Chapter 1: Evolution, the Themes of Biology, and Scientific Inquiry

1.1 Use examples to illustrate each theme of this book.
1.2 Summarize how evolution accounts for the unity and diversity of life.
1.3 Discuss the scientific process.
1.4 Evaluate the contribution of diversity among scientists to scientific progress.

This chapter will serve as a review of biological concepts that you may have learned in an earlier course and give you an overview of what you will study this year. It introduces the major themes of biology and provides a foundation for understanding scientific inquiry.

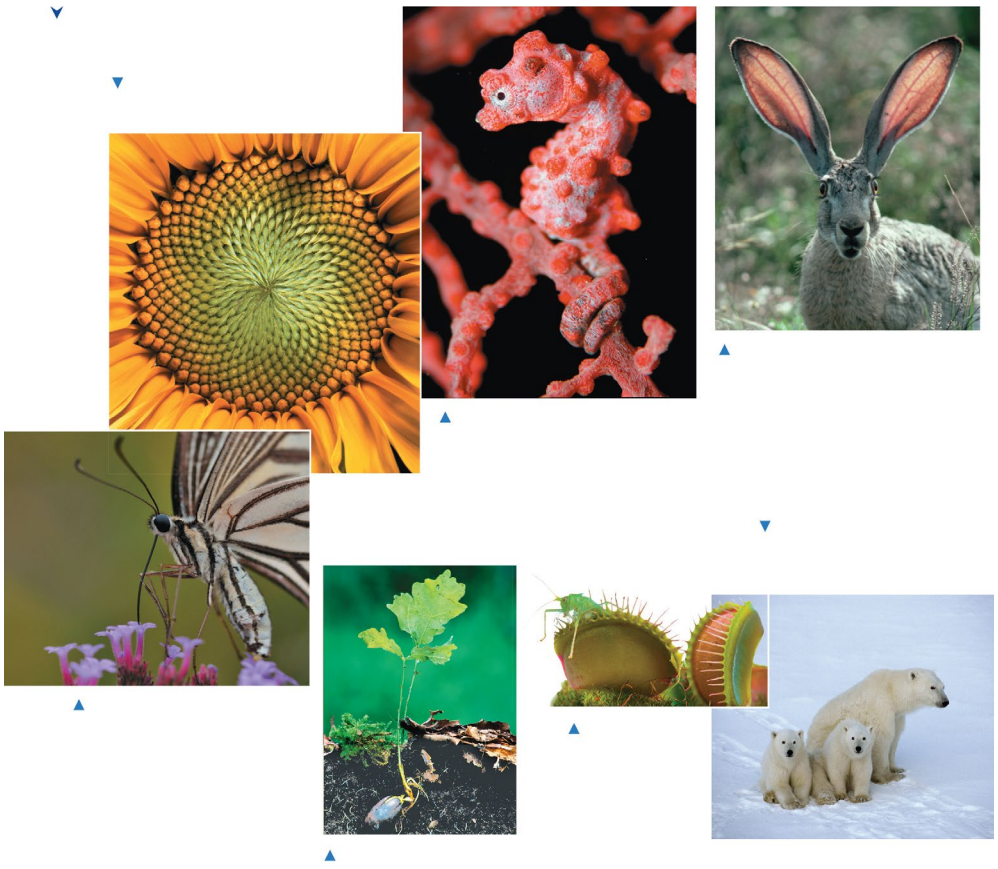
Study Tip: In Figure 1.1, notice the clearly recognizable hooked jaw and deep red colour of the sockeye salmon . This fish, like all organisms on Earth, demonstrates the unifying themes of biology. Read through the examples in this figure, as they will be visited repeatedly in your study of biology.

Concept 1.1 The study of life reveals unifying themes

LO 1.1: Use examples to illustrate each theme of this book.

1. In the overview in your text, Figure 1.2 notes many of the properties of life. Label the seven properties illustrated in the following figure and give a *different* example of each.

   See text for the labeled figure.



Additional examples may vary.

2. What are **emergent properties?** Give two examples.

   Emergent properties are new properties that arise with each step upward in the hierarchy of life, owing to the arrangement and interactions of parts as complexity increases. Possible examples include the specific organization of molecules in a chloroplast necessary for photosynthesis to take place, and the lack of brain function after head trauma, despite the presence of necessary brain tissue.

3. Life is organized on many scales. Figure 1.3 in your text zooms you in from viewing Earth from space all the way to the level of molecules. As you study the figure in your text, write in a brief definition of each level.

   See the text for the labeled figure.

1. **The Biosphere**: The entire portion of Earth inhabited by life; the sum of all the planet's ecosystems.

2. **Ecosystems**: All the organisms in a given area as well as the abiotic factors with which they interact; one or more communities and the physical environment around them.

3. **Communities**: All the organisms that inhabit a particular area; an assemblage of populations of different species living close enough together for potential interaction.

4. **Populations**: A group of individuals of the same species that live in the same area and interbreed, producing fertile offspring.

5. **Organisms**: Individual living things.

6. **Organs and Organ Systems**: A group of organs that work together in performing vital body functions.

7. **Tissues**: An integrated group of cells with a common structure, function, or both.

8. **Cells**: Life's fundamental unit of structure and function.

9. **Organelles**: Any of several membrane-enclosed structures with specialized functions, suspended in the cytosol of eukaryotic cells.

10. **Molecules**: Two or more atoms held together by covalent bonds.

4. Our study of biology will be organized around recurring themes. Make a list here of the themes that are presented and give an example that illustrates each theme. This will help you see the big picture and organize your thinking. (Go to the *Summary of Key Concepts* for a concise look at the themes.)

Theme Description	Example
New properties emerge at successive levels of biological organization.	Examples may vary.
Life's processes involve the expression and transmission of genetic information.	Examples may vary.
Life requires the transfer and transformation of energy and matter.	Examples may vary.
From molecules to ecosystems, interactions are important in biological systems.	Examples may vary.
Evolution accounts for the unity and diversity of life.	Examples may vary.

5. As you read this concept on unifying themes, you may be reminded of things you have studied in an earlier course. Because this material will be presented in detail in future chapters, you will come back to these ideas, so don't fret if some of the concepts presented are unfamiliar. However, to guide your study, define these terms as you come to them.

eukaryotic cell: A type of cell with a membrane-enclosed nucleus and membrane-enclosed organelles. Organisms with eukaryotic cells (protists, plants, fungi, and animals) are called eukaryotes.

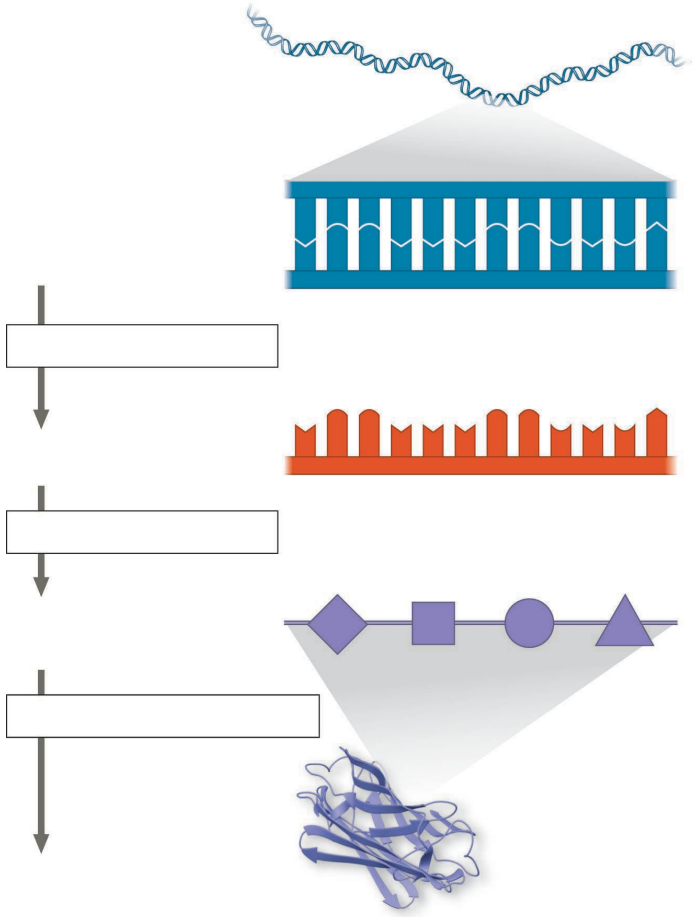
prokaryotic cell: A type of cell lacking a membrane-enclosed nucleus and membrane-enclosed organelles. Organisms with prokaryotic cells (bacteria and archaea) are called prokaryotes.

genes: Discrete units of hereditary information consisting of a specific nucleotide sequence in DNA (or RNA, in some viruses).

gene expression: The entire process by which the information in a gene directs the manufacture of a cellular product.

genome: The genetic material of an organism or virus; the complete complement of an organ ism's or virus's genes along with its noncoding nucleic acid sequences.

6. All organisms, from bacteria to you, produce proteins from DNA instructions. Refer to Figure 1.8b in your text, and then label the gene, DNA, RNA, amino acids and protein on the figure below. Next label the three steps in the process and describe each.



See the text for the labeled figure.

7. Study Figure 1.9 in the text. Describe the difference between the movement of energy and the movement of chemicals in an ecosystem.

Energy flows into an ecosystem from sunlight, which is converted to chemical energy via photosynthesis. This chemical energy is stored in molecules such as sugars, and becomes food to provide energy for other organisms, which lose much of this energy as heat. Chemicals, however, are cycled through organisms and the physical environment.

8. Describe three ways in which organisms interact with either other organisms or their environment.

   Answers may vary.

9. Interactions can be controlled by feedback regulation. Explain and give an example of each type of feedback.

   negative feedback: **Negative feedback** is a form of regulation in which accumulation of an end product of a process slows the process; in physiology, it is a primary mechanism of homeostasis, whereby a change in a variable triggers a response that counteracts the initial change. Examples may vary.

   positive feedback: **Positive feedback** is a form of regulation in which an end product of a process speeds up that process; in physiology, it is a control mechanism in which a change in a variable triggers a response that reinforces or amplifies the change. Examples may vary.

Concept 1.2 The Core Theme: Evolution accounts for the unity and diversity of life

LO 1.2: Summarize how evolution accounts for the unity and diversity of life.

10. Explain how the process of evolution accounts for both the unity and diversity of life on Earth.

    Species accumulate differences from their ancestors as they adapt to different environments over time leading to diversity, but there can be unifying traits from a common ancestor that are shared by their descendants.

11. Taxonomy is the branch of biology that names and classifies organisms. Because of new molecular information, there have been many changes in the placement of certain groups in recent years. All life is now organized into three domains. Which two domains are prokaryotic, and which one is eukaryotic? What four major life groups form the Eukarya?

    See the text for the labeled Figure 1.13.

    Bacteria: They are classified into multiple kingdoms, but taxonomic work continuing. No kingdoms are listed at this point for this prokaryotic domain.

    Archaea: They are classified into multiple kingdoms, with taxonomic work continuing. No kingdoms listed at this point for this prokaryotic domain.

    Eukarya: All of the eukaryotes are grouped into this domain that includes four subgroups: kingdom Plantae, kingdom Fungi, kingdom Animalia, and the protists.

12. What two main points were articulated in Darwin's *The Origin of Species*?

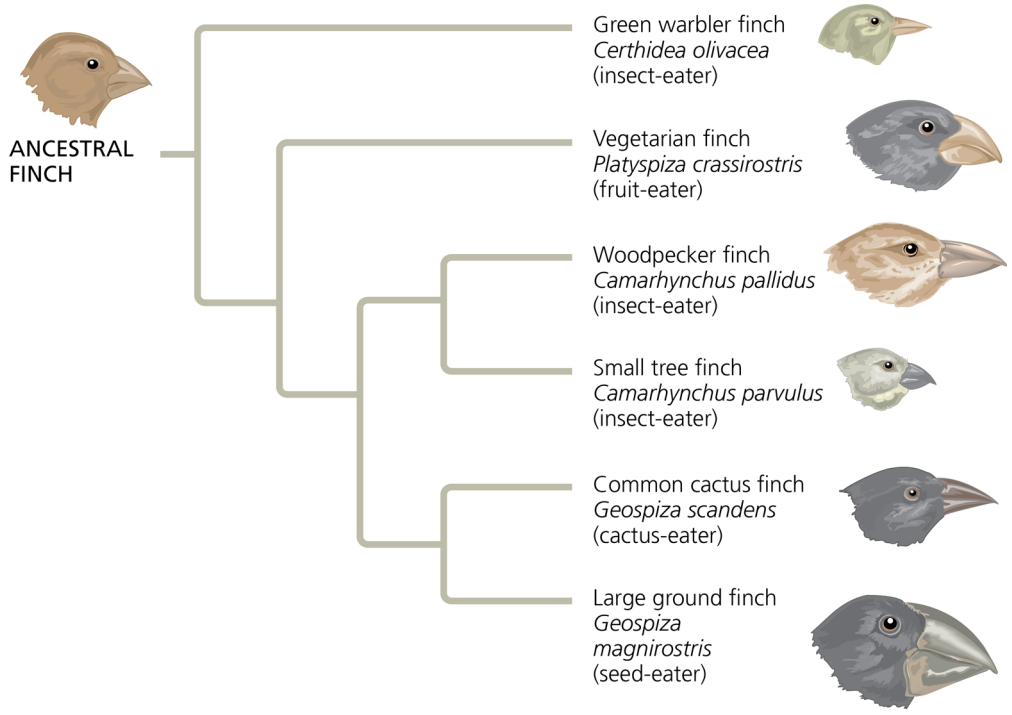
Contemporary species arose from a succession of ancestors, "descent with modification" and a proposed mechanism for descent with modification, "natural selection."

13. What did Darwin propose as the mechanism of evolution? Use Figure 1.18 as your example to summarize this three-part mechanism.

Natural selection: A process in which individuals that have certain inherited traits tend to survive and reproduce at higher rates than other individuals because of those traits.

There are variable traits in a population, some individuals are eliminated because of a particular trait, other individuals with a different trait survive and are able to pass on the more favorable version of the trait to their offspring so the frequency of the favorable trait in the population increases.

14. Study Figure 1.20 from your text (shown in the following), which shows an evolutionary "tree." What is indicated by each twig? What do the branch points represent? Label the branch point that represents the ancestral point for all species of finch.



See the text for the labeled figure.

Each twig represents one species. Each branch point represents the common ancestor of the evolutionary lineages originating there and their descendants. The "common ancestor" of the Galápagos finches originated on the South American mainland.

Concept 1.3 In studying nature, scientists form and test hypotheses

LO 1.3: Discuss the scientific process.

15. In your Biology course, you will be involved in *inquiry*. What does this mean, and what may be involved?

Inquiry is a search for information and explanations of natural phenomena. However, this may take many diverse approaches that rely on careful observations and testable hypotheses. In testing these hypotheses, more observations may inspire revisions of old hypotheses or development of new ones. In your course, you will have the opportunity to approach a biological problem by generating your own questions and designing your own experiment.

16. What is *data*?

Data are items of information upon which scientific inquiry is based.

17. Distinguish between *quantitative* and *qualitative data*. Which type would be presented in a data chart and could be graphed? Which type is found in the field sketches made by Jane Goodall?

Quantitative data are generally recorded as measurements, and can be organized into a chart or graph.

Qualitative data are often recorded in the form of descriptions, rather than numerical measurements, such as the field sketches made by Jane Goodall.

18. In science, how do we define *hypothesis*?

A hypothesis is a testable explanation for a set of observations based on the available data and guided by inductive reasoning. A hypothesis must lead to predictions that can be tested by making additional observations or by performing experiments.

19. A scientific hypothesis has two important qualities. The first is that it is *testable*. What is the second?

That it is falsifiable.

20. Can a scientific hypothesis be proven? Explain your answer!

No. No amount of experimental testing can prove a hypothesis beyond a shadow of a doubt, because it is impossible to test all alternative hypotheses.

21. What types of hypotheses do not meet the criteria of science, that is, are not testable?

Hypotheses that address supernatural phenomena or religious issues do not meet the criteria of testable hypotheses.

22. Study Figure 1.23 in your book to get a better idea of the scientific process. Notice that it does not follow the steps of what has been called "the scientific method" but rather shows how making and testing hypotheses are interwoven with other activities to answer questions. This realistically portrays what you will encounter in your own inquiry labs. For example, in what different directions may the data you collect lead?

Answers may vary.

23. What is a *controlled experiment*?

A controlled experiment is one that is designed to compare an experimental group with a control group.

24. Explain the difference between the *dependent* and *independent variable.* Understanding this will be useful when you analyze and graph your data.

The *dependent variable* refers to the factor that is being measured in an experiment and the *independent variable* is the factor that is being manipulated by the researcher.

25. The text points out a common misconception about the term *controlled experiment*. In the mouse colouration experiment, what factors were held *constant*?

In this experiment, plastic mouse models were employed that differed only in their coloration, so other variables are cancelled out by the use of a control group. In this case, the control group is the camouflaged mouse normally resident in the area.

26. Explain what is meant by a scientific *theory* by giving the three ways your text distinguishes a theory from a hypothesis or mere speculation.

a. A scientific theory is much broader in scope than a hypothesis.

b. A scientific theory is general enough to spin off many new, testable hypotheses.

c. A scientific theory, compared to any one hypothesis, is generally supported by a much greater body of evidence.

Concept 1.4 Science benefits from a cooperative approach and diverse viewpoints

LO 1.4. Evaluate the contribution of diversity among scientists to scientific progress.

27. What is a *model organism*?

Model organisms are species that have been extensively studied and are used to understand biology of other species, including humans. Examples include *Drosophila melanogaster*, *Danio rerio*, *Mus musculus,* and others.

28. Explain why diverse backgrounds amongst scientists are important.

Answers may vary.

Test Your Understanding

Now you should be ready to test your knowledge. Place your answers here:

1. B 2. C 3. C 4. B 5. C 6. A 7. D

Answers to Problem-Solving Exercises and Interpret the Data Questions for Instructors

Lisa A. Urry
Mills College
Michael L. Cain
Bowdoin College
Steven A. Wasserman
University of California
Peter V. Minorsky
Mercy College
Rebecca B. Orr
Collin College

Fiona E. Rawle
University of Toronto
Dion G. Durnford
University of New Brunswick
Chris D. Moyes
Queen's University
Kevin Scott
University of Manitoba
Vivian R. Dayeh
University of Waterloo

Biology
Fourth Canadian Edition

Urry, Cain, Wasserman,
Minorsky, Orr, Rawle, Durnford, Moyes, Scott

Answers for Instructors
Campbell BIOLOGY, Fourth Canadian Edition

Appendix A of the book includes answers for students for Figure Questions, Concept Check Questions, Summary of Key Concepts Questions, end-of-chapter multiple-choice questions, and Draw It Questions. This document for instructors includes suggested answers and teaching tips for the Scientific Skills Exercises and suggested answers for the Problem-Solving Exercises, Interpret the Data Questions, and the short-answer essay questions at the end of each chapter.

The Scientific Skills Exercises, Problem-Solving Exercises, Interpret the Data Questions, and additional questions for the Visualizing Figures
can be assigned in Mastering Biology, where they are graded automatically.

Tips for Grading Short-Answer Essays

The ability to communicate clearly in writing is essential for almost any profession your students choose to pursue. As instructors, it is often frustrating to be faced with a large class full of students who have had inadequate preparation in writing skills, knowing that you don't have the resources to help your students develop these skills.

The **Write About a Theme** questions at the end of each chapter are an attempt on the part of the authors to partner with you in this endeavor. At the end of each chapter, we ask the student to write a short essay of 100-150 words that relates the material they learned in the chapter to one of the themes introduced in Chapter 1 and featured throughout the book. The **Write About a Theme** questions can be used as in-class or outside-of-class assignments.

For ease of grading, sample key points and sample top-scoring answers for the **Write About a Theme** questions are provided for instructors and TAs in this document. The list of key points provides a guide to the ideas that students should include in their essays. In addition, suggested answers to all of the Evaluating/Creating Short Answer questions can be found in this document.

The time necessary to grade writing exercises has prohibited many instructors from assigning them. Using a grading rubric, however, can streamline the process. Some instructors have found they can train TAs or even students to grade short essays accurately. (Students can grade their own essays or those of their classmates.) A suggested grading rubric for the **Write About a Theme** essays is shown at the end of these tips and in the Study Area of Mastering Biology. This rubric can also be modified to use with the other Evaluating/Creating Short Answer questions.

The simplest way to use the rubric is to read through each essay and determine how well the writer has accomplished the four aims listed at the top of the columns. The essay can then be graded as a 4, 3, 2, 1, or 0 based on the overall quality of the essay. Alternatively, you could assign 0 to 4 points for *each* of the aims, and then total the points out of 16 possible points.

You can also weight one of the aims more highly. For example, if you want to focus primarily on writing skills (aim #4: Quality of Writing) with the other aims weighted equally, the

score for each aim can be multiplied by a "weighting factor." Aim #4 could be assigned 40% of the total points, with aims # 1, 2, and 3 each worth 20%. The score (out of 4) obtained for aim #4 is multiplied by 40, and each of the others multiplied by 20, giving a total of 400 points (160 + 80 + 80 + 80 = 400).

To train TAs to grade essays in a large class, the instructor should first read through some of the essays, looking for a representative example of each of the five scores (4, 3, 2, 1, and 0 for the simplest grading scheme described above). Copies of the five representative essays (with scores hidden) can be passed out to TAs, asking them to grade the essays based on the rubric and a 0-4 grading scheme. Subsequent discussion with the TAs about their essay rankings should clarify the standards, after which they can be given a few "test" essays to grade to ensure consistency in grading practices. This training exercise should take no more than 30-45 minutes. Using a similar rubric and training scheme, the Montgomery County Public School System in Maryland has been able to train a team of instructors to grade thousands of short essays consistently in a relatively short time.

There is also a web-based program called Calibrated Peer Review (CPR) (developed at UCLA with funding from the National Science Foundation and the Howard Hughes Medical Institute) that trains students to evaluate their own work or that of their classmates ("peers"). The program is described at **http://cpr.molsci.ucla.edu/**.

When assigning essays, the instructor should point out the rubric to students (in the Study Area of Mastering Biology) or provide a customized rubric to students. Students can then refer to the rubric before writing to see what is expected of them. They can also check their essay before submitting it to make sure they have met all the criteria in the rubric. Instructors should also encourage students to read the Writing Tips provided under "Additional Resources / Writing Tips and Rubric" in the Study Area of Mastering Biology, which also includes the suggested grading rubric.

Suggested Grading Rubric for "Write About a Theme" Short-Answer Essays				
	Understanding of Theme and Relationship to Topic	**Use of Supporting Examples or Details**	**Appropriate Use of Terminology**	**Quality of Writing**
4	Evidence of full and complete understanding	Examples well chosen, details accurate and applied to theme	Accurate scientific terminology enhances the essay	Excellent organization, sentence structure, and grammar
3	Evidence of good understanding	Examples or details are generally well applied to theme	Terminology is correctly used	Good sentence flow, sentence structure, and grammar
2	Evidence of a basic understanding	Supporting examples and details are adequate	Terminology used is not totally accurate or appropriate	Some organizational and grammatical problems
1	Evidence of limited	Examples and details	Appropriate	Poorly organized;

	understanding	are minimal	terminology is not present	grammatical and spelling errors detract from essay
0	Essay shows no understanding of theme	Examples lacking or incorrect	Terminology lacking or incorrect	Essay is very poorly written

Suggested Answers and Teaching Tips

CHAPTER 1 EVOLUTION, THE THEMES OF BIOLOGY, AND SCIENTIFIC INQUIRY

Scientific Skills Exercise

Teaching objective: Students build scientific skills by interpreting data in a pair of bar graphs and relating the data to the biological system it came from.

Teaching tips: A version of this Scientific Skills Exercise can be assigned in Mastering Biology.

If this is the first exercise the students are doing related to interpreting graphs, then you will need to spend time reviewing independent and dependent variables. If the students are confused by having two independent variables on one graph, have them cover one set of data while they look at the other (for example, cover the "full moon" portion of graph A while analyzing the "no moon" portion of it).

In these graphs, there are no statistical significance values given for comparisons between treatments. In the original paper, there was a statistical difference between predation levels of light brown versus dark brown mice in light-coloured soil enclosures with no moon and in dark-coloured soil enclosures under a full moon. The other two combinations, light-coloured soil under a full moon and dark-coloured soil with no moon, had no statistically significant difference between light and dark mice.

Answers:

1. (a) The independent variables for each graph are the coat colour of the mice (light or dark brown) and the presence or absence of moonlight (full moon or no moon). These are on the *x*-axis. Taking both graphs together, a third independent variable is the colour of soil in the enclosure. **(b)** The dependent variable is the amount of predation, measured as the number of mice caught. The dependent variable is on the *y*-axis of the two graphs.

2. (a) About 19. **(b)** About 12. **(c)** Based on the data, the mouse would be more likely to escape on dark soil. This might be because in the moonlight, a dark mouse on light soil would be more noticeable than one on dark soil.

3. (a) Under a full moon (12 were caught vs. 20 under no moon). **(b)** Under no moon (11 were caught vs. 18 under a full moon).

4. (a) Dark soil field with a full moon. **(b)** Light soil with no moon.

5. (a) No moon plus dark brown coat had the highest predation level in the light soil enclosure (38 mice were caught). **(b)** Full moon plus light brown coat had the highest predation level in the dark soil enclosure.

6. Being on the contrasting soil is most deadly for both colours of mice.

7. The total number of mice caught on moonlit nights was about 77, while the total caught on nights without moonlight was about 95. This suggests that owls hunting on moonlit nights are slightly less successful than are owls hunting on nights without moonlight.

Interpret the Data

Figure 1.25 In the beach habitat, approximately 27 light models and 73 dark models were attacked. In the inland habitat, approximately 76 light models and 24 dark models were attacked. Yes, mouse models with camouflage colouration were preyed on *less* often than non-camouflaged mouse models. In both habitats, the models whose pattern did not match their surroundings suffered much higher "predation" than did the camouflaged models. The results are consistent with the researchers' prediction: that mouse models with camouflage colouration would be preyed on less often than non-camouflaged mouse models. Thus, the experiment supports the camouflage hypothesis.

Suggested Answers for Evaluating/Creating Short Answer Questions

See the general information on grading short-answer essays and a suggested rubric at the beginning of this document.

9. Evolution Connection
Common ancestry explains this observation. The thousand-some-odd genes shared by humans and prokaryotes originated in early prokaryotes. They have been retained, with some modification, over the billions of years of eukaryotic evolution. These genes no doubt code for proteins and RNAs whose functions are essential for survival—for example, the genes that code for ribosomal RNA, which is important for protein synthesis in both prokaryotes and eukaryotes.

10. Scientific Inquiry
Many legitimate hypotheses could be proposed to extend the investigation. Here is one example.

If the camouflage colour has arisen through the processes of natural selection due to visual predators, then you might wonder what would happen if a population of beach mice lived in an area where predators were absent. It might be possible to do a long-term study in an area where you excluded predators. Mice have fairly short generation times, so if predation is "naturally selecting" lighter coloured mice, then in the absence of predation you might predict the fur colour would not remain predominantly light in such an experimental population.

11. Scientific Inquiry
Students are asked to use a PubMed search to identify an abstract of an article authored or co-authored by Hopi Hoekstra from 2015 forward. The range of abstracts from which students might choose will grow as the Hoekstra Lab generates additional publications.

12. Write About a Theme: Evolution
Sample key points:

- Darwin used reasoning based on observations to develop his theory of natural selection as a mechanism for evolution.
- His observations included:
    - Heritable variations exist in each population.
    - A population has more individuals than can be supported by the environment.
    - Each species seems suited for its particular environment.
- He proposed that the best-adapted individuals in a population would outcompete others for resources and disproportionately survive and produce more offspring, leading to an increase in the adaptations seen in the population.

Sample top-scoring answer:
Based on many observations of different species, Darwin proposed his theory that evolution by means of natural selection accounts for both the unity and diversity of life on Earth. He noticed that variations existed among the individuals in a population and that these variations seemed to be heritable. He also saw that populations could grow larger than could be supported by the resources around them. Finally, he observed that species (like the different species of finches) seemed to suit their environment. He proposed that the best-suited individuals in a population would survive and reproduce more successfully that those less adapted to their environment, and he called this "natural selection." In Darwin's view, this mechanism could account for both the unity and diversity of features among species. The descent of organisms from a common ancestor explains similar features, while the force of natural selection in different environments accounts for differences between organisms.

13. Synthesize Your Knowledge
It's difficult to pick out this gecko against the background of the tree trunk, because the gecko itself looks like mossy bark. This colouration likely makes it harder for the gecko to be seen by predators, thus enhancing its survival. This cryptic colouration pattern probably evolved over generations. The members of a gecko population that more closely resembled their background would have been less visible to predators, thus more likely to survive, reproduce, and leave offspring. The offspring would inherit the genes that generated the mossy bark colouration, and

the offspring that blended in better would survive better and reproduce more successfully. Over generations, the colouration would become a closer and closer match to the tree bark. (The mossy leaf-tailed gecko is endemic to Madagascar, meaning it is found only there and nowhere else in the world. Many endemic species live in Madagascar. This is because it is an island with land features and climatic factors that have allowed evolution of many species in isolation.)