MS Cell Division, Reproduction, and Protein Synthesis

Jean Brainard, Ph.D.

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AUTHOR
Jean Brainard, Ph.D.

EDITOR
Douglas Wilkin, Ph.D.

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Printed: March 8, 2015

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CHAPTER 1 MS Cell Division, Reproduction, and Protein Synthesis

CHAPTER OUTLINE

This baby boy is just a few days old, but his body already consists of billions of cells. By the time he's as big as his father, his body will contain trillions of cells. Like all other organisms, the baby actually started out in life as a single cell. How do we develop from a single cell into an organism with trillions of cells? The answer is cell division.

1.1 Cell Division

Lesson Objectives

- Outline the process of DNA replication.
- Compare and contrast cell division in prokaryotic and eukaryotic cells.
- Describe the four phases of mitosis in eukaryotic cells.
- Identify the stages of the cell cycle in prokaryotic and eukaryotic cells.

Lesson Vocabulary

- anaphase
- binary fission
- cell cycle
- cell division
- chromosome
- cytokinesis
- DNA (deoxyribonucleic acid)
- DNA replication
- interphase
- metaphase
- mitosis
- prophase
- telophase

Introduction

Cell division is the process in which a cell divides to form two new cells. The original cell is called the parent cell. The two new cells are called daughter cells. All cells contain DNA. DNA is the nucleic acid that stores genetic information. Before a cell divides its DNA must be copied. That way, each daughter cell gets a complete copy of the parent cell's genetic material.

Copying DNA

DNA stands for deoxyribonucleic acid. It is a very large molecule. It consists of two strands of smaller molecules called nucleotides. Before learning how DNA is copied, it's a good idea to review its structure.

DNA Structure

As you can see in **Figure** 1.1, each nucleotide includes a sugar, a phosphate, and a nitrogen base. The sugar in DNA is called deoxyribose. There are four different nitrogen bases in DNA: adenine (A), thymine (T), cytosine (C), and guanine (G). Chemical bonds between the bases hold the two strands of DNA together. Adenine always bonds with thymine, and cytosine always bonds with guanine. These pairs of bases are called complementary base pairs.

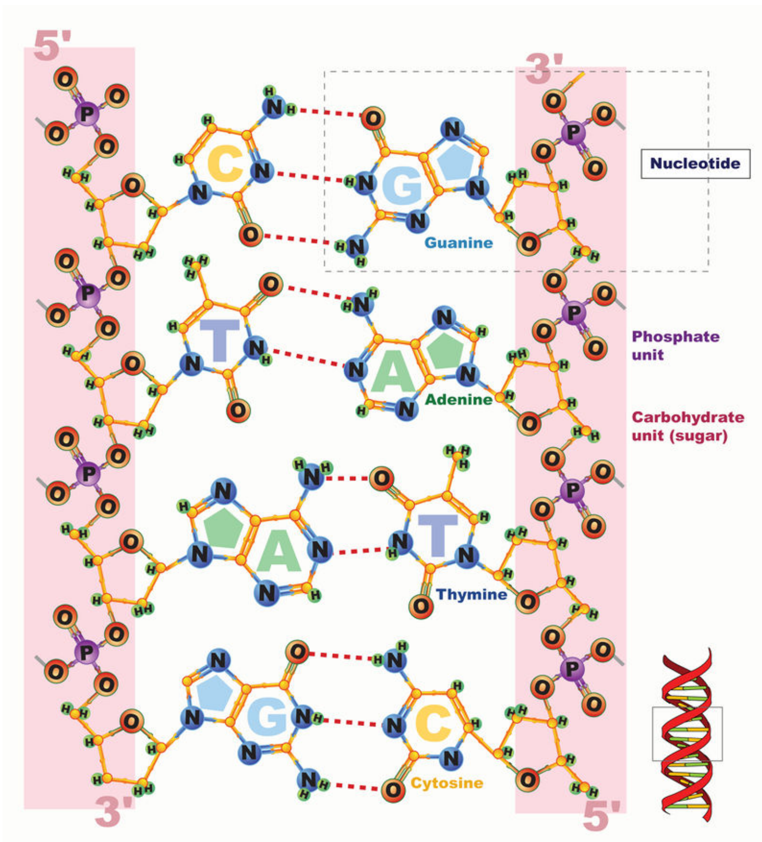


FIGURE 1.1
Structure of DNA

Chromosomes

As a cell prepares to divide, its DNA first forms one or more structures called chromosomes. A **chromosome** consists of DNA and protein molecules coiled into a definite shape. Chromosomes are circular in prokaryotes and rodlike in eukaryotes. You can see an example of a human chromosome in **Figure** below. The rest of the time, DNA looks like a tangled mass of strings. In this form, it would be very difficult to copy and divide.

DNA Replication

The process in which DNA is copied is called **DNA replication**. You can see how it happens in **Figure** 1.3. An enzyme breaks the bonds between the two DNA strands. Another enzyme pairs new, complementary nucleotides with those in the original chains. Two daughter DNA molecules form. Each contains one new chain and one original chain.

FIGURE 1.2
Human chromosome

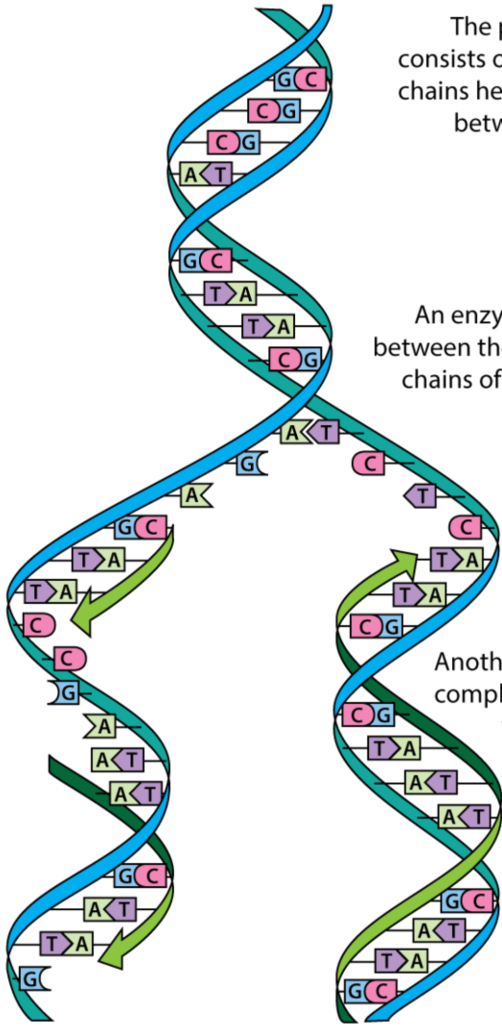


FIGURE 1.3
DNA replication

Cell Division in Prokaryotic and Eukaryotic Cells

How cell division proceeds depends on whether a cell has a nucleus. Prokaryotic cells lack a nucleus. Their DNA is in the cytoplasm. It forms just one circular chromosome. Eukaryotic cells have a nucleus holding their DNA. Their DNA forms multiple rodlike chromosomes, like the one in Figure 5.2. Eukaryotic cells also have other organelles. For these reasons, cell division is more complex in eukaryotic cells.

Prokaryotic Cell Division

You can see how a prokaryotic cell divides in **Figure** 1.4. This type of cell division is called binary fission. The cell simply splits into two equal halves. Binary fission occurs in bacteria and other prokaryotes. It takes place in three continuous steps:

1. The cell's chromosome is copied to form two identical chromosomes. This is DNA replication.
2. The copies of the chromosome separate from each other. They move to opposite poles, or ends, of the cell. This is called chromosome segregation.

3. The cell wall grows toward the center of the cell. The cytoplasm splits apart, and the cell pinches in two. This is called **cytokinesis**.

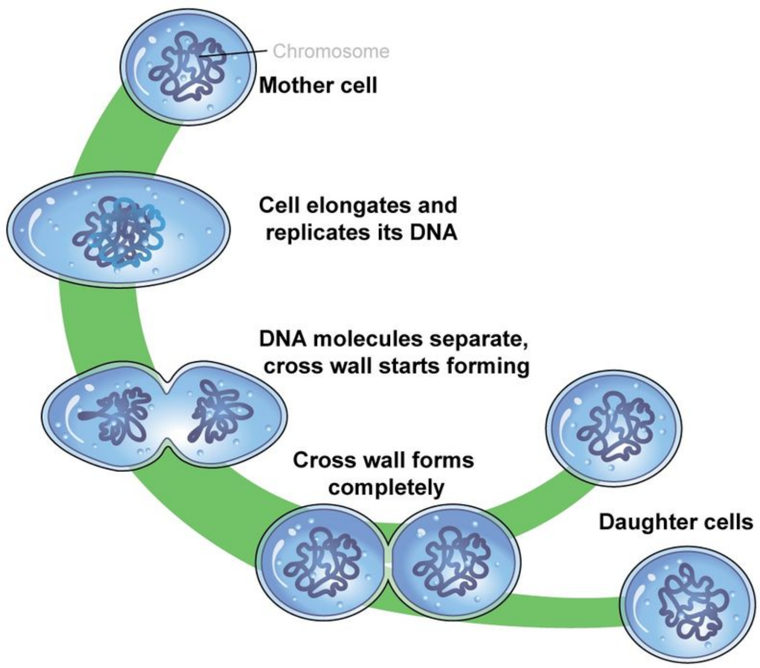


FIGURE 1.4
Binary fission in a prokaryotic cell

Eukaryotic Cell Division

Before a eukaryotic cell divides, the nucleus and other organelles must be copied. Only then will each daughter cell have all the needed structures.

1. The first step in eukaryotic cell division, as it is in prokaryotic cell division, is DNA replication. As you can see in **Figure** 1.5, each chromosome then consists of two identical copies. The two copies are called sister chromatids. They are attached to each other at a point called the centromere.

2. The second step in eukaryotic cell division is division of the cell's nucleus. This includes division of the chromosomes. This step is called mitosis. It is a complex process that occurs in four phases. The phases of mitosis are described below.

3. The third step is the division of the rest of the cell. This is called cytokinesis, as it is in a prokaryotic cell. During this step, the cytoplasm divides, and two daughter cells form.

These three steps are shown in **Figure** 1.6.

Mitosis

Mitosis, or division of the nucleus, occurs only in eukaryotic cells. By the time mitosis occurs, the cell's DNA has already replicated. Mitosis occurs in four phases, called prophase, metaphase, anaphase, and telophase. You can see what happens in each phase in **Figure** below. The phases are described below. You can also learn more about the phases of mitosis by watching this video: https://www.youtube.com/watch?v=gwcwSZIfKlM .

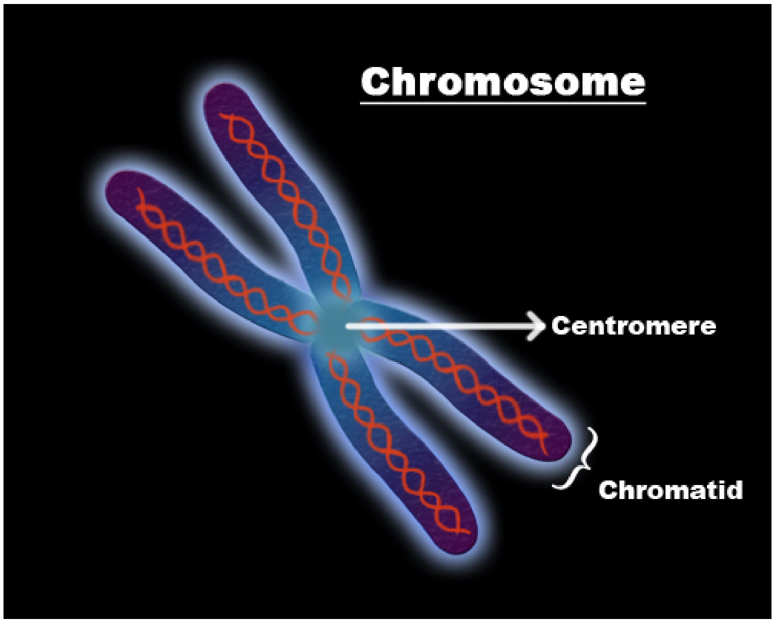


FIGURE 1.5

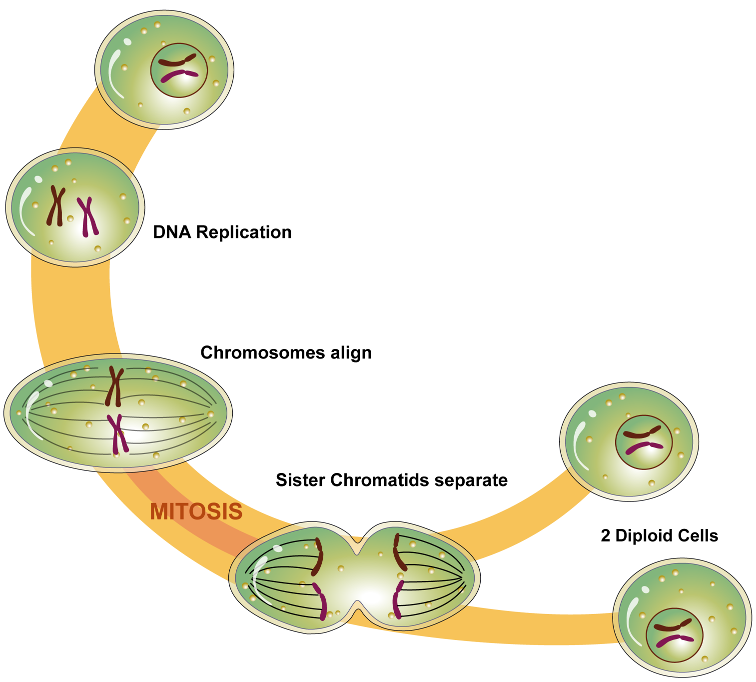
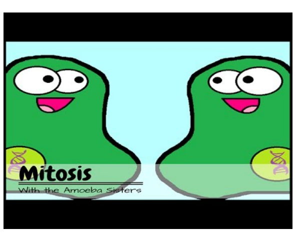


FIGURE 1.6
Cell division in a eukaryotic cell



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Phases of mitosis

1. **Prophase**: Chromosomes form, and the nuclear membrane breaks down. In animal cells, the centrioles near the nucleus move to opposite poles of the cell. Fibers called spindles form between the centrioles.
2. **Metaphase**: Spindle fibers attach to the centromeres of the sister chromatids. The sister chromatids line up at the center of the cell.
3. **Anaphase**: Spindle fibers shorten, pulling the sister chromatids toward the opposite poles of the cell. This gives each pole a complete set of chromosomes.
4. **Telophase**: The chromosomes uncoil, and the spindle fibers break down. New nuclear membranes form.

The Cell Cycle

Cell division is just one of the stages that a cell goes through during its lifetime. All of the stages that a cell goes through make up the **cell cycle**.

Prokaryotic Cell Cycle

The cell cycle of a prokaryotic cell is simple. The cell grows in size, its DNA replicates, and the cell divides.

Eukaryotic Cell Cycle

In eukaryotes, the cell cycle is more complicated. The diagram in **Figure** 1.7 shows the stages that a eukaryotic cell goes through in its lifetime. There are two main stages: interphase and mitotic phase. They are described below. You can watch a eukaryotic cell going through the phases of the cell cycle at this link: http://www.cellsalive.com/cell_cycle.htm

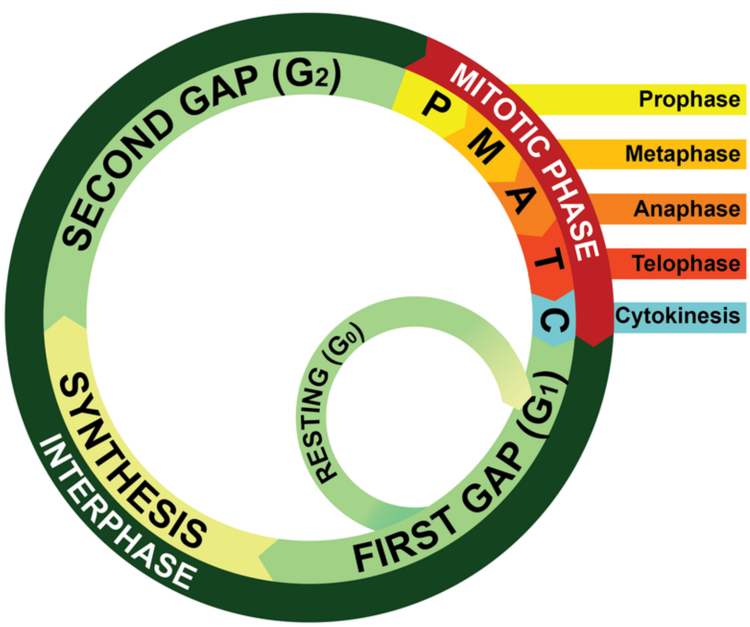


FIGURE 1.7
Eukaryotic cell cycle

Interphase is longer than mitotic phase. Interphase, in turn, is divided into three phases:

1. Growth phase 1 (G1): The cell grows rapidly. It also carries out basic cell functions. It makes proteins needed for DNA replication and copies some of its organelles. A cell usually spends most of its lifetime in this phase.
2. Synthesis phase (S): The cell copies its DNA. This is DNA replication.
3. Growth phase 2 (G2): The cell gets ready to divide. It makes more proteins and copies the rest of its organelles.

Mitotic phase is when the cell divides. It includes mitosis (M) and cytokinesis (C).

Lesson Summary

- DNA is the nucleic acid that stores genetic information. It must be copied before a cell divides. DNA replication is the process in which DNA is copied.
- Cell division is the process in which a parent cell divides to form two daughter cells. It occurs by binary fusion in most prokaryotic cells. It is more complex in eukaryotic cells.
- Mitosis is the process by which the nucleus of a eukaryotic cell divides. It happens in four phases: prophase, metaphase, anaphase, and telophase.
- Cell division is just one stage of the cell cycle. The cell cycle includes all of the stages in the life of a cell. The cell cycle is more complex in eukaryotic than prokaryotic cells.

Lesson Review Questions

Recall

1. What is DNA replication? When and why does it occur?
2. What are chromosomes? When do chromosomes form?
3. Identify the steps of cell division in a prokaryotic cell.
4. List the phases of mitosis and what happens during each phase.

Apply Concepts

5. A single-celled organism belongs to the Eukarya Domain. Apply lesson concepts to describe how the organism's cells divide.

Think Critically

6. Explain why cell division is more complicated in eukaryotic than prokaryotic cells.
7. Compare and contrast the cell cycles of prokaryotic and eukaryotic cells.

Points to Consider

Cell division is how organisms grow and replace worn out or damaged cells. It's also how they produce offspring. Producing offspring is known as reproduction.

- How do you think prokaryotes reproduce?
- How do you think multicellular eukaryotes reproduce?

1.2 Reproduction

Lesson Objectives

- Identify three methods of asexual reproduction.
- Give an overview of sexual reproduction.
- Explain how meiosis produces haploid gametes.
- State advantages of asexual and sexual reproduction.

Lesson Vocabulary

- asexual reproduction
- diploid
- egg
- fertilization
- gamete
- haploid
- homologous chromosomes
- meiosis
- sexual reproduction
- sperm
- zygote

Introduction

Reproduction is how organisms produce offspring. The ability to reproduce is a characteristic of all living things. In some species, all the offspring are genetically identical to the parent. In other species, each offspring is genetically unique. Look at the kittens in **Figure** 1.8. They are brothers and sisters, but they are all different from each other. Why does this happen in some species but not others? It's because there are two types of reproduction. Reproduction can be sexual or asexual.

Asexual Reproduction

Asexual reproduction is simpler than sexual reproduction. It involves just one parent. The offspring are genetically identical to each other and to the parent. All prokaryotes and some eukaryotes reproduce this way. There are several different methods of asexual reproduction. They include binary fission, fragmentation, and budding.

FIGURE 1.8
These kittens have the same parents, but each kitten is unique.

Binary Fission

Binary fission occurs when a parent cell simply splits into two daughter cells. This method is described in detail in the lesson "Cell Division." Bacteria reproduce this way. You can see a bacterial cell reproducing by binary fission in **Figure** 1.9.

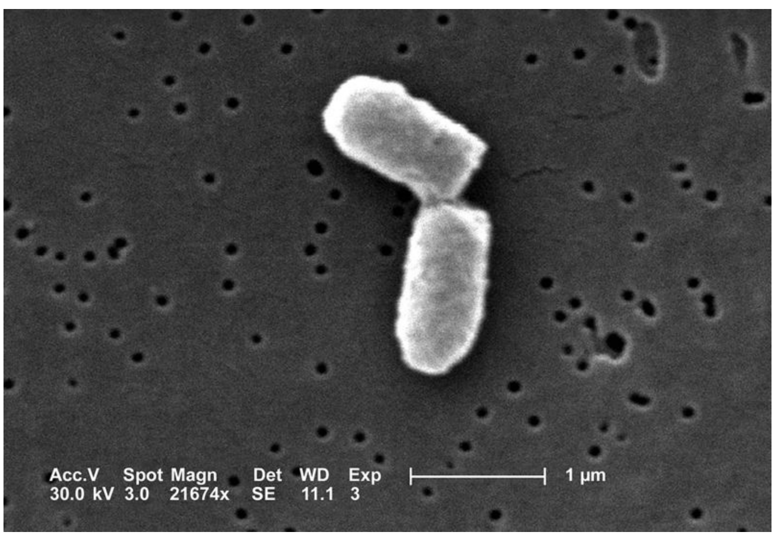


FIGURE 1.9
Binary fission in a bacterium

Fragmentation

Fragmentation occurs when a piece breaks off from a parent organism. Then the piece develops into a new organism. Sea stars, like the one in **Figure** 1.10, can reproduce this way. In fact, a new sea star can form from a single "arm."

FIGURE 1.10
A sea star can reproduce by asexually by fragmentation. It can also reproduce sexually.

Budding

Budding occurs when a parent cell forms a bubble-like bud. The bud stays attached to the parent while it grows and develops. It breaks away from the parent only after it is fully formed. Yeasts can reproduce this way. You can see two yeast cells budding in **Figure** 1.11.

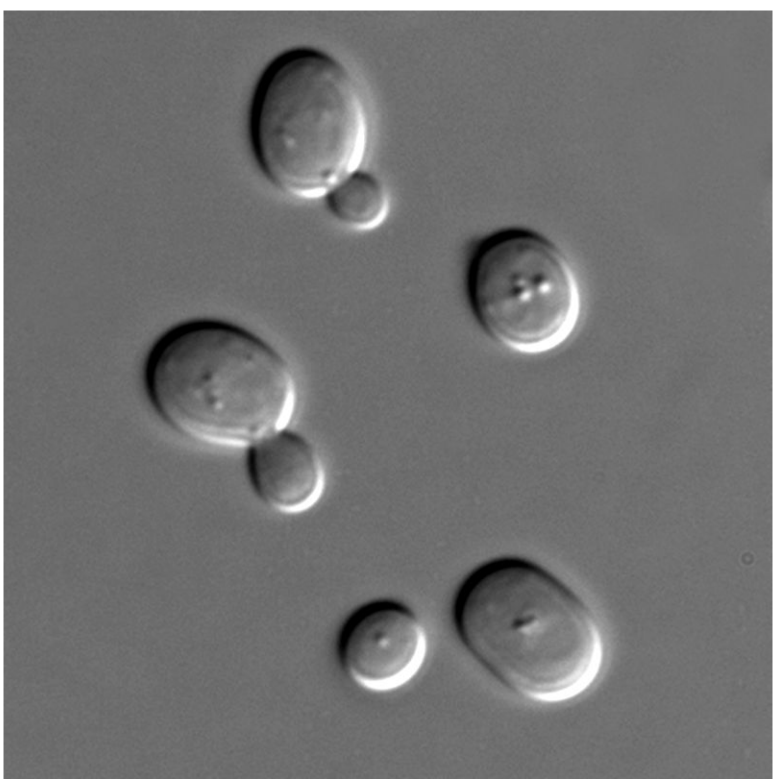


FIGURE 1.11
Budding in yeast cells

Sexual Reproduction

Sexual reproduction is more complicated. It involves two parents. Special cells called **gametes** are produced by the parents. A gamete produced by a female parent is generally called an **egg**. A gamete produced by a male parent is usually called a **sperm**. An offspring forms when two gametes unite. The union of the two gametes is called **fertilization**. You can see a human sperm and egg uniting in **Figure** 1.12. The initial cell that forms when two gametes unite is called a **zygote**.

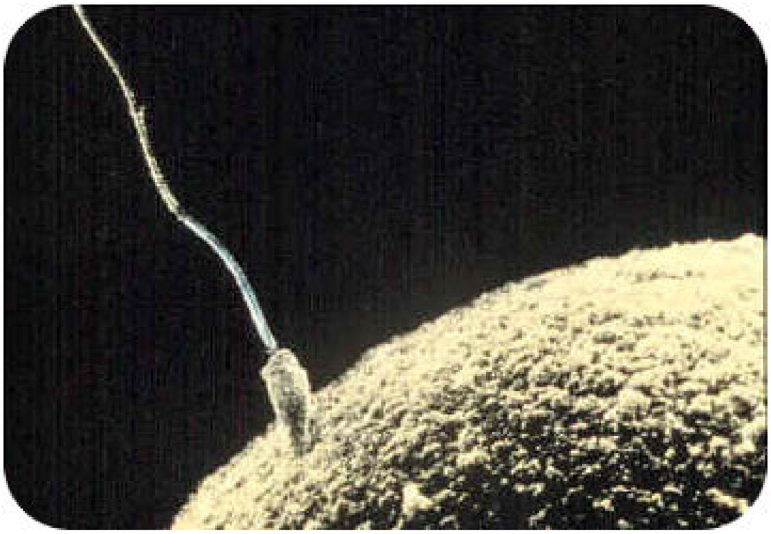


FIGURE 1.12
Fertilization: human sperm and egg

Chromosome Numbers

In species with sexual reproduction, each cell of the body has two copies of each chromosome. For example, human beings have 23 different chromosomes. Each body cell contains two of each chromosome, for a total of 46 chromosomes. You can see the 23 pairs of human chromosomes in **Figure** 1.13. The number of different types of chromosomes is called the haploid number. In humans, the haploid number is 23. The number of chromosomes in normal body cells is called the diploid number. The diploid number is twice the haploid number. In humans, the diploid number is two times 23, or 46.

Homologous Chromosomes

The two members of a given pair of chromosomes are called **homologous chromosomes**. We get one of each homologous pair, or 23 chromosomes, from our father. We get the other one of each pair, or 23 chromosomes, from our mother. A gamete must have the haploid number of chromosomes. That way, when two gametes unite, the zygote will have the diploid number. How are haploid cells produced? The answer is meiosis.

Meiosis

Meiosis is a special type of cell division. It produces haploid daughter cells. It occurs when an organism makes gametes. Meiosis is basically mitosis times two. The original diploid cell divides twice. The first time is called

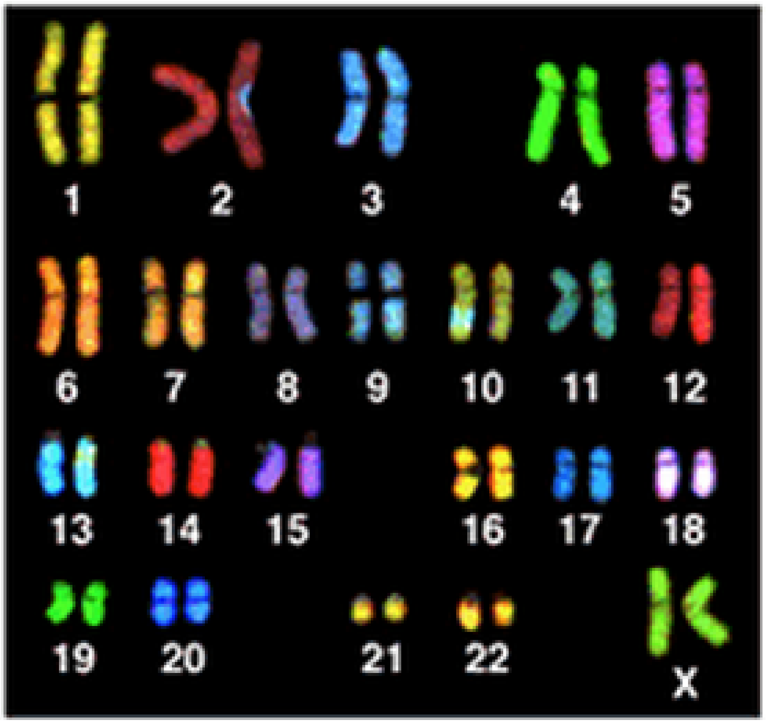
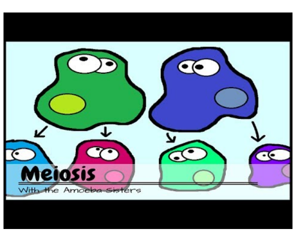


FIGURE 1.13
Humans have 23 pairs of chromosomes in each body cell

meiosis I. The second time is called meiosis II. However, the DNA replicates only once. It replicates before meiosis I but not before meiosis II. This results in four haploid daughter cells.

Meiosis I and meiosis II occurs in the same four phases as mitosis. The phases are prophase, metaphase, anaphase, and telophase. However, meiosis I has an important difference. In meiosis I, homologous chromosomes pair up and then separate. As a result, each daughter cell has only one chromosome from each homologous pair.

Figure 1.14 is a simple model of meiosis. It shows both meiosis I and II. You can read more about the stages below. You can also learn more about them by watching this video: http://www.youtube.com/watch?v=toWK0fIyFlY .



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Meiosis I

After DNA replicates during interphase, the nucleus of the cell undergoes the four phases of meiosis I:

1. Prophase I: Chromosomes form, and the nuclear membrane breaks down. Centrioles move to opposite poles of the cell. Spindle fibers form between the centrioles. *Here's what's special about meiosis*: Homologous chromosomes pair up! You can see this in **Figure** below.
2. Metaphase I: Spindle fibers attach to the centromeres of the paired homologous chromosomes. The paired chromosomes line up at the center of the cell.

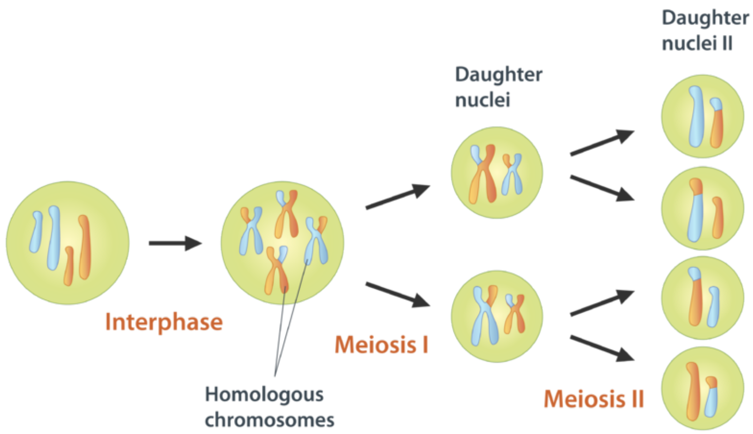


FIGURE 1.14
Meiosis occurs in two stages: meiosis I and meiosis II

3. Anaphase I: Spindle fibers shorten, pulling apart the chromosome pairs. The chromosomes are pulled toward opposite poles of the cell. One of each pair goes to one pole. The other of each pair goes to the opposite pole.
4. Telophase I: The chromosomes uncoil, and the spindle fibers break down. New nuclear membranes form.

Phases of meiosis I

Meiosis I is followed by cytokinesis. That's when the cytoplasm of the cell divides. Two haploid daughter cells result. Both of these cells go on to meiosis II.

Meiosis II

Meiosis II is just like mitosis.

1. Prophase II: Chromosomes form. The nuclear membrane breaks down. Centrioles move to opposite poles. Spindle fibers form.
2. Metaphase II: Spindle fibers attach to the centromeres of sister chromatids. Sister chromatids line up at the center of the cell.
3. Anaphase II: Spindle fibers shorten. They pull the sister chromatids to opposite poles.
4. Telophase II: The chromosomes uncoil. The spindle fibers break down. New nuclear membranes form.

Meiosis II is also followed by cytokinesis. This time, four haploid daughter cells result. That's because both daughter cells from meiosis I have gone through meiosis II. The four daughter cells must continue to develop before they become gametes. For example, in males, the cells must develop tails, among other changes, in order to become sperm.

Advantages of Sexual and Asexual Reproduction

Both types of reproduction have certain advantages.

Advantage of Asexual Reproduction

Asexual reproduction can happen very quickly. It doesn't require two parents to meet and mate. Under ideal conditions, 100 bacteria can divide to produce millions of bacteria in just a few hours! Most bacteria don't live under ideal conditions. Even so, rapid reproduction may allow asexual organisms to be very successful. They may crowd out other species that reproduce more slowly.

Advantage of Sexual Reproduction

Sexual reproduction is typically slower. However, it also has an advantage. Sexual reproduction results in offspring that are all genetically different. This can be a big plus for a species. The variation may help it adapt to changes in the environment.

How does genetic variation arise during sexual reproduction? It happens in three ways: crossing over, independent assortment, and the random union of gametes.

- Crossing over occurs during meiosis I. It happens when homologous chromosomes pair up during prophase I. The paired chromosomes exchange bits of DNA. This recombines their genetic material. You can see where crossing over has occurred in Figures 5.15 and 5.16.
- Independent assortment occurs when chromosomes go to opposite poles of the cell in anaphase I. Which chromosomes end up together at each pole is a matter of chance. You can see this in Figures 5.15 and 5.16 as well.
- In sexual reproduction, two gametes unite to produce an offspring. Which two gametes is a matter of chance. The union of gametes occurs randomly.

Due to these sources of variation, each human couple has the potential to produce more than 64 trillion unique offspring. No wonder we are all different!

Lesson Summary

- Asexual reproduction involves just one parent. It produces offspring that are genetically identical to the parent. Methods of asexual reproduction include binary fission, fragmentation, and budding.
- Sexual reproduction involves two parents. It produces offspring that are all genetically unique. It requires the production of haploid gametes. The union of gametes is called fertilization. It results in a diploid zygote.
- Haploid gametes are produced through meiosis. This is a special type of cell division. The cell divides twice, called meiosis I and meiosis II. However, the DNA replicates just once. Homologous chromosomes separate. The outcome is four haploid cells.
- Asexual reproduction has the advantage of occurring quickly. Sexual reproduction has the advantage of creating genetic variation. This can help a species adapt to environmental change. The genetic variation arises due to crossing over, independent assortment, and the random union of gametes.

Lesson Review Questions

Recall

1. What are three methods of asexual reproduction? For each method, give an example of an organism that can reproduce that way.
2. Briefly describe sexual reproduction.
3. Define haploid and diploid numbers. Which cells are haploid and which are diploid?

Apply Concepts

4. If you don't have an identical twin, how likely is it that a brother or sister would be just like you?

Think Critically

5. A single-celled organism belongs to the Eukarya Domain. Apply lesson concepts to describe how the organism divides."
6. Some organisms can reproduce sexually or asexually. Under what conditions might each type of reproduction be an advantage?

Points to Consider

All of our cells contain DNA. Meiosis ensures that each gamete receives a copy of each chromosome.

- Why do cells need DNA?
- What specific role does DNA play?

1.3 Protein Synthesis

Lesson Objectives

- Identify the structure and functions of RNA.
- Describe the genetic code and how to read it.
- Explain how proteins are made.
- List causes and effects of mutations.

Lesson Vocabulary

- codon
- genetic code
- mutagen
- mutation
- protein synthesis
- RNA (ribonucleic acid)
- transcription
- translation

Introduction

Blueprints, like those pictured in **Figure** 1.15, contain the instructions for building a house. Your cells also contain "blueprints." They are encoded in the DNA of your chromosomes.

DNA, RNA, and Proteins

DNA and RNA are nucleic acids. DNA stores genetic information. RNA helps build proteins. Proteins, in turn, determine the structure and function of all your cells. Proteins consist of chains of amino acids. A protein's structure and function depends on the sequence of its amino acids. Instructions for this sequence are encoded in DNA.

In eukaryotic cells, chromosomes are contained within the nucleus. But proteins are made in the cytoplasm at structures called ribosomes. How do the instructions in DNA reach the ribosomes in the cytoplasm? RNA is needed for this task.

Comparing RNA with DNA

RNA stands for ribonucleic acid. RNA is smaller than DNA. It can squeeze through pores in the membrane that encloses the nucleus. It copies instructions in DNA and carries them to a ribosome in the cytoplasm. Then it helps build the protein.

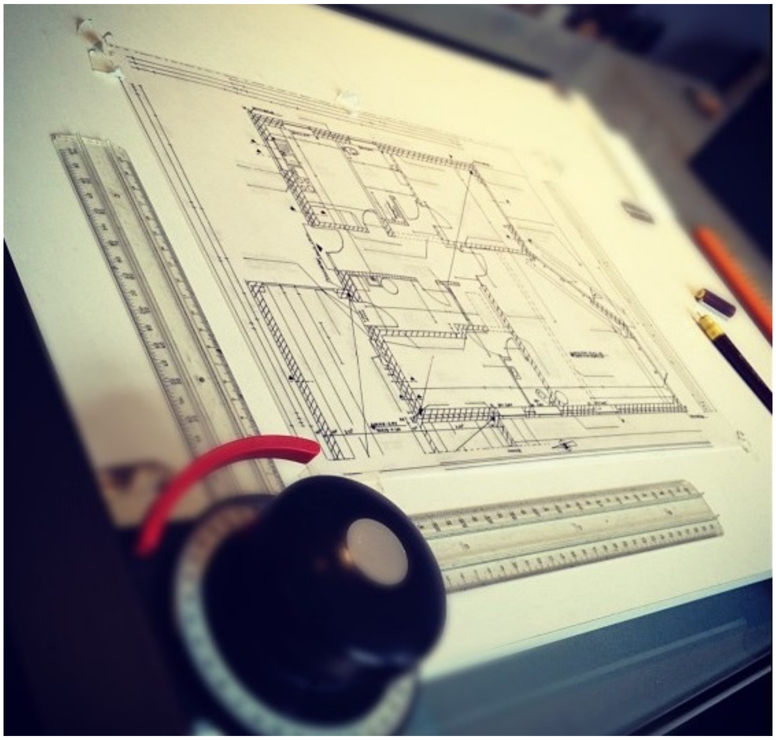


FIGURE 1.15
Blueprints for a house

RNA is not only smaller than DNA. It differs from DNA in other ways as well. It consists of one nucleotide chain rather than two chains as in DNA. It also contains the nitrogen base uracil (U) instead of thymine (T). In addition, it contains the sugar ribose instead of deoxyribose. You can see these differences in **Figure** 1.16.

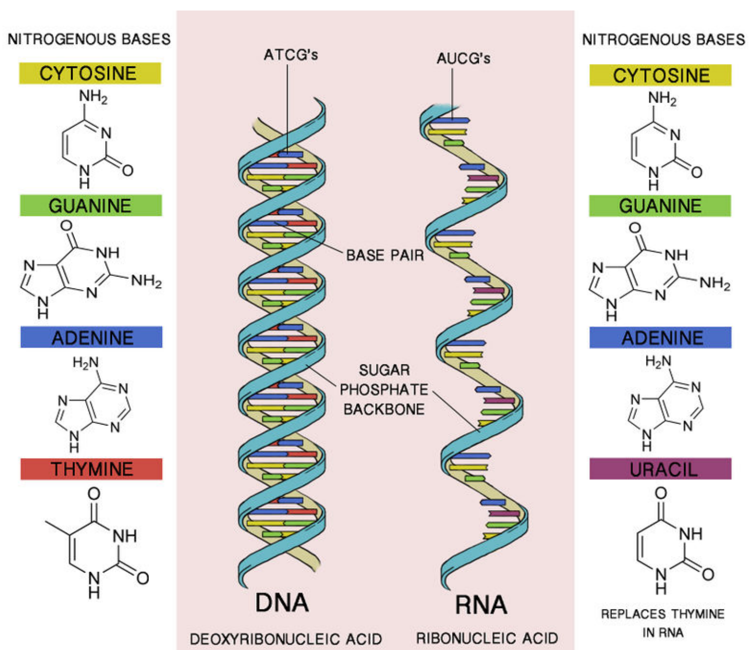


FIGURE 1.16
Comparison of RNA and DNA

Types of RNA

There are three different types of RNA. All three types are needed to make proteins.

- Messenger RNA (mRNA) copies genetic instructions from DNA in the nucleus. Then it carries the instructions to a ribosome in the cytoplasm.
- Ribosomal RNA (rRNA) helps form a ribosome. This is where the protein is made.
- Transfer RNA (tRNA) brings amino acids to the ribosome. The amino acids are then joined together to make the protein.

The Genetic Code

How is the information for making proteins encoded in DNA? The answer is the genetic code. The genetic code is based on the sequence of nitrogen bases in DNA. The four bases make up the "letters" of the code. Groups of three bases each make up code "words." These three-letter code words are called codons. Each codon stands for one amino acid or else for a start or stop signal.

There are 20 amino acids that make up proteins. With three bases per codon, there are 64 possible codons. This is more than enough to code for the 20 amino acids plus start and stop signals. You can see how to translate the genetic code in **Figure** 1.17. Start at the center of the chart for the first base of each three-base codon. Then work your way out from the center for the second and third bases.

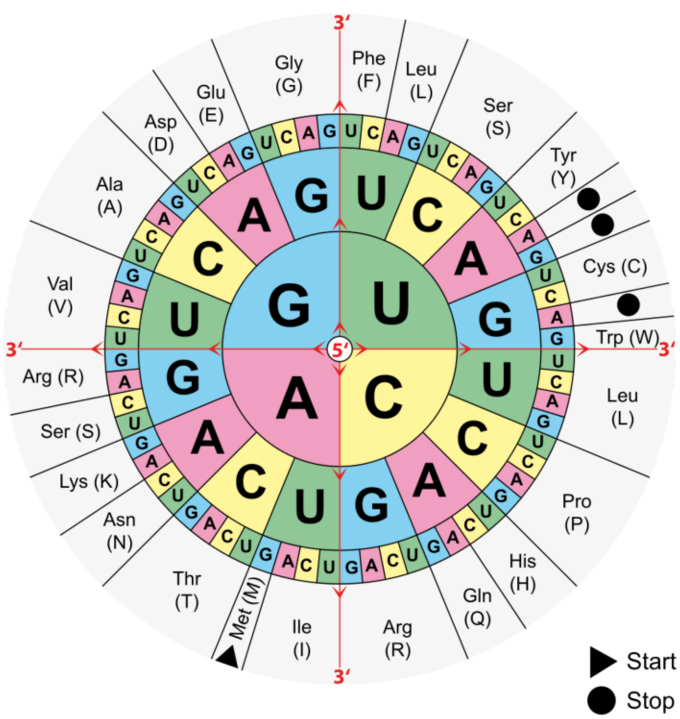


FIGURE 1.17
Translating the genetic code

Find the codon AUG in **Figure** 1.17. It codes for the amino acid methionine. It also codes for the start signal. After an AUG start codon, the next three letters are read as the second codon. The next three letters after that are read as the third codon, and so on. You can see how this works in **Figure** 1.18. The figure shows the bases in a molecule of RNA. The codons are read in sequence until a stop codon is reached. UAG, UGA, and UAA are all stop codons. They don't code for any amino acids.

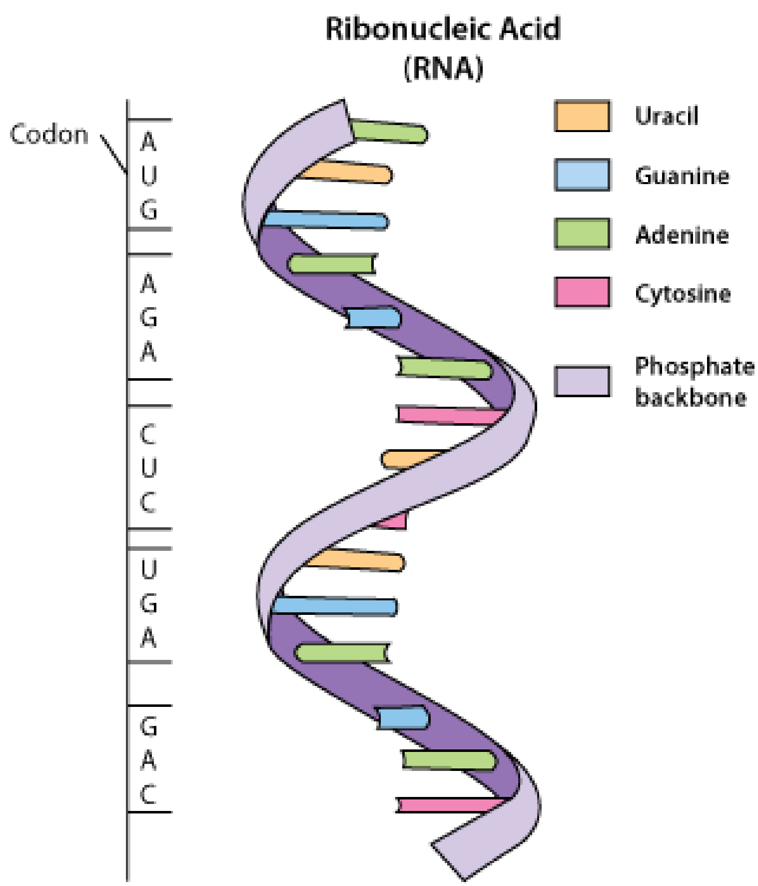


FIGURE 1.18
How the genetic code is read

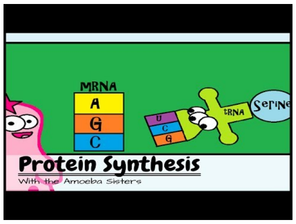
Characteristics of the Genetic Code

The genetic code has three other important characteristics.

- The genetic code is the same in all living things. This shows that all organisms are related by descent from a common ancestor.
- Each codon codes for just one amino acid (or start or stop). This is necessary so the correct amino acid is always selected.
- Most amino acids are encoded by more than one codon. This is helpful. It reduces the risk of the wrong amino acid being selected if there is a mistake in the code.

Protein Synthesis

The process in which proteins are made is called protein synthesis. It occurs in two main steps. The steps are transcription and translation. Watch this video for a good introduction to both steps of protein synthesis: http://www.youtube.com/watch?v=h5mJbP23Buo .



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Transcription: DNA → RNA

Transcription is the first step in protein synthesis. It takes place in the nucleus. During transcription, a strand of DNA is copied to make a strand of mRNA. How does this happen? It occurs by the following steps, as shown in **Figure** 1.19.

1. An enzyme binds to the DNA. It signals the DNA to unwind.
2. After the DNA unwinds, the enzyme can read the bases in one of the DNA strands.
3. Using this strand of DNA as a template, nucleotides are joined together to make a complementary strand of mRNA. The mRNA contains bases that are complementary to the bases in the DNA strand.

FIGURE 1.19

Transcription step of protein synthesis

Translation is the second step in protein synthesis. It is shown in **Figure** 1.20. Translation takes place at a ribosome in the cytoplasm. During translation, the genetic code in mRNA is read to make a protein. Here's how it works:

1. The molecule of mRNA leaves the nucleus and moves to a ribosome.
2. The ribosome consists of rRNA and proteins. It reads the sequence of codons in mRNA.
3. Molecules of tRNA bring amino acids to the ribosome in the correct sequence.
4. At the ribosome, the amino acids are joined together to form a chain of amino acids.
5. The chain of amino acids keeps growing until a stop codon is reached. Then the chain is released from the ribosome.

Causes of Mutations

Mutations have many possible causes. Some mutations occur when a mistake is made during DNA replication or transcription. Other mutations occur because of environmental factors. Anything in the environment that causes a

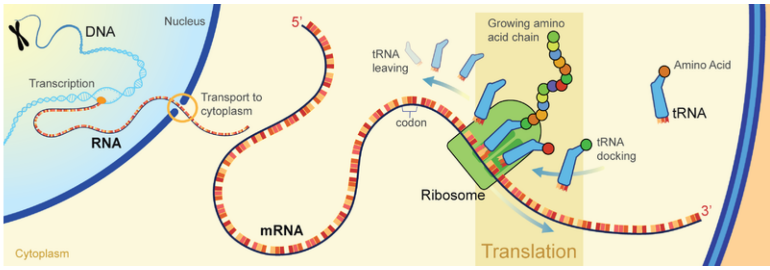

FIGURE 1.20
Translation step of protein synthesis

mutation is known as a **mutagen**. Examples of mutagens are shown in **Figure** 1.21. They include ultraviolet rays in sunlight, chemicals in cigarette smoke, and certain viruses and bacteria.

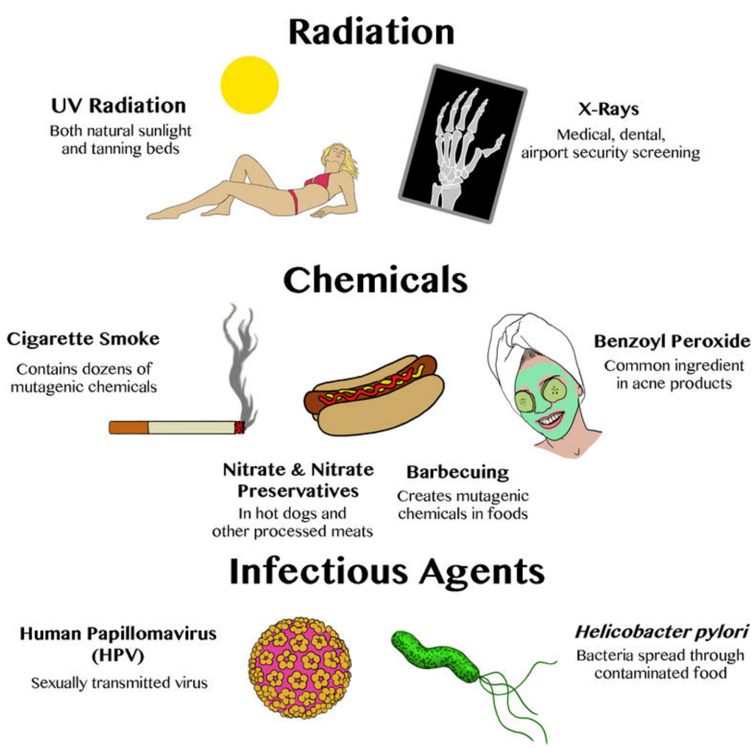

FIGURE 1.21
Examples of mutagens

Effects of Mutations

Many mutations have no effect on the proteins they encode. These mutations are considered neutral. Occasionally, a mutation may make a protein even better than it was before. Or the protein might help the organism adapt to a new environment. These mutations are considered beneficial. An example is a mutation that helps bacteria resist antibiotics. Bacteria with the mutation increase in numbers, so the mutation becomes more common. Other mutations are harmful. They may even be deadly. Harmful mutations often result in a protein that no longer can do its job. Some harmful mutations cause cancer or other genetic disorders.

Mutations also vary in their effects depending on whether they occur in gametes or in other cells of the body.

- Mutations that occur in gametes can be passed on to offspring. An offspring that inherits a mutation in a

gamete will have the mutation in all of its cells.
- Mutations that occur in body cells cannot be passed on to offspring. They are confined to just one cell and its daughter cells. These mutations may have little effect on an organism.

Types of Mutations

The effect of a mutation is likely to depend as well on the type of mutation that occurs.

- A mutation that changes all or a large part of a chromosome is called a chromosomal mutation. This type of mutation tends to be very serious. Sometimes chromosomes are missing or extra copies are present. An example is the mutation that causes Down syndrome. In this case, there is an extra copy of one of the chromosomes.
- Deleting or inserting a nitrogen base causes a frameshift mutation. All of the codons following the mutation are misread. This may be disastrous. To see why, consider this English-language analogy. Take the sentence "The big dog ate the red cat." If the second letter of "big" is deleted, then the sentence becomes: "The bgd oga tet her edc at." Deleting a single letter makes the rest of the sentence impossible to read.
- Some mutations change just one or a few bases in DNA. A change in just one base is called a point mutation. **Table** 1.1 compares different types of point mutations and their effects.

TABLE 1.1: Types of point mutations

Type	Description	Example	Effect
Silent	mutated codon codes for the same amino acid	CAA (glutamine) → CAG (glutamine)	none
Missense	mutated codon codes for a different amino acid	CAA (glutamine) → CCA (proline)	variable
Nonsense	mutated codon is a premature stop codon	CAA (glutamine) → UAA (stop)	serious

Lesson Summary

- DNA encodes instructions for proteins. RNA copies the genetic code in DNA and carries it to a ribosome. There, amino acids are joined together in the correct sequence to make a protein.
- The genetic code is based on the sequence of nitrogen bases in DNA. A code "word," or codon, consists of three bases. Each codon codes for one amino acid or for a *Protein synthesis is the process in which proteins are made. In the first step, called transcription, the genetic code in DNA is copied by RNA. In the second step, called translation, the genetic code in RNA is read to make a protein.
- A mutation is a change in the base sequence of DNA or RNA. Environmental causes of mutations are called mutagens. The effects of a mutation depend on the type of mutation and whether it occurs in a gamete or body cell.

Lesson Review Questions

Recall

1. What are three types of RNA? What role does each type play in protein synthesis?
2. Describe the genetic code and its characteristics.
3. Give an overview of the transcription step of protein synthesis. Where does it take place?
4. What is a mutation? What are some causes of mutations?

Apply Concepts

5. Use Figure 1.17 to translate the following sequence of RNA bases into a chain of amino acids: AUGUACCC-CACAGACUAA.

Think Critically

6. Compare and contrast RNA and DNA.
7. Explain what happens during the translation step of protein synthesis.
8. Why is a single base insertion or deletion likely to drastically change how the rest of the genetic code is read?

Points to Consider

Offspring generally resemble their parents. This is true even when the offspring are not genetically identical to the parents.

- Can you apply your knowledge of reproduction and protein synthesis to explain why offspring and parents have similar traits?

1.4 References

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