Chapter 4

A Tour of the Cell

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.

Figure 4.0
Figure 4.0a
Figure 4.0b

- 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.

Figure 4.1
Figure 4.1a
Figure 4.1b
Figure 4.1c

- 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.

Figure 4.2
Figure 4.3
Figure 4.3a
Figure 4.3b

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.

The Two Major Categories of Cells

- 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.

Figure 4.4
Figure 4.4a
Figure 4.4b

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.

Figure 4.5
Figure 4.5a
Figure 4.5b

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**.

Figure 4.6
Figure 4.6a
Figure 4.6b

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.

The Process of Science:
What Makes a Superbug?

- **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).

Figure 4.7a-1
Figure 4.7a-2
Figure 4.7a-3
Figure 4.7b

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.

Figure 4.8
Figure 4.8a
Figure 4.8b
Figure 4.8c

- 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.

Figure 4.9

Ribosomes

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

Figure 4.10

- 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.

Figure 4.11

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.

Figure 4.12-1
Figure 4.12-2
Figure 4.12-3

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.

Figure 4.13
Figure 4.13a
Figure 4.13b

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.

Figure 4.14

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.

Figure 4.15
Figure 4.15a
Figure 4.15b

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.

Figure 4.16
Figure 4.16a
Figure 4.16b
Figure 4.16c

- 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.

Figure 4.17
Figure 4.17a
Figure 4.17b

- To review, the endomembrane system interconnects the
  - nuclear envelope,

- ER,
- Golgi,
- lysosomes,
- vacuoles, and
- plasma membrane.

Figure 4.18
Figure 4.18a
Figure 4.18b

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.

Figure 4.19
Figure 4.19a
Figure 4.19b

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**.

Figure 4.20
Figure 4.20a
Figure 4.20b

- 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.

Figure 4.21
Figure 4.21a
Figure 4.21b

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.

Figure 4.22
Figure 4.22a
Figure 4.22b
Figure 4.22c

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.

Figure 4.23
Figure 4.23a
Figure 4.23b
Figure 4.UN01
Figure 4.UN02
Figure 4.UN03
Figure 4.UN04
Figure 4.UN05
Figure 4.UN06
Figure 4.UN07
Figure 4.UN08
Figure 4.UN09
Figure 4.UN10
Figure 4.UN11
Figure 4.UN12
Figure 4.UN13