

**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.

| <b>Suggested Grading Rubric for “Focus on a Big Idea” Short-Answer Essays</b> |                                                         |                                                             |                                                         |                                                                      |
|-------------------------------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------------|
|                                                                               | <b>Understanding of Theme and Relationship to Topic</b> | <b>Use of Supporting Examples or Details</b>                | <b>Appropriate Use of Terminology</b>                   | <b>Quality of Writing</b>                                            |
| <b>4</b>                                                                      | 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              |
| <b>3</b>                                                                      | Evidence of good understanding                          | Examples or details are generally well applied to theme     | Terminology is correctly used                           | Good sentence flow, sentence structure, and grammar                  |
| <b>2</b>                                                                      | Evidence of a basic understanding                       | Supporting examples and details are adequate                | Terminology used is not totally accurate or appropriate | Some organizational and grammatical problems                         |
| <b>1</b>                                                                      | Evidence of limited understanding                       | Examples and details are minimal                            | Appropriate terminology is not present                  | Poorly organized; grammatical and spelling errors detract from essay |
| <b>0</b>                                                                      | 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 than 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  $270\ \mu\text{mol/kg}$ , the calcification rate would be approximately  $19\ \text{mmol CaCO}_3/\text{m}^2\cdot\text{day}$ . It would take 1 square meter of reef approximately 1.6 days to accumulate 30 mmol of  $\text{CaCO}_3$  [ $(30\ \text{mmol of CaCO}_3/\text{m}^2) / (19\ \text{mmol CaCO}_3/\text{m}^2\cdot\text{day}) = 1.6\ \text{days}$ ]. (b) If the seawater carbonate ion concentration was  $250\ \mu\text{mol/kg}$ , the calcification rate would be approximately  $12\ \text{mmol CaCO}_3/\text{m}^2\cdot\text{day}$ . It would take 1 square meter of reef 2.5 days to accumulate 30 mmol of  $\text{CaCO}_3$  [ $(30\ \text{mmol of CaCO}_3/\text{m}^2) / (12\ \text{mmol CaCO}_3/\text{m}^2\cdot\text{day}) = 2.5\ \text{days}$ ]. (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  $\text{CO}_3^{2-}$  and  $\text{Ca}^{2+}$  into  $\text{CaCO}_3$ , is measured in this experiment. (b) The results do support the hypothesis that increased concentration of atmospheric  $\text{CO}_2$  could lead to slower growth of coral reefs. It supports it because, according to the chemistry shown in Figure 2.24, more  $\text{CO}_2$  entering the ocean will push the reactions toward formation of more bicarbonate ions, decreasing the amount of  $\text{CO}_3^{2-}$  available for formation of  $\text{CaCO}_3$ . The results in the graph show that, under the experimental conditions, the lower the concentration of  $\text{CO}_3^{2-}$ , 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,  $\text{H}_2\text{O}$ . 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  $7.8 \times 10^{13}$  molecules of ghrelin ( $1.3 \times 10^{-10}$  moles per liter  $\times 6.02 \times 10^{23}$  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.

**CHAPTER 3 CARBON AND THE MOLECULAR DIVERSITY OF LIFE****Scientific Skills Exercise**

**Teaching objective:** In this exercise, students will examine aligned amino acid sequences from three different species to find any and all differences between them. They will calculate percent identity and create supportable hypotheses about relatedness among the species.

**Teaching tips:** A version of this Scientific Skills Exercise can be assigned in MasteringBiology. The sequences are too long to fit on one line, so some students may get confused and think there are three different sequences shown in the data, although you can point out that this is explained in the paragraph introducing the data. Also, a review of how to calculate percentage may be needed.

A key aspect of this exercise is using the data to support a hypothesis about evolutionary relationships. The “molecular genealogy” approach introduced in Chapter 3, and used in this exercise, may not be intuitive for students who have not yet studied evolution. The group game “Telephone” is an analogy that might help them to understand. In this game, one person whispers a sentence to the next person, and so on down the line, until the last person says it out loud. The farther away a person is from the source, the more errors will have been introduced into the sentence. Similarly, the more generations between species separations, the more changes there will be to the DNA and protein sequences.

If you would like to show your students the gorilla sequence of  $\alpha$  globin (mentioned in the text), it is at <http://www.ncbi.nlm.nih.gov/protein/P02024.2>.

**Answers:**

1. (a) There are eight amino acid differences between the human and monkey sequences (S/N, A/T, V/L, T/S, A/N, T/Q, R/K, P/Q). (b) There are two amino acid differences between the gibbon and the human (T/Q, P/Q).
2. For the rhesus monkey, 94.5% (138/146) of its amino acids are identical to the human sequence of  $\beta$  globin. For the gibbon, 98.6% (144/146) of its amino acids are identical to the human sequence.
3. Based solely on the  $\beta$ -globin amino acid sequences, one can hypothesize that gibbons are more closely related to humans than rhesus monkeys are. The reasoning is that the more similar the amino acid sequences, the more closely related two species are. This is based on the premise that there has been less evolutionary change since gibbons and humans shared a common ancestor—in other words, fewer mutations have occurred and thus there has been less divergence of the DNA and polypeptide sequences of these species. Conversely, a more distantly related pair of species (here, human and monkey) would have a more divergent sequence because there has been more time for evolutionary change since they shared a common ancestor.
4. Other evidence could include amino acid sequences of other proteins, DNA sequences, and morphological and biochemical similarities and differences. The same principles of similarity/divergence and relatedness would apply.

**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.

**12. Scientific Inquiry**

DNA has many phosphate groups along the backbone of each strand, so the molecule has many negative charges. Therefore, you might expect a DNA-binding protein to have many amino acids with positively charged side chains. These are the basic amino acids in Figure 3.18: lysine, arginine, and histidine. (In fact, DNA-binding proteins do have regions that are rich in these three amino acids.)

**13. Focus on Evolution**

Some cellular functions are more essential than others to the survival of the organism. Proteins perform most cellular functions, so some proteins could be considered more essential than others. You should therefore expect the amino acid sequences of more essential proteins to be more highly conserved (retained with little or no change) than those of less essential proteins. Moreover, different species often live in different habitats and experience different selection pressures. Consequently, you should expect different degrees of divergence among the proteins shared by species that live in different habitats.

**14. Focus on Organization**

**Sample key points:**

- Amino acids share common chemical groups but have unique side chains that allow for variation.

- Common components allow the formation of polypeptides, whose repeating units interact to establish secondary structure.
- Interactions of the varying side chains determine tertiary structure.
- The combination allows for an almost infinite number of possible different structures, each with a different function.

**Sample top-scoring answer:**

The structure of an amino acid, including both common and varying groups, is key to its function. The common groups (amino and carboxyl groups attached to an  $\alpha$  carbon) allow amino acids to link together into a polypeptide of any length via peptide bonds. The repeating subunits of the polymer can interact with each other, forming  $\alpha$  helices and  $\beta$  pleated sheets that establish secondary structure. The varying groups are the amino acid side chains. Each polypeptide therefore has a unique sequence of side chains attached to the common backbone. Interactions between the side chains determine the tertiary structure of the polypeptide. A combination of secondary and tertiary structure establishes the overall 3-D structure of a protein (or one of its subunits), which determines its function. Amino acid structure thus allows for an almost infinite number of possible protein structures, accounting for the diversity of proteins functioning in a cell.

**15. Synthesize Your Knowledge**

A developing chick is growing rapidly, increasing its number of cells. To build new cells it needs large stores of cell membrane components, including cholesterol and lipids, and other cell components such as proteins. It also requires energy to fuel all this construction, and that is available in the form of fats. Fat molecules are a rich source of energy when metabolized.

SAMPLE