Chapter 1

Introduction: Biology Today

PowerPoint® Lectures for
Campbell Essential Biology, Fifth Edition, and
Campbell Essential Biology with Physiology, Fourth Edition
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Lectures by Edward J. Zalisko
We are living in a golden age of biology.

Scientists are studying a myriad of questions that are relevant to our lives.

- How can errors in cell growth lead to cancer?
- How do plants trap solar energy?
- How do living creatures form ecological networks and how do human activities disrupt them?
THE SCOPE OF LIFE
The Properties of Life

• **Biology** is the **scientific study of life**.

• The study of biology encompasses
  
  – a wide **scale of size** and
  
  – a huge **variety of life**, both past and present.
Order

Response to the environment

Evolution

Growth and development

Regulation

Energy processing

Reproduction

Reproduction
Figure 1.2-3

Life at Its Many Levels

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

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• Biologists explore life at levels ranging from the **biosphere** to the **molecules** that make up cells.

**Ecosystems**

• Each organism interacts continuously with its environment.
  
  – All the living organisms in a specific area, along with all of the nonliving factors with which they interact, form an **ecosystem**.

The **dynamics** of any ecosystem depend on two main processes:
  - recycling of chemical nutrients and
  - flow of energy.
Figure 1.3

ECOSYSTEM

Inflow of light energy

Outflow of heat energy

Producers (plants and other photosynthetic organisms)

Consumers (animals)

Decomposers (in soil)

Chemical energy (food)

Cycling of nutrients
Cells and Their DNA

- The cell is the level at which the properties of life emerge.
- Cells are the lowest level of structure that can perform all activities required for life.
- All organisms are composed of cells.

All cells are enclosed by a membrane that regulates the passage of materials between the cell and its surroundings.

Every cell uses DNA as its genetic information.
We can distinguish two major types of cells:

1. The prokaryotic cell is
   - simpler and usually smaller and
   - characteristic of bacteria.

2. The eukaryotic cell is
   - subdivided by internal membranes into different functional compartments called organelles and
   - found in plants and animals.
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

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Cells and Their DNA

- All cells use DNA as the chemical material of genes, the units of inheritance that transmit information from parents to offspring.
- The chemical language of DNA is common to all organisms.

The entire “book” of genetic instructions that an organism inherits is called its genome.
Life in Its Diverse Forms

• Diversity is a hallmark of life.
  – The diversity of known life includes about 1.8 million species that biologists have identified and named.
  – Estimates of the total number of species range from 10 million to over 100 million.
Grouping Species: The Basic Concept

• Categorizing life into groups helps us deal with its complexity.

• **Taxonomy** is the branch of biology that names and classifies species.
  
  – It formalizes the hierarchical ordering of organisms into broader and broader groups.
The Three Domains of Life

• The three **domains** of life are
  – Bacteria
  – Archaea
  – Eukarya

• Bacteria and Archaea have **prokaryotic** cells.
• Eukarya have **eukaryotic** cells.
The Three Domains of Life

- Eukarya include
  - Kingdom Plantae
  - Kingdom Fungi
  - Kingdom Animalia
  - Protists (multiple kingdoms).

- Most plants, fungi, and animals are multicellular.

- Protists are generally single-celled (unicellular).
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 **ingesting (eating)** and, after that, **digesting other organisms**.
Figure 1.8

Kingdom Plantae

Kingdom Fungi

Kingdom Animalia

Protists (multiple kingdoms)
Unity in the Diversity of Life

• Underlying the diversity of life is a striking unity, especially at the lower levels of biological organization.
  – 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 constantly changing Earth billions of years old.

- Fossils document this history.
• Life evolves.
  – Each species is one twig of a branching tree of life extending back in time through ancestral species more and more remote.
  – Species that are very similar, such as the brown bear and polar bear, share a more recent common ancestor.

The Darwinian View of Life

• The evolutionary view of life came into focus in 1859 when Charles Darwin published *On the Origin of Species by Means of Natural Selection.*
Figure 1.10

Millions of years ago

Giant panda
Common ancestor of polar bear and brown bear
Common ancestor of all modern bears
Ancestral bear

20 25 10 15 30 5

Mammals

Spectacled bear
Sloth bear
Sun bear
American black bear
Asiatic black bear
Polar bear
Brown bear
Darwin’s book developed **two main points**:

1. Species living today **descended** from a succession of ancestral species in what Darwin called “**descent with modification**,” capturing the duality of life’s
   - unity (descent) and
   - diversity (modification).

2. **Natural selection is the mechanism** for descent with modification.
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

• Observation 2: Individual variation

• Conclusion: Unequal reproductive success
  – 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.
Figure 1.12

1. Population with varied inherited traits

2. Elimination of individuals with certain traits

3. Reproduction of survivors

4. Increasing frequency of traits that enhance survival and reproductive success
Figure 1.13a

(a) Vegetables descended from wild mustard

Wild mustard

- Cabbage from end buds
- Brussels sprouts from side buds
- Kohlrabi from stems
- Kale from leaves
- Broccoli from flowers and stems
- Cauliflower from flower clusters

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.

(b) Domesticated dogs descended from wolves
Observing Natural Selection

• There are many examples of natural selection in action.
  – In Galápagos finches, beak size becomes better suited to the size and shape of available seeds.
  – Antibiotic resistance in bacteria evolves 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 PROCESS OF SCIENCE

• The word *science* is derived from a Latin verb meaning “to know.”
  – *Science* is a way of knowing, based on inquiry.
  – Science developed from our curiosity about ourselves and the world around us.

• There are **two** main scientific approaches:
  – Discovery science is mostly about describing nature.
  – Hypothesis-driven science is mostly about explaining nature.
**Discovery Science**

- Discovery science can stimulate us to ask questions and seek explanations and
- uses a process of inquiry called the **scientific method**, consisting of a series of steps that provide a loose guideline for scientific investigations.

**Hypothesis-Driven Science**

- Most modern scientific investigations can be described as **hypothesis-driven science**.
  - A **hypothesis** is a tentative answer to a question - an explanation on trial.
Once a hypothesis is formed, an investigator can use logic to test it.

- A 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: The remote doesn’t work.

Question: What’s wrong?

Hypothesis: The batteries are dead.

Prediction: With new batteries, it will work.

Experiment: Replace batteries.

Revise:

Experiment does not support hypothesis;
make more predictions and test.
The Process of Science: Are Trans Fats Bad for You?

- 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 fats are a non-natural form produced through manufacturing processes called hydrogenation.
- Trans fats
  - add texture,
  - increase shelf life, and
  - are inexpensive to prepare.

- A study of 120,000 female nurses found that a diet with high levels of trans fats 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?, and
- formed the **hypothesis** that healthy patients’ body fat would contain less trans fats 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 experienced a heart attack.

They compared these patients to the data for 167 patients who had not experienced 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 fats in the bodies of the heart attack patients.

You would do well to read nutrition labels and avoid trans fats as much as possible in your own diet.
Figure 1.16

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

Heart attack patients: 1.77
Control group: 1.48

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Theories in Science

- What is a scientific theory, and how is it different from a hypothesis?
  - A scientific **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, religion, and art are **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.
  – Scientists are generally skeptics.
Science has two key features that distinguish it from other forms of inquiry. Science

- depends on observations and measurements that others can verify and

- requires that ideas (hypotheses) are testable by experiments that others can repeat.
Science, Technology, and Society

- **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 60 years ago led to a variety of DNA technologies.
Evolution Connection: Evolution in Our Everyday Lives

• Antibiotics are drugs that help cure 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.
Figure 1.19

Take Care Of Your Skin:
TIPS FOR ATHLETES

Keep it clean! Washing hands and showering with soap and water protect against skin infections.

Stay healthy. To avoid skin infections:

- Wash your hands frequently.
- Shower after playing sports; use a clean towel.
- Keep cuts and scrapes clean and covered with a bandage.

Tell your coach or athletic trainer if you think you have a skin infection.

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Order

Regulation

Growth and development

Energy processing

Response to the environment

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Evolution
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<td>Domain Eukarya</td>
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Figure 1.UN03

Observations

- Overproduction and competition
- Individual variation

Conclusion

Unequal reproductive success (natural selection)
Figure 1.UN04

Observation → Question → Hypothesis → Prediction → Experiment → Revise and repeat