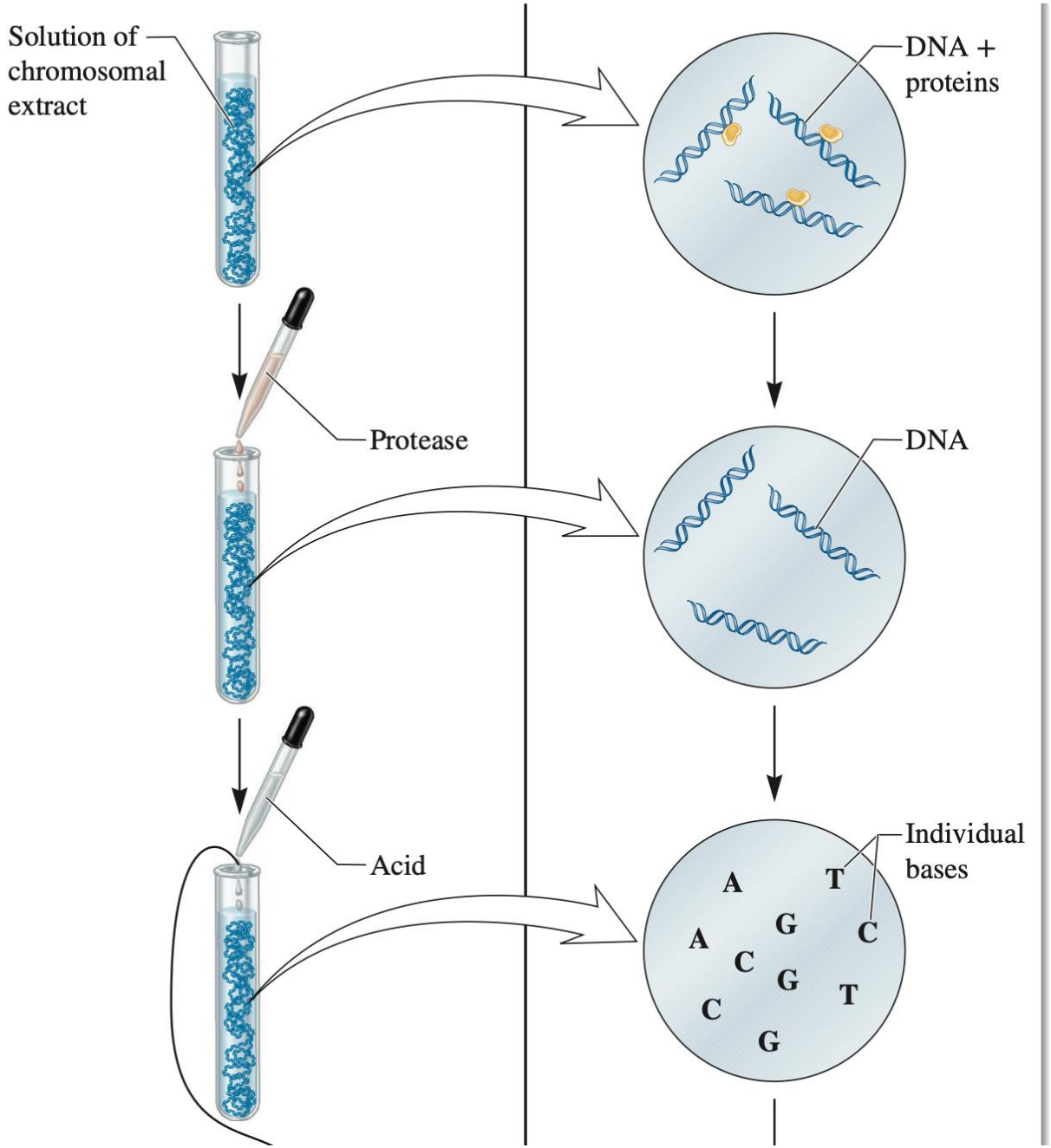
1. *Helical structure*
2. *Diameter is too wide for it to be made only by a single strand helix*
3. *Diffraction pattern indicated that the helix contains about 10 bp per complete turn.*

ERWIN CHARGAFF (1940-1950)

1. For each type of cell, extract the chromosomal material. This can be done in a variety of ways, including treatment with concentrated salt solution, detergent, or mild alkali. Note: The chromosomes contain both DNA and protein.

2. Remove the protein. This can be done in several ways, including treatment with protease.

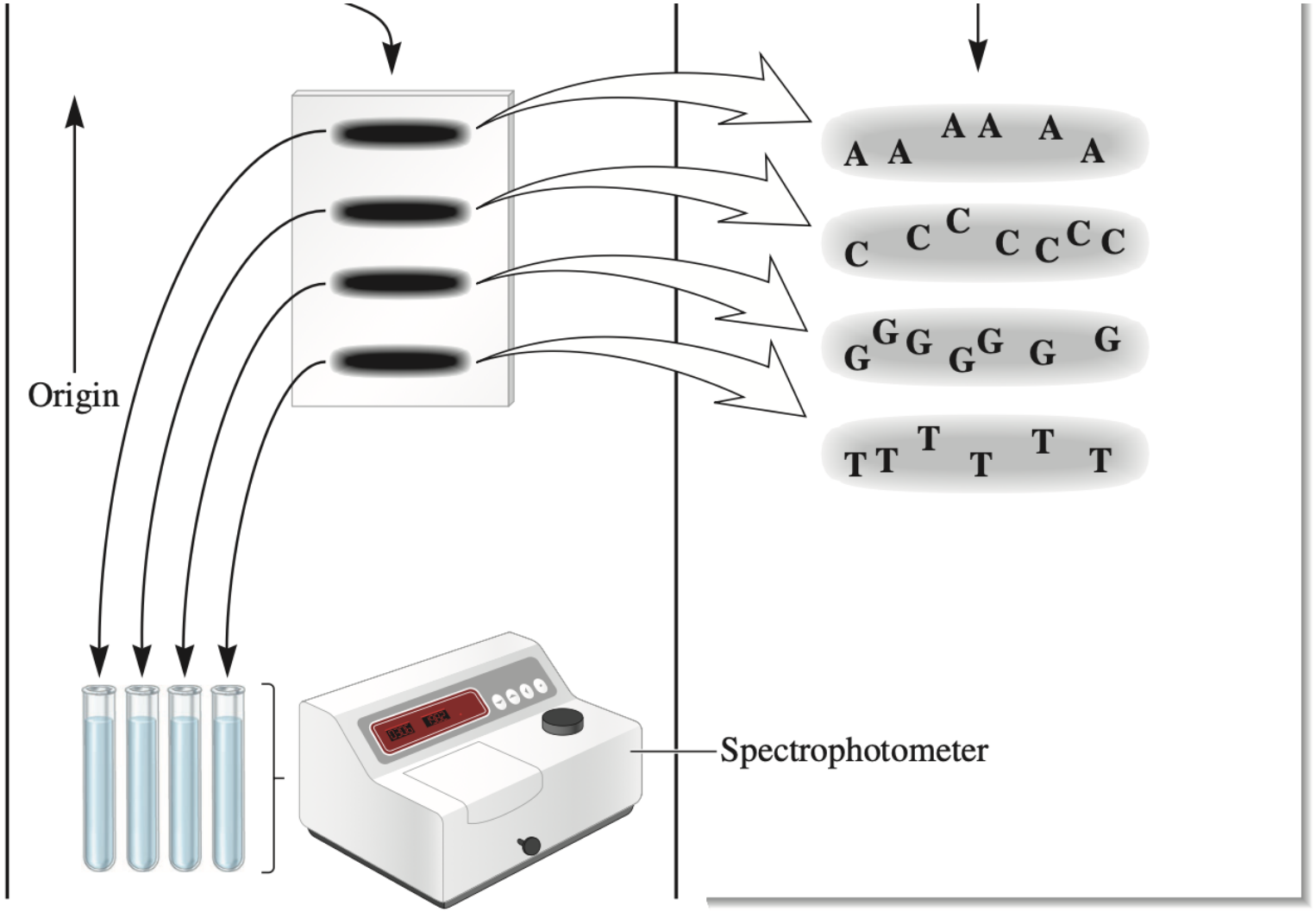
3. Hydrolyze the DNA to release the bases from the DNA strands. A common way to do this is by strong acid treatment.



4. Separate the bases by chromatography. Paper chromatography provides an easy way to separate the four types of bases. (The technique of chromatography is described in Appendix A.)

5. Extract bands from paper into solutions and determine the amounts of each base by spectroscopy. Each base will absorb light at a particular wavelength. By examining the absorption profile of a sample of base, it is then possible to calculate the amount of the base. (Spectroscopy is described in Appendix A.)

6. Compare the base content in the DNA from different organisms.



THE DATA

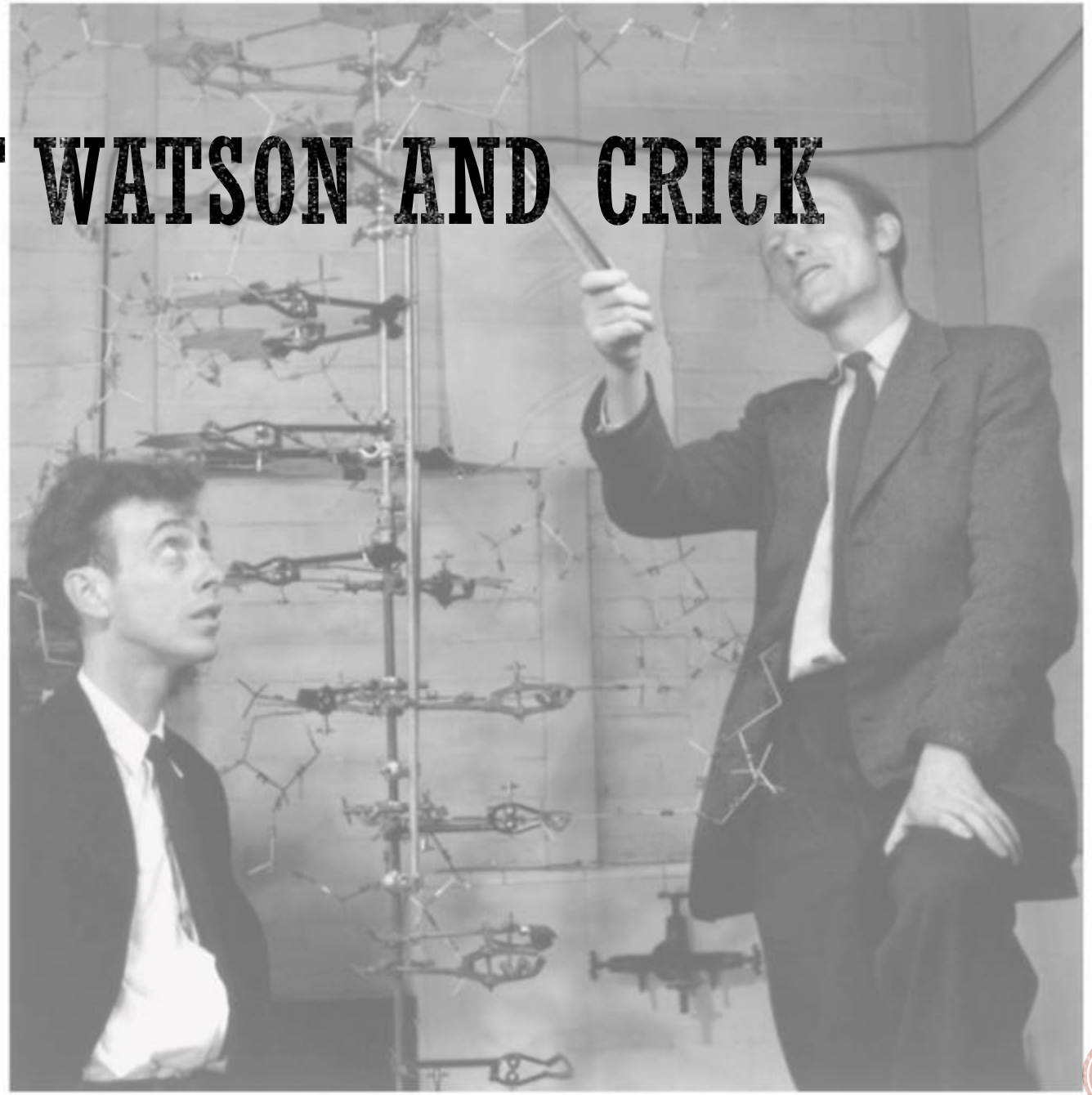
Base Content in the DNA from a Variety of Organisms*

	Percentage of Bases (Based on Molarity)			
Organism	*Adenine*	*Thymine*	*Guanine*	*Cytosine*
E. coli	26.0	23.9	24.9	25.2
S. pneumoniae	29.8	31.6	20.5	18.0
Yeast	31.7	32.6	18.3	17.4
Turtle red blood cells	28.7	27.9	22.0	21.3
Salmon sperm	29.7	29.1	20.8	20.4
Chicken red blood cells	28.0	28.4	22.0	21.6
Human liver cells	30.3	30.3	19.5	19.9

WATSON AND CRICK

ASSUMPTIONS OF WATSON AND CRICK

1. DNA is made up of nucleotides linked together in a linear fashion
2. Chemical linkage between two nucleotides is always the same.



STRUCTURE OF THE DNA DOUBLE HELIX

GENERAL STRUCTURAL FEATURES OF A DOUBLE HELIX

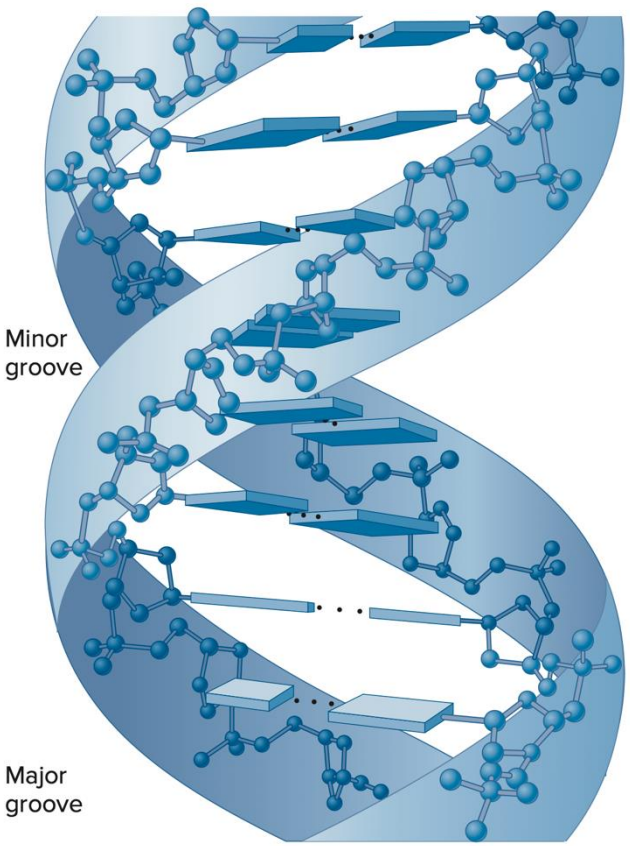
1. In a DNA double helix, two DNA strands are twisted together around a common axis to form a structure that resembles a spiral staircase.
2. The double stranded structure is stabilized by base pairs in opposite strand that are hydrogen bonded to each other. (The linear distance along a strand through such a complete turn is 3.4 nm; each base pair traverse 0.34 nm).
3. AT/GC rule keeps the width of the double helix relatively constant
4. G has 3 hydrogen bonds between C; A has 2 hydrogen bonds between T.

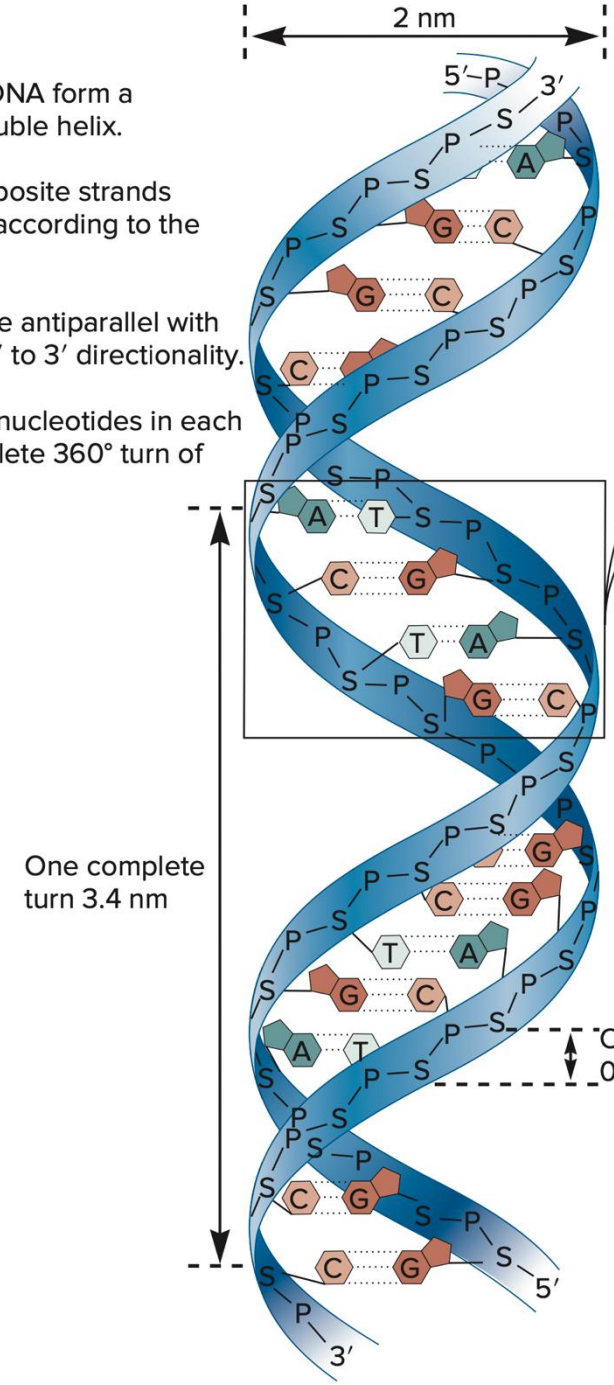
GENERAL STRUCTURAL FEATURES OF A DOUBLE HELIX

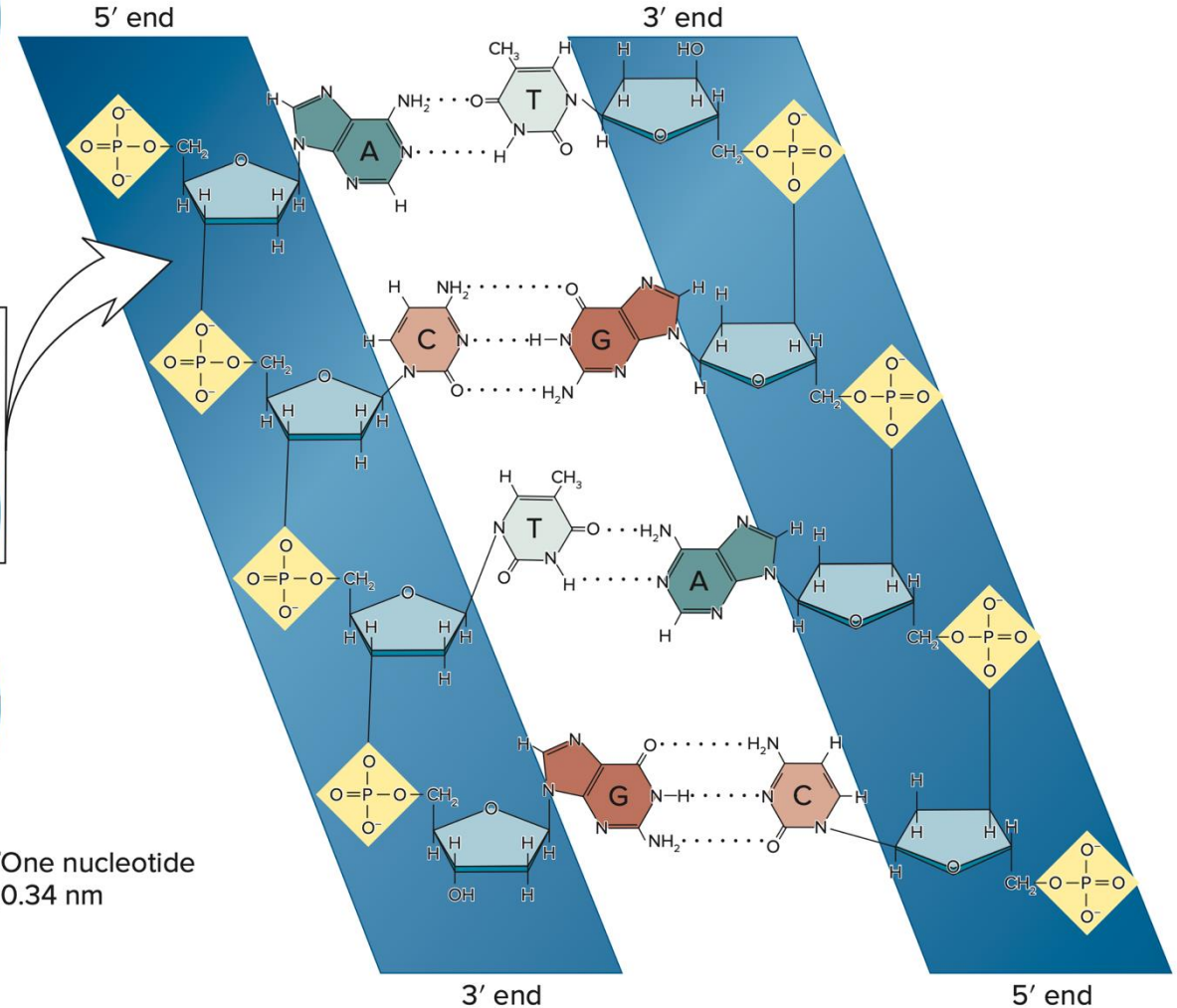
5. AT/GC rule allows the prediction of the sequence in one DNA strand if the sequence in the other strand is known. Called **complementary**.
6. Opposite direction of the two DNA strands is referred to as **antiparallel** arrangement.

Key Features

- Two strands of DNA form a right-handed double helix.
- The bases in opposite strands hydrogen bond according to the AT/GC rule.
- The 2 strands are antiparallel with regard to their 5′ to 3′ directionality.
- There are ~10.0 nucleotides in each strand per complete 360° turn of the helix.







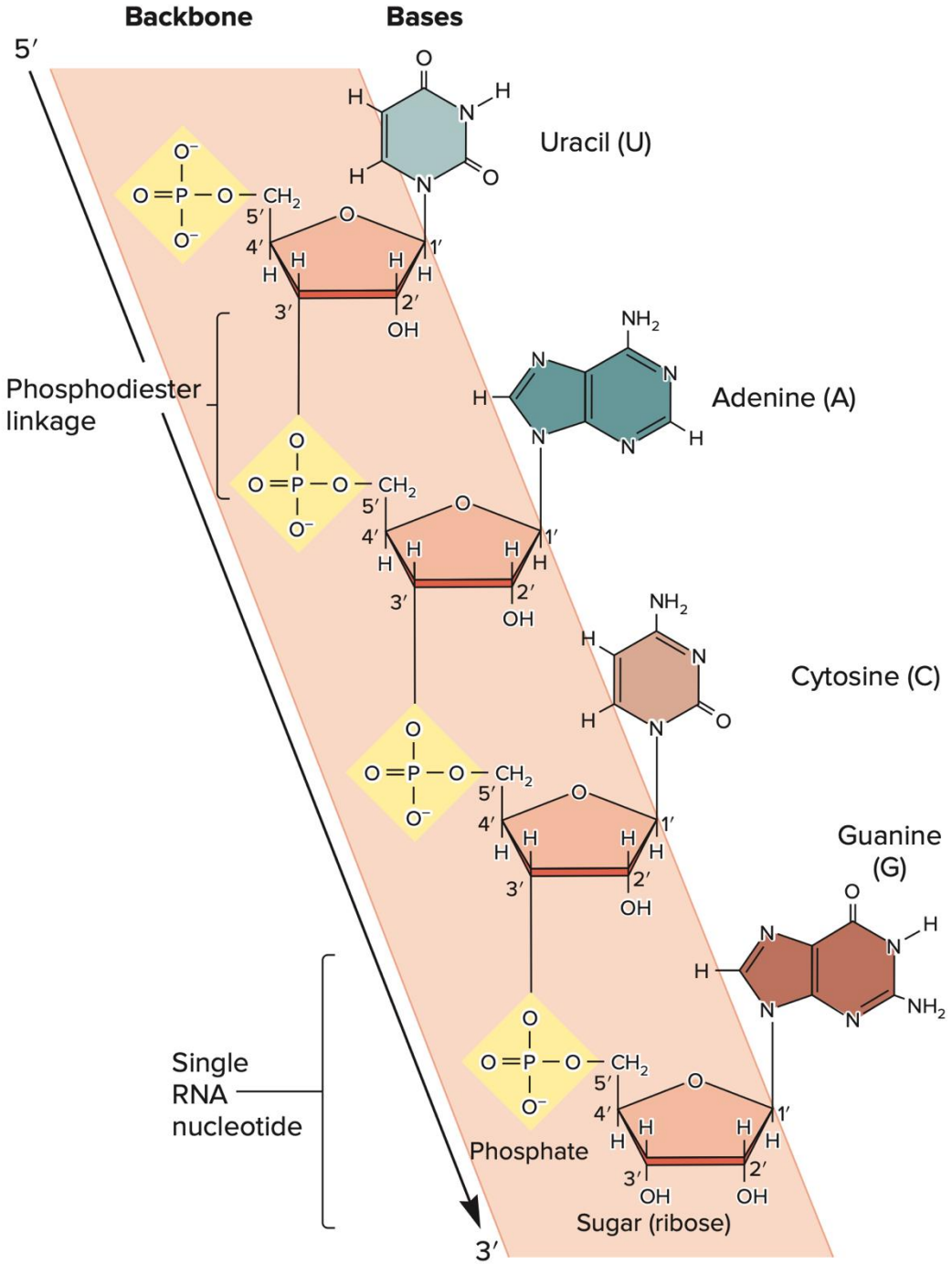
QUESTION

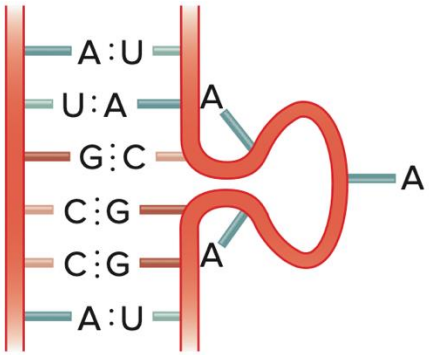
A double-stranded molecule of B DNA contains 340 nucleotides. How many complete turns occur in this double helix?

RNA STRUCTURE

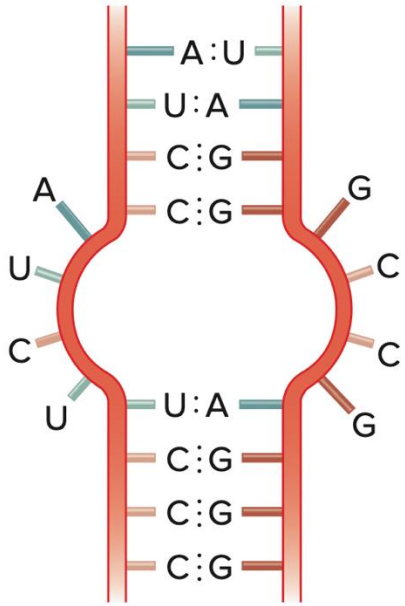
RNA

- Has shorter strands than DNA
- DNA is used as template for RNA during transcription (only one of the two strands is used)
- Base pairing between A and U and C and G may occur in one RNA molecule or 2 different RNA molecule. This may cause:
  - ✓Formation of double stranded region that is helical
  - ✓Bulge loops, an internal loop, a multibranched junction and a stem-loop (hairpin)

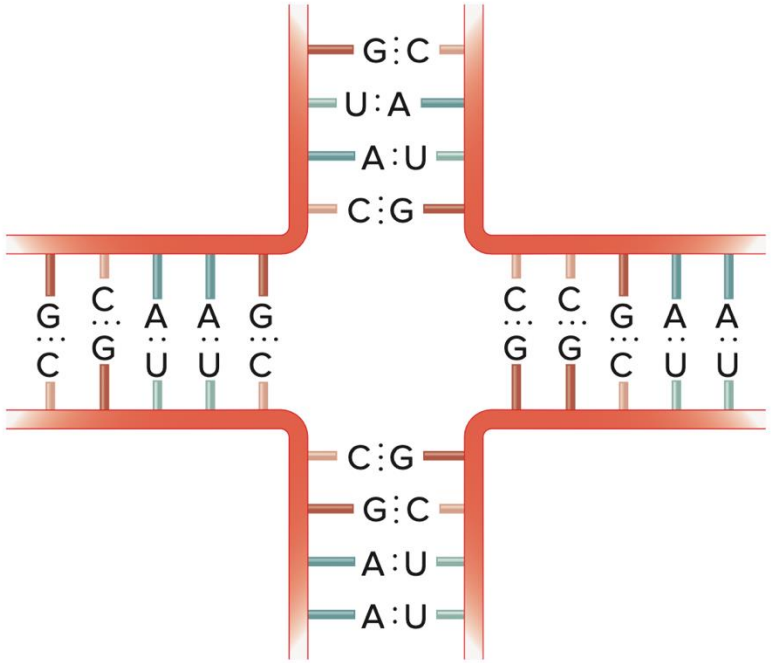




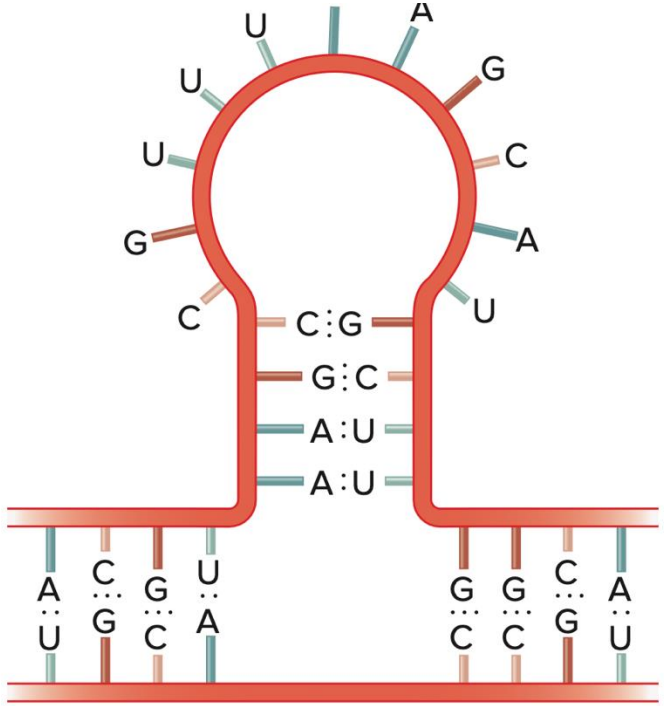
(a) Bulge loop



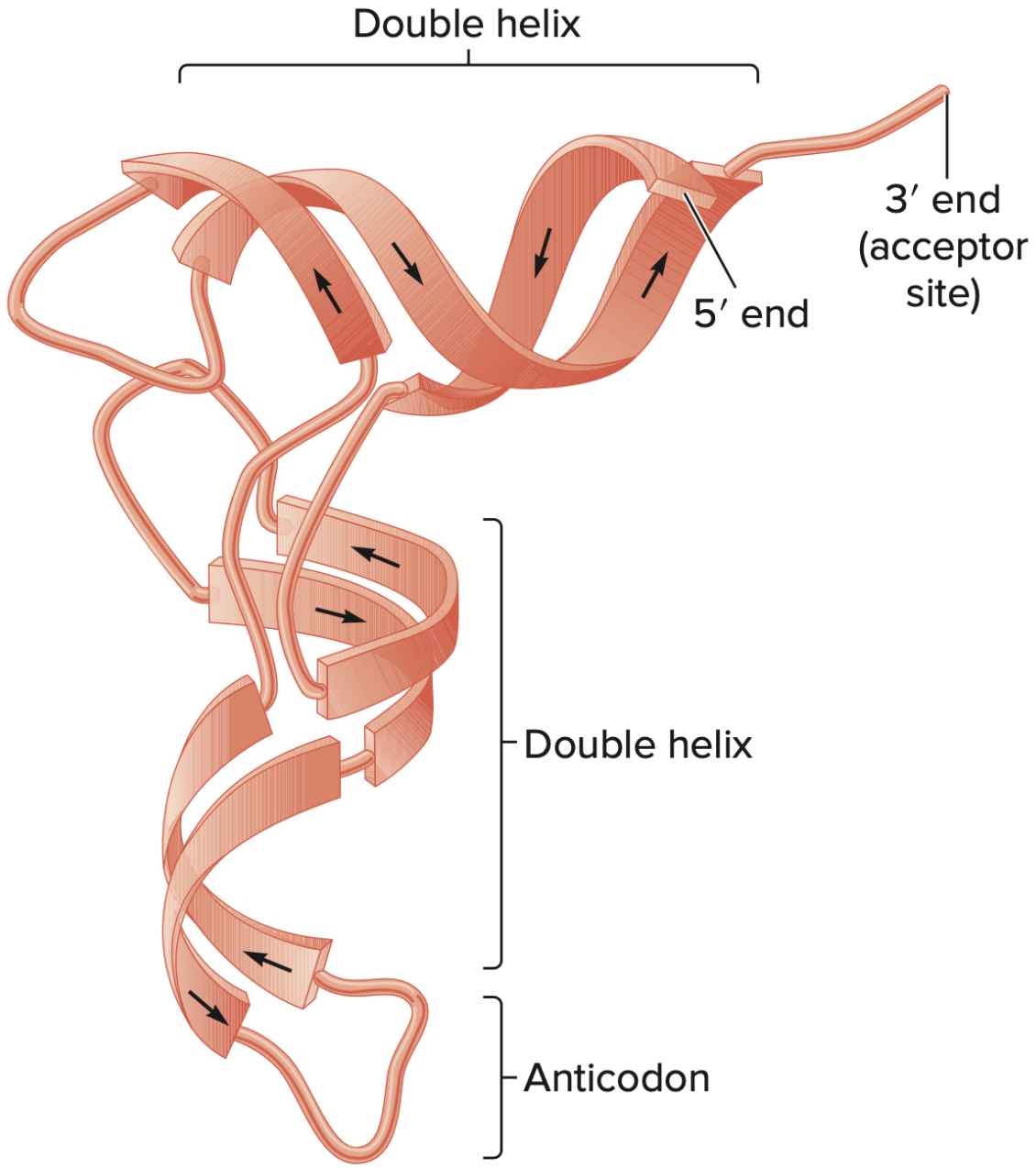
(b) Internal loop



(c) Multibranched junction



(d) Stem-loop



(a) Ribbon model

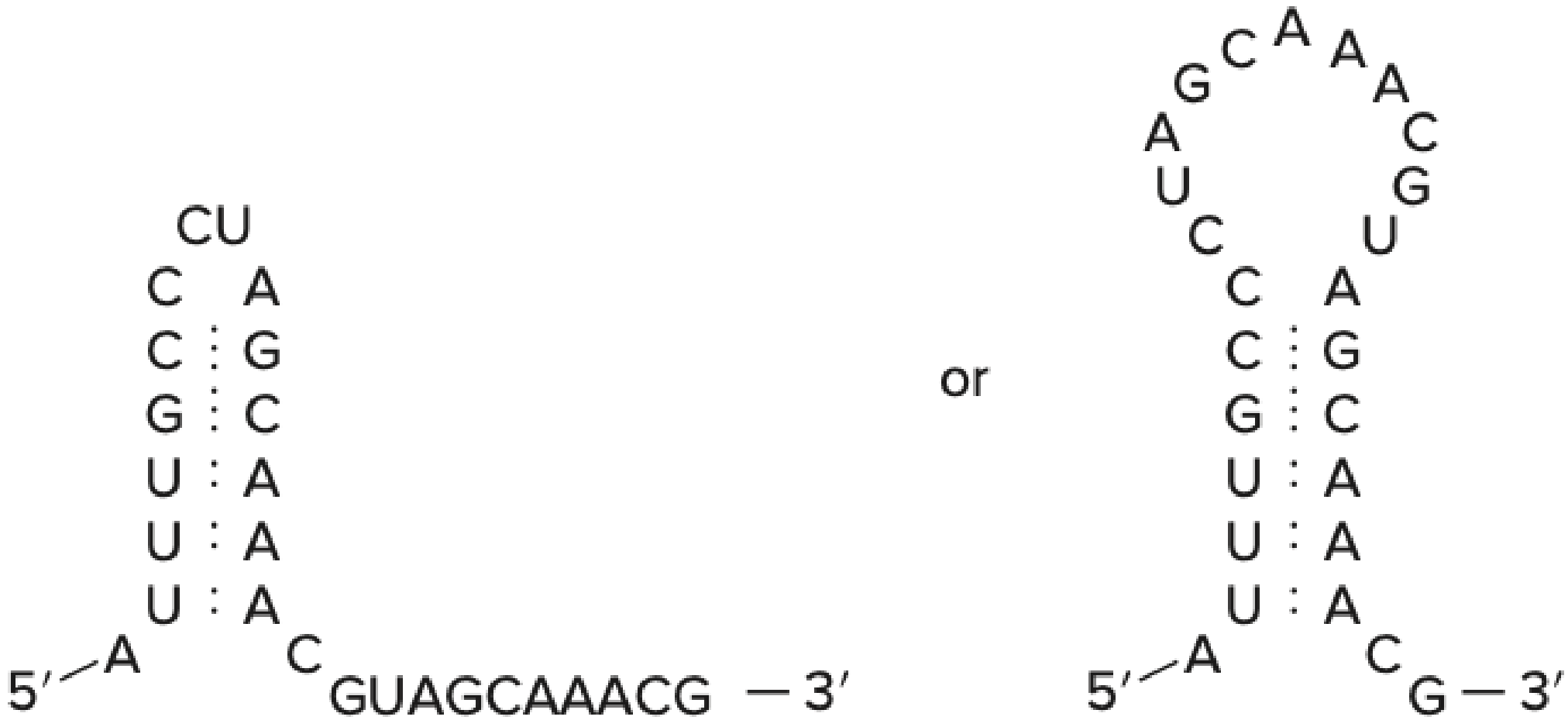
TASK

A hypothetical base sequence of an RNA molecule is

5’-AUUUGCCCUAGCAAACGUAGCAAACG-3’

Using two of the three underlined parts of this sequence, draw two possible stem-loop structures that might form in this RNA.

ANSWER:


CU
C A
C G
G C
U A
U A
U A
5′ A
C
GUAGCAAACG — 3′
or
C A A
G A
A C
U G
C U
C A
C G
G C
U A
U A
U A
5′ A
C
G — 3′