Answers for Teachers
Campbell Biology in Focus, AP* Edition

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Appendix A of the book includes answers for students for figure legend questions, Concept Check questions, Summary of Key Concepts questions, multiple-choice questions, and Draw It questions. This document for teachers includes suggested answers and teaching tips for the Scientific Skills Exercises and suggested answers for the Interpret the Data questions and the short-answer essay questions at the end of each chapter. The Scientific Skills Exercises can be assigned in MasteringBiology, 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 teachers, 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 Focus on a Big Idea 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 Big Ideas of biology that are introduced in Chapter 1 and featured throughout the book. The Focus on a Big Idea exercises 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 Focus on a Big Idea questions are provided for teachers 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 end-of-chapter essay questions can be found in this document.

The time necessary to grade writing exercises has prohibited many teachers from assigning them. Using a grading rubric, however, can streamline the process. A suggested grading rubric for the Focus on a Big Idea essays is shown at the end of these tips and in the Study Area of MasteringBiology. This rubric can also be modified to use with the other end-of-chapter essay 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).

Using a similar rubric, the Montgomery County Public School System in Maryland has been able to train a team of teachers to grade thousands of short essays consistently in a

relatively short time. To train teachers, the lead teacher 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) were passed out to the teachers, asking them to grade the essays based on the rubric and a 0-4 grading scheme. Subsequent discussion with the teachers about their essay rankings clarified the standards, after which they were given a few "test" essays to grade to ensure consistency in grading practices.

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 teacher should point out the rubric to students (in the Study Area of MasteringBiology) 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. Teachers should also encourage students to read the Writing Tips provided under "Writing Tips and Rubric" in the Study Area of MasteringBiology, which also includes the suggested grading rubric.

Suggested Grading Rubric for "Focus on a Big Idea" 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 understanding	Examples and details are minimal	Appropriate terminology is not present	Poorly organized; 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 INTRODUCTION: EVOLUTION AND THE FOUNDATIONS OF BIOLOGY

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 MasteringBiology.

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-colored soil enclosures with no moon and in dark-colored soil enclosures under a full moon. The other two combinations, light-colored soil under a full moon and dark-colored 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 color 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 color 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 colors of mice.

7. The total number of mice caught on moonlit nights was about 77 and on nights with no moon was about 95, so the dark nights seem to be slightly better overall for hunting for owls.

Interpret the Data

Figure 1.21 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.

Suggested Answers for End-of-Chapter Essay Questions

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

7. Scientific Inquiry
Many legitimate hypotheses could be proposed to extend the investigation. Here is one example. If the camouflage color 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 colored mice, then in the absence of predation you might predict the coat color would not remain predominantly light in such an experimental population.

8. 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 2014 forward. It is therefore expected that the range of abstracts from which students might choose will grow as the Hoekstra lab generates additional publications.

9. Focus on 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.

10. Focus on Information
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.

11. 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 coloration likely makes it harder for the gecko to be seen by predators, thus enhancing its survival. This cryptic coloration 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 coloration, and the offspring that blended in better would survive better and reproduce more successfully. Over generations, the coloration 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.)

CHAPTER 2 THE CHEMICAL CONTEXT OF LIFE

Scientific Skills Exercise

Teaching objective: This exercise is designed to give students practice in figuring out what is shown on a graph, how to describe the major trend(s) in the data, and extracting values from the graph to calculate related information. The student is then led back to the biological context of the data to draw a conclusion.

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

Most students can look at a graph and describe the slope of the data line. However, many struggle with writing out what the trend means in terms of the relationship between what was reported on one axis relative to the other axis. Thus, while a student may respond that the data line has a positive slope, they may also respond that a higher calcification rate results in a higher carbonate ion concentration. Helping them sort out dependent and independent variables should clear up the problem. Visual learners will benefit from drawing a mock-up of 1 square meter of the reef, with dots in the water to represent carbonate ions and arrows to indicate calcification.

In this example, students will need to make the additional mental step of reading the trend line right to left, instead of left to right (the natural tendency), to reach a conclusion about the effect of *decreased* carbonate ion concentration on calcification rate and reef growth.

Answers:

1. (a) The *x*-axis shows the concentration of carbonate ions in units of micromoles of carbonate ions per kilogram of seawater. (b) The *y*-axis shows the calcification rate in units of millimoles of calcium carbonate accumulated per square meter of reef per day. (c) Carbonate ion concentration is the independent variable. (d) Calcification rate is the dependent variable.

2. The data show that the rate of calcification is positively related to the concentration of carbonate ions in the seawater. As the concentration of carbonate ions increases, the rate of calcification increases.

3. (a) If the seawater carbonate ion concentration was 270 µmol/kg, the calcification rate would be approximately 19 mmol $CaCO_3/m^2 \cdot$day. It would take 1 square meter of reef approximately 1.6 days to accumulate 30 mmol of $CaCO_3$ [(30 mmol of $CaCO_3/m^2$) / (19 mmol $CaCO_3/m^2 \cdot$day) = 1.6 days]. (b) If the seawater carbonate ion concentration was 250 µmol/kg, the calcification rate would be approximately 12 mmol $CaCO_3/m^2 \cdot$day. It would take 1 square meter of reef 2.5 days to accumulate 30 mmol of $CaCO_3$ [(30 mmol of $CaCO_3/m^2$) / (12 mmol $CaCO_3/m^2 \cdot$day) = 2.5 days]. (c) If carbonate ion concentration decreases, the rate of calcification decreases, and it takes coral longer to grow.

4. (a) The final step of the process shown in Figure 2.24, the rate of conversion of CO_3^{2-} and Ca^{2+} into $CaCO_3$, is measured in this experiment. (b) The results do support the hypothesis that increased concentration of atmospheric CO_2 could lead to slower growth of coral reefs. It supports it because, according to the chemistry shown in Figure 2.24, more CO_2 entering the ocean will push the reactions toward formation of more bicarbonate ions, decreasing the amount of CO_3^{2-} available for formation of $CaCO_3$. The results in the graph show that, under the experimental conditions, the lower the concentration of CO_3^{2-}, the lower the rate of calcification, and thus the slower the growth of coral reefs (for example, 2.5 days versus 1.6 days to accumulate the same amount of calcium carbonate at a lower carbonate ion concentration, calculated in question 3).

Interpret the Data

Table 2.1 As you probably know, the human body is made up in large part of water, H_2O. The atoms of oxygen in water, one per water molecule, likely account for the high percentage of oxygen (65.0%) found in the human body.

Figure 2.19 The inland temperatures (100°F, 96°F, 106°F) are much higher than those along the coast (73°F, 75°F, 72°F) because oceans are large bodies of water that can absorb or release heat, moderating the climate nearer the coast.

Concept Check 2.5 #5 A liter of blood would contain 7.8×10^{13} molecules of ghrelin (1.3×10^{-10} moles per liter $\times$ 6.02×10^{23} molecules per mole).

Suggested Answers for End-of-Chapter Essay Questions

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

11. Scientific Inquiry
The complex shapes of biological molecules determine the great specificity with which they interact with one another and form weak or strong bonds.

(a) Hypothesis: Receptor cells on the filaments of the male luna moth's antennae contain cell-surface molecules that are complementary in shape to sex attractant molecules (pheromones) produced by the female luna moth.
(b) This hypothesis leads to several testable predictions. (1) Luna moth pheromones will

bind to specific sites on the cells of the filaments of the male's antennae. (2) If it is possible to synthesize molecules that are very similar in shape to luna moth pheromones, these molecules will also attract male luna moths. (3) Chemical or temperature treatments that modify the molecular shape of luna moth pheromones will reduce the attractiveness of these molecules to male luna moths.

(c) An experiment could be designed to test the third prediction. A number of male luna moths could be exposed to two separate treatments. In the first treatment, unaltered pheromones would be released near male luna moths, and the response of the moths would be noted. The second treatment would be identical in every way except that the pheromone would be heated to permanently modify its molecular shape before it was released.

12. Focus on Evolution

It would be surprising if the percentages of naturally occurring elements in most organisms were *not* roughly the same, because all organisms evolved on Earth (with its unique elemental composition) and all are genetically related to one another. (Species living under unusual conditions might differ more than others, though.) Further, we might predict that the more similar the percentages of naturally occurring elements are in two species, the more closely related those two species are.

13. Focus on Organization

Sample key points:

- Water's versatility as a solvent arises from the polar covalent bonds of water molecules.
- Water molecules form hydrogen bonds with atoms that are part of polar covalent bonds in other molecules.
- The partially charged regions of water molecules are attracted to oppositely charged ions.

Sample top-scoring answer:

Water is the solvent of life, a function emerging from the polar covalent bonds of water molecules. A water molecule consists of an oxygen atom bonded to two hydrogen atoms. Due to oxygen's high electronegativity, the shared electrons are attracted closer to the oxygen at the apex of this V-shaped molecule. The resulting partial negative charge associated with oxygen and partial positive charge associated with each hydrogen result in hydrogen bonding between adjacent water molecules.

Water molecules also form hydrogen bonds with atoms in polar covalent bonds in other molecules, dissolving those molecules. The partial positive and negative regions of water molecules are also attracted to negatively and positively charged ions, respectively, forming hydration shells around ions that separate them from each other and dissolve them. Most of the chemical reactions of life involve solutes that are dissolved in water, so the properties of water that allow it to form hydrogen bonds are crucial to life on Earth.

14. Synthesize Your Knowledge

The water adheres to the molecules on the cat's tongue, drawing it upward. The column of water forms due to both cohesion of water molecules within the column and the surface tension along the sides of the column. Adhesion, cohesion, and surface tension are possible because of extensive hydrogen bonding that takes place between water molecules, which in turn is because of the structure of the water molecule. The oxygen region of the water molecule has a partial negative charge while the hydrogens each carry a partial positive charge. This leads to an attraction between the hydrogen of one water molecule and the oxygen of an adjacent molecule. Hydrogen bonds constantly break and re-form between water molecules. Although they are individually weak, the large number of them means that

water sticks together very well—as well as to other hydrophilic molecules, such as those on a cat's tongue—allowing cats to drink in this way.