Molecular Biology

DNA and RNA structure

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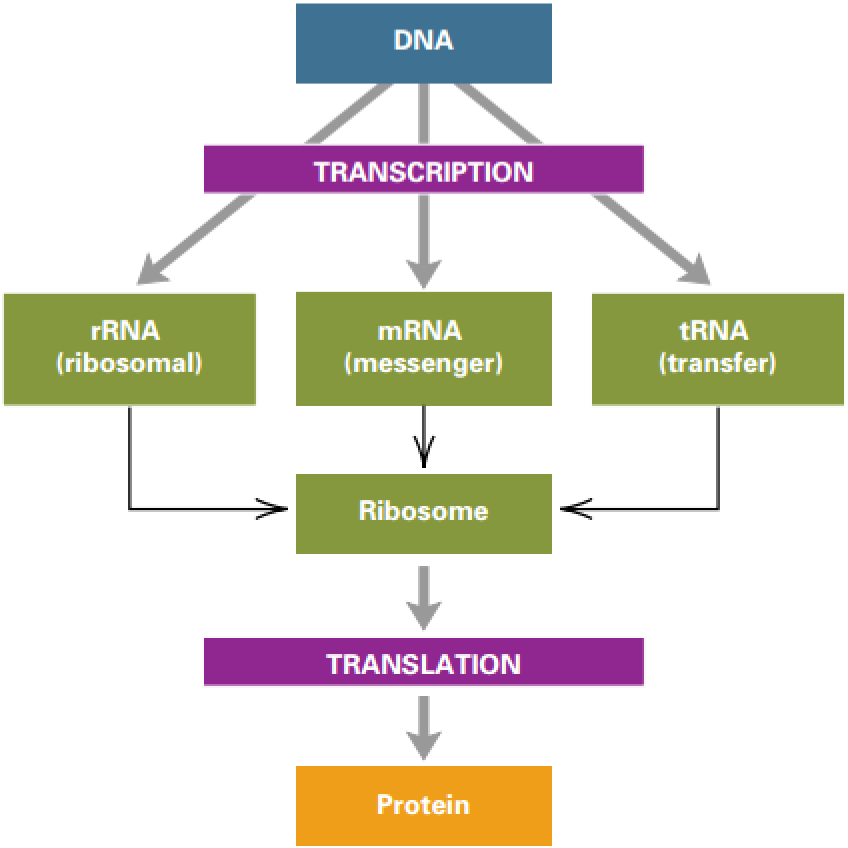
Out lines

- Chemical structure of nucleic acids
- Genes, Genomes and DNA

What is molecular biology

The branch of biology that deals with the nature of biological phenomena at the molecular level through the study of DNA and RNA, proteins, and other macro molecules involved in genetic information and cell function, characteristically making use of advanced tools and techniques of separation manipulation, imaging, and analysis

Central Dogma



The genome

The genome database is organized in six major organism groups:

- Eukaryotes,
- Bacteria,
- Archaea,
- Viruses,
- Viroids
- Plasmids.

Nucleic Acid Molecules Carry Genetic Information

- Genetic information is encoded by molecules named **nucleic acids** because they were originally isolated from the nucleus of eukaryotic cells.
- There are two related types of nucleic acid, **deoxyribonucleic acid** (**DNA**) and **ribonucleic acid** (**RNA**).
- Each nucleic acids composed of a building blocks called Nucleotide
- Nucleotide Monomer or subunit of a nucleic acid, consisting of a pentose sugar plus a base plus a phosphate group

Nucleotides

- Each nucleotide has three components: a phosphate group, a five-carbon sugar, and a nitrogen-containing base
- In DNA, the sugar is always deoxyribose; whereas, in RNA, it is ribose.
- Both sugars are pentoses, or five-carbon sugars. Deoxyribose has one less oxygen than ribose.
- Bases is alkaline chemical substance, in molecular biology especially refers to the cyclic nitrogen compounds found in DNA and RNA

Chemical Structure of Nucleic Acids

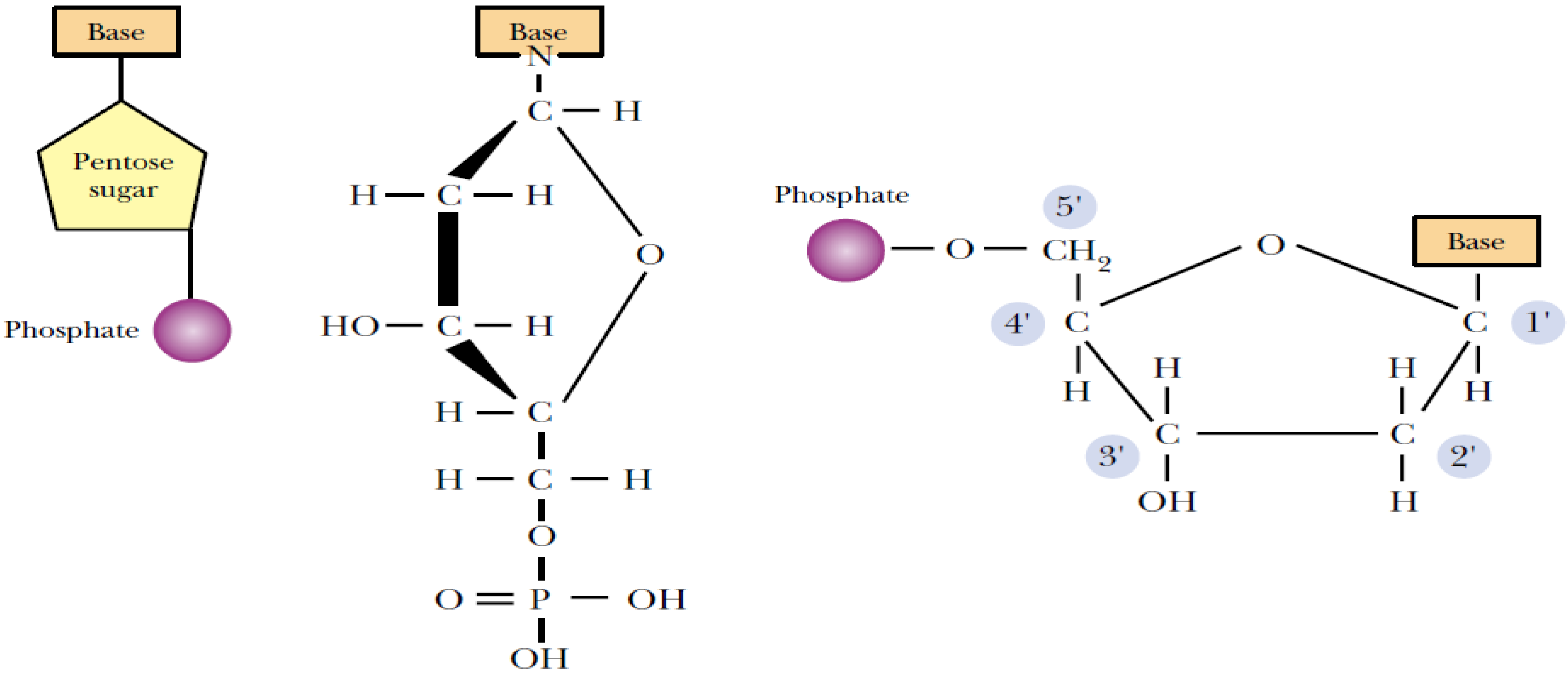
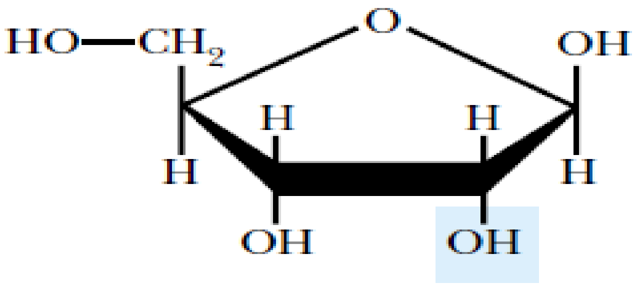
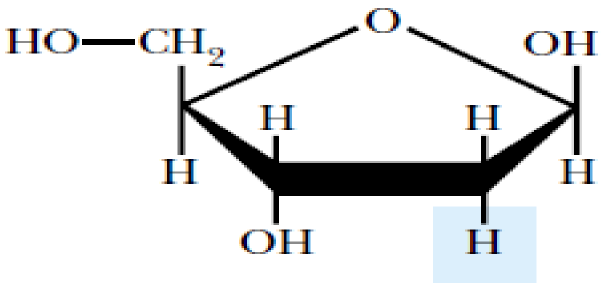


FIGURE 3.02 ***Three Views of a Nucleotide***

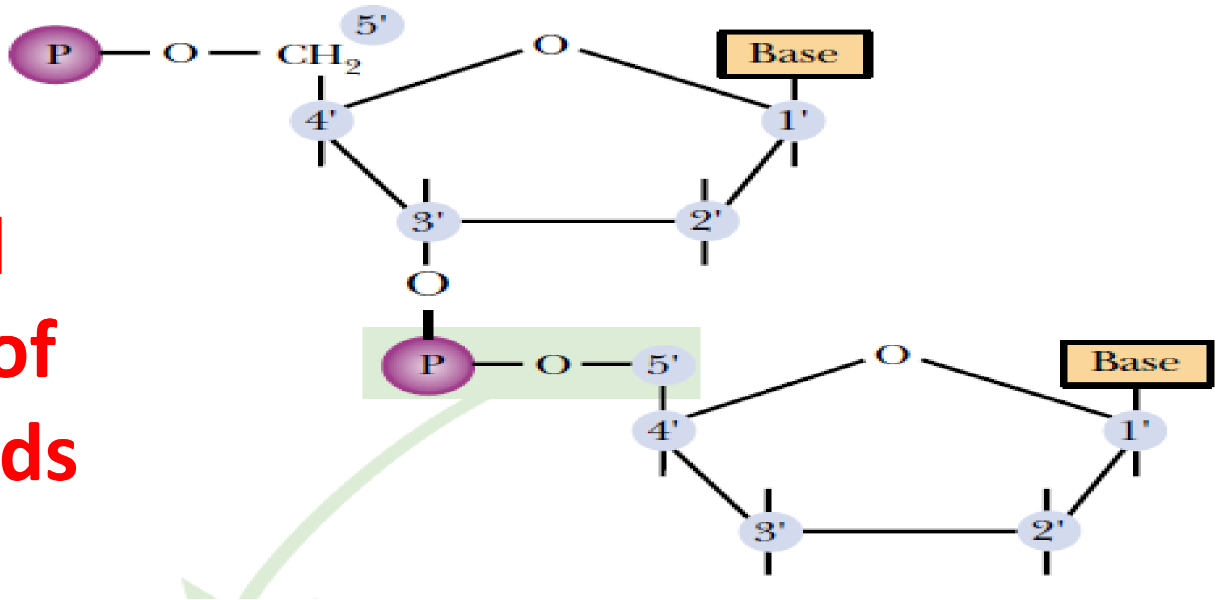


RIBOSE



DEOXYRIBOSE

Chemical Structure of Nucleic Acids



Chemical Structure of Nucleic Acids

- pentose A five carbon sugar, such as ribose or deoxyribose
- phosphate group : Group of four oxygen atoms surrounding a central phosphorus atom found in the backbone of DNA and RNA
- phosphodiester .The linkage between nucleotides in a nucleic acid that consists of a central phosphate group esterified to sugar hydroxyl groups
- on either side

DNA and RNA Each Have Four Bases

- There are five different types of nitrogenous bases associated with nucleotides.
- DNA contains the bases **adenine**, **guanine**, **cytosine** and **thymine**. These are often abbreviated to A, G, C and T, respectively. RNA contains A, G and C, but T is replaced by **uracil** (**U**). From the viewpoint of genetic information, T in DNA and U in RNA are equivalent.
- The bases found in nucleic acids are of two types, **pyrimidines** and **purines**.
- The smaller pyrimidine bases contain a single ring whereas the purines have a fused double ring.
- Adenine and guanine are purines; and thymine, uracil and cytosine are pyrimidines.
- The purine and pyrimidine ring systems and their derivatives

DNA and RNA Each Have Four Bases

- **Adenine (A)** A purine base that pairs with thymine, found in DNA or RNA
- **Cytosine (C)** One of the pyrimidine bases found in DNA or RNA and which pairs with guanine
- **Guanine (G)** A purine base found in DNA or RNA that pairs with cytosine
- **Purine** Type of nitrogenous base with a double ring found in DNA and RNA
- **Pyrimidine** Type of nitrogenous base with a single ring found in DNA and RNA
- **Thymine (T)** A pyrimidine base found in DNA that pairs with adenine
- **Uracil (U)** A pyrimidine base found in RNA that may pair with adenine

TABLE 3.01 Naming Bases, Nucleosides and Nucleotides

Base	Abbreviations		Nucleoside	Nucleotide
Adenine	ade	A	adenosine	adenosine monophosphate (AMP)
Guanine	gua	G	guanosine	guanosine monophosphate (GMP)
Cytosine	cyt	C	cytidine	cytidine monophosphate (CMP)
Thymine	thy	T	thymidine	thymidine monophosphate (TMP)
Uracil	ura	U	uridine	uridine monophosphate (UMP)

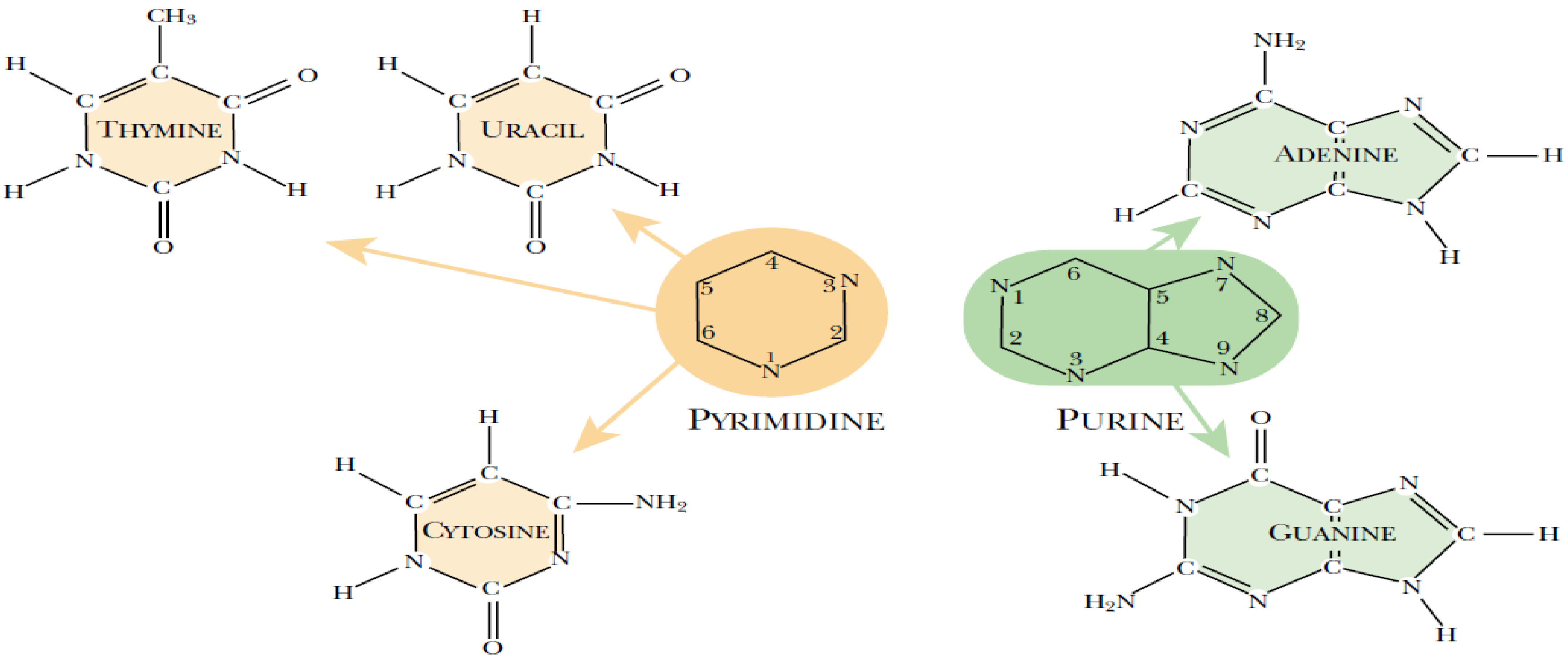
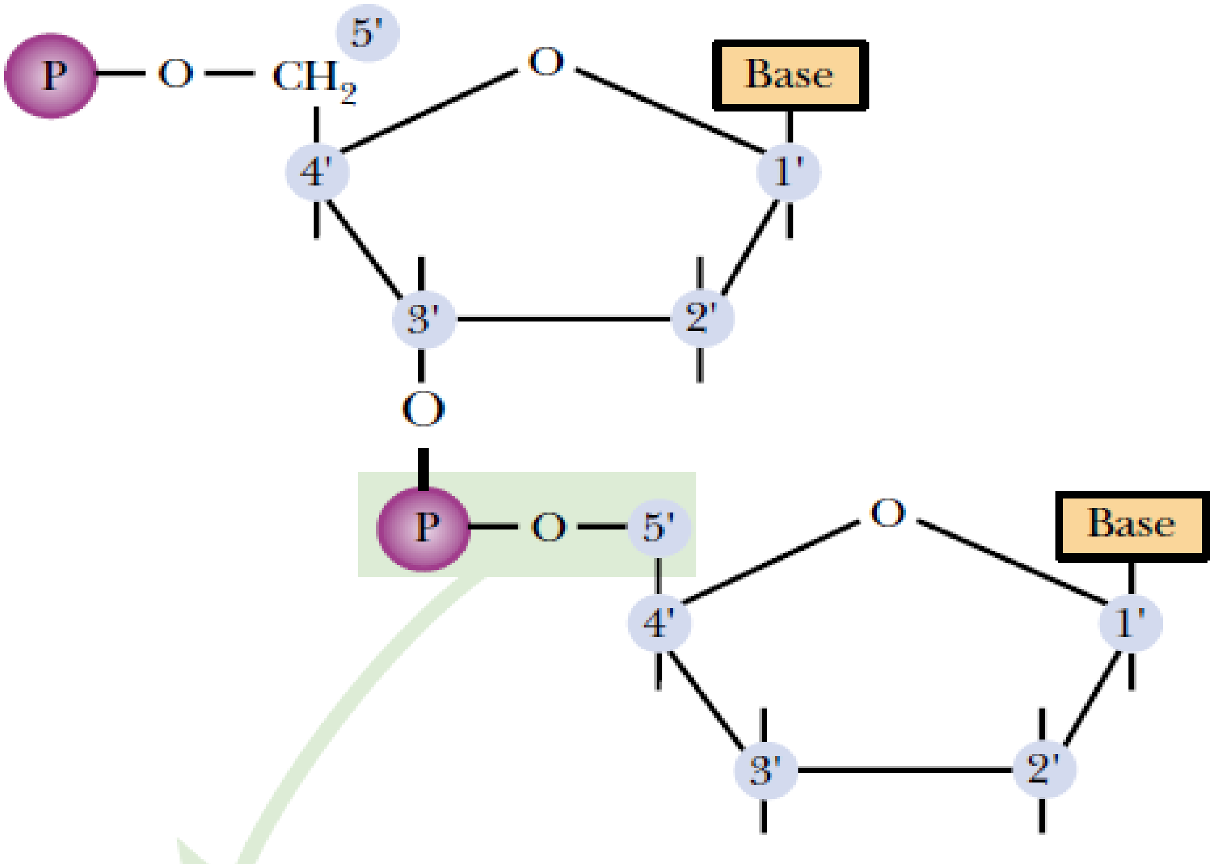


FIGURE 3.05 ***The Bases of the Nucleic Acids***

Nucleosides Are Bases Plus Sugars; Nucleotides Are Nucleosides Plus Phosphate

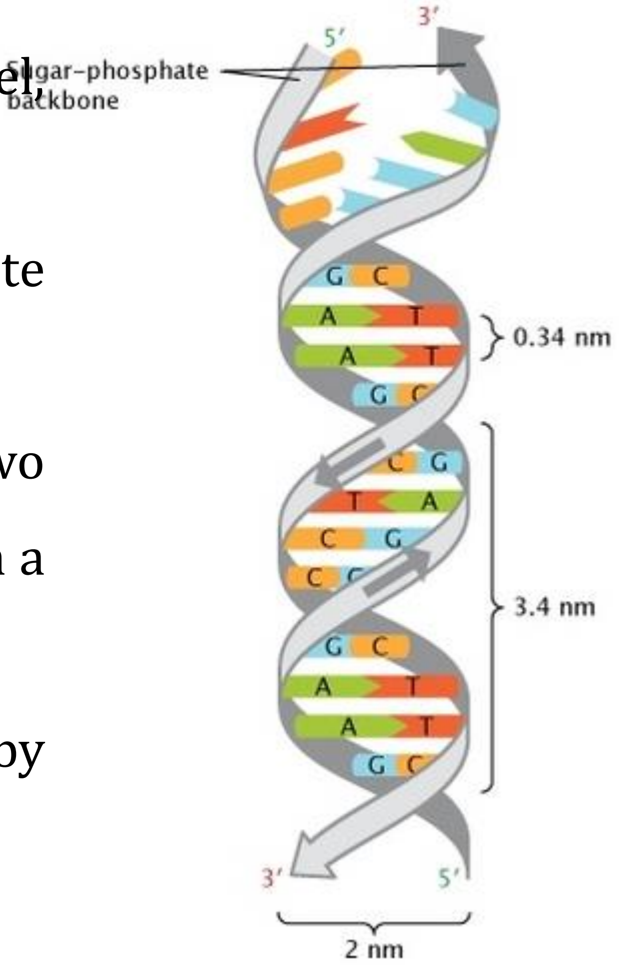
- **Nucleoside** **The union of a purine or pyrimidine base with a pentose sugar**
- **Nucleotide** **Monomer or subunit of a nucleic acid, consisting of a pentose sugar plus a base plus a phosphate group**
- **ribonucleoside** A nucleoside whose sugar is ribose (not deoxyribose)
- **ribonucleotide** A nucleotide whose sugar is ribose (not deoxyribose)
- **The "rungs" of the DNA strands are made of:base pairs**

Nucleosides and Nucleotides



Double Stranded DNA Forms a Double Helix

- ✓ The two strands of a DNA molecule are antiparallel, as they point in opposite directions.
- ✓ This means that the 5-end of one strand is opposite the 3-end of the other strand
- ✓ Not only is DNA double-stranded, but the two separate strands are wound around each other in a helical arrangement.
- ✓ This is the famous double helix first proposed by Francis Crick and James Watson in 1953.
- ✓ DNA forms a right-handed double helix.



Genes, Genomes and DNA

How Much Genetic Information Is Necessary to Maintain Life?

- The simplest living cell probably needs around 200–300 genes.
- Most bacteria have a few thousand genes.
- Some regions of DNA contain useful genetic information, other regions do not.
- Non-coding DNA accounts for the majority of the DNA in most higher animals and plants.
- In eukaryotes, the genes themselves are often interrupted by **stretches of noncoding DNA.**

Identification of DNA as the genetic materials

To fulfill its role, the genetic material must meet four criteria.

1. **Information:** The genetic material must contain the information necessary to construct an entire organism. In other words, it must provide the blueprint to determine the
inherited traits of an organism.

2. Transmission: During reproduction, the genetic material must be passed from parents to offspring.

3. Replication: Because the genetic material is passed from parents to offspring, and from mother cell to daughter cells during cell division, it must be copied.

4. Variation: Within any species, a significant amount of phenotypic variability occurs.

Identification of DNA as the genetic materials

- Along with Mendel's work in the early 1900s, the data of many other geneticists were consistent with these four properties: information, transmission, replication, and variation.

- In the 1880s, August Weismann and Carl Nigel the idea that a chemical substance within living cells is responsible for the transmission of traits from parents to offspring.

IDENTIFICATION OF DNA AS THE GENETIC MATERIAL

- Experiments with Pneumococcus Suggested that DNA is the genetic material

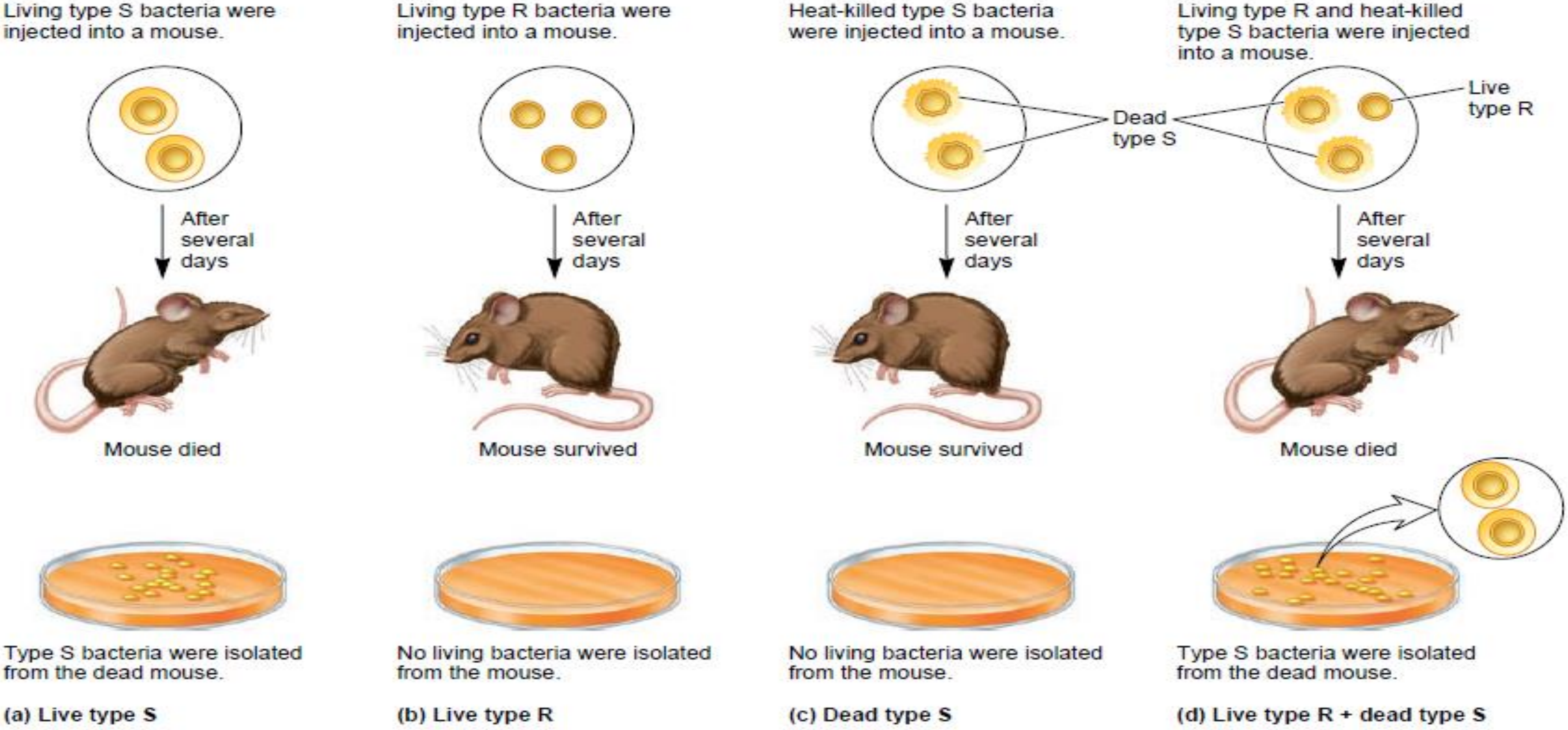
- Frederick Griffith studied a type of bacterium known then as pneumococci and now classified as *Streptococcus pneumoniae.*

Experiments with Pneumococcus Suggested That DNA Is the Genetic Material

- Certain strains of *S. pneumoniae* secrete a polysaccharide capsule, whereas other strains do not. When streaked onto petri plates containing a solid growth medium, capsule-secreting strains have a smooth colony morphology, whereas those strains unable to secrete a capsule have a rough appearance.

- The different forms of *S. pneumoniae* also affect their virulence, or ability to cause disease. When smooth strains of *S. pneumoniae* infect a mouse, the capsule allows the bacteria to escape attack by the mouse's immune system.

Experiments with Pneumococcus Suggested That DNA Is the Genetic Material



Experiments with Pneumococcus Suggested That DNA Is the Genetic Material

- Griffith called this process **transformation,** and the unidentified substance causing this to occur was termed the transformation principle

A Few Key Events Led to the Discovery of the Double-Helix Structure

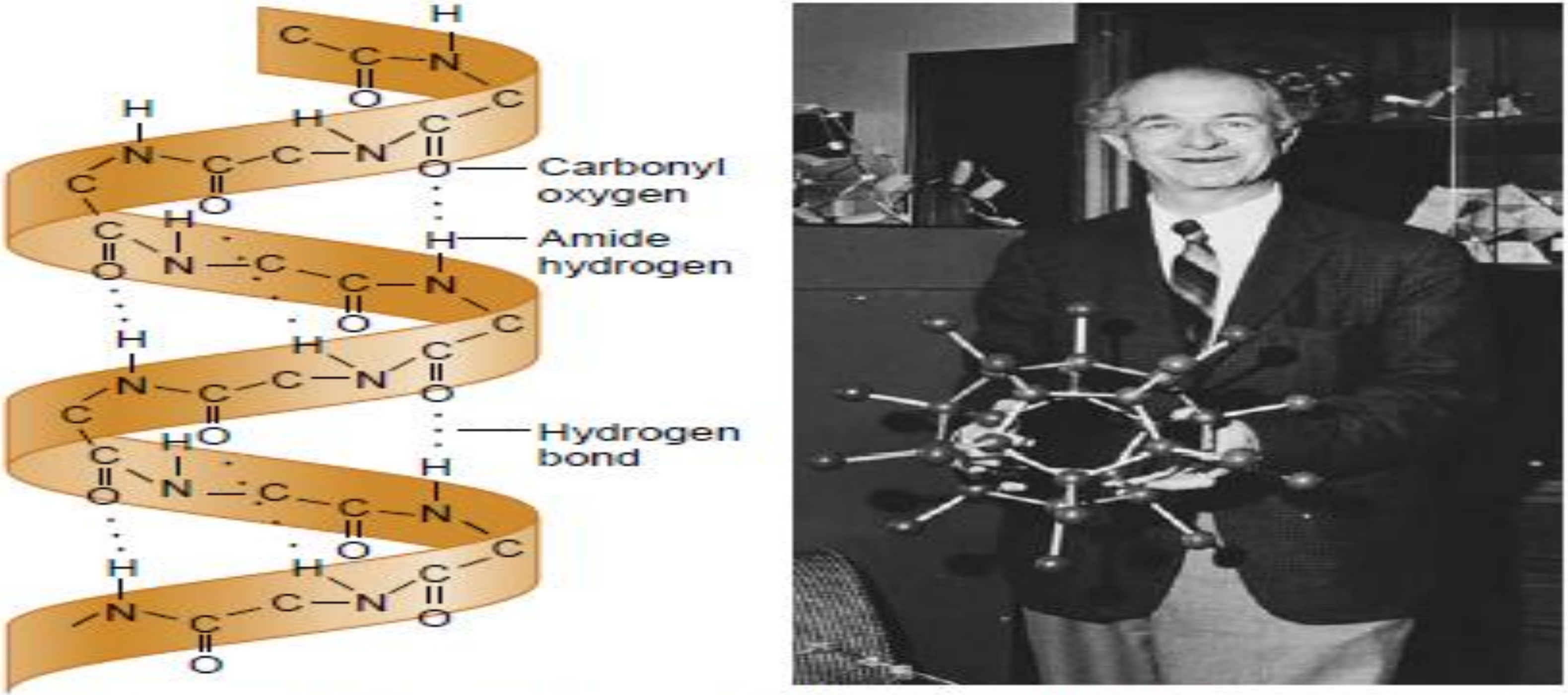
A Few Key Events Led to the Discovery of the Double-Helix Structure

- A major discovery in molecular genetics was made in 1953 by Watson and Crick.
- Watson and Crick committed themselves to determine the structure of DNA because they felt this knowledge was needed to understand the functioning of genes.
- Other researchers, such as Rosalind Franklin and Maurice Wilkins, shared this view. Before we examine the characteristics of the double helix, let's consider the events that provided the scientific framework for Watson and Crick's breakthrough.
- In the early 1950s, Linus Pauling proposed that regions of proteins can fold into a secondary structure known as an α helix

A Few Key Events Led to the Discovery of the Double-Helix Structure

- A second important development that led to the elucidation of the double helix was X-ray diffraction data.
- When a purified substance, such as DNA, is subjected to X-rays, it produces a well-defined diffraction pattern if the molecule is organized into a regular structural pattern.
- An interpretation of the diffraction pattern (using mathematical theory) can ultimately provide information concerning the structure of the molecule.
- Rosalind Franklin, working in the same laboratory as Maurice Wilkins, used X-ray diffraction to study wet DNA fibers.

A Few Key Events Led to the Discovery of the Double-Helix Structure

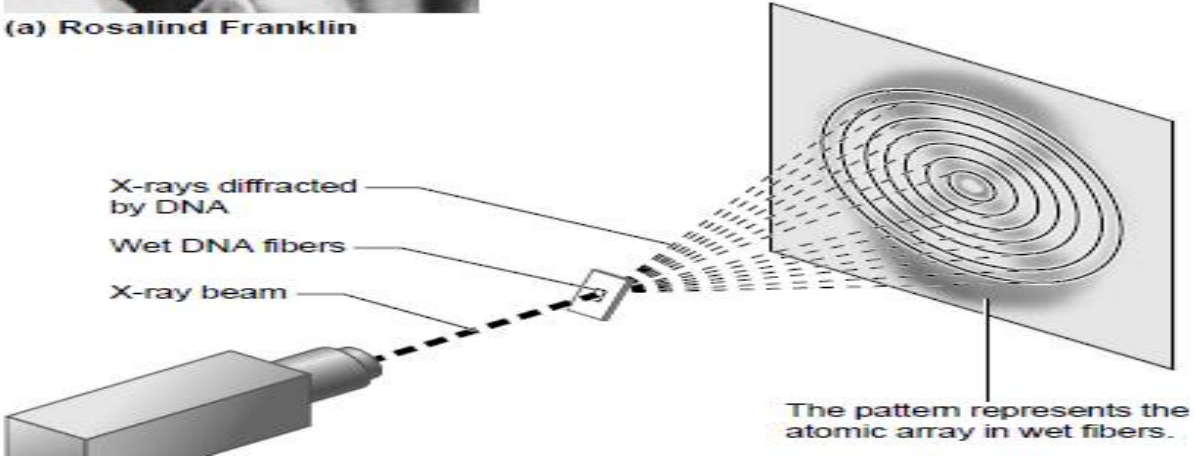


(a) An α helix in a protein

(b) Linus Pauling

A Few Key Events Led to the Discovery of the Double-Helix Structure

(a) Rosalind Franklin



Chargaff ’s rule

The compelling observation was that the amount of adenine was similar to that of thymine, and the amount of guanine was similar to cytosine. The idea that the amount of A in DNA equals the amount of T, and the amount of G equals C, is known as **Chargaff ’s rule.**

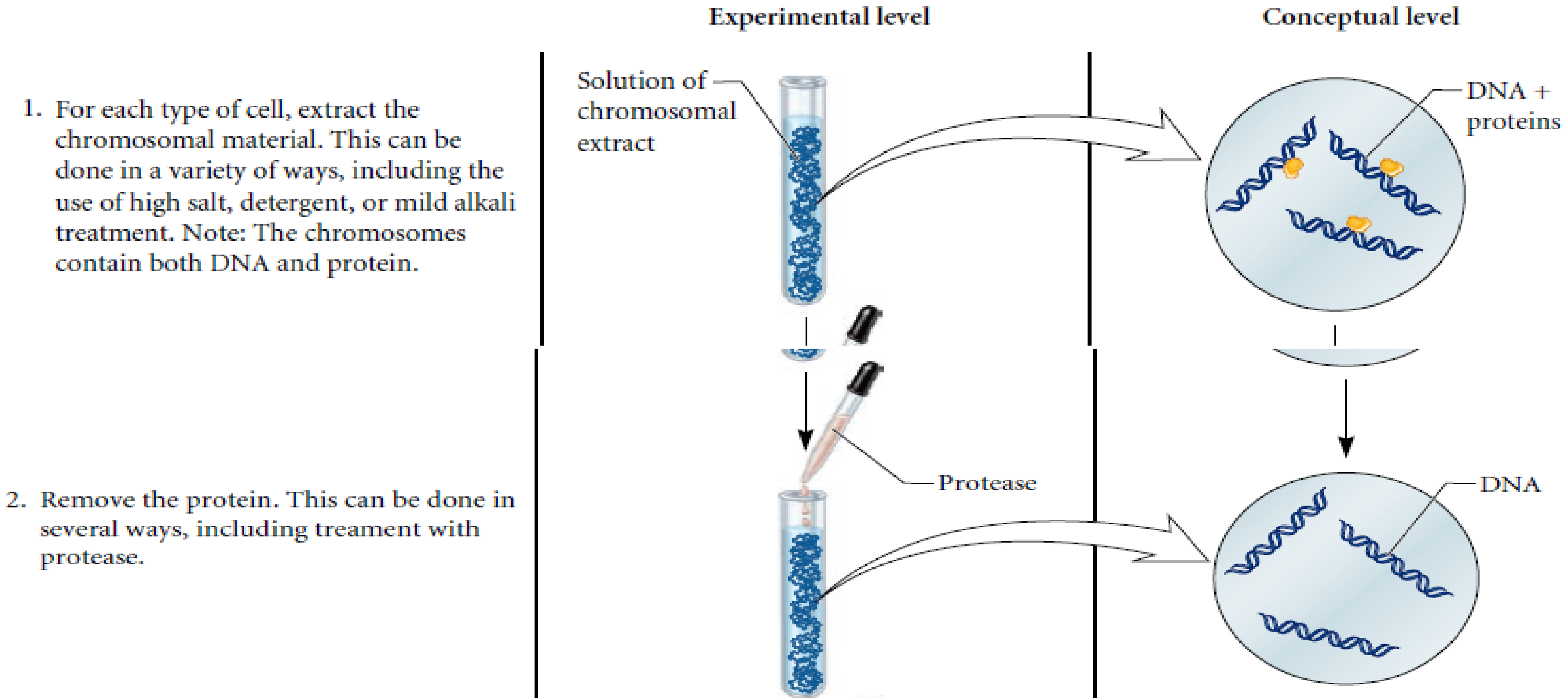
THE DATA

Base Content in the DNA from a Variety of Organisms*

	Percentage of Bases (based on molarity)			
Organism	*Adenine*	*Thymine*	*Guanine*	*Cytosine*
Escherichia coli	26.0	23.9	24.9	25.2
Streptococcus 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

Chargaff ’s rule

The experimental protocol of Chargaff is described in the **Figure 9.13**



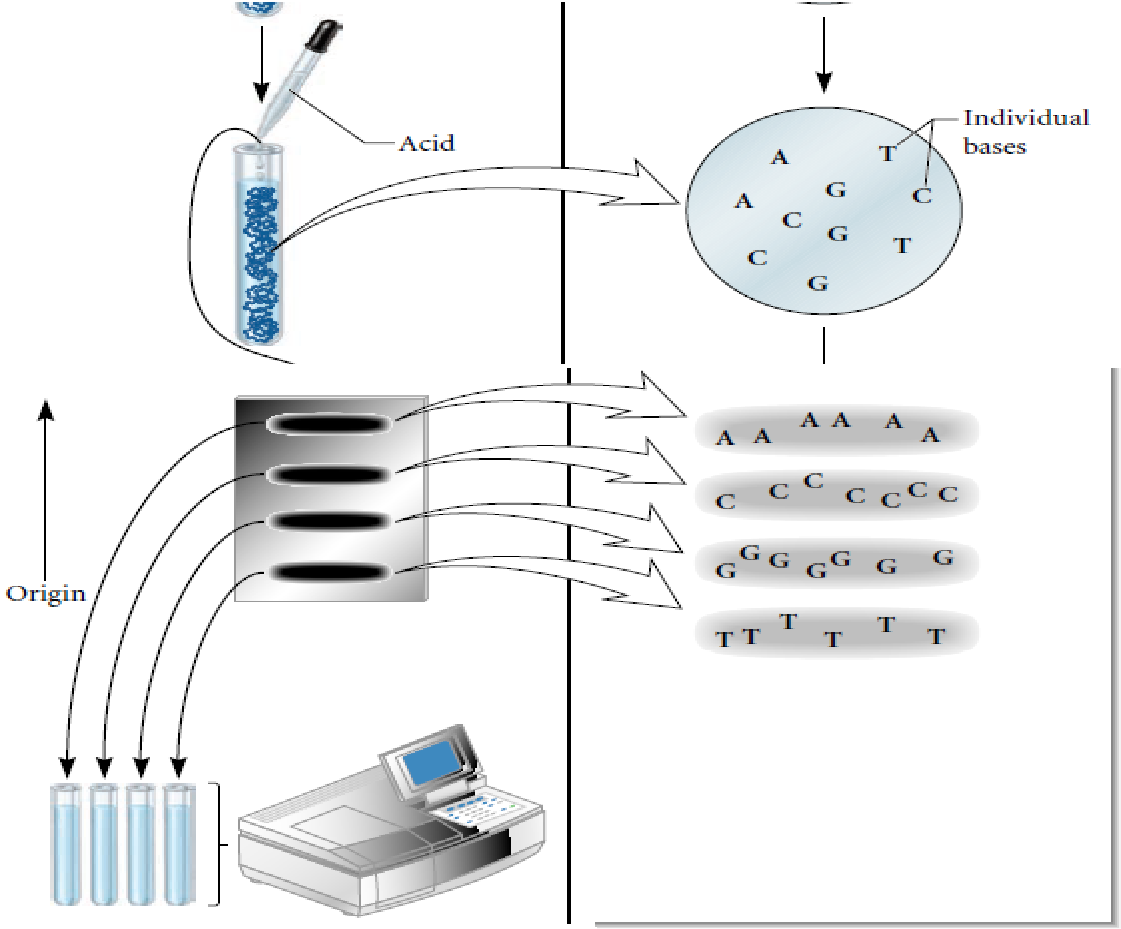
Chargaff 's rule

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 the Appendix.)

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 the Appendix.)

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



Watson and Crick Deduced the Double-Helical Structure of DNA

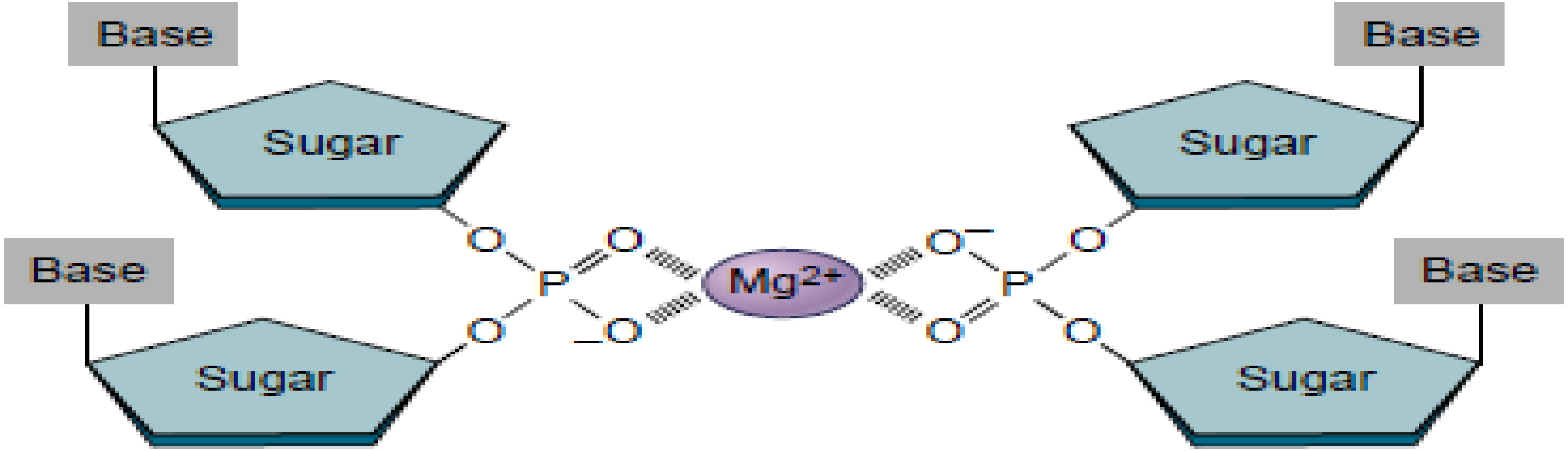


FIGURE 9.14 An incorrect hypothesis for the structure of the DNA double helix. This illustration shows an early hypothesis of Watson and Crick's, suggesting that two DNA strands interact by a cross-link between the negatively charged phosphate groups in the backbone and divalent Mg^{2+} cations.

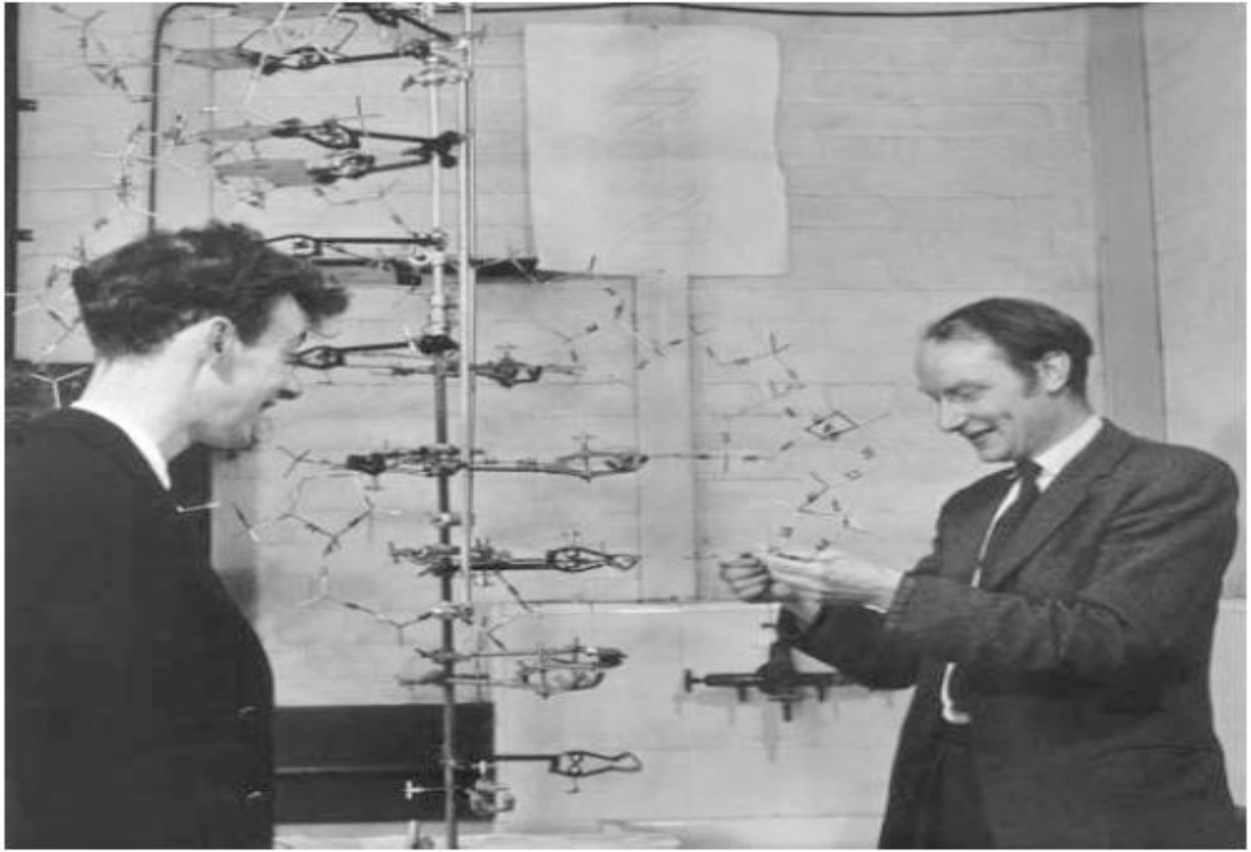
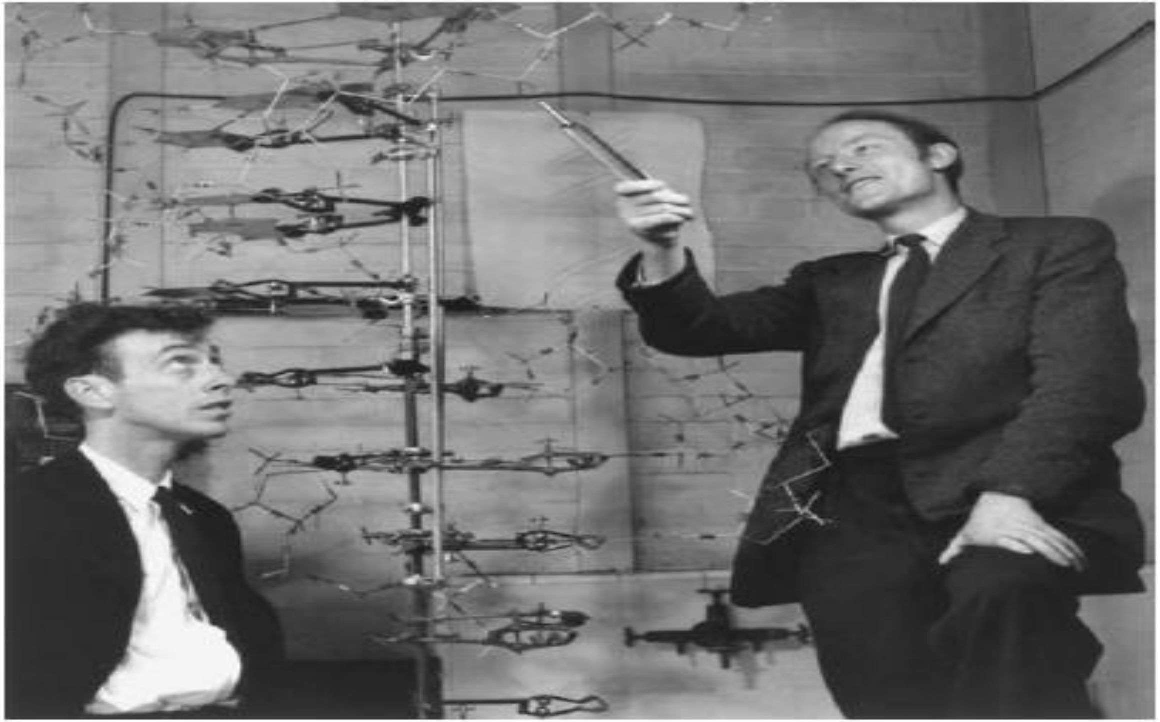


FIGURE 4.01 *Watson and Crick in the 1950s*

Watson and Crick Deduced the Double-Helical Structure of DNA



(a) Watson and Crick

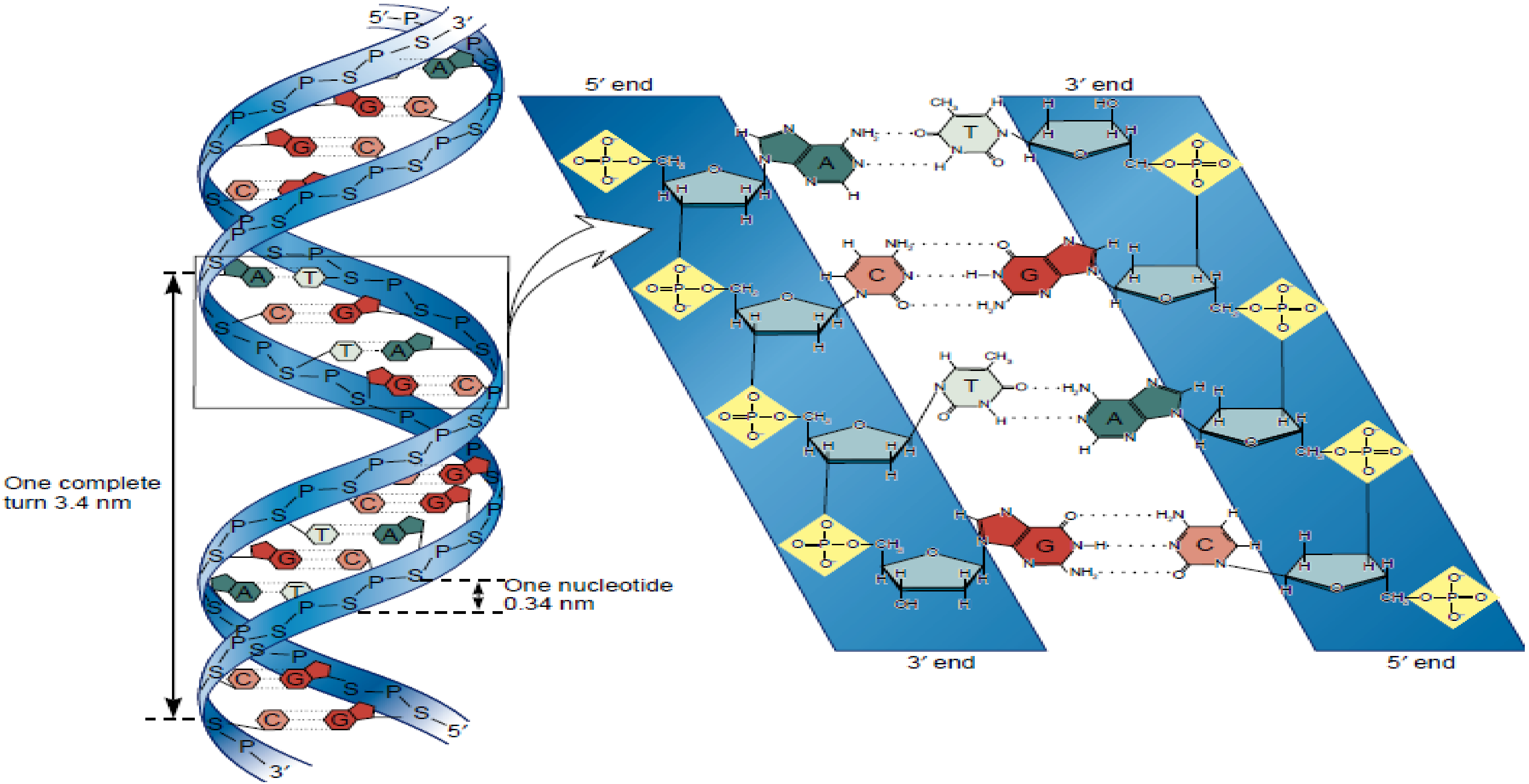
FIGURE 9.15 Watson and Crick and their model of the DNA double helix. (a) James Watson is shown here on the left and Francis Crick on the right. (b) The molecular model they originally proposed for the double helix. Each strand contains a sugar-phosphate backbone. In opposite strands, A hydrogen bonds to T, and G hydrogen bonds with C.

The Molecular Structure of the DNA :Double Helix Has Several Key Features

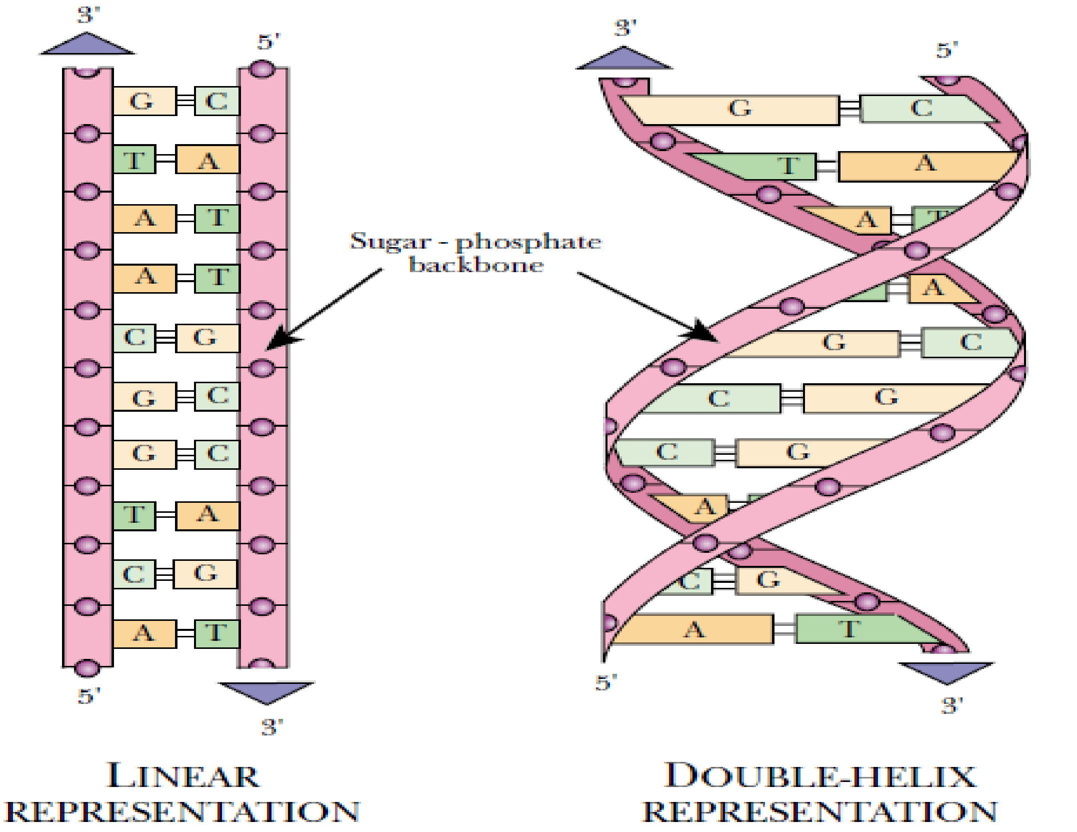
Key Features

- Two strands of DNA form a right-handed double helix (B-form).
- 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.

The Molecular Structure of the DNA :Double Helix Has Several Key Features



Base Pairs are Held Together by Hydrogen Bonds

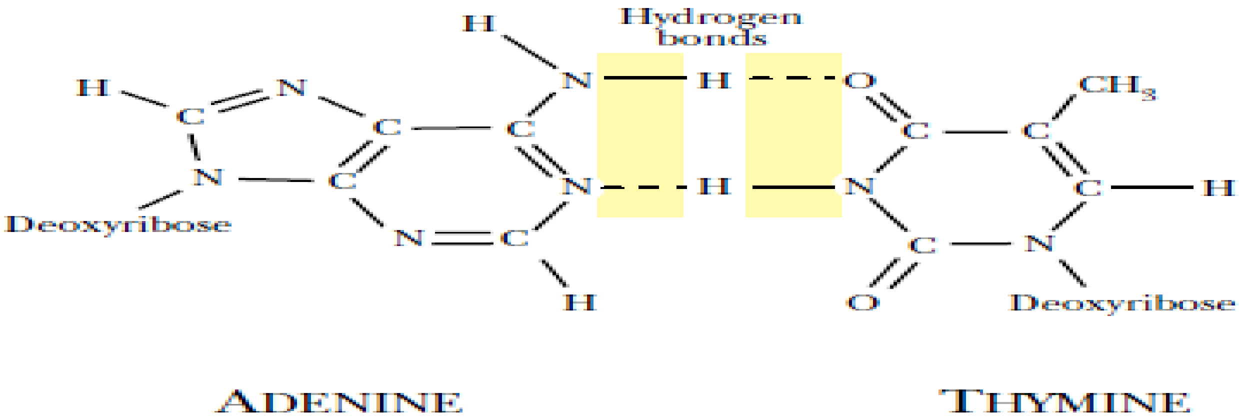


Base Pairs are Held Together by Hydrogen Bonds

- In double stranded DNA, the bases on each strand protrude into the center of the double helix where they are paired with the bases in the other strand by means of **hydrogen bonds**. Adenine (A) in one strand is always paired with thymine (T) in the other, and guanine (G) is always paired with cytosine (C).
- Consequently, the number of adenines in DNA is equal to the number of thymines, and similarly the numbers of guanine and cytosine are equal.
-

Base Pairs are Held Together by Hydrogen Bonds

- **Antiparallel** Parallel, but running in opposite directions
- **Base pair** Two bases held together by hydrogen bonds
- **Double helix** Structure formed by twisting two strands of DNA spirally around each other
- **Hydrogen bond** Bond resulting from the attraction of a positive hydrogen atom to both of two other atoms with negative charges
- **Base pairing** A pair of two complementary bases (A with T or G with C) held together by hydrogen bonds
- **Complementary sequences** Two nucleic acid sequences whose bases pair with each other because A, T, G, C in one sequence correspond to T, A, C, G, respectively, in the other



Base Pairs are Held Together by Hydrogen Bonds

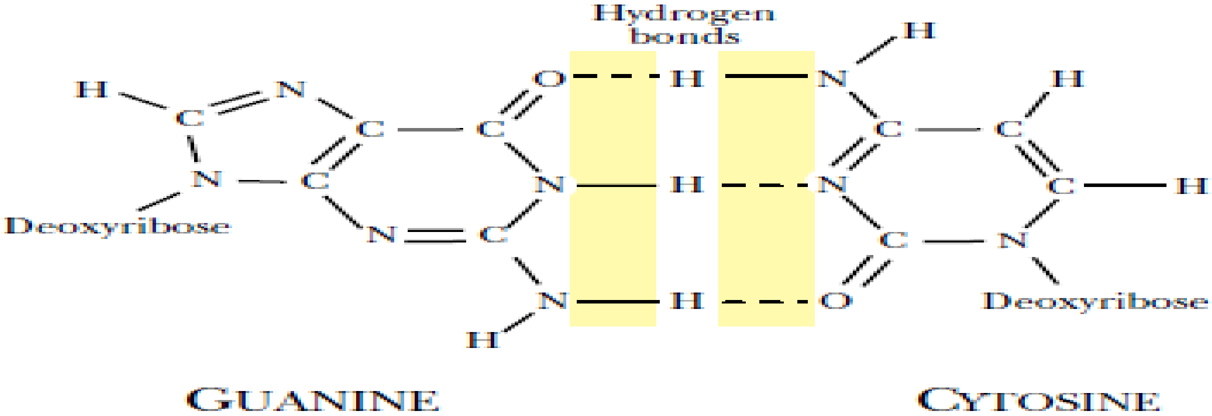
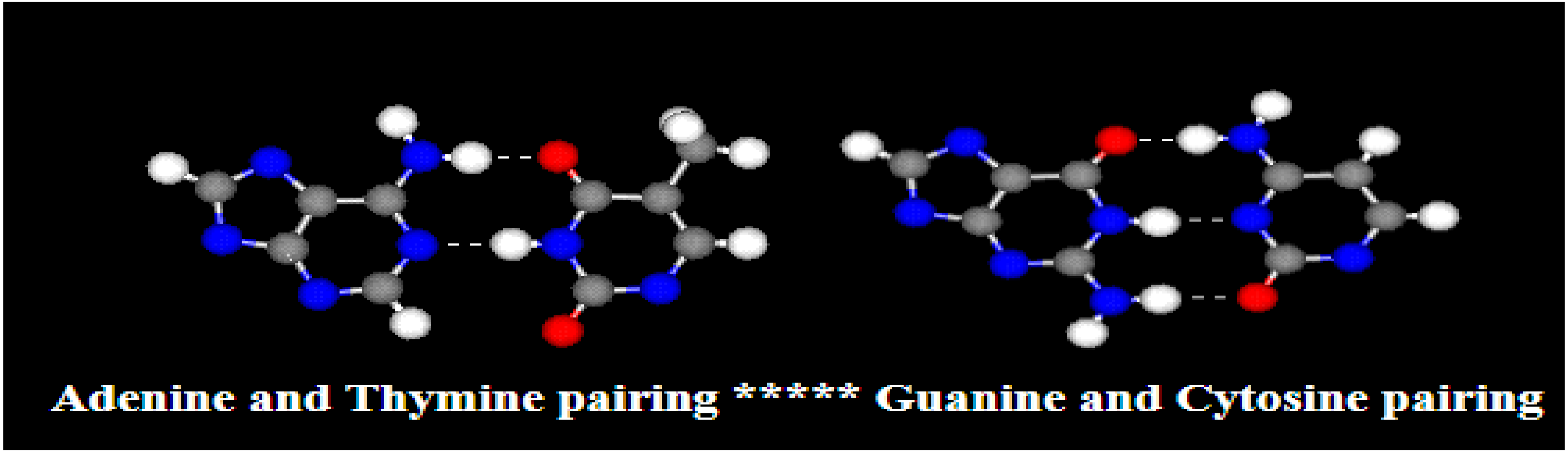
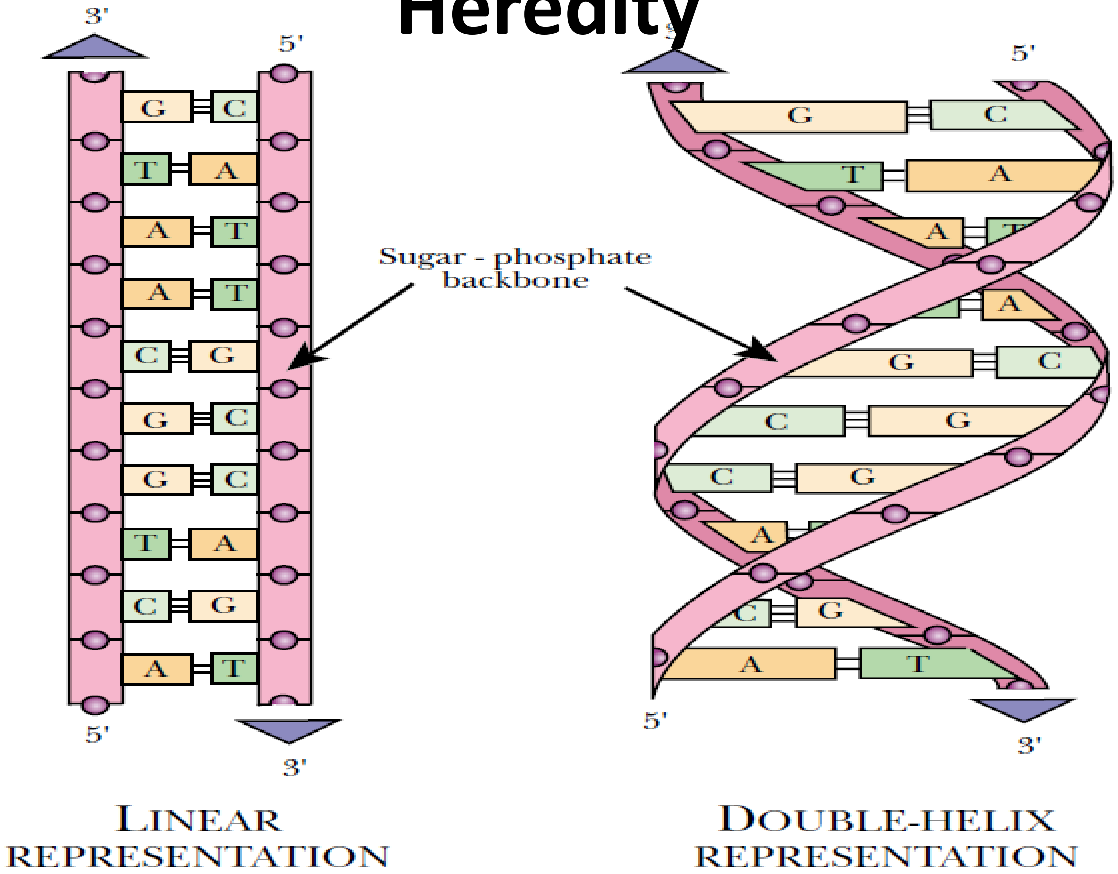


FIGURE 3.10 ***Base Pairing by Hydrogen Bond Formation***

Base Pairs are Held Together by Hydrogen Bonds



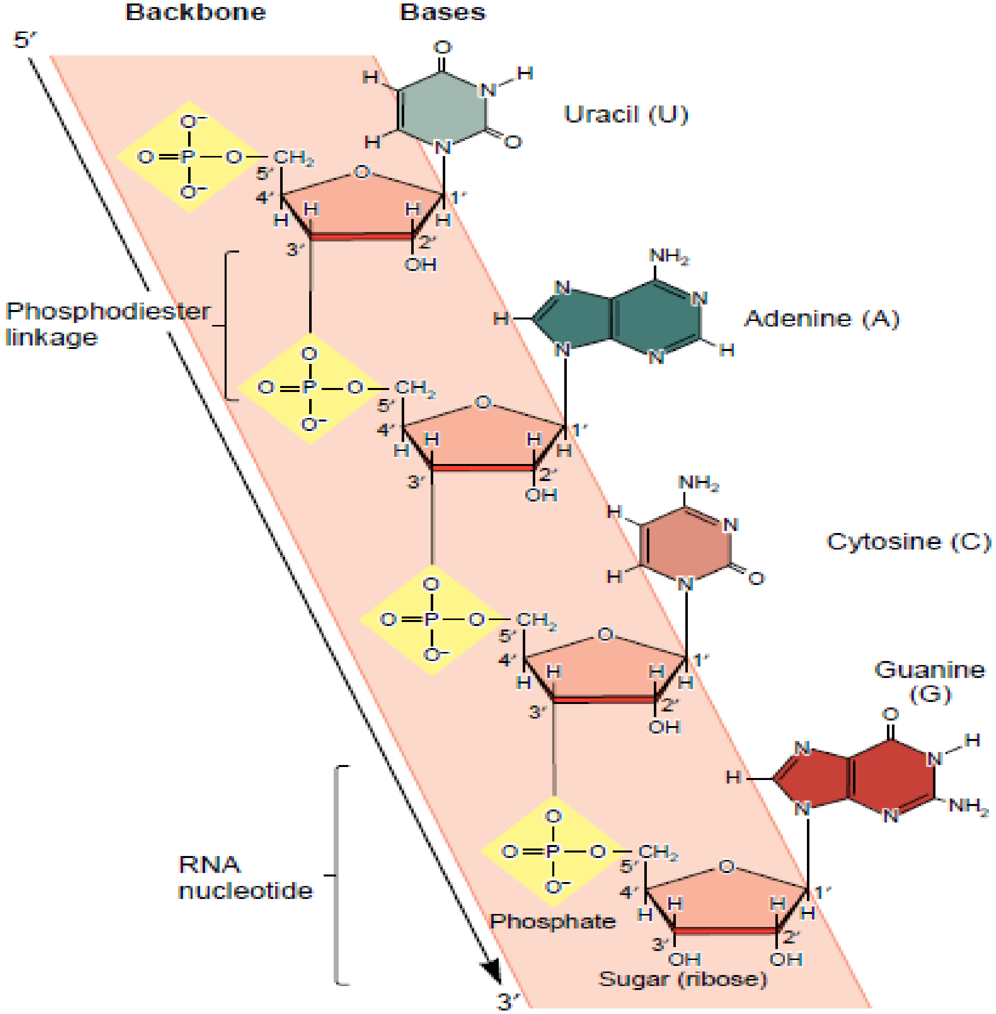
Complementary Strands Reveal the Secret of Heredity



RNA Molecules Are Composed of Strands That Fold into Specific Structures

- The structure of an RNA strand is much like a DNA strand
- Strands of RNA are typically several hundred or several thousand nucleotides in length, which is much shorter than chromosomal DNA.
- When RNA is made during transcription, the DNA is used as a template to make a copy of single-stranded RNA.

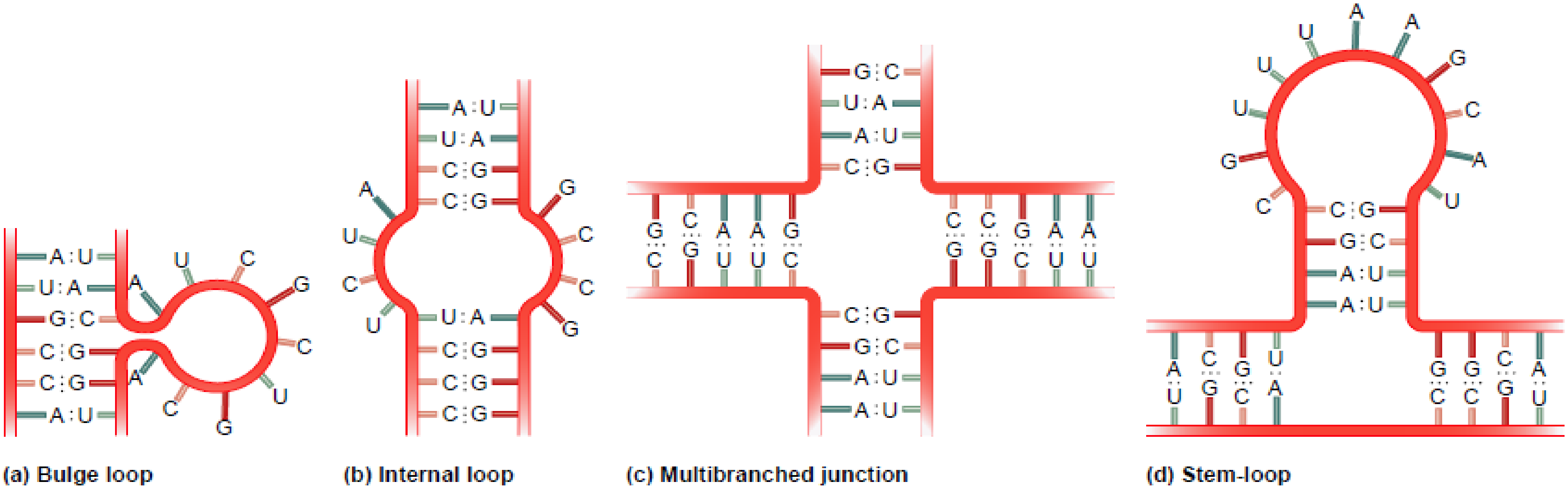
RNA Molecules



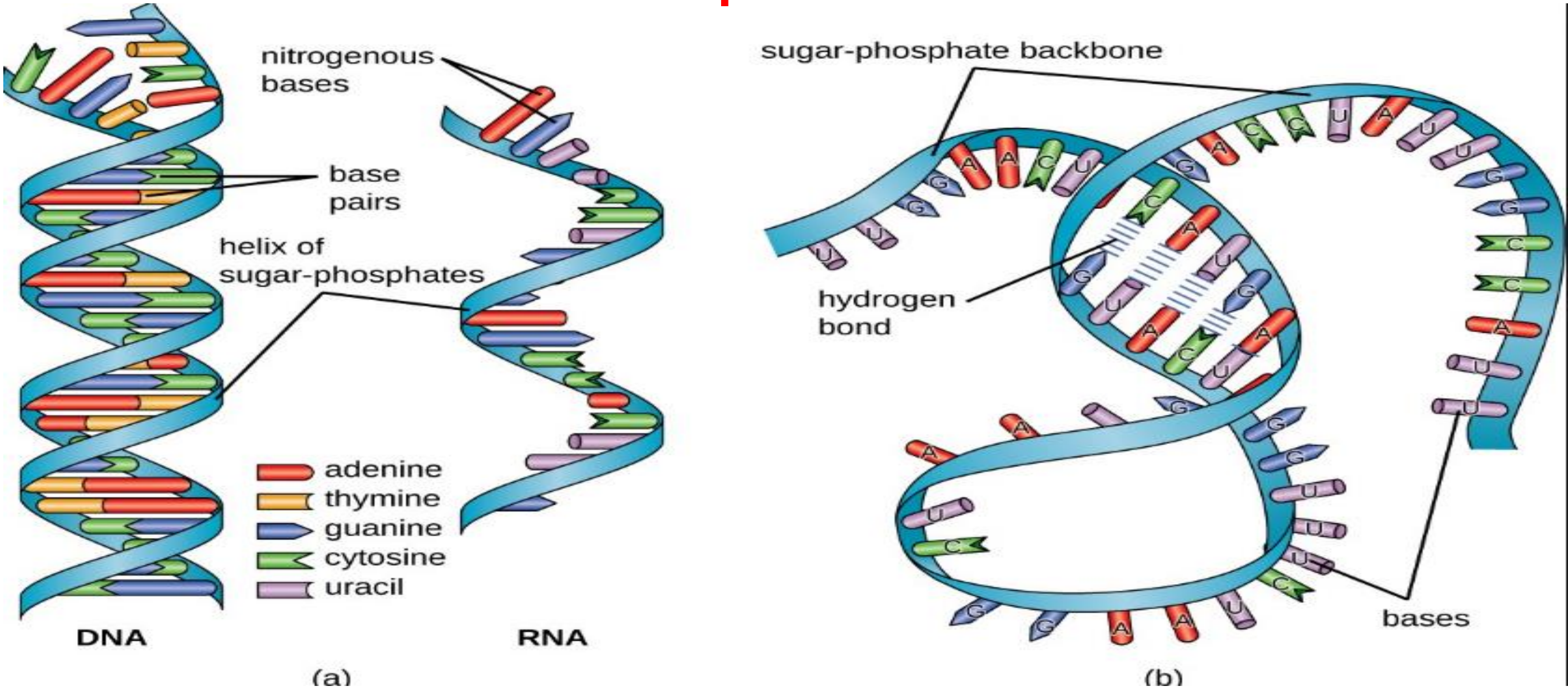
RNA Molecules

- The helical structure of RNA molecules is due to the ability of complementary regions to form base pairs between A and U and between G and C. This base pairing allows short segments to form a double-stranded region.
- different types of structural patterns are possible. These include bulge loops, internal loops, multibranched junctions, and stem-loops. also called hairpins).

RNA Molecules Are Composed of Strands That Fold into Specific Structures

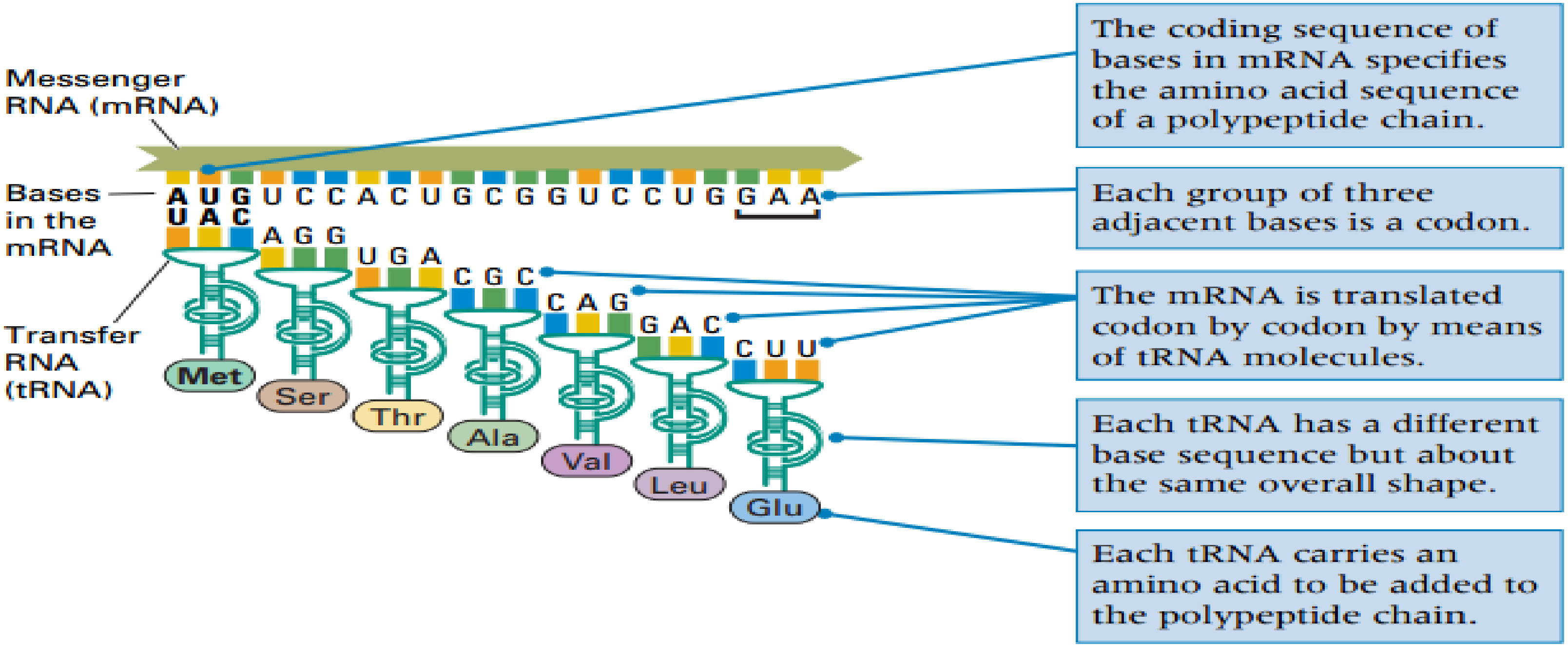


RNA Molecules Are Composed of Strands That Fold into Specific Structures



RNA Molecules Are Composed of Strands That Fold into Specific Structures

- Many factors contribute to the structure of RNA molecules. These include:
- the base-paired double-stranded helices,
- stacking between bases,
- and hydrogen bonding between bases and
- backbone regions.
- In addition, interactions with ions, small molecules, and large proteins may influence RNA structure.



The role of messenger RNA in translation is to carry the information contained in a sequence of DNA bases to a ribosome, where it is translated into a polypeptide chain.

Questions