CHAPTER 3

Cell Structure and Function
Chapter 3 Learning Outcomes

3-1
- List the main points of the cell theory.

3-2
- Describe the functions of the plasma membrane and the structures that enable it to perform those functions.

3-3
- Describe the processes of cellular diffusion, osmosis, and filtration, and explain their physiological roles.

3-4
- Describe carrier-mediated transport and vesicular transport mechanisms, and explain their functional roles in cells.

3-5
- Describe the organelles of a typical cell and indicate their specific functions.
Chapter 3 Learning Outcomes

• 3-6
  • Explain the functions of the cell nucleus.

• 3-7
  • Summarize the process of protein synthesis.

• 3-8
  • Describe the stages of the cell life cycle, including mitosis, interphase, and cytokinesis, and explain their significance.

• 3-9
  • Discuss the relationship between cell division and cancer.

• 3-10
  • Define differentiation and explain its importance.
Cell Theory (3-1)

- Four basic concepts

1. Cells are building blocks of plants and animals
2. Cells are smallest functioning units of life
3. Cells are produced through division of preexisting cells
4. Each cell maintains homeostasis
The Study of Cells (3-1)

• **Cytology**
  • A combination of knowledge about cells from microscopic study, chemistry, and physics

• **Microscopic techniques**
  • *Light microscopy* (LM)
  • *Electron microscopy* (EM)
  • *Transmission electron microscopy* (TEM)
  • *Scanning electron microscopy* (SEM)
An Overview of Cell Anatomy (3-1)

• Cytology starts with looking at the "typical" cell and its components

• In reality, cells in the body are very diverse, each type built for a specific function

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Figure 3-1 The Diversity of Cells in the Human Body.
Checkpoint (3-1)

1. The cell theory was developed over many years. What are its four basic concepts?

2. The study of cells is called ______________.
The Plasma Membrane (3-2)

- Contains lipids, proteins, and carbohydrates
- Four key functions
  1. Provides cell with physical isolation from extracellular fluid
  2. Regulates exchange with the external environment
  3. Allows for sensitivity to the environment
  4. Provides for structural support

*ANIMATION* Membrane Transport: Cell Membrane Barrier
Figure 3-2 Anatomy of a Model Cell

- Plasma membrane
- Nonmembranous organelles
- Membranous organelles

- Secretory vesicles
- Centrioles
- Cytoskeleton
  - Microfilament
  - Microtubule
- Plasma membrane
- Cytosol
  (distributes materials by diffusion)
- Microvilli

- CYTOSOL
- NUCLEUS
- Free ribosomes
- Ribosomes

- Proteasomes
- Peroxisomes
- Lysosomes

- Cilia
- Golgi apparatus
- Mitochondria
- Endoplasmic reticulum (ER)
  - Rough ER modifies and packages newly synthesized proteins
  - Smooth ER synthesizes lipids and carbohydrates

- Chromatin
- Nuclear envelope
- Nucleolus
  (site of rRNA synthesis and assembly of ribosomal subunits)
- Nuclear pore

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Figure 3-3 The Plasma Membrane.

- **EXTRACELLULAR FLUID**
  - Carbohydrate chains
  - Phospholipid bilayer
  - Protein with channel
  - Hydrophobic tails
  - Proteins

- **CYTOPLASM**
  - Cholesterol
  - Protein with gated channel
  - Hydrophilic heads
  - Cytoskeleton

- **Plasma membrane**
Six major functions

1. Receptors
2. Channels
3. Carriers
4. Enzymes
5. Anchors
6. Identifiers
Membrane Lipids (3-2)

- Major components
  - Phospholipids with **hydrophilic** "head" facing ECF and ICF
  - **Hydrophobic** "tails" face each other
    - Creates **phospholipid bilayer**
    - Cholesterol molecules mixed in with phospholipids
  - Only lipid-soluble compounds and gases can easily cross the lipid part of membrane
<table>
<thead>
<tr>
<th>Class</th>
<th>Function</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptor proteins</td>
<td>Sensitive to specific extracellular materials that bind to them and trigger a change in a cell’s activity.</td>
<td>Binding of the hormone insulin to membrane receptors increases the rate of glucose absorption by the cell.</td>
</tr>
<tr>
<td>Channel proteins</td>
<td>Form a central pore, or channel, that permits water, ions, and other solutes to bypass lipid portion of plasma membrane.</td>
<td>Calcium ion movement through channels is crucial to muscle contraction and the conduction of nerve impulses.</td>
</tr>
<tr>
<td>Carrier proteins</td>
<td>Bind and transport solutes across the plasma membrane. This process may or may not require ATP energy.</td>
<td>Carrier proteins bring glucose into the cytoplasm and also transport sodium, potassium, and calcium ions into and out of the cell.</td>
</tr>
<tr>
<td>Enzymes</td>
<td>Catalyze reactions in the extracellular fluid or cytosol (intracellular fluid).</td>
<td>Dipeptides are broken down into amino acids by enzymes on the exposed membranes of cells lining the intestinal tract.</td>
</tr>
<tr>
<td>Anchoring proteins</td>
<td>Attach the plasma membrane to other structures and stabilize its position.</td>
<td>Inside the cell, anchor proteins bind to the cytoskeleton (network of supporting filaments). Outside the cell, anchor proteins attach the cell to extracellular protein fibers or to another cell.</td>
</tr>
<tr>
<td>Recognition proteins (Identifiers)</td>
<td>Identify a cell as self or nonself, normal or abnormal, to the immune system.</td>
<td>One group of such recognition proteins is the major histocompatibility complex (MHC) (discussed in Chapter 14).</td>
</tr>
</tbody>
</table>
Membrane Carbohydrates (3-2)

- Combine with lipids
  - To form *glycolipids*

- Combine with proteins
  - To form *glycoproteins*

- Function as lubricants and adhesives, receptors, and identifiers
3. List the general functions of the plasma membrane.

4. Which component of the plasma membrane is primarily responsible for its ability to form a physical barrier between the cell's internal and external environments?

5. Which functional class of membrane proteins allows water and small ions to pass through the plasma membrane?
Permeability (3-3)

- The property that determines what substances can cross the membrane
  - **Impermeable**
    - Nothing can cross
  - **Freely permeable**
    - Anything can cross
  - **Selectively permeable**
    - Some things can cross; others cannot
    - Describes plasma membranes
Passive Transport (3-3)

- Passive processes
  - Use kinetic energy, and proceed to equilibrium

- Active processes
  - Use cellular energy, usually ATP

- Two types of passive processes
  1. Diffusion and osmosis (a type of diffusion)
  2. Filtration
Diffusion (3-3)

• Molecules move from area of high concentration to area of low concentration
  • Or down a concentration gradient
  • Can occur in a general area or can occur across the cell membrane
Figure 3-4 Diffusion.
Diffusion across Plasma Membranes (3-3)

- Lipid-soluble molecules
  - Pass across lipid portion of membrane easily
- Non-lipid-soluble molecules
  - Can diffuse through channel proteins

ANIMATION Membrane Transport: Diffusion
Figure 3-5 Diffusion across Plasma Membranes.

**EXTRACELLULAR FLUID**

Lipid-soluble molecules diffuse through the plasma membrane.

Plasma membrane

Channel protein

Water, small water-soluble molecules and ions diffuse through membrane channels.

Large molecules that cannot diffuse through lipids cannot cross the plasma membrane unless they are transported by a carrier mechanism.

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Three characteristics of osmosis

1. Diffusion of water molecules across a selectively permeable membrane

2. Occurs across a selectively permeable membrane that is freely permeable to water, but not freely permeable to solutes

3. Water flows from low solute concentration to high solute concentration
Osmotic Pressure (3-3)

• The force of the water of one solution moving into another solution
  • Toward the higher concentration of solutes, until equilibrium is reached
Figure 3-6 Osmosis.

1. Two solutions containing different solute concentrations are separated by a selectively permeable membrane. Water molecules (small blue dots) begin to cross the membrane toward solution B, the solution with the higher concentration of solutes (large pink dots).

2. At equilibrium, the solute concentrations on the two sides of the membrane are equal. The volume of solution B has increased at the expense of that of solution A.

3. Osmosis can be prevented by resisting the change in volume. The osmotic pressure of solution B is equal to the amount of hydrostatic pressure required to stop the osmotic flow.
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Tonicity (3-3)

• The effect of solute concentrations on the shape of the cell membrane

• **Isotonic** solution

  • One that has the same concentration as the ICF
  • No net movement of water occurs
  • The cell membrane remains intact
Tonicity (3-3)

- **Hypotonic** solution
  - One whose concentration of solutes is lower than the ICF
  - Water will move into the cell, causing swelling and perhaps lysis
  - In red blood cells, this is called **hemolysis**

- **Hypertonic** solution
  - One whose concentration of solutes is greater than the ICF
  - Water will move out of the cell, causing shrinking or crenation
In an isotonic saline solution, no osmotic flow occurs, and the red blood cell appears normal.

Immersion in a hypotonic saline solution results in the osmotic flow of water into the cell. The swelling may continue until the plasma membrane ruptures, or lyses.

Exposure to a hypertonic saline solution results in the movement of water out of the cell. The red blood cells shrivel and become crenated.
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Filtration (3-3)

- Passive process
- Hydrostatic pressure forces water across a membrane
- If solute molecules are small enough to fit through membrane pores, they will be carried along with the water
6. What is meant by "selectively permeable," when referring to a plasma membrane?

7. Define diffusion.

8. How would a decrease in the concentration of oxygen in the lungs affect the diffusion of oxygen into the blood?

9. Define osmosis.

10. Relative to a surrounding hypertonic solution, the cytosol of a red blood cell is ____________.
Carrier-Mediated Transport (3-4)

• Requires membrane proteins to move substrates and ions
• Proteins show specificity
• Can be passive (no ATP required) or active (ATP dependent)
Carrier-Mediated Transport (3-4)

- **Cotransport**
  - Moves two substances in same direction

- **Countertransport**
  - Moves two substances in opposite directions

- **Examples of carrier-mediated transport:**
  - Facilitated diffusion
  - Active transport
Facilitated Diffusion (3-4)

- Uses carrier proteins to passively move larger compounds down concentration gradient
  - Compound binds to \textit{receptor site} on carrier protein
  - Protein changes shape and moves compound across membrane
  - Limited number of carriers can slow rate of diffusion
Figure 3-8 Facilitated Diffusion.

EXTRACELLULAR FLUID

Glucose molecule

Receptor site

Carrier protein

CYTOPLASM

Glucose released into cytoplasm
Active Transport (3-4)

- Requires energy from ATP
- Can move substances against concentration gradient
- **Ion pumps** carry essential ions to one side of a membrane from the other
- **Exchange pump** is an ATP-driven countertransport mechanism
  - Best example is sodium–potassium exchange pump
Figure 3-9 The Sodium–Potassium Exchange Pump.

The Sodium–potassium exchange pump

- **EXTRACELLULAR FLUID**
  - 3 Na⁺

- **CYTOPLASM**
  - 2 K⁺
  - ATP
  - ADP
Vesicular Transport (3-4)

- Moves larger amounts of materials into or out of cell in small membrane sacs called vesicles

- Two major categories
  1. Endocytosis
  2. Exocytosis
Endocytosis (3-4)

• Requires cellular energy, usually ATP

• Packages extracellular material in vesicles at cell surface and moves them into the cell

• Three key types

1. Receptor-mediated endocytosis

2. Pinocytosis

3. Phagocytosis
Figure 3-10 Receptor-Mediated Endocytosis.

1. Target molecules (ligands) bind to receptors in plasma membrane.
2. Areas coated with ligands form deep pockets in membrane surface.
3. Pockets pinch off, forming coated vesicles.
4. Coated vesicles fuse with lysosomes.
5. Ligands are removed and absorbed into the cytoplasm.
6. The membrane with receptor molecules detaches from the lysosome.
7. The vesicle fuses with the plasma membrane, and the receptors may again bind ligands.
A phagocytic cell contacts a foreign object and sends pseudopodia (cytoplasmic extensions) around it.

The pseudopodia fuse to form a vesicle that traps the object and moves into the cytoplasm.

Lysosomes fuse with the vesicle.

This fusion activates digestive enzymes that break down the structure of the foreign object.

Nutrients are absorbed from the vesicle.

Any residue is ejected from the cell by exocytosis.
Exocytosis (3-4)

- Reverse of endocytosis
- Moving material out of the cell by packaging substances in a vesicle that merges with the membrane
- Requires cellular energy, usually ATP
11. What is the difference between active and passive transport processes?

12. During digestion, the concentration of hydrogen ions ($H^+$) in the stomach rises to many times that within the cells lining the stomach, where $H^+$ are produced. Is the type of transport process involved passive or active?

13. When certain types of white blood cells encounter bacteria, they are able to engulf them and bring them into the cell. What is this process called?
Cytosol and Organelles (3-5)

• **Cytoplasm**
  
  • Is found in the cell and contains *cytosol* and *organelles*
The Cytosol (3-5)

• Is the *intracellular fluid* (ICF)
  • Is higher in $K^+$ and lower in $Na^+$ than the ECF
  • Dissolved proteins include enzymes and other proteins that "thicken" the cytosol
  • Usually contains nutrient molecules for energy production
  • **Inclusions** contain insoluble stored nutrients
The Organelles (3-5)

- Membrane-enclosed organelles are isolated from the cytosol
  - Allow storage and manufacturing of substances
- Nonmembranous organelles provide structure and "tools" for cells to do their work
Cytoskeleton (3-5)

- Threadlike filaments and hollow tubules made of protein giving strength and flexibility
- Most important cytoskeletal elements in most cells
  - Microfilaments
  - Intermediate filaments
  - Microtubules
Microvilli (3-5)

- Finger-shaped projections on exposed surface of some cells
- Provide additional surface area
- Found on cells that transport substances from ECF
Figure 3-12 The Cytoskeleton.

- Microvillus
- Microfilaments
- Plasma membrane
- Mitochondrion
- Intermediate filaments
- Endoplasmic reticulum
- Microtubule
- Secretory vesicle
Centrioles, Cilia, and Flagella (3-5)

- **Centrioles**
  - Cylindrical in shape, move DNA strands in cell division

- **Cilia**
  - Use ATP to move substances across surface of cell

- **Flagella**
  - Look like long cilia, but are used to move the cell through its environment
Ribosomes and Proteasomes (3-5)

• **Ribosomes**
  - Manufacture proteins
  - Two major types
    1. **Free ribosomes**
       - Spread throughout cytosol
    2. **Fixed ribosomes**
       - Attached to *endoplasmic reticulum* (ER)

• **Proteasomes**
  - Organelles containing protein-breaking proteolytic enzymes, or *proteases*
Endoplasmic Reticulum (3-5)

- Four key functions
  1. Synthesis of proteins, carbohydrates, and lipids
  2. Storage of materials, isolating them from the cytosol
  3. Transport of materials through the cell
  4. Detoxification of drugs or toxins
Endoplasmic Reticulum (3-5)

• Two types

1. Smooth Endoplasmic Reticulum (SER)
   • Has no ribosomes
   • Is where lipids and carbohydrates are synthesized

2. Rough Endoplasmic Reticulum (RER)
   • Has fixed ribosomes on the membrane
   • Is where proteins are synthesized
Figure 3-13 The Endoplasmic Reticulum.

Rough endoplasmic reticulum with fixed (attached) ribosomes

Smooth endoplasmic reticulum
Golgi Apparatus (3-5)

• Made of flattened membranous discs called *cisternae*

• Three major functions

  1. Modifies and packages secretions (*secretory vesicles*)
  2. Renews or modifies plasma membrane (*membrane renewal vesicles*)
  3. Packages enzymes (*lysosomes*)
Protein synthesis begins when a gene on DNA produces messenger RNA (mRNA), the template for protein synthesis. The mRNA leaves the nucleus and attaches to a free ribosome in the cytoplasm, or a fixed ribosome on the RER. Proteins constructed on free ribosomes are released into the cytoplasm for use within the cell. Protein released into cytoplasm.

When a protein is synthesized on fixed ribosomes, it is threaded into the hollow tubes of the ER where it begins to fold into its 3-dimensional shape. The proteins are then modified within the hollow tubes of the ER. A region of the ER then buds off, forming a transport vesicle containing the modified protein.

The transport vesicles move the proteins generated in the ER to the receiving face of the Golgi apparatus. The transport vesicles then fuse with the Golgi apparatus, emptying their contents into the flattened chambers called cisternae. Multiple transport vesicles combine to form cisternae on the receiving face of the Golgi apparatus. The proteins are modified within the Golgi apparatus. Enzymes modify the arriving proteins and glycoproteins. Further modification and packaging occur as the cisternae migrate toward the shipping face, which usually faces the cell surface. On the shipping side, different types of vesicles bud off with the modified proteins packaged inside. One type of vesicle becomes a lysosome, which contains digestive enzymes.

Two other types of vesicles proceed to the plasma membrane: secretory and membrane renewal. Secretory vesicles fuse with the plasma membrane and empty their products outside the cell by exocytosis. Membrane renewal vesicles add new lipids and proteins to the plasma membrane.

[Diagram and text]
Lysosomes (3-5)

- Produced by Golgi apparatus and contain digestive enzymes.
- Help with cleanup and recycling of materials within the cell.
- Help with immunity.
- Can trigger autolysis, also called cell death.
Peroxisomes (3-5)

• Formed from existing peroxisomes
• Enzymes break down fatty acids
• By-product is $\text{H}_2\text{O}_2$, a *free radical* that is highly reactive and can be destructive to cells
  • **Free radicals**
    • Ions or molecules that contain unpaired electrons
Mitochondria (3-5)

- Formed of a double membrane
  - The outer surrounds the organelle
  - The inner is folded to form the *cristae*
- Cristae increase surface area exposed to fluid *matrix*
- Site of major ATP production through *aerobic metabolism*, or *cellular respiration*
Figure 3-15 Mitochondria.

- Inner membrane
- Cytoplasm of cell
- Matrix Cristae
- Cristae
- Matrix
- Organic molecules and $O_2$
- $CO_2$
- ATP
- Mitochondrion
- TEM x 46,332
14. Describe the difference between the cytoplasm and the cytosol.

15. Identify the membranous organelles, and list their functions.

16. Cells lining the small intestine have numerous fingerlike projections on their free surface. What are these structures, and what is their function?

17. How does the absence of centrioles affect a cell?
18. Why do certain cells in the ovaries and testes contain large amounts of smooth endoplasmic reticulum (SER)?

19. What does the presence of many mitochondria imply about a cell's energy requirements?
The Nucleus (3-6)

- Largest organelle in cell that is the control center of cell
  - Dictates cell function and structure by controlling protein synthesis

- The nuclear envelope is a double membrane that surrounds the nucleus
  - Has nuclear pores that allow some movement of substances in and out of the nucleus
Nuclear Structure and Contents (3-6)

- **Nucleoli**
  - Found in most nuclei and synthesize ribosomal RNA (rRNA)

- **Chromosomes**
  - Found in the nucleus and store instructions for protein synthesis

- **Chromatin**
  - Loosely coiled DNA found in cells that are not dividing
Figure 3-16 The Nucleus.
Figure 3-17 DNA Organization and Chromosome Structure.

- Nucleus
- Cell prepared for division
- Chromosome
- Supercoiled region
- Nondividing cell
- Chromatin in nucleus
- DNA double helix
- Nucleosome
- Histones
Information Storage in the Nucleus (3-6)

- DNA strands
  - Contain the **genetic code** that dictates an organism's inherited traits
  - Genetic code is arranged in triplets
- Genes
  - Are the functional units of heredity
  - Contain all the triplets needed to produce specific proteins
20. Describe the contents and structure of the nucleus.

21. What is a gene?
DNA Control of Cell Function (3-7)

• **Protein synthesis**
  
  • Genes are tightly coiled with histones, keeping them inactive
  
  • Enzymes must break bonds and remove histone, revealing the promoter segment
  
• Two stages
  
  1. *Transcription*
  
  2. *Translation*
Transcription (3-7)

- Forms **messenger RNA (mRNA)**
  - To get DNA blueprint for protein synthesis from the nucleus out to the cytosol
Three Steps of Transcription (3-7)

1. RNA polymerase binds to promoter gene and "unzips" the DNA

2. New RNA **codon** triplets are formed, using uracil instead of thymine

3. At DNA "stop" signal, mRNA detaches and "unzipped" DNA reattaches
Figure 3-18  Transcription.

After transcription, the two DNA strands reattach.

KEY
- A = Adenine
- U = Uracil (RNA)
- G = Guanine
- T = Thymine (DNA)
- C = Cytosine
Figure 3-18 Transcription. (1 of 3)

DNA

Gene

Promoter

Triplet 1

Triplet 2

Triplet 3

Triplet 4

RNA polymerase

Complementary triplets

KEY

A  Adenine

U  Uracil (RNA)

G  Guanine

T  Thymine

C  Cytosine

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Figure 3-18 Transcription. (2 of 3)

KEY
- A = Adenine
- U = Uracil (RNA)
- G = Guanine
- T = Thymine (DNA)
- C = Cytosine

RNA nucleotide

Codon 1

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Figure 3-18  Transcription. (3 of 3)
Translation (3-7)

- Uses new mRNA codons to signal the assembly of specific amino acids in series
- mRNA leaves the nucleus and binds to a ribosome in cytoplasm
- **Transfer RNA (tRNA)** delivers amino acids to ribosomes
- Each tRNA has a complement to the codon called an **anticodon**
Five Steps of Translation (3-7)

1. "Start" codon of mRNA combines with small ribosomal subunit and first tRNA
   - Coding for methionine with the base sequence AUG

2. Small and large ribosomal subunits enclose the mRNA

3. 2nd tRNA brings another amino acid
   - Its anticodon binds to 2nd codon of mRNA
Five Steps of Translation (3-7)

4. Ribosomal enzymes remove 1st amino acid and attach it to the 2nd with a peptide bond
   • Ribosome moves along the codons repeating these steps

5. Amino acids continue to be added until ribosome reaches the "stop" codon at end of mRNA
   • Ribosome detaches leaving the strand of mRNA and a newly completed polypeptide
The mRNA strand binds to the small ribosomal subunit and is joined at the start codon by the first tRNA, which carries the amino acid methionine. Binding occurs between complementary base pairs of the codon and anticodon.

The small and large ribosomal subunits interlock around the mRNA strand.
Figure 3-19A  Translation.

3. A second tRNA arrives at the adjacent binding site of the ribosome. The anticodon of the second tRNA binds to the next mRNA codon.

4. The first amino acid is detached from its tRNA and is joined to the second amino acid by a peptide bond. The ribosome moves one codon farther along the mRNA strand; the first tRNA detaches as another tRNA arrives.

5. The chain elongates until the stop codon is reached; the components then separate.
<table>
<thead>
<tr>
<th>DNA Triplet</th>
<th>mRNA Codon</th>
<th>tRNA Anticodon</th>
<th>Amino Acid (and/or instruction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>UUU</td>
<td>AAA</td>
<td>Phenylalanine</td>
</tr>
<tr>
<td>AAT</td>
<td>UUA</td>
<td>AAU</td>
<td>Leucine</td>
</tr>
<tr>
<td>ACA</td>
<td>UGU</td>
<td>ACA</td>
<td>Cysteine</td>
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<tr>
<td>CAA</td>
<td>GUU</td>
<td>CAA</td>
<td>Valine</td>
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<tr>
<td>GGG</td>
<td>CCC</td>
<td>GGG</td>
<td>Proline</td>
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<tr>
<td>CGA</td>
<td>GCU</td>
<td>CGA</td>
<td>Alanine</td>
</tr>
<tr>
<td>TAC</td>
<td>AUG</td>
<td>UAC</td>
<td>Methionine; start codon</td>
</tr>
<tr>
<td>ATT</td>
<td>UAA</td>
<td>[none]</td>
<td>Stop codon</td>
</tr>
</tbody>
</table>

Table 3-3 Examples of the Triplet Code
22. How does the nucleus control the cell's activities?

23. What process would be affected by the lack of the enzyme RNA polymerase?

24. During the process of transcription, a nucleotide was deleted from an mRNA sequence that coded for a protein. What effect would this deletion have on the amino acid sequence of the protein?
Stages of a Cell's Life Cycle (3-8)

- **Cell division**
  - The growing of new *somatic cells* and replacing old

- **Mitosis**
  - Is the DNA replication of the genetic material in nucleus

- **Meiosis**
  - Is the production of sex cells—the sperm and ova

- **Apoptosis**
  - Is genetically controlled cell death for cells that do not divide
Interphase (3-8)

- The time a cell spends performing its function and preparing for mitosis
  - $G_1$ phase is when the cell duplicates organelles and adds cytosol
  - $S$ phase is when DNA is replicated in the nucleus
  - $G_2$ phase is when centrioles are replicated
Figure 3-20 Stages of a Cell’s Life Cycle.

**INTERPHASE**
- **G1**
  - Normal cell functions plus cell growth, duplication of organelles, protein synthesis
- **S**
  - DNA replication, synthesis of histones
- **G2**
  - Protein synthesis

8 or more hours

**THE CELL CYCLE**

6 to 8 hours

**MITOSIS AND CYTOKINESIS**

(see Fig. 3-22)
Figure 3-21  DNA Replication.

DNA polymerase

DNA nucleotide

Segment 1

Segment 2

KEY
- Adenine
- Guanine
- Cytosine
- Thymine

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Four Stages of Mitosis (3-8)

1. Prophase
2. Metaphase
3. Anaphase
4. Telophase

A&P FLIX™ Mitosis
Prophase (3-8)

- DNA has already been replicated and is coiled tightly enough to be seen under a microscope
  - Each of the two copies of DNA is called a *chromatid*, and they are connected to each other at a point called the *centromere*
  - Nucleoli then disappear, two pairs of centrioles move to opposite poles, and *spindle fibers* appear
Metaphase (3-8)

- Chromatids move to central zone called **metaphase plate**
- Chromatids line up parallel to the plate
Anaphase (3-8)

- Centromere of each chromatid splits creating daughter chromosomes
- Daughter chromosomes are pulled apart and move toward the centrioles
Telophase (3-8)

- Nuclear membranes form
  - DNA uncoils
- Cells are preparing to enter interphase again
Cytokinesis (3-8)

• Cytoplasmic division that forms two daughter cells
  • Usually begins in late anaphase
  • Continues throughout telophase
  • Is usually completed after a nuclear membrane has re-formed around each daughter nucleus
Figure 3-22A Interphase, Mitosis, and Cytokinesis.

**INTERPHASE**
- Nucleus (contains replicated DNA)
- MITOSIS BEGINS

**STAGE 1a EARLY PROPHASE**
- Centrioles (two pairs)
- Spindle fibers

**STAGE 1b LATE PROPHASE**
- Centriole
- Chromosome with two sister chromatids
- Centromeres
Figure 3-22B  Interphase, Mitosis, and Cytokinesis.

STAGE 2  METAPHASE

STAGE 3  ANAPHASE

Metaphase plate

Daughter chromosomes

Cleavage furrow

STAGE 4  TELOPHASE

INTERPHASE

Daughter cells

CYTOKINESIS
25. Give the biological terms for (a) cellular reproduction and (b) cell death.

26. Describe interphase, and identify its stages.

27. Define mitosis, and list its four stages.

28. What would happen if spindle fibers failed to form in a cell during mitosis?
Tumors (3-9)

- Are a result of abnormal cell growth and division
  - **Benign tumors**
    - Are usually encapsulated and rarely life threatening
  - **Malignant tumors**
    - Spread from original tissue capsule through a process called *invasion*
      - Having spread to other tissues and organs, the tumor has *metastasized*
Cancer (3-9)

- The result of very active malignant cells
- Stimulates additional blood vessel growth
- Triggers a positive feedback mechanism of further growth and metastasis
29. An illness characterized by mutations that disrupt normal control mechanisms and produce potentially malignant cells is termed __________.

30. Define metastasis.
Cellular Differentiation (3-10)

- All somatic cells in the body have the same chromosomes and genes
  - Yet develop to form a wide variety of cell types

- **Differentiation**
  - Occurs when specific genes are turned off, leaving the cell with limited capabilities
  - A collection of cells with specific functions is called a tissue
31. Define differentiation.