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Answers for Instructors
Campbell BIOLOGY IN FOCUS, Third Edition

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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 Focus on 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 Focus on 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 Focus on 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 end-of-chapter essay 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 Focus on 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 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

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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 "Focus on 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 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

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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 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-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.

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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, 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 1.21 In the beach habitat, approximately 14 light models and 36 dark models were attacked. In the inland habitat, approximately 38 light models and 12 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 2016 forward. The range of abstracts from which students might choose will grow as the Hoekstra lab generates additional publications.

9. Focus on 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:

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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 a Theme: 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 Mastering Biology.

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

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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 CO_3^{-2} (carbonate) ions in units of micromoles (μmol) of CO_3^{-2} per kilogram of seawater. **(b)** The *y*-axis shows the calcification rate in units of millimoles of $CaCO_3$ 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 CO_3^{-2} in the seawater. As the concentration of CO_3^{-2} increases, the rate of calcification increases.

3. If the seawater CO_3^{-2} 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].

4. (a) The final step of the process shown in Figure 2.25, 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 2.25, more CO_2 entering the ocean will push the reactions toward formation of more HCO_3^- (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. (As an example, if you do the same calculation as in question 3 for a CO_3^{-2} concentration of 250 μmol/kg, you will see it takes 2.5 days instead of 1.6 days to accumulate the same amount of calcium carbonate at this lower CO_3^{-2} concentration.)

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.

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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 a Theme: 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 a Theme: 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

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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 Mastering Biology.

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.

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If you would like to show your students the gorilla sequence of β-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 β-globin. For the gibbon, 98.6% (144/146) of its amino acids are identical to the human sequence.

3. Based solely on the β-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.

Problem-Solving Exercise

Teaching objective: In this exercise, students will use short DNA sequences from three species of salmon to try to determine the species identification of a sample.

Teaching tip: A version of this Problem-Solving Exercise can be assigned in Mastering Biology.

1.

	Sample labeled as *O. kisutch* (coho salmon)	5′–CGGCACCGCCCTAAGTCTCT–3′
Standard sequences	Sequence for *O. kisutch* (coho salmon)	5′–AGGCACCGCCCTAAGTCTAC–3′
	Sequence for *O. keta* (chum salmon)	5′–AGGCACCGCCCTGAGCCTAC–3′
	Sequence for *Salmo salar* (Atlantic salmon)	5′–CGGCACCGCCCTAAGTCTCT–3′

2. **(a)** 3 **(b)** 5 **(c)** 0

3. **(a)** *O. kisutch* 17/20 = 85% identical to sample

(b) *O. keta*: 15/20 = 75% identical to sample

(c) *S. salar*: 20/20 = 100% identical to sample

4. Hypothesis: My fish sample is *Salmo salar*, Atlantic salmon, not *O. kisutch* as it was labeled. Reasoning: The DNA sequence of the sample matches the standard sequence of *S. salar* but not the standard sequences of *O. kisutch* or *O. keta*. The DNA from individuals of the same species will have more similar DNA than the DNA from individuals of different species. Therefore, it appears that the sample is *S. salar,* based on these data alone.

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 a Theme: 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 a Theme: 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 α 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 α helices and β 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

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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.

CHAPTER 4 A TOUR OF THE CELL

Scientific Skills Exercise

Teaching objective: This exercise is designed to give students practice using a scale bar to measure the size of a cell in a micrograph and to use the measurement to calculate volume and surface area of the cell.

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

Most students have difficulty grasping the relationship between the scale bar and the size of the object shown in the image. It may help to sketch (or photocopy) the picture at one size, then again in a larger size, to emphasize that the scale bar is enlarged along with the object. For both sizes, you can have the student make a small "ruler" the same size as the scale bar and use it to manually measure the cell. This will illustrate that even though the image size and ruler length have changed, the cell remains the same size. There will be some variation in measurements using the scale bar, according to where students delineate the edges of the cells in the image. As long as they are consistent between the two cells, the relationships will hold.

Answers:

1. If the 1-µm scale bar is 5 mm long and the diameter of the image of the parent cell is 20 mm, dividing 20 by 5 yields a cell diameter of 4 µm. Since the diameter of the image of the new cell is 15 mm, the actual diameter of that cell is 15 ÷ 5 = 3 µm. Another way to put it is that the diameter of the parent cell is 4 scale bars long, and the scale bar is 1 µm long, so 4 × 1 µm = 4 µm. The diameter of the new cell is 3 scale bars long, and 3 × 1 µm = 3 µm.

2. (a) For the parent cell with radius 2 µm, the volume is $\frac{4}{3}\pi(2\ \mu m)^3 = 33.5\ \mu m^3$. For the new cell with radius 1.5 µm, the volume is $\frac{4}{3}\pi(1.5\ \mu m)^3 = 14.1\ \mu m^3$. **(b)** The new cell will need to synthesize 19.4 μm^3 of cytoplasm to reach its mature volume (33.5 μm^3 – 14.1 μm^3 = 19.4 μm^3).

3. (a) For the parent cell with radius 2 µm, the surface area is $4\pi(2\ \mu m)^2 = 50.2\ \mu m^2$. For the new cell with radius 1.5 µm, the surface area is $4\pi(1.5\ \mu m)^2 = 28.3\ \mu m^2$. **(b)** The new cell will need to

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synthesize 21.9 μm^2 of plasma membrane to reach its mature size (50.2 μm^2 – 28.3 μm^2 = 21.9 μm^2).

4. When it is mature, the new cell will be approximately 2.4 times its current volume (33.5 $\mu m^3 \div$ 14.1 $\mu m^3 \approx 2.4$) and 1.8 times its current surface area (50.2 $\mu m^2 \div 28.3\ \mu m^2 \approx 1.8$).

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.

7. Scientific Inquiry
You could start by examining the organism and especially its mystery organelle by TEM at high magnification, looking closely for structural similarities with known organelles. Then, starting with a suspension of the organism in an aqueous solution, you could carry out cell fractionation: successive centrifugations at higher and higher speeds, saving the pellet at each stage. Using electron microscopy on material from the pellets, you could identify the pellet containing the organelles of interest. You could then re-suspend these organelles in solution, and test them for the activities of various enzymes, which might reveal the organelle's function in the cell. You could also attempt to isolate DNA from the organelles and compare any you find with DNA from normal mitochondria and chloroplasts. If, for example, the organelles contain enzymes known to participate in cellular respiration and also contain DNA similar to known mitochondrial DNA, you could conclude that the mystery organelle is most likely a mitochondrion. An organelle unrelated or more distantly related to known organelles might take much additional study to figure out.

8. Focus on a Theme: Evolution
(a) Unity is best revealed by cell structures that are shared. Almost all biological membranes are phospholipid bilayers. This feature arose early in the evolution of life on Earth and has been consistently retained by all subsequent life-forms. Ribosomes also originated early and are found in all cells. Mitochondria arose early in the origin of eukaryotic cells, all of which seem to contain mitochondria or related organelles.
(b) The less commonly shared a structure is, the more likely it is a specialized adaptation. Cilia and flagella of the "9 + 2" variety are seen only in motile eukaryotes and in eukaryotic cells that move fluid substances past them.

9. Focus on a Theme: Organization
Sample key points:
- Life emerges from the integration of the functions performed by individual cell components.
- Organelles and cellular structures are not alive on their own; their activities must be integrated with those of other components.
- Some of the characteristics of life include the ability to transform energy, to respond to the environment, and to reproduce and pass along characteristics to offspring.
- Although the nucleus contains instructions for all cell components, other cell components are required to carry them out.
- "Life" as a phenomenon is an emergent property of the parts of a cell.

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Sample top-scoring answer:
The phenomenon we call "life" emerges from the integration of all the functions performed by the individual structures and organelles of a cell. Not one of the cellular components could exist indefinitely on its own. Integrating the activity of all cellular components allows a cell to display the fundamental characteristics of life: the ability to transform energy, to respond to the environment and interact with other organisms, and ultimately to reproduce and pass along characteristics to offspring. The nucleus houses the genetic instructions for the proteins needed for a cell's functions, but it could not carry out those instructions without the cooperation of ribosomes on which to build proteins, the endoplasmic reticulum and Golgi apparatus to modify them, and mitochondria to convert fuel energy to ATP to drive the process. Furthermore, the arrangement of all these organelles in relation to each other is crucial. Life is an emergent property that results from the intricate organization and orchestrated functioning of these and other cellular components.

10. Synthesize Your Knowledge
Epithelial cells in the small intestine function both in the absorption of nutrients from partially digested food and as a barrier between the substances in the small intestine and the blood supply. The microvilli—the many hair-like projections of the plasma membrane at the top of each cell in the SEM—function to increase the surface area of the cell to allow more area for absorption (see Figure 4.24). The microvilli are supported internally by microfilaments, filaments made of actin monomers. The cells in the epithelial sheet must be tightly joined to each other so that the sheet can act as a barrier. This is accomplished by tight junctions, specialized regions on each cell where it is bound by proteins to cells surrounding it (see Figure 4.27; the red dashed arrow at the top of the cell shows that substances can't get across). Tight junctions among the entire sheet of cells hold together the whole sheet. The cells are also anchored together by desmosomes, further strengthening the sheet.

CHAPTER 5 MEMBRANE TRANSPORT AND CELL SIGNALING

Scientific Skills Exercise

Teaching objective: The main objective of this exercise is to give students practice in interpreting a graph, especially in regard to recognizing and comparing the major trends in two sets of data. Secondary objectives include encouraging students to deal with a real-life activity of one of the membrane transport proteins they read about in this chapter and, as they're thinking about hypothesis formulation and testing, to realize that what they're learning in this chapter connects to topics in other chapters.

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

The instructor may want to point out that the rate of glucose "uptake" was not being measured directly; rather, the experimenters were measuring the concentration of radioactive glucose in the cells at successive time points, with the results reflecting the differing rates of glucose uptake. In answering question 3, some students may observe that, for both data sets, the uptake of glucose increases more slowly as incubation time increases—that is, the slopes of the curves are

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Chapter 2: The Chemical Context of Life

KEY CONCEPTS

2.1 Matter consists of chemical elements in pure form and in combinations called compounds

2.2 An element's properties depend on the structure of its atoms

2.3 The formation and function of molecules depend on chemical bonding between atoms

2.4 Chemical reactions make and break chemical bonds

2.5 Hydrogen bonding gives water properties that help make life possible on Earth

This chapter covers the basics that you may have learned in your chemistry class. The questions that follow should help you focus on the most important points. The ideas in this chapter are fundamental to understanding the text, so do the work you need.

Many of the important concepts in each chapter are summarized in the figures. Don't be tempted to ignore these and just read the text. To help you learn, this Reading Guide will ask you to redraw and/or label some of the most important figures. The opening figure of this chapter summarizes much of Concept 2.5. We will come back to it later.

Concept 2.1 Matter consists of chemical elements in pure form and in combinations called compounds

1. Define and give an example of the following terms:

   matter:

   element:

   compound:

2. What four elements make up 96% of all living matter?

3. What is the difference between an essential element and a trace element?

   Essential element:

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Trace element:

Concept 2.2 An element's properties depend on the structure of its atoms

4. Sketch a model of an atom of helium in the space below, showing the electrons, protons, neutrons, and atomic nucleus.

5. What is the atomic number of helium? _____ What is the atomic mass?_____

6. Here are some more terms that you should firmly grasp. Define each term.

   Neutron:

   Proton:

   Electron:

   Atomic nucleus:

   Atomic number:

   Mass number:

   Isotope:

   Electron shells:

   Energy:

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7. Consider the entry in the periodic table for carbon, shown below.

   What is the atomic mass? _____What is the atomic number? _____

   How many electrons does carbon have? _____How many neutrons? _____



8. What are *isotopes*? Use carbon as an example in your explanation.

9. What are radioactive isotopes? Give one medical application that uses them.

10. What is the only subatomic particle that is directly involved in the chemical reactions between atoms?

11. What is *potential energy*?

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12. Explain which has more potential energy in each pair:

    a. boy at the top of a slide/boy at the bottom:

    b. electron in the first electron shell/electron in the third electron shell:

    c. water/glucose:

13. Label the diagram as shown in Figure 2.5. The cellular processes of photosynthesis and cellular respiration center on the movement of electrons. How is the movement of electrons shown in the diagram related to photosynthesis?

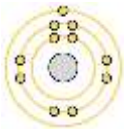


14. What determines the chemical behavior of an atom?

15. What are *valence electrons?*

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16. Here is an electron distribution diagram for sodium: 

    a. How many valence electrons does it have? _____ Circle the valence electron(s).

    b. How many protons does it have? _____

Concept 2.3 The formation and function of molecules depend on chemical bonding between atoms

17. What is a *covalent bond***?**

18. *Define molecule*.

19. What is the valence of hydrogen _____, oxygen _____,

    nitrogen _____, and carbon _____ ?

20. Now, refer to your definition of a *compound* and fill in the following chart:

	Molecule? (y/n)	Compound? (y/n)	Molecular Formula	Structural Formula
Water				
Carbon dioxide				
Methane				
Oxygen				

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21. In the formation of a water molecule why is the ratio two hydrogens to one oxygen?

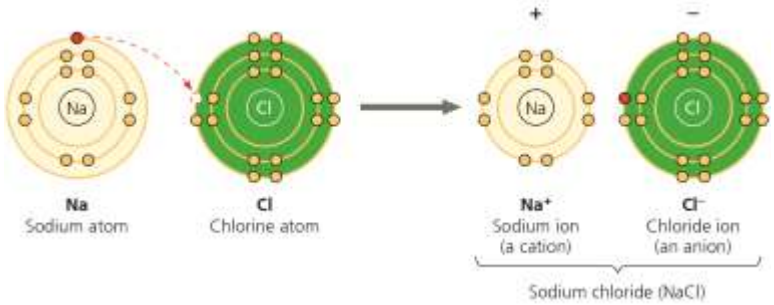
22. What type of bond is seen in O_2? Explain what this means.

23. What is meant by *electronegativity*?

24. Explain the difference between a *nonpolar covalent bond* and a *polar covalent bond*.

25. Make an electron distribution diagram of water. (See Figure 2.8 (c).) Which element is most electronegative? Why is water considered a *polar* molecule? Label the regions that are more positive or more negative. (This is a very important concept. Spend some time with this one!)

26. Another bond type is the *ionic bond*. Explain what is happening in the following figure.

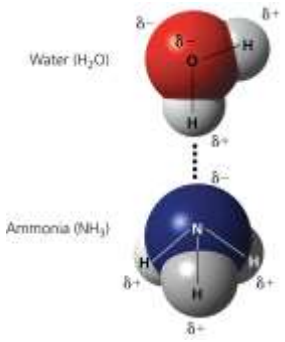


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27. Define *anion* and *cation*. In the preceding example, which is the anion?

28. What is a *hydrogen bond*? Indicate where the hydrogen bond occurs in the following figure.



29. Explain *van der Waals interactions*. Although they represent very weak attractions, when these interactions are numerous they can stick a gecko to the ceiling!

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30. Here is a list of the types of bonds and interactions discussed in this section. Place them in order from the strongest to the weakest: hydrogen bonds, Van der Waals interactions, covalent bonds, ionic bonds.



31. Use morphine and endorphins as examples to explain why molecular shape is crucial in biology.

Concept 2.4 Chemical reactions make and break chemical bonds

32. Write the chemical shorthand equation for photosynthesis. Label the *reactants* and the *products*.

33. For the equation you just wrote, how many molecules of carbon dioxide are there? _____ How many molecules of glucose? _____ How many elements in glucose? _____

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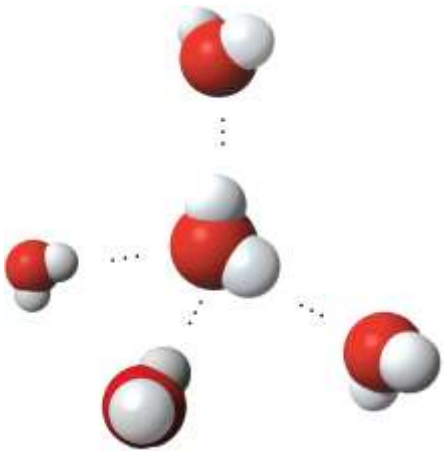
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34. What is meant by *dynamic equilibrium*? Does this imply equal concentrations of each reactant and product?

Concept 2.5 Hydrogen bonding gives water properties that help make life possible on Earth

Living systems depend on properties of water that result from its polarity and hydrogen bonding. Be sure you understand how these properties impact life processes.

35. Study the water molecules below. On the central molecule, label oxygen (O) and hydrogen (H). Now, add + and − signs to indicate the charged regions of *each* molecule. Then, indicate the hydrogen bonds.



36. Water is considered a polar molecule. What does this mean?

37. Explain *hydrogen bonding*. How many hydrogen bonds can a single water molecule form?

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38. Distinguish between *cohesion* and *adhesion*.

39. Which property explains the ability of a water spider to walk on water?

40. Which property is demonstrated when paper towels absorb a water spill?

41. The calorie is a unit of heat. Define *calorie*.

42. Water has high *specific heat*. What does this mean?

43. Explain how hydrogen bonding contributes to water's high specific heat.

44. Summarize how water's high specific heat contributes to the moderation of temperature. How is this property important to life?

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45. Define *evaporation*. What is *heat of vaporization*? Explain at least three effects of this property on living organisms.

46. Ice floats! So what? Consider what would happen if ponds and other bodies of water accumulated ice at the bottom. Describe why this property of water is important.

47. Now, explain *why* ice floats. Why is 4°C the critical temperature?

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48. **STUDY TIP** **Make a visual study guide** Go back to the chapter opening figure on p. 22. In the space on the left, draw and label a diagram that shows the molecular structure of two molecules of water. Then complete the table by explaining how the structure of water supports life for each of the properties of water.

The Properties of Water	
Cohesion of water molecules	Moderation of temperature
Floating of ice	The solvent of life

Sketch of two water molecules

Comment

49. Review and define these terms:

Solvent:

Solution:

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Solute:

aqueous solution:

50. Consider coffee to which you have added sugar. Which of these is the solvent? Which is the solute?

51. Explain why water is such a fine solvent.

52. Distinguish between *hydrophobic* and *hydrophilic substances*. Give an example of each.

53. You already know that some materials, such as olive oil, will not dissolve in water. In fact, oil will float on top of water. Explain this property in terms of hydrogen bonding.

54. Study the section "Solute Concentration in Aqueous Solutions." What is the *molecular mass* of glucose ($C_6H_{12}O_6$)? Show the steps in your calculation.

55. What is a *mole (mol)?* Based on your calculation above, what would be the mass of 1 mol of glucose?

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56. Now, let's do a little work that will enable you to prepare solutions and apply what you have just learned. Read the section on solute concentrations carefully and show your calculations here for preparing a 1-molar (1 *M*) solution of sucrose. Steps to help you do this follow. The first step is done for you. Fill in the steps below.

Comment [MU(1]: TS: Please update. All should be in a single box

Steps to Prepare a Solution

a. Write the molecular formula.

$$(C_{12}H_{22}O_{11})$$

b. Use the periodic table (Appendix B in the textbook) to calculate the atomic mass of each element. Multiply by the number of atoms of the element. (For example, oxygen has a mass of 16. Therefore, oxygen has a total mass of $16 \times 11 = 176$ grams.)

c. Add the masses of each element in the molecule.

d. Add water to the total molar mass you determined and bring the solution to a volume of 1 L. This makes a liter of a 1-*M* solution.

57. *Further Application* Can you prepare 1 L of a 0.5-*M* solution of *glucose*? Show your work here. You can check the answer at the end of this chapter.

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Acids and Bases

58. Define *molarity.*

59. What two ions form when water dissociates?

(You should have answered "hydronium (H_3O^+) and hydroxide ions (OH^-)" in the preceding question. However, by convention, we will represent the hydronium ion as H^+.)

60. Draw and label the chemical reaction that occurs when water dissociates.

61. What is the concentration of H^+ and OH^- in pure water at 25°C?

62. Water has a pH of 7. pH is defined as the negative log of the hydrogen ion concentration $[H^+]$. Explain why water is assigned a pH of 7.

63. To go a step further, the product of H^+ and OH^- concentrations is constant at 10^{-14}.

$$\left[H^+\right]\left[OH^-\right]=10^{-14}$$

Water, which is neutral with a pH of 7, has an equal number of H^+ and OH^- ions. Now, define:

Acid:

Base:

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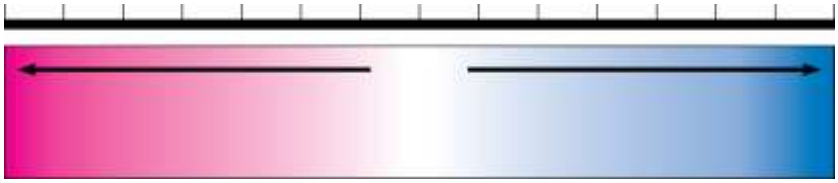
64. Because the pH scale is logarithmic, each numerical change represents a tenfold (10×) change in ion concentration.

    a. How many times more acidic is a pH of 3 compared to a pH of 5?

    b. How many times more basic is a pH of 12 compared to a pH of 8?

    c. Explain the difference between a pH of 8 and a pH of 12 in terms of H^+ concentration.

65. On the pH scale below, label pH 1–14. Label *neutral*, *acid*, and *base*. Indicate the locations of pure water, urine, gastric juice, and bleach.



66. Even a slight change in pH can be harmful! How do *buffers* moderate pH change?

67. Exercise will result in the production of CO_2, which will acidify the blood. Explain the buffering system that minimizes blood pH changes.

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68. Using Figure 2.25 in the text as a starting point, discuss how CO_2 emissions affect marine life and ecosystems.

Answer to Question 57: The formula for glucose is $C_6H_{12}O_6$ which gives a molar mass of 180 g. A 0.5-*M* solution would require 90 g of glucose, adding water to bring the total volume to 1 L.

Test Your Understanding, p. 43

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

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

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