MOLECULAR BIOLOGY OF THE GENE

10.2 DNA and RNA are polymers of nucleotides

- DNA and RNA are nucleic acids consisting of long chains (polymers) of chemical units (monomers) called **nucleotides**.
- One of the two strands of DNA is a DNA **polynucleotide**, a nucleotide polymer (chain).

10.2 DNA and RNA are polymers of nucleotides

- A nucleotide is composed of a
  - nitrogenous base,
  - five-carbon sugar, and
  - phosphate group.
- The nucleotides are joined to one another by a **sugar-phosphate backbone**.
- Each type of DNA nucleotide has a different nitrogen-containing base: **adenine** (A), **cytosine** (C), **thymine** (T), and **guanine** (G).

10.2 DNA and RNA are polymers of nucleotides

- The full name for **DNA** is **deoxyribonucleic acid**, with *nucleic* referring to DNA's location in the nuclei of eukaryotic cells.
- RNA (ribonucleic acid) is unlike DNA in that it
  - uses the sugar ribose (instead of deoxyribose in DNA) and
  - has a nitrogenous base **uracil** (U) instead of thymine.

Checkpoint question Compare and contrast DNA and RNA polynucleotides.

Figure 10.2a

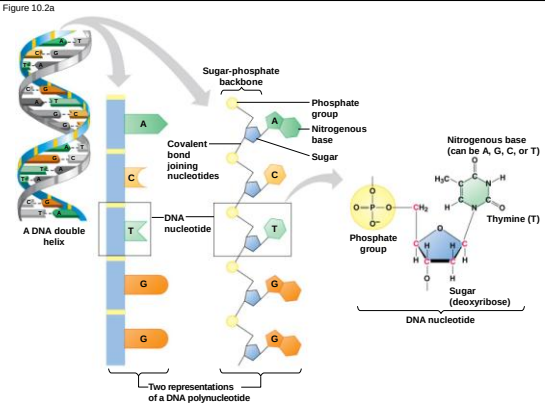


Figure 10.2b

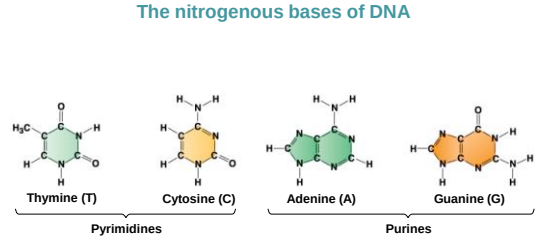
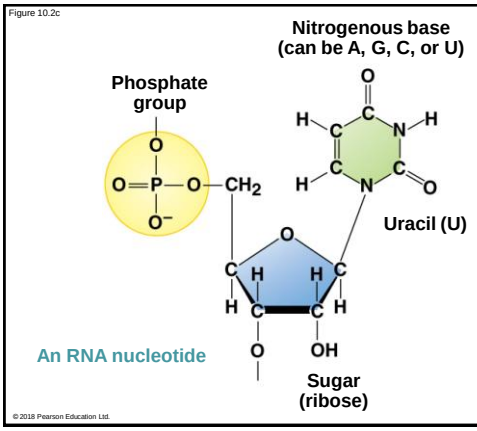


Figure 10.2c



10.3 DNA is a double-stranded helix

- Watson and Crick worked out the three-dimensional structure of DNA: two polynucleotide strands wrapped around each other in a **double helix**.
  - Hydrogen bonds between bases hold the strands together.
  - Each base pairs with a complementary partner: A with T, G with C.

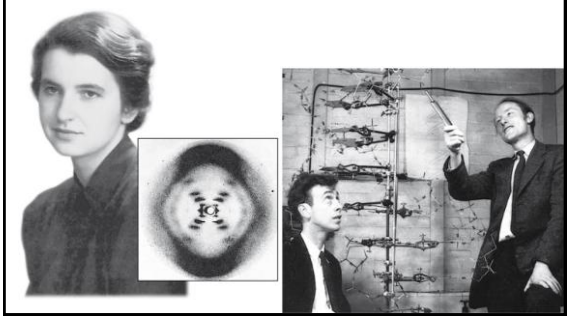
10.3 DNA is a double-stranded helix

- In 1962, the Nobel Prize was awarded to James D. Watson, Francis Crick, and Maurice Wilkins.
  - Rosalind Franklin probably would have received the prize as well but for her death from cancer in 1958.
  - Nobel Prizes are never awarded posthumously.
- The Watson-Crick model gave new meaning to the words *genes* and *chromosomes*. The genetic information in a chromosome is encoded in the nucleotide sequence of DNA.

Building a Structural Model of DNA: *Scientific Inquiry*

- Maurice Wilkins and Rosalind Franklin were using a technique called X-ray crystallography to study molecular structure
- Franklin produced a picture of the DNA molecule using this technique
- Franklin's X-ray crystallographic images of DNA enabled Watson to deduce that DNA was helical
- The X-ray images also enabled Watson to deduce the width of the helix and the spacing of the nitrogenous bases

- The pattern in the photo suggested that the DNA molecule was made up of two strands, forming a **double helix**

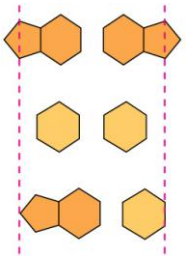


10.3 DNA is a double-stranded helix

Checkpoint question In DNA, which type of bonds form between (a) adjacent nucleotides and (b) complementary bases?

WHY is DNA a double-stranded helix?

- At first, Watson and Crick thought the bases paired like with like (A with A, and so on), but such pairings did not result in a uniform width
- Instead, pairing a purine (A or G) with a pyrimidine (C or T) resulted in a uniform width consistent with the X-ray data



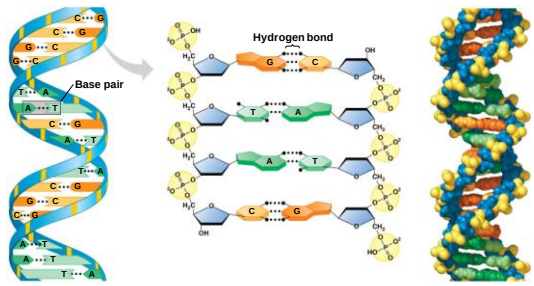
Purine + purine: too wide

Pyrimidine + pyrimidine: too narrow

Purine + pyrimidine: width consistent with X-ray data

Figure 10.3d

Three representations of DNA



DNA REPLICATION

10.4 DNA replication depends on specific base pairing

- DNA replication starts with the separation of DNA strands.
- Enzymes then use each strand as a template to assemble new nucleotides into a complementary strand.

10.4 DNA replication depends on specific base pairing

- DNA replication follows a **semiconservative model**.
  - The two DNA strands separate.
  - Each strand then becomes a template for the assembly of a complementary strand from a supply of free nucleotides.
  - Each new DNA helix has one old strand with one new strand.

Figure 10.4a_3

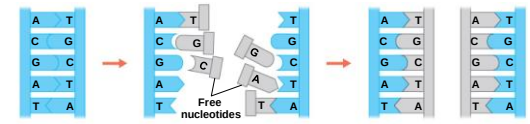
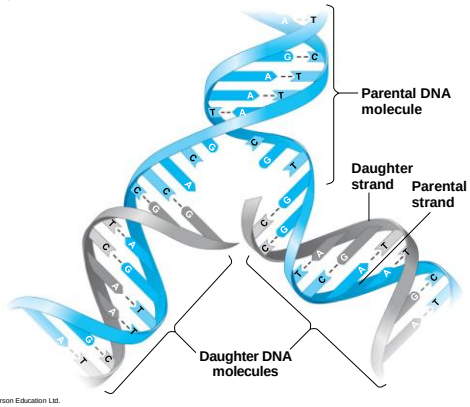


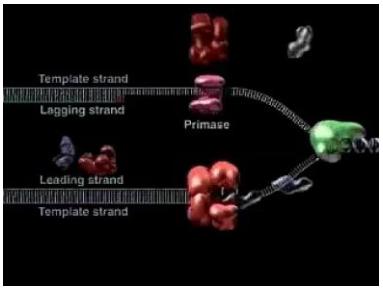
Figure 10.4b



10.5 DNA replication proceeds in two directions at many sites simultaneously

- Using the enzyme **DNA polymerase**, the cell synthesizes one daughter strand as a continuous piece.
- The other strand is synthesized as a series of short pieces, which are then connected by the enzyme **DNA ligase**.

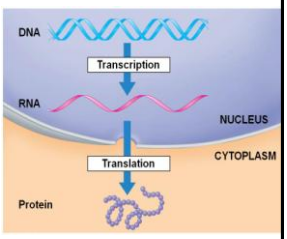
Animation: DNA Replication Review



The Flow of Genetic Information from DNA to RNA to Protein

10.6 Genes control phenotypic traits through the expression of proteins

- The DNA of a gene—a linear sequence of many nucleotides—is transcribed into RNA, which is translated into a polypeptide.
- **Transcription** is the synthesis of RNA under the direction of DNA.
- **Translation** is the synthesis of proteins under the direction of RNA.



10.6 Genes control phenotypic traits through the expression of proteins

- Currently, a gene is defined as a region of DNA that can be expressed to produce a functional product that is either a polypeptide or an RNA molecule.

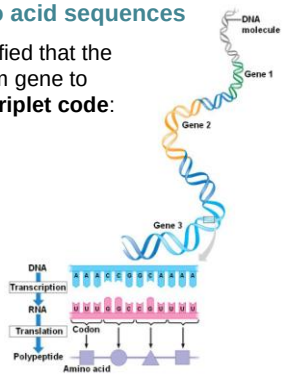
Checkpoint question In a eukaryotic cell, where do the processes of transcription and translation occur, and which molecule is produced in each process?

10.7 Genetic information written in codons is translated into amino acid sequences

- The sequence of nucleotides in DNA provides a code for constructing a protein.
- Translation is the conversion of the nucleic acid language to the polypeptide language.
  - there is a change in language from the nucleotide sequence of the RNA to the amino acid sequence of the polypeptide.

10.7 Genetic information written in codons is translated into amino acid sequences

- Experiments have verified that the flow of information from gene to protein is based on a **triplet code**:
  - The genetic instructions for the amino acid sequence of a polypeptide chain are written in DNA and RNA as a series of nonoverlapping three-base "words" called **codons**.



10.8 The genetic code dictates how codons are translated into amino acids

- The **genetic code** is the set of rules that dictates the amino acid translations of each of the mRNA nucleotide triplets.
- Nearly all organisms use an identical genetic code to convert the mRNA codons transcribed from a gene to the amino acid sequence of a polypeptide.

Checkpoint question Translate the RNA sequence CCAUUUACG into the corresponding amino acid sequence.

Figure 10.8a

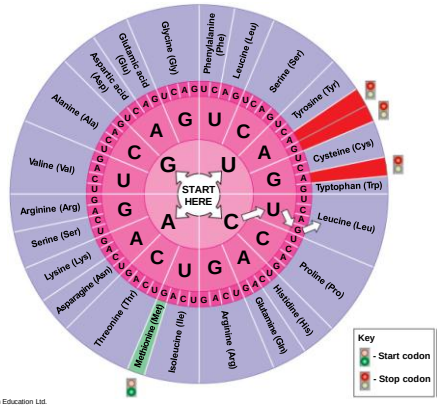
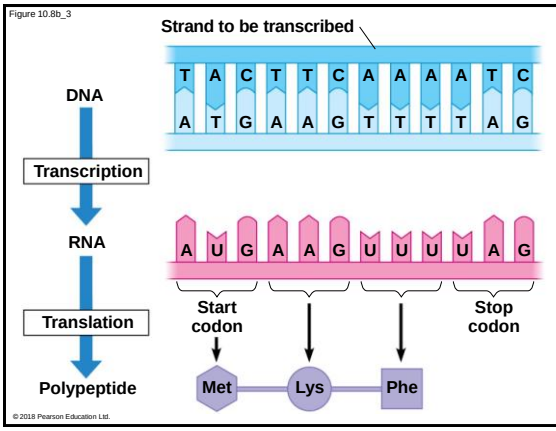


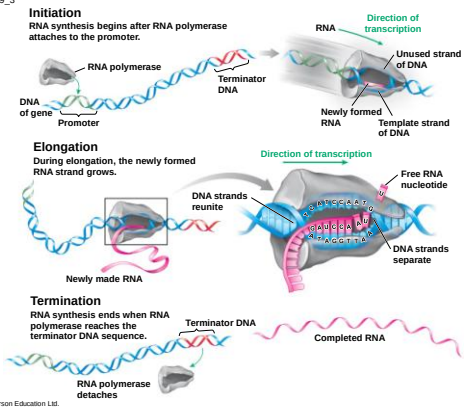
Figure 10.8b_3



10.9 VISUALIZING THE CONCEPT: Transcription produces genetic messages in the form of RNA

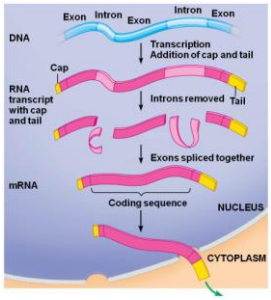
- In the nucleus, the DNA helix unzips, and RNA nucleotides line up and **RNA polymerase** joins them along one strand of the DNA, following the base-pairing rules.
  - A specific nucleotide sequence called a **promoter** acts as a binding site for RNA polymerase and determines where transcription starts.
  - RNA polymerase adds RNA nucleotides until it reaches a sequence of DNA bases called the **terminator**, which signals the end of the gene.

Figure 10.9_3



10.10 Eukaryotic RNA is processed before leaving the nucleus as mRNA

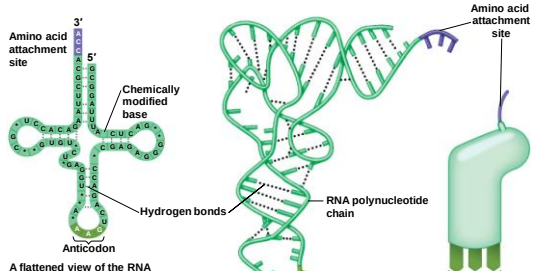
- The kind of RNA that encodes amino acid sequences is called **messenger RNA (mRNA)** because it conveys genetic messages from DNA to the translation machinery of the cell.



10.11 Transfer RNA molecules serve as interpreters during translation

- Translation takes place in the cytoplasm.
  - A ribosome attaches to the mRNA and translates its message into a specific polypeptide, aided by **transfer RNAs (tRNAs)**.
  - Each tRNA is a folded molecule bearing a base triplet called an **anticodon** on one end and a specific amino acid attachment site at the other end.

Figure 10.11a

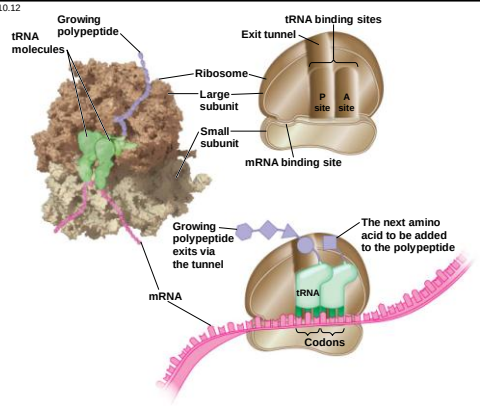


10.12 Ribosomes build polypeptides

- **Ribosomes**
  - are made of **ribosomal RNA (rRNA)** and proteins and
  - have binding sites for tRNAs and mRNA.

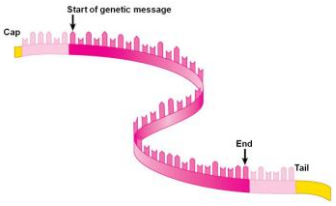
Checkpoint question How does a ribosome facilitate protein synthesis?

Figure 10.12



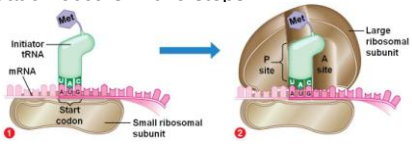
10.13 An initiation codon marks the start of an mRNA message

- Translation can be divided into the same three phases as transcription:
  1. initiation,
  2. elongation,
  3. termination.



10.13 An initiation codon marks the start of an mRNA message

- Initiation brings together
  - mRNA,
  - a tRNA bearing the first amino acid, and
  - the two subunits of a ribosome.
- Initiation occurs in two steps



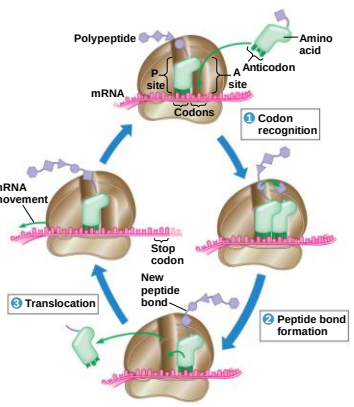
Checkpoint question What would happen if a genetic mutation in a gene changed a start codon to some other codon?

10.14 Elongation adds amino acids to the polypeptide chain until a stop codon terminates translation

- As the mRNA moves one codon at a time relative to the ribosome, a tRNA with a complementary anticodon pairs with each codon, adding its amino acid to the growing polypeptide chain.
- Elongation continues until a **stop codon** reaches the ribosome's A site.

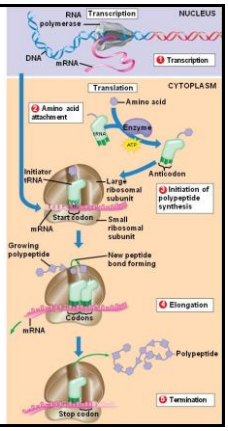
Checkpoint question What would happen if a mutation caused a codon in the middle of an mRNA to change from UUA to UAA?

Figure 10.14_4



10.15 Review: The flow of genetic information in the cell is DNA → RNA → protein

Checkpoint question
Which of the types of nucleic acids you've learned about does not participate directly in translation?

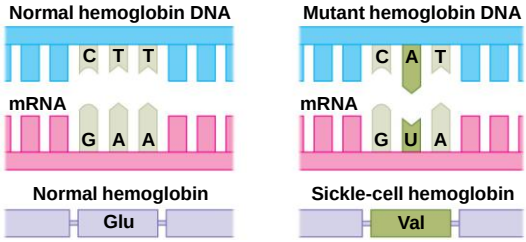


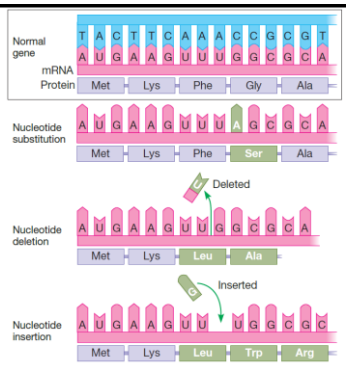
10.16 Mutations can affect genes

- **Mutations** are changes in the genetic information of a cell or virus, caused by errors in DNA replication or recombination, or by physical or chemical agents called **mutagens**.
- Substituting, inserting, or deleting nucleotides alters a gene, with varying effects.

Checkpoint question How could a single nucleotide substitution result in a shortened protein product?

Figure 10.16a





▲ **Figure 10.16B** Types of mutations and their effects. Note that mutations occur in the DNA; we show corresponding changes to the mRNA here.