DNA, RNA, and Proteins Chapter 13

The Structure of DNA

Section 1

DNA: The Genetic Material

Key Idea: DNA is the primary material that causes inheritable characteristics in related groups of organisms.

- A gene is the instructions for inherited traits.
- DNA is a simple molecule, composed of only four different subunits.

The Genetic Material

- DNA is a simple molecule, composed of only four different subunits.

Reading Check

What are genes composed of?

A small segment of deoxyribonucleic acid, or DNA, that is located in a chromosome.

Searching For The Genetic Material

Key Idea: Three major experiments led to the conclusion that DNA is the genetic material in cells. These experiments were performed by Griffith, Avery, and Hershey and Chase.

Griffith's Discovery of Transformation

- Griffith's experiment led to the conclusion that genetic material could be transferred between cells.

Avery's Experiment with Nucleic Acids

- Avery's experiments led to the conclusion that DNA is responsible for transformation in bacteria.

Hershey-Chase Experiments

- By using radioactive isotopes, Hershey and Chase showed that DNA not protein, is the genetic material in viruses.

The Shape of DNA

Key Idea: A DNA molecule is shaped like a spiral staircase and is composed of two parallel strands of linked subunits.

- Nucleotide is made up of three parts: a phosphate group, a five-carbon sugar group, and a nitrogen-containing base.

A Winding Staircase

- The spiral shape of DNA is known as a *double helix*.

Parts of the Nucleotide Subunits

- The phosphate groups and the sugar molecules link together to form s "backbone".
- The five-carbon sugar in DNA is called deoxyribose.

DNA

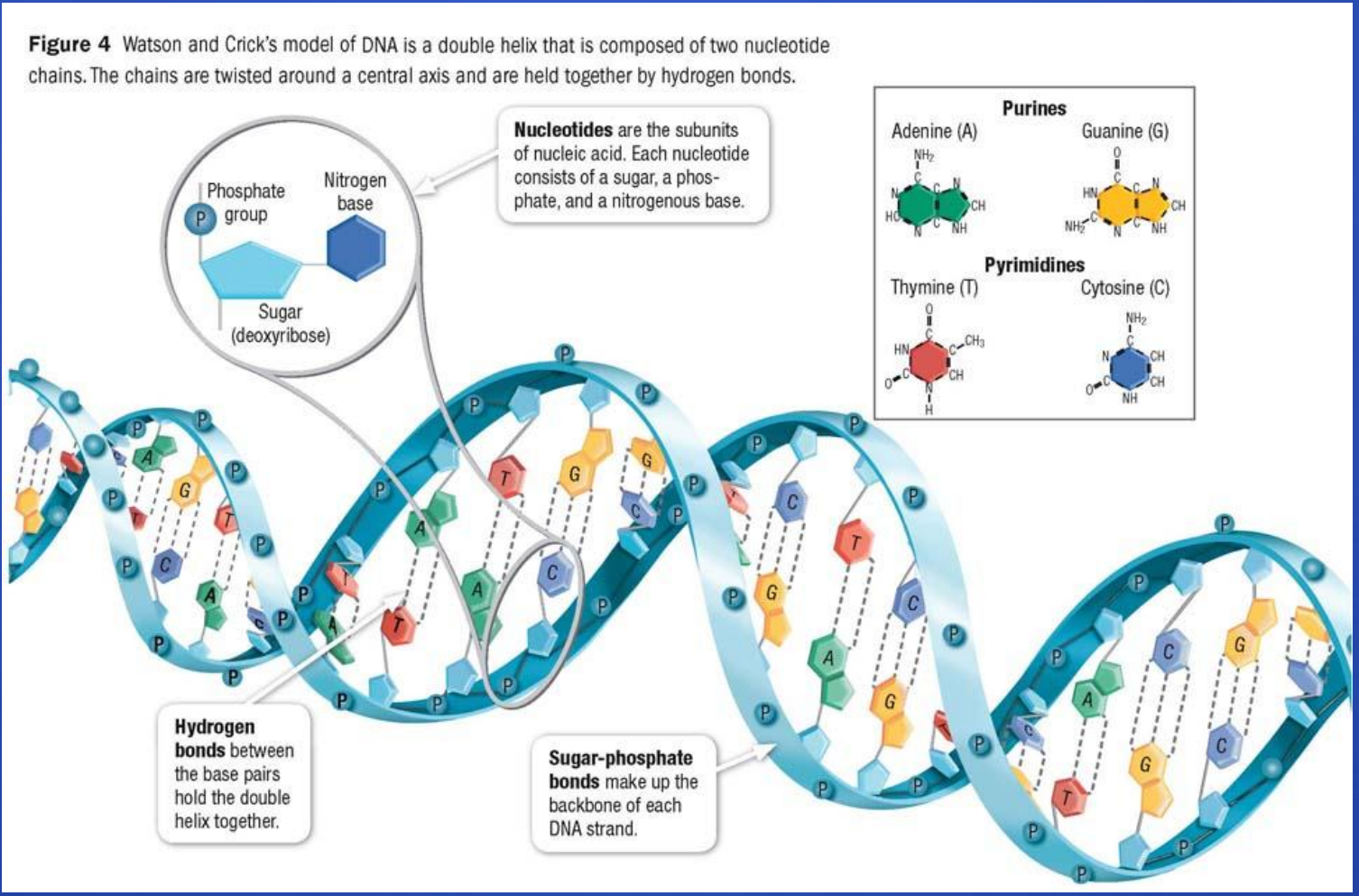

Figure 4 Watson and Crick's model of DNA is a double helix that is composed of two nucleotide chains. The chains are twisted around a central axis and are held together by hydrogen bonds.

The Information In DNA

Key Idea: The information in DNA is contained in the order of the bases, while the base-pairing structure allows the information to be copied.

- A purine is a double-ring structure and has bases Adenine (A) and Guanine.
- A pyrimidine is a single-ring structure and has bases Thymine (T) and Cytosine (C).
- The word complementary means "fitting together like puzzle pieces".

Nitrogenous Bases

- The information in DNA is contained in the order of the bases.
- Each nucleotide can have one of four nitrogenous bases.

Base-Pairing Rules

- Adenine always pairs with thymine.
- Guanine always pairs with cytosine.

Complementary Sides

- The sequence of bases is known for one strand of DNA, then the sequence of bases for the complementary strand can be quickly identified.

Reading Check

How are base-pairs held together?

The hydrogen bonds between bases keep the two strands of DNA together.

Discovering DNA's Structure

Key Idea: Watson and Crick used information from experiments by Chargaff, Wilkins, and Franklin to determine the three-dimensional structure of DNA.

Observing Patterns: Chargaff's Observations

- Chargaff showed that the amount of adenine always equaled the amount of thymine, and the amount of guanine always equaled the amount of cytosine.

Using Technology: Photographs of DNA

- Franklin and Wilkins developed X-ray diffraction images of strands of DNA that suggested the DNA molecule resembled a tightly coiled helix.

Watson and Crick's Model of DNA

- The three-dimensional model of DNA showed a "spiral staircase" in which two strands of nucleotides twisted around a central axis.

Reading Check

How was X-ray diffraction used to model the structure of DNA?

It suggested the DNA molecule resembled a tightly coiled helix.

Replication of DNA
Section 2

DNA Replication

Key Idea: In DNA replication, the DNA molecule unwinds, and the two sides split. Then, new bases are added to each side until two identical sequences result.

- DNA replication is the process of making a copy of DNA.

DNA Replication

- Each double-stranded DNA helix is made of one new strand of DNA and one original strand of DNA.

Replication Proteins

Key Idea: During the replication of DNA, many proteins form a machinelike complex of moving parts.

- A DNA helicase is a protein that unwinds the DNA double helix during DNA replication.
- A DNA polymerase is a protein that catalyzes the formation of the DNA molecule by moving along each strand and adding nucleotides that pair with each base.

DNA Helicase

- These enzymes wedge themselves between the two strands of the double helix and break the hydrogen bonds between the base pairs.

DNA Polymerase

- DNA polymerases also have a "proofreading" function.
- The DNA polymerase can backtrack, remove the incorrect nucleotide, and replace it with the correct one.

Reading Check

Why is proofreading critical during replication?

Checks for errors in the new DNA strand and removes the incorrect paired nucleotide and replaces it with the correct one.

Prokaryotic and Eukaryotic Replication

Key Idea: In prokaryotic cells, replication starts at a single site. In eukaryotic cells, replication starts at many sites along the chromosome.

- The word distinct means distinguished as not being the same.

Prokaryotic DNA Replication

- Replication in prokaryotes begins at one place along the loop.
- Replication occurs in opposite directions until the forks meet on the opposite side of the loop.

Eukaryotic DNA Replication

- Replication starts at many sites along the chromosome. This process allows eukaryotic cells to replicate their DNA faster than prokaryotes.

Reading Check

How is a "replication bubble" formed?

Two distinct replication forks form at each start site, and replication occurs in opposite directions.

RNA and Gene Expression Section 3

RNA and Gene Expression

Key Idea: Gene expression produces proteins by transcription and translation. This process takes place in two stages, both of which involve RNA.

- RNA is a second type of nucleic acid which takes the information from DNA and makes protein.
- Gene expression is the manifestation of genes into specific traits.
- Transcription is the process of making RNA from the information in DNA.
- Translation is the use of information in RNA to make specific protein.

Transcription: DNA to RNA

- Transcription is similar to copying (transcribing) notes from the board (DNA) to a notebook (RNA).

Translation: RNA to Proteins

- Translation is similar to translating a sentence in one language (RNA, the nucleic acid "language") to another language (protein, the amino acid "language").

RNA: A Major Player

Key Idea: In cells, three types of RNA complement DNA and translate the genetic code into proteins.

RNA Versus DNA

- RNA is composed of *one strand* of nucleotides rather than two strands.
- RNA nucleotides contain the five-carbon sugar *ribose* rather than the sugar deoxyribose.
- RNA nucleotides have a nitrogenous base called *uracil* (U) instead of the base thymine (T).

Types of RNA

- **Messenger RNA:** (mRNA) is produced when DNA is transcribed into RNA.
- **Transfer RNA:** (tRNA) "reads" the instructions carried by the mRNA, then translates the mRNA sequence into protein subunits called amino acids.
- **Ribosomal RNA:** (rRNA) is an RNA molecule that is part of the structure of ribosomes.

Types of RNA

- Ribosomes are the cellular structure where protein production occurs using the three main types of RNA.

Reading Check

What are the structural differences between RNA and DNA?

One strand for RNA, Two for DNA

Ribose for RNA, Deoxyribose for DNA

Uracil for RNA, Thymine for DNA

Transcription: Reading the Gene

Key Idea: During transcription, the information in a specific region of DNA (a gene) is transcribed, or copied, into mRNA.

Transcription Versus Replication

- In transcription, a new molecule of RNA is made from the DNA. In DNA replication, a new molecule of DNA is made from the DNA.

Reading Check

What is the role of a promoter?

A specific DNA sequence in the gene where transcription begins when RNA polymerase binds to it.

The Genetic Code: Three-Letter "Words"

Key Idea: The genetic code is based on codons that each represents a specific amino acid.

- A codon is a three-nucleotide sequence that corresponds to 1 of 20 amino acids.

Codons of mRNA

- There are 64 mRNA codons. Each codon specifies only one amino acid, but several amino acids have more than one codon.

Translation: RNA to Proteins

Key Idea: Translation occurs in a sequence of steps, involves three kinds of RNA, and results in a complete polypeptide.

Steps of Translation

Step 1: The mRNA joins with a ribosome and tRNA.

Step 2: A tRNA molecule that has the correct anticodon and amino acid binds to the second codon on the mRNA.

Step 3: A peptide bond forms between the two amino acids, and the first tRNA is released from the ribosome.

Step 4: The ribosome then moves one codon down the mRNA.

Step 5: This process is repeated until one of three stop codons is reached. Then the amino acid chain is released.

Translation: RNA to Proteins

- Translation takes place in the cytoplasm, where tRNA, rRNA, and mRNA interact to assemble proteins.

Repeating Translation

- Many copies of the same protein can be made rapidly from a single mRNA molecule because several ribosomes can translate the same mRNA at the same time.

Reading Check

How do codons and anticodons differ?

An anticodon is a three-nucleotide sequence on tRNA that is complementary to an mRNA codon.

Complexities of Gene Expression

Key Idea: The relationship between genes and their effects is complex. Despite the neatness of the genetic code, every gene cannot be simply linked to a single outcome.

Complexities of Gene Expression

- Gene expression produces proteins by transcription and translation. this process takes place in two stages, both of which involve RNA.