Chapter 1

Introduction: Biology Today

PowerPoint® Lectures for
*Campbell Essential Biology, Fourth Edition*
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*Campbell Essential Biology with Physiology, Third Edition*
  – Eric Simon, Jane Reece, and Jean Dickey

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We are living in a golden age of biology.

Biology provides exciting breakthroughs changing our culture.

- Molecular biology is solving crimes and revealing ancestries - using DNA.
- Ecology helps us address environmental issues - BP oil spill in the Gulf.
- Neuroscience and evolutionary biology are reshaping psychology and sociology - behavior and mental health.
Biology is Everywhere!
THE SCOPE OF LIFE

The Properties of Life

• **Biology** is the scientific study of life.
  
  – Life is structured on a size scale ranging from the molecular to the global.
  
  – Biology’s scope stretches across the enormous diversity of life on Earth.
(a) Order – complex organization

(b) Regulation - homeostasis

(c) Growth and development – information in our genes

(d) Energy utilization – life needs energy

Figure 1.1a
(e) Response to the environment

(f) Reproduction – of their own kind

(g) Evolution – population change over time

Figure 1.1b
Life at Its Many Levels

- Biologists explore life at levels ranging from the biosphere to the molecules that make up cells.
Figure 1.2-3

1. Biosphere
2. Ecosystems
3. Communities
4. Populations
5. Organisms
6. Organ Systems and Organs
7. Tissues
8. Cells
9. Organelles
10. Molecules and Atoms

Atom
Nucleus

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Ecosystems

• Each organism interacts continuously with its environment.
  – Organisms interact continuously with the living and nonliving factors in the environment.
  – The interactions between organisms and their environment take place within an ecosystem.

• The dynamics of any ecosystem depend on two main processes:
  – Cycling of nutrients
  – Flow of energy
Inflow of light energy

Chemical energy \( (food) \)

Cycling of nutrients

Consumers (animals)

Producers (plants and other photosynthetic organisms)

Decomposers (in soil)

Loss of heat energy

ECOSYSTEM

Figure 1.3 
Nutrient and Energy Flow in an Ecosystem
Cells and Their DNA

• The cell is the lowest level of structure that can perform all activities required for life.
  – All organisms are composed of cells.

• We can distinguish two major types of cells:
  – Prokaryotic
  – Eukaryotic
• The **prokaryotic cell** is simpler and smaller and contains no organelles.

• Bacteria have prokaryotic cells.

• The **eukaryotic cell** is larger, more complex, and contains organelles.

• The nucleus is the largest organelle in most eukaryotic cells.

• Plants and animals are composed of eukaryotic cells.
Prokaryotic cell (bacterium)
- Smaller
- Simpler structure
- DNA concentrated in nucleoid region, which is not enclosed by membrane
- Lacks most organelles

Eukaryotic cell
- Larger
- More complex structure
- Nucleus enclosed by membrane
- Contains many types of organelles

Figure 1.4
• All cells use DNA as the chemical material of genes.
  – Genes are the units of inheritance that transmit information from parents to offspring.

• The language of DNA contains just four letters:
  – A, G, C, T

• The entire book of genetic instructions that an organism inherits is called its genome.
The four chemical building blocks of DNA

A DNA molecule

Figure 1.5
• Genetic engineering and biotechnology have allowed us to manipulate the DNA and genes of organisms.

• Bacteria can make insulin because a gene for insulin production was transplanted into their DNA.
DNA technology in the drug industry – bacteria are producing human proteins
Life in Its Diverse Forms

• Diversity is the hallmark of life.
  – The diversity of known life includes 1.8 million species.
  – Estimates of the total diversity range from 10 million to over 100 million species.
Biodiversity can be beautiful but overwhelming.

Taxonomy is the branch of biology that names and classifies species.

- It formalizes the hierarchical ordering of organisms.
A small sample of biodiversity
The Three Domains of Life

• The three domains of life are
  – Bacteria
  – Archaea
  – Eukarya
Domains **Bacteria** and **Archaea** have prokaryotic cells.
Eukarya includes

- Kingdom Plantae - multicellular
- Kingdom Fungi - multicellular
- Kingdom Animalia - multicellular
- Protists (multiple kingdoms) – single cells
These three multicellular kingdoms are distinguished by how they obtain food.

- Plants produce their own sugars and other foods by photosynthesis.
- Fungi are mostly decomposers, digesting dead organisms.
- Animals obtain food by eating and digesting other organisms.
Unity in the Diversity of Life

• Underlying the diversity of life is a striking unity, especially at the lower levels of structure.
  
  – For example, all life uses the genetic language of DNA.

• Biological evolution accounts for this combination of unity and diversity.
The history of life is a saga of a restless Earth billions of years old.

- Fossils document this history.
A paleontologist digs into the past.
• Life evolves.

  – Each species is one twig of a branching tree of life extending back over 3 billion years.

  – Species that are very similar, such as brown bears and polar bears, share a more recent common ancestor.
Ancestral bear

Common ancestor of polar bear and brown bear

Giant panda
Spectacled bear
Sloth bear
Sun bear
American black bear
Asiatic black bear
Polar bear
Brown bear

Millions of years ago

Figure 1.10
The Darwinian View of Life

• The evolutionary view of life came into focus in 1859 when Charles Darwin published *The Origin of Species*.

Darwin’s book developed two main points:

1. Descent with modification
2. Natural selection
Natural Selection

• Darwin was struck by the diversity of animals on the Galápagos Islands.

• He thought that adaptation to the environment and the origin of new species were closely related processes.
  
  – As populations separated by a geographic barrier adapted to local environments, they became separate species.
Darwin’s Inescapable Conclusion

• Darwin synthesized the theory of natural selection from two observations that were neither profound nor original.
  – Others had the pieces of the puzzle, but Darwin could see how they fit together.
• **Observation 1**: Overproduction and competition – more consumers of food than the environment can support

• **Observation 2**: Individual variation – inherited traits vary in species

• **Conclusion**: Unequal reproductive success – those with the “best” traits survive and produce more progeny
  
  – It is this unequal reproductive success that Darwin called **natural selection**.
  
  – The product of natural selection is adaptation.

• Natural selection is the mechanism of evolution.
Natural selection

Population with varied inherited traits

Elimination of individuals with certain traits

Reproduction of survivors

Increasing frequency of traits that enhance survival and reproductive success

Figure 1.12
Observing Artificial Selection

- Artificial selection is the selective breeding of domesticated plants and animals by humans.
- In artificial selection, humans do the selecting instead of the environment.
(a) Vegetables descended from wild mustard

Wild mustard

Cabbage from terminal bud
Brussels sprouts from lateral buds
Kohlrabi from stem
Kale from leaves
Broccoli from flower and stems
Cauliflower from flower clusters
(b) Domesticated dogs descended from wolves

Domesticated dogs

Gray wolves
Domesticated dogs

Figure 1.13ba
Different dog breeds descended from wolves

Gray wolves

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Observing Natural Selection

• There are many examples of natural selection in action.
  
  – Galápagos finches change beak size depending upon the size and shape of available seeds.

  – Antibiotic-resistant bacteria have evolved in response to the overuse of antibiotics.
• Darwin’s publication of *The Origin of Species* fueled an explosion in biological research.
  
  – Evolution is one of biology’s best demonstrated, most comprehensive, and longest lasting theories.
  
  – Evolution is the unifying theme of biology.
The word *science* is derived from a Latin verb meaning “to know.”

- Science is a way of knowing.
- Science developed from people’s curiosity about themselves and the world around them.
Discovery Science

• Science seeks natural causes for natural phenomena.
  – This limits the scope of science to the study of structures and processes that we can observe and measure.
• Verifiable observations and measurements are the data of discovery science.
  
  – In biology, discovery science enables us to describe life at its many levels.
Careful observation and measurement: the raw data for discovery science
Jane’s observation of the chimps recorded in her notebook
Discovery science can lead to important conclusions based on a type of logic called inductive reasoning.

- An inductive conclusion is a generalization that summarizes many concurrent observations.
Hypothesis-Driven Science

• As a formal process of inquiry, the scientific method consists of a series of steps.
  – The key element of the scientific method is hypothesis-driven science.
• A **hypothesis** is a proposed explanation for a set of observations—an idea on trial.

• Once a hypothesis is formed, an investigator can use deductive logic to test it.
  
  – In deduction, the reasoning flows from the general to the specific.
In the process of science, the deduction usually takes the form of predictions about experimental results.

– Then the hypothesis is tested by performing an experiment to see whether results are as predicted.

– This deductive reasoning takes the form of “If…then” logic.
Observation: My flashlight doesn’t work.

Question: What’s wrong with my flashlight?

Hypothesis: The flashlight’s batteries are dead.

Prediction: If I replace the batteries, the flashlight will work.
Observation: My flashlight doesn’t work.

Question: What’s wrong with my flashlight?

Hypothesis: The flashlight’s batteries are dead.

Prediction: If I replace the batteries, the flashlight will work.

Experiment: I replace the batteries with new ones.

Experiment supports hypothesis; make additional predictions and test them.
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Revise

Revise hypothesis; revise hypothesis or pose new one.

Figure 1.15-3
One way to better understand how the process of science can be applied to real-world problems is to examine a case study, an in-depth examination of an actual investigation.
• Dietary fat comes in different forms.

• Trans fat is a non-natural form produced through manufacturing processes.

• Trans fat
  – Adds texture
  – Increases shelf life
  – Is inexpensive to prepare

A study of 120,000 female nurses found that high levels of trans fat nearly doubled the risk of heart disease.
• A hypothesis-driven study published in 2004

  – Started with the **observation** that human body fat retains traces of consumed dietary fat.

  – Asked the **question**: Would the adipose tissue of heart attack patients be different from a similar group of healthy patients?

  – Formed the **hypothesis** that healthy patients’ body fat would contain less trans fat than the body fat in heart attack victims.
• The researchers set up an experiment to determine the amounts of fat in the adipose tissue of 79 patients who had a heart attack.

• They compared these patients to the data for 167 patients who had not had a heart attack.

• This is an example of a controlled experiment, in which the control and experimental groups differ only in one variable—the occurrence of a heart attack.

• The results showed significantly higher levels of trans fat in the bodies of the heart attack patients.
Heart attack patients

Control group

Trans fats in adipose tissue (g trans fat per 100 g total fat)

1.77

1.48

Figure 1.16
Theories in Science

• What is a scientific theory, and how is it different from a hypothesis?
  
  – A **theory** is much broader in scope than a **hypothesis**.
  
  – Theories only become widely accepted in science if they are supported by an accumulation of extensive and varied evidence.

• Scientific theories are not the only way of “knowing nature.”

• Science and religion are two very different ways of trying to make sense of nature.
The Culture of Science

• Scientists build on what has been learned from earlier research.
  – They pay close attention to contemporary scientists working on the same problem.

• Cooperation and competition characterize the scientific culture.
  – Scientists check the conclusions of others by attempting to repeat experiments.
Science is a social process – explaining observations, sharing knowledge
Science and technology are interdependent.

– New technologies advance science.

– Scientific discoveries lead to new technologies.

– For example, the discovery of the structure of DNA about 50 years ago led to a variety of DNA technologies.
– Technology has improved our standard of living in many ways, but it is a double-edged sword.

– Technology that keeps people healthier has enabled the human population to double to nearly 7 billion in just the past 40 years.

– The environmental consequences of this population growth may be devastating.
Examining DNA from a crime scene
Evolution Connection: Evolution in Our Everyday Lives

- Antibiotics are drugs that help fight bacterial infections.
- When an antibiotic is taken, most bacteria are typically killed.
- Those bacteria most naturally resistant to the drug can still survive.
- Those few resistant bacteria can soon multiply and become the norm and not the exception.
• The evolution of antibiotic-resistant bacteria is a huge problem in public health.

• Antibiotics are being used more selectively.

• Many farmers are reducing the use of antibiotics in animal feed.
Antibiotic resistant strains of TB. The bacteria are highlighted in red.