

Introduction: The Scientific Study of Life

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We are living in the golden age of biology. More biologists (and people who have taken a biology course) are alive today than have lived in all of history. Biology has always been important to human life—from the earliest times we have had to understand our bodies, the plants and animals in our surroundings, and how to obtain food—but in recent years biological issues have taken on a new urgency. Problems such as global warming, overpopulation, emerging diseases, bioterrorism, the challenges of genetic engineering, and depletion of global biodiversity demand that we apply more sophisticated knowledge to biological questions and issues. Just as “war is too important to be left to the generals,” biology is too important to be left to the biologists. This chapter introduces the science of biology and its importance in all our lives.

Organizing Your Knowledge

Exercise 1 (Module 1.1)

Web/CD Activity 1A *The Levels of Life Card Game*

This module discusses the hierarchy of structural levels into which life is organized. Each of these levels has unique properties, which arise from the organization of its component parts. Review this structural hierarchy by completing the chart below.

<i>Level</i>	<i>Description</i>
Ecosystem	1.
	2. All the organisms in a particular area
Population	3.
	4. An individual living thing
	5. Organs that work together to perform particular functions
Organ	6.
	7. A group of similar cells with a specific function
	8. A unit of living matter, separated from its environment by a membrane
	9. A cluster of atoms

Exercise 2 (Modules 1.2 – 1.3)

Review the scientific method by filling in the blanks in the following story. Choose from **variable, hypothesis, question, induction, control, prediction, deduction, hypothetico-deductive reasoning, descriptive, observation, experiment, experimental, and scientific method**. Answers may be used more than once.

While investigating the insect life of the Australian forest, a zoologist captured several specimens of a previously unknown species of butterfly. The butterfly was mostly black, but had conspicuous red and yellow stripes on its wings. It was very similar in appearance and structure to an all-black species found in the same area. Carefully comparing the two species, the zoologist concluded that they were closely related—members of the same family. Looking at many examples (of butterflies) and deriving a general principle (the characteristics of the butterfly family) employs a kind of logic called ¹ _____. This kind of thinking is often involved when a scientist does ² _____ science, also called “discovery” science.

A different process is followed when a scientist seeks explanations for natural events. The second method of inquiry is called ³ _____-driven science. It employs a series of steps sometimes called the ⁴ _____. Although it is not a single method, its key element is the kind of logic called ⁵ _____.

In our example, like many examples of hypothesis-driven science, the process started with a simple ⁶ _____. The zoologist noticed that predatory birds avoided the brightly colored butterflies even though they rested in tree branches in plain sight. This evoked a ⁷ _____. Is there something about the butterflies that the birds don’t like? The researcher had a hunch; she suspected that the striped butterflies tasted bad, and that their bright colors acted as a sort of “warning” to predators to stay away. This kind of tentative explanation is called a ⁸ _____.

The zoologist decided to test this in the laboratory, under conditions that she could manipulate and monitor. Such a test is called a controlled ⁹ _____. She captured insect-eating birds native to the area and put them in cages at a nearby research station. Then she netted a number of brightly striped butterflies and their black cousins. For her first experiment, she allowed the birds to choose between a black butterfly and a striped one. The birds invariably chose the black butterflies and avoided the striped ones. This confirmed her field observations.

But did the striped butterflies taste bad? The researcher set up another controlled experiment, designed to compare a ¹⁰ _____ group—striped butterflies with their wings painted black—with a ¹¹ _____ group of “normal” striped butterflies. (Actually, the “normal” butterflies were also handled and painted with clear paint, so that only one factor, or ¹² _____, would differ between the two groups.) Her hypothesis led the zoologist to make a ¹³ _____ about how she thought the experiment would turn out: *If* the stripes really acted as a warning, *then* the birds would be fooled and eat the butterflies when the stripes were covered—and that *if* the striped butterflies tasted bad, *then* the birds would spit them out. Such “if-then” thinking is called ¹⁴ _____, and is the second part of the hypothetico-deductive method.

Just as the researcher hypothesized, the birds chose the black-painted butterflies in every trial. Also, most of the birds quickly spat out the black-painted butterflies, and those that swallowed the butterflies became ill. Just to cover things, the zoologist performed

another experiment in which she painted the wings of the edible black-winged butterflies. The birds ate them with gusto, demonstrating that the paint itself was not distasteful, and produced no ill effects.

After repeating the experiments several times, the researcher wrote a paper describing her hypothesis, experiments, results, and conclusions. It was published in the *Australian Journal of Entomology*. There other scientists could read about the experiments, repeat and expand upon them, even challenge the results—all part of the process of science.

Exercise 3 (Module 1.4)

Web/CD Activity 1B Classification Schemes

Review the three domains of life by matching each statement on the right with the correct domain. Write your answer in the first column. In addition, name the kingdom for each of the organisms in Domain Eukarya, and write your answer in the second column. Choose from:

Domain Bacteria

Domain Archaea

Domain Eukarya

protists (several kingdoms)

Kingdom Plantae

Kingdom Fungi

Kingdom Animalia

Domain	Kingdom	
_____	_____	1. Rain forest trees and bromeliads
_____	_____	2. Prokaryotes
_____	_____	3. Another domain of prokaryotes
_____	_____	4. Multicellular eukaryotes that eat other organisms
_____	_____	5. Molds, yeasts, and mushrooms
_____	_____	6. Algae and protozoa
_____	_____	7. Organisms whose cells lack a nucleus
_____	_____	8. Flying fox, sloth, and spider
_____	_____	9. Multicellular photosynthetic organisms that live on land
_____	_____	10. Single-celled eukaryotes such as <i>Amoeba</i>

Exercise 4 (Module 1.5)

Web/CD Activity 1C DNA Molecules: Blueprints of Life

This module discusses the common features shared by all living things. Write a paragraph describing how a living thing familiar to you—a college student—displays these features of life.

Exercise 5 (Module 1.6)Web/CD Activity 1D *Evolution: Seahorse Camouflage Video*

Fill in the blanks in the following story to review the concepts of evolution.

Biologists have long marveled at the diversity of insect life in the tropics. ¹ _____, the English biologist who wrote *The Origin of Species*, was surprised by the large number of insect species he encountered in the rain forests of South America. In fact, biologists estimate that most species of living things are rain forest insects.

Like Darwin, the zoologist whose experiments were described in Exercise 2 concluded that the black butterfly and the new species looked alike because they were both descended from a common ² _____. But why the difference in color pattern? When she first encountered the striped butterflies, she speculated that the red and yellow stripes were an ³ _____, a beneficial feature that evolved by means of natural selection. But how could a bright color pattern be of any possible benefit? Wouldn't brightly colored butterflies be attacked by predators?

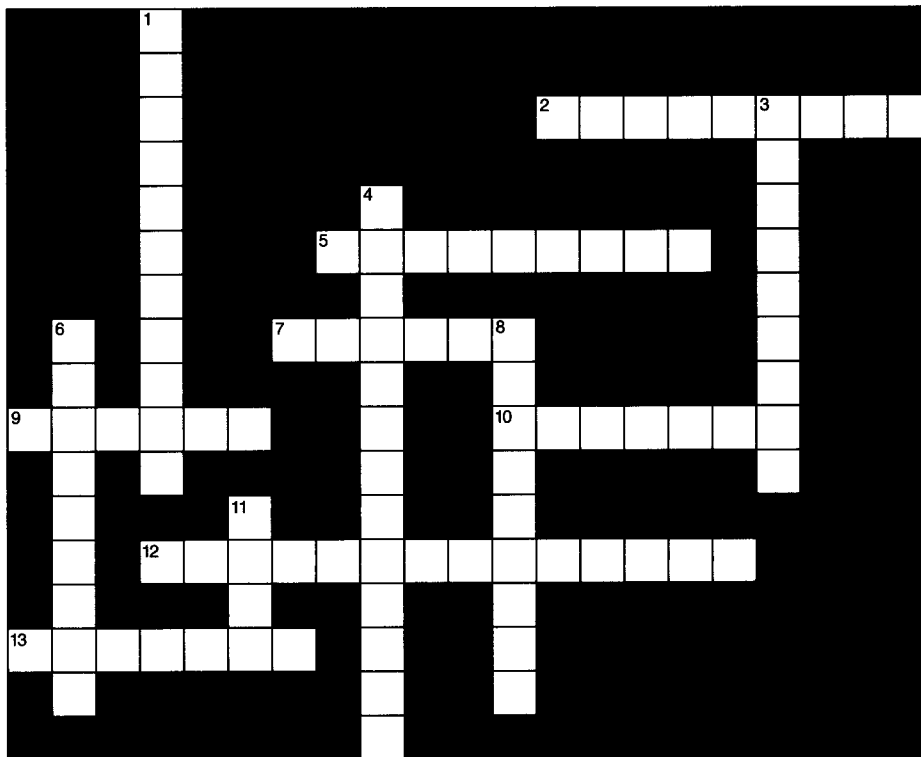
Her suspicions intensified when the zoologist saw the red and yellow winged butterfly resting on a tree limb. A predatory bird landed nearby and peered at the butterfly. The butterfly responded by rapidly flapping its wings, displaying their striped pattern, and the bird flew off.

This is what first caused the zoologist to suspect that the bright wing pattern was an example of "warning coloration," often seen in harmful or bad-tasting animals—for example, the conspicuous yellow and black stripes of bees and wasps. How could such a color pattern have evolved in this species of butterfly? Insects are delicate and unlikely to be preserved, so ⁴ _____ offer little evidence of their evolution. The zoologist speculated that at one time a ⁵ _____ of black butterflies existed in this area, breeding among themselves but not with other members of their species. These butterflies exhibited ⁶ _____ traits—slightly different wing shapes, sizes, behaviors, and so on. They also may have tasted different. Perhaps some were able to make a bad-tasting substance or store a bad-tasting substance obtained from food plants. Just as Darwin reasoned, the zoologist realized that ⁷ _____ variation must be present in the population for natural selection to operate. In the population of butterflies, good-tasting butterflies were more likely to be eaten by ⁸ _____ than bad-tasting ones before they had a chance to ⁹ _____. The surviving bad-tasting butterflies were able to reproduce, and they passed their ability to make the bad-tasting chemical on to their ¹⁰ _____. Over time, the bad-tasting butterflies became more numerous. Among the bad-tasting butterflies, there may have been variation in wing coloration. Butterflies with bright colors on their wings were easier for predators to remember and avoid. They had more offspring than less-conspicuous individuals, and eventually bright-colored, bad-tasting butterflies became the norm in the population. In this situation, as in others explained by Charles Darwin, ¹¹ _____ occurs as heritable ¹² _____ are exposed to ¹³ _____ factors that favor the ¹⁴ _____ success of some individuals over others.

The zoologist concluded that, over a long period, the changes in palatability, wing pattern, and other characteristics must have combined, and a new ¹⁵ _____ of butterfly came into existence. According to Darwin, the ¹⁶ _____ of new species results from the accumulation of minute changes resulting from natural selection over ¹⁷ _____. This short story is just one illustration of evolution, biology's central ¹⁸ _____—an idea, or ¹⁹ _____, with great explanatory power.

Exercise 6 (Module 1.7)

This module describes how organisms interact with their environments. Review the web of interactions by completing this crossword puzzle.



Across

2. Chemical ____ cycle within the ecosystem's web.
5. Darwin's theory of evolution by natural ____ focuses on the responses of organisms to their environment.
7. ____ produce much of the food that supports the ecosystem.
9. ____ comes into an ecosystem in the form of sunlight.
10. Decomposers ____ chemical nutrients.
12. Plants and certain prokaryotes and protists trap energy in the process of ____.
13. ____ eat plants or other animals.

Down

1. ____ such as prokaryotes and fungi convert dead matter to usable nutrients.
3. An ____ is the highest level in nature's hierarchy.
4. All organisms in an ecosystem are connected by a web of ____.
6. In an ecosystem, there are many interactions among living organisms, and between living organisms and their ____ environment.
8. In an ecosystem or organism, function comes from ____.
11. Plants absorb mineral nutrients from the ____.

Exercise 7 (Module 1.8)

List six ways in which you think the science of biology and its technological applications may affect society in the next decade. Which of these are primarily scientific? Which are technological? Which do you think will have the most effect on you personally?

Testing Your Knowledge

Multiple Choice

- All organisms have which of the following in common?
 - They exhibit complex organization.
 - They store genetic information in DNA molecules.
 - They utilize energy.
 - They reproduce.
 - all of the above
- Extrapolating from general premises to specific results is a kind of logic called
 - induction.
 - synthesis.
 - deduction.
 - experimentation.
 - observation.
- Biologists group living things into ____ domains.
 - 2
 - 3
 - 4
 - 5
 - about 10
- A bacterium and an amoeba are placed in different domains because
 - a bacterium is single-celled.
 - an amoeba is photosynthetic.
 - an amoeba can move.
 - a bacterial cell is much simpler.
 - an amoeba is single-celled.
- Most of the organisms in Kingdom ____ are photosynthetic.
 - Animalia
 - Protista
 - Plantae
 - Fungi
 - none of the above
- At the most fundamental level in life's hierarchy, all living things contain the same basic kinds of
 - cells.
 - organs.
 - molecules.
 - tissues.
 - systems.
- An educated guess posed as a tentative explanation is called a
 - theory.
 - control.
 - variable.
 - prediction.
 - hypothesis.
- The information in ____ underlies all of the properties that distinguish life from nonlife.
 - carbon
 - DNA
 - proteins
 - populations
 - chemical nutrients

9. The ____ is the highest level in life's structural hierarchy.
 - a. ecosystem
 - b. cell
 - c. organism
 - d. population
 - e. molecule
10. There are many interdependencies in an ecosystem. Prokaryotes and fungi play an important role in the ecosystem primarily because they
 - a. cause diseases that keep populations in check.
 - b. trap water, which is then used by other organisms.
 - c. decompose the remains of dead organisms.
 - d. are responsible for producing energy.
 - e. do photosynthesis, which makes the food for other species.

Essay

1. Name the three domains of life and briefly describe their distinguishing characteristics.
2. Name the kingdoms of Domain Eukarya, identify the organisms in each, and briefly describe the criteria that separate each kingdom from the others.
3. What kinds of questions can be answered and what kinds of problems can be solved by science? What kinds of questions are outside the realm of science?
4. Explain how the information in DNA relates to the common features that characterize life.

Applying Your Knowledge

Multiple Choice

1. A crop scientist noted that, over a period of 10 years, a beetle species that feeds on rice gradually became resistant to insecticide. Which of the following best explains this in terms of natural selection?
 - a. The insecticide mutated the beetles exposed to the biggest doses.
 - b. Some beetles learned to tolerate the insecticide and passed this ability to their offspring.
 - c. Beetles learned to avoid the spray and passed the knowledge to their offspring.
 - d. The insecticide caused the beetles to reproduce more quickly than normal.
 - e. Those beetles with natural resistance to the insecticide had the most offspring.
2. Researchers testing new drugs usually give the drug to one group of people and give placebos, "sugar pills," to another group. The group receiving the sugar pills
 - a. constitutes the experimental group.
 - b. is needed so that the test will be repeated enough times.
 - c. is the control group.
 - d. is a backup in case some of the people getting the drug drop out of the test.
 - e. is the experimental variable.
3. ____ has characteristics that result from the organization of its component ____ .
 - a. A population . . . ecosystems
 - b. A tissue . . . organs
 - c. A cell . . . tissues
 - d. An organism . . . organ systems
 - e. A molecule . . . cells
4. An ecologist studied the effect of nutrients and predators on the population growth of bacteria on the bottom of a pond. His study of bacteria could not involve which of the following levels in life's structural hierarchy?
 - a. ecosystem
 - b. organ
 - c. organism
 - d. population
 - e. molecule
5. A rain forest primate called an aye-aye has a long middle finger that it uses to probe for insects in cracks and crevices in tree bark. This connection between structure and function developed gradually as a result of
 - a. reproduction.
 - b. population growth.
 - c. natural selection.
 - d. DNA replication.
 - e. energy exchange.

6. Which of the following does *not* illustrate technology?
 - a. DNA research is used to cure an inherited disease.
 - b. Scientists develop a bacterium that destroys toxic wastes.
 - c. A biologist identifies a new species of monkey.
 - d. A chemical that slows cell division is used to treat cancer.
 - e. Biologists breed a disease-resistant kind of corn.

Essay

1. Choose a familiar wild animal—a squirrel, a toad, or a duck, for example—and describe some of the web of relationships that connect it with other organisms in its ecosystem.
2. Beavers are descendants of land-dwelling rodents similar to rats. Explain how natural selection could have shaped the beaver's flat tail and webbed feet, which it uses for swimming.
3. Jason tried a new fertilizer called MegaGro on his garden. He said, "I used it on all my tomato plants this year, and they grew much better than they did last year! MegaGro is fantastic!" Was Jason's test of MegaGro scientifically valid? Why or why not?
4. Tropical birds called oilbirds nest in caves and emerge at night to forage for seeds. Biologists think that oilbirds might be able to avoid obstacles in their caves and in the tangled growth of the rain forest much the way bats do—by making sounds and listening to the echoes. Describe a controlled experiment to test this hypothesis.
5. Explain how each of the following shows the connection between biological structure and function: your hand, a leaf, a hawk's beak, a frog's hind legs.
6. Describe the hierarchy of structural levels of which your body is composed. Give a specific example of a feature at one level that is not seen in the parts that make it up.
7. A camera sends back pictures of purple gelatinous blobs in near-boiling water near volcanic vents on the ocean floor. What properties should scientists look for to determine whether the blobs represent life?
8. How is human DNA different from the DNA of a chimpanzee? The DNA of a goldfish?

Extending Your Knowledge

1. Take a short walk outside, or look out a window, and describe how what you see relates to life's domains and kingdoms, life's hierarchy of structural organization, the common features that characterize life, and the interconnectedness of living things.
2. For one week, keep a list of biological issues in the news—the newspaper, magazines, television, radio, and conversations with friends and family. How many different issues did you encounter during the week? What were the major categories of biological issues in the news? Which of the news items are related to science, and which to technology?