Chapter 1: Biology, the Study of Life

The chapter provides a preview of the entire text by touching on the major theories in biology. Major theories discussed include cell theory, gene theory, theory of homeostasis, theory of ecosystems, and theory of evolution. The importance of hypotheses, experimentation, and control groups are discussed. Concepts presented will reoccur throughout the text.

Learning Outcomes

The Process of Science

- Describe the four steps of the scientific method. (1.1)
- Analyze the five basic theories of biology. (1.1)
- Analyze a scientific experiment and identify the test and control groups. (1.2)
- Recognize that science is ongoing and progressive. (1.2)

The Cell Theory

- Identify two major principles of the cell theory. (1.3)
- Recognize that cells reproduce and use materials and energy to stay alive. (1.3)

The Gene Theory

- Restate the gene theory in your own words. (1.4)
- Identify several applications of DNA technology. (1.4)

The Theory of Homeostasis

- Explain the theory of homeostasis (1.5)
- Analyze the relationship between homeostasis and response to a stimulus. (1.5)

The Theory of Ecosystems

- Discuss the theory of ecosystems and how ecosystems function. (1.6)
- Identify various ways humans threaten the existence of ecosystems such as tropical rain forests and coral reefs. (1.6)

The Theory of Evolution

- Relate the theory of evolution to common descent and categorize the data that support this concept. (1.7)
- Determine how the branching pattern of an evolutionary tree indicates evolutionary relationships. (1.7)
- List the major categories of classification starting with the least inclusive category. (1.8)
- Identify the evolutionary relationship of the domains Bacteria, Archaea, and Eukarya. (1.8)
- Recognize the scientific name of organisms and classify organisms to the same extent as in this section. (1.8)
- Explain how the process of natural section allows a species to become adapted to its environment. (1.9)
- Use the concept of common descent to explain why organisms share the same characteristics. (1.10)
- Identify the basic characteristics of life. (1.10)

Chapter Outline

I. Fire Ants Protect Their Own

A. Fire ants take their name from their ability to sting.
B. Fire ants sting in order to defend their home.
C. The queen and worker ants live in chambers within the mound or slightly below it.
D. The purpose of the queen is to produce eggs, which develop into larvae.
E. Most offspring are sterile worker ants, but a few are male and female ants with the ability to reproduce.
   1. These male and female ants mate and start another colony.
F. The colony can be viewed as a superorganism. The queen serves as the reproductive system, while the workers serve as the digestive and urinary systems, as well as all the other systems.
   1. Ants communicate by pheromones.
G. This is a successful social system from an evolutionary point of view.

II. The Process of Science

Critical concepts include: the nature of science, science as one way of knowing, how to design a scientific experiment with a control group, and how science leads to technology.

1.1 Scientists use a preferred method

The scientific method consists of four parts: making observations, formulating a hypothesis, performing experiments and making observations, and coming to a conclusion.

A. Making Observations
   1. **Observations** are details of the natural world we notice using our senses.
   2. Observations also include the integration of previous data.
B. Formulating a Hypothesis
   1. A scientist uses **inductive reasoning**, which is creative thinking to combine isolated facts into a cohesive whole.
   2. A **hypothesis** is developed following observations and is a possible explanation for a natural event.
   3. A good hypothesis is testable.
C. Performing Experiments and Making Observations
   1. Scientists often perform an experiment, a series of procedures to test a hypothesis.
      a) When an experiment is done in a laboratory, all conditions are kept constant, except for an **experimental variable**, which is deliberately changed.
      b) One or more **test groups** are exposed to the experimental variable, but the **control group** is not.
   2. Scientists often use a model, a representation of an actual object.
   3. The results of an experiment or further observations are referred to as the **data**.

a) Mathematical data are often displayed in graphs or tables.

D. Coming to a Conclusion

1. Scientists analyze the data in order to reach a **conclusion** about whether a hypothesis is supported or not.
   a) The data can support a hypothesis, but they do not prove it "true." They can, however, prove it false.
2. Scientists report their findings in scientific journals in order to allow other scientists to have access to them.
3. Experiments and observations must be repeatable.

E. Scientific Theory

1. A **scientific theory** is one supported by a broad range of observations, experiments, and data from a variety of disciplines.
2. Five basic theories are present in biology.
   a) The Cell Theory: all organisms are made of cells, and new cells come from preexisting cells.
   b) The Gene Theory: all organisms contain coded information that dictates their form, function, and behavior.
   c) The Homeostasis Theory: all organisms have an internal environment that must stay relatively constant within a range protective of life.
   d) The Ecosystem Theory: all organisms are members of populations that interact with each other and with the physical environment within a particular locale.
   e) The Evolution Theory: all organisms have a common ancestor, but each is adapted to a particular way of life.

1.2 Many experiments have test and control groups

A. A pigeon pea is a **legume,** a plant with root nodules where bacteria convert atmospheric nitrogen to a form that plants such as winter wheat can use.

B. An experiment was designed to test the following hypothesis: A winter wheat/pigeon pea rotation will cause winter wheat production to increase as well as or better than the application of artificial fertilizer treatment.
1. Control pots: winter wheat planted in clay pots with no fertilization
2. Test pots I: winter wheat planted in clay pots with artificial fertilizer treatment
3. Test pots II: winter wheat grown in clay pots following pigeon pea plants grown in the summertime and turned over in the soil

C. Results

1. Color-coded bar graph (Fig. 1.2b)
2. Winter wheat yield was higher in test pots treated with artificial fertilizer treatment than in control pots or in pigeon pea pots.

D. Conclusion: The hypothesis was not supported.

E. Follow-Up Experiment and Results
1. New hypothesis: A sustained pigeon pea/winter wheat rotation will eventually cause an increase in winter wheat production.
2. The experiment was continued with the same design as before.

3. After two years, the yield from pots treated with artificial fertilizer was less than the first year, and less than the pigeon pea pot.
4. After three years, the wheat yield increased almost fourfold in pots with the pigeon peas.

F. Conclusion: The hypothesis was supported.

G. The results were published in a scientific journal.

How Biology Impacts Our Lives

1A Organic Farming

A. Organic farming is part of a movement to make agriculture sustainable by using farming methods that protect the health of people and ecosystems and preserve the land.

B. There has been a price for using modern agricultural methods that increase yield.
1. Topsoil depletion
2. Groundwater contamination

C. Farmers have applied more and more synthetic nitrogen fertilizer rather than growing legumes.
1. This leads to contamination of drinking water and huge bodies of water.
a) Contaminated drinking water can lead to health problems.

D. Organic farmers limit the use of nitrogen fertilizers and rely on crop rotation with a nitrogen-providing legume and a nitrogen-requiring crop.

E. Organic farmers also decrease their use of herbicides and pesticides.
1. Long term use of these chemicals is associated with health problems such as birth defects, nerve damage, and cancer.

F. Each of us can contribute to an organic lifestyle by limiting the use of synthetic chemicals on our lawns and gardens.

III. The Cell Theory

Critical concepts include: cell theory, the reproduction of cells, and the need of cells for materials and energy.

1.3 Cells are the fundamental unit of all living things

A. **Cell theory** states that cells are the *fundamental unit of living things*.

B. The organization of life
1. **Atoms**, the smallest portions of an element, combine with themselves or other atoms to form **molecules**.
2. Cells, not molecules, are alive.
3. Similar cells combine to form a **tissue**, and tissues make up **organs**.
4. Organs work together in **organ systems**.
5. Organ systems are joined together to form a complete living thing, or **organism**.

C. A microscope reveals that organisms are composed of cells (Fig 1.3B).

D. Cells only come from a previous cell, and organisms only come from another organism.
1. Cells and organisms reproduce.

2. Bacteria, protists, and other unicellular organisms simply split in two.
3. Reproduction in multicellular organisms is more complex, and involves the pairing of a sperm and an egg.

E. Cells use materials and energy.
1. Nutrients function as building blocks or for energy.
2. **Energy** is the capacity to do work.
3. The term **metabolism** encompasses all the chemical reactions that occur in a cell.
4. The ultimate source of energy for nearly all life on Earth is the sun.
a) Plants and certain other organisms capture solar energy and carry on photosynthesis, a process that transforms solar energy into the chemical energy of organic nutrients.

IV. The Gene Theory

Critical concepts include: how gene and cell theory are related, how genes code for proteins that directly bring about an organism's traits, and several applications of gene theory.

1.4 Organisms have a genetic inheritance

A. Gregor Mendel is often called the father of genetics because he was the first that concluded that units of heredity, now called **genes**, are passed from parents to offspring.
B. James Watson and Francis Crick discovered that genes are composed of DNA (deoxyribonucleic acid).
C. These lead to the first premise of **gene theory**: *Genes are hereditary units composed of DNA.*
D. DNA is composed of four different types of nucleotides which can **mutate** (undergo permanent changes).
E. Each type of organism has its own particular nucleotide sequence.
F. DNA contains coded information for **proteins,** cellular molecules that determine what the cell and the organism are like.
G. This leads to the second premise of gene theory: *Genes control the structure and function of cells and organisms* by coding for proteins.
H. Applications of Gene Theory
1. Basic genetic research
2. Medicine
3. Relationship of Species

V. Organisms are Homeostatic

Critical concepts include: the concept of homeostasis, how homeostasis is maintained, and how organisms respond to stimuli.

1.5 Organisms regulate their internal environment

A. To survive, cells and organisms must maintain a state of biological balance, or **homeostasis.**
B. The **theory of homeostasis** tells us that *cells and organisms have an internal environment and that cells regulate this environment so that it stays fairly*

constant.

C. Animals have intricate feedback and control mechanisms for maintaining homeostasis that do not require conscious activity.

D. Many animals depend on behavior to regulate their internal environment.
   1. Students become hungry and go eat.
   2. Iguanas raise their internal temperature by basking in the sun.

E. Plants are homeostatic to some extent. They bend toward sunlight and have mechanisms to contain damage done to them.

F. Organisms respond to stimuli.
   1. Plants, unicellular organisms, and multicellular organisms all respond to stimuli.
   2. The responses of multicellular organisms are more complex.
   3. Daily activities are termed the behavior of an organism.
      a) These behaviors, such as searching and competing for energy, nutrients, shelter, and mates, as well as communication, hunting, and defensive behaviors, assist homeostasis.

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VI. Organisms Live in Ecosystems

Critical concepts include: higher levels of organization such as populations, community, ecosystems, and the biosphere; chemical cycling; and energy flow.

1.6 The biosphere is divided into ecosystems

A. Levels of biological organization
   1. Individual organisms belong to a **population**, all the members of a species within a particular area.
   2. Populations within a **community** interact among themselves and with the physical environment, thereby forming an **ecosystem**.
   3. The **biosphere** is the zone of air, land, and water at Earth's surface where living organisms are found.

B. The **theory of ecosystems** says *that organisms form units in which they interact with the biotic (living) and abiotic (nonliving) components of the environment*.
   1. An example of an ecosystem is a North American grassland.
   2. The populations interact by forming food chains in which one population feeds on another.

C. Ecosystems are characterized by *chemical cycling* and *energy flow*.
   1. These both begin when plants take in solar energy and inorganic nutrients to produce food by photosynthesis.
   2. Chemical cycling occurs as chemicals move from one population to another in a food chain until they are returned to the photosynthesizers.
   3. Energy flows from the sun through plants and the other members of the food chain, and eventually dissipates as heat.
   4. Energy does not cycle. Therefore, ecosystems are dependent on solar energy and photosynthesizers.

D. The biosphere
   1. Climate largely determines where different ecosystems are found in the

biosphere.
2. Tropical rain forests and coral reefs, the two most biologically diverse ecosystems, occur where solar energy is most abundant.
3. The human population tends to modify ecosystems for its own purposes.
4. Tropical rain forests and coral reefs are home to many organisms.
5. Humans depend on healthy ecosystems for food, medicines, and various raw materials.

VII. Organisms Are Related and Adapted to Their Environment

Critical concepts include: evolutionary trees, major categories of classification, adaptation and natural selection, seven characteristics that define life, and the theory of evolution.

1.7 The ancestry of species can be determined

A. Evolution, the unifying concept of biology, explains the unity and diversity of life.
1. All organisms share the same characteristics because they are descended from a common source.
2. Life changes as different forms become adapted to their environment.

B. The **theory of evolution** says that *organisms have shared characteristics because of common descent*.
1. An **evolutionary tree** shows how a group of organisms have descended from a **common ancestor**.
2. It is possible to trace the evolution of any group by using molecular data, the fossil record, the anatomy and physiology of organisms, and the embryonic development of organisms.
a) Based on the fossil record, birds are now classified as reptiles.
3. Natural selection is the mechanism that results in adaptation to the environment.
4. Only species, not individual organisms, evolve.
5. Genetics help explain how evolution occurs.

1.8 Evolutionary relationships help biologists group organisms

A. Organisms share certain characteristics because they descended from a common ancestor.

B. **Taxonomy** is the discipline of identifying and classifying organisms according to certain rules.

C. Basic classification categories (taxa) are arranged from least to most inclusive:
Species→Genus→Family→Order→Class→Phylum→Kingdom→Domain
1. A species is defined as a group of interbreeding individuals.
2. Each successive classification category contains more organisms than the preceding one.

D. Domains
1. Largest classification category
2. Three domains: **Bacteria, Archaea, Eukarya**
3. **Prokaryotes** are unicellular organisms that lack a membrane bound nucleus and make up the domains Bacteria and Archaea.

4. **Eukaryote** cells have a membrane bound nucleus and make up the domain Eukarya.
5. Eukarya split off from the archaeal line of descent.
6. Archaea are the least evolved forms of life.

E. Kingdoms
1. Archaea and Bacteria are still in flux regarding further classification.
2. Eukarya contains four kingdoms:
a) **Protists** include multicellular and unicellular forms that vary in metabolic processes as well as complexity.
b) **Plants** are multicellular photosynthetic organisms.
c) **Fungi** includes molds, mushrooms, and decomposers.
d) **Animals** are multicellular organisms that must ingest and process their food.

F. Scientific Names
1. Binomial nomenclature is used to assign two-part scientific names.
2. The genus is the first word of the name, and the **specific epithet** of a species within that genus is the second word.
3. The genus may be abbreviated, and if the species is unknown it may be indicated by "sp.".
4. Scientific names are in Latin and are universally used to avoid confusion.

1.9 Evolution through natural selection results in adaptation to the environment

A. Common Descent With Modification
1. Sums up the process of evolution
2. Natural selection is the process that makes modification, or **adaptation**, possible.
3. As evolution occurs, ***natural selection*** *brings about adaptation to the environment*.

B. Natural Selection
1. Some aspect of the environment selects which traits are more apt to be passed on to the next generation.
a) The selective agent can be *abiotic* or *biotic*.
2. Not all individuals within a population have the ability to reproduce, or do so with the same success.
3. Living things change over time, and these changes are passed on from one generation to the next.
a) Examples: predatory deer and plants with hair leaves, rockhopper penguins

How Life Changes

Evolution's Many Applications

A. The principles of evolution help us solve practical problems that impact our lives.

B. Agriculture
1. Humans have produced large, soft, sweet bananas by using artificial selection.

2. Most agricultural products were produced by this method.
3. Understanding the evolution of agricultural plants helps us keep them healthy.
4. Farmers using pesticides have selected for insects that carry genes for pesticide resistance.

C. Medicine
1. Bacteria have evolved resistance to antibiotics.
2. Evolution helps scientists develop drugs to kill pathogens.

D. Conservation
1. Evolution helps scientists decide which technologies can help save the environment.
2. Humans need a renewable resource to produce energy.
   a) Example: corn or waste products for ethanol production
3. Evolution helps save endangered species as well.

1.10 Evolution from a common ancestor accounts for the characteristics of life

A. All living things share seven characteristics.
1. Life is organized.
   a) The levels of biological organization extend from cells to the biosphere.
2. Life uses materials and energy.
   a) The metabolic pathways that allow an organism to maintain its organization and to grow are the same in all organisms.
3. Life reproduces.
   a) Unicellular organisms simply divide when they reproduce.
   b) Multicellular organisms have more complex schemes, often beginning with a fertilized egg.
   c) When organisms reproduce, genetic differences arise that allow evolution to occur.
4. Life is homeostatic.
   a) Regulatory mechanisms allow cells and organisms to keep their internal environment relatively constant.
5. Life responds to stimuli
   a) Organisms respond to internal and external stimuli, and this allows them to maintain homeostasis.
6. Life forms ecosystems.
   a) Interactions are a hallmark of living things.
   b) Populations interact in ecosystems.
7. Life evolves.
   a) The history of life began with a common source, but as life reproduces it passes on genes that can mutate.
   b) Adaptation to different environments accounts for the variety of life on Earth.

Connecting the Concepts

1. Give your own example (not taken from this reading) to show that two theories are

related.
2. Explain in your own words how bacteria become resistant to an antibiotic.

Lecture Enrichment Activities

1. Ask the students to list the characteristics common to all life. Discuss each item and give individual examples for each characteristic. Provide the students with examples of living and non-living specimens and ask them to try to apply each characteristic to the items in question and record which characteristics apply. Use to demonstrate how having only one of the characteristics is not adequate to represent life.

2. List common organisms with which students should be familiar. Have the students place the organisms in the correct kingdom based on their known characteristics. Then provide a second list of organisms that the students may not be familiar with and ask the students to determine the kingdom they belong to. Ask the students for their rationale.

3. The kingdoms of life represent a wide variety of diversity. Select various examples from each kingdom and ask the students to identify the adaptations present in the organism that: (1) contribute to survival and (2) place it in a specific kingdom.

4. Describe scenarios such as “conifers that are photosynthesizing” or “sucrose in solution in the phloem” and ask the students to determine what level of organization is being described.

5. Present the students with pictures of the various ecosystems of the world and have them list all of the abiotic and biotic components that might be represented in the picture. Discuss what might not be visible but is known to be present, such as the chemical cycles and energy flow.

6. Have the students make observations of an object (a leaf or branch) and propose a hypothesis of the function of the object. Then have the students propose an experiment that could be developed to test the hypothesis. Discuss what experimental variables and controls would need to be included.

7. Have the students bring in newspapers from home and identify articles that demonstrate use of the scientific method (consumer reports or medical research). Discuss the design of the experiments and the results.

8. Examine tabloid magazines that have article or advertisements that make amazing claims and discuss why they do not fulfill scientific standards.

9. Discuss the scientific theories and divide the class into groups. Assign each group the task of designing experiments to investigate the theories. Base the investigations on the scientific method and ensure that controls and feasible variables have been described. Use to demonstrate the various experimental approaches that can be used to investigate the same question while everyone uses the same basic scientific method.

10. Present the students with two scenarios, a pristine forest and a forest that has a region that has been logged. Ask the students what changes would result for the human action of logging the forest at the biosphere, ecosystem, community, population, and organism levels.

Discussion Questions

1. The exploration of other planets, especially Mars, has captured the attention of many people with the possibility of finding life there. If an unusual object were found on another planet, what observations of the object would need to be made in order to classify it as alive?

1A. Evidence of a specific order or organization of the object would be the first observation. The physical appearance of the object might have specialized adaptations that allow it to respond to and survive in its natural environment. The potential to mate and reproduce could be observed if more objects of the same kind were found. In addition, evidence of a metabolism might be observed if the organism consumed any materials. At the molecular level the object might have DNA or some similar molecular material that is passed on to any offspring resulting from a mating.

2. Life on Earth interacts in very complex and diverse ways. Consider two common organisms found almost everywhere, a butterfly and a flowering plant. Describe how the interactions of these two organisms influence each of the levels of biological organization.

2A. Both organisms live on Earth and so are part of the biosphere. Because both organisms live in the same area and utilize chemicals and energy from the environment, they are part of the ecosystem. Specifically, the plant absorbs light energy and converts it to chemical energy via photosynthesis and takes up nutrients and water from the soil as well as carbon dioxide from the atmosphere. The butterfly would use water and consume nutrients in the form of pollen produced by the flowering plant. At the community level, both organisms are alive and would interact as described such that the butterfly survives due to the presence of the plant. At the population level the numbers of plants determine how many butterflies can live in the community based on food (pollen) availability. As organisms they would come into physical contact with each other. At the organ system and organ level, the butterfly would take in pollen and absorb the nutrients. At the tissues, cells, molecules, and atom levels, the butterfly would use the nutrients absorbed to build up each of the mentioned structures. Upon the death of the butterfly, the nutrients used to construct tissues, organs, etc., would be returned to the soil where the plant would be able to take them up for use in the synthesis of its own molecules, cells, tissues, and organs.

3. A researcher has many options when investigating questions regarding the behavior of an organism. Two such options include whether to test a hypothesis by designing an experiment to take place outside in the organism's natural environment or to design an experiment to take place in the laboratory using artificial environmental conditions that simulate the environment. What are the advantages and disadvantages of each of these possible options regarding the design and implementation of an experiment using the scientific method?

3A. While both options would allow the researchers to investigate their question, they both have limitations. In order for an experiment to be well designed, experimental variables need to be identified and should be simplified such that only one variable can be investigated at a time. In addition, control tests need to be performed that do not have the variable being tested. Typically this can be accomplished at both levels. However, in the outdoor experiment, the natural setting would allow more variability to exist between the different experimental and control tests in the form of subtle differences in physical aspects such as wind, light, moisture, temperature, or soil quality. Also it may not be possible to eliminate other members of the community from interacting with the experimental variables. However, this experiment might benefit from the presence of previously unknown components. Regarding the indoor experiment, the physical aspects can be regulated with much greater accuracy and biological components can be restricted, but the experiment might be limited due to the absence of some critical factor which may influence the results of the experiment but may have gone previously unnoticed in the original observations.