Chapter 4

A Tour of the Cell

PowerPoint® Lectures for
Campbell Essential Biology, Fifth Edition, and
Campbell Essential Biology with Physiology, Fourth Edition
– Eric J. Simon, Jean L. Dickey, and Jane B. Reece

Lectures by Edward J. Zalisko
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.
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.
Microscopes as Windows on the World of Cells

• **Magnification** is an increase in the object’s image size compared to its actual size.

• **Resolving power** is the ability of an optical instrument to show two objects as separate.
• Cells were first described in 1665 by Robert Hooke.

• By the mid-1800s, the accumulation of scientific evidence led to the **cell theory**, which states that
  – all living things are composed of cells and
  – all cells come from other cells.
The electron microscope (EM) uses a beam of electrons, which results in 100-fold better resolution than light microscope.

Two kinds of electron microscopes reveal different parts of cells.

Scanning electron microscopes (SEMs) examine cell surfaces.

Transmission electron microscopes (TEMs) are useful for studying the internal structure of a cell.
Figure 4.1

<table>
<thead>
<tr>
<th>TYPES OF MICROGRAPHS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Micrograph (LM)</td>
<td>Scanning Electron Micrograph (SEM)</td>
<td>Transmission Electron Micrograph (TEM)</td>
</tr>
</tbody>
</table>

© 2013 Pearson Education, Inc.
Figure 4.1a

Light Micrograph (LM)
(for viewing living cells)

Light micrograph of a protist, *Paramecium*
Scanning Electron Micrograph (SEM) (for viewing surface features)

Scanning electron micrograph of Paramecium
Transmission electron micrograph of *Paramecium*
• 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 4.3a

- **Human height**
- **Length of some nerve and muscle cells**
- **Chicken egg**
- **Frog eggs**

**Unaided eye**

© 2013 Pearson Education, Inc.
Figure 4.3b

100 µm
- Plant and animal cells

10 µm
- Nuclei
- Most bacteria

1 µm
- Mitochondria

100 nm
- Smallest bacteria
- Viruses
- Ribosomes

10 nm
- Proteins
- Lipids

1 nm
- Small molecules

0.1 nm
- Atoms
The Two Major Categories of Cells

- The countless cells on Earth fall into two basic categories:
  1. **Prokaryotic cells** — Bacteria and Archaea and
  2. **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.
The Two Major Categories of Cells

• 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.
The Two Major Categories of Cells

- 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.
Plasma membrane (encloses cytoplasm)

Cell wall (provides rigidity)

Capsule (sticky coating)

Prokaryotic flagellum (for propulsion)

Ribosomes (synthesize proteins)

Nucleoid (contains DNA)

Pili (attachment structures)
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.
BioFlix Animation: Tour Of A Animal Cell
BioFlix Animation: Tour Of An Plant Cell
IDEALIZED ANIMAL CELL

- Ribosomes
- Centriole
- Lysosome
- Nucleus
- Plasma membrane
- Mitochondrion
- Rough ER
- Golgi apparatus
- Smooth ER

© 2013 Pearson Education, Inc.
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.
• Most membranes have specific proteins embedded in the phospholipid bilayer.

• These proteins help regulate traffic across the membrane and perform other functions.
The plasma membrane is a **fluid mosaic**.

- Fluid because molecules can move freely past one another.
- A mosaic because of the diversity of proteins in the membrane.
Figure 4.6

(a) Phospholipid bilayer of membrane

(b) Fluid mosaic model of membrane
Figure 4.6a

(a) Phospholipid bilayer of membrane

Outside of cell

Hydrophilic head

Hydrophobic tail

Phospholipid

Cytoplasm (inside of cell)
Figure 4.6b

(b) Fluid mosaic model of membrane

Outside of cell

Proteins

Hydrophilic region of protein

Hydrophilic head

Hydrophobic tail

Hydrophobic regions of protein

Cytoplasm (inside of cell)
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.
The Process of Science: What Makes a Superbug?

- **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

1. MRSA bacterium producing PSM proteins

Methicillin-resistant *Staphylococcus aureus* (MRSA)
1. MRSA bacterium producing PSM proteins

2. PSM proteins forming hole in human immune cell plasma membrane
1. MRSA bacterium producing PSM proteins

2. PSM proteins forming hole in human immune cell plasma membrane

3. Cell bursting, losing its contents through the holes
Methicillin-resistant *Staphylococcus aureus* (MRSA)
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.
Animation: Desmosomes

Right click slide / select “Play”
Animation: Gap Junctions

Right click slide / select “Play”
Animation: Tight Junctions

Right click slide / select “Play”
• 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 4.8a

- Ribosomes
- Chromatin fiber
- Nuclear envelope
- Nucleolus
- Nuclear pore

© 2013 Pearson Education, Inc.
Surface of nuclear envelope
Figure 4.8c

Nuclear pores

© 2013 Pearson Education, Inc.
• 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

DNA molecule

Chromatin fiber

Proteins

Chromosome
Ribosomes

- **Ribosomes** are responsible for protein synthesis.
- Ribosome components are made in the nucleolus but assembled in the cytoplasm.
Figure 4.10

Ribosome

mRNA

Protein

© 2013 Pearson Education, Inc.
Ribosomes

• 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

Ribosomes in cytoplasm

Ribosomes attached to 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.
Figure 4.12-1

Synthesis of mRNA in the nucleus

1. Synthesis of mRNA in the nucleus

DNA

mRNA

Nucleus

Cytoplasm
Figure 4.12-2

1. Synthesis of mRNA in the nucleus

2. Movement of mRNA into cytoplasm via nuclear pore
Figure 4.12-3

1 Synthesis of mRNA in the nucleus

2 Movement of mRNA into cytoplasm via nuclear pore

3 Synthesis of protein in the cytoplasm
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 4.13a

- Nuclear envelope
- Ribosomes
- Rough ER
- Smooth ER
Figure 4.13b

TEM

Rough ER

Ribosomes

Smooth 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.
Proteins are modified in the ER. Vesicles bud off from the ER. A ribosome links amino acids. Proteins are modified in the ER. Ribosome. Transport vesicle. Polypeptide. Protein. 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.
“Receiving” side of the Golgi apparatus

New vesicle forming

Transport vesicle from rough ER

“Shipping” side of the Golgi apparatus

Plasma membrane

© 2013 Pearson Education, Inc.
Figure 4.15a

Transport vesicle from rough ER

"Receiving" side of the Golgi apparatus

New vesicle forming

Transport vesicle from the Golgi apparatus

"Shipping" side of the Golgi apparatus

Plasma membrane

© 2013 Pearson Education, Inc.
Figure 4.15b

“Receiving” side of the Golgi apparatus

Colorized SEM

New vesicle forming
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.
Animation: Lysosome Formation
Right click slide / select “Play”
Figure 4.16

(a) A lysosome digesting food

(b) A lysosome breaking down the molecules of damaged organelles
(a) A lysosome digesting food
Figure 4.16b

(b) A lysosome breaking down the molecules of damaged organelles
Figure 4.16c

Vesicle containing two damaged organelles

Organelle fragment

TEM
Lysosomes

- 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.
Vacuoles

- **Central vacuoles** of plants
  - store organic nutrients,
  - absorb water, and
  - may contain pigments or poisons.
Video: Chlamydomonas
Video: Paramecium Vacuole
Figure 4.17

(a) Contractile vacuole in *Paramecium*

(b) Central vacuole in a plant cell
Figure 4.17a

(a) Contractile vacuole in Paramecium
(b) Central vacuole in a plant cell
Transport vesicles carry enzymes and other proteins from the rough ER to the Golgi for processing.

Lysosomes carrying digestive enzymes can fuse with other vesicles.

Vacuoles store some cell products.

New vesicle forming

Transport vesicle from the Golgi apparatus

Some products are secreted from the cell.

© 2013 Pearson Education, Inc.
Vacuoles store some cell products.

Transport vesicles carry enzymes and other proteins from the rough ER to the Golgi for processing.

Lysosomes carrying digestive enzymes can fuse with other vesicles.

Some products are secreted from the cell.
Figure 4.18b

New vesicle forming

Transport vesicle from the Golgi apparatus

Plasma membrane

Golgi apparatus
Cells require a continuous energy supply to perform the work of life.

Two organelles act as cellular power stations:

1. chloroplasts and
2. 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

- Chloroplasts are divided into three major compartments by internal membranes:
  
  1. the space between the two membranes,
  
  2. the **stroma**, a thick fluid within the chloroplast, and
  
  3. the space within **grana**, membrane-enclosed discs and tubes that trap light energy and convert it to chemical energy.
Figure 4.19

- Inner and outer membranes
- Space between membranes
- Stroma (fluid in chloroplast)
- Granum

© 2013 Pearson Education, Inc.
Figure 4.19a

Inner and outer membranes

Space between membranes

Stroma (fluid in chloroplast)

Granum
Figure 4.19b

Stroma (fluid in chloroplast)

Granum

TEM

© 2013 Pearson Education, Inc.
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:

1. an outer smooth membrane and
2. an inner membrane that
   - has numerous infoldings called *cristae* and
   - encloses a thick fluid called the *matrix*. 

Mitochondria © 2013 Pearson Education, Inc.
Blast Animation: Mitochondrion
Select “Play”
Figure 4.20b

Outer membrane

Inner membrane

Cristae

Matrix

Space between membranes

TEM
Mitochondria

- 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** 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.
Maintaining Cell Shape

- The cytoskeleton is dynamic.
- Changes in the cytoskeleton contribute to the amoeboïd (crawling) movements of
  - the protist *Amoeba* and
  - some of our white blood cells.
Figure 4.21

(a) Microtubules in the cytoskeleton

(b) Microtubules and movement
Figure 4.21a

(a) Microtubules in the cytoskeleton

© 2013 Pearson Education, Inc.
(b) Microtubules and movement
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.
Cilia and Flagella

• Cilia may extend from nonmoving cells.
• On cells lining the human trachea, cilia help sweep mucus with trapped debris out of the lungs.
Animation: Cilia and Flagella

Right click slide / select “Play”
Video: Paramecium Cilia
Figure 4.22

(a) Flagellum of a human sperm cell

(b) Cilia on a protist

(c) Cilia lining the respiratory tract
Figure 4.22a

(a) Flagellum of a human sperm cell
Figure 4.22b

(b) Cilia on a protist

Colorized SEM

© 2013 Pearson Education, Inc.
(c) Cilia lining the respiratory tract
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.

© 2013 Pearson Education, Inc.
Figure 4.23

Thanks to PENICILLIN
...He Will Come Home!

FROM ORDINARY MOLD—
the Greatest Healing
Agent of this War!

When the thousand battles of this war have subsided to pages of silent pain in a history book, the greatest news event of World War II may well be the discovery and development — not of some vicious secret weapon that destroys — but of a weapon that saves lives. That weapon, of course, is penicillin.

Every day, penicillin is performing some unbelievable act of healing on some far battlefront. Thousands of men will return home who otherwise would not have had a chance. Better still, more and more of this precious drug is now available for civilian use ... to save the lives of patients of every age.

A year ago, production of penicillin was difficult, costly. Today, due to specially-designed methods of mass-production, in use by Schenley Laboratories, Inc. and the 20 other firms designated by the government to make penicillin, it is available in increased quantities at progressively lower cost.

SCHENLEY LABORATORIES, INC.
Producers of PENICILLIN-Schenley

Short. Sniffle. Sneeze.
No Antibiotics Please.

Treat colds and flu with care.
Talk to your doctor.

As a parent, you want to help your child feel better. But antibiotics aren't always the answer. They don't fight the viruses that cause colds and flu. What will help and plenty of rest is best. Talk to your doctor. Find out when antibiotics work — and when they don't. The best care is the right care.

For more information, please call 1-888-246-2675 or visit www.cdc.gov/getsmart.
Thanks to PENICILLIN
...He Will Come Home!

FROM ORDINARY
MOLD—
the Greatest Healing
Agent of this War!

On the grayish-green and yellow mold
abode, called Penicillium notatum in the
laboratory, grows the miraculous substance
first discovered by Professor Alex-
ander Fleming in 1928. Named penicillin
by its discoverer, it is the most potent
weapon ever developed against many of
the most virulent infections known to
man. Because research on molds was already
a part of Schenley Laboratories, its produc-
tion was able to meet the needs of large-scale production of peni-
cillin, where the great need for it arose.

When the thunderous drums of this war have subsided to pages of silent print in a
history book, the greatest news items of World War II may well be the discovery and
development—not of some vicious secret weapon that(None)
— but of a weapon that
ever loses. That weapon, of course, is penicillin.

Every day, penicillin is performing some unbelievable act of healing on some far
battlefront. Thousands of men will return home who otherwise would not have had a
chance. Better still, more and more of this precious drug is now available for civilian
use—to save the lives of patients of every age.

A year ago, production of penicillin was difficult, costly. Today, due to specially-
devised methods of mass-production, in use by Schenley Laboratories, Inc. and the
20 other firms designated by the government to make penicillin, it is available in ever-
increasing quantity, at progressively lower cost.

SCHENLEY LABORATORIES, INC.

Producers of PENICILLIN-Schenley

© 2013 Pearson Education, Inc.
No Antibiotics Please.
Treat colds and flu with care.
Talk to your doctor.
As a parent, you want to help your child feel better. But antibiotics aren’t always the answer. They don’t fight the viruses that cause colds and flu. What will? Rest and plenty of rest are best. Talk to your doctor, find out when antibiotics work — and when they don’t. The best care is the right care.
For more information, please call 1-888-246-2675 or visit www.cdc.gov/getsma
Figure 4.UN01
<table>
<thead>
<tr>
<th>CATEGORIES OF CELLS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prokaryotic Cells</strong></td>
<td><strong>Eukaryotic Cells</strong></td>
</tr>
<tr>
<td>• Smaller</td>
<td>• Larger</td>
</tr>
<tr>
<td>• Simpler</td>
<td>• More complex</td>
</tr>
<tr>
<td>• Most do not have organelles</td>
<td>• Have organelles</td>
</tr>
<tr>
<td>• Found in bacteria and archaea</td>
<td>• Found in protists, plants, fungi, animals</td>
</tr>
</tbody>
</table>

© 2013 Pearson Education, Inc.
Figure 4.UN12

Outside of cell

Protein

Phospholipid

Hydrophilic

Hydrophobic

Hydrophilic

Cytoplasm (inside of cell)