Chapter 4

Biology and Society: Antibiotics: Drugs that Target Bacterial Cells

- Antibiotics were first isolated from mold in 1928.
- The widespread use of antibiotics drastically decreased deaths from bacterial infections.

- Most antibiotics kill bacteria while minimally harming the human host by binding to structures found only on bacterial cells.
- Some antibiotics bind to the bacterial ribosome, leaving human ribosomes unaffected.
- Other antibiotics target enzymes found only in the bacterial cells.

THE MICROSCOPIC WORLD OF CELLS

- Organisms are either
  - single-celled, such as most prokaryotes and protists, or
  - multicelled, such as
    - plants,
    - animals, and
    - most fungi.

Microscopes as Windows on the World of Cells

- **Light microscopes** can be used to explore the structures and functions of cells.
- When scientists examine a specimen on a microscope slide,
  - light passes through the specimen and
  - lenses enlarge, or magnify, the image.
- The most powerful electron microscopes can
  - magnify up to 100,000 times and
  - distinguish between objects 0.2 nanometers apart.
- Light microscopes are still very useful for studying living cells.

The Two Major Categories of Cells

- The countless cells on Earth fall into two basic categories:
  - **Prokaryotic cells** — Bacteria and Archaea and
  - **Eukaryotic cells** — protists, plants, fungi, and animals.
- All cells have several basic features.
  - They are all bounded by a thin **plasma membrane**.
  - Inside all cells is a thick, jelly-like fluid called the **cytosol**, in which cellular components are suspended.
  - All cells have one or more **chromosomes** carrying genes made of DNA.
  - All cells have **ribosomes**, tiny structures that build proteins according to the instructions from the DNA.
- Prokaryotic cells are older than eukaryotic cells.
  - Prokaryotes appeared about 3.5 billion years ago.
  - Eukaryotes appeared about 2.1 billion years ago.
- Prokaryotic cells are
  - usually smaller than eukaryotic cells and

  - simpler in structure.
- Eukaryotes
  - Only eukaryotic cells have **organelles**, membrane-enclosed structures that perform specific functions.
  - The most important organelle is the **nucleus**, which
    - houses most of a eukaryotic cell's DNA and
    - is surrounded by a double membrane.
- A prokaryotic cell lacks a nucleus. Its DNA is coiled into a nucleus-like region called the **nucleoid**, which is not partitioned from the rest of the cell by membranes.

An Overview of Eukaryotic Cells

- Eukaryotic cells are fundamentally similar.
- The region between the nucleus and plasma membrane is the **cytoplasm**.
- The cytoplasm consists of various organelles suspended in the liquid cytosol.
- Unlike animal cells, plant cells have
  - chloroplasts, which convert light energy to the chemical energy of food in the process of photosynthesis, and
  - protective cell walls.
- Only animal cells have lysosomes, bubbles of digestive enzymes surrounded by membranes.

MEMBRANE STRUCTURE

- The plasma membrane separates the living cell from its nonliving surroundings.

- The remarkably thin membranes of cells are composed mostly of
  - lipids and
  - proteins.
- The lipids belong to a special category called **phospholipids**.
- Phospholipids form a two-layered membrane, the **phospholipid bilayer**.

The Process of Science:
What Makes a Superbug?

- Particularly dangerous strains of bacteria, known as MRSA, are unaffected by several common antibiotics.
- **Observation**: Some bacteria use a protein called PSM to disable human immune cells by forming holes that rip apart the plasma membrane.
- **Question**: Does PSM play a role in MRSA infections?
- **Hypothesis**: MRSA bacteria lacking the ability to produce PSM would be less deadly than normal MRSA strains.
- **Experiment**: Researchers infected
  - seven mice with normal MRSA and
  - eight mice with MRSA that does not produce PSM.
- **Results**:
  - All seven mice infected with normal MRSA died.
  - Five of the eight mice infected with MRSA that does not produce PSM

survived.

- **Conclusions**:
  - MRSA strains appear to use the membrane-destroying PSM protein, but
  - factors other than PSM protein contributed to the death of mice (possibly other membrane-destroying proteins).

Cell Surfaces

- Plant cells have rigid cell walls surrounding the membrane.
- Plant cell walls
  - are made of cellulose,
  - protect the cells,
  - maintain cell shape, and
  - keep cells from absorbing too much water.
- Animal cells
  - lack cell walls and
  - typically have an **extracellular matrix,** which
    - helps hold cells together in tissues and
    - protects and supports them.
- The surfaces of most animal cells contain **cell junctions**, structures that connect cells together into tissues, allowing them to function in a coordinated way.

THE NUCLEUS AND RIBOSOMES: GENETIC CONTROL OF THE CELL

- The nucleus is the chief executive of the cell.
  - Genes in the nucleus store information necessary to produce proteins.
  - Proteins do most of the work of the cell.

Structure and Function of the Nucleus

- The nucleus is separated from the cytoplasm by a double membrane called the **nuclear envelope**.
- Pores in the envelope allow materials to move between the nucleus and cytoplasm.
- The nucleus contains a **nucleolus** where ribosomes are made.

- Stored in the nucleus are long DNA molecules and associated proteins that form fibers called **chromatin.**
- Each long chromatin fiber constitutes one chromosome.
- The number of chromosomes in a cell depends on the species.

Ribosomes

- **Ribosomes** are responsible for protein synthesis.
- Ribosome components are made in the nucleolus but assembled in the cytoplasm.

- Ribosomes may assemble proteins while the ribosomes are
  - suspended in the fluid of the cytoplasm or
  - attached to the outside of the nucleus or an organelle called the endoplasmic reticulum.

How DNA Directs Protein Production

- DNA programs protein production in the cytoplasm by transferring its coded information into messenger RNA (mRNA).
- Messenger RNA exits the nucleus through pores in the nuclear envelope.
- A ribosome moves along the mRNA, translating the genetic message into a protein with a specific amino acid sequence.

THE ENDOMEMBRANE SYSTEM: MANUFACTURING AND DISTRIBUTING CELLULAR PRODUCTS

- Many membranous organelles forming the **endomembrane system** in a cell are interconnected either
  - directly by their membranes or
  - by transfer of membrane segments between them.

The Endoplasmic Reticulum

- The **endoplasmic reticulum (ER)** is one of the main manufacturing facilities in a cell.
- The ER
  - produces an enormous variety of molecules,
  - is connected to the nuclear envelope, and
  - is composed of smooth and rough ER.

Rough ER

- The "rough" in **rough ER** refers to ribosomes that stud the outside of this portion of the ER membrane.
- These ribosomes produce membrane proteins and secretory proteins.
- Some products manufactured by rough ER are dispatched to other locations in the cell by **transport vesicles**, sacs made of membrane that bud off from the rough ER.

Smooth ER

- The **smooth ER**
  - lacks surface ribosomes,
  - produces lipids, including steroids, and
  - helps liver cells detoxify circulating drugs.

The Golgi Apparatus

- The **Golgi apparatus**
  - works in partnership with the ER and
  - receives, refines, stores, and distributes chemical products of the cell.

Lysosomes

- A **lysosome** is a membrane-bound sac of digestive enzymes found in animal cells.
- Lysosomes are absent from most plant cells.
- Enzymes in a lysosome can break down large molecules such as
  - proteins,
  - polysaccharides,
  - fats, and
  - nucleic acids.

- Lysosomes have several types of digestive functions.
  - Many cells engulf nutrients in tiny cytoplasmic sacs called food vacuoles.
  - These food vacuoles fuse with lysosomes, exposing food to enzymes to digest the food.
  - Small molecules from digestion leave the lysosome and nourish the cell.
- Lysosomes can also
  - destroy harmful bacteria,
  - break down damaged organelles, and
  - sculpt tissues during embryonic development, helping to form structures such as fingers.

Vacuoles
- Vacuoles are large sacs of membrane that bud from the
  - ER,
  - Golgi apparatus, or
  - plasma membrane.
- Contractile vacuoles of protists pump out excess water in the cell.
- **Central vacuoles** of plants
  - store organic nutrients,
  - absorb water, and
  - may contain pigments or poisons.

CHLOROPLASTS AND MITOCHONDRIA: ENERGY CONVERSION
- Cells require a continuous energy supply to perform the work of life.
- Two organelles act as cellular power stations:
  - chloroplasts and
  - mitochondria.

Chloroplasts
- Most of the living world runs on the energy provided by photosynthesis.
- Photosynthesis is the conversion of light energy from the sun to the chemical energy of sugar and other organic molecules.
- **Chloroplasts** are
  - unique to the photosynthetic cells of plants and algae and
  - the organelles that perform photosynthesis.
- Chloroplasts are divided into three major compartments by internal membranes:
  - the space between the two membranes,
  - the **stroma**, a thick fluid within the chloroplast, and
  - the space within **grana**, membrane-enclosed discs and tubes that trap light energy and convert it to chemical energy.

Mitochondria
- **Mitochondria**
  - are the organelles of cellular respiration,
  - are found in almost all eukaryotic cells, and

- produce ATP from the energy of food molecules.

- An envelope of two membranes encloses the mitochondrion:
  - an outer smooth membrane and
  - an inner membrane that
    - has numerous infoldings called **cristae** and
    - encloses a thick fluid called the **matrix**.
- Mitochondria and chloroplasts contain their own DNA, which encodes some of their proteins.
- This DNA is evidence that mitochondria and chloroplasts evolved from free-living prokaryotes in the distant past.

THE CYTOSKELETON: CELL SHAPE AND MOVEMENT

- The **cytoskeleton** is a network of fibers extending throughout the cytoplasm.

Maintaining Cell Shape

- The cytoskeleton
  - provides mechanical support to the cell and
  - helps a cell maintain its shape.
- The cytoskeleton contains several types of fibers made from different proteins:
  - **Microtubules** are straight and hollow tubes that guide the movement of organelles and chromosomes.
  - Intermediate filaments and microfilaments are thinner and solid.
- The cytoskeleton provides anchorage and reinforcement for many organelles.
- The cytoskeleton is dynamic.
- Changes in the cytoskeleton contribute to the amoeboid (crawling) movements of
  - the protist *Amoeba* and
  - some of our white blood cells.

Cilia and Flagella

- Cilia and flagella are motile appendages that aid in movement.
  - **Flagella** propel the cell through their undulating, whiplike motion.
  - **Cilia** move in a coordinated back-and-forth motion.
  - Cilia and flagella have the same basic architecture, but cilia are generally shorter and more numerous than flagella.

Evolution Connection:
The Evolution of Antibiotic Resistance

- Many antibiotics disrupt cellular structures of invading microorganisms.
- Introduced in the 1940s, penicillin worked well against such infections.
- But over time, bacteria that were resistant to antibiotics, such as the MRSA strain, were favored.
- The widespread use and abuse of antibiotics continue to favor bacteria that resist antibiotics.