Mader: *Essentials of Biology*, 5e

Instructor’s Manual

Chapter 1 Biology: The Science of Life

# Learning Outcomes

## 1.1 The Characteristics of Life

**1.** Explain the basic characteristics that are common to all living organisms.

**2.** Distinguish between the levels of biological organization.

**3.** Summarize how the terms *homeostasis, metabolism,* and *adaptation* relate to all living organisms.

**4.** Contrast chemical cycling and energy flow within an ecosystem.

## 1.2 Evolution: The Core Concept of Biology

**1.** Define the term *evolution*.

**2.** Explain the process of natural selection and its relationship to evolutionary processes.

**3.** Summarize the general characteristics of the domains and major kingdoms of life.

## 1.3 Science: A Way of Knowing

**1.** Identify the steps of the scientific method.

**2.** Describe the basic requirements for a controlled experiment.

**3.** Distinguish between a theory and a hypothesis.

## 1.4 Challenges Facing Science

**1.** Distinguish between science and technology.

**2.** Summarize some of the major challenges currently facing science.

# Extended Lecture Outline

## 1.1. The Characteristics of Life

Living organisms are organized from the cell as the basic unit of life to tissues, organs, and organ systems. Organisms are further organized through populations, communities, ecosystems, and the biosphere. Species are defined as interbreeding individuals that produce viable and fertile offspring.

### Life Requires Materials and Energy

All life needs the input of energy beginning with the capture of solar energy by photosynthetic organisms (producers) such as plants. Energy is the capacity to do work, which is necessary to maintain organization. Metabolism refers to all of the chemical reactions that occur in a cell, and photosynthesis refers to the transformation of solar energy to chemical energy in nutrient molecules. Energy flows from the sun to photosynthetic organisms and then to other members of a food chain as they feed. As energy is transferred from one organism to the next, some energy is lost as heat. Death and decomposition enable inorganic nutrients to be reused by producers.

### Living Organisms Maintain an Internal Environment

Living organisms need to keep themselves stable in temperature, moisture level, acidity, and other factors that are critical to maintaining life. The maintenance of internal conditions within certain boundaries is called homeostasis.

### Living Organisms Respond

All living organisms respond in some fashion to their environment.

### Living Organisms Reproduce and Develop

All living organisms produce offspring, passing on genes (located on DNA) that control how the offspring develops. This process is called reproduction.

### Living Organisms Have Adaptations

Living organisms have adaptations that enable them to survive in certain environments. Evolution is the process by which species become adapted to their environments.

## 1.2 Evolution: The Core Concept of Biology

All organisms share the same basic characteristics, suggesting that they share a common ancestor—the first cell or cells. Changes in a population occur over time and passing on those changes to the next generation takes place when evolution occurs.

### Natural Selection and Evolutionary Processes

Natural selection, proposed by Charles Darwin and Alfred Russel Wallace, is the mechanism by which evolution occurs. Adaptations that result in greater reproductive success appear more frequently in a population as evolution takes place. Through evolution (common descent with modification), one species can be the common ancestor to multiple species, each of which has adaptations suited to a specific environment.

The overuse of antibiotics serves as a selective agent for bacteria resistant to the antibiotics, leading to an increased number of bacteria that are resistant and a greater number of infections that cannot be treated with once-effective antibiotics.

### Organizing the Diversity of Life

Taxonomy involves identifying and classifying organisms, and systematics involves determining the evolutionary relationship between organisms.

Classification includes species, genus, family, order, class, phylum, kingdom, and domain from the least inclusive to the most inclusive. Three domains exist based on biochemical evidence; they are **Bacteria**, **Archaea**, and **Eukarya**. Bacteria and Archaea contain prokaryotes. Kingdoms of protists, fungi, plants, and animals are found in the Eukarya domain. Organisms are identified using scientifically based binomial names.

## 1.3 Science: A Way of Knowing

The scientific method is typically used to study the natural world.

### Start with an Observation

Observation, the first step in the scientific method, includes an individual’s observations, as well as observations of other scientists found in scientific literature. Instrumentation extends a scientist’s ability to observe.

### Develop a Hypothesis

Hypotheses are often proposed and conclusions are often provided using inductive reasoning.

### Make a Prediction and Perform Experiments

Experimental design includes an experimental variable and a control group. Models are often used. Data collected is often mathematical.

### Develop a Conclusion

Based on the experimental data, conclusions can be drawn as to whether the hypothesis was supported or not. Experiments must be repeatable.

### Scientific Theory

Scientific theories explain how the natural world works.

### An Example of a Controlled Study

Experimental design and data are presented for an investigation of the effectiveness of two different antibiotics used to treat ulcers. In experimental systems, there are often test groups and control groups.

### Publishing the Results

Scientific studies are published in scientific journals through a process of rigorous review; this makes studies available to the entire scientific community.

## 1.4 Challenges Facing Science

The importance of scientific knowledge in order for everyone to make informed decisions about the use of technology is presented.

### Biodiversity and Habitat Loss

Humans modify ecosystems for their own purposes, which may lead to the extinction, or death, of many species or a larger taxonomic group. Many unintended effects, such as flooding problems or the loss of the next miracle drug, are associated with the destruction of healthy ecosystems, such as tropical rain forests and coral reefs.

### Emerging and Reemerging Diseases

Changes in human behavior and use of technology can lead to emerging diseases, such as avian and swine flu, and increased cases of known diseases, such as Ebola.

### Climate Change

Human activities have affected climate change—changes to the normal cycle of the Earth’s climate.

# Lecture Enrichment Topics

## 1.1 The Characteristics of Life

1. Choose an ecosystem, such as the campus or students’ backyards, and have students list some ways living organisms interact with their physical environment. How do students interact with their physical environment? For example, food chains and food webs unify the diversity of life, which is described later.
2. Ask students for some ways that humans maintain homeostasis. For example, how do they maintain homeostasis of fluid or temperature when they are exercising and perspiring, or when they walk outside in cold weather without wearing a coat?

## 1.2 Evolution: The Core Concept of Biology

1. To reinforce the need for scientific names, present the following common names for the snake, *Bothrops asper*: Belize—yellow-jaw tommygoff; Guatamala and Honduras—barba amarilla; Mexico—cola blanca, palancaloca, tephocho; Venezuela—macagua, tigra.

## 1.3 Science: A Way of Knowing

In presenting the scientific method, present students with different fields of biology. Do scientists in the different fields use the same techniques or different techniques to conduct their investigations?

1. In presenting the parts of the scientific method, give an ongoing example of how people use the scientific method in everyday life. One example may be the use of premium versus regular gasoline. Students can propose conditions that should remain constant, as well as the type of mathematical data that could be collected and analyzed.
2. Propose a “study” as follows: A report on the television states that a 12-year study of a new dog food will allow your dog to live longer if fed to the dog throughout its life. Ask students what questions they might have about the report in order to discern its validity.
3. Explain the importance of objectivity (one reason mathematical data is so important) in experimental design. Using the example in #2 above, categorize the following statements about the example into objective statements versus subjective statements. Have the students include reasons why they categorized each statement as objective or subjective.

* “The dogs that ate the new dog food seemed to have shinier coats.”
* “78% of the control dogs did not eat all of their food within the time allotted.”
* “Most of the experimental dogs needed fewer teeth cleanings.”
* “Half of the experimental dogs were more playful after eight years of using the new dog food.”
* “The new dog food probably tasted better as the experimental dogs ate their food in less time.”

1. Present when Charles Darwin proposed the evolution theory (1859); when Schleiden and Schwann proposed the cell theory (1838); and when Mendel (1866), and Watson and Crick (1953) proposed the gene theory. Emphasize the length of time and number of studies that must have occurred during this time that support these theories.
2. Discuss the scientific definition of *theory* versus the everyday use of the word *theory*. Presenting a dictionary’s definition should include both aspects. Explain why saying “It’s *just* a theory” may not be appropriate with regard to scientific theories. (See also #4).

## 1.4 Challenges Facing Science

1. Ask for a list of biology-related concerns currently in the news (cloning, stem cell research, habitat loss due to development or other human activites, species newly classified as threatened or endangered). Students could bring in headlines or articles from newspapers. Point out that at the end of this course, students should be better able to decide their positions on these issues.

# Critical Thinking Questions

1. Discuss the difference in meaning between the terms “supported” and “proven.” Why is the term “supported” used with regard to hypotheses? For example, “A hypothesis is supported by experimental data.”

Ans: The term “proven” indicates a greater degree of certainty with no indication suggested for further search of information. The term “supported” indicates that with the current knowledge, the hypothesis appears to be true, but further experimentation may indicate otherwise.

1. Regarding the example of a controlled study in the text using winter wheat and pea plants as fertilizer, what specific aspects of environmental conditions would be included as conditions that were kept constant?

Ans: Answers will vary but may include:

* amount and type of nutrients in soil before addition of nitrogen fertilizer or pea plants
* amount of water the plants received
* amount of sunlight the plants received
* the temperatures throughout the test period
* the size of the pots
* pH of soil

# Essay Questions

1. Give an example of how behavior contributes to homeostasis.

Ans: (Students may be able to come up with some of their own examples.) Animals such as lizards need to regulate their body temperature by moving about their environment. If they are cold, they move to a sunny area; if hot, they move to a shaded area. A plant may grow its leaves to follow the position of the sun to maintain a certain rate of photosynthesis.

1. Explain why scientific binomial names are important.

Ans: People often have many different common names for living organisms, varying between geographical areas or languages. Scientists need a name for each species that does not change no matter what language is spoken or what geographical area is being considered. Each known species has an assigned scientific binomial name that is accepted by all scientists.

1. Describe the importance of using models in experimental design.

Ans: Models, or modeling, can be used instead of the actual subject. This can be important in forecasting the impact of human activity on ecosystems. Also, animals can be used as models when testing chemicals or processes being developed for humans.

1. Which model organism are best for:

a) Field investigations?

b) Lab investigations?

Consider the size, reproductive habit, and the life cycle of the organisms.

**Laboratory**

**1**

**Scientific Method**

**MATERIALS AND PREPARATIONS**

Instructions are grouped by procedure. Some materials may be used in more than one procedure.

**Special Requirements**

**Living material.** Live pillbugs, *Armadillidium vulgare,* for all sections of the lab.

**Earthworm alternative.** Refer to the section titled “Earthworm Alternative” at the end of this laboratory if you wish to use earthworms instead of pillbugs.

**Fresh material.** Substances for instructor to feed pillbugs and substances for students to test pillbug behavior are listed in Section 1.4.

**1.2 Observing a Pillbug**

\_\_\_\_\_ pillbugs, *Armadillidium vulgare,* live (Carolina 14-3082)

\_\_\_\_\_ pen, white (or correction fluid, white) or taped tags

\_\_\_\_\_ magnifying lenses or stereomicroscopes

\_\_\_\_\_ small glass or plastic dishes, such as disposable Petri dishes

\_\_\_\_\_ graduated cylinders or small beakers for observing pillbug movement

\_\_\_\_\_ rulers, metric, 30 cm plastic

\_\_\_\_\_ stopwatch

**Live pillbugs.** Obtain 50 pillbugs for a class of 20 to 35 or more students. Order pillbugs so that they arrive as close as possible to the date they will be needed. Use one container of fresh pillbugs for each lab.

Care and feeding of pillbugs: Follow care and feeding instructions provided with the pillbug order. Withdraw food 1–2 days prior to the experiment.

Use white correction fluid, different colors of nail polish, or tape tabs to number the pillbugs for identification.

**Collecting pillbugs.** Pillbugs like moisture, and avoid sunlight. They can be found next to brick buildings along the grass line or next to sidewalks, or under logs and planks of wood. They are attracted to wet grass covered with a cardboard box or plastic tarp. Encourage students to collect their own pillbugs and give them lab participation points. Collect pillbugs in the spring, summer, and fall as they are hard to find in the winter.

**Maintaining pillbugs in the lab.** After collecting, pillbugs can be easily maintained in a terrarium to keep a fresh supply all year long. They feed primarily on decaying organic matter; they like moisture and avoid sunlight. They like carrots and cucumbers. Change the food daily to prevent mold growth.

**1.4 Performing the Experiment and Coming to a Conclusion**

\_\_\_\_\_ pillbugs, *Armadillidium vulgare,* live (Carolina 14-3082)

\_\_\_\_\_ small beakers, 35-mm film cans, watch glasses, or small Petri dishes for distributing test substances

\_\_\_\_\_ Petri dishes, preferably 150 mm (or else 100 mm) for testing the pillbugs

\_\_\_\_\_ small plastic bottle for spritzing

\_\_\_\_\_ distilled water

\_\_\_\_\_ cotton balls

Suggested test substances:

\_\_\_\_\_ flour

\_\_\_\_\_ cornstarch or brand flakes

\_\_\_\_\_ coffee creamer

\_\_\_\_\_ baking soda

\_\_\_\_\_ fine sand (control)

\_\_\_\_\_ milk

\_\_\_\_\_ orange juice or apple juice

\_\_\_\_\_ ketchup

\_\_\_\_\_ applesauce

\_\_\_\_\_ carbonated beverage

\_\_\_\_\_ water (control)

Do not use salt, vinegar, or honey, as these substances are harmful to pillbugs.

Plain water is used as a control for liquids. Fine sand is used as a control for powders.

**Experimental design.** These methods are recommended: For a dry substance, make a circle of the test substance in a Petri dish and put the pillbug in the center of the circle. For a liquid, put a cotton ball soaked with the test substance in the pillbug's path. Rinse pillbugs between testing procedures by spritzing with distilled water and then placing them on a paper towel to dry.

**Cleanup.** Cleanup is easier and the experiment goes well if there is a limited number of test substances and each student chooses only two dry and two liquid test substances. Substances can be distributed to several stations in small beakers, 35-mm film cans, watch glasses, or small Petri dishes. Testing pillbugs in 150 mm Petri dishes works well.

**EXERCISE QUESTIONS**

**1.1 Using the Scientific Method**

**Why does the scientific method begin with observations?** *To study the natural world, scientists have to observe natural phenomena.*

**What is the benefit of formulating a hypothesis?** *The hypothesis tells what is to be tested by experiment or further observations.*

**Why must a scientist keep a complete record of an experiment?** *They keep a complete record so that others can repeat the experiment and check that the data are valid.*

**What is the purpose of the conclusion?** *The conclusion tells whether the hypothesis was supported or not.*

**How is a scientific theory different from a conclusion?** *Each experiment has a conclusion. A scientific theory is based on many conclusions from various experiments in related fields.*

**1.2 Observing a Pillbug**

***Observation: Pillbug’s External Anatomy***

**1.**

* **How can you recognize the head end of a pillbug?** *The head bears antennae and eyes.*
* **How many segments and pair of walking legs are in the thorax?** *There are* *7 segments and 7 pairs of legs.*

***Observation: Pillbug’s Motion***

**1.**

1. **Describe the action of the feet and any other motion you see.** *The seven pairs of legs move with the front pair leading, and each pair moves in succession thereafter.*
2. **Allow a pillbug to crawl on your hand. Describe how it feels.** *It tickles the skin as it moves.*
3. **Does a pillbug have the ability to move directly forward?** *yes*
4. **Do you see evidence of mouthparts on the underside of the pillbug?** *A pillbug has four pairs of mouthparts.*

**2. As you watch the pillbug, identify:**

1. **the anatomical parts that allow a pillbug to identify and take in food.** *antennae, eyes, and mouthparts*
2. **behaviors that will allow a pillbug to acquire food.** **For example, is the ability of a pillbug to move directly forward a help in acquiring food? Explain.** *Yes, because it is the most efficient way to reach food****.***

**What other behaviors allow a pillbug to acquire food?***A pillbug has appropriate mouth parts for taking in and eating food.*

1. **a behavior that helps a pillbug avoid dangerous situations.** *The pillbug rolls into a ball when it is threatened.*

**Table 1.1 Pillbug Speed\***

|  |  |  |  |
| --- | --- | --- | --- |
| Pillbug | Millimeters (mm) Traveled | Time (sec) | Speed (mm/sec) |
| 1 | *71* | *30* | *2.36* |
| 2 | *122* | *60* | *2.20* |
| 3 | *64* | *30* | *2.12* |

Average speed: *2.23 mm/sec*

*\*Answers will vary. The answers provided here are examples.*

**1.3 Formulating Hypotheses**

**1-3.** *See Table 1.2 showing* *three possible student hypotheses regarding flour. Students use "0" for no response, "—" for moves away from the substance, and "+" for moves toward the substance and eats it.*

**Table 1.2 Hypotheses about Pillbug’s Response to Potential Foods**

|  |  |  |
| --- | --- | --- |
| Substance | Hypothesis About  Pillbug’s Response to Potential Foods | Reason for Hypothesis |
| *Flour* | *0* | *Flour is a bland substance.* |
| *Flour* | *—* | *Flour is a dry substance.* |
| *Flour* | *+* | *Flour is a food substance.* |

**1.4 Performing the Experiment and Coming to a Conclusion**

***Experimental Procedure: Pillbug’s Response to Potential Foods***

**Table 1.3 Pillbug’s Response to Potential Foods**

|  |  |  |
| --- | --- | --- |
| Substance | Pillbug’s Response | Hypothesis supported? |
| *Flour* | *+* | *Depends on hypotheses* |
| *Cornstarch* | *+* |  |
| *Coffee creamer* | *+* |  |
| *Baking soda* | *—* |  |
| *Fine sand* | *0\** |  |
| *Milk* | *+* |  |
| *Orange juice* | *—* |  |
| *Ketchup* | *—* |  |
| *Applesauce* | *+* |  |
| *Carbonated beverage* | *+* |  |
| *Water* | *0\** |  |

*\*Pillbugs may move toward these substances but not eat them.*

***Conclusion***

**5.** **Do your results support your hypotheses*?*** *Answer depends on results.*

**6. Are there any hypotheses that were not supported by the experimental results (data)? Does this difference give you more insight into pillbug behavior? Explain.** *Answer depends on student hypotheses.*

**Table 1.4 Pillbug's Response to Potential Foods: Class Results**

*Answers will vary depending on class data.*

**8. On the basis of the class data do you need to revise your conclusion for any particular pillbug response?** *depends on class data*

**Why is this the best methodology?** *The more trials, the more likely the results are valid.*

**9. Did the billbugs respond as expected to the controls, i.e., did not eat them.** *depends on student results* **If they did not respond as expected, what can you conclude about your experimental results?** *The results may be invalid.*

**LABORATORY REVIEW 1**

**1. What kind of animal is a pillbug?** *Crustacean*

**2. What kind of skeleton does a pillbug have?** *Exoskeleton*

**3. What structures do pillbugs use for gas exchange and what condition must these structure be in to function properly?** *Gills; moist*

**4. What do scientists do first when they begin to study a specific topic?** *Make observations*

**5. What is a tentative decision about the outcome of an experiment?** *Hypothesis*

**6. What do we call the sample that lacks the factor being tested and goes through all the experimental steps?** *A control*

**7. What do scientists call the information they collect while doing experiments or making observations?** *Data*

**8. Which is made by a scientist following experiments and observations, a theory or a conclusion?** *Conclusion*

**9. What do scientists develop after many years of experimentation and a lot of similar individual conclusions?** *Scientific theory*

**10. If your hypothesis was your pillbug would be attracted to applesauce and your pillbug moved toward the applesauce, what would you say about your hypothesis?** *It was correct.*

**For questions 11 and 12, indicate whether the statements are hypotheses, conclusions or scientific theories.**

**11. All living things are made of cells.** *Scientific theory*

**12. The data show that trans-fat intake raises cholesterol and contributes to heart disease.**

*Conclusion*

**13. If a pillbug travels 3mm in 30 seconds, what is its rate of speed?** *0.1 mm/sec*

**14. If a pillbug moves toward a substance, is it attracted to or repelled by that substance?**

*Attracted to*

**Thought Questions**

**15. Why is a theory more comprehensive than a conclusion?** *A conclusion is based on data obtained from one experiment. A theory is based on many conclusions made by multiple researchers in the same field.*

**16. Why is it important to have a control substance for an experiment?** *The results associated with the control determine if the procedure is flawed or the hypothesis is false.*

**17. Why is it important to test a pillbug's response using one substance at a time?** *Only then can you be certain of the pillbug’s reaction to that particular substance.*

**Earthworm Alternative**

Earthworms can be used instead of pillbugs for all of the exercises in this laboratory.

Place earthworms in large rectangular plastic storage containers and let them roam around for approximately 15 min. These containers can also be used to keep earthworms between experiments. Plexiglass is also needed to place test substances on while holding earthworms above to see behavior towards substances.

Earthworms want to move rapidly to escape. They are inclined to move away from light, move under things, and seem to want to move downward. They are expected to move away from a heat source. They also move toward each other and pile up on each other. They can move up and down on glass at a 45° angle.

With regard to what students already know about earthworm activity, they might predict certain behaviors. Earthworms live (or hide) in the soil, so they would move down and through soil. Soil prevents desiccation and keeps them cool and moist. By moving under things, they could stay cooler, stay moist, and stay hidden in the dark. Perhaps light bothers them also.

Earthworms can move backward and forward from both ends. When they are investigating a substance, they make a long, skinny point out of the end they are investigating with, and if they are repelled by a substance, they pull back and the end becomes thick and round.

When testing with liquids, if the earthworm even gets close to the substance, the substance will be pulled along the earthworm’s body without the earthworm doing anything. Capillary action or cohesion tension? To prevent this, hold the earthworm above the substance, in case the substance (especially lemon juice) might harm the earthworm. Just let the worm move its pointed end into or near the substance. You can tell when it is repelled as it will pull away. Rinse the earthworm right away if it touches a substance (especially lemon juice).

WHEN FINISHED WITH EARTHWORMS, mix damp potting soil with some oatmeal, potato peels, lettuce, or other organic matter from the test—not too much, just enough to give the earthworms something to eat. Add earthworms. Cover container with newspaper. Keep soil damp. When completely finished, release earthworms into garden or greenhouse soil.