# CHAPTER 10

# Molecular Biology of the Gene

## THE STRUCTURE AND REPLICATION OF DNA

- DNA
  - Was known as a chemical in cells by the end of the nineteenth century
  - Has the capacity to store genetic information
  - Can be copied and passed from generation to generation.



## DNA and RNA: Polymers of Nucleotides

- DNA and RNA are nucleic acids
  - They consist of chemical units called nucleotides
  - The nucleotides are joined by a sugar-phosphate backbone Fig. 10.3 to Fig. 10.5, p. 174-5
  - Nucleic acids consist of long chains (polymers) of chemical units (monomers).

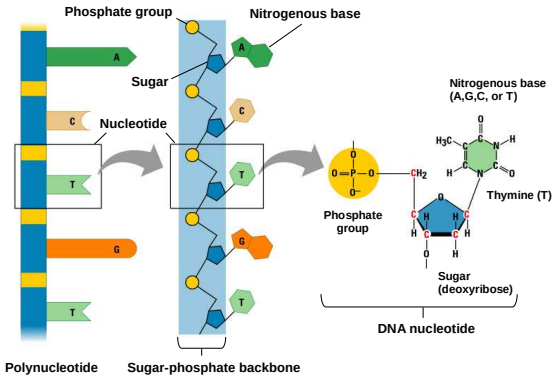



Figure 10.2

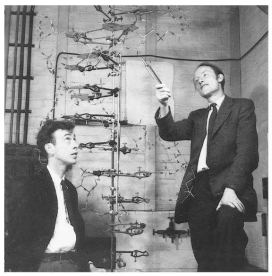


- The four nucleotides found in DNA
  - Differ in their nitrogenous bases
  - Are thymine (T), cytosine (C), adenine (A), and guanine (G)
- RNA has uracil (U) in place of thymine.



## Watson and Crick's Discovery of the Double Helix

- James Watson and Francis Crick determined that DNA is a double helix.



(a) James Watson and Francis Crick

Figure 10.3a

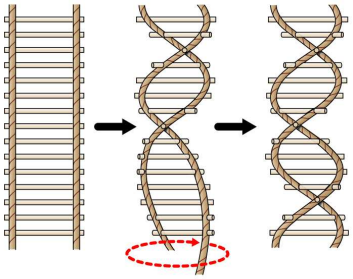
- Watson and Crick used X-ray crystallography data to reveal the basic shape of DNA
  - Rosalind Franklin collected the X-ray crystallography data.

(b) Rosalind Franklin

Figure 10.3b



- The model of DNA is like a rope ladder twisted into a spiral.



Twist

Figure 10.4



- Detailed representations of DNA
  - Notice that the bases pair in a complementary fashion.

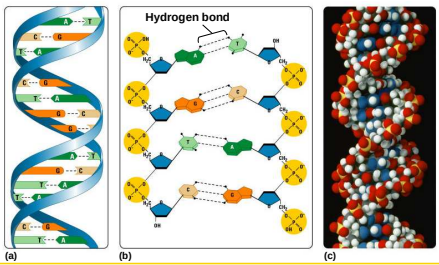



Figure 10.5

## DNA Replication

- When a cell or organism reproduces, a complete set of genetic instructions must pass from one generation to the next  Fig. 10.6, p. 176.



- Watson and Crick's model for DNA suggested that DNA replicated by a template mechanism.

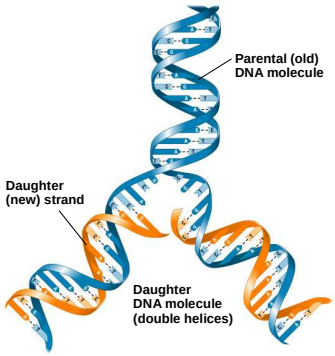



Figure 10.6



- DNA can be damaged by ultraviolet light
  - The enzymes and proteins involved in replication can repair the damage.

Figure 10.7

- DNA replication
  - Begins at specific sites on a double helix
  - Proceeds in both directions

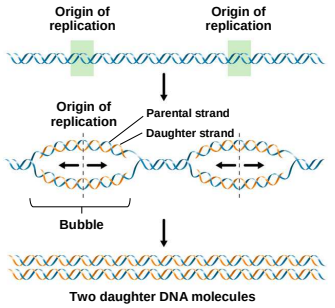



Figure 10.8



## How an Organism's DNA Genotype Produces Its Phenotype

- An organism's genotype, its genetic makeup is the sequence of nucleotide bases in DNA
  - The phenotype is the organism's specific traits



- DNA specifies the synthesis of proteins in two stages
  - Transcription
  - Translation

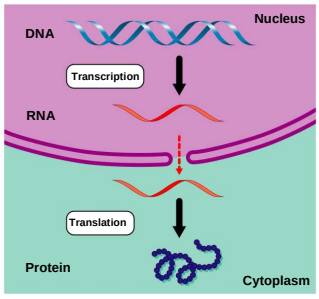



Figure 10.9. P. 177

- The one gene–one protein hypothesis states that the function of an individual gene is to dictate the production of a specific protein



## From Nucleotide Sequence to Amino Acid Sequence: An Overview

- The information, or "language," in DNA is ultimately translated into the language of polypeptides



- What is the language of nucleic acids?
  - In DNA, it is the linear sequence of nucleotide bases

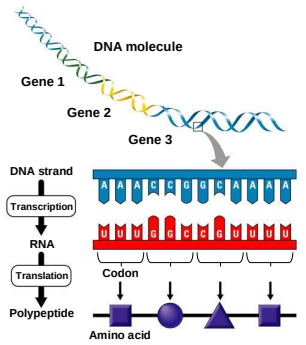



Figure 10.10

- When DNA is transcribed, the result is an RNA molecule
- RNA is then translated into a sequence of amino acids in a polypeptide. Translation is the conversion of the nucleic acid language into the polypeptide language. P. 178.
- Like nucleic acids, polypeptides are polymers, but the monomers that make them up are the 20 amino acids common to all organisms.



- What is the correspondence between the nucleotides of an RNA molecule and the amino acids of a polypeptide?
- If A, T, G, C coded for only one amino acid: 4 of 20
- If they code in combinations of two lettered words: $4^2$= 16 of 20 amino acids



- Triplets of bases
  - Specify all the amino acids
  - The triplets are called codons, Fig. 10.10, p. 178.
  - Codons in figure 10.11, p. 179 are triplets found in RNA

## The Genetic Code

- The genetic code is the set of rules relating nucleotide sequence to amino acid sequence

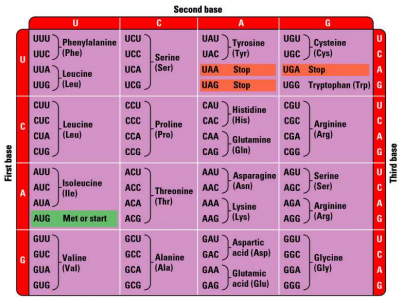


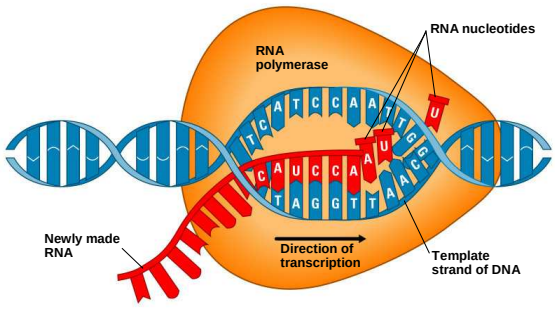

Figure 10.11



## Transcription: From DNA to RNA

- In transcription
  - Genetic information is transferred from DNA to RNA
  - An RNA molecule is transcribed from a DNA template






(a) A close-up view of transcription

Figure 10.13a

- Transcription of an entire gene

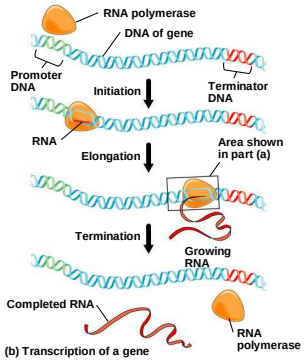



Figure 10.13b



## *Initiation of Transcription*

- The "start transcribing" signal is a nucleotide sequence called a promoter
- The first phase of transcription is initiation
  - RNA polymerase attaches to the promoter
  - RNA synthesis begins



## *RNA Elongation*

- The second phase of transcription is elongation
  - The RNA grows longer

## *Termination of Transcription*

- The third phase of transcription is termination
  - RNA polymerase reaches a sequence of DNA bases called a terminator



## The Processing of Eukaryotic RNA

- The eukaryotic cell processes the RNA after transcription



- RNA processing includes
  - Adding a cap and tail
  - Removing introns
  - Splicing exons together

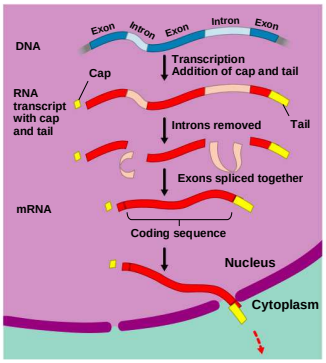



Figure 10.14

## Translation: The Players

- Translation
  - Is the conversion from the nucleic acid language to the protein language



## *Messenger RNA (mRNA)*

- mRNA
  - Is the first ingredient for translation



## *Transfer RNA (tRNA)*

- tRNA
  - Acts as a molecular interpreter
  - Carries amino acids
  - Matches amino acids with codons in mRNA using anticodons

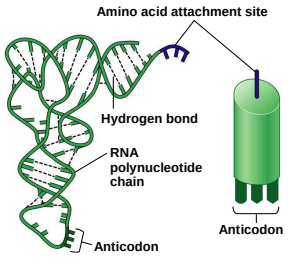
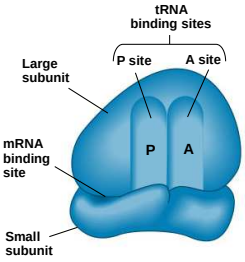



Figure 10.15

## *Ribosomes*

- Ribosomes
  - Are organelles that actually make polypeptides, p. 183
  - Are made up of two protein subunits
  - Contain ribosomal RNA (rRNA)

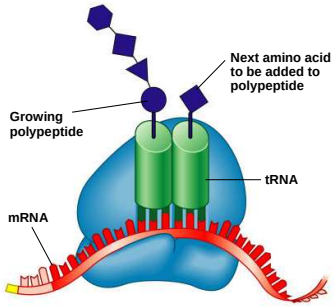



(a)

Figure 10.16a



- A fully assembled ribosome holds tRNA and mRNA for use in translation




(b)

Figure 10.16b



## Translation: The Process

- Translation is divided into three phases
  - Initiation
  - Elongation
  - Termination

## *Initiation*

- The first phase brings together
  - The mRNA
  - The first amino acid with its attached tRNA
  - The two subunits of the ribosome



- An mRNA molecule has a cap and tail that help it bind to the ribosome

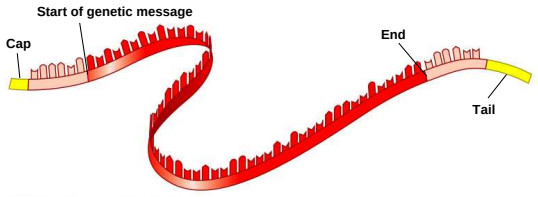



Figure 10.17



- The process of initiation

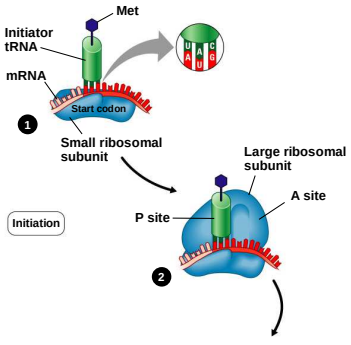



Figure 10.18.1

## *Elongation*

- Step 1, codon recognition
  - The anticodon of an incoming tRNA pairs with the mRNA codon



- Step 2, peptide bond formation
  - The ribosome catalyzes bond formation between amino acids. That is, peptide bonds form between amino acids. P. 184



- Step 3, translocation
  - A tRNA leaves the P site of the ribosome
  - The ribosome moves down the mRNA

- The process of elongation

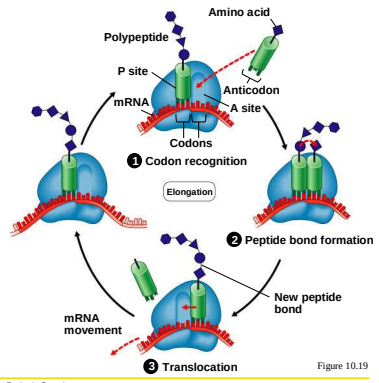



Figure 10.19



## *Termination*

- Elongation continues until the ribosome reaches a stop codon



## Review: DNA→ RNA→ Protein

- The flow of genetic information in a cell

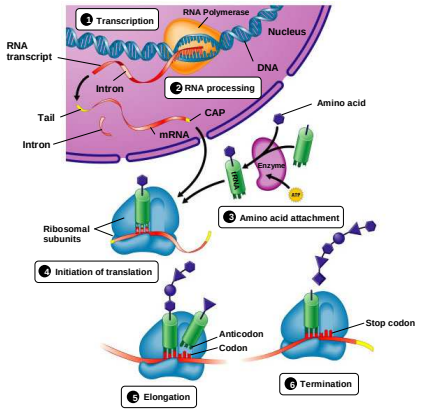



Figure 10.20



- In eukaryotic cells
  - Transcription occurs in the nucleus
  - Translation occurs in the cytoplasm



- Transcription and Translation
  - Are the processes whereby genes control the structures and activities of cells

## Mutations

- A mutation
  - Is any change in the nucleotide sequence of DNA

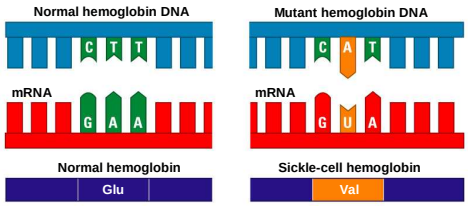



Figure 10.21



## *Types of Mutations*

- Mutations within a gene
  - Can be divided into two general categories
  - Can result in changes in the amino acids in proteins

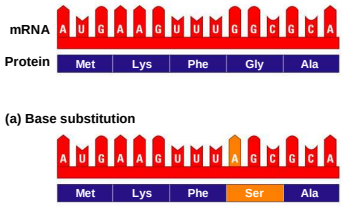



Figure 10.22a



- Insertions and deletions
  - Can have disastrous effects
  - Change the reading frame of the genetic message

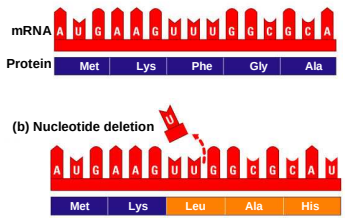



Figure 10.22b

## *Mutagens*

- Mutations may result from
  - Errors in DNA replication
  - Physical or chemical agents called mutagens



- Although mutations are often harmful
  - They are the source of the rich diversity of genes in the living world
  - They contribute to the process of evolution by natural selection

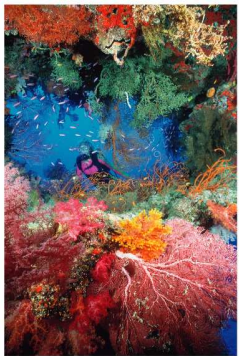


Figure 10.23



## VIRUSES: GENES IN PACKAGES

- Viruses sit on the fence between life and nonlife
  - They exhibit some but not all characteristics of living organisms

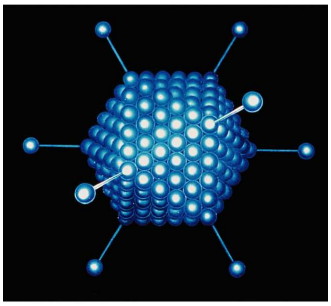


Figure 10.24

## Bacteriophages

- Bacteriophages, or phages
  - Attack bacteria

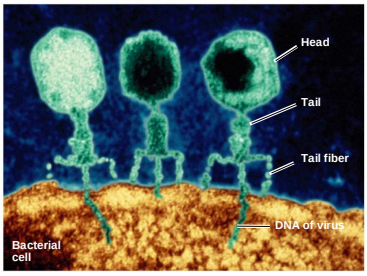



Figure 10.25



- Phages have two reproductive cycles

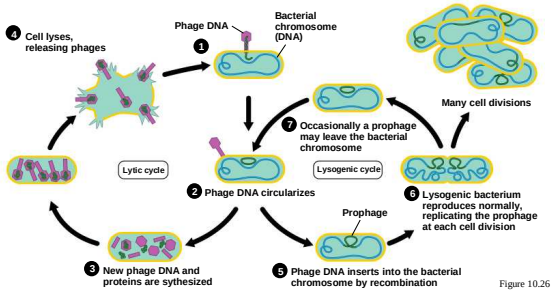



Figure 10.26



## Plant Viruses

- Viruses that infect plants
  - Can stunt growth and diminish plant yields
  - Can spread throughout the entire plant

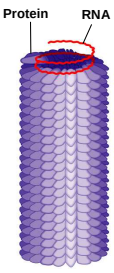



Figure 10.27

- The reproductive cycle of an enveloped virus, p. 190



## Mumps virus, p.190

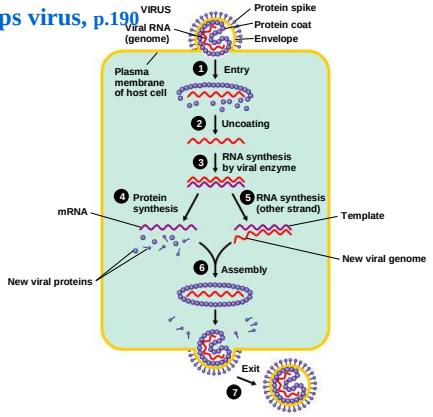
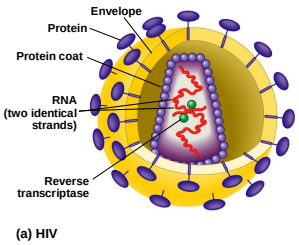



Figure 10.29



## HIV, the AIDS Virus, p. 192

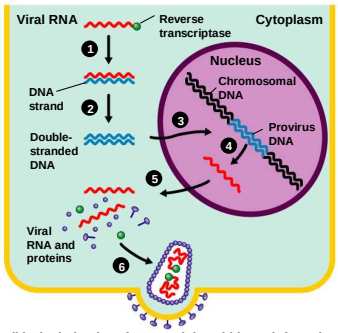
- HIV is a retrovirus
  - A retrovirus is an RNA virus that reproduces by means of a DNA molecule
  - It copies its RNA to DNA using reverse transcriptase




(a) HIV

Figure 10.30a

- How HIV reproduces inside a cell



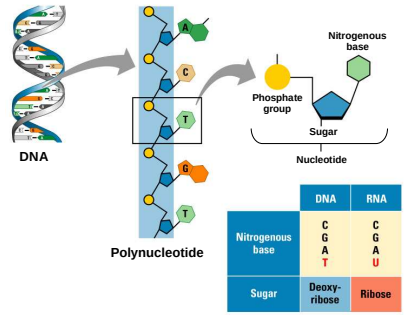

(b) The behavior of HIV nucleic acid in an infected cell

Figure 10.30b



## SUMMARY OF KEY CONCEPTS

- DNA and RNA: Polymers of Nucleotides

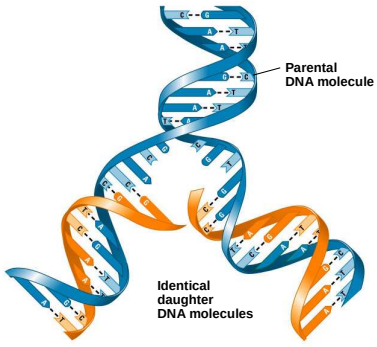



| | DNA | RNA |
|---|---|---|
| Nitrogenous base | C G A T | C G A U |
| Sugar | Deoxy-ribose | Ribose |

Visual Summary 10.1

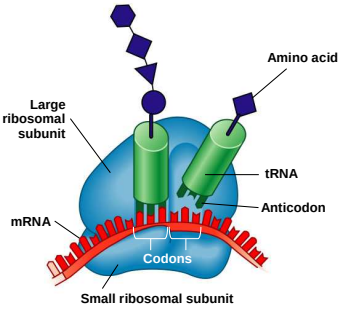


- DNA Replication




Visual Summary 10.2

- Translation: The Players




Visual Summary 10.3