Experiments showed that DNA is the genetic material

- Frederick Griffith discovered that a "transforming factor" could be transferred into a bacterial cell
  - Disease-causing bacteria were killed by heat
  - Harmless bacteria were incubated with heat-killed bacteria
  - Some harmless cells were converted to disease-causing bacteria, a process called transformation
  - The disease-causing characteristic was inherited by descendants of the transformed cells

Experiments showed that DNA is the genetic material

Alfred Hershey and Martha Chase used bacteriophages to show that DNA is the genetic material

1. **Bacteriophages** are viruses that infect bacterial cells

2. **Phages** were labeled with radioactive sulfur to detect proteins or radioactive phosphorus to detect DNA

3. Bacteria were infected with either type of labeled phage to determine which substance was injected into cells and which remained outside

4. The sulfur-labeled protein stayed with the phages outside the bacterial cell, while the phosphorus-labeled DNA was detected inside cells

5. Cells with phosphorus-labeled DNA produced new bacteriophages with radioactivity in DNA but not in protein
Review: DNA and RNA are polymers of nucleotides

- The monomer unit of DNA and RNA is the nucleotide, containing
  - Nitrogenous base
  - 5-carbon sugar
  - Phosphate group

- DNA and RNA are polymers called polynucleotides
  - A sugar-phosphate backbone is formed by covalent bonding between the phosphate of one nucleotide and the sugar of the next nucleotide
  - Nitrogenous bases extend from the sugar-phosphate backbone

Nitrogenous base (A, G, C, or T)

Sugar (deoxyribose)
Pyrimidines

Guanine (G)

Adenine (A)

Cytosine (C)

Thymine (T)

Purines

Sugar (ribose)

Uracil (U)

Nitrogenous base (A, G, C, or U)

Phosphate group

DNA is a double-stranded helix

- James D. Watson and Francis Crick deduced the secondary structure of DNA, with X-ray crystallography data from Rosalind Franklin and Maurice Wilkins
- DNA is composed of two polynucleotide chains joined together by hydrogen bonding between bases, twisted into a helical shape
  - The sugar-phosphate backbone is on the outside
  - The nitrogenous bases are perpendicular to the backbone in the interior
  - Specific pairs of bases give the helix a uniform shape
    - A pairs with T, forming two hydrogen bonds
    - G pairs with C, forming three hydrogen bonds
DNA replication depends on specific base pairing

DNA replication follows a **semiconservative model**

- The two DNA strands separate
- Each strand is used as a pattern to produce a complementary strand, using specific base pairing
- Each new DNA helix has one old strand with one new strand

DNA replication proceeds in two directions at many sites simultaneously

- DNA replication begins at the origins of replication
  - DNA unwinds at the origin to produce a “bubble”
  - Replication proceeds in both directions from the origin
  - Replication ends when products from the bubbles merge with each other
- DNA replication occurs in the **5’→3’ direction**
  - Replication is continuous on the 3’→5’ template
  - Replication is discontinuous on the 5’→3’ template, forming short segments
DNA replication proceeds in two directions at many sites simultaneously

- Proteins involved in DNA replication
  - DNA polymerase adds nucleotides to a growing chain
  - DNA ligase joins small fragments into a continuous chain

The DNA genotype is expressed as proteins, which provide the molecular basis for phenotypic traits

- A gene is a sequence of DNA that directs the synthesis of a specific protein
  - DNA is transcribed into RNA
  - RNA is translated into protein
- The presence and action of proteins determine the phenotype of an organism
- Demonstrating the connections between genes and proteins
  - The one gene–one enzyme hypothesis was based on studies of inherited metabolic diseases
  - The one gene–one protein hypothesis expands the relationship to proteins other than enzymes
  - The one gene–one polypeptide hypothesis recognizes that some proteins are composed of multiple polypeptides

THE FLOW OF GENETIC INFORMATION FROM DNA TO RNA TO PROTEIN
Genetic information written in codons is translated into amino acid sequences

- The sequence of nucleotides in DNA provides a code for constructing a protein
  - Protein construction requires a conversion of a nucleotide sequence to an amino acid sequence
  - Transcription rewrites the DNA code into RNA, using the same nucleotide "language"
  - Each "word" is a codon, consisting of three nucleotides
  - Translation involves switching from the nucleotide "language" to amino acid "language"
  - Each amino acid is specified by a codon
    - 64 codons are possible
    - Some amino acids have more than one possible codon
Transcription produces genetic messages in the form of RNA

- Overview of transcription
  - The two DNA strands separate
  - One strand is used as a pattern to produce an RNA chain, using specific base pairing
    - For A in DNA, U is placed in RNA
  - RNA polymerase catalyzes the reaction

Transfer RNA molecules serve as interpreters during translation

- **Transfer RNA (tRNA) molecules match an amino acid to its corresponding mRNA codon**
  - tRNA structure allows it to convert one language to the other
    - An amino acid attachment site allows each tRNA to carry a specific amino acid
    - An **anticodon** allows the tRNA to bind to a specific mRNA codon, complementary in sequence
      - A pairs with U, G pairs with C

Ribosomes build polypeptides

- Translation occurs on the surface of the ribosome
  - Ribosomes have two subunits: small and large
  - Each subunit is composed of ribosomal RNAs and proteins
  - Ribosomal subunits come together during translation
  - Ribosomes have binding sites for mRNA and tRNAs
Review: The flow of genetic information in the cell is DNA → RNA → protein

- Does translation represent:
  - DNA → RNA or RNA → protein?

- Where does the information for producing a protein originate:
  - DNA or RNA?

- Which one has a linear sequence of codons:
  - rRNA, mRNA, or tRNA?

- Which one directly influences the phenotype:
  - DNA, RNA, or protein?
Mutations can change the meaning of genes

- **A mutation** is a change in the nucleotide sequence of DNA
  - Base substitutions: replacement of one nucleotide with another
    - Effect depends on whether there is an amino acid change that alters the function of the protein
  - Deletions or insertions
    - Alter the reading frame of the mRNA, so that nucleotides are grouped into different codons
    - Lead to significant changes in amino acid sequence downstream of mutation
    - Cause a nonfunctional polypeptide to be produced

Mutations can be
- Spontaneous: due to errors in DNA replication or recombination
- Induced by mutagens
  - High-energy radiation
  - Chemicals

Normal hemoglobin DNA  Mutant hemoglobin DNA

Viral DNA may become part of the host chromosome
- Viruses have two types of reproductive cycles
  - **Lytic cycle**
    - Viral particles are produced using host cell components
    - The host cell lyses, and viruses are released
  - **Lysogenic cycle**
    - Viral DNA is inserted into the host chromosome by recombination
    - Viral DNA is duplicated along with the host chromosome during each cell division
    - The inserted phage DNA is called a **prophage**
    - Most prophage genes are inactive
    - Environmental signals can cause a switch to the lytic cycle
Many viruses cause disease in animals and plants

- Both DNA viruses and RNA viruses cause disease in animals
- Some animal viruses reproduce in the cell nucleus
- Most plant viruses are RNA viruses
  - They breach the outer protective layer of the plant
  - They spread from cell to cell through plasmodesmata
  - Infection can spread to other plants by animals, humans, or farming practices

EVOLUTION CONNECTION: Emerging viruses threaten human health

- How do emerging viruses cause human diseases?
  - Mutation
    - RNA viruses mutate rapidly
  - Contact between species
    - Viruses from other animals spread to humans
    - Spread from isolated populations
- Examples of emerging viruses
  - HIV
  - Ebola virus
  - West Nile virus
  - RNA coronavirus causing severe acute respiratory syndrome (SARS)
  - Avian flu virus
The AIDS virus makes DNA on an RNA template

- **AIDS** is caused by **HIV**, human immunodeficiency virus
- HIV is a **retrovirus**, containing
  - Two copies of its RNA genome
  - **Reverse transcriptase**, an enzyme that produces DNA from an RNA template

Viroids and prions are formidable pathogens in plants and animals

- Some infectious agents are made only of RNA or protein
  - **Viroids**: circular RNA molecules that infect plants
    - Replicate within host cells without producing proteins
    - Interfere with plant growth
  - **Prions**: infectious proteins that cause brain diseases in animals
    - Misfolded forms of normal brain proteins
    - Convert normal protein to misfolded form

10.22 Bacteria can transfer DNA in three ways

- Three mechanisms allow transfer of bacterial DNA
  - **Transformation** is the uptake of DNA from the surrounding environment
  - **Transduction** is gene transfer through bacteriophages
  - **Conjugation** is the transfer of DNA from a donor to a recipient bacterial cell through a cytoplasmic bridge
- Recombination of the transferred DNA with the host bacterial chromosome leads to new combinations of genes
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<tr>
<td>1. Compare and contrast the structures of DNA and RNA</td>
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<td>2. Describe how DNA replicates</td>
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<td>3. Explain how a protein is produced</td>
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<td>4. Distinguish between the functions of mRNA, tRNA, and rRNA in translation</td>
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<td>5. Determine DNA, RNA, and protein sequences when given any complementary sequence</td>
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<td>6. Distinguish between exons and introns and describe the steps in RNA processing that lead to a mature mRNA</td>
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<td>7. Explain the relationship between DNA genotype and the action of proteins in influencing phenotype</td>
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<td>8. Distinguish between the effects of base substitution and insertion or deletion mutations</td>
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<td>9. Distinguish between lytic and lysogenic viral reproductive cycles and describe how RNA viruses are duplicated within a host cell</td>
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<td>10. Explain how an emerging virus can become a threat to human health</td>
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<td>11. Identify three methods of transfer for bacterial genes</td>
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<td>12. Distinguish between viroids and prions</td>
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<td>13. Describe the effects of transferring plasmids from donor to recipient cells</td>
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