Answers to *Conceptual Integrated Science* End-of-Chapter Questions

Chapter 1: About Science

Answers to Chapter 1 Review Questions

1 The era of modern science in the 16th century was launched when Galileo Galilei revived the Copernican view of the heliocentric universe, using experiments to study nature's behavior.
2 In *Conceptual Integrated Science*, we believe that focusing on math too early is a poor substitute forconcepts.
3 We mean that it must be capable of being proved wrong.
4 Nonscientific hypotheses may be perfectly reasonable; they are nonscientific only because they are not
falsifiable—there is no test for possible wrongness.

5 Galileo showed the falseness of Aristotle's claim with a single experiment—dropping heavy and lightobjects from the Leaning Tower of Pisa.
6 A scientific fact is something that competent observers can observe and agree to be true; a hypothesis is an explanation or answer that is capable of being proved wrong; a law is a hypothesis that has been tested over and over and not contradicted; a theory is a synthesis of facts and well-tested hypotheses.
7 In everyday speech, a theory is the same as a hypothesis—a statement that hasn't been tested.
8 Theories grow stronger and more precise as they evolve to include new information.
9 The term *supernatural* literally means "above nature." Science works within nature, not above it.
10 They rely on subjective personal experience and do not lead to testable hypotheses. They lie outside the realm of science.
11 Science, art, and religion can work very well together; like strings on a guitar, when played together, the chord they produce can be a chord of profound richness.
12 Science is concerned with gathering knowledge and organizing it. Technology lets humans use that knowledge for practical purposes, and it provides the instruments scientists need to conduct their investigations.
13 Chemistry builds on physics by telling us how matter is put together, how atoms combine to form molecules, and how the molecules combine to make the materials around us. Biology is more complex than physical science (physics and chemistry), because it involves matter that is alive and, therefore, engaged in complex biochemical processes.
14 Integrated science is valuable because the real-life phenomena we are interested in typically involve principles from more than one branch of science; put another way, we study integrated science because the world is integrated.

Answers to Chapter 1 Integrated Science Concepts

Chemistry and Biology: An Investigation of Sea Butterflies

1 The disciplines of biology and chemistry are needed to understand the behavior of the Antarctic amphipod.

2 The control used in the investigation was the pellets fed to the predator fish that were not treated with sea-butterfly extracts. The control was needed to see whether the chemical deterrent isolated from the sea butterfly deterred the predator fish.
3 McClintock and Baker's hypothesis was that amphipods carry sea butterflies because sea butterflies pro-duce a chemical that deters a predator of the amphipod. This is a scientific hypothesis because it would be proven wrong if the secreted chemical were found to not deter amphipod predators.

Answers to Chapter 1 Exercises

1. Are the various branches of science separate or do they overlap? Give several examples to support your answer.

   The various branches of science overlap as we see by the existence of these hybrid fields: astrobiology; biochemistry; biophysics; ecology (biology and earth science); geochemistry, etc.

2. What do science, art, and religion have in common? How are they different?

   Science, art, and religion are all searches for deeper understanding of the world. The differences can be summed up as follows: science asks *how*, art asks *who*, and religion asks *why*. The most important difference between religion and science is that religion asks *why* and science asks *how*.

3. Can a person's religious beliefs be proven wrong? Can a person's understanding of a particular scientific concept be proven wrong ?

   No; religion is a subjective area of study so that it cannot be wrong in the sense of being provably false. However, religions that do claim to be based on a factual knowledge of the physical world that is prov-ably false can be said to be logically flawed. A person can certainly be wrong in their understanding of scientific concepts—experiments and observation often can correct such misunderstandings.

4. In what sense is science grand and breathtaking? In what sense is it dull and painstaking?

   Science is grand and breathtaking in its remarkable insights into the mechanisms of the universe; it is dull and painstaking in that careful, disciplined, and sometimes even tedious research is needed to reach those conclusions.

5. How is the printing press like the Internet in terms of the history of science?

   The printing press greatly accelerated the progress of science by facilitating communication—suddenly practitioners of science could collaborate across distance. The Internet takes communication to a new level because it is so fast, open, and accessible.

Solutions to Chapter 1 Problems

1. The more candy bars you add to your diet per day, the more weight you gain (all other factors such as the amount of exercise you get being equal). Is this an example of a direct proportion or an inverse proportion?

   Direct proportion

2. State the above relation in mathematical form. (*Hint*: Don't forget to use a proportionality constant with appropriate units.)

   We set *W* weight gain/week and *C* candy bars eaten/week. Then the more candy bars you add to your diet per week, the more weight you gain per week is expressed like this: *W C*, where is the proportionality constant. Because *W* has units of lb/week and *C* has units of candy bars/week, *W/C* has units of lb/candy bars. Given values for *W* and *C*, one can solve for the numerical value of . For example, if eating seven candy bars per week results in a 1-lb per week weight gain, 1/7 lb/candy bars.

3. What is an example of an inverse proportion that you have observed in your daily life? Express it in mathematical form.

   Sample answer: The more you practice shooting a basketball (P), the fewer shots you miss (m); P k/m.

Chapter 2: Describing Motion

Answers to Chapter 2 Review Questions

1 Aristotle classified motion into two kinds: *natural motion* and *violent motion.*
2 Aristotle believed forces were necessary. It was Galileo who later refuted this idea and established the concept of inertia.

1 Galileo discredited the idea that heavy objects fall faster than light ones, and that a force is necessary to maintain motion.
2 Experiment. In conducting experiments, Galileo ushered in the age of modern science.
3 Inertia.
4 Weight depends on gravity, while mass does not.
5 Your weight is greater on the Earth because of its stronger gravity. Your mass is the same at all locations.
6 Newtons for weight, kilograms for mass.
7 Less.
8 Any amount of water has the same density.
9 The net force on the box is 10 N to the right.
10 Both magnitude and direction.
11 Tension.
12 20 N.
13 F 0 means that the vector sum of all the forces that act on an object in equilibrium equal zero. Forces cancel.
14 Because it acts at right angles to the surface. Normal is another term for “right angle.”
15 The same. You actually read the support force by the scale, which is the same as your weight when the scale is stationary.
16 It is in equilibrium if its velocity is not changing.
17 Because it slides in equilibrium (constant velocity), we know the friction must be equal and opposite to our push. That way, they cancel, and the crate slides without changing speed.
18 Opposite, always.
19 To the left.
20 Yes, opposite to your push, just enough so that F 0.
21 speed distance/time
22 Velocity involves both magnitude (speed) and direction. Speed involves only magnitude.
23 Instantaneous speed.
24 You can be at rest relative to the Earth but moving at 100,000 km/h relative to the sun.
25 acceleration change in velocity/time interval
26 Acceleration is zero, and the net force is therefore zero.
27 It appears once for the unit of velocity, and again for the time during which velocity changes.
28 It decreases by 10 m/s each second.

Answers to Chapter 2 Multiple-Choice Questions

1c, 2d, 3b, 4a, 5a

Answers to Chapter 2 Integrated Science Concepts

Biology: Friction Is Universal

1 Synovial fluid is a lubricant. It protects the bones against the wearing effects of friction—bones rub

against the lubricating synovial fluid instead of against each other.

2 Possible examples include physics–air resistance; chemistry–lubricants; biology–fingerprints; earthscience–earthquakes; atronomy–meteors.

3. One might argue that friction prevents earthquakes in the sense that large blocks of rock are held still because of the friction between them. However, friction truly is implicated as a cause of earthquakes because if there were no friction, the blocks of rock could move along one another smoothly, never building up the strain that is released violently and suddenly in an earthquake.

Biology: Hang Time

1 Your speed is zero at the top of your jump.
2 Length of legs and strength of leg muscles.

Answers to Exercises

1. A bowling ball rolling along a lane gradually slows as it rolls. How would Aristotle interpret this observation? How would Galileo interpret it?

   Aristotle would likely say the ball slows to reach its natural state. Galileo would say the ball is encountering friction, an unbalanced force that slows it.

2. What Aristotelian idea did Galileo discredit in his fabled Leaning Tower of Pisa experiment? With his inclined plane experiments?

   The Leaning Tower experiment discredited the idea that heavy things fall proportionally faster. The incline plane experiments discredited the idea that a force was needed for motion.

3. What physical quantity is a measure of how much inertia an object has?

   Mass.

4. Does a dieting person more accurately lose mass or lose weight?

   Mass. To lose weight, the person could go to the top of a mountain where gravity is less. But the amount of matter would be the same.

5. One cm^3 of lead has a mass of 11.3 g. What is its density? Two grams of aluminum has a mass of 5.4 g. What is the density of aluminum?

   The density of lead is 11.3 g/cm^3. The density of aluminum is 5.4 g/2 cm^3 2.7 g/cm^3.

6. Which has the greater density—5 kg of lead or 10 kg of aluminum?

   Density is a ratio of weight or mass per volume, and this ratio is greater for any amount of lead than for any amount of aluminum, so 5 kg of lead has a greater density than 10 g of aluminum.

7. Consider a pair of forces, one with a magnitude of 25 N, and the other 15 N. What maximum net force is possible for these two forces? What is the minimum net force possible?

   Maximum, 25 N 15 N 40 N. Minimum, 25 N 15 N 10 N.

8. The sketch shows painter's scaffold in mechanical equilibrium. The person in the middle weighs 250 N, and the tensions in each rope are 200 N. What is the weight of the scaffold?

   From *F* 0, the upward forces are 400 N and the downward forces are 250 N weight of the scaf-fold. The scaffold must weigh 150 N.

9. A different scaffold that weighs 300 N supports two painters, one 250 N and the other 300 N. The reading in the left scale is 400 N. What is the reading in the right scale?

From *F* 0, the upward forces are 400 N tension in right scale. This sum must equal the downward forces of 250 N 300 N 300 N. Arithmetic shows the reading on the right scale is 450 N.

10. Can an object be in mechanical equilibrium when only a single force acts on it? Explain.

No, not unless the force is zero. A net force will accelerate the object.

11. Nellie Newton hangs at rest from the ends of the rope, as shown. How does the reading on the scale compare to her weight?

Each scale shows half her weight.

12. Harry the painter swings year after year from his bosun's chair. His weight is 500 N, and the rope, unknown to him, has a breaking point of 300 N. Why doesn't the rope break when he is supported? One day Harry is painting near a flagpole, and, for a change, he ties the free end of the rope to the flagpole instead of to his chair as shown to the right. Why did Harry end up taking his vacation early?

In the left figure, Harry is supported by two strands of rope that share his weight (like the little girl in the previous exercise). So, each strand supports only 250 N, below the breaking point. Total force up supplied by ropes equals weight acting downward, giving a net force of zero and no acceleration. In the right figure, Harry is now supported by one strand, which for Harry's well-being requires that the tension be 500 N. Because this is above the breaking point of the rope, it breaks. The net force on Harry is then only his weight, giving him a downward acceleration of g. The sudden return to zero velocity changes his vacation plans.

13. Consider the two forces acting on the person who stands still, namely, the downward pull of gravity and the upward support of the floor. Are these forces equal and opposite?

Yes, the forces are equal and opposite and cancel to zero putting the person in equilibrium.

14. Can we accurately say that if something moves at constant velocity that there are no forces acting on it? Explain.

No, we cannot, for there may well be forces that cancel to zero. We can say no net force acts on it.

15. At the moment an object tossed upward into the air reaches its highest point, is it in equilibrium? Defend your answer.

No, for the force of gravity acts on the object. Its motion is undergoing change, as a moment later should be evident.

16. If you push horizontally on a crate and it slides across the floor, slightly gaining speed, how does the friction acting on the crate compare with your push?

If the crate speeds up, then your force is greater than the force of friction.

17. What is the impact speed when a car moving at 100 km/h bumps into the rear of another car traveling in the same direction at 98 km/h?

Relative speed is 2 km/h.

18. Harry Hotshot can paddle a canoe in still water at 8 km/h. How successful will he be at canoeing upstream in a river that flows at 8 km/h?

Not very, for his speed will be zero relative to the land.

19. A destination of 120 miles is posted on a highway sign, and the speed limit is 60 miles/hour. If you drive at the posted speed, can you reach the destination in 2 hours? Or more than 2 hours?

More than 2 hours, for you cannot maintain an average speed of 60 miles/hour without

exceeding the speed limit. You begin at zero, and end at zero, so even if there's no slowing down along the way you'll have to exceed 60 mi/h to average 60 mi/h. So it will take you more than 2 hours.

20. Suppose that a freely falling object were somehow equipped with a speedometer. By how much would its speed reading increase with each second of fall?

    10 m/s.

21. Suppose that the freely falling object in the preceding exercise were also equipped with an odometer. Would the readings of distance fallen each second indicate equal or unequal distances of fall for successive seconds? Explain.

    Distance increases as the square of the time, so each successive distance covered is greater than the preceding distance covered.

22. When a ball player throws a ball straight up, by how much does the speed of the ball decrease each second while ascending? In the absence of air resistance, by how much does it increase each second while descending? How much time is required for rising compared to falling?

    The ball slows by 10 m/s each second and gains 10 m/s when descending. The time up equals the time down if air resistance is nil.

23. Someone standing at the edge of a cliff (as in Figure 2.24) throws a ball straight up at a certain speed and another ball straight down with the same initial speed. If air resistance is negligible, which ball has the greater speed when it strikes the ground below?

    Both hit the ground with the same speed (but not in the same time).

24. For a freely falling object dropped from rest, what is its acceleration at the end of the 5th second of fall? The 10th second? Defend your answer (and distinguish between velocity and acceleration).

    Acceleration is 10 m/s^2, constant, all the way down. (Velocity, however, is 50 m/s at 5 seconds, and 100 m/s at 10 seconds.)

25. Two balls, A and B, are released simultaneously from rest at the left end of the equal-length tracks A and B as shown. Which ball will reach the end of its track first?

    The ball on B finishes first, for its average speed along the lower part as well as the down and up slopes is greater than the average speed of the ball along track A.

26. Refer to the tracks. (a) Does ball B roll faster along the lower part of track B than ball A rolls along track A? (b) Is the speed gained by ball B going down the extra dip the same as the speed it loses going up near the right-hand end—and doesn't this mean the speed of balls A and B will be the same at the ends of both tracks? (c) On track B, won't the average speed dipping down and up be greater than the average speed of ball A during the same time? (d) So overall, does ball A or ball B have the greater average speed? (Do you wish to change your answer to the previous exercise?)

    (a) Average speed is greater for the ball on track B. (b) The instantaneous speed at the ends of the tracks is the same, because the speed gained on the down-ramp for B is equal to the speed lost on the up-ramp side. (Many people get the wrong answer for Exercise 25, because they assume that because the balls end up with the same speed that they roll for the same time. Not so.)

Solutions to Chapter 2 Problems

1. Find the net force produced by a 30-N force and a 20-N force in each of the following cases:

    (a) Both forces act in the same direction.
    (b) The two act in opposite directions.
    (a) 30 N 20 N 50 N. (b) 30 N 20 N 10 N.

2. A horizontal force of 100 N is required to push a box across a floor at constant velocity.

(a) What is the net force acting on the box?
(b) How much is the friction force that acts on the box?
(a) Net force is zero (because velocity is constant!). (b) Friction 100 N.

3. A firefighter with a mass of 100 kg slides down a vertical pole at constant speed. What is the force of friction provided by the pole?

From F 0, friction equals weight, mg, (100 kg)(9.8 m/s^2) 980 N.

4. The ocean's level is currently rising at about 1.5 mm per year. At this rate, in how many years will sea level be 3 meters higher than now?

dd

From v , t .

tv

3000 mm

We convert 3 m to 3000 mm, and t 2000 years.

1.5 mm/year

5. A vehicle changes its velocity from 90 km/h to a dead stop in 10 s. Show that its acceleration in doing so is 2.5 m/s^2.

***change in velocity* 90 km/h**

***a* 2.5 km/h s.**

***time interval* 10 s(The vehicle decelerates at 2.5 km/h s.)**

6. A ball is thrown straight up with an initial speed of 40 m/s. (a) Show that its time in the air is about 8 seconds. (b) Show that its maximum height, neglecting air resistance, is about 80 m.

Because it starts going up at 40 m/s and loses 10 m/s each second, its time going up is 4 seconds. Its time returning is also 4 seconds, so it's in the air for a total of 8 seconds. Distance up (or down) is 1/2 gt^2 5 4^2 80 m. Or from d vt, where average velocity is (40 0)/2 20 m/s, and time is 4 seconds, we also get d 20 m/s 4 s 80 m.

1 Extend Table 2.2 (which gives values of from 0 to 5 s) to 0 to 10 s, assuming no air resistance.

8. A ball is thrown with enough speed straight up so that it is in the air several seconds. (a) What is the velocity of the ball when it reaches its highest point? (b) What is its velocity 1 s before it reaches its highest point? (c) What is the change in its velocity during this 1-s interval? (d) What is its velocity 1 s after it reaches its highest point? (e) What is the change in velocity during this 1-s interval? (f) What is the change in velocity during the 2-s interval? (Caution: velocity, not speed!) (g) What is the acceleration of the ball during any of these time intervals and at the moment the ball has zero velocity?

(a) The velocity of the ball at the top of its vertical trajectory is instantaneously zero.

(b) One second before reaching its top, its velocity is 10 m/s.

(c) The amount of change in velocity is 10 m/s during this 1-second interval (or any other 1-second interval).

(d) One second after reaching its top its, velocity is 10 m/s—equal in magnitude but oppositely directed to its value 1 second before reaching the top.

(e) The amount of change in velocity during this (or any) 1-second interval is 10 m/s.

(f) In 2 seconds, the amount of change in velocity, from 10 m/s up to 10 m/s down, is 20 m/s (not zero!)

(g) The acceleration of the ball is 10 m/s^2 before reaching the top, when reaching the top, and

after reaching the top. In all cases, acceleration is downward, toward the Earth.

Time (*in seconds*)	Velocity (*in meters/second*)	Distance (*in meters*)
0	**0**	**0**
1	**10**	**5**
2	**20**	**20**
3	**30**	**45**
4	**40**	**80**
5	**50**	**125**
6	**60**	**180**
7	**70**	**245**
8	**80**	**320**
9	**90**	**405**
10	**100**	**500**

Chapter 3: Newton’s Laws of Motion

Answers to Chapter 3 Review Questions

1 Every object continues in a state of rest, or in a state of motion in a straight line at constant speed, unless it is compelled to change that state by forces exerted upon it.
2 Straight line.
3. The acceleration produced by a net force on an object is directly proportional to the net force, is in the same direction as the net force, and is inversely proportional to the mass of the object.
2 Acceleration is directly proportional to force. As an example, if the net force on a body is doubled, the
acceleration doubles also.

2 No change in acceleration.
2 10 m/s^2.
2 When in free fall, the ratio of weight/mass is the same for all objects.
2 Zero.
2 Air resistance depends on speed and surface area.
2 The greater weight of the heavier person compared to air drag produces a greater acceleration until terminal velocity is reached.
2 Two.
2 When you push on the wall, the wall pushes on you. It is the force of the wall on your fingers that bends them.
2 He can’t exert any more force on the tissue paper than the tissue paper can exert on him. The tissue paper has insufficient inertia for a great force.
2 Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.
2 Ball against the bat.
2 Simultaneously.
2 Each of the equal forces acts on different masses.
2 An external force is needed to accelerate a system.
2 Force, velocity, and acceleration are vector quantities. Time, speed, and volume are scalar

quantities.
2 The resultant is 22 times greater than each of the equal-length, right-angled vectors.
2 The diagonal represents the resultant vector.
2 (a) Yes. (b) Yes.

Answers to Chapter 3 Multiple-Choice Questions

1d, 2b, 3a, 4c, 5d

Answers to Chapter 3 Integrated Science Concepts

Biology: Gliding

1 Gliding describes a mode of locomotion in which animals move through the air in a controlled fall.
2 The more air resistance an animal encounters, the slower and more controllable its fall. And, the amount of air resistance a falling object encounters depends on the object's surface area.
3 "Flying" squirrels have large flaps of skin between their front and hind legs; Draco lizards have long extendable ribs that support large gliding membranes; "flying" frogs have very long toes with extensive webbing between them; gliding geckos have skin flaps along their sides and tails in addition to webbed toes.

Biology: Animal Locomotion

1 In animal locomotion, an animal typically pushes against some medium (the ground, water, or air) that pushes back on it, providing the force needed for the animal to accelerate.
2 Newton's third law: the squid pushes the water, the water pushes the squid.
3 The force of friction between your back foot and the floor pushes you forward.
4 The slippery surface cannot provide a large reaction force to the duck's push against it.

Answers to Chapter 3 Exercises

1. In the orbiting space shuttle, you are handed two identical closed boxes, one filled with sand and the other filled with feathers. How can you tell which is which without opening the boxes?

   Poke or kick the boxes. The one that more greatly resists a change in motion is the one with the greater mass—the one filled with sand.

2. Your empty hand is not hurt when it bangs lightly against a wall. Why is it hurt if it is carrying a heavy load? Which of Newton's laws is most applicable here?

   Mainly the first law, for the bag in motion tends to continue in motion, which results in a squashed hand.

3. Each of the chain of bones forming your spine is separated from its neighbors by disks of elastic tissue. What happens, then, when you jump heavily on your feet from an elevated position? Can you think of a reason why you are a little taller in the morning than in the night? (*Hint:* Think about how Newton's first law of motion applies in this case.)

   Newton's first law again—when you jump, you tighten the disks. This is similar to how you can tighten a hammerhead by banging it against a surface. The greater inertia of the massive hammerhead makes it harder to stop than the less massive hammer handle. Similarly, when you jump you tighten your verte-brae. This effect also explains why you're shorter at the end of the day. At night, while lying prone, relaxation undoes the compression and you're taller!

4. As you stand on a floor, does the floor exert an upward force against your feet? How much force does it exert? Why are you not moved upward by this force?

   Yes, an upward support force acts on you while standing on a floor, which is equal and opposite to the force of gravity on you—your weight. You are not moved upward by this force,

because it is only one of two vertical forces acting on you, making the net force zero.

5. To pull a wagon across a lawn with constant velocity, you have to exert a steady force. Reconcile thisfact with Newton's first law, which says that motion with constant velocity indicates no force.

You exert a force to overcome the force of friction. This makes the net force zero, which is why the wagon moves without acceleration. If you pull harder, then net force will be greater than zero, and acceleration will occur.

6. A rocket becomes progressively easier to accelerate as it travels through space. Why is this so? (*Hint:*About 90% of the mass of a newly launched rocket is fuel.)

Let Newton's second law guide the answer to this: *a F/m*. As *m* gets less (much the mass of the fuel), acceleration *a* increases for a constant force.

7. As you are leaping upward from the ground, how does the force that you exert on the ground compare with your weight?

The force that you exert on the ground is greater than your weight, for you momentarily accelerate upward. Then the ground simultaneously pushes upward on you with the same amount of force.

8. A common saying goes, "It's not the fall that hurts you; it's the sudden stop." Translate this intoNewton's laws of motion.

The sudden stop involves a large acceleration. So in accord with *a F/m*, a large *a* means a large *F*. Ouch!

9. On which of these hills does the ball roll down with increasing speed and decreasing acceleration along the path? (Use this example if you wish to explain to someone the difference between speed and acceleration.)

Only on hill B does the acceleration along the path decrease with time, for the hill becomes less steep as motion progresses. When the hill levels off, acceleration will be zero. On hill A, acceleration is constant. On hill C, acceleration increases as the hill becomes steeper. In all three cases, speed increases.

10. Neglecting air resistance, if you drop an object, its acceleration toward the ground is 10 m/s^2. If you throw it down instead, would its acceleration after throwing be greater than 10 m/s^2? Why or why not?

When air resistance affects motion, the ball thrown upward returns to its starting level with less speed than its initial speed, and also less speed than the ball tossed downward. The downward thrown ball hits the ground below with a greater speed.

11. In the preceding exercise, can you think of a reason why the acceleration of the object thrown downward through the air would actually be less than 10 m/s^2?

Air resistance on the thrown object decreases the net force on it (*mg R*), making its acceleration less than that of free fall.

12. You hold an apple over your head. (a) Identify all the forces acting on the apple and their reaction forces.

(b) When you drop the apple, identify all the forces acting on it as it falls and the corresponding reaction forces.

(a) Two force pairs act; Earth's pull on the apple (action), and the apple's pull on the Earth (reaction). Hand pushes apple upward (action), and apple pushes hand downward (reaction). (b) If air drag can be neglected, one force pair acts; Earth's pull on apple, and apple's pull on Earth. If air drag counts, then air pushes upward on apple (action), and apple pushes downward on air (reaction).

13. Does a stick of dynamite contain force? Defend your answer.

Neither a stick of dynamite nor anything else “contains” force. We will see later that a stick of dynamite contains *energy*, which is capable of producing forces when an interaction of some kind occurs.

14. Can a dog wag its tail without the tail, in turn, “wagging the dog”? (Consider a dog with a relatively massive tail.)

No, for in action–reaction fashion, the tail also wags the dog. How much depends on the relative masses of the dog and its tail.

15. If the Earth exerts a gravitational force of 1000 N on an orbiting communications satellite, how much force does the satellite exert on the Earth?

1000 N.

16. If you exert a horizontal force of 200 N to slide a crate across a factory floor at constant velocity, how much friction is exerted by the floor on the crate? Is the force of friction equal and oppositely directed to your 200-N push? Does the force of friction make up the reaction force to your push? Why not?

The friction on the crate is 200 N, which cancels your 200-N push on the crate to yield the zero net force that accounts for the constant velocity (zero acceleration). Although the friction force is equal and oppositely directed to the applied force, the two do *not* make an action–reaction pair of forces. That’s because both forces *do* act on the same object—the crate. The reaction to your push on the crate is the crate’s push back on you. The reaction to the frictional force of the floor on the crate is the opposite friction force of the crate on the floor.

17. If a Mack truck and motorcycle have a head-on collision, upon which vehicle is the impact force greater? Which vehicle undergoes the greater change in its motion? Explain your answers.

In accord with Newton’s third law, the force on each will be of the same magnitude. But the effect of the force (acceleration) will be different for each because of the different mass. The more massive truck undergoes less change in motion than the motorcycle.

18. Two people of equal mass attempt a tug-of-war with a 12-m rope while standing on frictionless ice. When they pull on the rope, they each slide toward each other. How do their accelerations compare, and how far does each person slide before they meet?

The forces on each are the same in magnitude, and their masses are the same, so their accelerations will be the same. They will slide equal distances of 6 meters to meet at the midpoint.

19. Suppose in the preceding exercise that one person has twice the mass of the other. How far does each person slide before they meet?

The person with twice the mass slides half as far as the twice-as-massive person. That means the lighter one slides 4 feet, and the heavier one slides 8 feet (for a total of 12 feet).

20. Which team wins in a tug-of-war; the team that pulls harder on the rope, or the team that pushes harder against the ground? Explain.

The winning team pushes harder against the ground. The ground then pushes harder on them, producing a net force in their favor.

21. The photo shows Steve Hewitt and his daughter Gretchen touching. Is Steve touching Gretchen, or is Gretchen touching Steve? Explain.

In accord with Newton’s third law, Steve and Gretchen are touching each other. One may initiate the touch, but the physical interaction can’t occur without contact between both Steve and Gretchen. Indeed, you cannot touch without being touched!

22. When your hand turns the handle of a faucet, water comes out. Does your push on the handle and the water coming out comprise an action–reaction pair? Defend your answer.

No. The reaction to the force of your hand on the handle is the force of the handle on your hand. A on B, action; B on A, reaction (not C on A!).

23. Why is it that a cat that falls from the top of a 50-story building will hit the ground no faster than if it fell from the 20th story?

The terminal speed attained by the falling cat is the same whether it falls from 50 stories or 20 stories. Once terminal speed is reached, falling extra distance does not affect the speed. (The low terminal velocities of small creatures enable them to fall without harm from heights that would kill larger creatures.)

24. Free fall is motion in which gravity is the only force acting. (a) Is a sky diver who has reached terminal speed in free fall? (b) Is a satellite circling the Earth above the atmosphere in free fall?

(a) A skydiver encountering no air resistance is in free fall. One at terminal velocity does encounter air resistance and is not in free fall. (b) The only force acting on a satellite is that due to gravity, so a satellite is in free fall (much more about this in Chapter 5).

25. How does the weight of a falling body compare to the air resistance it encounters just before it reaches terminal velocity? After?

Before reaching terminal velocity, weight is greater than air resistance. After reaching terminal velocity, both weight and air resistance are of the same magnitude. Then the net force and acceleration are both zero.

26. You tell your friend that the acceleration of a skydiver decreases as falling progresses. Your friend then asks if this means the skydiver is slowing down. What is your response?

Your friend is correct; the skydiver is, in fact, slowing down as acceleration decreases in a dive. Eventually the acceleration will become zero, in which case the diver has reached terminal velocity.

27. If and when Galileo dropped two balls from the top of the Leaning Tower of Pisa, air resistance was not really negligible. Assuming both balls were the same size yet one much heavier than the other, which ball struck the ground first? Why?

Air resistance is not really negligible for so high a drop, so the heavier ball does strike the ground first. But although a twice-as-heavy ball strikes first, it falls only a little faster, and not twice as fast, which is what followers of Aristotle believed. Galileo recognized that the small difference is due to friction and would not be present if there were no friction.

28. If you simultaneously drop a pair of tennis balls from the top of a building, they will strike the ground at the same time. If one of the tennis balls is filled with lead pellets, will it fall faster and hit the ground first? Which of the two will encounter more air resistance? Defend your answers.

The heavier tennis ball will strike the ground first for the same reason the heavier parachutist in Figure
3.10 strikes the ground first. Note that although the air resistance on the heavier ball is smaller relative to the weight of the ball, it is actually greater than the air resistance that acts on the other ball. Why? Because the heavier ball falls faster, and air resistance is greater for greater speed.

29. Which is more likely to break, the ropes supporting a hammock stretched tightly between a pair of trees or one that sags more when you sit on it? Defend your answer.

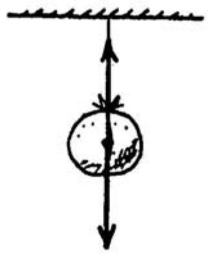
A hammock stretched tightly has more tension in the supporting ropes than one that sags. The tightly stretched ropes are more likely to break.

30. A stone is shown at rest on the ground. (a) The vector shows the weight of the stone. Complete the vector diagram showing another vector that results in zero net force on the stone. (b) What is the conventional name of the vector you have drawn?

(a) The other vector is upward as shown. (b) It is called the normal force.

31. Here a stone is suspended at rest by a string. (a) Draw force vectors for all the forces that act on the stone. (b) Should your vectors have a zero resultant? (c) Why, or why not?

(a) As shown.
(b) Yes.
(c) Because the stone is in equilibrium.



32. Here the same stone is being accelerated vertically upward. (a) Draw force vectors to some suitable scale showing relative forces acting on the stone. (b) Which is the longer vector, and why?

(a) As shown.
(b) Upward tension force is greater to result in upward net force.

33. Suppose the string in the preceding exercise breaks, and the stone slows in its upward motion. Draw a force vector diagram of the stone when it reaches the top of its path.

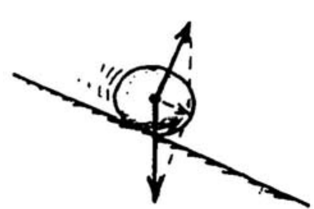
It would be the same except that the upward vector would be absent. Only the downward *mg* vector acts.

34. What is the net force on the stone in the preceding exercise at the top of its path? Its instantaneous velocity? Its acceleration?

The acceleration of the stone at the top of its path, or anywhere where the net force on the stone is *mg*, is *g*.

35. Here is the stone sliding down a friction-free incline. (a) Identify the forces that act on it and draw appropriate force vectors.

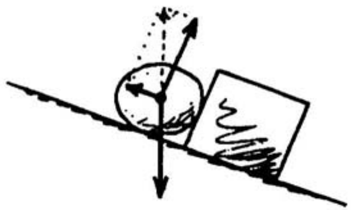
(b) By the parallelogram rule, construct the resultant force on the stone (carefully showing it has a direction parallel to the incline—the same direction as the stone's acceleration).
(a) Weight and normal force only. (b) As shown.



36. Here is the stone at rest, interacting with both the surface of the incline and the block. (a) Identify all

the forces that act on the stone, and draw appropriate force vectors. (b) Show that the net force on the stone is zero. (*Hint 1*: There are two normal forces *on* the stone. *Hint 2*: Be sure the vectors you draw are for forces that act on the stone, not *by* the stone on the surfaces.)

(a) As shown.



(b) Note the resultant of the normals is equal and opposite to the stone's weight.

Solutions to Chapter 3 Problems

1. A 400-kg bear grasping a vertical tree slides down at constant velocity. Show that the friction that acts on the bear is about 4000 N.

   Constant velocity means zero acceleration and, therefore, zero net force. So the friction force must be equal to the bear's weight, *mg*.

2. When two horizontal forces are exerted on a cart, 600 N forward and 400 N backward, the cart undergoes acceleration. Show that the additional force needed to produce nonaccelerated motion is 200 N.

   The given pair of forces produce a net force of 200 N forward, which accelerates the cart. To make the net force zero, a force of 200 N backward must be exerted on the cart.

3. You push with 20-N horizontal force on a 2-kg mass on a horizontal surface against a horizontal friction force of 12 N. Show that the acceleration is 4 m/s^2.

   Acceleration a F_{net}/m (20 N 12 N)/2 kg 8 N/2 kg 4 m/s^2.

4. You push with 40-N horizontal force on a 4-kg mass on a horizontal surface. The horizontal friction force is 12 N. Show that the acceleration is 7 m/s^2.

   Acceleration a F_{net}/m (40 N 24 N)/4 kg 16 N/4 kg 4 m/s^2.

5. A cart of mass 1 kg is accelerated 1 m/s^2 by a force of 1 N. Show that a 2-kg cart pushed with a 2-N force would also accelerate at 1 m/s^2.

   Acceleration a F_{net}/m 2 N/2 kg 1 m/s^2, the same.

6. A rocket of mass 100,000 kg undergoes an acceleration of 2 m/s^2. Show that the force developed by the rocket engines is 200,000 N.

   F ma (100,000 kg)(2 m/s^2) 200,000 N.

7. A 747 jumbo jet of mass 30,000 kg experiences a 30,000-N thrust for each of its engines during take-off. Show that its acceleration is 4 m/s^2.

   Acceleration a F_{net}/m (4 30,000 N)/30,000 kg 4 m/s^2.

8. Suppose the jumbo jet in the previous problem flies against an air resistance of 90,000 N while the thrust of all four engines is 100,000 N. Show that its acceleration will be about 0.3 m/s2. What will the

acceleration be when air resistance builds up to 100,00 N?

air resistance 90,000 N
thrust 100,000 N

F_{net} **100,000 N -90,000 N 10,000 N** $a = \frac{}{m} = \frac{}{30,000\ kg} = \frac{}{30,000\ kg} = 0.33\ m/s^2$

When air resistance equals 100,000 N it will equal the forward thrust force. The net force will be zero, as will acceleration.

9. A boxer punches a sheet of paper in midair, bringing it from rest to a speed of 25 m/s in 0.05 second. If the mass of the paper is 0.003 kg, show that the force the boxer exerts on it is only 1.5 N.

F ma m v/t **0.003 kg [(25 m/s)/0.05 s] 1.5 N.**

10. Suppose that you are standing on a skateboard near a wall and that you push on the wall with a force of 30 N. (a) How hard does the wall push on you? (b) Show that if your mass is 60 kg your acceleration while pushing will be 0.5 m/s^2.

The wall pushes as much on you, 30 N. Acceleration $a\ F_{net}/m$ **30 N/60 kg 0.5** m/s^2**.**

11. If raindrops fall vertically at a speed of 3 m/s and you are running horizontally at 4 m/s, show that the drops will hit your face at a speed of 5 m/s.

By the Pythagorean theorem, V 2**[(3m/s)**^{2} **(4 m/s)**^{2}**] 5 m/s.**

12. Horizontal forces of 3 N and 4 N act at right angles on a block of mass 5 kg. Show that the resulting acceleration will be 1 m/s^2.

Acceleration $a\ F_{net}/m$ 2**[(3.0 N)**^{2} **(4.0 N)**^{2}**]/5 kg 1.0** m/s^2**.**

13. Suzie Skydiver with her parachute has a mass of 50 kg. (a) Before opening her chute, show that the force of air resistance she encounters when reaching terminal velocity is about 500 N. (b) After her chute is open and she again reaches a smaller terminal velocity, show that the force of air resistance she encounters is also about 500 N. (c) Discuss why your answers are the same.

(a) Force of air resistance will be equal to her weight, *mg*, or 500 N.
(b) She'll reach the same air resistance, but at a slower speed, 500 N.
(c) The answers are the same, but for different speeds. In each case, she attains equilibrium (no acceleration).

14. An airplane with an air speed of 120 km/h encounters a 90-km/h crosswind. Show that its groundspeed is 150 km/h.

By the Pythagorean theorem, V 2**[(120 m/s)**^{2} + **(90 m/s)**^{2}**] 150 m/s.**

Chapter 4: Momentum and Energy

Answers to Chapter 4 Review Questions

1 Moving skateboard; anything at rest has *no* momentum.
2 Enormous momentum due to huge mass.
3 Force is a push or pull, while impulse is the product of force and time.
4 By increasing force, or increasing the time the force is exerted.
5 A cannonball will have more momentum coming from the long cannon due to the force acting over a longer time.

6 (3) (Twice the change occurs if speed thrown is the same as speed caught.)

7 (3) (Twice if speed thrown is the same as speed caught.)
8 No because, although you produce impulse on the car, the car produces an equal and opposite impulse on you, so the sum of the impulses equals zero net impulse.
9 That it remains unchanged in a process.
10 An elastic collision is a collision in which colliding objects rebound without lasting deformation or the generation of heat; an inelastic collision is a collision in which the colliding objects become distorted, generate heat, and possibly stick together. Momentum is conserved during elastic collisions.
11 Has the same initial speed of A.
12 Half speed.
13 When it undergoes a change—as when being transferred or transformed.
14 *Work*, which changes *energy*.
15 Joules.
16 True.
17 Four watts.
18 Twice.
19 Twice.
20 Four times as much.
21 Whether or not it experiences a change in energy.

1 16 times as much work to stop the car.
2 With no external work input or output, the energy of a system doesn't change. Energy cannot be created or destroyed.
3 The source of energy is sunlight that evaporated water from the ocean, which ended up as rain in mountains and trapped behind dams.
4 Yes. Yes. No! (There is no way to increase energy without doing work.)
5 Twice the force through half the distance.
6 No way! If that is done, new physics is afoot! Such would violate the conservation of energy.

Answers to Chapter 4 Multiple-Choice Questions

1c, 2c, 3a, 4b, 5a

Answers to Chapter 4 Integrated Science Concepts

Biology: The Impulse–Momentum Relationship in Sports

1 (a) An extended hand has room to move backward when the ball is caught. This stretches the time,resulting in less force. (b) The force of impact will be less if momentum changes over a long time. Bymaking *t* long, *F* will be smaller. (c) The shorter time is accompanied by a greater force when themomentum of the arm is reduced.
2 In accord with Newton's third law, the forces are equal. Only the resilience of the human hand and the training she has undergone to toughen her hand allow her to perform this without breaking any bones.
3 The impulse will be greater if her hand bounces from the bricks. If the time of contact is not increased, a greater force is then exerted on the bricks (and on her hand).

Biology and Chemistry: Glucose—Energy for Life

1 The "burning" that goes on in cells differs from the burning or combustion of a log on a campfire in that the cellular process is much slower and more controlled.
2 You are powered by solar energy in the sense that the energy you use to perform the biochemical andphysical processes needed to sustain life comes from your food which stores chemical energy. Thischemical energy is solar energy that has been transformed by photosynthesizing organisms.

Answers to Chapter 4 Exercises

1. What is the purpose of a "crumple zone" (which has been manufactured to collapse steadily in a crash) in the front section of an automobile?

   A steady collapse in a crash extends the time that the seat belt and air bags slow the

passengers less violently.

2. To bring a supertanker to a stop, its engines are typically cut off about 25 kg from port. Why is it so difficult to stop or turn a supertanker?

   Supertankers are so massive, that even at modest speeds, their motional inertia, or *momenta*, are enormous. This means enormous impulses are needed for changing motion. How can large impulses be produced with modest forces? By applying modest forces over long periods of time. Hence, the force of the water resistance over the time it takes to coast 25 kilometers sufficiently reduces the momentum.

3. Why might a wine glass survive a fall onto a carpeted floor but not onto a concrete floor?

   The time during which momentum decreases is lengthened, thereby decreasing the force that brings the wine glass to rest. Less force means less chance of breaking.

4. If you throw an egg against a wall, the egg will break. If you throw an egg at the same speed into a sagging sheet, it won't break. Why?

   When the moving egg makes contact with a sagging sheet, the time it takes to stop it is extended. More time means less force, and a less-likely broken egg.

5. Why is a punch more forceful with a bare fist than with a boxing glove?

   Impact with a boxing glove extends the time during which momentum of the fist is reduced and lessens the force. A punch with a bare fist involves less time and, therefore, more force.

6. A boxer can punch a heavy bag for more than an hour without tiring but will tire quickly when boxing with an opponent for a few minutes. Why? (*Hint*: When the boxer's punches are aimed at the bag, what supplies the impulse to stop them? When aimed at the opponent, what (or who) supplies the impulse to stop the punches that are missed?)

   When a boxer hits his or her opponent, the opponent contributes to the impulse that changes the momentum of the punch. When punches miss, no impulse is supplied by the opponent—all effort that goes into reducing the momentum of the punches is supplied by the boxer. This tires the boxer. This is very evident to a boxer who can punch a heavy bag in the gym for hours and not tire, but who finds by contrast that a few minutes in the ring with an opponent is a tiring experience.

7. Railroad cars are loosely coupled so that there is a noticeable time delay from the time the first car is moved and the time the last cars are moved from rest by the locomotive. Discuss the advisability of this loose coupling and slack between cars from an impulse–momentum point of view.

   Without this slack, a locomotive might simply sit still and spin its wheels. The loose coupling enables a longer time for the entire train to gain momentum, requiring less force of the locomotive wheels against the track. In this way, the overall required impulse is broken into a series of smaller impulses. (This loose coupling can be very important for braking as well.)

8. A fully dressed person is at rest in the middle of a pond on perfectly frictionless ice and must reach the shore. How can this be accomplished?

   To get to shore, the person may throw keys or coins or an item of clothing. The momentum of what is thrown will be accompanied by the thrower's oppositely directed momentum. In this way, one can recoil toward shore. (One can also inhale facing the shore and exhale facing away from the shore.)

9. A high-speed bus and an innocent bug have a head-on collision. The sudden change in momentum of the bus is greater, less, or the same as the change in momentum of the unfortunate bug?

   The momentum of both bug and bus change by the same amount, because the amount of force

and the time and, therefore, the amount of impulse, are the same on each. Momentum is conserved. Speed is another story. Because of the huge mass of the bus, its reduction of speed is very tiny—too small for the passengers to notice.

10. Why is it difficult for a firefighter to hold a hose that ejects large quantities of water at a high speed?

The large momentum of the spurting water is met by a recoil that makes the hose difficult to hold, just as a shotgun is difficult to hold when it fires birdshot.

11. You're on a small raft next to a dock and jump from the raft only to fall into the water. What physics principle did you fail to take into account?

Oops, the conservation of momentum was overlooked. Your momentum forward equals (approximately) the momentum of the recoiling raft.

12. Your friend says the conservation of momentum is violated when you step off a chair and gain momentum as you fall. What do you say?

Whether or not momentum is conserved depends on the system. If the system in question is you as you fall, then there is an external force acting on you (gravity), and momentum increases and is, therefore, not conserved. But if you enlarge the system to be you and the Earth that pulls you, then momentum is conserved, for the force of gravity on you is internal to the system. Your momentum of fall is balanced by the equal but opposite momentum of the Earth coming up to meet you!

13. If a Mack truck and a Honda Civic have a head-on collision, which vehicle will experience the greater force of impact? The greater impulse? The greater change in its momentum? The greater acceleration?

The magnitude of force, impulse, and change in momentum will be the same for each. The Civic undergoes the greater acceleration, because its mass is less.

14. Would a head-on collision between two cars be more damaging to the occupants if the cars stuck together or if the cars rebounded upon impact?

Cars brought to a rapid halt experience a change in momentum and a corresponding impulse. But greater momentum change occurs if the cars bounce, with correspondingly greater impulse and, therefore, greater damage. Less damage results if the cars stick upon impact than if they bounce apart.

15. In Chapter 3, rocket propulsion was explained in terms of Newton's third law. That is, the force that propels a rocket is from the exhaust gases pushing against the rocket, the reaction to the force the rocket exerts on the exhaust gases. Explain rocket propulsion in terms of momentum conservation.

If the rocket and its exhaust gases are treated as a single system, the forces between rocket and exhaust gases are internal, and momentum in the rocket–gases system is conserved. Any momentum given to the gases is equal and opposite to momentum given to the rocket. A rocket attains momentum by giving momentum to the exhaust gases.

16. Suppose there are three astronauts outside a spaceship, and two of them decide to play catch with the third man. All the astronauts weigh the same on Earth and are equally strong. The first astronaut throws the second one toward the third one and the game begins. Describe the motion of the astronauts as the game proceeds. In terms of the number of throws, how long will the game last?

We assume the equal strengths of the astronauts means that each throws with the same speed. Because the masses are equal, when the first throws the second, both the first and second move away from each other at equal speeds. Say the astronaut moves to the right with velocity *V*, and the first recoils with velocity *V*. When the third makes the catch, both she and the second move to the right at velocity *V*/2 (twice the mass moving at half the speed, like the freight cars in Figure 4.11). When the third makes her throw, she recoils at velocity *V* (the same speed she

imparts to the thrown astronaut) which is added to the $V/2$ she acquired in the catch. So, her velocity is V $V/2$ $3V/2$, to the right—too fast to stay in the game. Why? Because the velocity of the second astronaut is $V/2$ V $V/2$, to the left—too slow to catch up with the first astronaut who is still moving at V. The game is over. Both the first and the third got to throw to the second astronaut only once!

17. How is it possible that a flock of birds in flight can have a momentum of zero, but not have zero kinetic energy?

They may fly in opposite directions wherein the momenta cancel to zero. But if moving, there is no way kinetic energy can cancel. Hence, the difference between a vector quantity (momentum) and a scalar quantity (kinetic energy).

18. When a cannon with a long barrel is fired, the force of expanding gases acts on the cannonball for a longer distance. What effect does this have on the velocity of the emerging cannonball?

When a cannon with a long barrel is fired, more work is done as the cannonball is pushed through the longer distance. A greater KE is the result of the greater work, so of course, the cannonball emerges with a greater velocity. (It might be mentioned that the force acting on the bullet is not constant but decreases with increasing distance inside the barrel.)

19. You and a flight attendant toss a ball back and forth in an airplane in flight. Does the KE of the ball depend on the speed of the airplane? Carefully explain.

The KE of the tossed ball relative to occupants in the airplane does not depend on the speed of the airplane. The KE of the ball relative to observers on the ground below, however, is a different matter. KE, like velocity, is relative.

20. Can something have energy without having momentum? Explain. Can something have momentum without having energy? Defend your answer.

If an object has KE, then it must have momentum—for it is moving. But it can have potential energy with-out being in motion and, therefore, without having momentum. And every object has "energy of being"— stated in the celebrated equation $E\ mc^2$. Whether an object moves or not, it has some form of energy. If it has KE, then with respect to the frame of reference in which its KE is measured, it also has momentum.

21. To combat wasteful habits, we often urge others to "conserve energy" by turning off lights when they are not in use, for example, or by setting thermostats at a moderate level. In this chapter, we also speak of "energy conservation." Distinguish between these two usages.
In the physical science sense, energy cannot be created or destroyed. When consuming energy, however, we can use more than we need and be wasteful. So we speak of saving energy, using it more wisely, and not in the science sense of conserving it.

22. An inefficient machine is said to "waste energy." Does this mean that energy is actually lost? Explain.

Energy is dissipated into nonuseful forms in an inefficient machine and is "lost" only in the loose sense of the word. In the strict sense, it can be accounted for and is therefore not lost.

23. A child can throw a baseball at 20 mph. Some professional ball players can throw a baseball 100 mph, five times as fast. How much more energy does the pro ball player give to the faster ball?

Twenty-five times as much energy (as speed is squared for kinetic energy).

24. If a golf ball and a Ping-Pong ball both move with the same kinetic energy, can you say which has the greater speed? Explain in terms of KE. Similarly, in a gaseous mixture of massive molecules and light molecules with the same average KE, can you say which have the greater speed?

If KEs are the same but masses differ, then the ball with smaller mass has the greater speed. That is, $1/2\ Mv^2\ \ 1/2\ mV^2$, and likewise with molecules, where lighter ones move faster on the average than more massive ones. (We will see in Chapter 6 that temperature is a measure of

average molecular KE—lighter molecules in a gas move faster than same-temperature heavier molecules.)

25. Consider a pendulum swinging to and fro. At what point in its motion is the KE of the pendulum bob at a maximum? At what point is its PE at a maximum? When its KE is half its maximum value, how much PE does it have?

The KE of a pendulum bob is maximum where it moves fastest, at the lowest point; PE is maximum at the uppermost points. When the pendulum bob swings by the point that marks half its maximum height, it has half its maximum KE, and its PE is halfway between its minimum and maximum values. If we define PE 0 at the bottom of the swing, the place where KE is half its maximum value is also the place where PE is half its maximum value, and KE PE at this point. (In accordance with energy conservation: total energy KE PE.)

26. A physics instructor demonstrates energy conservation by releasing a heavy pendulum bob, as shown in the sketch, allowing it to swing to and fro. What would happen if in his exuberance he gave the bob a slight shove as it left his nose? Why?

If the ball is given an initial KE, it will return to its starting position with that KE (moving in the other direction!) and hit the instructor. (The usual classroom procedure is to release the ball from the nose at rest. Then when it returns it will have no KE and will stop short of bumping the nose.)

27. Discuss the design of the roller coaster shown in the sketch in terms of the conservation of energy.

The design is impractical. Note that the summit of each hill on the roller coaster is the same height, so the PE of the car at the top of each hill would be the same. If no energy were spent in overcoming friction, the car would get to the second summit with as much energy as it starts with. But in practice, there is considerable friction, and the car would not roll to its initial height and have the same energy. So the maximum height of succeeding summits should be lower to compensate for friction.

28. Consider the identical balls released from rest on Tracks A and B as shown. When each ball has reached the right end of its track, which will have the greater speed? Why is this question easier to answer than the similar question asked in Exercise 25 back in Chapter 2?

Both will have the same speed, because both have the same PE at the ends of the track and, therefore, the same KEs. This is a relatively easy question to answer because *speed* is asked for, whereas the similar question in Chapter 2 asked for which ball got to the end sooner. The question asked for *time*—which meant first establishing which ball had the greater average speed.

29. Strictly speaking, does a car burn more gasoline when the lights are turned on? Does the overall consumption of gasoline depend on whether or not the engine is running? Defend your answer.

Yes, a car burns more gasoline when its lights are on. The overall consumption of gasoline does not depend on whether or not the engine is running. Lights and other devices run off the battery, which "run down" the battery. The energy used to recharge the battery ultimately comes from the gasoline.

30. If an automobile had an engine that was 100% efficient, would it be warm to your touch? Would its exhaust heat the surrounding air? Would it make any noise? Would it vibrate? Would any of its fuel go unused?

An engine that is 100% efficient would not be warm to the touch, its exhaust would not heat the air, and it would not make any noise or vibrate. This is because all these are transfers of energy, which cannot happen if all the energy given to the engine is transformed to useful work.

Solutions to Chapter 4 Problems

1. A car with a mass of 1000 kg moves at 20 m/s. Show that the braking force needed to bring the car to a halt in 10 s is 2000 N.

From *Ft mv*, *F mv/t* (1000 kg)(20 m/s)/10 s 2000 N.[Can you see this could also be solved by

Newton's second law:*F ma* (1000 kg)(20 m/s/10 s) 2000 N.]

2. A railroad diesel engine weighs four times as much as a freight car. If the diesel engine coasts at 5 km per hour into a freight car that is initially at rest, show that the two coast at 4 km/h after they couple together.

The answer is 4 km/h. Let *m* be the mass of the freight car, 4*m* the mass of the diesel engine, and *v* the speed after both have coupled together. Before collision, the total momentum is due only to the diesel engine, 4*m*(5 km/h), because the momentum of the freight car is 0. After collision, the combined mass is (4*m* *m*), and combined momentum is (4*m* *m*)*v*. By the conservation of momentum equation:

$$\textbf{momentum}_{\textbf{before}}\ \textbf{momentum}_{\textbf{after}}$$

4*m*(5 km/h) 0 (4*m*

#

m*)*v* (20*m

km/h)

***v* 4 km/h**

5*m*(Note that you don't have to know *m* to solve

the problem.)

3. A 5-kg fish swimming at 1 m/s swallows an absent-minded 1-kg fish at rest. (a) Show that the speed ofthe larger fish after lunch is 5 m/s. (b)What would be its speed if the smaller fish were swimmingtoward it at 4 m/s?

(a) Momentum before lunch momentum after lunch(5 kg)(1 m/s) 0 (5 kg 1 kg)*v*5 kg m/s (6 kg) *vv* 5/6 m/s.

(b) Momentum before lunch momentum after lunch(5 kg)(1 m/s) 1 kg (4 **m/s) (5 kg 1 kg)3*v*5 kg m/s 4 kg m/s (6 kg)*vv* 1/6 m/s**

4. Comic-strip hero Superman meets an asteroid in outer space and hurls it at 800 m/s, as fast as a bullet. The asteroid is a thousand times more massive than Superman. In the strip, Superman is seen at rest after the throw. Taking physics into account, what would be his recoil velocity?

By momentum conservation,asteroid mass 800 m/s Superman's mass *v*.Because the asteroid's

mass is 1000 times Superman's,(1000*m*)(800 m/s) *mvv* 800,000 m/s. This is nearly 2 million miles

per hour!

5. Consider the inelastic collision between the two freight cars in Figure 4.11. The momentum before and after the collision is the same. The KE, however, is less after the collision than before the collision. How much less, and what has become of this energy?

The freight cars have only half the KE possessed by the single car before collision. Here's how to figure it:

.

$$\mathbf{KE_{before}\ \ 1/2\ \mathit{mv}^2}$$

$$\mathrm{KE}_{\mathbf{after}}\ \ \mathbf{1/2\ (2\mathit{m})(\mathit{v}/2)^2\ \ 1/2\ (2\mathit{m})\mathit{v}^2/4}\ \ 1/4\ \mathbf{\mathit{mv}^2}\ .$$

What becomes of this energy? Most of it goes into nature's graveyard—thermal energy.

6. This question is typical on some driver's license exams: A car moving at 50 km/h skids 15 m with locked brakes. How far will the car skid with locked brakes at 150 km/h?

At three times the speed, it has nine times (3^2) the KE and will skid nine times as far—135 m. Because the frictional force is about the same in both cases, the distance has to be nine times as great for nine times as much work done by the pavement on the car.

7. In the hydraulic machine shown, it is observed that, when the piston is pushed down 10 cm, the large piston is raised 1 cm. If the small piston is pushed down with a force of 100 N, show that the large piston is capable of exerting 1000 N of force.

$$(\mathbf{Fd})_{\text{input}}$$
$$(\mathbf{Fd})_{\text{output}}\ (\mathbf{100\ N\ \ 10\ cm})_{\text{input}}$$
$$(\mathbf{?\ \ 1\ cm})_{\text{output}}$$

So we see that the output force is 1000 N (or less if the efficiency is less than 100%).

8. Consider a car with a 25% efficient engine that encounters an average retarding force of 1000 N. Assume that the energy content of the gasoline is 40 MJ/L. Show that the car will get 20 km per liter of fuel.

At 25% efficiency, only 1/4 of the 40 megajoules in one liter, or 10 MJ, will go into work. This work is *F* *d* 500 N *d* 10 MJ. Solve this for *d* and convert MJ to J to get *d* 10 MJ/500 N 10,000,000 J/500 N 20,000 m 20 km. Under these condition

s, the car gets 20 kilometers per liter (which is 47 miles per gallon).

9. When a cyclist expends 1000 W of power to deliver mechanical energy to her bicycle at a rate of 100 W, show that the efficiency of her body is 10%.

   Efficiency (mechanical power output)/(power input) 100 W/1000 W 1/10, or 10%.

10. The decrease in PE for a freely falling object equals its gain in KE, in accord with the conservation of energy. (a) By simple algebra, find an equation for an object's speed *v* after falling a vertical distance *h*. Do this by equating KE to its change of PE. (b) Then figure out how much higher a freely falling object must fall to have twice the speed when it hits ground.

    ***v* 22gh. As an object falls through a distance *h*, its loss of PE is *mgh*. This is converted to <u>KE</u> (1/2 mv^2). From *mgh* 1/2 mv^2, we see after canceling *m* and rearranging terms that *v* 22*gh*.**

Chapter 5: Gravity Answers to Chapter 5 Review Questions

1 He realized they were both under the influence of Earth's gravity.
2 Tangential velocity is velocity that is parallel to (tangent) the curve at every point.
3 The moon falls beneath the straight line it would follow if no forces acted on it.
4 Every mass attracts every other mass with a force that for any two masses is directly proportional to the product of the masses involved and inversely proportional to the square of the distance separating them.

$$F \quad \frac{m_1 m_2}{d^2}$$

5. The force is $\frac{1}{4}$ as much in accord with the inverse square law: 6.67 10^{11} N.

1 The paint is $\frac{1}{4}$ as thick (inv-sq law).
2 Brightness is $\frac{1}{4}$ as much (inv-sq law).
3 Nowhere! It approaches zero with great distances but never actually reaches zero. (At the Earth's center, however, gravitation *cancels* to zero!)
4 6.67 10^{11} N.
5 9.8 N.
6 More compressed; less compressed.
7 Oops, almost a trick question: The scale readings would be unchanged. They change only with *changes* in velocity—acceleration.
8 When you are in a state of zero acceleration on the Earth's surface. Then any support force also has the value *mg*.
9 Your weight is more than *mg* when you're in an elevator that accelerates upward (or a rotating habitat with excess rotation).
10 You have zero weight when you're in free fall, or when you're in a part of the universe where gravitational forces on you are nil.

11 Inward, toward the center of the circle.
12 Weight is simulated by the centripetal force acting on a person moving in a circular path.
13 A projectile is any object projected by some means that continues in motion by its own inertia.
14 10 m/s
15 The same.
16 The vertical component changes the same way a ball tossed straight upward changes, and changes on the way down just as a stone does in free fall.
17 It remains the same.
18 15 degrees (the complimentary angle to 75 degrees).
19 30 m/s, the same as the initial point.
20 Both are less due to air drag.
21 Because 8-km/s tangential speed is sufficient for the 5-m vertical drop at the end of the first second to match the corresponding 5-m drop of Earth's curvature.
22 The 8 km/s will persist only in the absence of air drag. Hence, the motion must be above the Earth's atmosphere.
23 Yes indeed!
24 Gravitational force varies, because the distance between gravitationally attracting masses varies.
25 Because half the time it is going away from gravity, and the other half going with gravity. When going against gravity, speed decreases; when going with gravity, speed increases.

Answers to Chapter 5 Multiple-Choice Questions

1c, 2b, 3a, 4d, 5c

Answers to Chapter 5 Integrated Science Concepts

Biology: Your Biological Gravity Detector

1 Yes, people have sense organs that allow them to sense gravity. They are called the vestibular organs, and they are located in the inner ear.
2 The feelings of nausea and disorientation suffered by astronauts happen because the vestibular organs cannot sense a gravitational gradient. The sense of body position in space—the vestibular sense—is set according to the direction of the gravitational field. Without this sense of direction, an astronaut becomes disoriented.

Biology: Center of Gravity of People

1 Its center of gravity lies within its base.
2 It expands the area of his base.

Astronomy: Escape Speed

1 Minimum speed is 8 km/s; maximum speed is 11.2 km/s. An object projected from the Earth at a speed greater than 11.2 km/s will escape the Earth's gravitational field and no longer orbit the earth.
2 Pioneer 10 was launched with a speed of 15 km/s—more than the escape velocity of the Earth but less than the escape speed of the solar system, 42 km/s. The spacecraft was directed toward Jupiter as it approached Earth. Pioneer was boosted by Jupiter's gravitational field, gaining speed in the process. The speed thus gained allowed Pioneer 10 to escape the solar system from the distance of Jupiter.

Answers to Chapter 5 Exercises

1. What would be the path of the Moon if somehow all gravitational force on the Moon vanished to zero?

   In accord with the law of inertia, the Moon would move in a straight-line path instead of circling both the Sun and Earth.

2. Is the force of gravity stronger on a piece of iron than it is on a piece of wood if both have the same mass? Defend your answer.

The force of gravity is the same on each, because the masses are the same, as Newton's equation for gravitational force verifies.

3. Is the force of gravity on a piece of paper stronger when it is crumpled? Defend your answer.

   The force of gravity is the same on each, because the masses are the same, as Newton's equation for gravitational force verifies. When dropped, the crumpled paper falls faster only because it encounters less air drag than the sheet.

4. What is the magnitude and direction of the gravitational force that acts on a professor who weighs 1000 N at the surface of the Earth?

   1000 N, directed toward the center of the Earth (about 220 lb).

5. The Earth and the Moon are attracted to each other by gravitational force. Does the more massive Earth attract the less massive Moon with a force that is greater than, smaller than, or the same as the force with which the Moon attracts Earth?

   The Earth and Moon pull on each other equally in a single interaction. In accord with Newton's Third Law, the pull of Earth on the Moon is equal and opposite to the pull of the Moon on Earth.

6. What would you say to a friend who says that, if gravity follows the inverse-square law, the effect of gravity on you when you are on the 20th floor of a building should be one-fourth as much as it would be if you were on the tenth floor?

   You tell your friend that the force of gravity is measured from the center of the Earth, not from the ground up. Compared with the distance to the Earth's center, gravitational force is about the same on an object on the 10th and 20th floors. The difference is infinitesimal and can be neglected.

7. Why do the passengers of high-altitude jet planes feel the sensation of weight, while passengers in an orbiting space vehicle, such as a space shuttle, do not?

   The high-flying jet plane is not in free fall. It moves at approximately constant velocity so a passenger experiences no net force. The upward support force of the seat matches the downward pull of gravity, providing the sensation of weight. The orbiting space vehicle, on the other hand, is in a state of free fall. No support force is offered by a seat, for it falls at the same rate as the passenger. With no support force, the force of gravity on the passenger is not sensed as weight.

8. Is gravitational force acting on a person who falls off a cliff? Is it acting on an astronaut inside an orbiting space shuttle?

   Gravitational force is indeed acting on a person who falls off a cliff, and on a person in a space shuttle. Both are falling under the influence of gravity.

9. If you were in a freely falling elevator and you dropped a pencil, it would hover in front of you rather than falling to the floor. Is there a force of gravity that is acting on the pencil? Defend your answer.

   The pencil has the same state of motion that you have. The force of gravity on the pencil causes it to accelerate downward alongside of you. Although the pencil hovers relative to you, it and you are falling relative to the Earth.

10. Are the planets of the solar system simply projectiles falling around the sun?

    Yes!

11. What path would you follow if you fell off a rotating merry-go-round? What force prevents you from following this path while you're on the merry-go-round?

    You'd follow a straight-line path; the force preventing this motion while you are riding is the

centripetal force applied to you by the merry-go-round platform.

12. A heavy crate accidentally falls from a high-flying airplane just as it flies over a shiny red sports car parked in a car lot. Relative to the car, where will the crate crash?

The crate will not hit the car but will crash a distance beyond it determined by the height and speed of the plane.

13. How does the vertical component of motion for a ball kicked off a high cliff compare with the motion of vertical free fall?

When air drag is negligible, the vertical component of motion is identical to free fall.

14. In the absence of air drag, why does the horizontal component of a ball's motion not change, while the vertical component does?

There are no forces horizontally (neglecting air resistance), so there is no horizontal acceleration, and hence, the horizontal component of velocity doesn't change. Gravitation acts vertically, which is why the vertical component of velocity changes.

15. At what point in its trajectory does a batted baseball have its minimum speed? If air drag can be neglected, how does this compare with the horizontal component of its velocity at other points?

Minimum speed occurs at the top, which is the same as the horizontal component of velocity anywhere along the path.

16. Each of two golfers hits a ball at the same speed, one at 60°, and the other at 30°, above the horizontal. Which ball goes farther? Which hits the ground first? (Ignore air resistance.)

Both balls have the same range (see Figure 5.29). The ball with the initial speed of 30°, however, is in the air for a shorter time and hits the ground first.

17. A park ranger shoots a monkey hanging from a branch of a tree with a tranquilizing dart. The ranger aims directly at the monkey, not realizing that the dart will follow a parabolic path and, therefore, will fall below the monkey's position. The monkey, however, sees the dart leave the gun and lets go of the branch to avoid being hit. Will the monkey be hit anyway? Defend your answer.

The bullet falls beneath the projected line of the barrel. To compensate for the bullet's fall, the barrel is elevated. How much elevation depends on the velocity and distance to the target. Correspondingly, the gunsight is raised so the line of sight from the gunsight to the end of the barrel extends to the target. If a scope is used, it is tilted downward to accomplish the same line of sight.

18. Since the Moon is gravitationally attracted to the Earth, why doesn't it simply crash into the Earth?

The Moon's tangential velocity is what keeps the Moon coasting around the Earth rather than crashing into it. If its tangential velocity were reduced to zero, then it would fall straight into the Earth!

19. Does the speed of a falling object depend on its mass? Does the speed of a satellite in orbit depend on its mass? Defend your answers.

Neither the speed of a falling object (without air resistance) nor the speed of a satellite in orbit depends on its mass. In both cases, a greater mass (greater inertia) is balanced by a correspondingly greater gravi-tational force, so the acceleration remains the same (*a F/m*, Newton's second law).

20. If you have ever watched the launching of an Earth satellite, you may have noticed that the rocket starts vertically upward, then departs from a vertical course and continues its climb at an angle. Why does it start vertically? Why does it not continue vertically?

The initial vertical climb gets the rocket through the denser, retarding part of the atmosphere most quickly. Eventually the rocket must acquire enough tangential speed to remain in orbit

without thrust, so it must tilt until finally its path is horizontal.

21. A satellite can orbit at 5 km above the moon, but not at 5 km above the Earth. Why?

The moon has no atmosphere (because escape velocity at the moon's surface is less than the speeds of any atmospheric gases). A satellite 5 km above the Earth's surface is still in considerable atmosphere, as well as in range of some mountain peaks. Atmospheric drag is the factor that most determines orbiting altitude.

Solutions to Chapter 5 Problems

1. If you stood atop a ladder that was so tall that you were three times as far from the Earth's center than you would be if you were standing on the Earth's surface, how would your weight compare with its present value?

From F GmM/d^2, three times d squared is $9d^2$, which means the force is one-ninth of surface weight.

2. Find the change in the force of gravity between two planets when the masses of both planets are doubled, and the distance between them stays the same.

From F GmM/d^2, $(2m)(2M)$ $4mM$, which means the force of gravity between them is four times greater.

3. Find the change in the force of gravity between two planets when the masses remain the same but the dis-tance between them is **increased** by ten.

From F GmM/d^2, $10d$ squared is 1/100 d^2, with a force 100 times smaller.

4. Find the change in the force of gravity between two planets when distance between is *decreased* by ten.

From F GmM/d^2, five times d squared is 1/100 d^2, which means the force is 100 times greater.

5. Find the change in the force of gravity between two planets when the masses of the planets don't change, but the distance between them is decreased by five.

From F GmM/d^2, five times d squared is 1/25 d^2, with a force 25 times greater.

6. By what factor would your weight change if the Earth's diameter were doubled and its mass were also doubled?

From F $G2m2M/(2\,d^2)$ 2/4 (GmM/d^2), with one-half the force of gravitation.

7. Find the change in the force of gravity between two objects when both masses are doubled, and the distance between them is also doubled.

From F $G2m2M/(2\,d^2)$ 4/4 (GmM/d^2), with the same force of gravitation.

8. Consider a bright point light source located 1 m from a square opening with area of one-square meter. Light passing through the opening illuminates an area of 4m^2 on a wall 2 m from the opening. (a) Find the area illuminated if the wall is moved to distances of 3 m, 5 m, or 10 m. (b) How can the same amount of light illuminate more area as the wall is moved farther away?

(a) At 3 m it will cover 3^2 or 9 square meters; at 5 m it will cover 5^2 or 25 square meters; at 10 m it will cover 10^2 or 100 square meters. (b) The light is "spread out" over greater and greater area and gets dimmer and dimmer.

9. Calculate the force of gravity between the Earth (6.4 10^{24} kg) and the Sun (2 10^{30} kg, and 1.5 10^{11} m distant).

F GmM/d^2 $[(6.67\ 10^{11}\ \mathrm{N\ m^2/kg^2})(6\ 10^{24}\ \mathrm{kg})(2\ 10^{30}\ \mathrm{kg})]/(1.5\ 10^{11}\ \mathrm{m})^2$ $3.6\ 10^{22}$ N.

10. Students in a lab roll a steel ball off the edge of a table. They measure the speed of a horizontally laundched ball to be 4.0m/s. They also know that if they simply dropped the ball from rest off the edge of the table, it would take 0.5 seconds to hit the floor. Question: How far from the bottom of the table should they place a small piece of paper so that the ball will hit it when it lands?

The distance wanted is horizontal velocity time. The time to follow the parabolic path is the same 0.5 seconds it takes to drop vertically. So, distance from the edge of the table should be 4.0 m/s 0.5 s 2.0 m.

11. Calculate the speed in m/s at which the Earth revolves about the Sun. You may assume that the Earth's orbit is nearly circular.

One way is *v* *distance/time*, where distance is the circumference of the Earth's orbit and time is 1 year. Then

d **2pr2p(1.5 * 10^{11} m)**

v = = = **= 3 * 10^4 m/s = 30 km/s.**

t **1 year 365 day * 24 h/day * 3600 s/h**

Chapter 6: Heat Answers to Chapter 6 Review Questions

1 The thermal energy in a substance is the total energy of all its atoms and molecules, consisting of both the potential and kinetic energy of the particles in a substance.
2 Matter is made up of tiny particles, atoms or molecules, that are always moving.
3 Atoms in the metal jostle faster.
4 0°C, 32°F, 100°C, 212°F.
5 Average.
6 Both the thermometer and whatever it measures reach a common temperature (thermal equilibrium). So, a thermometer measures its own temperature.
7 Zero.
8 Zero.
9 Energy travels, so when a cold surface is touched, energy goes from your hand to the surface.
10 Temperature is a measure of the average translational kinetic energy per molecule, while heat is the thermal energy transferred from one thing to another due to a temperature difference.
11 Temperature difference; heat flows from high to low temperatures.
12 Both are units of energy; 4.18 J 1 cal.
13 The first law *is* the conservation of energy applied to thermal systems.
14 Increases. Increases.
15 It defines the direction—from hot to cold.
16 Silver (which has a lower specific heat).
17 Low.
18 Very high in comparison.
19 Liquids.
20 Ice crystals are open structured. So when water freezes, the crystals occupy more space. More volume means lower density.
21 As water goes through 4°C on the way to freezing, it sinks to the bottom—not cold enough to freeze. Any 0°C water floats at the top, where it freezes.
22 Loose electrons conduct energy by collisions throughout a substance.
23 Electrons are free to roam in conductors, which easily conduct heat. Electrons are firmly attached in insulators, which therefore don't conduct heat well.
24 Wood is a poor conductor, even when red hot. Very little heat conducts from the coal to your feet.
25 Because they are composed largely of air spaces, which are good insulators.
26. By movement of heated fluid—by currents.
25 The temperature decreases (as is evidenced by blowing on your hand with puckered lips).
25 In the daytime, the shore is warmed more than water, so winds blow from water toward shore. At night the reverse occurs; the shore cools more than water, and winds blow in the opposite direction.
25 (a) Energy of electromagnetic waves. (b) Electromagnetic radiation in the infrared part of the spectrum.

25 Frequency and absolute temperature are directly proportional.
25 All objects are also absorbing energy from the surroundings. Temperature will decrease only if the object is a *net* emitter—if it emits more than it absorbs.

Answers to Chapter 6 Multiple-Choice Questions

1a, 2a, 3b, 4b, 5c

Answers to Chapter 6 Integrated Science Concepts

Astronomy, Earth Science, Biology, Chemistry: Entropy—The Universal Tendency Toward Disorder

1 When energy is transformed, some of it is converted to heat. Heat is the least useful form of energy,
because it is the least concentrated form.

2 Entropy is the physicist's term for the measure of energy dispersal.
3 No, it is not thermodynamically favored, because the products have less entropy than the reactants. So
this reaction will not proceed without an energy input.

4 No, the deer converts grass to tissue, which represents a decrease in entropy. However, to perform thisfunction, the deer uses energy. The second law says that entropy-increasing processes are spontaneous;processes reducing entropy require energy input.

Earth Science: The Specific Heat Capacity of Water Affects Global Temperature

1 North Atlantic water cools, and releases energy to the air, which blows over Europe.
2 The climate of Iceland is moderated by the surrounding water.
3 In winter months when the water is warmer than the air, the air is warmed by the water to produce a seacoast climate warmer than inland. In summer months when the air is warmer than the water, the air is cooled by the water to produce a seacoast climate cooler than inland. This is why seacoast communities and especially islands do not experience the high and low temperature extremes that characterize inland locations.

Answers to Chapter 6 Exercises

1. In your room there are things such as tables, chairs, other people, and so forth. Which of these things has a temperature (1) lower than, (2) greater than, and (3) equal to the temperature of the air?

   Inanimate things such as tables, chairs, furniture, and so on, have the same temperature as the surrounding air (assuming they are in thermal equilibrium with the air—i.e., no sudden gush of different-temperature air or such). People and other mammals, however, generate their own heat and have body temperatures that are normally higher than air temperature.

2. Why can't you establish whether you are running a high temperature by touching your own forehead?

   You cannot establish by your own touch whether or not you are running a fever because there would be no temperature difference between your hand and forehead. If your forehead is a couple of degrees higher in temperature than normal, your hand is also a couple of degrees higher.

3. Which is greater, an increase in temperature of 1°C or one of 1°F?

Because Celsius degrees are larger than Fahrenheit degrees, an increase of 1°C is larger. It's 9/5 as large.

4. Which has the greater amount of internal energy, an iceberg or a cup of hot coffee? Explain.

   The hot coffee has a higher temperature, but not a greater internal energy. Although the iceberg has less internal energy per mass, its enormously greater mass gives it a greater total energy

than that in the small cup of coffee. (For a smaller volume of ice, the fewer number of more energetic molecules in the hot cup of coffee may constitute a greater total amount of internal energy—but not compared to an iceberg.)

5. Use the laws of thermodynamics to defend the statement that 100% of the electrical energy that goes into lighting a lamp is converted to thermal energy.

   Only a small percentage of the electric energy that goes into lighting a lamp becomes light. The rest is thermal energy. But even the light is absorbed by the surroundings, and also ends up as thermal energy. So by the first law, all the electrical energy is ultimately converted to thermal energy. By the second law, organized electrical energy degenerates to the more disorganized form, thermal energy.

6. When air is rapidly compressed, why does its temperature increase?

   Work is done in compressing the air, which in accord with the first law of thermodynamics, increases its thermal energy. This is evident by its increased temperature.

7. What happens to the gas pressure within a sealed gallon can when it is heated? Cooled? Why?

   Gas pressure increases in the can when heated and decreases when cooled. The pressure that a gas exerts depends on the average kinetic energy of its molecules and, therefore, on its temperature.

8. After driving a car for some distance, why does the air pressure in the tires increase?

   The tires heat up, which heats the air within. The molecules in the heated air move faster, which increases air pressure in the tires.

9. If you drop a hot rock into a pail of water, the temperature of the rock and the water will change until both are equal. The rock will cool and the water will warm. Does this hold true if the hot rock is dropped into the Atlantic Ocean? Explain.

   The hot rock will cool and the cool water will warm, regardless of the relative amounts of each. The amount of temperature change, however, does depend in great part on the relative masses of the materials. For a hot rock dropped into the Atlantic Ocean, the change in temperature would be too small to measure. Keep increasing the mass of the rock or keep decreasing the mass of the ocean and the change will be evident.

10. In the old days, on a cold winter night, it was common to bring a hot object to bed with you. Which would be better to keep you warm through the cold night—a 10-kilogram iron brick or a 10-kilogram jug of hot water at the same temperature? Explain.

    The brick will cool off too fast, and you'll be cold in the middle of the night. Bring a jug of hot water with its higher specific heat to bed and you'll make it through the night.

11. Why does adding the same amount of heat to two different objects not necessarily produce the same increase in temperature?

    Different substances have different thermal properties due to differences in the way energy is stored internally in the substances. When the same amount of heat produces different changes in temperatures in two substances of the same mass, we say they have different specific heat capacities. Each substance has its own characteristic specific heat capacity. Temperature measures the average kinetic energy of random motion, but not other kinds of energy.

12. Why will a watermelon stay cool for a longer time than sandwiches when both are removed from a cooler on a hot day?

    Water has a high specific heat capacity, which is to say, it normally takes a long time to heat up, or cool down. The water in the watermelon resists changes in temperature, so once cooled,

it will stay cool longer than sandwiches or other nonwatery substances under the same conditions. Be glad water has a high specific heat capacity the next time you're enjoying cool watermelon on a hot day!

13. Cite an exception to the claim that all substances expand when heated.

Water is an exception. Below 4 degrees Celsius, it expands when cooled.

14. An old method for breaking boulders was to put them in a hot fire then douse them with cold water. Why would this fracture the boulders?

When doused, the outer part of the boulders cooled while the insides were still hot. This caused a difference in contraction, which fractured the boulders.

15. Would you or the gas company gain by having gas warmed before it passed through your gas meter?

Gas is sold by volume. The gas meter that tallies your gas bill operates by measuring the number of volume units (such as cubic feet) that pass through it. Warm gas is expanded gas and occupies more space, and if it passes through your meter, it will be registered as more gas than if it were cooled and more compact. The gas company gains if gas is warm when it goes through your meter, because the same amount of warmer gas has a greater volume.

16. A metal ball is just able to pass through a metal ring. When the ball is heated, however, it will not pass through the ring. What would happen if the ring, rather than the ball, were heated? Does the size of the hole increase, stay the same, or decrease?

Every part of a metal ring expands when it is heated—not only the thickness, but the outer and inner circumference as well. Hence, the ball that normally passes through the hole when the temperatures are equal will more easily pass through the expanded hole when the ring is heated. (Interestingly enough, the hole will expand as much as a disk of the same metal undergoing the same increase in temperature. Blacksmiths mounted metal rims in wooden wagon wheels by first heating the rims. Upon cooling, the contraction resulted in a snug fit.)

17. After a machinist very quickly slips a hot, snugly fitting iron ring over a very cold brass cylinder, there is no way that the two can be separated intact. Can you explain why this is so?

Brass expands and contracts more than iron for the same changes in temperature. Because they are both good conductors and are in contact with each other, one cannot be heated or cooled without also heating or cooling the other. If the iron ring is heated, it expands—but the brass expands even more. Cooling the two will not result in separation either, for even at the lowest temperatures, the shrinkage of brass over iron would not produce separation.

18. Suppose you cut a small gap in a metal ring. If you heat the ring, will the gap become wider or narrower?

The gap in the ring will become wider when the ring is heated. Try this: draw a couple of lines on a ring where you pretend a gap to be. When you heat the ring, the lines will be farther apart—the same amount as if a real gap were there. Every part of the ring expands proportionally when heated uniformly— thickness, length, gap, and all.

19. Suppose that water is used in a thermometer instead of mercury. If the temperature is at 4°C and then changes, why can't the thermometer indicate whether the temperature is rising or falling?

Water has the greatest density at 4°C; therefore, either cooling or heating at this temperature will result in an expansion of the water. A small rise in water level would be ambiguous and make a water thermometer impractical in this temperature region.

20. Why is it important to protect water pipes so they don't freeze?

It is important to keep water in pipes from freezing, because when the temperature drops below freezing, the water expands as it freezes, whereas the pipes (if metal) will fracture if water in them freezes.

21. Wrap a fur coat around a thermometer. Will the temperature rise?

No, the coat is not a source of heat but merely keeps the thermal energy of the wearer from leaving rapidly.

22. If you hold one end of a metal nail against a piece of ice, the end in your hand soon becomes cold. Does cold flow from the ice to your hand? Explain.

Energy "flows" from higher to lower temperature, from your hand to the ice. It is the energy, heat, flowing from your hand that produces the sensation of coolness. There is no flow from cold to hot, only from hot to cold.

23. In terms of physics, why do some restaurants serve baked potatoes wrapped in aluminum foil?

The main reason for serving potatoes wrapped in aluminum foil is to increase the time that the potatoes remain hot after being removed from the oven. Heat transfer by radiation is minimized, as radiation from the potatoes is internally reflected; heat transfer by convection is minimized, as circulating air cannot make contact with the shielded potatoes. The foil also serves to retain moisture.

24. Wood is a better insulator than glass. Yet fiberglass is commonly used as an insulator in wooden buildings. Explain.

Air is an excellent insulator. The reason that fiberglass is a good insulator is principally because of the vast amount of air spaces trapped in it.

25. Visit a snow-covered cemetery and note that the snow does not slope upward against the gravestones but, instead, forms depressions around them. Can you think of a reason for this?

Heat from the relatively warm ground is conducted by the gravestone to melt the snow in contact with the gravestone. Likewise for trees or any materials that are better conductors of heat than snow, and that extend into the ground.

26. Why is it that you can safely hold your bare hand in a hot pizza oven for a few seconds, but, if you were to touch the metal inside, you'd burn yourself?

Air is a poor conductor, whatever the temperature. So holding your hand in hot air for a short time is not harmful, because very little heat is conducted by the air to your hand. But if you touch the hot conducting surface of the oven, heat readily conducts to you—ouch!

27. In a still room, smoke from a candle will sometimes rise only so far, not reaching the ceiling. Explain why.

The smoke, like hot air, is less dense than the surroundings and is buoyed upward. It cools with contact with the surrounding air and becomes more dense. When its density matches that of the surrounding air, its buoyancy and weight balance and rising ceases.

28. From the rules that a good absorber of radiation is a good radiator and a good reflector is a poor absorber, state a rule relating the reflecting and radiating properties of a surface.

A good reflector is a poor radiator of heat, and a poor reflector is a good radiator of heat.

29. Suppose at a restaurant you are served coffee before you are ready to drink it. In order that it be as warm as possible when you are ready for it, would you be wiser to add cream to it right away or just before you are ready to drink it?

Put the cream in right away for at least three reasons. Because black coffee radiates more heat than white coffee, make it whiter right away so it won't radiate and cool so quickly while you are waiting. Also, by Newton's Law of Cooling, the higher the temperature of the coffee above the surroundings, the greater will be the rate of cooling—so again add cream right away and lower the temperature to that of a reduced cooling rate, rather than allow it to cool fast and then bring the temperature down still further by adding the cream later. Also, by adding the cream, you increase the total amount of liquid, which for the same surface area, cools more slowly.

Answers to Chapter 6 Problems

1. Pounding a nail into wood makes the nail warmer. Consider a 5-gram steel nail 6 cm long, and a hammer that exerts an average force of 500 N on it when it is being driven into a piece of wood. Show that the increase in the nail's temperature will be 13.3°C. (Assume the specific heat capacity of steel is 450 J/kg°C.)

   Work the hammer does on the nail is given by *F d*, and the temperature change of the nail can be found from using *Q cm T*. First, we get everything into more convenient units for calculating: 5 grams 0.005 kg; 6 cm 0.06 m. Then *F d* 500 N 0.06 m 30 J, and 30 J (0.005 kg) (450 J/kg°C)(*T*) which we can solve to get *T* 30/(0.005 450) 13.3°C. (You will notice a similar effect when you remove a nail from a piece of wood. The nail that you pull out is noticeably warm.)

2. If you wish to warm 100 kg of water by 20°C for your bath, how much heat is required? (Show that 8730 kJ of heat is required.)

   Each kilogram requires 1 kilocalorie for each degree change, so 100 kg needs 100 kilocalories for each degree change. Twenty degrees means 20 times this, which is 2000 kcal. By formula, *Q mcT* (100,000 g)(1 cal/g°C)(20°C) 2000 kcal. We can convert this to joules knowing that 4.18 J 1 cal. In joules, this quantity of heat is 8360 kJ.

3. The specific heat capacity of copper is 0.092 calories per gram per degree Celsius. Show that the heat required to raise the temperature of a 10-gram piece of copper from 0ºC to 100ºC is 92 calories.

   Raising the temperature of 10 gm of copper by 1 degree takes 10 0.092 0.92 calories, and raising it through 100 degrees takes 100 times as much, or 92 calories. By formula, *Q mcT* (10 g)(0.092 cal/g°C)(100°C) 92 cal.

Heating 10 grams of water through the same temperature difference takes 1000 calories, more than 10 times more than for the copper—another reminder that water has a large specific heat capacity.

4. When 100 g of 40ºC iron nails are submerged in 100 g of 20ºC water, show that the final temperature of the water will be 22.1ºC. (The specific heat of iron is 0.12 cal/g C°. Here you should equate the heat gained by the water to the heat lost by the nails.)

   Heat gained by water heat lost by nails(*cm T*)water (*cm T*)nails(1)(100) (*T* 20) (0.12)(100)(40

   ***T*), giving *T* 22.1°C.**

5. A 10-kg iron ball is dropped onto a pavement from a height of 100 m. If half of the heat generated goes into warming the ball, show that the temperature increase of the ball will be 1.1ºC. (In SI units, the specific heat capacity of iron is 450 J/kg ºC.) Why is the answer the same for an iron ball of any mass?

   0.5*mgh cm TT* 0.5*mgh/cm* 0.5*gh/c* (0.5)(9.8 m/s^2)(100 m)/450 J/kg 1.1°C.

   Again, note that the mass cancels, so the same temperature would hold for any mass ball, assuming half the heat generated goes into warming the ball. As in the previous problem, the units check because 1 J/kg 1 m^2/s^2.

Chapter 7: Electricity and Magnetism

Answers to Chapter 7

Review Questions

1 Nucleus (with protons) is positive; electrons are negative.

2 That charge is rearranged and always there. It is not created or destroyed, similar to the way energy is conserved.

3 Both are similar in form, both an inverse-square law. Different in that there are both attractive andrepelling forces in Coulomb's law, but only attractive in Newton's law of gravitation.
4 Very large. The charge of 6.25 billion electrons 1 coulomb.
5 Gravitational, electrical (later, we'll see magnetic).
6 Field direction is defined to be the same as the force on a positive charge in the field.
7 Electric potential energy is measured in joules. Electric potential is potential energy *per* unit of charge—a ratio, measured in volts.
8 No, it means it has several thousand joules of energy *per coulomb of charge*. Only if the charge is 1coulomb is the energy several thousand joules.
9 It's a matter of degree: conductors conduct electricity readily, semiconductors less so, and insulators even less.
10 Metals—they are good conductors, because their outer electrons are loosely attached to the nucleus and able to flow.
11 A temperature difference; a voltage difference.
12 A sustained voltage difference.
13 Protons are anchored in the nucleus. Electrons, at least the outermost ones in metals, are not strongly tied to the nuclei and can flow.
14 AC is alternating current, where charges surge to and fro. DC is direct current, where charges flow in only one direction.
15 Thin wire has more resistance, like a thin pipe is to water flow.
16 The unit of electrical resistance is the ohm ().
17 Doubled also. If voltage and resistance are doubled, then there is no change.
18 1.5 A.

1 Parallel. If it were wired in series and one lamp burns out, all go out!
2 Adds up to equal the current in the source.
3 Power current voltage.
4 The kilowatt is a unit of energy; the kilowatt-hour is a unit of power.
5 Just as like charges repel and unlikes attract, like poles repel and unlikes attract.
6 Whereas electric charges can be isolated, magnetic poles cannot. Electrons and protons are entities by themselves.
7 A magnetic field is produced by the motion of electric charge.
8 Wood has no concentrations of iron atoms and therefore no magnetic domains.
9 The direction of the magnetic force is always perpendicular to both the magnetic field lines and the beam of charged particles.
10 A galvanometer indicates current. When calibrated to measure current, it is an ammeter; when calibrated to measure voltage, it is a voltmeter.
11 By moving a loop of wire near a magnet; by moving a magnet near a loop of wire, or by changing the current in a nearby loop.
12 An electric field; a magnetic field.

Answers to Chapter 7 Multiple-Choice Questions

1c, 2c, 3b, 4d, 5d, 6a

Answers to Chapter 7 Integrated Science Concepts

Biology: Electric Shock

1 Electric current passing through the body produces electric shock.
2 Your own body.
3 In the first case, the current passes through your chest; in the second case, current passes though your
arm only. You can cut off your arm and survive but cannot survive without your heart.

Biology, Earth Science: Earth's Magnetic Field and the Ability of Organisms to Sense It

1 Animals sense Earth’s magnetic field and orient themselves with respect to it.
2 There is some uncertainty about the source of Earth’s magnetic field; the predominant contributor appears to be the circulating charges in the outer core.

Answers to Chapter 7 Exercises

1. With respect to forces, how are electric charge and mass alike? How are they different?

   Charge and mass are alike in that both determine the strength of a force between objects. Both appear in an inverse-square law of force. They differ in that charge can be positive or negative, while mass is always positive. They differ also in the strength of force they determine.

2. When combing your hair, you scuff electrons from your hair onto the comb. Is your hair then positively or negatively charged? How about the comb?

   Excess electrons rubbed from your hair leave it with a positive charge; excess electrons on the comb give it a negative charge.

3. An electroscope is a simple device consisting of a metal ball that is attached by a conductor to two thin leaves of metal foil protected from air disturbances in a jar, as shown. When the ball is touched by a charged body, the leaves, which normally hang straight down, spread apart. Why?

   The leaves, like the rest of the electroscope, acquire charge from the charged object and repel each other because they both have the same sign of charge. The weight of the conducting gold foil is so small that even tiny forces are clearly evident.

4. The five thousand billion billion freely moving electrons in a penny repel one another. Why don’t they fly out of the penny?

   The electrons don’t fly out of the penny because they are attracted to the five thousand billion billion positively charged protons in the atomic nuclei of atoms in the penny.

5. Two equal charges exert equal forces on each other. What if one charge has twice the magnitude of the other? How do the forces they exert on each other compare?

   The forces they exert on each other are still the same! Newton’s third law applies to electrical forces as well as all forces.

6. Suppose that the strength of the electric field about an isolated point charge has a certain value at a distance of 1 m. How will the electric field strength compare at a distance of 2 m from the point charge? What law guides your answer?

   At twice the distance, the field strength will be 1/4, in accord with the inverse-square law.

7. Why is a good conductor of electricity also a good conductor of heat?

   For both electricity and heat, the conduction is via electrons, which in a metal are loosely bound, easy flowing, and easy to get moving. (Many fewer electrons in metals take part in heat conduction than in electric conduction, however.)

8. When a car is moved into a painting chamber, a mist of paint is sprayed around it. When the body of the car is given a sudden electric charge and mist is attracted to it, presto—the car is quickly and uniformly painted. What does the phenomenon of polarization have to do with this?

   The paint particles in the mist are polarized and are therefore attracted to the charged chassis.

9. If you place a free electron and a free proton in the same electric field, how will the forces acting on them compare? How will their accelerations compare? How will their directions of travel compare?

   The forces on the electron and proton will be equal in magnitude but opposite in direction. Because of the greater mass of the proton, its acceleration will be less than that of the electron

and will be in the direction of the electric field. How much less? Because the mass of the proton is nearly 2000 times that of the elec-tron, its acceleration will be about 1/2000 that of the electron. The greater acceleration of the electron will be in the direction opposite to the electric field. The electron and proton accelerate in opposite directions.

10. You are not harmed by contact with a charged metal ball, even though its voltage may be very high. Is the reason similar to why you are not harmed by a Fourth-of-July sparkler, even though the temperatures of each of those sparks is greater than 1000ºC? Defend your answer in terms of the energies that are involved.

Yes, in both cases we have a ratio of energy per something. In the case of temperature, the ratio is energy/molecule. In the case of voltage, it is energy/charge. Even with a small numerator, the ratio can be large if the denominator is small enough. Such is the case with the small energies involved to produce high-temperature sparklers and high-voltage metal balls.

11. In which of the circuits below does a current exist to light the bulb?

Only circuit number 5 is complete and will light the bulb. (Circuits 1 and 2 are “short circuits” and will quickly drain the cell of its energy. In circuit 3, both ends of the lamp filament are connected to the same terminal and are therefore at the same potential. Only one end of the lamp filament is connected to the cell in circuit 4.)

12. Sometimes you hear someone say that a particular appliance “uses up” electricity. What is it that the appliance actually uses up, and what becomes of it?

An electric device does not “use up” electricity, but rather *energy*. And strictly speaking, it doesn’t “use up” energy but transforms it from one form to another. It is common to say that energy is used up when it is transformed to less-concentrated forms—when it is degraded. Electrical energy ultimately becomes heat energy. In this sense, it is used up.

13. Will the current in a lightbulb connected to a 220-V source be greater or less than the current in the same bulb when it is connected to a 110-V source?

Current will be greater in the bulb connected to the 220-volt source. Twice the voltage would produce twice the current if the resistance of the filament remained the same. (In practice, the greater current produces a higher temperature and greater resistance in the lamp filament, so the current is greater than that produced by 110 volts but appreciably less than twice as much for 220 volts. A bulb rated for 110 volts has a very short life when operated at 220 volts.)

14. Are automobile headlights wired in parallel or in series? What is your evidence?

Auto headlights are wired in parallel. Then when one burns out, the other remains lit. If you’ve ever seen an automobile with one burned out headlight, you have evidence they’re wired in parallel.

15. A car’s headlights dissipate 40 W on low beam and 50 W on high beam. Is there more resistance or less resistance in the high-beam filament?

There is less resistance in the higher wattage lamp. Because power current voltage, more power for the same voltage means more current. And by Ohm’s law, more current for the same voltage means less resistance. (Algebraic manipulation of the equations $P\ IV$ and $I\ V/R$ leads to $P\ V^2/R$.)

16. To connect a pair of resistors so their equivalent resistance will be greater than the resistance of either one, should you connect them in series or in parallel?

The equivalent resistance of resistors in series is their sum, so connect a pair of resistors in series for more resistance.

17. Why might the wingspan of birds be a consideration in determining the spacing between parallel wires on power poles?

If the parallel wires are closer than the wingspan of birds, a bird could short circuit the wires by contacting them with its wings, be killed in the process, and possibly interrupt the delivery of power.

18. In the circuit shown, how do the brightnesses of the individual lightbulbs compare? Which lightbulb draws the most current? What will happen if bulb A is unscrewed? If bulb C is unscrewed?

Bulb C is the brightest, because the voltage across it equals that of the battery. Bulbs A and B share the voltage of the parallel branch of the circuit and have half the current of bulb C (assuming resistances are independent of voltages). If bulb A is unscrewed, the top branch is no longer part of the circuit, and current ceases in both A and B. They no longer give light, while bulb C glows as before. If bulb C is instead unscrewed, then it goes out, and bulbs A and B glow as before.

19. As more and more bulbs are connected in series to a flashlight battery, what happens to the brightness of each bulb? Assuming heating inside the battery is negligible, what happens to the brightness of each bulb when more and more bulbs are connected in parallel?

As more bulbs are connected in series, more resistance is added to the single circuit path, and the resulting current produced by the battery is diminished. This is evident in the dimmer light from the bulbs. On the other hand, when more bulbs are connected to the battery in parallel, the brightness of the bulbs is practically unchanged. This is because each bulb, in effect, is connected directly to the battery with no other bulbs in its electrical path to add to its resistance. Each bulb has its own current path.

20. Since every iron atom is a tiny magnet, why aren't all things made of iron themselves magnets?

All iron materials are not magnetized because the tiny magnetic domains are most often oriented in random directions and cancel one another's effects.

21. What surrounds a stationary electric charge? A moving electric charge?

An electric field surrounds a stationary electric charge. An electric field and a magnetic field surround a moving electric charge. (And a gravitational field also surrounds both.)

22. A strong magnet attracts a paper clip to itself with a certain force. Does the paper clip exert a force on the strong magnet? If not, why not? If so, does it exert as much force on the magnet as the magnet exerts on it? Defend your answers.

Newton's third law again: Yes, the paper clip, as part of the interaction, certainly does exert a force on the magnet—just as much as the magnet pulls on it. The magnet and paper clip pull equally on each other to comprise the single interaction between them.

23. Wai Tsan Lee shows iron nails that have become induced magnets. Is there similar physics here with the sticking balloon of Figure 7.5? Defend your answer.
Yes, the physics is similar. The iron nails become magnetized as their domains are induced into alignment by the magnet's strong magnetic field. Similarly, the electric field of the balloon induces a charge on the surface of the wall.

24. Can an electron at rest in a magnetic field be set into motion by the magnetic field? What if it were at rest in an electric field?

An electron has to be moving across lines of magnetic field in order to feel a magnetic force. So an electron at rest in a stationary magnetic field will feel no force to set it in motion. In an electric field, however, an electron will be accelerated whether or not it is already moving. (A combination of magnetic and electric fields is used in particle accelerators such as cyclotrons. The electric field accelerates the charged particle in its direction, and the magnetic field accelerates it perpendicular to its direction, causing it to follow a nearly circular path.)

25. Residents of northern Canada are bombarded by more intense cosmic radiation than are residents

of Mexico. Why is this so?

Charged particles moving through a magnetic field are deflected most when they move at right angles to the field lines, and least when they move parallel to the field lines. If we consider cosmic rays heading toward the Earth from all directions and from great distance, those descending toward northern Canada will be moving nearly parallel to the magnetic field lines of the Earth. They will not be deflected very much, and secondary particles they create high in the atmosphere will also stream downward with little deflection. Over regions closer to the equator, like Mexico, the incoming cosmic rays move more nearly at right angles to the Earth's magnetic field, and many of them are deflected back out into space before they reach the atmosphere. The secondary particles they create are less intense at the Earth's surface. (This "latitude effect" provided the first evidence that cosmic rays from outer space consist of charged particles—mostly protons, as we now know.)

26. A magician places an aluminum ring on a table, underneath which is hidden an electromagnet. When the magician says "abracadabra" (and pushes a switch that starts current flowing through the coil under the table), the ring jumps into the air. Explain his "trick."

The changing magnetic field produced when the current starts to flow induces a current in the aluminum ring. This current, in turn, generates a magnetic field that opposes the field produced by the magnet under the table. The aluminum ring becomes, momentarily, a magnet that is repelled by the hidden magnet. Why repelled? Lenz's law. The induced field opposes the change of the inducing field. (This ques-tion will stimulate a discussion of Lenz's law—worthy but beyond the scope of this book.)

27. A friend says that changing electric and magnetic fields generate one another, and this gives rise to visible light when the frequency of change matches the frequency of light. Do you agree? Explain.

Agree with your friend, for light is electromagnetic radiation having a frequency that matches the frequency to which our eyes are sensitive.

28. Write a letter to Grandma and convince her that whatever electric shocks she may have received over the years have been due to the movement of electrons already in her body—not electrons coming from somewhere else.

Answers will vary.

Solutions to Chapter 7 Problems

1. Two point charges are separated by 6 cm. The attractive force between them is 20 N. Show that the force between them when they are separated by 12 cm is 5 N.

By the inverse-square law, twice as far is 1/4 the force; 5 N. The solution involves relative distance only, so the magnitude of charges is irrelevant.

2. A droplet of ink in an industrial ink-jet printer carries a charge of $1.6\ 10^{10}$ C and is deflected ontopaper by a force of $3.2\ 10^{4}$ N. Show that the strength of the electric field required to produce thisforce is $2\ 10^{6}$ N/C.

Electric field is force divided by charge: $E = \frac{F}{q} = \frac{3.2 * 10^{-4}\,\text{N}}{1.6 * 10^{-10}\,\text{C}} = 2\ 10^{6}$ **N/C. (The unit N/C is the same as the unit V/m, so the field can be expressed as 2 million volts per meter.)**

3. Find the voltage change when (a) an electric field does 12 J of work on a 0.0001 C charge, and (b) the same electric field does 24 J of work on a 0.0002 C.

energy 12 J

(a) *V* 120,000 volts.
charge 0.0001 C
24 J

(b) *V* for twice the charge is same 120 kV.

0.0002

4. Rearrange this equation

voltageCurrent resistance

to express resistance in terms of current and voltage. Then consider the following: A certain device in a 120-V circuit has a current rating of 20 A. Show that the resistance of the device is 6 .

voltage voltage 120 V

From current , resistance 6 ohms.

resistance current 20A

5. Using the formula Power current voltage, find that the current drawn by a 1200-W hair dryer connected to 120 V is 10 A. Then using the method you used in the previous problem, show that theresistance of the hair dryer is 12 .

power 1200 W

From power current voltage, current 10 A.

voltage

120 V

voltage

120 V

From the formula derived above, resistance 12 ohms.

current 10 A

6. Show that it costs $3.36 to operate a 100-W lamp continuously for a week if the power utility rate is 20¢/kWh.

$3.36. First, 100 watts 0.1 kilowatt. Second, there are 168 hours in 1 week (7 days 24 hours/day 168 hours). So, 168 hours 0.1 kilowatt 16.8 kilowatt-hours, which at 20 cents per kWh comes to $3.36.

Chapter 8: Waves and Sound

Answers to Chapter 8

Review Questions

1 *Period* is the time for one complete vibration. *Amplitude* is the distance from the midpoint to the crest (or trough) of a wave. *Wavelength* is the distance along the wave between any successive identical parts of the wave. *Frequency* specifies the number of to-and-fro vibrations in a given time, usually 1 second.

2 A vibration.
3 Energy (also, a disturbance).
4 No. A *disturbance* in a medium moves, energy, not the medium itself. Water in a pond or grass in a field propagate waves, but go nowhere.
5 Wave speed frequency wavelength.
6 (a) Perpendicular (or transverse) to the direction of wave travel. (b) Along the direction of wave travel.
7 As the name implies, compression is a bunching of a medium, rarefaction is a spreading.
8 The wavelength of sound equals the distance between successive compressions (or refractions) in air (or other medium).
9 Sound cannot travel through a vacuum. It requires a medium, because sound waves are made up of zones of dense molecules (compressions) and zones of fewer molecules (rarefactions.)
10 It sets the surface of the table vibrating, which has greater area.
11. Forced vibration occurs at any frequency, whereas resonance occurs when vibration is at a frequency matching an object's natural frequency.
10 Different frequencies. Different frequencies.
10 The frequency of the electromagnetic wave as it vibrates through space is identical to the frequency of the oscillating electric charge that generates it.
10 The angle of incidence equals the angle of reflection.
10 Yes; for individual rays. Overall, the light is redirected in many directions.
10 Transmission (re-emission for molecule to molecule in glass).
10 (a) Resonance and absorption. Energy is passed on to neighboring atoms as heat, so UV is absorbed by glass. (b) Transmission (re-emitted from molecule to molecule in the glass).
10 Slower in glass, fastest in vacuum.
10 Color is determined by frequency (or equivalently, by wavelength).
10 Light is reflected by the blank part of a page and absorbed by ink.
10 It transmits light of all visible frequencies equally well.
10 Bending is caused by a change in light speed.
10 Both.
10 Converging lens converges parallel rays of light; diverging lens diverges the same.
10 Longer wavelength.
10 Asset in radio broadcast, where diffraction fills in shadow regions, particularly for longer wavelength AM radio. Asset for dolphins who use diffraction to sense detail in their environment. Liability in microscopy, where fuzziness of an image occurs.
10 Interference is characteristic of all waves.
10 Constructive interference results from crest-to-crest reinforcement; destructive interference results from crest-to-crest cancellation.
10 Successive waves have a shorter distance to travel, so distance between successive crests decreases.
10 Open: trains and whistles are common examples.
10 Interference. Photoelectric effect.
10 Violet, because each photon has more energy.
10 Light behaves as a stream of photons when it interacts with film or any detector and behaves as a wave in traveling from a source to the place where it is detected.

Answers to Chapter 8 Multiple-Choice Questions

1c, 2c, 3d, 4c, 5c, 6b

Answers to Chapter 8 Integrated Science Concepts

Biology: Sensing Pitch

1 The higher the pitch of a sound, the higher its frequency.
2 The shorter frequencies are heard by bats. (Higher frequencies have shorter wavelengths.)

Biology: Mixing Colored Lights

1 All colors of light can be obtained from red, green, and blue light, as described by the principles of additive color mixing. Because any color can be obtained by sensing red, green, and blue light, sensing these three primary colors of light is all that is needed.

2 The cones in your retina receptive to the color of the paper become fatigued; so you see an afterimage of the complementary color when you look at the white area. This is because the fatigued cones send a weaker signal to the brain. All the colors produce white, but all the colors minus one produce the complement of what's missing.

Astronomy: The Doppler Shift and the Expanding Universe

1 The pitch of the buzzer increases as it gets closer to your ears and decreases as it moves away. The reason is that, as the Doppler effect explains, the frequency of the waves increases as the source of sound approaches and decreases as the sound source gets farther away.

2 Radiation we receive from stars and other astronomical bodies is Doppler-shifted, which indicates they are receding.

Answers to Chapter 8 Exercises

1. What kind of motion should you impart to a stretched coiled spring (or to a Slinky) to produce a transverse wave? A longitudinal wave?

   Shake the Slinky up and down to produce a transverse wave; push the Slinky horizontally to produce a longitudinal wave.

2. What does it mean to say that a radio station is "at 101.1 on your FM dial"?

   The carrier frequency of electromagnetic waves emitted by the radio station is 101.1 MHz.

3. At the stands of a race track you notice smoke from the starter's gun before you hear it fire. Explain.

   Light travels about a million times faster than sound in air, so you see a distant event a million times sooner than you hear it.

4. What is the danger posed by people in the balcony of an auditorium stamping their feet in a steady rhythm?

   The rhythm may match the resonant frequency of the balcony, which could result in its collapse. (This mishap has happened before.)

5. The sitar, an Indian musical instrument, has a set of strings that vibrate and produce music, even though they are never plucked by the player. These "sympathetic strings" are identical to the plucked strings and are mounted below them. What is your explanation?

   The lower strings are resonating with the upper strings.

6. A railroad locomotive is at rest with its whistle shrieking, and then it starts moving toward you. (a) Does the frequency that you hear increase, decrease, or stay the same? (b) How about the wavelength reaching your ear? (c) How about the speed of sound in the air between you and the locomotive?

   (a) The frequency increases. (b) The wavelength decreases. (c) The speed is unchanged (because the air remains motionless relative to you).

7. What is the fundamental source of electromagnetic radiation?

   The fundamental source of electromagnetic radiation is oscillating electric charges, which emit oscillating electric and magnetic fields.

8. Which has the shorter wavelengths, ultraviolet or infrared? Which has the higher frequencies?

   Ultraviolet has shorter waves than infrared. Correspondingly, ultraviolet also has the higher frequencies.

9. Do radio waves travel at the speed of sound, at the speed of light, or at some speed in between?

Radio waves most certainly travel at the speed of every other electromagnetic wave—the speed of light.

10. What determines whether a material is transparent or opaque?

Transparency or opaqueness is determined by the match between incident light frequencies and the resonant frequency of the material. A substance that is transparent to a range of light frequencies will be opaque to those frequencies that match its own resonant frequency.

11. You can get a sunburn on a cloudy day, but you can't get a sunburn even on a sunny day if you are behind glass. Explain.

Clouds are transparent to ultraviolet light, which is why clouds offer no protection from sunburn. Glass, however, is opaque to ultraviolet light, and will therefore shield you from sunburn.

12. Suppose that sunlight falls on both a pair of reading glasses and a pair of dark sunglasses. Which pair of glasses would you expect to become warmer? Defend your answer.
The sunglasses will be warmer in sunlight than regular reading glasses. This is because the reading glasses transmit most of the light energy that is incident upon them, whereas the sunglasses absorb more light energy, which increases their internal energy.

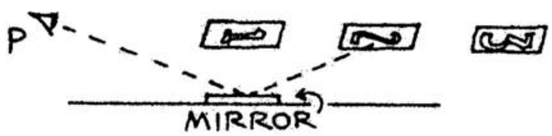
13. Fire engines used to be red. Now many of them are yellow-green. Why the change of color?

They are most likely to be noticed if they are yellow-green. That is where the eye is most sensitive.

14. The radiation curve of the Sun (Figure 8.29) shows that the brightest light from the Sun is yellow-green. Why then do we see the Sun as whitish instead of yellow-green?

We see not only yellow-green, but also red and blue. All together, they mix to produce the white light we see.

15. Her eye at point P looks into the mirror. Which of the numbered cards can she see reflected in the mirror?



Only light from card number 2 reaches her eye.

16. Cowboy Joe wishes to shoot his assailant by ricocheting a bullet off a mirrored metal plate. To do so, should he simply aim at the mirrored image of his assailant? Explain.

Cowboy Joe should simply aim at the mirrored image of his assailant, for the ricocheting bullet will follow the same changes in direction when its momentum changes (angle of incidence angle of rebound) that light follows when reflecting from a plane surface.

17. If, while standing on the bank of a stream, you wished to spear a fish swimming in the water out in front of you, would you aim above, below, or directly at the observed fish to make a direct hit? If you decided instead to zap the fish with a laser, would you aim above, below, or directly at the observed fish? Defend your answers.

You would throw the spear below the apparent position of the fish, because the effect of refraction is to make the fish appear closer to the surface than it really is. But in zapping a fish with a laser, make no cor-rections and aim directly at the fish. This is because the light from the fish you see has been refracted in getting to you, and the laser light will refract along the same path in getting to the fish. A slight correction may be necessary, depending on the colors of the

laser beam and the fish.

18. What happens to light of a certain frequency when it is incident on a material that has a natural frequency that is the same as the frequency of the light?

It is absorbed.

19. The ocean wave is cyan. What color(s) of light does it absorb? What colors does it reflect?

A cyan wave absorbs red light and reflects blue-green light.

20. A rule of thumb for estimating the distance in kilometers between an observer and a lightning strike is to divide the number of seconds in the interval between the flash and the sound by 3. Is this rule correct?

The rule of thumb is correct. This is because the speed of sound in air (340 m/s) can be rounded off to 1/3 km/s. Then, from distance speed time (1/3) km/s (number of seconds). Note that the time in seconds divided by 3 yields the same value.

21. If a single disturbance some unknown distance away sends out both transverse and longitudinal waves that travel at distinctly different speeds in the medium, such as the ground during earthquakes, how could the origin of the disturbance be located?

If a single disturbance at some unknown distance away sends longitudinal waves at one known speed, and transverse waves at a lesser known speed, and you measure the difference in time of the waves as they arrive, you can calculate the distance. The wider the gap in time, the greater the distance—which could be in any direction. If you use this distance as the radius of the circle on a map, you know the disturbance occurred somewhere on that circle. If you telephone two friends who have made similar measurements of the same event from different locations, you can transfer their circles to your map, and the point where the three circles intersect is the location of the disturbance.

22. A bat flying in a cave emits a sound and receives its echo 0.1 s later. How far away is the cave wall?

Assuming the speed of sound to be 340 m/s, the cave is 17 meters away. This is because the sound took
0.05 second to reach the wall (and 0.05 second to return). Distance speed time 340 m/s
0.05 s 17 m.

23. Why do radio waves diffract around buildings, whereas light waves do not?

Radio waves are much larger and therefore diffract more than the shorter waves of light.

24. Sun tanning produces cellular damage in the skin. Why is ultraviolet radiation capable of producing this damage whereas visible radiation is not?

More energy is associated with each photon of ultraviolet light than with photons that make up visible light. This extra energy per photon alters the skin, producing the sunburn.

25. Explain briefly how the photoelectric effect is used in the operation of at least two of the following: an electric eye, a photographer’s light meter, and the sound track of a motion picture.

Electric eye: **A beam of light is directed to a photosensitive surface that completes the path of an electric circuit. When the beam is interrupted, the circuit is broken, compromising a switch for another circuit.** ***Light meter:*** **the variation of photoelectric current with variations in light intensity.** ***Sound track:*** **An optical sound track on motion picture film is a strip of emulsion of variable density that transmits light onto a photoelectric surface, which in turn produces a variable current. This current is amplified and activates a speaker.**

26. Does the photoelectric effect prove that light is made of particles? Do interference experiments prove that light is composed of waves? (Is there a distinction between what something is and how it behaves?)

The photoelectric effect doesn't prove that light is corpuscular, but rather supports the corpuscular model of light, which is compatible with the particle-like behavior observed. The same is true with interference experiments that support the wave model of light and are compatible with the wave-like behavior of light. We have models to help us conceptualize what something is; knowledge of the details of how something behaves helps us to refine the model. It is important that we keep in mind our models for understanding nature as just that: models.

27. Write a letter to Grandpa explaining why we now say that light is not just a particle, and is not just a wave, but in fact is both—a "wavicle"!

Letters to Grandpa should discuss the wave behavior of light as indicated by the wave properties it exhibits including interference. Letters should also discuss the particle behavior of light in its interaction with matter: the photoelectric effect. Taking into account all observations of light, scientists conclude it has properties of both waves and particles and therefore is both—a "wavicle."

Solutions to Chapter 8 Problems

1. What is the frequency, in hertz, that corresponds to each of the following periods: (a) 0.10 s, (b) 5 s, (c) 1/60 s?

(a) *f* 1/*T* 1/0.10 s 10 Hz; (b) *f* 1/5 0.2 Hz; (c) *f* 1/(1/60) s 60 Hz.

2. The nearest star beyond the Sun is Alpha Centauri, $4.2\ \ 10^{16}$ meters away. If we were to receive a radio message from this star today, show that it would have been sent $1.4\ \ 10^{8}$ seconds ago (4.4 years ago).

$$d\ 4.2 : 10^{16}\ \text{m}$$

As in the previous problem, $t\ \ 1.4\ 10^{8}$ **s.**

$$v\ 3 : 10^{8}\ \text{m/s}$$

Converting to years by dimensional analysis,

$$1.4\ 10^{8}\ \text{s}\ \frac{1\ \text{h}}{3600\ \text{s}}\ \frac{1\ \text{day}}{24\ \text{h}}\ \frac{1\ \text{yr}}{365\ \text{day}}\ \ 4.4\ \text{yr.}$$

3. Blue-green light has a frequency of about $6\ \ 10^{14}$ Hz. Use the relationship $c\ \ f$ to show that the wavelength of this light in air is $5\ \ 10^{7}$ meters. How does this wavelength compare with the size of an atom, which is about 10^{10} m?

$$c\ 3 * 10^{8}\ \text{m/s}$$

From c $c\ f$, $\frac{}{6 * 10^{14}\ \text{Hz}}$ f **5 10**^{7} **m, or 500 nanometers. This is 5000 times larger than the size of an atom, which is 0.1 nanometer. (The nanometer is a common unit of length in atomic**

and optical physics.)

4. The wavelength of light changes as light goes from one medium to another, while the frequency remains the same. Is the wavelength longer or shorter in water than in air? Explain in terms of the equation: speed frequency wavelength.

$$c\ 0.75c$$

Light in water travels at 0.75*c*. for light in a vacuum (or air), and for light in water. The

ff

ratio of $_{water}$ to $_{air}$ is, therefore, 0.75, the same for all frequencies.

5. A certain blue-green light has a wavelength of 600 nm (6 10^{7} m) in air. Show that its wavelength in water, where light travels at 75% of its speed in air is 450 nm. Show that its speed in Plexiglas, where light travels at 67% of its speed in air, is 400 nm. (1 nm 10^{9} m).

   $_{air}$ 600 nm (6 10^{7} m). So $_{water}$ (0.75)(6 10^{7} m) 4.5 10^{7} m 450 nm. And $_{Plexiglas}$ (0.67)(6 10^{7} m) 4.0 10^{7} m 400 nm

6. A certain radar installation used to track airplanes transmits electromagnetic radiation of wavelength 3 cm. (a) What is the frequency of this radiation, measured in billions of hertz (GHz)? (b) What is the time required for a pulse of radar waves to reach an airplane 5 km away and return?

(a) Frequency speedwavelength (3 10^{8} ms)(0.03 m) 1.0 10^{10} Hz 10 GHz.

(b) Distance speed time, so time distancespeed (10,000 m)(3 10^{8} ms) 3.3 10^{5} s. (Note the importance of consistent SI units to get the right numerical answers.)

7. Suppose that you walk toward a mirror at 2 ms. Show that you and your image both approach eachother at a speed of 4 ms (and not 2 ms).

   You and your image are both walking at 2 ms.

Chapter 9: The Atom

Answers to Chapter 9 Review Questions

1 An element.
2 Just as all words in the English language are made from 26 letters combined in different ways, so are all materials composed of atoms combined in different ways.
3 The nucleus—neutrons and protons.
4 Atoms are smaller than the wavelength of visible light. Therefore, they cannot be seen.
5 Atoms differ in the number of protons in their nuclei.
6 A proton is nearly 2000 times more massive than an electron.
7 A proton has a charge equal to, but opposite, that of an electron.
8 Atomic number is the number of protons in the nucleus of an atom.
9 Elements are listed in the periodic table by increasing atomic number.
10 Isotopes are atoms of the same element that contain different numbers of neutrons. Isotopes are identified by mass number.
11 Protons and neutrons are two nucleons.
12 Because isotopes of an element differ only in mass, not in electric charge, and therefore have similar chemical behavior.
13 No; different atoms emit different frequencies of light.

1 Atomic spectra are unique to each element.
2 The sum of the frequencies of two lines often equals the frequency of a third spectral line.
3 Energy is quantized.
4 It moves away from the nucleus and gains energy.
5 The energy of an emitted photon equals the difference in energy between the two orbits.
6 Due to their wave nature—the circumference of the smallest orbit can be no smaller than a single wavelength.
7 The wave nature of electrons in atoms is pronounced, because electrons move at speeds of about 2 million meters per second.
8 A probability cloud is therefore a close approximation to the actual shape of an electron's three-dimensional wave.
9 The *s* orbital is spherical. The *p* orbital consists of two lobes and resembles an hourglass.

Answers to Chapter 9 Multiple-Choice Questions

1c, 2d, 3b

Answers to Chapter 9 Integrated Science Concepts

Chemistry, Biology, Earth Science: Physical and Conceptual Models

1 When we use a scanning tunneling microscope, we see atoms indirectly, because we are seeing acomputer-generated diagram of the contours of atoms.
2 Atoms are smaller than the wavelength of visible light. Therefore, they cannot be seen.
3 A physical model is tangible, while a conceptual model is a mental image.
4 An atomic model predicts the behavior of a system that we cannot see.

Chemistry: The Shell Model

1 The valence electrons are the electrons most responsible for the properties of an atom.
2 This model suffices to explain the organization of the periodic table. Remember that the value of a model lies in its utility as much as in its accuracy.
3 There are eight orbitals present in the third shell.

Solutions to Chapter 9 Exercises

1. A cat strolls across your backyard. An hour later, a dog with its nose to the ground follows the trail of the cat. Explain what is going on in terms of atoms.

   The cat leaves a trail of molecules on the grass. These, in turn, leave the grass and mix with the air, where they enter the dog's nose, activating its sense of smell.

2. Which are older, the hydrogen atoms in a young star or those in an old star?

   The age of the atoms in either a young star or in an old star are the same; appreciably older than the solar system.

3. In what sense can you truthfully say that you are a part of every person around you?

   You really are a part of every person around you in the sense that you are composed of atoms not only from every person around you, but from every person who ever lived on Earth!

4. Where are the atoms that make up a newborn baby manufactured?

   The atoms that make up a newborn baby are manufactured deep in the interior of stars.

5. Considering how small atoms are, what are the chances that at least one of the atoms exhaled in your first breath will be in your last breath?

   With every breath of air you take, it is highly likely that you inhale one of the atoms exhaled during your very first breath. This is because the number of atoms of air in your lungs is about the same as the number of breaths of air in the atmosphere of the world.

6. Name ten elements that you have access to in macroscopic quantities as a consumer here on Earth.

   Here is a list of eighteen. Aluminum (as in aluminum foil); tin (as in tin foil and tin cans); carbon (as in graphite and diamond); helium (as in a helium balloon); nitrogen (which comprises about 78% of the air we breathe); oxygen (which comprises about 21% of the air we breathe); argon (which comprises about 1% of the air we breathe); silicon (as in integrated circuits for computers and calculators); sulfur (a mineral used for many industrial processes); iron (as in most metal structures); chromium (as in chromium bumpers on cars); zinc (as in the coating of any galvanized nail or as the insides of any post-1982 copper penny); copper (as in copper pennies); nickel (as in nickel nickels); silver (as in jewelry and old silver coins); gold (as in jewelry); platinum (as in jewelry); and mercury (as in mercury thermometers).

7. Which of the following diagrams best represents the size of the atomic nucleus relative to the atom?

   The one on the far right where the nucleus is not visible.

8. Which contributes more to an atom's mass: electrons or protons? Which contributes more to an atom's size?

   The proton contributes much more to an atom's mass than does the electron. The electron, however, contributes much more to an atom's volume than does the proton.

9. If two protons and two neutrons are removed from the nucleus of an oxygen atom, a nucleus of which element remains?

   The remaining nucleus is that of Carbon-12.

10. What element results if one of the neutrons in a nitrogen nucleus is converted by radioactive decay into a proton?

    Oxygen, O.

11. The atoms that constitute your body are mostly empty space, and structures such as the chair you're sitting on are composed of atoms that are also mostly empty space. So why don't you fall through the chair?

    The outsides of the atoms of the chair are made of negatively charged electrons, as are the outsides of the atoms that make up your body. Atoms don't pass through one another because of the repulsive forces that occur between these electrons. When you sit on the chair, these repulsive forces hold you up against the force of gravity, which is pulling you downward.

12. If an atom has 43 electrons, 56 neutrons, and 43 protons, what is its approximate atomic mass? What is the name of this element?

    Atomic mass would be 99 amu, and the element would be technetium, Tc, atomic number 43.

13. The nucleus of an electrically neutral iron atom contains 26 protons. How many electrons does this iron atom have?

    The iron atom is electrically neutral when it has 26 electrons to balance its 26 protons.

14. Why are the atomic masses listed in the periodic table not whole numbers?

    The atomic masses listed in the periodic table are average numbers that reflect the variety of isotopes that exist for an element.

15. Where did the carbon atoms in Leslie's hair originate? (Shown below is a photo of Leslie Hewitt at age 16.)

    The carbon atoms that make up Leslie's hair or anything else in this world originated in the explosions of ancient stars.

16. Would you use a physical model or a conceptual model to describe the following: brain, mind, solar sys-tem, birth of the universe, stranger, best friend, gold coin, dollar bill, car engine, virus, spread of a cold virus?

    Many objects or systems may be described just as well by a physical model as by a conceptual model. In general, the physical model is used to replicate an object or system of objects on a different scale. The conceptual model, by contrast, is used to represent abstract ideas or to demonstrate the behavior of a system. Of the examples given in the exercise, the following might be adequately described using a physical model: the brain, the solar system, a stranger, a gold coin, a car engine, and a virus. The following might be adequately described using a conceptual model: the mind, the birth of the universe, your best friend (whose complex behavior you have some understanding of), a dollar bill (which represents wealth but is really only a piece of paper), and the spread of a contagious disease, such as a cold.

17. How might you distinguish a sodium vapor street lamp from a mercury vapor street lamp?

Observe the atomic spectra of each using a spectroscope.

18. How can a hydrogen atom, which has only one electron, have so many spectral lines?

The one electron can be boosted to many energy level and, therefore, make many combinations of transitions to lower levels. Each transition is of a specific energy and is accompanied by the emission of a photon of a specific frequency. Thus, the variety of spectral lines is seen.

19. Which color of light comes from the higher energy transition, red or blue? Explain.

The blue frequency is a higher frequency and, therefore, corresponds to a higher energy level transition.

20. Which has the greatest energy, a photon of infrared light, a photon of visible light, or a photon of ultraviolet light?

The photon of ultraviolet light has the greatest energy.

21. If we take a piece of metal at room temperature and begin to heat it continuously in a dark room, it will soon begin to glow visibly. What will be its first visible color, and why?

The first visible color will be red, because this is the visible frequency with the lowest amount of energy per photon.

22. Figure 9.20 shows three energy-level transitions that produce three spectral lines in a spectroscope. Note that the distance between the n 1 and n 2 levels is greater than the distance between the n 2 and n 3 levels. Would the number of spectral lines produced change if the distance between the n 1 and n 2 levels were exactly the same as the distance between the n 2 and n 3 level?

The drop from n 3 to n 2 would be the same energy difference as the drop from n 2 to n 1. The frequencies emitted from these transitions, therefore, would be the same and would overlap each other in the atomic spectrum. The effect would be that two otherwise separate lines would converge into a single more intense line.

23. What is the evidence for the claim that iron exists in the relatively cool outer layer of the Sun?

The spectral patterns emanating from the Sun indicate the spectral patterns of heated iron atoms.

24. What does it mean to say that something is *quantized*?

If something is "quantized," that means it consists of distinct units. Sand, for example, is quantized by each grain. Light is quantized by each photon.

25. The frequency of violet light is about twice that of red light. Compare the energy of the violet photon with the energy of a red photon.

Twice the frequency means twice the energy.

26. If a beam of red light and a beam of violet light have equal energies, which beam has the greater number of photons?

The red light will need more photons to match the energy of the violet light, because each red light photon carries less energy.

27. How does the wave model of electrons orbiting the nucleus account for the fact that the electrons can have only discrete energy values?

When a wave is confined, it is reinforced only at particular frequencies. The electron wave being confined to the atom, therefore, exhibits only particular frequencies, where each frequency represents a discrete energy value.

28. How might the spectrum of an atom appear if its electrons were not restricted to particular energy

levels?

An electron not restricted to particular energy levels would release light continuously as it spiraled closer into the nucleus. A broad spectrum of colors would be observed rather than the distinct lines.

29. How does an electron get from one lobe of a *p* orbital to the other?

Because of its wave nature, it would be better to say that the electron actually exists in both lobes at the same time.

30. Light is emitted as an electron transitions from a higher-energy orbital to a lower-energy orbital. How long does it take for the actual transition to take place? At what point is the electron found in between these two orbitals?

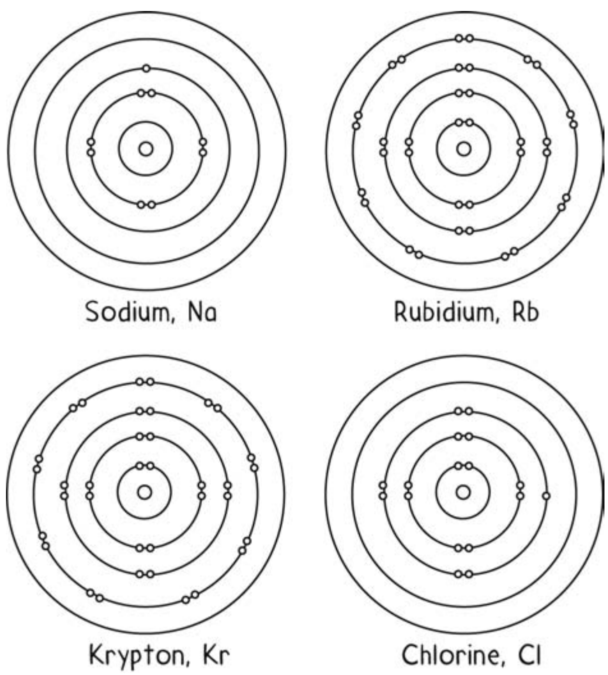
It takes no time at all for this transition to occur. It is instantaneous. At no point is the electron found in between these two orbitals.

31. Why is there only one spatial orientation for the *s* orbital?

The *s* orbital is a sphere that cannot be rotated without being in the same orientation—the sphere is perfectly symmetrical!

1 Place the proper number of electrons in each shell for sodium, Na (atomic number 11); rubidium, Rb (atomic number 37); krypton, Kr (atomic number 36); and chlorine, Cl (atomic number 17).

2 Which element is represented by the model shown in Figure 9.26 if all seven shells are filled to capacity?



This would make the element 118.

34. Does an orbital or shell have to contain electrons in order to exist?

A shell is just a region of space in which an electron may reside. This region of space exists with or without the electron.

35. Use the shell model to explain why a potassium atom, K, is larger than a sodium atom, Na.

Both the potassium and sodium atoms are in group 1 of the periodic table. The potassium atom, however, is larger than the sodium atom, because it contains an additional shell of

electrons.

36. Light has been described as being a wave, and then as being a particle, and then again as a wave. Does this indicate that light's true nature probably lies somewhere in between these models?

No. Light truly does behave as a particle just as it truly behaves as a wave. What we need to understand is that it's okay to use different models to describe different behaviors. The utility of one model doesn't negate the utility of another.

37. Write a letter to Grandma telling her to what extent we can now "see" atoms.

Answers will vary.

Solutions to Chapter 9 Problems

1. Chlorine (atomic number 17) is composed of two principal isotopes, chlorine-35, which has a mass of 34.9689 atomic mass units, and chlorine-37, which has a mass of 36.9659 atomic mass units. Assume that 75.77 percent of all chlorine atoms are the chlorine-35 isotope and 24.23 percent are the chlorine-37 isotope. Show that the atomic mass of natural chlorine is 35.45.

[(0.7553) (34.97)] [(0.2447) (36.95)] 35.4545.

1 Lithium (atomic number 3) is composed of two principle isotopes. The isotope lithium-7 has a mass of 7.0160 atomic mass units, and the isotope lithium-6 has a mass of 6.0151 atomic mass units. Assume that 92.58 percent of all lithium atoms found in nature are lithium-7 and 7.42 percent are lithium-6. Show that the atomic mass of lithium is 6.94.

2 The element bromine, Br (atomic number 35), has two major isotopes of similar abundance, both approximately 50%. The atomic mass of bromine is reported in the periodic table as 79.904 atomic mass units. Choose the most likely set of mass numbers for these two bromine isotopes: (a) ^{80}Br, ^{81}Br; (b) ^{79}Br, ^{80}Br; (c) ^{79}Br, ^{81}Br.

Contributing . . .	**(mass in amu)**	**(fraction of abundance)**		
. . . mass of Li-6:	**6.0151**	**0.0742**	**0.446**	
. . . mass of Li-7:	**7.0160**	**0.9258**	**6.495**	
			6.941	**(atomic mass)**

A 50:50 mix of Br-80 and Br-81 would result in an atomic mass of about 80.5, while a 50:50 mix of Br-79 and Br-80 would result in an atomic mass of about 79.5. Neither of these is as close to the value reported in the periodic table as is a 50:50 mix of Br-79 and Br-81, which would result in an atomic mass of about 80.0. The answer is (c).

4. Gas A is composed of diatomic molecules (two atoms to a molecule) of a pure element. Gas B is composed of monatomic molecules (one atom to a "molecule") of another pure element. Gas A has three times the mass of an equal volume of Gas B at the same temperature and pressure. Show that the atomic mass of Element A is $^{3}/_{2}$ the mass of Element B.

The atomic mass of element A is $^{3}/_{2}$ the mass of element B. Why? Gas A has three times the mass of Gas
B. If the equal number of molecules in A and B had equal numbers of atoms, then the atoms in Gas A would simply be three times as massive. But there are twice as many atoms in A, so the mass of each atom must be half of three times as much—$^{3}/_{2}$.

5. The diameter of an atom is about 10^{10} m. (a) How many atoms make a line a millionth of a meter (10^{6} m) long? (b) Show that 10^{8} atoms cover a square a millionth of a meter on a side. (c) Show that 10^{12} atoms

fill a cube a millionth of a meter on a side. (d) If a dollar were attached to each atom, what could you buy with your line of atoms? With your square of atoms? With your cube of atoms?

(a) 10^{4} atoms (length 10^{6} m divided by size 10^{10} m).
(b) 10^{8} atoms (10^{4} 10^{4}).
(c) 10^{12} atoms (10^{4} 10^{4} 10^{4}).
(d) $10,000 buys a good used car, for instance. $100 million buys a few jet aircraft and an airport at which to store them, for instance. $1 trillion buys a medium-sized country, for instance. (Answers limited only by the imagination of the student.)

6. Assume that the present world population of about 6 10^{9} people is about $\frac{1}{20}$ of the people who ever lived on Earth. Show that the number of people who ever lived is incredibly small compared to the number of air molecules in a single breath.

The total number of people who ever lived (6 10^{9} 20 120 10^{9}, which is roughly 10^{11} people altogether) is enormously smaller than 10^{22}. How does 10^{22} compare to 10^{11}? 10^{22} is $(10^{11})^{2}$! Multiply the number of people who ever lived by the same number, and you'll get 10^{22}, the number of air molecules in a breath of air. Suppose each person on Earth journeyed to a different planet in the galaxy, and every one of those planets contained as many people as the Earth now contains. The total number of people on all these planets would still be less than the number of molecules in a breath of air. Atoms are indeed small—and numerous!

Chapter 10: Nuclear Physics

Answers to Chapter 10 Review Questions

1 Most of the radiation we encounter is natural background radiation that originates in Earth and in space.

2 Atoms with unstable nuclei.
3 Alpha particles have a positive charge; beta particles have a negative charge; gamma rays are neutral.
4 It has been ejected from a nucleus.
5 About 20%.
6 REM.
7 The electrical force.
8 The strong nuclear force may be weaker than the repulsive electrical force.
9 To hold the nucleus together through the strong force.
10 More electrical repulsion.
11 The time it takes for half of an original quantity of an element to decay.
12 Radium-226 has a half-life of 1620 years; uranium-238 has a half-life of 4.5 billion years.
13 True.
14 There is a change in atomic number—a different element is formed.
15 No.
16 Artificial transmutation.
17 When an element ejects an alpha particle from its nucleus, the mass number of the resulting atom is decreased by four, and its atomic number is decreased by two.
18 Bombarding it with alpha particles.
19 About seven million times the energy released by the combustion of one TNT molecule.
20 A nuclear explosion occurs.
21 Reactors contain a moderator, a substance that slows neutrons.
22 Mass.

23 Less mass per nucleon.
24 Iron is the most stable nucleus, because it has the lowest mass per nucleon.
25 They liberate energy.

26. In both chemical and nuclear burning, a high temperature starts the reaction; the release of energy by the reaction maintains a high enough temperature to spread the fire. The net result of the chemical reaction is a combination of atoms into more tightly bound molecules. In nuclear fusion reactions, the net result is more tightly bound nuclei. In both cases, mass decreases as energy is released.

Answers to Chapter 10 Multiple-Choice Questions

1c, 2b, 3d, 4a, 5c

Answers to Chapter 10 Integrated Science Concepts

Biology: Doses of Radiation

1 Because the biological effects of radiation exposure are cumulative, the radiation received from artificial sources increases the potential hazards of radiation.
2 Radiation oncology; atomic bombs.
3 The most significant artificial source of radioactivity is smoking; which can be eliminated by giving up
this habit which is hazardous in many ways.

4 Radioactivity can break molecules apart by disrupting chemical bonds.
5 A cell can survive a dose of radiation that would otherwise be lethal if the dose is spread over a long
period of time to allow intervals for healing.

Biology, Earth Science: Isotopic Dating

1 The proportion of lead and uranium tells us that the oldest rocks are nearly 3.7 billion years old. Rock, for the moon, dates 4.2 billion years.
2 It loses a proton to become the carbon-14 isotope.
3 Radioactive isotopes are produced by cosmic-ray-induced transmutation.
4 The amount of carbon-14 in a fossil tells the amount of time that has elapsed since the organism died. The organism replenishes the carbon-14, in its body as it eats plants or plant-eating animals. When the organism dies, it no longer takes up carbon-14, so the proportion of decayed atoms indicates elapsed time.

Answers to Chapter 10 Exercises

1. Is radioactivity in the world something relatively new? Defend your answer.

   Radioactivity is a part of nature, going back to the beginning of time.

2. Why is a sample of radium always a little warmer than its surroundings?

   A radioactive sample is always a little warmer than its surroundings, because the radiating alpha or beta particles impart internal energy to the atoms of the sample. (Interestingly enough, the heat energy of the Earth largely originates with radioactive decay of the Earth's core and surrounding material.)

3. Some people say that all things are possible. Is it at all possible for a hydrogen nucleus to emit an alpha particle? Defend your answer.

   It is impossible for a hydrogen atom to eject an alpha particle, for an alpha particle is composed of a pair of hydrogen isotopes (deuterium). It is equally impossible for a 1-kilogram melon to spontaneously break into four 1-kilogram melons.

4. Why are alpha and beta rays deflected in opposite directions in a magnetic field? Why are gamma rays

undeflected?

Alpha and beta rays are deflected in opposite directions in a magnetic field because they are oppositely charged—alpha are positive and beta negative. Gamma rays have no electric charge and are therefore undeflected.

5. In bombarding atomic nuclei with proton "bullets," why must the protons be accelerated to high energies to make contact with the target nuclei?

The proton "bullets" need enough momentum to overcome the electric force of repulsion they experience once they get close to the atomic nucleus.

6. Just after an alpha particle leaves the nucleus, would you expect it to speed up? Defend your answer.

Yes, the alpha particle will accelerate substantially just as it leaves the nucleus because of the repulsive electric force between it and the positively charged nucleus.

7. Within the atomic nucleus, which interaction tends to hold it together and which interaction tends to push it apart?

The strong nuclear force holds the nucleons of the nucleus together, while the electric force pushes these nucleons apart.

8. What evidence supports the contention that the strong nuclear force is stronger than the electrical force at short internuclear distances?

The fusing of hydrogen atoms into helium atoms suggests that the electric force of repulsions can be overcome by the strong nuclear force if two atomic nuclei are able to get close enough to each other.

9. A friend asks if a radioactive substance with a half-life of 1 day will be entirely gone at the end of 2 days. What is your answer?

No, it will not be entirely gone. Rather, after 1 day, one-half of the sample will remain, while after 2 days, one-fourth of the original sample will remain.

10. Elements with atomic numbers greater than that of uranium do not exist in any appreciable amounts in nature because they have short half-lives. Yet there are several elements with atomic numbers smaller than that of uranium that have equally short half-lives and that do exist in appreciable amounts in nature. How can you account for this?

The elements below uranium in atomic number with short half-lives exist as the product of the radioactive decay of uranium. As long as uranium is decaying, their existence is assured.

11. You and your friend journey to the mountain foothills to get closer to nature and escape such things as radioactivity. While bathing in the warmth of a natural hot spring, she wonders aloud how the spring gets its heat. What do you tell her?

The Earth's natural energy that heats the water in the hot spring is the energy of radioactive decay, which keeps the Earth's interior molten. Radioactivity heats the water but doesn't make the water itself radioactive. The warmth of hot springs is one of the "nicer effects" of radioactive decay. You'll most likely encounter more radioactivity from the granite outcroppings of the foothills than from a nearby nuclear power plant. Furthermore, at high altitude, you'll be exposed to increased cosmic radiation. But these radiations are not appreciably different than the radiation one encounters in the "safest" of situations. The probability of dying from something or other is 100%, so in the meantime, we all should enjoy life anyway!

12. Coal contains minute quantities of radioactive materials, yet there is more environmental radiation surrounding a coal-fired power plant than a fission power plant. What does this

indicate about the shielding that typically surrounds these power plants?

Although there is significantly more radioactivity in a nuclear power plant than in a coal-fired power plant, the absence of shielding for coal plants results in more radioactivity in the environment of a typical coal plant than in the environment of a typical nuclear plant. All nukes are shielded; coal plants are not.

13. When we speak of dangerous radiation exposure, are we customarily speaking of alpha radiation, beta radiation, or gamma radiation? Defend your answer.

    Gamma radiation is generally the most harmful radiation, because it is so penetrating. Alpha and beta radiation is dangerous if you ingest radioactive material, which is comparatively uncommon.

14. People who work around radioactivity wear film badges to monitor the amount of radiation that reaches their bodies. These badges consist of small pieces of photographic film enclosed in a light-proof wrapper. What kind of radiation do these devices monitor?

    Film badges monitor gamma radiation, which is very high-frequency X-rays. Like photographic film, the greater the exposure, the darker the film upon processing.

15. A friend produces a Geiger counter to check the local background radiation. It ticks. Another friend, who normally fears most that which is understood least, makes an effort to keep away from the region of the Geiger counter and looks to you for advice. What do you say?

    You can tell your friend who is fearful of the radiation measured by the Geiger counter that his attempt to avoid the radiation by avoiding the instrument that measures it, is useless. He might as well avoid thermometers on a hot day in effort to escape the heat. If it will console your fearful friend, tell him that he and his ancestors from time zero have endured about the same level of radiation he receives whether or not he stands near the Geiger counter. There are no better options.

16. When food is irradiated with gamma rays from a cobalt-60 source, does the food become radioactive? Defend your answer.

    There are no fast-flying subatomic particles in gamma rays that might collide with the nuclei of the atoms within the food. Transformations within the nuclei of the atoms of the food, therefore, are not possible. Rather, the gamma rays are lethal to any living tissues within the food, such as those of pathogens. The gamma rays kill these pathogens, which helps to protect us from dangerous diseases such as botulism.

17. Why will nuclear fission probably not be used directly for powering automobiles? How could it be used indirectly?

    Nuclear fission is a poor prospect for powering automobiles primarily because of the massive shielding that would be required to protect the occupants and others from the radioactivity, and the problem of radioactive waste disposal.

18. Why does a neutron make a better nuclear bullet than a proton or an electron?

    A neutron makes a better "bullet" for penetrating atomic nuclei because it has no electric charge and is, therefore, not deflected from its path by electrical interactions, nor is it electrically repelled by an atomic nucleus.

19. U-235 releases an average of 2.5 neutrons per fission, while Pu-239 releases an average of 2.7 neutrons per fission. Which of these elements might you therefore expect to have the smaller critical mass?

    Because plutonium triggers more reactions per atom, a smaller mass will produce the same neutron flux as a somewhat larger mass of uranium. So, plutonium has a smaller critical mass than a similar shape of uranium.

20. Why is lead found in all deposits of uranium ores?

Because uranium transforms to lead.

21. Why does plutonium not occur in appreciable amounts in natural ore deposits?

Plutonium has a short half-life (24,360 years), so any plutonium initially in the Earth's crust has long since decayed. The same is true for any heavier elements with even shorter half-lives from which plutonium might originate. Trace amounts of plutonium can occur naturally in U-238 concentrations, however, as a result of neutron capture, where U-238 becomes U-239 and after beta emission becomes Np-239, and further beta emission to Pu-239. (There are elements in the Earth's crust with half-lives even shorter than plutonium's, but these are the products of uranium decay, between uranium and lead in the periodic table of elements.)

22. Why does a chain reaction not occur in uranium mines?

U-235 isn't in concentrated form in ordinary uranium ore.

23. A friend makes the claim that the explosive power of a nuclear bomb is due to static electricity. Do you agree or disagree? Defend your answer.
A nucleus undergoes fission because the electric force of repulsion overcomes the strong nuclear force of attraction. This electric force of repulsion is of the very same nature as static electricity. So, in a way, your friend's claim that the explosive power of a nuclear bomb is due to static electricity is valid.

24. If a nucleus of 232/90Th absorbs a neutron, and the resulting nucleus undergoes two successive beta decays (emitting electrons), what nucleus results?

This results in the uranium-233 isotope.

25. How does the mass per nucleon in uranium compare with the mass per nucleon in the fission fragments of uranium?

Less in the fission fragments.

26. How is chemical burning similar to nuclear fusion?

Both convert mass to energy.

27. To predict the approximate energy release of either a fission or a fusion reaction, explain how a physicist makes use of the curve of Figure 10.27 or a table of nuclear masses and the equation $E\ mc^2$.

To predict the energy release of a nuclear reaction, simply find the difference in the mass of the beginning nucleus and the mass of its configuration after the reaction (either fission or fusion). This mass difference (called the "mass defect") can be found from the curve of Figure 10.27 or from a table of nuclear masses. Multiply this mass difference by the speed of light squared: $E\ mc^2$. That's the energy released!

28. Which process would release energy from gold, fission or fusion? From carbon? From iron?

Energy would be released by the fissioning of gold and from the fusion of carbon, but by neither fission nor fusion for iron. Neither fission nor fusion will result in a decrease of mass for iron nucleons.

29. If uranium were to split into three segments of equal size instead of two, would more energy or less energy be released? Defend your answer in terms of Figure 10.27.

If uranium were split into three parts, the segments would be nuclei of smaller atomic numbers, more toward iron on the graph of Figure 10.27. The resulting mass per nucleon would be less, and there would be more mass converted to energy in such a fissioning.

30. Explain how radioactive decay has always warmed the Earth from the inside, and nuclear fusion has always warmed the Earth from the outside.

The radioactive decay of radioactive elements found under the Earth's surface warms the insides of the Earth and is responsible for the molten lava that spews from volcanoes. The thermonuclear fusion of our Sun is responsible for warming everything on our planet's surface exposed to the Sun.

31. Write a letter to Grandma to dispel any notion she might have about radioactivity being something new in the world. Tie this to the idea that people sometimes have the strongest views about that which they know the least.

Letters to Grandma should discuss natural sources of radiation, including the radioactive decay that occurs in Earth's interior, which is as old as Earth itself. Letters also should relate the public's fear of radioactivity to the general lack of knowledge of this subject.

Solutions to Chapter 10 Problems

1. Radiation from a point source obeys the inverse-square law. If a Geiger counter 1 m from a small sample reads 360 counts per minute, what will be its counting rate 2 m from the source? 3 m from the source?

   In accord with the inverse-square law, at 2 m, double the distance, the count rate will be 1/4 of 360, or 90 counts/minute. At 3 m, the count rate will be 1/9 of 360, or 40 counts/min.

2. If a sample of a radioactive isotope has a half-life of 1 year, how much of the original sample will be left at the end of the second year? End of the third year? End of the fourth year?

   At the end of the second year, 1/4 will remain. At the end of the third year, 1/8 will remain. At the end of the fourth year, 1/16 will remain.

3. A certain radioactive substance has a half-life of 1 hour. If you start with 1 g of the material at noon, how much will be left at 3:00 PM? at 6:00 PM? at 10:00 PM?

   At 3:00 PM (after 3 half-lives) there will be 1/8 of the original remaining, 0.125 grams. At 6:00 PM, after 3 more half-lives, there are 1/8 of 1/8 left, 0.016 grams. At 10:00 PM the amount remaining has halved ten times, which leaves (1/2)10, or about 1/1000 of the original. So, the remaining amount will be 0.001 g, or 1 mg.

4. A sample of a particular radioisotope is placed near a Geiger counter, which is observed to register 160 counts per minute. Eight hours later, the detector counts at a rate of 10 counts per minute. Show that the half-life of the material is 2 hours.

   Two hours.

5. The isotope cesium-137, which has a half-life of 30 years, is a product of nuclear power plants. How long will it take for this isotope to decay to about one-sixteenth its original amount?

   It will take four half-lives to decrease to one-sixteenth the original amount. Four half-lives of cesium-137 corresponds to 120 years.

6. Suppose that you measure the intensity of radiation from carbon-14 in an ancient piece of wood to be 6% of what it would be in a freshly cut piece of wood. Show that this artifact is 22,920 years old.

   Six percent corresponds to about one-sixteenth, which means that the carbon-14 has undergone about four half-lives. Four half-lives of carbon-14 equals 5730 years times 4 equals 22,920 years.

7. Suppose that you want to find out how much gasoline is in an underground storage tank. You pour in 1 gallon of gasoline that contains some long half-life radioactive material that gives off 5000 counts per minute. The next day, you remove a gallon from the underground tank and measure its radioactivity to be 10 counts per minute. How much gasoline is in the tank?

   Your count is 10/5000 for the gallon you remove. That's a ratio of 1/500, which means the tank must hold 500 gallons of gasoline.

8. The kiloton, which is used to measure the energy released in an atomic explosion, is equal to 4.2 10^{12} J (approximately the energy released in the explosion of 1000 tons of TNT). Recall that 1 kilocalorie of energy raises the temperature of 1 kilogram of water by 1ºC and that 4184 joules is equal to 1 kilocalorie, show that 4.0 10^{8} kilograms of water can be heated 50ºC by a 20-kiloton atomic bomb. **The energy released by the explosion in kilocalories is (20 kilotons)(4.2 10^{12} J/kiloton)/(4,184 J/kilocalorie) 2.0 10^{10} kilocalories. This is enough energy to heat 2.0 10^{10} kg of water by 1 ºC. Dividing by 50, we conclude that this energy could heat 4.0 10^{8} kilograms of water by 50 ºC. This is nearly half a million tons.**

9. An atom of uranium (*m* 232.03174 amu) radioactively decays into an atom of thorium (*m* 228.02873 amu) plus an atom of helium (*m* 4.00260 amu). Show that about 6.1 10^{14} J of energy is released in this decay.

The atom of uranium has an initial mass *m* 232.03174 amu. The products of radioactive decay have a combined mass of 228.02873 amu 4.00260 amu 232.03133 amu. Thus, a mass equal to 232.03174 amu 232.03133 amu 0.00041 amu has been “lost” or converted to energy in this reaction. Since 1 amu 1.6605 10^{27} kg, the converted mass (0.00041 amu) (1.6605 10^{27} kg/1 amu) 6.81 10^{31} kg. By *E mc*^{2}, the energy released in the decay of uranium to thorium and helium is: E (6.81 10^{31} kg)(3.0 10^{8} m/s)^{2} 6.1 10^{14} J.

Chapter 11: Investigating Matter

Answers to Chapter 11

Review Questions

1 Chemistry is often called a central science, because it touches all of the sciences.

2 The members of the Chemical Manufacturers Association pledge to manufacture without causing environmental damage through a program called Responsible Care.

3 Molecules are made of atoms. Atoms link together to form larger but still small basic units of mattercalled *molecules.*

4 The macroscopic, microscopi, and submicroscopic

5 Shape and volume of a gas are determined by its container.

6 Energy: In a solid, the particles are fixed in a three-dimensional arrangement. In a liquid, the particles have energy to overcome the bonds between them, and they tumble loosely around one another. The particles in a gas have so much energy that they overcome their attractions to each other and expand to fill all of the space available.

7 As heat is added to the solid, the particles vibrate more and more violently. If enough heat is added, the attractive forces between the particles are no longer able to hold them together. The solid melts.

8 Boiling.

9 The amount of energy needed to change any substance from solid to liquid (and vice versa) is the heat of fusion for the substance; the amount of energy required to change any substance from liquid to gas (and vice versa) is the heat of vaporization for the substance.

10 During a physical change, the chemical composition of a substance does not change.

11 New materials are formed by a change in the way atoms are bonded together.

12 Restoring the original conditions restores a substance to its original form.

13 Elements are made of atoms.

14 Eight.

15 Metals are shiny, opaque, good conductors of electricity and heat, *malleable,* and *ductile* in contrast to nonmetals.

16 7 periods, 18 groups.

17 (a) Elements of group 2 also form alkaline solutions when mixed with water. Furthermore, medieval alchemists noted that certain minerals (which we now know are made up of group 2 elements) do not melt or change when placed in fire. These fire-resistant substances were known to the alchemists as

"earth." As a holdover from these ancient times, group 2 elements are known as the *alkaline-earth metals.* (b) Elements of group 17 are known as the *halogens* ("salt-forming" in Greek) because of their tendency to form various salts.

18 Inserting the inner transition metals into the main body of the periodic table results in a long and cumbersome table.

19 Elements contain only one type of atom, in contrast to compounds, which contain more than one type of atom.

20 Indeed not!

21 This system is designed so that a compound's name reflects the elements it contains and how those elements are put together.

22 MgO.

23 Common names are more convenient or have been used traditionally for many years.

Answers to Chapter 11 Multiple-Choice Questions

1d, 2c, 3b, 4d, 5a, 6c, 7d, 8b, 9d, 10d

Answers to Chapter 11 Integrated Science Concepts

Astronomy: Origin of the Moon

1 Summaries should discuss the chemical analysis of moon rocks, specifically the similarity of the chemical composition of moon rocks to Earth's mantle and the lack of water and other volatile compounds from moon rocks.

2 No—no chemical elements beyond the periodic table are known to exist anywhere in the universe.

Physics and Biology: Evaporation Cools You Off, Condensation Warms You Up

1 Evaporation is a change of phase from liquid to gas at the surface of a liquid. Faster molecules evaporate, leaving slower ones.

2 Condensation is a change of phase from gas to liquid. Molecules gain speed when attracted to the liquid's surface and, therefore, warm the liquid.

3 Steam gives up considerable energy when it changes phase, condensing to a liquid and wetting the skin.

4 You are warmed by the condensation of water vapor in air upon your skin.

Answers to Chapter 11 Exercises

1. In what sense is a color computer monitor or television screen similar to our view of matter? Place a drop (and only a drop) of water on your computer monitor or television screen for a closer look.

   When looked at macroscopically, matter appears continuous. On the submicroscopic level, however, we find that matter is made of extremely small particles, such as atoms or molecules. Similarly, a TV screen looked at from a distance appears as a smooth continuous flow of images. Up close, however, we see this is an illusion. What really exists are a series of tiny dots (pixels) that change color in a coordinated way to produce the series of images.

2. Is chemistry the study of the submicroscopic, the microscopic, the macroscopic, or all three? Defend your answer.

   Chemistry is the careful study of matter and can take place at a number of different levels, including the submicroscopic, microscopic, or macroscopic levels.

3. Which has stronger attractions among its submicroscopic particles: a solid at 25°C or a gas at 25°C? Explain.

   At 25°C there is a certain amount of thermal energy available to all the submicroscopic particles of a material. If the attractions between the particles are not strong enough, the particles may separate from each other to form a gaseous phase. If the attractions are strong, however, the

particles may be held together in the solid phase. We can assume, therefore, that the attractions among the submicroscopic particles of a material in its solid phase at 25°C are stronger than they are within a material that is a gas at this temperature.

4. Gas particles travel at speeds of up to 500 meters per second. Why, then, does it take so long for gas molecules to travel the length of a room?

   The gas particles take time to cross a room because they bump into each other as well as other particles in the air.

5. Humidity is a measure of the amount of water vapor in the atmosphere. Why is humidity always very low inside your kitchen freezer?

   At the cold temperatures of your kitchen freezer, water molecules in the vapor phase are moving relatively slowly, which makes it easier for them to stick to inner surfaces within the freezer or to other water molecules.

6. A cotton ball is dipped in alcohol and wiped across a tabletop. Explain what happens to the alcohol molecules deposited on the tabletop. Is this a physical or chemical change? Would the resulting smell of the alcohol be more or less noticeable if the tabletop were much warmer? Explain.
   The molecules of the alcohol evaporate into the gaseous phase, which is a physical change; more noticeable.

7. Alcohol wiped across a tabletop rapidly disappears. What happens to the temperature of the tabletop? Why?

   As the alcohol evaporates, it soaks up energy from the tabletop which is thus cooled. This transfer of energy that occurs during a change in phase was discussed in more detail in Chapter 8.

8. Try to explain how alcohol evaporates from the surface of a tabletop, assuming that matter is continuous and NOT made of tiny atoms and molecules.

   If matter were continuous and not made of atoms and molecules, then this implies that there is no such thing as empty space! For example, just as you see no empty space when submerged in a swimming pool, you'd still see no empty space if you magically got to be infinitely small within that swimming pool. It must have been mind blowing when people first discovered that the atmosphere gets thinner and thinner at higher and higher altitudes, as was confirmed by high-altitude balloon flights in the 1800s. This might imply that beyond the atmosphere there was empty space. Interestingly, this idea was so inconceivable that most scientists at that time believed that beyond the atmosphere there was an essence they called aether. This hypothesis, of course, turned out to be wrong. Enough musing. Back to trying to explain the evaporation of alcohol without the idea of atoms and molecules. Sorry, I can't do it. Such a thought is too inconceivable for your author who has been too entrenched in this atom and molecule concept. The evidence for atoms and molecules and the empty space between them is too overwhelming.

9. A skillet is lined with a thin layer of cooking oil followed by a layer of unpopped popcorn kernels. Upon heating, the kernels all pop, thereby escaping the skillet. Identify any physical or chemical changes.

   As each kernel is heated, the water within each kernel is also heated to the point that it would turn into water vapor. The shell of the kernel, however, is airtight, and this keeps the water as a superheated liquid. Eventually, the pressure exerted by the superheated water exceeds the holding power of the kernel, and the water bursts out as a vapor, which causes the kernel to pop. These are physical changes. The starches within the kernel, however, are also cooked by

the high temperatures, and this is an example of a chemical change.

10. Red-colored Kool-Aid crystals are added to a still glass of water. The crystals sink to the bottom. Twenty-four hours later, the entire solution is red, even though no one stirred the water. Explain.

    Even though the water appears to be still, the water molecules are bustling with kinetic energy. The red dye of the Kool-Aid gets knocked around by these molecules to the point that the dye is eventually dispersed throughout the water. This is another case where the existence of molecules helps to explain the observed phenomenon.

11. Gas molecules move 500 meters per second at room temperature, yet there is a noticeable delay in the time it takes for you to smell someone's perfume when she walks into the room. Explain.

    The gas particles take time to cross a room because they bump into each other as well as other particles in the air.

12. Oxygen, O_2, has a boiling point of 90 Kelvin (183°C), and nitrogen, N_2, has a boiling point of 77 Kelvin (196°C). Which is a liquid and which is a gas at 80 Kelvin (193°C)?

    Expose the air to an object that is somewhere between 91K and 77K. The oxygen in the air will condense onto this object as a liquid, much like the water vapor in the air condenses onto the outer surface of a cold can of soda.

13. What happens to the properties of elements across any period of the periodic table?

    Across any period (horizontal row), the properties of elements gradually change until the end of the period. The next element in the next period has properties that are abruptly different.

14. Each sphere in the diagrams below represents an atom. Joined spheres represent molecules. Which box contains a liquid phase? Why can you not assume that Box B represents a lower temperature?

Box B appears to contain a liquid as evidenced by the randomly oriented molecules condensed at the bottom of the box. These molecules in the liquid phase of Box B represent a compound, because they consist of different types of atoms joined together. The physical properties of the compound in Box B will be markedly different from the elements in Box A. For example, if the two boxes are of the same temperature, we would see that the compound of Box B has a higher boiling point. It could be, however, that the boiling point of the substance in Box B is lower than either of the elements in Box A. In such a case, the temperature of Box B must be lower than that of Box A. In short, there's no way to assume the relative temperatures of the boxes based upon the phases of the materials they contain, because these materials are uniquely different from each other.

15. Based on the information given in the following diagrams, which substance has the lower boiling point?

    The change from A to B represents a physical change, because no new types of molecules are formed. The collection of blue/red molecules on the bottom of B represents these molecules in the liquid or solid phase after having been in the gaseous phase in A. This must occur with a decrease in temperature. At this lower temperature, the purely red molecules are still in the gaseous phase, which means that they have a lower boiling point, while the blue/red molecules have a higher boiling point.

16. What physical and chemical changes occur when a wax candle burns?

    The melting of the wax near the flame is an example of a physical change. This liquid wax is drawn up the wick where it is burned, which is an example of a chemical change.

17. Germanium, Ge (number 32), computer chips operate faster than silicon, Si (number 14), computer chips. So how might a gallium, Ga (number 31), chip compare with a germanium chip?

    Based upon its location in the periodic table we find that gallium, Ga, is more metallic in

character than germanium, Ge. This means that gallium should be a better conductor of electricity. Computer chips manufactured from gallium, therefore, operate faster than chips manufactured from germanium. (Gallium has a low melting point of 30°C, which makes it impractical for use in the manufacture of computer chips. Mixtures of gallium and arsenic, however, have found great use in the manufacture of ultrafast, though relatively expensive, computer chips.)

18. Helium, He, is a nonmetallic gas and the second element in the periodic table. Rather than being placed adjacent to hydrogen, H, however, helium is placed on the far right of the table. Why?

Helium is placed over to the far right-hand side of the periodic table in group 18 because it has physical and chemical properties most similar to those of the other elements of group 18.

19. Strontium, Sr (number 38), is especially dangerous to humans, because it tends to accumulate in calcium-dependent bone marrow tissues (calcium, Ca, number 20). How does this fact relate to what you know about the organization of the periodic table?

Calcium is readily absorbed by the body for the building of bones. Because calcium and strontium are in the same atomic group, they have similar physical and chemical properties. The body, therefore, has a hard time distinguishing between the two, and strontium is absorbed just as though it were calcium.

20. Do all the molecules in a liquid have about the same speed, or do they have a wide variety of speeds? Likewise, do all the molecules in a gas have the same speeds?

Molecules have a wide variety of speeds in liquids and gases.

21. Why does increasing the temperature of a solid make it melt?

At higher temperatures the molecules of the material have sufficient kinetic energy to break loose of the attractions to neighboring molecules to form new attractions to other neighboring molecules and so on. In this way, the molecules are able to tumble around one another much like marbles in a bag, which describes the liquid phase.

22. (a) How many atoms are there in one molecule of H_3PO_4? (b) How many atoms of each element are there in one molecule of H_3PO_4?

(a) eight; (b) hydrogen-3; phosphorus-1; oxygen-4.

23. Why does decreasing the temperature of a liquid make it freeze?

At lower temperatures the molecules of the material have insufficient kinetic energy to prevent the electrical attractions between them from holding them within fixed positions.

24. Write a letter to Grandpa to explain to him, in molecular terms, why he will stay warmer if he pats him-self dry in the stall after a shower.

Letters to Grandpa should explain that the rate of evaporation of water molecules from Grandpa's skin will be slower in the humid shower stall than in dry air.

Solution to Chapter 11 Problem

Calculate the height from which a block of ice at 0°C must be dropped to completely melt upon impact. Assume no air resistance and that all the energy goes into melting the ice. [*Hint:* Equate the joules of gravitational potential energy to the product of the mass of ice and its heat of fusion (in SI units, 335,000 J/kg). Do you see why the answer doesn't depend on mass?]

mgh mL, **so *gh L* and *h L/g.***

***h* (334000 J/kg)/(9.8 m/s^2) 34000 m 34 km.**

Note that the mass cancels and that the unit J/kg is the same as the unit m^2/s^2. So in the ideal case of no energy losses along the way, any piece of ice that freely falls 34 km would completely

melt upon impact. Taking air resistance into account, only partial melting would occur.

Chapter 12: The Nature of Chemical Bonds

Answers to Chapter 12 Review Questions

1 Seven
2 It can *share* electrons with another atom or *transfer* electrons to another atom through bonding.
3 Valence electrons
4 An ion has a net electric charge, while an atom is neutral.
5 Gain electrons.
6 Ionic compounds typically consist of elements found on opposite sides of the periodic table.
7 2^+
8 Ionic
9 The mobility of electrons in a metal accounts for the metal's ability to conduct electricity and heat.
10 Atoms that tend to form covalent bonds are primarily atoms of the nonmetallic elements in the upper right corner of the periodic table (with the exception of the noble-gas elements).
11 Electric
12 Four
13 An atom or molecule that has an uneven distribution of charge so that one end is positive and the other negative.
14 Electronegativity is greatest for elements (such as fluorine) at the upper right of the periodic table and lowest for elements at the lower left (such as cesium).
15 Uneven charge distribution.
16 Carbon dioxide is an example—symmetry.
17 Strength of attractive force.
18 Ion-dipole attraction.
19 A hydrogen bond is an unusually strong dipole–dipole attraction between molecules that have a hydrogen atom covalently bonded to a highly electronegative atom, usually nitrogen, oxygen, or fluorine.
20 The component present in the largest amount is the solvent and the other component(s) the solute(s).

1 Solution A contains 2 grams of sucrose per liter of solution; Solution B contains 0.5 grams of sucrose per liter of solution. Which solution is more concentrated? Which is more dilute? A sucrose–water solution containing 2 grams of sucrose per liter of solution is more *concentrated*, and one containing only 0.5 gram of sucrose per liter of solution is less concentrated, or more *dilute*.
2 A saturated solution is one in which no more solute can dissolve. A solution that has not reached the limit of solute that will dissolve is called an unsaturated solution.
3 An interparticle attraction between solvent (water) molecules and solute (water) molecules.
4 A precipitate is solute that comes out of solution once it cools below its saturation point.

Answers to Chapter 12 Multiple-Choice Questions

1c, 2b, 3c, 4b, 5b, 6b, 7d, 8a, 9c, 10a

Answers to Chapter 12 Integrated Science Concepts

Physics, Biology: How Geckos Walk on Walls—The Adhesive Force

1 The adhesive force is an interparticle force that acts between two different substances, while the cohesive force is an interparticle force that acts between molecules of a single substance. The force between a wall and molecules in a gecko's setae is an adhesive force; cohesive forces between water molecules pull water into spherical drops.
2 A gecko's feet are covered with millions of microscopic hairs, spatulae. Each spatulae is only 100 millionth of a meter long. Adhesive forces between the spatulae and a climbing surface keep the gecko "glued" to the surface, because individual molecules on the spatulae and surface attract one another.

Because there is so much surface area on all the tiny spatulae, the total adhesive force is enough to keep the gecko clinging to walls and ceilings.

Biology, Earth Science: Mixtures

1 A skin cell and Earth's layered atmosphere are examples of heterogeneous mixtures.
2 The particles making up a mixture held together by intermolecular forces.

Biology: Fish Depend on Dissolved Oxygen

1 The solubilities of gases in liquids *decrease* with increasing temperature.
2 The oxygen is dissolved in the water they live in.
3 In warmer water, there is less dissolved oxygen—causing fish to suffocate sometimes during hot summer months.

Answers to Chapter 12 Exercises

1. What happens when hydrogen's electron gets close to the valence shell of a fluorine atom?

   Hydrogen's electron joins the valence shell of the fluorine atom. Meanwhile, fluorine's unpaired valence electron joins the valence shell of hydrogen.

2. An atom loses an electron to another atom. Is this an example of a physical or a chemical change?

   This is an example of a chemical change involving the formation of ions, which are uniquely different from the neutral atoms from which they are made.

3. Why doesn't the neon atom tend to gain any electrons? Why doesn't it tend to lose any electrons?

   The neon atom tends not to gain electrons because there is no more room available in its outermost occupied shell; it doesn't lose electrons because its outermost electrons are held tightly to the atom by a relatively strong effective nuclear charge.

4. Which should be larger, the potassium atom, K, or the potassium ion, K?

   The potassium atom, K, with an additional shell of electrons is larger.

5. Which should have a higher melting point, sodium chloride, NaCl, or aluminum oxide, Al_2O_3?

   The charges on the aluminum and oxide ions of aluminum oxide are greater than the charges on the sodium and chloride ions of sodium chloride. The network of aluminum and oxide ions within aluminum oxide, therefore, is more strongly held together, which gives the aluminum oxide a much higher melting point. (More thermal energy is required to allow these ions to roll past one another within a liquid phase.)

6. Two fluorine atoms join together to form a covalent bond. Why don't two potassium atoms do the same thing?

   The valence electrons of a potassium atom are weakly held by the nucleus. The potassium atom has a hard enough time holding onto its one valence electron, let alone a second one, which is what would happen if the potassium joined in a covalent bond.

7. Why doesn't a hydrogen atom form more than one covalent bond?

   The hydrogen atom has only one electron to share.

8. Is there an abrupt or gradual change between ionic and covalent bonds? Explain.

   There is a gradual change. We get this change by noting the relative positions of the bonding elements across the periodic table. If they are close together toward the upper right-hand corner, then the bond is more covalent. When the elements are on opposite sides of the periodic table, the chemical bond between them is more ionic. For the bonding of atoms between these two extremes, the bonding tends to be a blend of both, which is also referred to as *polar covalent*.

9. Atoms of metallic elements can form ionic bonds, but they are not very good at forming covalent bonds. Why?

To form a covalent bond, an atom must have a fairly strong attraction for at least one additional electron. Metals atoms, however, tend not to have such an attraction. Instead, they tend to lose electrons to form positively charged metal ions.

10. What is the source of an atom's electronegativity?

The source of an atom's electronegativity is positive charge of the nucleus. More specifically, it is the effective nuclear charge experienced within the shell that the bonding electrons are occupying.

11. Which molecule is most polar?:

(a) SCS (b) OCO (c) OCS

The most polar molecule is the least symmetrical molecule (c) OCS

12. Which is more polar, a sulfur–bromine (S—Br) bond or a selenium–chlorine (Se—Cl) bond?

A selenium–chlorine bond should be more polar. Observe their relative positions in the periodic table. Sulfur and bromine are more equidistant from the upper right-hand corner.

13. Water, H_2O, and methane, CH_4, have about the same mass and differ by only one type of atom. Why is the boiling point of water so much higher than that of methane?

Water is a polar molecule, because in its structure the dipoles do not cancel. Polar molecules tend to stick to one another, which gives rise to relatively high boiling points. Methane, on the other hand, is nonpolar because of its symmetrical structure, which results in no net dipole and a relatively low boiling point. The boiling points of water and methane are less a consequence of the masses of their molecules and more a consequence of the attractions that occur among their molecules.

14. Three kids sitting equally apart around a table are sharing jelly beans. One of the kids, however, tends only to take jelly beans and only rarely gives one away. If each jelly bean represents an electron, who ends up being slightly negative? Who ends up being slightly positive? Is the negative kid just as negative as one of the positive kids is positive? Would you describe this as a polar or nonpolar situation? How about if all three kids were equally greedy?

The single greedy kid ends up being slightly negative, while the two more generous kids are slightly positive (deficient of electrons). The greedy negative kids is actually twice as negative as one of the positive kids is positive. In other words, if the greedy kid had a charge of 1, each positive kid would have a charge of 0.5. This is a polar situation where the electrons are not distributed evenly. If all three kids were equally greedy, then the situation would be more balanced, that is, nonpolar.

15. Which is stronger: the covalent bond that holds atoms together within a molecule or the dipole—dipole attraction between two neighboring molecules?

The covalent bonds within a molecule are many times stronger than the attractions occurring between neighboring molecules. We know this because, while two molecules can move away from each other (as occurs in the liquid or gaseous phase), the atoms within a molecule remain stuck together as a single unit. To pull the atoms apart requires some form of chemical change.

16. Why is a water molecule more attracted to a calcium ion than a sodium ion?

The calcium ion, Ca^{2}, has twice the positive charge. You might think, therefore, that water is attracted twice as much. Not so! The calcium ion is also larger, which means that the water cannot get so close to the source of this positive charge, which is the atomic nucleus.

17. The charges within sodium chloride are all balanced—for every positive sodium ion, there is a

corresponding negative chloride ion. Because its charges are balanced, how can sodium chloride be attracted to water, and vice versa?

The charges in sodium chloride are balanced, but they are not neutralized. As a water molecule gets close to the sodium chloride, it can distinguish the various ions, and it is, thus, attracted to an individual ion by ion–dipole forces. This works because sodium and chloride ions and water molecules are of the same scale. We, on the other hand, are much too big to be able to distinguish individual ions within a crystal of sodium chloride. From our point of view, the individual charges are not apparent.

18. The volume of many liquid solvents expands with increasing temperature. What happens to the concentration of a solution made with such a solvent as the temperature of the solution is increased?

Assuming concentration is given in units of mass (or moles) of solute in a given volume of solution, then the concentration necessarily decreases with increasing temperature.

19. Suggest why sodium chloride, NaCl, is insoluble in gasoline. Consider the electrical attractions.

Salt is composed of ions that are too attracted to themselves. Gasoline is nonpolar, so salt and gasoline will not interact very well.

20. Would you expect to find more dissolved oxygen in ocean water around the North Pole or in ocean water close to the equator? Why?

No, because of the warmer temperatures. The solubility of oxygen in water *decreases* with increasing temperature.

21. Why are the melting points of most ionic compounds far higher than the melting points of most covalent compounds?

When an ionic compound melts, the ionic bonds between the ions are overcome. When a covalent compound melts, the molecular attractions between molecules are overcome. Because ionic bonds are so much stronger than molecular attractions, the melting points of ionic compounds are typically much higher.

Solutions to Chapter 12 Problems

1. Show that there are 2.5 grams of sucrose in 5 liters of an aqueous solution of sucrose having a concentration of 0.5 gram of sucrose per liter of solution.

Multiply concentration by volume: (0.5 g/L)(5 L) 2.5 g.

2. Show that 45 grams of sodium chloride is needed to make 15 L of a solution having a concentration of 3.0 grams of sodium chloride per liter of solution.

Mass (Concentration)(Volume) 3.0 g/L)(15 L) 45 g.

3. If water is added to 1 mole of sodium chloride in a flask until the volume of the solution is 1 liter, show that the molarity of this solution is 1 M. Show that a 4-M solution results when water is added to 2 moles of sodium chloride to make 0.5 liter of solution.

1 mole 2 moles

a) 1 Molar (1 M) b) 4 Molar (4 M)

1 Liter 0.5 Liters

4. Show that one mole of sugar equals 342 grams.

No calculations are necessary. As shown in the figure, one mole of sucrose equals 342 grams.

Chapter 13: Chemical

Reactions Answers to

Chapter 13 Review Questions

1 Solid is represented by (*s*), (*l*) stands for liquid, (*g*) stands for gas, and (*aq*) for aqueous.
2 A chemical equation must be balanced, because the law of conservation of mass says that mass can neither be created nor destroyed. There must be the same number of each atom on both sides of the equation.
3 The subscript describes how the molecule is put together and cannot be changed or it will describe a
different molecule.

4 An acid is any chemical that donates a hydrogen ion and a base is any chemical that accepts a hydrogen ion.
5 A hydronium ion, H_3O, is a water molecule after accepting a hydrogen ion. A hydroxide ion, OH, is a water molecule after losing a hydrogen ion.
6 When added to water, ammonia (NH_3) behaves as a base; water behaves as an acid
7 In everyday language, the word *salt* implies sodium chloride, NaCl, table salt. In the language ofchemistry, however, *salt* is a general term meaning any ionic compound formed from the reactionbetween an acid and a base.
8 Salts are generally far less corrosive than the acids and bases from which they are formed.
9 Water has the ability to react with itself; in behaving as an acid, a water molecule donates a hydrogen ion to a neighboring water molecule, which in accepting the hydrogen ion is behaving as a base.
10 In an acidic solution, there is a higher concentration of hydronium ions than hydoxide ions, and just the reverse in a basic solution. A neutral solution has equal concentrations of hydronium and hydroxide ions.
11 Acidic solutions have pH values less than 7; basic solutions have pH values greater than 7.
12 Increase.
13 The electrons lost by one chemical are gained by the other.
14 The gain of hydrogen atoms indicates reduction; the gain of oxygen atoms indicates oxidation.
15 Zinc.
16 Corrosion is the deterioration of a metal by oxygen. Combustion is a redox reaction between a nonmetal and oxygen.
17 It increases the frequency of collisions between reacting particles.
18 To increase the rate of collisions is to increase the concentration of reactants; increase temperature; increase pressure.
19 436 kilojoules.
20 Energy in the form of heat.
21 Energy in the form of heat.
22 Into the surroundings.
23 If the reaction results in an overall increase in entropy, then the answer is yes.

Answers to Chapter 13 Multiple-Choice Questions

1b, 2a, 3c, 4c, 5b, 6a, 7d, 8a, 9d, 10d

Answers to Chapter 13 Integrated Science Concepts

Earth Science: Acid Rain

1. It is the alkaline character of limestone (also known as calcium carbonate) that serves to neutralize waters that might be acidified in the Midwestern United States.

1 Acid rain is rain having a pH lower than 5.
2 The burning of fossil fuels produces sulfur dioxide, which reacts with water to produce sulfuric acid,
acidifying rain.

Physics: Fuel Cells

1 As long as fuel is supplied, fuel cells don't run down, but batteries die when the electron-producing chemicals are consumed.

2 The answer is a. H_2.

Physics, Biology, Earth Science: The Effect of Temperature on Reaction Rate

1 Lightning results in the formation of nitrogen monoxide in the atmosphere, which reacts further to produce nitrates, which are chemicals plants need to survive.

2 The body temperature of an ectotherm rises and falls with its environment, slowing its biochemical reactions, which results in slowed movements.

Answers to Chapter 13 Exercises

1. Balance these equations:

   a. $Fe(s)\ \ O_2(g) : Fe_2O_3(s)$
   b. $H_2(g)\ \ N_2(g) : NH_3(g)$
   c. $Cl_2(g)\ \ KBr(aq) : Br_2(l)\ \ KCl(aq)$
   d. $CH_4(g)\ \ O_2(g) : CO_2(g)\ \ H_2O(l)$

   a) 4, 3, 2 b) 3, 1, 2 c) 1, 2, 1, 2 d) 1, 2, 1, 2 (Remember that, by convention, 1's are not shown in the balanced equation.)

2. Is the following chemical equation balanced?4 $C_6H_7N_5O_{16}(s)$ 19 $O_2(g)$: 24 $CO_2(g)$ 20 $NO_2(g)$ 14 $H_2O(g)$

   This equation is balanced.

3. Is this reaction balanced?

   There are the same numbers and types of atoms on both sides of the arrow, which means this reaction is balanced: atoms are neither created nor destroyed.

4. How many diatomic molecules are represented?

   Only two diatomic molecules are represented (not three!). These are the two shown in the left box, one of which is also shown in the right box. Remember, the atoms before and after the arrow in a balanced chemical equation are the same atoms only in different arrangements.

5. Which equation best describes this reaction?

   a. 2 AB_2 2 DCB_3 B_2 : 2 DBA_4 2 CA_2
   b. 2 AB_2 2 CDA_3 B_2 : 2 C_2A_4 2 DBA
   c. 2 AB_2 2 CDA_3 A_2 : 2 DBA_4 2 CA_2
   d. 2 BA_2 2 DCA_3 A_2 : 2 DBA_4 2 CA_2

   Equation "d" best describes the reacting chemicals.

6. What is the relationship between a hydroxide ion and a water molecule?

   A hydroxide ion is a water molecule minus a hydrogen nucleus.

7. What atom in the hydronium ion, H_3O, bears the positive charge?

   The oxygen atom.

8. Identify the acid or base behavior of each substance in these reactions:

:

a. H_3O Cl ; H_2O HCl
b. H_2PO_4 H_2O :H_3O HPO_4

For (a) note that the H_3O transforms into a water molecule. This means that the H_3O loses a hydrogen ion, which is donated to the Cl . The H_3O, therefore, is behaving as an acid, while the Cl is behaving as a base. In the reverse direction, we see the H_2O gaining a hydrogen ion (behaving as a base) to become H_3O. It gets this hydrogen ion from the HCl, which in donating is behaving as an acid. You should be able to make similar arguments for (b) to arrive at the following answers:

a) acid, base, base, acid

b) acid, base, acid, base

9. What happens to the corrosive properties of an acid and a base after they neutralize each other? Why?

The corrosive properties are no longer present, because the acid and base no longer exist. Instead they have chemically reacted with each other to form completely new substances—salt and water—that are not so corrosive.

10. Why do we use the pH scale to indicate the acidity of a solution rather than simply stating the concentration of hydronium ions?

The concentration of hydronium ions is typically so small it needs to be stated using scientific notation. The pH scale, therefore, is one of convenience.

11. What is the concentration of hydronium ions in a solution that has a pH of 3? Why is such a solution impossible to prepare?

This solution would have a hydronium ion concentration of 10^{3} M, or 1000 moles per liter. The solution would be impossible to prepare because only so much acid can dissolve in water before the solution is saturated and no more will dissolve. The greatest concentration possible for hydrochloric acid, for example, is 12 M. Beyond this concentration, any additional HCl, which is a gas, added to the water simply bubbles back out into the atmosphere.

12. What happens to the pH of an acidic solution as pure water is added?

As water is added to an acidic solution, the hydronium ions (and anything else that is dissolved in this acidic solution) become more dilute, that is, less concentrated. Thus, the pH increases.

13. A weak acid is added to a concentrated solution of hydrochloric acid. Does the solution become more or less acidic?

The hydrochloric acid solution becomes more dilute with hydronium ions as the weak acid is added to it. The pH of the hydrochloric acid solution, therefore, increases. Conversely, the pH of the weak acid solution has a relative decrease in its pH as the many hydronium ions from the hydrochloric acid solution are mixed in.

14. Many of the smelly molecules of cooked fish are alkaline compounds. How might these smelly molecules be conveniently transformed into less smelly salts just prior to eating the fish?

Squeeze lemon juice upon the fish. The citric acid found in lemon juice reacts with these smelly alkaline compounds to form less smelly salts. The smell and taste of the lemon also helps to mask any additional undesirable fishy odors.

15. What elements are oxidized in the following equations, and what elements are reduced?
a. Sn_2 2 Ag : Sn 2 Ag b. I_2 2 Br : 2 I Br_2

(a) The tin ion, Sn^{2}, gains electrons and is reduced, while the silver atom, Ag, loses electrons and is oxidized. (b). The iodine atoms, I, gain electrons and are reduced, while the bromine ions, Br, lose electrons and are oxidized.

16. What element behaves as the oxidizing agent in each of the following equations and what element behaves as the reducing agent? a. Sn_2 2 Ag : Sn 2 Ag b. I_2 2 Br : 2 I Br_2

(a) The tin ion, Sn^{2}, is the oxidizing agent, because it causes the silver, Ag, to lose electrons. Meanwhile, the silver atoms, Ag, are the reducing agents, because they cause the tin ion to gain electrons. (b) The **iodine atoms, I, are the oxidizing agents, because they cause the bromine ions, Br, to lose electrons. Meanwhile, the bromine ions, Br, are the reducing agents, because they cause the iodine atoms to gain electrons.**

17. The general chemical equation for photosynthesis is shown below. Through this reaction is the carbon oxidized or reduced? Are the oxygen atoms of the water molecules being oxidized or reduced? 6 CO_2 6 H_2O : $C_6H_{12}O_6$ 6 O_2

Within carbon dioxide there are two oxygen atoms for every one carbon. With the product of photosynthesis (glucose), however, there is only one oxygen for every one carbon. Furthermore, the carbon now has more hydrogens around it. This all tells us that carbon is getting reduced. The oxygen of the water molecule winds up with fewer hydrogen atoms whether it ends up being an oxygen within the carbon-based product ($C_6H_{12}O_6$, glucose, where it needs to share these hydrogens with carbon) or within the oxygen molecule, O_2. This tells us that the oxygen of the water molecule is getting oxidized, which is not an easy thing for oxygen. It takes the energy of sunlight to make this happen.

18. During strenuous exercise there is little oxygen, O_2, available for muscle cells. Under these conditions, the muscle cells derive most of their energy from the anaerobic conversion of pyruvic acid, $C_3H_4O_3$, into lactic acid, $C_3H_6O_3$. The buildup of lactic acid makes the muscles ache and fatigue quickly. Is the pyruvic acid oxidized or reduced as it transforms into lactic acid?

There is a greater ratio of hydrogen atoms in the lactic acid product, which tells us that the pyruvic acid is being reduced.

19. As we digest and subsequently metabolize food, is the food gradually oxidized or reduced? What evidence do you have?

We exhale carbon dioxide and water vapor, which are the products of the oxidation of the food we eat.

20. Are the chemical reactions that take place in a disposable battery exothermic or endothermic? What evidence supports your answer? Is the reaction going on in a rechargeable battery while it is recharging exothermic or endothermic?

It is an exothermic reaction because of the energy that batteries provide.

21. Why do exothermic reactions typically favor the formation of products?

As an exothermic reaction proceeds from reactants to products, the result is a release (dispersion) of thermal energy, which is favorable. Typically, this amount of energy dispersion is significantly larger than the difference in chemical entropies of the products and reactants.

22. As the Sun shines on a snow-capped mountain, much of the snow sublimes instead of melts. How is this favored by entropy?

Water vapor has more entropy than liquid water.

Solutions to Chapter 13 Problems

1. When the hydronium ion concentration of a solution equals 1 mole per liter, what is the pH of the solution? Is the solution acidic or basic?

H =-log [H_3O^+] =-log (1) =-(-0) =0

This is an acidic solution. Yes, pH can be equal to zero!

2. When the hydronium ion concentration of a solution equals 10 moles per liter, what is the pH of the solution? Is the solution acidic or basic?

Use a calculator to find the log of 2 (it's 0.301)pH log [H_3O] log (2) (0.301) 0.301This is a very acidic solution. Yes, pHs can be negative!

3. Use the bond energies in Table 13.2 and the accounting format shown in Section 13.9 determine whether these reactions are exothermic or endothermic:

H_2 + Cl_2 : 2HCl **Energy released from bond formation:**

2 HC#CH 5 O_2 : 4 CO_2 2 H_2O H!Cl 431 kJ**Energy to break bonds:** H!Cl 431 kJH!H 436 kJ Total 862 kJ releasedCl!Cl 243 kJTotal 679 kJ absorbed

NET 679 kJ absorbed 862 kJ released = 83KJ released (exothermic)Energy to break bonds:

Energy released from bond formation:

C#C 837 kJ 4 O"C 3212 kJH!C 414 kJ 4 C"O 3212 kJC!H 414 kJ H!O 464 kJO"O 498 kJ H!O 464 kJO"O 498 kJ O!H 464 kJO"O 498 kJ O!H 464 kJO"O 498 kJ **Total 8280 kJ released**O"O 498 kJ**Total 4155 kJ absorbed**

NET 4155 kJ absorbed 8280 kJ released 4125 kJ released (very exothermic)

Chapter 14: Organic Chemistry Answers to

Chapter 14 Review Questions

1 These differ from one another by the number of carbon and hydrogen atoms they contain.
2 Structural isomers have different physical and chemical properties and different structures. They are
similar in that they have the same molecular formula.

3 The hydrocarbons we use are obtained primarily from fossil fuels—coal and petroleum.
4 The term *saturated* means that each carbon has as many atoms bonded to it as possible—four.
5 An unsaturated hydrocarbon contains a multiple bond—either double or triple.
6 Aromatic compounds contain a benzene ring.
7 A heteroatom is any atom other than carbon or hydrogen in an organic molecule.
8 Organic molecules are classified according to the functional groups they contain.
9 Alcohols are often soluble in water because of the polarity of the oxygen–hydrogen bond. Water is also polar.
10 Alcohols are organic molecules in which a *hydroxyl group* is bonded to a saturated carbon; Phenols contain a phenolic group.
11 Ethers are organic compounds structurally related to alcohols. The oxygen atom in an ether group, however, is bonded not to a carbon and a hydrogen but rather to two carbons.

1 Amines are organic compounds that contain the amine group—a nitrogen atom bonded to one, two, or three saturated carbons.
2 Two appropriately named amines are putrescine and cadaverine, which have the odor of decaying flesh.
3 The carbonyl group consists of a carbon atom double bonded to an oxygen atom.
4 A ketone is a carbonyl-containing organic molecule in which the carbonyl carbon is bonded to two

carbon atoms. In an aldehyde, the carbonyl carbon is bonded either to one carbon atom and one hydrogen atom, or, in the special case of formaldehyde, to two hydrogen atoms.
5 The aldehyde vanillin, introduced at the beginning of this chapter, is the key flavoring molecule derived from the vanilla orchid.
6 An amide is a carbonyl-containing organic molecule in which the carbonyl carbon is bonded to a nitrogen atom. A carboxylic acid is a carbonyl-containing organic molecule in which the carbonyl carbon is bonded to a hydroxyl group.
7 Salicylic acid is an important analgesic (painkiller), but it causes nausea and stomach upset because of its relatively high acidity.
8 Describe the general structure of a polymer.

Polymers are exceedingly long molecules that consist of repeating molecular units called monomers. Monomers have relatively simple structures consisting of anywhere from 4 to 100 atoms per molecule.

20. What happens to the double bond of a monomer participating in the formation of an addition polymer?

Polymerization occurs when two of the electrons from each double bond split away from each other to form new covalent bonds with neighboring monomer molecules.

21. What is released in the formation of a condensation polymer?

A small molecule, such as water or hydrochloric acid.

Answers to Chapter 14 Multiple-Choice Questions

1c, 2e, 3a, 4d, 5d, 6a, 7c, 8c, 9b, 10d

Answers to Chapter 14 Integrated Science Concepts

Biology: Drug Action and Discovery

1 The drug is viewed as the key.
2 Molecular interactions, such as hydrogen bonding, hold a drug to its receptor site.
3 Whether a drug is isolated from nature or synthesized in the laboratory makes no difference as to "how good it may be for you." There are a multitude of natural products that are downright harmful, just as there are many synthetic drugs that are also harmful. The effectiveness of a drug depends on its chemical structure, not the source of this chemical structure.

Solutions to Chapter 14 Exercises

1. According to Figure 14.3, which has a higher boiling point: gasoline or kerosene?

To make it to the top of the fractionating column, a substance must remain in the gaseous phase. Only substances with very low boiling points, such as methane (bp–160°C) are able to make it to the top. According to Figure 14.3, gasoline travels higher than kerosene and so it must have a lower boiling point. Kerosene, therefore, has the higher boiling point.

2. According to Figure 14.3, which consists of smaller molecules: kerosene or diesel?

A hydrocarbon with smaller molecules tends to have a lower boiling point because of weaker attractions among the molecules. From Figure 14.3 you can tell that kerosene has a lower boiling point because it travels higher in the column. Kerosene, therefore, is made of smaller molecules.

3. There are five atoms in the methane molecule, CH_4. One out of these five is a carbon atom, which is 1/5 100 20% carbon. What is the percent carbon in ethane, C_2H_6? Propane, C_3H_8? Butane, C_4H_{10}?

The percent carbon increases as the hydrocarbon gets bigger. Methane's percent carbon is 20%; ethane, 25%; propane, 27%; butane, 29%.

4. What is the chemical formula of the following structure?

$C_4H_{10}O$

5. What is the chemical formula of the following structure?

C_4H_8O

6. Of the structures shown in Exercises 4 and 5, which is more oxidized?

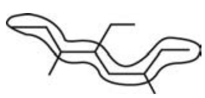
According to Chapter 13, adding hydrogens to a compound is reduction, while subtracting hydrogens is oxidation. Transforming the compound of Exercise 4 into the compound of Exercise 5 requires the loss of hydrogens, which is an oxidation process. The ketone structure of Exercise 5 is more oxidized.

7. List the following compounds in order of least oxidized to most oxidized:

In order of least to most oxidized b P a P d P c, whereas c is the most oxidized. Note how this was the order of their presentation within the chapter. The most reduced hydrocarbons were introducted first, followed by the alcohols, followed by the aldehydes, followed by the carboxylic acids.

8. Circle the longest chain of carbon atoms in the following structure. How many carbon atoms are in this chain?

There are eight carbons in the longest chain:



9. Carbon–carbon single bonds can rotate, while carbon–carbon double bonds cannot rotate. How many different structures are shown below?

The second and the fourth structures are the same. In all, there are three different structures shown.

10. Heteroatoms make a difference in the physical and chemical properties of an organic molecule, because

a. they add extra mass to the hydrocarbon structure.
b. each heteroatom has its own characteristic chemistry.
c. they can enhance the polarity of the organic molecule.
d. all of the above.

Answer: d.

11. One of the skin-irritating components of poison oak is tetrahydrourushiol. The long, nonpolar hydrocarbon tail embeds itself in a person's oily skin, where the molecule initiates an allergic response. Scratching the itch spreads tetrahydrourushiol molecules over a greater surface area, causing the zone of irritation to grow. Is this compound an alcohol or a phenol? Defend your answer.

The long, nonpolar hydrocarbon tail embeds itself in a person's oily skin, where the molecule initiates an allergic response. Scratching the itch spreads tetrahydrourushiol molecules over a greater surface area, causing the zone of irritation to grow.

12. Explain why caprylic acid, $CH_3(CH_2)_6COOH$, dissolves in a 5% aqueous solution of sodium hydroxide, but caprylaldehyde, $CH_3(CH_2)_6CHO$, does not.

The caprylic acid reacts with the sodium hydroxide to form a water-soluble salt, which dissolves in water. The aldehyde, on the other hand, is not acidic, so it will not form a water-soluble salt.

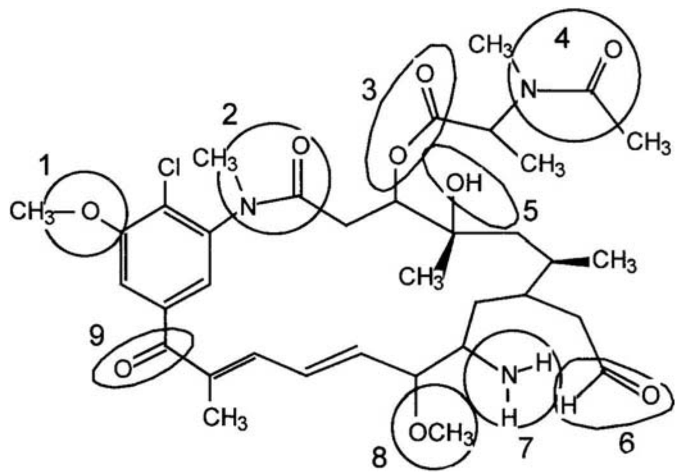
13. Suggest an explanation for why aspirin has a sour taste.

Aspirin's chemical name is acetyl salicylic acid. It is the acidic nature of aspirin that gives rise

to its sour taste.

14. Identify the following functional groups in this organic molecule—amide, ester, ketone, ether, alcohol, aldehyde, amine:

1 **ether**
2 **amide**
3 **ester**
4 **amide**
5 **alcohol**
6 **aldehyde**
7 **amine**
8 **ether**
9 **ketone**



15. Benzaldehyde is a fragrant oil. If stored in an uncapped bottle, this compound will slowly tranform into benzoic acid along the surface. Is this an oxidation or a reduction?

The transformation of benzaldehyde to benzoic acid is an oxidation.

16. Which would you expect to be more viscous, a polymer made of long molecular strands or one made of short molecular strands? Why?

A polymer made of long chains is likely to be more viscous because of the tendency of longer chains to get tangled among themselves.

17. Hydrocarbons release a lot of energy when ignited. Where does this energy come from?

Ultimately, this is the energy that was capture from the sun by photosynthetic plants that turned into fossil fuels after decaying under anaerobic conditions.

18. What type of polymer would be best to use in the manufacture of stain-resistant carpets?

A fluorine-containing polymer such as Teflon.

19. The copolymer styrene-butadiene rubber (SBR), shown here, is used for making tires as well as bubble gum. Is it an addition polymer or a condensation polymer?

Note the similarities between the structure of SBR and polyethylene and polystyrene, all of which possess no heteroatoms. SBR is an addition polymer made from the monomers 1,3-butadiene and styrene mixed together in a 3:1 ratio. Notably, SBR is the key ingredient that allows the formation of bubbles within bubble gum.

20. Many of the natural product molecules synthesized by plants are formed by the joining together of isoprene monomers via an addition polymerization. A good example is the nutrient beta-carotene, which consists of eight isoprene units. Find and circle these units within the structure

shown here.

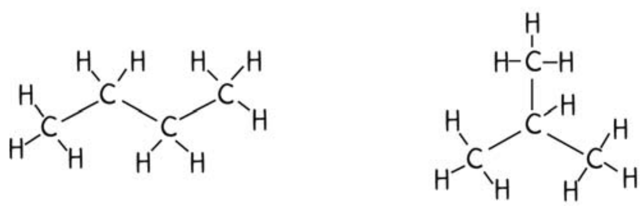
Initially, the beta-carotene structure looks rather complex. Upon careful examination, however, we find that this molecule is simply the result of the joining together of smaller units. Similarly, many of the molecules that you've been studying in this chapter may have initially looked rather intimidating. With a basic understanding of the concepts of chemistry, however, you'll find that you already have much insight into their properties.

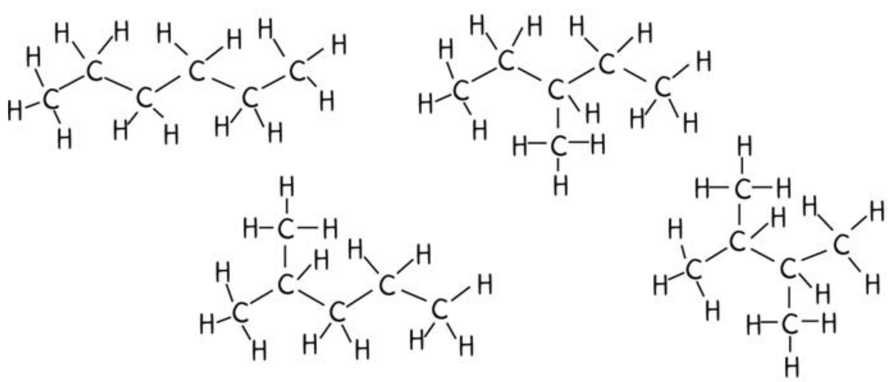
21. Write a letter to Grandma summarizing how polymers were important in winning World War II. If Grandma lived through World War II, ask her if she was aware of the role polymers played!

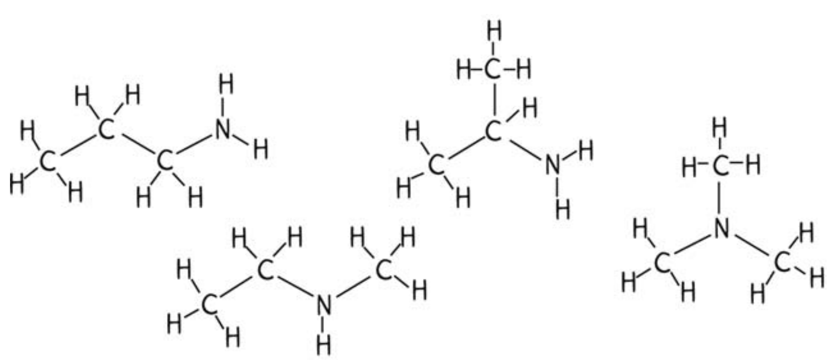
Dear Grandma, today we take polymers and their remarkable properties for granted. Not so back during the time of World War II when their remarkable properties had a significant impact on how the war was won—Nylon for parachutes, synthetic rubber for tires, polyethylene for RADAR, Plexiglas for airplane gunner turets, and Teflon to help in the development of the nuclear bomb.

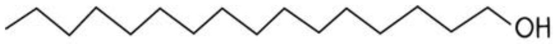
Solutions to Chapter 14 Problems

1 Draw all the structural isomers for hydrocarbons having the molecular formula C_4H_{10}.
2 Draw all the structural isomers for hydrocarbons having the molecular formula C_6H_{14}.
3 Draw all the structural isomers for amines having the molecular formula C_3H_9N.
4 Cetyl alcohol, $C_{16}H_{33}OH$, is a common ingredient of soaps and shampoos. It was once commonly obtained from whale oil, which is where it gets its name (*cetyl* is derived from *cetacean*). Draw the chemical structure for this compound.









Cetyl alcohol

Chapter 15: The Basic Unit of Life—The Cell **Answers to Chapter 15 Review Questions**

1. Living things share a set of characteristics. For one thing, living things all *use energy*. Living things *develop* and *grow*. Living things *maintain themselves.* Living things have the capacity to *reproduce.* Finally, living things are part of populations that *evolve*.

1 Populations do not remain constant from one generation to the next but change over time, across generations.

2 Eukaryotic cells have their DNA in a distinct nucleus, whereas prokaryotic cells lack a nucleus. In addition, the DNA of eukaryotic cells is found in linear, rather than circular, chromosomes. Eukaryotic cells also have numerous organelles, structures that perform specific functions for the cell, that are not present in prokaryotes. Finally, eukaryotic cells are larger than prokaryotic cells—where prokaryotic cells measure 0.1 to 10 micrometers, eukaryotic cells generally measure 10 to 100 micrometers.

3 The DNA of prokaryotes is found in circular chromosomes; the DNA of eukaryotes is found in linear chromosomes.

4 Some of the organelles in eukaryotic cells look suspiciously like whole prokaryotes. Mitochondria, organelles that obtain energy for the cell's use, are contained within their own membrane and have their own DNA, just like prokaryotes. Furthermore, mitochondrial DNA, like that of prokaryotes, exists in the form of a single circular chromosome. This has led to the hypothesis that certain prokaryotes started to live within early eukaryotes and eventually evolved into organelles.

5 The nucleus is a distinct structure within eukaryotic cells surrounded by a double membrane. The nucleus contains the cell's DNA, or genetic material, in the form of linear chromosomes.

6 *Mitochondria* are organelles that break down organic molecules to obtain energy for cells. *Ribosomes* are organelles that assemble proteins. *Lysosomes* are the garbage disposals of a cell—these organelles break down organic materials. Finally, in plants, organelles called *chloroplasts* capture energy from sunlight in order to build organic molecules.

7 The three primary components of the cell membrane are phospholipids, proteins, and short carbohydrates.

8 Phospholipids have hydrophilic "heads" and hydrophobic "tails." The hydrophilic heads are naturally drawn to the watery environment inside and outside the cell, whereas the hydrophobic tails naturally try to avoid it. The result is that the phospholipids form a double layer, or bilayer, with the hydrophobic tails pointing in and the hydrophilic heads pointing out.

9 Membrane proteins serve a variety of functions—they help cells communicate with other cells, control transport into and out of cells, control the chemical reactions that occur in cells, and join cells to one another.

10 Many hydrophobic molecules, including gases such as oxygen and carbon dioxide, can pass directly through the double layer of hydrophobic phospholipid tails. In addition, small, uncharged hydrophilic molecules—most importantly, water—are able to cross the cell membrane directly through tiny pores.

11 *Diffusion* is the tendency for molecules to move from an area of high concentration to an area of low concentration, that is, down a concentration gradient.

12 Carrier proteins are very specific for what they let through the cell membrane. This is because a molecule fits into its carrier protein the way a key fits in a lock—only the right combination will work.

13 In endocytosis, a portion of the cell membrane folds inward and pinches off, enclosing the material to be brought into the cell within a vesicle. In exocytosis, the opposite process occurs—a vesicle

fuses its membrane with the cell membrane and dumps its contents outside the cell.
14 In animals and plants, special structures allow very local messages to pass directly from one cell to an adjacent cell. Plasmodesmata serve this function in plant cells. Plasmodesmata are slender threads of cytoplasm that link adjacent plant cells.
15 The binding of a message molecule to its receptor sets off a series of chemical reactions that results ultimately in the target cell's response to the message.
16 No—receptors are extremely specific about the molecules they bind. This is because a message molecule and its receptor fit together like a key in a lock—only the right combination will work.

18. The stages of the cell cycle are gap 1, synthesis, gap 2, and mitosis. During synthesis, or *S*, the cell creates an exact copy of its genetic material—its DNA.
16 The phases of mitosis are prophase, metaphase, anaphase, and telophase. During *prophase*, the normally loosely packed chromosomes condense, and the membranes surrounding the nucleus break down. When the chromosomes condense, it becomes clear that each consists of two identical sister chromatids attached at a point called the centromere. The mitotic spindle also forms during prophase. The mitotic spindle consists of a series of fibers that attach to the duplicated chromosomes and is responsible for splitting the genetic material between the two daughter cells. During *metaphase*, the chromosomes line up at the equatorial plane, the plane that passes through the imaginary "equator" of the cell. During *anaphase*, the two sister chromatids are pulled apart by the shortening of the mitotic spindle fibers and move to opposite poles of the cell. During *telophase*, new nuclear membranes form around each set of chromosomes, and the chromosomes decondense.
16 In mitosis, one parent cell divides into two daughter cells, each of which contains the same genetic information as the parent cell.
16 Cells rely on catalysts to lower the activation energy of reactions and allow them to happen more quickly. These catalysts are large, complex proteins called enzymes.
16 In competitive inhibition, an inhibitor binds to the active site of an enzyme, preventing it from binding its substrate. (If a substrate fits into an enzyme like a key in a lock, the inhibitor is like bubble gum stuck in the keyhole.) This type of inhibition is called competitive, because the inhibitor and substrate compete for the active site. In noncompetitive inhibition, an inhibitor binds to an enzyme somewhere other than the active site, changing the enzyme so that it can no longer bind its substrate.
16 The antibiotic penicillin kills bacteria by inhibiting an enzyme they need to build cell walls.
16 Almost all life on earth is either directly or indirectly dependent on photosynthesis for organic molecules and energy. This is because photosynthesizers (primarily plants) are food for herbivores, which are, in turn, food for carnivores. Organisms that photosynthesize are thus the ultimate source of all food.
16 During the light-dependent reactions, energy is captured from sunlight. During the light-independent reactions, carbon is fixed—that is, carbon atoms are moved from atmospheric carbon dioxide to carbon-containing organic molecules—specifically, glucose.
16 The end products of photosynthesis are glucose and oxygen.
16 During glycolysis, the six-carbon glucose molecule is split into two molecules of pyruvic acid, each of which contains three carbon atoms. Two molecules of ATP are produced in the process.
16 About 38 molecules of ATP are produced from a single molecule of glucose. The products of cellular respiration are carbon dioxide, water, and ATP.
16 In alcoholic fermentation, pyruvic acid is broken down into ethanol and carbon dioxide.
16 In animal muscle cells, lactic acid fermentation occurs during strenuous exercise, when oxygen supply— despite hard breathing—can't quite meet demand. By regenerating the molecules required for glycolysis, lactic acid fermentation allows muscle cells to continue to make ATP without oxygen. The lactic acid produced causes the familiar burning sensation. Red blood cells, which lack mitochondria, also rely on lactic acid fermentation to obtain ATP.
16 Telomeres are lengths of DNA at the ends of chromosomes that protect them from damage. Every time DNA is copied for cell division, the telomeres get a little shorter. This is because the machinery for copying DNA is unable to copy the linear chromosomes of eukaryotes all the way to their ends. It is sort of like peeling a carrot—because you have to hold the carrot at one end, that end doesn't get peeled all the way. When telomere shortening reaches a critical stage, the cell can no longer divide without losing critical genetic information from the ends of its chromosomes.
16 No, not all cells have a finite life span. The germ line cells that produce our eggs and sperm have a lot of telomerase and are immortal. Some abnormal cells, such as the tumor cells in cancers, also have a lot of telomerase, enabling them to divide indefinitely.

Answers to Chapter 15 Multiple-Choice Questions

1d, 2a, 3c, 4a, 5c, 6c, 7c, 8b, 9d, 10b

Answers to Chapter 15 Integrated Science Concepts

Chemistry: Macromolecules Needed for Life

1 Proteins perform a wide range of functions in living organisms. The protein keratin provides structure in the form of skin, hair, and feathers. Insulin is a protein that acts as a hormone, allowing cells to communicate with one another. Actin and myosin are proteins that allow muscles to contract. Hemoglobin, a protein found in red blood cells, transports oxygen to body tissues. Antibodies are proteins that protect the body from disease. And proteins known as digestive enzymes break down food during digestion.

2. (a) Glucose, fructose, starch, and glycogen are mentioned in the text. Other answers are possible.

(b) Cellulose.

2 Four nitrogenous bases are used in DNA—adenine, cytosine, guanine, and thymine.

Physics: The Microscope

1 With a resolution of 10^{6} meters, light microscopes allow us to view cells and to make out the larger features within them, such as the nucleus and mitochondria. However, they do not really allow us to see organelles and other cellular structures in detail.

2 Electron microscopes are able to resolve objects about a nanometer (10^{9} meter) in size, which allows cellular structures to be viewed in fine detail.

Chemistry: Chemical Reactions in Cells

1 ATP consists of an adenosine molecule and three phosphate groups. Energy is obtained from ATP when one of its phosphate groups is removed, leaving adenosine diphosphate, or ADP. The ATP reaction releases seven kilocalories of energy per mole, an amount of energy that is suitable for most biological reactions.

2 No, it costs more energy to make ATP than cells eventually get out of it. This is consistent with the second law of thermodynamics.

3 ATP is required for the carrier protein to shift and open to the outside of the cell, where it then releases sodium ions and binds potassium ions.

Answers to Chapter 15 Exercises

1. What are the characteristics of life? Discuss how these are evident in human beings.

   Like other living things, humans use energy when we move, speak, or perform any activity. Like other animals, we obtain this energy from the food we eat. Humans certainly develop and grow—think how much a newborn differs from a two-year-old, and how much a two-year-old differs from you! Humans maintain themselves by repairing injuries to skin and bone and other organs, and we maintain a stable internal environment where body temperature, oxygen, water content, and numerous other variables are carefully controlled. (This will be discussed further in Chapter 19 and Chapter 20). Humans have the capacity to reproduce through sexual reproduction. And human populations evolve. In Chapter 16, for example, we will learn why the sickle cell anemia allele is comparatively common in people of African descent, but not in other human groups.

2. During their annual migrations, many birds fly hundreds or even thousands of miles over a relatively short period of time. Why do birds put on a layer of fat before their annual migration? Why don’t

they store this energy as carbohydrates?

Birds need large energy supplies to complete long, strenuous migratory flights. If they store the energy as fat rather than as carbohydrate, they won't weight themselves down as much, because 1 gram of fat contains a lot more energy than 1 gram of carbohydrate.

3. Is it true that *all* the DNA contained in an eukaryotic cell is in the nucleus? If not, why not? How doesthis support the argument that there were once prokaryotes living inside eukaryotes?

   Eukaryotic cells also have some DNA in their mitochondria (and in their chloroplasts, if they are plant cells). Both mitochondria and chloroplasts have their own cell membrane and their own circular chromosome of DNA—because of this resemblance to prokaryotes, it has been hypothesized that these organelles evolved from prokaryotes living inside early eukaryotes.

4. What organelle is found only in plants? What does it do? Does this explain why animals have to eat but plants don't?

   Chloroplasts are found only in plant cells. Chloroplasts are responsible for photosynthesis. This does explain why plants don't need to eat but animals do—through photosynthesis, plants are able to make their own organic molecules that they can use to build structures or that can be broken down for energy.

5. Certain cells in the body, including nerve cells, muscle cells, and liver cells, have large numbers of mitochondria. Bone cells and fat cells generally have few mitochondria. What can you tell about a cell from the number of mitochondria it contains?

   Cells with lots of mitochondria require lots of energy. The mitochondria are there to make lots of ATP for these busy cells.

6. In this chapter, we had three examples of molecules fitting together like "lock and key"? What were these? Why do you think it is important in each of these contexts to have such a specific fit?

   Enzymes and their substrates fits together like lock and key—this assures that each enzyme catalyzes one specific reaction. Carrier proteins and the molecules they transport across cell membranes also fit together like lock and key—this assures that a carrier protein only transports a specific molecule. Finally, message molecules and their receptors fit together like lock and key—this assures that a receptor only responds to a specific message.

7. In all the instances of molecules fitting together like "lock and key," you'll notice that the molecules involved are proteins. How are proteins able to achieve the specificity required?

   Proteins are made of carefully folded chains of amino acids—the varying amino acid sequences combined with the complex folding allows proteins to take on the complex shapes required to create many different types of "locks" and "keys."

8. We mentioned that controlling water flow in and out of cells is a problem all cells face. We also knowthat water is able to cross the cell membrane directly. Are organisms that occupy freshwater habitatslikely to have the problem of too little water entering their cells or too much water entering their cells?Why?

   Freshwater organisms have the problem of too much water entering their bodies. This is because organisms consist of water plus some solutes, whereas their environments consist of water with very few solutes. So, because of osmosis, water tends to move from the environment (few solutes, i.e., high concentration of water molecules) into the bodies of organisms (more solutes, i.e., lower concentration of water molecules). Because of this, many freshwater organisms have some means for getting rid of large amounts of water. Some single-celled organisms have special contractile vacuoles for disposing of water. Vertebrates such as fish get rid of water by excreting very dilute urine.

9. Glucose gets into cells through facilitated diffusion. Why isn't active transport of glucose necessary? That is, why is there usually a higher concentration of glucose molecules outside the cell than inside the cell?

   Glucose is quickly broken down by cells to make ATP (through the process of cellular respiration). As a result, there usually isn't much glucose inside cells.

10. Why does oxygen diffuse into cells rather out of them? Why does carbon dioxide diffuse out of cells rather than into them?

    Oxygen is used up by cells for cellular respiration. As a result, oxygen concentration in cells is low, and so oxygen diffuses in. Carbon dioxide, on the other hand, is a product of cellular respiration, and so its concentration in cells is higher than that outside cells. As a result, carbon dioxide diffuses out of cells.

11. In plants, roots absorb water (among other functions). Why are the roots of many plants highly branched?

    Highly branched roots increase the amount of available surface area for absorption of water and other soil nutrients.

12. What is the difference between endocytosis and using a carrier protein to cross the cell membrane?

    In endocytosis, a portion of the cell membrane folds inward and pinches off the transported material within a vesicle inside the cell. With a carrier protein, the molecule entering the cell binds to the carrier protein, the protein shifts, and the molecule is released inside the cell.

13. How are gap junctions and plasmodesmata similar? How do they differ?

    Both gap junctions and plasmodesmata allow messages to pass directly from one cell to an adjacent cell. So, they have similar functions. However, they are different structurally. Gap junctions are tiny channels in the cell membrane surrounded by specialized proteins. Plasmodesmata are slender threads of cytoplasm that link adjacent plant cells.

14. If a cell goes through all the phases in the cell cycle but for some reason fails to undergo cytokinesis, how will that cell differ from normal cells?

    It will have two nuclei, and twice the genetic material of a normal cell.

15. The figure below shows a cell in the process of cell division. Which stage of the cell cycle is it in?

    Mitosis.

16. The lethal nerve gas sarin binds to an enzyme called acetylcholinesterase, which breaks down acetylcholine in the body. If acetylcholine is not broken down, muscles are unable to relax after contracting. Without prompt treatment, sarin exposure leads to respiratory collapse and death. Sarin works by binding to acetylcholinesterase at the site where acetylcholine normally binds. What form of enzyme regulation does this represent?

    This is competitive inhibition, because it binds at the enzyme's active site, where the substrate normally binds.

17. Global warming has occurred because of the large amounts of carbon dioxide released by burning fossil fuels. Carbon dioxide traps heat. Why might deforestation, the loss of large forests, also contribute to global warming?

    Plants remove carbon dioxide from the atmosphere during photosynthesis.

18. What are some differences between fermentation and cellular respiration? Which process produces more ATP? Why do some cells in the human body use fermentation?

    Fermentation does not require oxygen, whereas cellular respiration does. Fermentation produces no ATP, in contrast to cellular respiration, which produces a lot of ATP. In humans, muscles use lactic acid fermentation when there isn't enough oxygen to meet demand. Red blood

cells use fermentation because they have no mitochondria and, therefore, cannot conduct cellular respiration.

19. Where do the bubbles in champagne come from? *Hint*: unlike nonbubbly wines, champagne goes through an extra round of fermentation during which the bottles are capped tight.

The bubbles come from carbon dioxide released during alcoholic fermentation.

20. Some animals that live in desert environments, like the kangaroo rat shown in the figure below, go their entire lives without drinking a drop of water. Kangaroo rats subsist entirely on the starches and fats found in the dry seeds they eat. Yet we know that all living organisms need water, and in fact, the bodies of kangaroo rats have about the same water content as those of other animals. How do kangaroo rats get their water?

Kangaroo rats get water from cellular respiration—water is one of the products of this process.

21. Do prokaryotes have telomeres? Why don't they need them?

Prokaryotes don't have or require telomeres, because they have circular, rather than linear, chromosomes.

Solutions to Chapter 15 Problems

1. As energy-storage substances, carbohydrates produce about 4 kilocalories of energy per gram, whereas fats produce about 9 kilocalories of energy per gram. The American black bear may hibernate for as long as seven months in the winter, during which it does not eat. Before hibernating, black bears put on a lot of weight, often spending 20 hours a day eating and storing as much as 50 kilograms of fat. Show that the bear would have to gain 112.5 kilograms if it stored energy as carbohydrate instead of as fat.

The amount of energy the bear stores for the winter is:(50 kilograms of fat) (1000 grams/1 kilogram) (9 kilocalories/gram) 450,000 kilocalories.In order to store the same amount of energy as carbohydrate:(*x* kilograms of carbohydrate) (1000 grams/1 kilogram) (4 kilocalories/gram) 450,000 kilocalories*x* 450,000/(4)(1000) 112.5 kilograms

2. A typical cell in the body makes about 10 million molecules of ATP per second. About how many molecules of glucose does it break down per second?

We know that about 38 molecules of ATP are obtained from the breakdown of one glucose molecule. So 10,000,000/38 about 263,158 molecules of glucose.

3. Two bacteria have radii of 1 micrometer and 5 micrometers, respectively. What is the surface area ofeach cell? How does surface area compare to volume for each cell—that is, what is the surface area tovolume ratio? Why is the larger cell able to obtain more molecules through diffusion? Why is itnonetheless more challenging for the larger cell to meet its needs through diffusion? (Recall that thesurface area of a sphere is $4r^2$, and the volume of a sphere is $4/3r^3$.)

For 1 micrometer cell, surface area $4(1)^2$ 4For 5 micrometer cell, surface area $4(5)^2$ 100

Volume of a sphere is $^4/3r^3$

For 1 micrometer cell, volume $^4/3(1)^3$ $^4/3$

For 5 micrometer cell, volume $^4/3(5)^3$ $^{500}/3$

So the surface area to volume ratio is

For 1 micrometer cell, surface area/volume 4/ $^4/3$ 3

For 5 micrometer cell, surface area/volume 100/$\frac{500}{3}$ 3/5

The larger cell is able to obtain more molecules through diffusion because it has a larger surface area. It is nonetheless more challenging for the larger cell to meet its needs through diffusion because it has a smaller surface area to volume ratio—this ratio measures how easy it is for a cell to meet its needs through diffusion, because a cell's need for molecules depends on its volume, and its ability to obtain these molecules depends on its surface area.

4. We mentioned that diffusion works best over small distances. This is because the average time it takes a molecule to diffuse a certain distance is proportional to the square of that distance. If two cells have diameters of 1 micrometer and 5 micrometers, respectively, show that it takes a molecules 25 times longer to diffuse across the larger cell than the smaller cell.

   The average time it takes a molecule to diffuse a certain distance is proportional to the square of that distance, so the ratio of diffusion time across the larger cell to the diffusion time across the smaller cell is $(5)^2/(1)^2$ 25; that is, it takes 25 times longer to diffuse across the 5 micrometer cell than the 1 micrometer cell.

5. Proteins are folded strings of amino acids. All the proteins in living organisms are made up of only 20 different amino acids. How many different ways can you make a string of two amino acids? A string of three amino acids? A string of 10 amino acids? Do you see why the number of proteins living organisms can make is practically countless?
   A chain of two amino acids can include 20 amino acids for the first position and 20 amino acids for the second position, so the number of possibilities is (20)(20) 400.

   A chain of three amino acids can have any of 20 amino acids in the first position, any of 20 amino acids in the second position, and any of 20 amino acids in the third position—so the number of possibilities is (20)(20)(20) 8000.

   For 10 amino acids, the number of possibilities is

   (20)(20)(20)(20)(20)(20)(20)(20)(20)(20) 10,240,000,000,000.

Chapter 16: Genetics Answers to Chapter 16 Review Questions

1 A gene is a section of DNA that contains the instructions for making a protein.
2 Each chromosome consists of a single long strand of DNA as well as small proteins called histones. DNA is wrapped around histone "spools" like string.
3 Most cells have two of each kind of chromosome, like a pair of matched shoes. These cells are diploid. Some cells, such as sperm and eggs, have only one of each kind of chromosome—these cells are haploid**.**
4 DNA is copied in a process called replication. During replication, DNA's two strands are separated as if the spiral ladder were unzipped down the middle. Because of the specific way the bases pair—because A always goes with T, and G always goes with C—each strand can serve as a template for building a new partner.
5 Because of the way replication occurs, with each old strand serving as the template for building a new
partner, every new DNA molecule includes one old strand and one new strand.

6 RNA differs from DNA in three ways—RNA is single-stranded rather than double-stranded, it uses the sugar ribose rather than deoxyribose, and it uses the base uracil (U) instead of thymine (T).
7 Where DNA has bases A, C, G, and T, the mRNA transcript has U, G, C, and A, respectively.
8 First, a cap and tail are added to the beginning and end of the molecule—these allow the cell to recognize the mRNA molecule as mRNA. Second, stretches of nucleotides not relevant to building protein are removed from the mRNA molecule.
9 A codon is a triplet of nucleotides along the mRNA strand that stands for one of the 20 amino acids that make up proteins.
10 The binding of codon and anticodon follows the usual base-pairing rules—that is, A binds with U,

and G binds with C.

11 *Crossing over* occurs when one chromosome exchanges corresponding parts with its homologue. It takes place during metaphase I of meiosis.

12 In meiosis, one diploid parent cell, with two of each kind of chromosome, divides into four haploid daughter cells, each with only one of each kind of chromosome.

13 Until 1900, the dominant theory of inheritance—how traits pass from one generation to the next—was blending inheritance. Under blending inheritance, the mixing of parental hereditary material was thought to produce offspring intermediate between the parents.

14 Mendel found that all the offspring resembled *one* of the two parents.

15 Mendel saw that the recessive trait, which had disappeared in the first generation, reappeared in this second generation.

16 In codominance, the combination of two alleles in a heterozygote results in both traits being expressed. For example, a person with blood type *AB* has both “A” and “B” molecules on his or her red blood cells—that is, both the *A* trait and the *B* trait are expressed. Consequently, the *A* and *B* alleles are codominant.

17 The genes for Mendel’s pea traits happened to lie on different chromosomes, so they follow Mendel’s law of independent assortment. However, if two genes are found on the *same* chromosome, they are often

inherited together (not quite all of the time, because sometimes crossing over shuffles them up) and do not obey Mendel’s law of independent assortment.

1 Because males have only one X chromosome, they have only one allele for sex-linked traits. Consequently, males need only one recessive allele for the recessive trait to appear, whereas females need two. As a result, recessive sex-linked traits show up more frequently in males than in females.

2 No, most of the bases in the human genome are not part of genes. In fact, less than 2% of the genome carries instructions for making proteins!

3 SNPs, or single nucleotide polymorphisms, are locations in the genome where the base pair sequence differs among human beings.

4 A *point mutation* occurs when one nucleotide is substituted for another.

5 A *nonsense mutation* creates a stop codon in the middle of a protein-coding sequence. Nonsense mutations result in the production of shorter, often nonfunctional proteins.

6 A mutation in a single gene is never enough to produce cancer—mutations in many key genes are required.

7 *Oncogenes* stimulate abnormal cell division. *Tumor suppressor genes* prevent cancer by inhibiting cell division. Oncogenes behave as dominants—a mutation in only one of the two alleles promotes abnormal cell division. Tumor suppressor genes behave as recessives—both alleles have to be mutated before the protective effect is lost.

Answers to Chapter 16 Multiple-Choice Questions

1c, 2d, 3c, 4d, 5a, 6a, 7b, 8d, 9a, 10d

Answers to Chapter 16 Integrated Science Concepts

Chemistry: The Structure of DNA

1 DNA is often described as a double helix, because it consists of two strands twisted into a spiral or helix.

2 The “sides” of the ladder are made up of alternating molecules of deoxyribose sugar and phosphate. The “rungs” of the ladder are made up of paired nitrogenous bases (either A and T or G and C).

3 The four nitrogenous bases in DNA are adenine (A), guanine (G), cytosine (C), and thymine (T). A pairs with T, and G pairs with C.

Physics: How Radioactivity Causes Genetic Mutations

1 Radioactive materials release ionizing radiation—gamma rays, beta particles, and alpha particles. When these forms of radiation strike electrons in the body with enough energy, they free the electrons from

the atoms they were orbiting. The free electrons can then strike and damage DNA directly. More frequently, however, the damage occurs indirectly when an electron freed by ionizing radiation hits a water molecule in a cell, producing a free radical. A free radical is a group of atoms that has an unpaired electron and is consequently unstable and highly reactive. Free radicals will react with a wide variety of molecules in the body, including DNA. Their interactions with DNA damage it, causing one or more genetic mutations.

2 Frequently dividing cells are particularly vulnerable to radiation damage. These include cells in the bone marrow (where blood cells are made), in the lining of the gastrointestinal tract, in the testes, and in the developing fetus.

3 Cancer cells divide frequently, so are particularly vulnerable to radiation damage.

Earth Science: Environmental Causes of Cancer

1 The most important cancer-related environmental risk factors include tobacco, diet, ionizing radiation, UV light, disease-causing viruses and bacteria, and mutagens present in air, water, and soil.

2 Exposure to UV light can impair a cell's ability to undergo programmed cell death when it is damaged. (It is this programmed death that causes skin to peel after a sunburn.) Without this ability, damaged cells survive, their DNA continues to accumulate mutations, and they ultimately give rise to cancer.

9. Radon is a radioactive gas produced by the decay of uranium. Because minute amounts of uranium are found in many rocks, radon is present in many areas. When radon decays, it releases small radioactive particles that can be inhaled. These radioactive particles damage DNA in lung cells, making lung cancer more likely to develop.

Answers to Chapter 16 Exercises

1. Look at your finger. Is it made of diploid cells or haploid cells?

   Your finger is made of diploid cells, like most of your body except for your sex cells (and, in women, eggs do not actually complete meiosis and become haploid until they are fertilized!).

2. What kind of sex chromosomes do you have? Where in your body are sex chromosomes found?

   Females are XX, males are XY. Sex chromosomes are found in every cell in your body (with the exception of cells that lack nuclei, such as red blood cells).

3. Explain why every new DNA molecule has one old strand and one new strand.

   Every new DNA molecule has one old strand and one new strand because during DNA replication, the old molecule is unzipped, and each strand is used as a template for putting together a new strand.

4. How is transcription similar to DNA replication? How is it different?

   Transcription is similar to DNA replication in that, in both processes, DNA is unzipped, and one strand is used as a template for building a new nucleic acid strand using base pairing. However, during transcription, a molecule of RNA is made, whereas during replication, a strand of DNA is made. Thus, differences would include the sugar used in the new strand (ribose for RNA and deoxyribose for DNA) as well as the nucleotides in the strand (RNA has uracil in place of thymine).

5. We compared mRNA processing to editing "*aggfr uidosa to be dfjklsdf or rewerwe not to be*" to obtain "*to be or not to be.*" In this analogy, is "*aggfr*" an exon or an intron? Is "*not*" an exon or an intron?

   "*aggfr*" is an intron "*not*" is an exon.

6. Do all codons code for amino acids? If not, what else can they code for?

   Some codons are stop codons that tell the ribosome there are no more amino acids in the

protein being assembled.

7. Examine the genetic code table. Are point mutations in the first, second, and third positions of a codon equally likely to cause a change in the amino acid sequence of a protein? What type of point mutation is least likely to change the amino acid sequence?

Point mutations in the different positions of a codon are not equally likely to change the amino acid sequence of a protein. Changes in the third position are least likely to change amino acid sequence.

8. If there were no such thing as recombination, would the offspring of two parents all be identical? Why or why not?

No. Recall that each pair of homologous chromosomes separates independently during meiosis I. Even without crossing over and recombination, each egg would receive either the chromosome the woman inherited from her mother or the chromosome she inherited from her father. One egg could receive chromosomes 1, 3, 4, 5, 7, 10, 13, and so forth, from her mother and chromosomes 2, 6, 8, 9, 11, 12, and so forth, from her father. A second egg she produces is almost certain to receive a different set of chromosomes, perhaps chromosomes 2, 3, 5, 6, 7, and so forth, from her mother and chromosomes 1, 4, 8, 9, and so forth, from her father. It is clear that the independent separation of homologous chromosomes alone produces a huge number of possible egg cells. Crossing over and recombination only expand the possibilities.

9. The figure below shows a set of human chromosomes. What is unusual about this person's genetic makeup? What health issues might this person suffer from? How does meiosis relate to this condition?

This person has Down syndrome, which is a result of trisomy 21 (having three copies of chromosome 21 rather than two). Down syndrome is characterized by mental retardation and defects of the heart and respiratory system. Chromosomal abnormalities such as trisomies usually result from mistakes that occur during meiosis resulting in an egg or sperm having two copies of a chromosome rather than the usual single copy. (The third copy is added at fertilization.)

10. Explain how a trait can "skip" generations.

Recessive traits can skip generations. For example, a straight hairline father can pass a straight hairline allele to his son. However, the son will have a widow's peak if he inherits a widow's peak hairline from his mother. Then, when the son has a child, he can pass the recessive straight hairline allele to his child. If this child also inherits a straight hairline allele from her mother, she'll have a straight hairline. The straight hairline allele thus appears to have skipped a generation to show up again in the granddaughter.

11. At first sight, incomplete dominance might be mistaken for blending inheritance. For example, the fact that breeding a red-flowered snapdragon with a white-flowered snapdragon produces pink-flowered offspring could be explained by either. How can you prove that blending inheritance is not what's going on here? *Hint*: Try breeding two of the pink-flowered offspring. What would you expect under blending inheritance? Is this what you get?

If you breed two pink-flowered snapdragons, blending inheritance predicts you get all pink-flowered snapdragons. However, what you get are pink, red, and white snapdragons. Specifically, breeding two pink-flowered snapdragons RW RW yields a quarter RR (red-flowered), half RW (pink-flowered), and a quarter WW (white-flowered) offspring.

12. Can you tell what alleles a pea plant with round seeds has? What about the alleles that a red snapdragon has? Why the difference?

A pea plant with round seeds is either WW or Ww, because having round seeds is dominant. A red snapdragon must be RR, because flower color in snapdragons shows incomplete dominance.

13. Is it possible for two parents with widow's peaks to have a child that has a straight hairline? Is it possible for two parents with straight hairlines to have a child with a widow's peak?

It is possible for two parents with widow's peaks to have a child that has a straight hairline if both parents are heterozygotes (Ss) and the child inherits a recessive (s) allele from each parent. Two parents with straight hairlines must be ss, so all their children will only inherit s alleles and will also have straight hairlines. Thus, two parents with straight hairlines cannot have a child with a widow's peak.

14. In birds, sex is determined by a pair of sex chromosomes, just like in mammals. However, birds differ from mammals in that females have two different sex chromosomes (WZ) and males have two of the same sex chromosome (ZZ). Do you think female birds or male birds suffer from more recessive sex-linked conditions? Why?

Females do because they only have one Z chromosome. This means that they need only one recessive allele for the recessive trait to appear, whereas males need two.

15. People with type O blood are called universal donors because they can donate blood to anyone without having problems arise. Why is this? Which blood type do universal receivers—people who can receive blood from any other blood type—have? Why?

People with type O blood are universal donors because their blood cells have neither A nor B molecules that could cause the cells to be rejected and attacked. People with type AB blood are universal receivers—their bodies accept both A and B molecules, so they can receive type O, type A, type B, or type AB blood.

16. Suppose you are studying traits in a mouse, and you notice that two traits seem to be found together more often than you would expect under Mendel's law of independent assortment. For example, you keep noticing that mice with blue eyes are often deaf too. Can you think of two possible explanations for this?

This could be a situation of pleiotropy, in which a single gene causes both blue eyes and deafness. It could also be caused by linked genes, in which the blue-eye gene and the deafness gene are found close together and blue-eye alleles and deafness alleles are associated with each other more frequently than either is with non-blue-eye-color alleles and nondeafness alleles.

17. Duchenne muscular dystrophy is a condition that affects far more males than females. What might you guess about the way it is inherited? What chromosome do you think the relevant gene lies on?

Because it's a condition that affects more males than females, it is likely to be (and, in fact, is) asex-linked trait found on the X chromosome.

18. At their genetic counseling session, a couple learns that one partner is a carrier of cystic fibrosis, while the other is not. Are their children at risk for inheriting the condition? Could their children be carriers of the disease?

Because cystic fibrosis is recessive, children are only at risk if both parents carry a recessive allele (that is, are carriers or are ill with the disease). So, the couple's children are not at risk for cystic fibrosis. However, they could be carriers if they inherit the carrier parent's disease allele.

19. Suppose you are studying two different mutations in a gene that codes for a protein. In the first, a nonsense mutation occurs near the beginning of the gene. In the second, a nonsense mutation occurs near the end of the gene. Which mutation is more likely to disrupt protein function?

A nonsense mutation produces a stop codon in the middle of a gene-coding sequence. The one that occurs near the beginning of the gene (and therefore ends amino acid assembly earlier) is more likely to affect protein function than the one that occurs near the end of the gene.

20. Suppose you are studying two different mutations in a gene that codes for a protein. In one mutation, a single nucleotide is inserted near the beginning of the gene. In the other mutation, three nucleotides are inserted near the beginning of the gene. Which mutation is more likely to disrupt protein function?

Why?

The insertion of a single nucleotide is more likely to disrupt protein function because it will throw the codon reading frame off, i.e., cause a frameshift mutation drastically affecting the amino acid sequence. The insertion of three nucleotides causes the insertion of an extra amino acid, but the bulk of the amino acid sequence remains unaffected.

21. Although offspring typically resemble their parents in many ways, it is also possible for a child to differ from both of her parents in some trait. Think of at least three possible explanations for this observation.

First, with a trait that shows incomplete dominance, the child would resemble neither parent but have a phenotype in between. Second, the child could inherit a recessive allele from each heterozygous parent; thus, the parents would have the dominant phenotype and the child would have the recessive phenotype. Third, with codominance, the child could have a phenotype different from both parents—a blood type A mother and blood type B father could have a child with blood type AB.

22. If two genes are found on the same chromosome, are they always inherited together? Why or why not?

No—crossing over may shuffle them.

23. Give an example of a trait that is determined partly by an organism's genes and partly by the organism's environment. Give an example of a trait that is determined primarily by genes—that is, a trait the environment has little effect on.

Human height and weight are both determined partially by genetic factors and partially by environmental factors. The environment has little effect on traits such as eye color, dimples vs. no dimples, straight vs. widow's peak hairline, and so forth.

24. Write a letter to Grandpa telling him about the Human Genome Project. Tell him what it means that the human genome has been sequenced in its entirety and what implication that might have for medicine.

The Human Genome Project, completed in 2003, sequenced the entire human genome—that is, it determined the complete sequence of As, Ts, Gs, and Cs for all of the human chromosomes. As a follow-up to the Human Genome Project, scientists also identified more than 3 million locations in the genome where the base-pair sequence differs among human beings. These differences are called single nucleotide polymorphisms, or SNPs. SNPs make every person unique, of course, but may also help scientists identify genes related to human diseases.

Answers to Chapter 16 Problems

1. If an organism's diploid cells have 64 chromosomes, how many chromosomes will its haploid cells have?

64/2 32 chromosomes in its haploid cells.

2. One strand of DNA has the base sequence CTGAGGTCAGGA. What are the bases on the opposite strand?

Because G pairs with C and A pairs with T, the opposite strand has GACTCCAGTCCT.

3. Now suppose a molecule of mRNA is being constructed from the same sequence of DNA. What will the bases in the mRNA molecule be?

For RNA, G, C, A, and T pair with C, G, U, and A, respectively. (That is, RNA uses U instead of T). So the RNA molecule will have nucleotides GACUCCAGUCCU.

4. If living organisms used 100 different amino acids to make proteins (rather than only 20), show that atriplet codon would not be sufficient. Also show that a quadruplet codon *would* be sufficient.

A triplet codon allows for 4 4 4 64 different codons. This is enough to cover 20 different amino acids, but not 100. For 100, we'd need a quadruplet codon. 4 4 4 4 256 possible codons, more than enough.

5. Suppose a mRNA molecule with the nucleotide sequence AGUCGUUGGCAGGAAGUA is translated. What sequence of amino acids do you get?

We can break the sequence into triplet codons and consult the genetic code table. (AGU)(CGU)(UGG)(CAG)(GAA)(GUA) serine-arginine-tryptophan-glutamine-glutamic acid-valine.

6. What point mutation in the mRNA molecule in Problem 5 would produce a nonsense mutation?

UGA is a stop codon, so a mutation from G to A in the ninth position of the sequence (i.e., to AGUCGUUGACAGGAAGUA) would produce a nonsense mutation.

7. Suppose a gene has the DNA sequence ACGTGTCCAGACTAATTGCAA. Give two examples of point mutations in this sequence that would not affect the protein the sequence codes for.

Many answers are possible. ACATGTCCAGACTAATTGCAA and ACCTGTCCAGACTAATTGCAA are two possible answers—point mutations in the first codon still code for the amino acid threonine, so the amino acid sequence (and protein produced) are unaffected.

8. You have a pea plant with round seeds. Can you say for sure what pea shape alleles the plant carries? What are the two possibilities? You want to distinguish between these possibilities, so you decide to let the plant self-fertilize. What kind of offspring do you expect in each case?

The two possibilities are WW and Ww, because round seeds are dominant. If you let a WW plant self-fertilize, you expect all the offspring to be WW and have round seeds. If you let a Ww plant self-fertilize, you expect offspring with round seeds as well as offspring with wrinkled seeds in a 3:1 ratio.

9. A woman carries an allele for red-green colorblindness on one of her X chromosomes. Her husband is not red-green colorblind. Show that her daughters are not at risk for red-green colorblindness, but that her sons are at risk.

The red-green colorblindness allele is recessive, and the gene is found on the X chromosome. Because the woman's husband is not red-green colorblind, his allele must be normal. All the daughters will inherit this normal allele (because they all inherit an X chromosome from their father), so they will not be red-green colorblind no matter which allele they inherit from their mother. The sons, however, only receive an X chromosome from their mother, so they have a 50/50 chance of being red-green colorblind (because she has one red-green colorblindness allele and one normal allele).

Chapter 17: The Evolution of Life

Answers to Chapter 17

Review Questions

1 Pasteur designed a flask that kept out dust and other airborne particles, filled the flask with sterile meat broth, let the concoction sit, and watched for life to emerge. Pasteur observed that life did not arise from nonlife.

2 Miller and Urey modeled the early Earth by mixing together an "atmosphere" of water vapor, ammonia, methane, and hydrogen, and placing that atmosphere over a "sea" of water. They then shot electric sparks through the mixture to simulate lightning storms. The results were staggering—within a week, complex organic molecules had formed, including amino acids, the building blocks of proteins. Not only had these molecules formed quickly, there were lots of them. Further experiments showed that all the

important organic molecules that make up life—amino acids, as well as sugars, lipids, even the nitrogenous bases found in RNA and DNA—can be generated in a similar way.

3 Liposomes have double membranes and behave in ways that are eerily cell-like, growing and shrinking, even budding and dividing. Liposomes also control the absorption of materials and run chemical reactions within their membranes.

4 Even without cells and enzymes, short strands of RNA can spontaneously assemble from individual nucleotides and even reproduce themselves.

5 Earth's early autotrophs included organisms that used sunlight energy to build molecules as well as chemoautotrophs that used energy from a variety of inorganic chemicals.

6 Cyanobacteria release oxygen as a by-product of photosynthesis, and it was their incredible success that first introduced oxygen into Earth's atmosphere.

7 Scientists believe mitochondria and chloroplasts evolved from prokaryotes living inside the earliest eukaryotic cells.

8 No, the nucleus and most eukaryotic organelles probably originated from inward foldings of the cell membrane.

9 According to Lamarck's theory, organisms acquired new characteristics over a lifetime of activity and then passed these characteristics onto their offspring.

10 Lyell, a geologist, argued that the geological features of the earth were created not by major catastrophic events—the favored theory of the time—but by gradual processes that produced their effects over long time periods. A deep canyon, for example, did not require a cataclysmic flood but could be the result of a river's slow erosion of rock over millenia. Darwin realized this could be true for biological organisms as well—the accumulation of gradual changes over long periods could produce all the diversity of living organisms, as well as all their remarkable features.

11 Malthus observed that human populations grow much faster than available food supplies and concluded, with despair, that famine was an inevitable feature of human existence. Darwin applied Malthus's idea to the natural world—because there are not enough resources for all organisms to survive and to reproduce as much as they can, living organisms are involved in an intense "struggle for existence." As a result, organisms with advantageous traits leave more offspring than organisms with other traits, causing populations to change over time. This process, which Darwin called natural selection, is the major driving force behind evolution.

12 The Galápagos finches showed remarkable variation in the size and shape of their beaks, with each beak being suited to, and used for, a different diet.

13 Variation describes the existence of traits that vary from individual to individual within a population.

14 Heritable traits are those that can be passed from parents to offspring.

15 Natural selection occurs when organisms with certain advantageous traits leave more offspring than organisms with other traits, causing populations to change over time.

16. Many of the adaptations organisms evolve through natural selection relate to survival. Other adaptations in organisms have evolved to help them acquire mates. Finally, many adaptations relate to bearing and raising young.

15 A species is a group of organisms whose members can interbreed among themselves but not with members of other species.

15 Prezygotic reproductive barriers prevent members of different species from mating in the first place or keep fertilization from occurring if they do mate. (A *zygote* is a fertilized egg, so *prezygotic* means before fertilization). There are many types of prezygotic barriers—organisms may differ in when they breed, where they breed, or in the details of their courtship rituals. Their sex organs may not fit together

properly, preventing successful sperm transfer, or other factors may prevent fertilization even if sperm is transferred. Postzygotic reproductive barriers act after fertilization has taken place. Postzygotic barriers occur when mating produces hybrids that either don't survive or are sterile—unable to breed themselves. The mule, the offspring of a horse and a donkey, is sterile and cannot reproduce. Likewise, a liger, the product of the mating of a lion and a tiger, is sterile.

15 In plants, sympatric speciation is often the result of sudden chromosomal changes. One such chromosomal change is *polyploidy*, which occurs when organisms inherit more than the usual two sets of chromosomes, usually as a result of improper meiosis. Another instance of sympatric speciation through chromosomal change is *hybridization,* which occurs when two species interbreed and produce fertile offspring.

15 The rise of the Isthmus of Panama 3 million years ago divided the Caribbean Sea from the Pacific Ocean, splitting hundreds of types of marine organisms into separate Caribbean and Pacific populations. Most of these subsequently speciated by evolving reproductive barriers.

15 An adaptive radiation is the evolution of a large number of new species, each adapted to a distinct way of life, from a single ancestor. Adaptive radiations are most often seen after a few members of a species colonize a new habitat.

15 Artificial selection is the selective breeding of organisms with desirable traits in order to produce offspring with the same traits. Artificial selection provides evidence for evolution because organismal evolution (change over generations) is visible during the process.

15 If each of these mammals had originated independently, we would expect their limbs to look completely different. Yet, in fact, all mammalian limbs resemble each other and are made up of the same set of bones. This suggests that mammals inherited their limbs from a common ancestor and that these limbs were then modified by evolution for different purposes over time.

15 The fossil record frequently shows species appearing suddenly, not changing much for a long time, and then disappearing.

15 Spurts of rapid change occur during speciation.

15 *Australopithecus* fossils show that an upright posture dates to at least 4 million years ago.

15 *Homo erectus* was the first hominid species to migrate out of Africa and into much of what is now Europe and Asia.

Answers to Chapter 17 Multiple-Choice Questions

1a, 2b, 3b, 4d, 5c, 6c, 7a, 8a, 9d, 10d

Answers to Chapter 17 Integrated Science Concepts

Astronomy: Did Life on Earth Originate on Mars?

1 Because in 1996, NASA scientists found what could be fossils of tiny bacteria in a Martian meteorite.

Moreover, the potential fossils were found very close to complex organic molecules and carbonate minerals that, on Earth, are associated with living organisms.

2 Scientists know that the meteorite is from Mars because of its similarity to another undoubtedly Martian meteorite that has gas bubbles that match the composition of the Martian atmosphere.

3 Perhaps, scientists proposed, life found its way to Earth in Martian dust set adrift in space when a comet collided with Mars.

4 Skeptics were quick to point out that the proposed fossils are much smaller than the tiniest bacteria on

Earth and that they are likely to be too small to contain all the DNA, proteins, and other molecules a bacterium needs to function.

Physics: Animal Adaptations to Heat and Cold

1 The heat an animal generates is proportional to its volume. The heat an animal dissipates is proportional to its surface area, because heat is lost to the environment through its body surface. Consequently, animals are better able to lose heat if they have a high surface-area-to-volume ratio and

better able to retain heat if they have a low surface-area-to-volume ratio.

2 Bergmann's Rule says that animals found in cold habitats are often larger than related forms in warm habitats. This is related to surface-area-to-volume ratio in that larger organisms tend to have smaller surface-area-to-volume ratios. This is because volume increases more quickly than surface area as organisms get bigger. An example of Bergmann's Rule is seen in bears. The smallest bear in the world is the sun bear, found in the tropical forests of Southeast Asia. Adult sun bears weigh between 27 and 65 kilograms (60 to 140 pounds). The largest bear in the world is the polar bear, which ranges throughout the Arctic. Adult polar bears weigh between 200 and 800 kilograms (440 to 1760 pounds).

3 Allen's Rule says that desert species typically have long legs and large ears that increase the surface area available for heat dissipation, whereas Arctic species typically have short appendages and small ears that help conserve heat. Desert and Arctic rabbit species provide an example of Allen's Rule.

4 Insulators conduct heat slowly and help retard heat loss. Insulators in animals include fur, feathers, and blubber.

Earth Science: Earth's Tangible Evidence of Evolution

1 Fossils of now-extinct relatives of the horse show that species grew larger in size over time, as well asmore specialized for eating grass and running. Some fossil whales exhibit some of the characteristics ofthe hoofed animals they evolved from—hind limbs, nostrils on their noses rather than blowholes, anddifferent types of teeth. *Archaeopteryx*, the famous 150-million-year-old fossil bird, has many birdlikefeatures—feathers, wings, a wishbone—but also has dinosaur-like features absent in modern birds,including claws on its wings, bones in its tail, and teeth.

2 Biogeography, the study of how species are distributed on Earth, is consistent with evolution rather than with the idea that organisms were purposefully distributed around the planet. For example, the argument that each organism was specially designed to fit into its habitat is undermined by the observation that similar habitats are often home to completely different species. New World tropical forests and Old World tropical forests are occupied by entirely different life-forms, as are the similar environments of the Arctic and Antarctic. In addition, closely related species tend to be found close together. All of Darwin's finches are found in or near the Galápagos, and all the honeycreepers in Hawaii. Most of the world's marsupials (pouched mammals, such as koalas and kangaroos) are found in Australia. Island species are most closely related to species found on the closest mainland. This pattern holds for fossils as well—fossil armadillos are found only in the New World, where modern armadillos also occur, and fossil apes are found only in Asia and Africa, where modern apes reside. Islands tend to be occupied by many flying animals, but few or no terrestrial ones. All these biogeographical patterns suggest that organisms were not dispersed purposefully, but instead evolved in a certain place and then spread and left descendants where they could.

Answers to Chapter 17 Exercises

1. What types of experiments were necessary to show that living organisms were not spontaneously generated in nonliving matter? Why do you think the idea of spontaneous generation survived so long— why was it so difficult to disprove?

   The types of environments where living organisms were thought to spontaneously appear—rotting carcasses or meat broths—had to be isolated from living organisms so that they would not be contaminated by life that already existed. This isolation proved difficult to achieve, and contamination often did occur.

2. Why didn't Miller and Urey include oxygen in their model of the young Earth?

   There was no oxygen in the atmosphere of the young Earth. Oxygen did not enter the atmosphere until the rise of the cyanobacteria much later in Earth history.

3. How are liposomes similar to cells? How are they different from real cells?
   Liposomes have double membranes and behave in ways that are eerily cell-like, growing and shrinking, even budding and dividing. Liposomes also control the absorption of materials and run chemical reactions within their membranes, like cells. However, they do not have genetic material like real cells.

4. How do scientists know that the first living organisms used anaerobic processes to obtain energy? Do any aerobic organisms predate cyanobacteria? Why or why not?

   The first living organisms used anaerobic processes to obtain energy because there was no oxygen in Earth's early atmosphere. Oxygen did not enter the atmosphere until the rise of the cyanobacteria much later in Earth history, so the first aerobic organisms would have appeared after that.

5. How might Lamarck have explained the streamlined shape of fish, which makes them effective swimmers? How would Darwin's theory of evolution by natural selection explain the same phenomenon?

   Lamarck would say that over a lifetime of swimming, the shapes of fish became more streamlined as they fought their way through the water. They then pass this more streamlined shape to their offspring. Darwin would say that fish vary in their body shape, and that more streamlined individuals were more effective swimmers, so survived and reproduced better, leaving more streamlined individuals in the population.

6. How is the story of myxoma virus and Australian rabbits similar to the story of antibiotic resistance in bacteria?

   In both cases, the administration of a lethal agent (antibiotics or myxoma virus) led to natural selection for resistant individuals in the population. These resistant individuals survived and reproduced. As a result, over time, populations evolved resistance to the lethal agent.

7. What are some human traits that do not show variation? What are some that do show variation?

   Answers will vary. Traits that don't show variation include having a four-chambered heart, five fingers on each hand, two arms, two legs, one nose, and so forth. Traits that show variation include height, weight, arm length, foot length, eye color, hair color, and so forth.

8. What are some heritable human traits? Some nonheritable human traits?

   Answers will vary. Heritable traits include having a four-chambered heart, five fingers on each hand, two arms, two legs, one nose, as well as height, weight, arm length, foot length, eye color, hair color, and so forth. Nonheritable traits include hairstyle, hair length, clothing, any scars, tattoos, pierced ears, language spoken, and so forth.

9. Nancy Burley of the University of California, Irvine, ran the following experiment—she placed red color bands on the feet of some male birds and green color bands on the feet of other male birds. Females preferred to mate with birds that had red color bands. Could this lead to natural selection? Why or why not?

   No, color band color is not a heritable trait.

10. How would you determine whether a trait you were interested in studying is heritable?

    One possibility would be to compare the traits of parents and offspring and see if offspring tend to resemble their parents more than they resemble nonparents. This experiment would have to be conducted in a controlled environment so that similarities between parents and offspring can be attributed to genetic rather than environmental factors.

11. You are studying a population of beetles that include some red individuals and some yellow individuals. You know that color is a heritable trait in the population. By counting the number of red and yellow beetles over a period of 5 years, you notice that the population is evolving toward more red individuals. How could you determine whether this is a result of natural selection? Are there other potential explanations?

    Alternative explanations are genetic drift, migration into or out of the population, and

mutation pressure. To determine whether natural selection is responsible for the shift, you could compare the fitness (number of offspring left) of red individuals vs. yellow individuals. If this turned out to be difficult, you could also compare their survival or ability to acquire mates in an attempt to identify underlying causes of potential fitness differences.

12. On islands, many large animals, such as elephants, evolve to become miniaturized in size. On the other hand, many small animals, including some rodents, evolve to be exceptionally large in size. Why might natural selection produce these results? Do you think this phenomenon sheds light on *Homo floresiensis,* the miniature human relative?

    The hypothesis is that large animals become miniaturized because of limited food resources on relatively small islands, and that small animals evolve to larger size because of the absence of predators. *Homo floresiensis*, the miniature human relative, was indeed found on a small island, so this could explain its small size.

13. In recent decades, average human height has increased in many parts of the world. Do you think this is an example of evolution?

    It could be, but it could also be the result of better nutrition.

14. In a population of mice that you are studying, tail length appears to be increasing over time. However, you find no evidence that natural selection is acting on tail length. What are two alternate explanations for your observation?

    Genetic drift could be affecting tail length, or perhaps migration from a population of longer-tailed individuals.

15. Two species of foxes are shown below. One is a kit fox in the Mojave Desert, California. The other is an Arctic fox in Manitoba, Canada. Which is which? How can you tell? Describe at least two traits that make each animal well-adapted to thermoregulating in its habitat.

    The kit fox is the one with pale brownish fur, large ears, and long limbs. The fur color helps it reflect heat and stay camouflaged in its environment. The large ears and long limbs help it increase surface area available for heat dissipation. The Arctic fox has white fur, which helps it stay camouflaged, and small ears and short limbs that help it decrease the surface area from which heat is lost.

16. Individuals of two different fish species sometimes mate, but the offspring die soon after hatching. Is this a prezygotic or postzygotic reproductive barrier?

    Postzygotic, because it occurs after fertilization.

17. Finches on two nearby islands look noticeably different from one another—individuals on one island have brown tail feathers, whereas individuals on the other island have black tail feathers. Can you conclude that they are two different species? What would you do to determine if they are, in fact, distinct species?

    No, you cannot conclude they are distinct species merely because they are distinguishable. You can determine whether they are distinct species by figuring out whether they interbreed.

18. At your field site, there are butterflies with yellow wings and butterflies with orange wings. After observing them carefully, you conclude that the yellow butterflies always mate in shady areas under trees, whereas the orange butterflies always mate in sunny meadows. Can you conclude that they are different species?

    Probably—your observations suggest that there is a prezygotic reproductive barrier.

19. Many of the living organisms on Hawaii are found nowhere else on earth. This includes species of plants, birds, insects, mammals, mushrooms, and so forth. Why do you think this is?

Hawaii is extremely isolated from all mainlands, so organisms that arrived there then had plenty of time to evolve in isolation and speciate from mainland species.

20. What are some examples of artificial selection? How are artificial selection and natural selection similar? How are they different?

    We saw artificial selection in the breeding of dogs as well as in the breeding of corn from teosinte. Artificial selection and natural selection are similar in that both are driven by differences in reproductive success (this is imposed by human beings in the case of artificial selection, and by the environment in the case of natural selection). Artificial selection and natural selection are different in that humans can impose whatever conditions they like on artificial selection, and perhaps produce forms that wouldn't do very well in the wild. Humans can also make artificial selection much more stringent than natural selection is, insofar as they can choose two specific racehorses and only breed those—as a result, evolution by artificial selection can occur surprisingly quickly compared to evolution by natural selection.

21. Islands tend to have fewer species than the mainlands they resemble. Furthermore, island species often include many flying organisms, and few terrestrial ones. Do these biogeographical patterns support evolution or the purposeful distribution of organisms? Why?

    Both these biogeographical patterns suggest that organisms dispersed where they could, not that they were purposefully distributed across the globe.

22. Write a letter to Grandma telling her about drug resistance in living organisms. Explain to her why drug resistance is such a common phenomenon—including why insects become more resistant to pesticides over time, and why diseases such as tuberculosis and malaria have become harder to treat in recent years.

    Dear Grandma—Drug resistance is an inevitable result of natural selection. During drug application, those organisms that are more resistant to the drug survive and reproduce better, passing on resistance genes to descendants. This has made insects resistant to commonly used pesticides over time and has also made pathogens resistant to medical drugs designed to eradicate them. Drug-resistant strains of tuberculosis and malaria in particular have appeared in recent years, worrying many public health officials.

Answers to Chapter 17 Problems

1. Let's look at how natural selection causes advantageous traits to become more common in populations. Suppose there is a population of bugs in which some individuals are green and some individuals are brown. Suppose that, because brown bugs are better camouflaged against predators, each brown bug leaves two brown offspring per generation, and each green bug leaves one green offspring per generation. (Is this natural selection? Why?) You start with two brown bugs and two green bugs in Generation 1. How many brown and green bugs are there in Generation 2? Calculate the number of brown and green bugs there are in Generations 1 to 10. Now what fraction of bugs is brown in Generation 1? Generation 2? Generation 5? Generation 10? What is happening here?

    Yes, this is natural selection, because color is a variable, heritable trait, and brown and green individuals have different fitness. What is happening here is that, over time, the population is shifting toward a greater and greater proportion of brown individuals.

Generation	**Brown**	**Green**	**Proportion Brown**
1	**2**	**2**	**0.50**
2	**4**	**2**	**0.67**
3	**8**	**2**	**0.80**
4	**16**	**2**	**0.89**

5 32 2 0.94

6 64 2 0.97

7 128 2 0.98

8 256 2 0.992

9 512 2 0.996

10 1024 2 0.998

2. Suppose that, in the population above, migration is operating in addition to natural selection. Suppose that three green bugs migrate into the population each generation. Again, calculate the number of brown and green bugs in Generations 1 to 10, and the fraction of brown bugs in each generation. How does this compare to the results you obtained with natural selection alone? What effect does migration have on how quickly this population is adapting to its environment?
In the first 10 generations,

Generation Brown Green Proportion Brown

1 2 2 0.50

2 4 5 0.44

3 8 8 0.50

4 16 11 0.59

5 32 14 0.70

6 64 17 0.79

7 128 20 0.86

8 256 23 0.92

9 512 26 0.95

10 1024 29 0.97

Because green individuals are continually migrating into the population, this population adapts more slowly to its environment.

3. Let's consider a very small population of snapdragons, one with only two individuals. One snapdragon has two red alleles for flower color—that is, it is RR. The other snapdragon has a red allele and a white allele for flower color—it is RW. (You may wish to read about the inheritance of flower color in snapdragons in Chapter 16.) Show that the frequency of the red allele R in the population is 0.75 and that the frequency of the white allele W is 0.25.

Because there is a RR organism and a RW organism, the frequency of the R allele in the population is 3/4 0.75. The frequency of the W allele is 1/4 0.25.

4. Now let's assume the two snapdragons in our tiny population mate and produce a single offspring. We now have a snapdragon population with only one individual. What are the two possibilities for the genotype of this individual? For each of the two possibilities, calculate the allele frequencies of the red and white alleles in the population. Show that, in either case, the allele frequencies are different from those found in the parental population (calculated in Problem 3). Is this an example of genetic drift?

The offspring of an RR and an RW snapdragon can have a genotype of either RR or RW. If the offspring is RR, then the frequency of the R allele is 1, and the frequency of the W allele is 0. If the offspring is RW, then the frequency of the R allele is 0.5, and the frequency of the W allele is

0.5. In either case, the frequencies are different from the parental generation, calculated in Problem 3 of the last page. Yes, this is an example of genetic drift.

Chapter 18: Biological Diversity **Answers to Chapter 18 Review Questions**

1 In the Linnaean system, species are grouped together based on shared similarities.
2 A *clade* is a group that includes an ancestral species and all of its descendants.
3 Birds are descended from the last common ancestor of the reptiles, and so are reptiles.
4 Life is classified into three domains—Bacteria, Archaea, and Eukarya. Eukarya includes all eukaryotic organisms, organisms with nucleated cells.

5 Bacteria typically reproduce asexually by dividing. Most species exchange genetic material at least occasionally, when they take up small pieces of naked DNA from the environment, when bacterial viruses inadvertently transfer DNA between organisms, or when two bacteria join together and one passes DNA to the other.

6. In poor conditions, many bacteria form hardy spores that remain dormant until conditions improve.
5 Without bacterial decomposition, carbon (C) would remain trapped in dead organic matter and there eventually would be none available for photosynthesis.

5 Some archaea are adapted to extreme environments, such as very salty ponds or the scalding waters of hot springs and hydrothermal vents. These archaea are called “extremophiles”—lovers of the extreme.

5 Chemoautotrophs make food using chemical energy rather than energy from sunlight.
5 Protists are eukaryotes that are not plants, animals, or fungi.
5 *Amoebas* move by extending part of their body forward as a pseudopodium, a temporary protrusion of the cell, and then pulling the rest of the body behind. Amoebas surround and engulf prey. *Ciliates* move by beating numerous hair-like projections called cilia. *Flagellates* move by whipping long flagella.
5 The plant vascular system consists of the xylem and the phloem. The *xylem* is made up of dead tube-shaped cells through which water and nutrients move up from the roots. The *phloem* consists of living cells that pass the sugars produced during photosynthesis down from the leaves.
5 Mosses are unique among plants in that the gametophyte is much larger than the sporophyte.
5 In conifers, pollen released by male cones is carried by wind to female cones. In flowering plants, pollen is often transported from one flower to another by insects or other animals.
5 Fruits help spread seeds around—when fruits are eaten by birds or mammals, for example, the seeds pass unharmed through the digestive tract and eventually emerge far from the parent plants. Some fruits help plants spread their seeds using other strategies—the burrs that catch on your socks during a hike are also fruits.
5 They obtain food by secreting digestive enzymes over organic matter and then absorbing the nutrients.
5 Fungal spores are tiny reproductive bodies that can exist in a dormant state until

conditions become favorable for growth.
5 In most plant species, roots and fungi form close associations known as mycorrhizae. The fungus receives nutrients from the plant while helping roots absorb water and minerals from soil.
5 Animals *ingest* food, taking it into their bodies for digestion. Fungi, those other multicellular heterotrophs, secrete digestive enzymes *out over* their food.
5 Cnidarians have a single opening that serves as both mouth and anus. Flatworms also have a single body opening that serves as both mouth and anus.
5 All arthropods have an external *exoskeleton* made of chitin that protects and supports the body. The exoskeleton is incapable of growth and must be shed periodically as animals grow. Arthropods also have segmented bodies and jointed legs.
5 Legs.
5 *Bivalves* have two hinged shells and include species such as clams, oysters, mussels, and scallops. Most bivalves are sedentary and feed by filtering small particles from the water. *Cephalopods* such as squids and octopuses are active predators that use arms (eight in octopuses and ten in squids) to capture prey. Cephalopods also have well-developed brains and eyes. *Gastropods* have a single, spiral shell and include species such as snails, abalone, and limpets. Most gastropods are herbivores.
5 *Annelids* are segmented worms. The muscles of annelids are arranged in both circular (around the body) and longitudinal (head-to-tail) orientations, allowing for great flexibility of motion.
5 Amphibians are restricted to moist environments because their skins are composed of living cells that are vulnerable to drying out. Amphibian eggs, which have no shells, also require moisture.
5 Ectotherms regulate their body temperature behaviorally, by seeking sun when they need to warm up and shade when they need to cool down. Endotherms maintain a constant and relatively high body temperature by metabolizing large amounts of food. During metabolism, when organic molecules are broken down to make ATP, energy is lost to the environment as heat—this energy helps warm the body. Birds and mammals are endotherms.

1 Monotremes such as the platypus and spiny echidna differ from other mammals in that they lay eggs.
2 Viruses are small pieces of genetic material wrapped in a protein coat.
3 Viruses reproduce by infecting a host cell and then using the cell’s enzymes and ribosomes to copy their genetic material and build viral proteins. These are then assembled to form new viruses.
4 Most scientists believe viruses originated when little pieces of host DNA or RNA evolved the ability to move from one cell to another.
5 Prions are misfolded proteins believed to cause mad cow disease and the related Creutzfeldt-Jakob disease in humans. Both of these conditions are characterized by fatal brain degeneration. Prions infect cells, where they “reproduce” by converting normal proteins to the misfolded, prion variety.

Answers to Chapter 18 Multiple-Choice Questions

1a, 2c, 3c, 4b, 5a, 6d, 7c, 8a, 9a, 10c

Answers to Chapter 18 Integrated Science Concepts

Earth Science: Coral Bleaching

1 Increases in seawater temperature that last for an extended period of time.
2 When corals evict their dinoflagellates during a bleaching event, the corals quite literally turn white,
because it is the dinoflagellates that give them their colors.

3 Because of continued global warming due to human greenhouse gas emissions.

Physics: How Birds Fly

1 The wings of birds are airfoils. The curved shape of the wing causes air to flow faster over the top of the wing than under the wing. This is because, as a bird cuts through the air, air molecules have a greater distance to travel over the wing and so must move faster. Bernoulli's Principle shows that when the speed of air over a surface increases, its pressure decreases. The result of greater air speed over the wing than under it is that air pressure above the wing is lower than air pressure below the wing. This produces lift, an upward force that counters gravity and keeps birds aloft.
2 Birds move forward through the air by flapping their wings. During the downstroke, the wings push
against the air and the air pushes back. This propels them forward.

3 Some birds manage to fly for long periods without flapping their wings—this is called soaring. You often see eagles and vultures soar. Soaring is possible because the birds have located a thermal, a pocket of rising hot air, and are floating on it. It's sort of like sitting on top of a geyser but (luckily for the birds) considerably more controlled.

Answers to Chapter 18 Exercises

1. Of the three domains of life, Bacteria and Archaea both consist of prokaryotes, whereas Eukarya consists of eukaryotes. Why can't we lump Bacteria and Archaea together and call them all Bacteria?

   Because archaea are more closely related to eukaryotes than either is to bacteria, classifying archaea and bacteria together to the exclusion of eukaryotes obscures the evolutionary history of the three groups. It is like the example in the text of grouping humans and daisies together to the exclusion of elephants. In terms of a cladistic classification, the fact that archaea and bacteria are both prokaryotes is not relevant—only the evolutionary relationships among the three groups matters in constructing biological groups.

2. What is the difference between a heterotroph and an autotroph? Name two groups of living organisms that include both heterotrophs and autotrophs.

   Heterotrophs obtain energy and organic molecules from outside sources, whereas autotrophs make their own. Bacteria and protists both include heterotrophs and autotrophs.

3. What is the advantage of being able to produce spores, as many bacteria and fungi do?

   Spores are very hardy, able to survive for long periods under tough conditions. This allows bacteria, fungi, and other organisms capable of generating spores to produce descendants that can survive tough periods and then germinate when conditions improve.

4. Why is decomposition important? What are some important groups of decomposers?

   Decomposition frees up resources that would otherwise be locked in the corpses of dead organisms. Important decomposers include fungi and bacteria, among other groups.

5. We saw that life on Earth would be impossible without bacteria. Would life on Earth be impossible without eukaryotes?

   No, life would do just fine without eukaryotes, as it did for billions of years before the first eukaryotes evolved.

6. Do all autotrophs use photosynthesis to make food? If not, what do they do?

   Some autotrophs are chemoautotrophs that use chemical energy rather than energy from sunlight to make food.

7. Of the three major plant groups we discussed, which is most dependent on living in a moist habitat? Why? Which is least dependent?

   Mosses are most dependent on living in a moist environment. This is because they have no vascular systems, instead, every part of a moss plant receives water directly from the environment. In addition, mosses have swimming sperm that require moisture in the environment in order to travel to and fertilize moss eggs. Seed plants are least dependent on living in a moist environment, because they use pollen rather than swimming sperm during sexual reproduction, and they have vascular systems. (Ferns, the third group, have vascular systems but also use swimming sperm, so are more moisture dependent than seed plants.)

8. You may have heard that moss most often grows on the north sides of trees—a potentially useful fact if you are ever lost in a forest! Why do mosses do best on the north sides?

   The north sides of trees are least sunny and most shaded, so are most likely to provide the moist environments mosses need to thrive.

9. Which plants produce pollen? What are some strategies plants use for pollination? What strategy do most flowering plants employ?

Seed plants produce pollen. Pollen is carried to the female flower/cone by wind or by animals. Most flowering plants use animal pollinators, particularly insects.

10. Some plants have green flowers. An artichoke, for example, is a green flower. How do you think green flowers are pollinated?

Green flowers are not particularly visible, so likely are not attracting vision-oriented pollinators. In fact, many are wind pollinated.

11. Some people are allergic to pollen. Do you think bee-pollinated plants or wind-pollinated plants are more likely to cause allergies? Why?

Wind-pollinated plants are most likely to cause allergies because they make larger quantities of pollen due to the haphazard nature of wind pollination.

12. What do fungi and animals have in common? How do they differ?

Fungi and animals are both heterotrophs. However, fungi tend to release digestive enzymes out over their food and absorb the nutrients, whereas animals tend to ingest their food, taking it into their bodies for digestion.

13. What are two different strategies used by different species of cnidarians to obtain food?

Many cnidarians, including jellyfish and sea anemones, catch prey using tentacles armed with barbed stinging cells. Corals, however, house dinoflagellates in their bodies and obtain the bulk of their nutrients from these photosynthesizers.

14. Although roundworms and arthropods are different in many ways, they are related groups. Name an important feature they have in common.

They have a tough outer cuticle that is shed during growth. In arthropods, this is the exoskeleton.

15. How do the muscles of roundworms and earthworms differ? What does this mean about the way each type of worm moves?

The muscles of roundworms all run longitudinally (from head to tail) down the body. As a result, roundworms move like flailing whips as muscles on alternate sides of the body contract. The muscles of annelids are arranged in both circular (around the body) and longitudinal (head-to-tail) orientations, allowing for great flexibility of motion. Unlike roundworms, for example, annelids are able to contract one part of the body while keeping the rest of the body still.

16. What features do insects and crustaceans share? How are they different?

Crustaceans and insects are arthropods, and so share arthropod features. For example, all arthropods have an external exoskeleton that protects and supports the body. The exoskeleton is incapable of growth and must be shed periodically as animals grow. Arthropods also have segmented bodies and jointed legs, as well as a brain and a number of highly developed sense organs. Crustaceans and insects differ in that crustaceans are primarily marine, whereas insects are primarily terrestrial, and most insects have wings. (Other answers are possible.)

17. Why are amphibians more dependent on living in a moist habitat than amniotes?

Amphibians have a skin made of living cells that is vulnerable to drying out. In addition, their eggs are unshelled and also vulnerable to drying out.

18. Many snakes can survive eating just once every few weeks. Why can’t birds do this?

Birds are endotherms and need a lot of food to help maintain their high, stable body temperatures. Snakes are also unusual in that they have adaptations for eating very large prey—this is part of the reason why they don't need to eat as frequently.

19. Birds and mammals are endotherms, and they both have four-chambered hearts. Why are birds classified as reptiles rather than as mammals?

Because birds are descended from the last common ancestor of all reptiles. What they do or do not have in common with mammals is not a factor in how they are classified.

20. What are some organisms that reproduce asexually? What are some advantages of asexual reproduction?

Most bacteria and archaea and many protists reproduce asexually. Fungi often reproduce asexually also. Asexual reproduction is less common in plants and animals but occurs sporadically in diverse groups. Asexual reproduction has the advantage that you needn't search for a mate—you can reproduce all on your own. From an evolutionary point of view, an organism that reproduces asexually passes all its genes to offspring, whereas one that reproduces sexually only contributes half the genetic material of the offspring.

21. Most living organisms reproduce sexually sometimes, or have some other mechanism for exchanging genetic material. What is the advantage of sexual reproduction or genetic exchange?

The advantage of genetic exchange is genetic diversity among the offspring. This way, you don't put all your eggs in one (genetic) basket, and at least some of your offspring are likely to do well under a wide array of potential environmental conditions.

22. Scientists have never been sure whether to classify viruses as living things or nonliving things. In what ways do viruses resemble living things? In what ways do they resemble nonliving things?

Viruses resemble living things in that they reproduce, possess genes, and evolve. However, they can reproduce only within a host cell. They also are not made up of cells.

23. Write a letter to Grandpa telling him about the current scare over bird flu. Be sure to explain to him what viruses are and why they sometimes mutate so quickly.

Viruses are small pieces of genetic material wrapped in a protein coat. Many viruses have normal, double-stranded DNA genomes, but others use single-stranded DNA, single-stranded RNA, or double-stranded RNA. Viruses reproduce by infecting a host cell and then using the cell's enzymes and ribosomes to copy their genetic material and build viral proteins. These are then assembled to form new viruses. One feature of viruses that makes them hard to deal with from the point of view of disease control is that they mutate very quickly. This is particularly true of viruses with RNA genomes, because there is no error-checking and repair system for copying RNA, as there is with DNA. Bird flu, which has devastated populations of domesticated birds, is caused by a virus that occurs naturally among wild birds. In 1997, the first case of a human infected by bird flu was reported in Hong Kong, and dozens of additional cases have been seen since then. So far, however, the virus cannot be transmitted easily from person to person. The evolution of this capability is the event scientists await with trepidation. This fear turns out to be more than justified. Scientists recently discovered that the infamous "Spanish flu" epidemic of 1918—which killed more people than any other disease over a similar length of time—was a bird flu that became easily transmissible among humans.

Answers to Chapter 18 Problems

1. Suppose a species of bacteria divides once every 20 minutes. You start with a single bacterium on your unrefrigerated egg-and-baloney sandwich at 8:00 a.m. Show that when you sit down to lunch at noon, there will be 4096 bacteria on your sandwich.

The population doubles every 20 minutes, or so.

8:00	**1**
8:20	**2**
8:40	**4**
9:00	**8**
9:20	**16**
9:40	**32**
10:00	**64**
10:20	**128**
10:40	**256**
11:00	**512**
11:20	**1024**
11:40	**2048**
12:00	**4096**

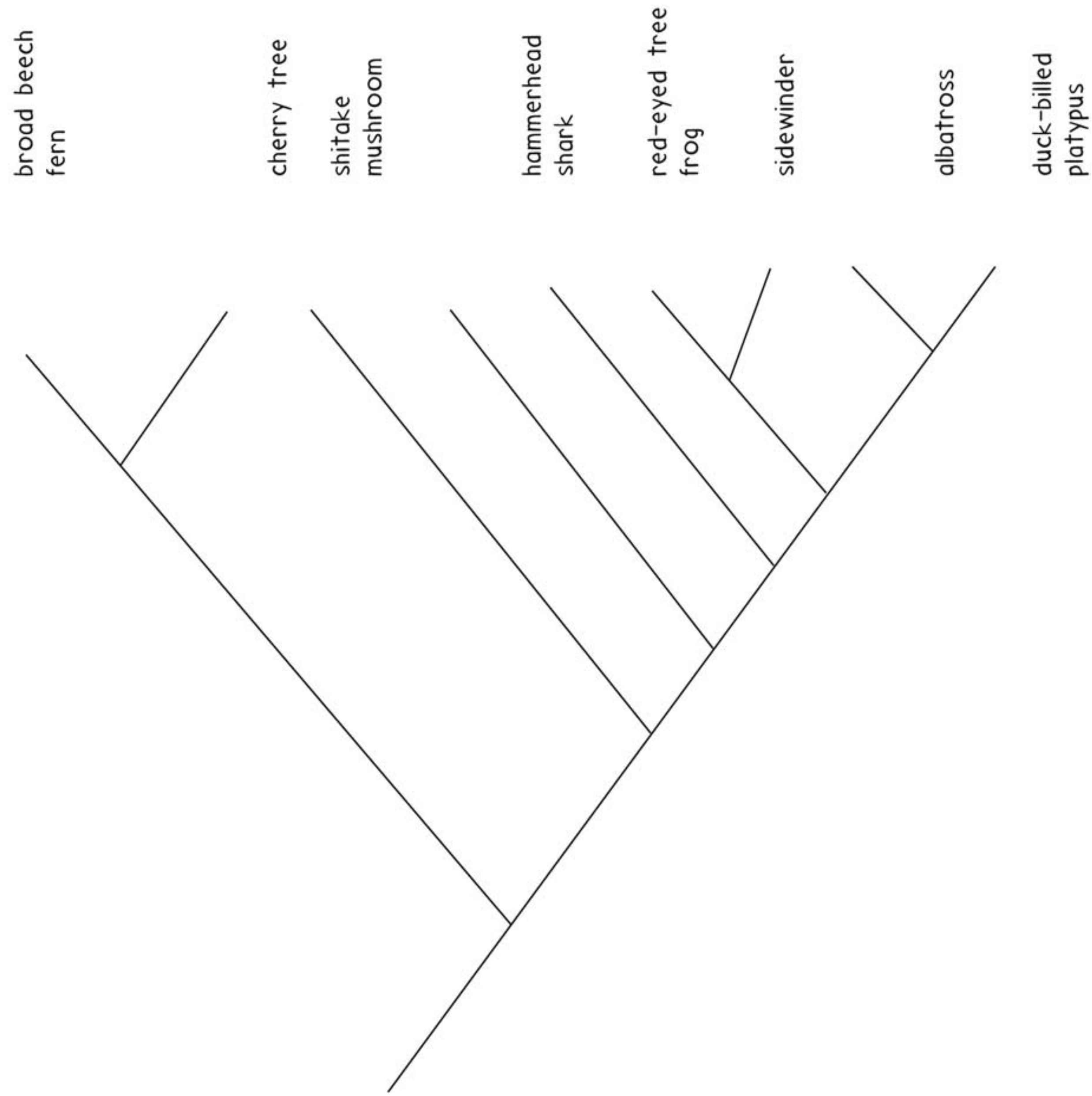
2. The lightest and heaviest flying birds are the bee hummingbird of Cuba, which weighs about 1.6 grams, and the great bustard of Europe and Asia, which can weigh as much as 21 kilograms. How much lift does each bird have to produce to stay aloft? Which species would you expect to have proportionally larger wings? Why?

Each bird has to produce enough lift to counter gravity. For the bee hummingbird,

$F \; mg \; (0.0016)(9.8) \; 0.01568$ **Newtons For the great bustard,**

$F \; mg \; (21)(9.8) \; 205.8$ **Newtons The great bustard has proportionally larger wings, because it is larger. Larger birds need disproportionately larger wings in order to produce enough lift. This is because all else being equal, volume increases more quickly than surface area, so larger birds have a harder time staying aloft. In order to help compensate for their greater size, larger birds have larger wings.**

3. Draw a diagram showing how the following organisms are related; broad beech fern, cherry tree, shitake mushroom, hammerhead shark, red-eyed treefrog, sidewinder, albatross, duck-billed platypus, Albert Einstein.



1 Tissue.
2 Organs, organ system.
3 Homeostasis is the maintenance of a stable internal environment.

4. Oxygen supply and body temperature are only two of the many variables the body carefully maintains. The amount of water in the body, the concentration of nutrients such as glucose and waste products in the blood, the concentrations of important ions inside and outside cells, and blood pH—all these are carefully controlled as part of maintaining homeostasis.

3 The brain stem controls many of the body's involuntary activities, including heartbeat, respiration, and digestion. It is also the brain stem that wakes you up every morning, bringing your body from sleep to a state of conscious wakefulness.

3 The cerebellum, located in the posterior portion of the head, controls

balance, posture, coordination, and fine motor movements.

3 The right hemisphere (right side) of the cerebrum receives information from and controls the left side of the body and vice versa, which is why damage to one side of the brain (such as from a tumor or stroke) affects functioning on the opposite side of the body.

3 The *frontal lobes* deal with reasoning, control of voluntary movements, and speech. The *parietal lobes* hold sensory areas for temperature, touch, taste, and pain. The *occipital lobes* process visual information. The *temporal lobes* interpret sound and play an essential role in comprehending language.

3 The nervous system has two parts—the central nervous system, which includes the brain and spinal cord, and the peripheral nervous system, which includes all the other nerves in the body.

3 A typical neuron consists of extensions called dendrites**,** which function to receive information from other neurons or cells; a cell body, which contains the nucleus and organelles; and an axon, a cell extension that transmits information to other neurons or cells.

3 The neurons of the nervous system are divided into three categories depending on the origin and destination of their messages—sensory neurons, interneurons, and motor neurons.

3 Motor neurons are divided into two groups, the *somatic nervous system*, which controls voluntary actions and stimulates our voluntary muscles, and the *autonomic nervous system*, which controls invol-untary actions and stimulates involuntary muscles and other internal organs.

3 First, like other cells, neurons have more potassium ions inside the cell than outside and more sodium ions outside the cell than inside. Second, neurons contain many other negatively charged ions, including proteins and other organic molecules. As a result of these two factors, the inside of a neuron is normally negatively charged, and the outside of a neuron is normally positively charged, creating a resting potential of about –70 millivolts (mV) across the cell membrane.

3 If a neuron’s membrane potential reaches a certain *threshold value*—typically around –55 mV—sodium channels in the neuron’s cell membrane suddenly open, allowing positively charged sodium ions to flow into the neuron. This influx of positively charged ions causes the membrane potential to spike and become positive.

3 If a neuron’s membrane potential reaches *threshold*, sodium channels in the neuron’s cell membrane suddenly open, allowing the action potential to begin.

3 A neuron either fires or it doesn’t. So, a neuron can’t fire “harder” when a stimulus is more intense.

3 When an action potential begins at the cell body end of the axon, sodium ions enter the axon there. These ions then diffuse into adjacent areas where, because of their positive charge, they cause the local membrane potential to increase. When this local membrane potential hits threshold, a new action potential, further along the axon, begins. In this way, the action potential travels down the entire axon.

3 In electrical synapses, ions flow directly from a neuron to a target cell through gap junctions, tiny channels in the cell membrane, and cause an action potential to happen in the target cell. In a chemical synapse, there is a narrow space between the neuron and its target cell. When the action potential arrives at the end of the axon, the neuron releases chemical messengers called neurotransmitters into this space. The neurotransmitters are released through exocytosis; that is, small vesicles containing the neurotransmitters fuse to the neuron's cell membrane and release their contents outside the cell. The neurotransmitters then diffuse across the space between the neuron and its target cell and bind to receptor proteins on the cell membrane of the target cell. The binding of neurotransmitters causes the receptor proteins to change, opening ion channels and allowing ions to flow into the target cell.

3 Light enters the eyes through a tough, transparent layer called the *cornea*, which is continuous with the whites of the eyes. It then passes through a small hole, the *pupil.* The *iris*, the part of the eye that gives us our eye color, controls the size of the pupil. In bright light, the pupil is small. In dim light, the pupil expands to let in more light. From the pupil, light passes through the *lens*, which focuses it on the *retina* at the back of the eyeball.

1 The two types of light-sensitive cells in the eyes are rods and cones. *Rods* are very sensitive to light and are responsible for vision in dim light. Rods cannot discriminate colors, and so allow us to see only black, white, and shades of gray. *Cones* detect color. Our eyes have three types of cones that respond most strongly to red, green, and blue light, respectively.

2 Sound waves move through the air to the outer ear, or *pinna*, which funnels them in. Inside the ear, the waves hit a thin membrane of skin—the *eardrum*—and cause it to vibrate, just the way blowing on a piece of paper causes it to shake. The eardrum's vibrations move three middle ear bones—the hammer, the anvil, and the stirrup—in sequence. These bones amplify the vibrations, making them more pronounced. The final bone, the stirrup, then transfers the vibrations on to the fluid-filled inner ear, where they enter the cochlea. The cochlea is a coiled tube that contains the *organ of Corti*, which holds the sensory cells responsible for hearing. Fluid vibrations in the inner ear move the organ of Corti's basilar membrane, causing sensory "hairs" embedded in it to bend against an overlying membrane. This bending opens ion channels, starting action potentials that are transmitted to the brain.

3 Chemicals bind to receptors on the surface of special chemosensory cells. The binding causes ion channels to open and action potentials to happen.

4 Pain receptors respond to stimuli that cause damage to the body. These sensory cells generally require strong stimulation before they will respond. However, damaged tissues release chemicals called *prostaglandins* that increase the sensitivity of pain receptors.

5 The two types of hormones are protein hormones and steroid hormones. Protein hormones bind to receptors on the cell membrane of their target cells. This binding initiates a series of chemical reactions that ends with the cell's response to the hormone. Steroid hormones cross the cell membrane and bind to

receptors in either the cytoplasm or nucleus of target cells. The hormone and receptor then bind to DNA in the nucleus and directly impact gene transcription.

6 The anterior pituitary is sometimes called the “master gland” because many of its hormones control the function of other endocrine organs.

7 The adrenal glands, located above the kidneys, secrete *epinephrine* (adrenaline) and *norepinephrine.* These hormones are involved in the “fight or flight” response.

8 *Antidiuretic hormone* helps regulate the amount of water in the body—it helps the body conserve water by producing a more concentrated urine.

9 Eggs are the result of *unequal meiosis*—during cell division, the future egg gets almost all the cytoplasm, while the other cells (which quickly degenerate) receive almost nothing. This maximizes the resources contained in the egg.

10 Enzymes released from the head of the sperm eat away at the *zona pellucida*.

11 The placenta provides oxygen and nutrients to the developing embryo, and carries away wastes.

12 All the fetus’s major organs and body parts develop during the first trimester.

13 One function of the skeleton is to protect the body. The skull surrounds and protects the brain, the vertebrae protect the spinal cord, and the ribs protect the heart and lungs. The skeleton also supports the body and, in cooperation with the muscles, moves it.

14 Motor neurons connect to muscles through a chemical synapse that uses the neurotransmitter *acetylcholine.* When acetylcholine binds to receptors on muscle cells, it starts an action potential in the cells, which respond by contracting.

15 When an action potential arrives at a muscle cell, calcium ions are released from the cell’s endoplasmic reticulum. Calcium ions allow a series of pivoting heads on the myosin fibers to attach to actin. The myosin heads attach and pivot, pulling on the actin. Each pull shortens the length of the sarcomere a tiny bit and, consequently, the length of the muscle as a whole. After pulling, the myosin heads release, re-cock, re-attach, and pull again. This cycle repeats until the signal to contract ends or until the muscle has fully contracted.

16 ATP is required for the myosin heads to release actin, an essential step in the contraction cycle.

Answers to Chapter 19 Multiple-Choice Questions

1b, 2c, 3a, 4c, 5d, 6a, 7d, 8d, 9c, 10b

Answers to Chapter 19 Integrated Science Concepts

Physics: How Fast Can Action Potentials Travel?

1 An action potential's speed depends in part on how quickly successive parts of the axon's cell membrane (that is, parts further down the axon) can be induced to increase to threshold. How quickly the membrane reaches threshold is, in turn, dependent on how fast sodium ions flow downstream to increase the membrane potential there. And how fast sodium ions flow down an axon depends on Ohm's Law. Ohm's Law tells us that current voltage/resistance, so the lower the resistance, the more current (that is, ions) flows and the faster the action potential travels. Like any other material, an axon has lower resistance if it is thicker around—a thick axon resists current less than a thin axon the same way a wide pipe resists water flow less than a thin pipe.

2 They take up too much space.

3 The myelin sheath that surrounds an axon insulates it so that ions cannot escape out the cell membrane but must flow down the axon. The end result is the same as for a giant axon—sodium ions are able to travel more efficiently down the axon. Moreover, in myelinated axons, the action potential is not regenerated at every point along the axon; instead, it "jumps" from one gap in the sheath to the next. An action potential at one gap causes sodium ions to move into the axon, flow down to the next gap, generate a new action potential there, and so on. This jumping propagation makes for extremely rapid signal transmission.

Chemistry: Endorphins

1 Endorphins are proteins made by the brain in times of stress or pain. Endorphins are neurotransmitters that bind to opiate receptors on neurons—the same receptors targeted by drugs such as morphine, codeine, opium, and heroin.

2 Because they bind to the same receptors (opiate receptors).

3 Besides sports, endorphin release has also been associated with activities such as laughter, orgasm, acupuncture, massage, and deep meditation. Certain foods—notably chocolate and chili peppers—also increase the release of endorphins.

Answers to Chapter 19 Exercises

1. You have a conversation with a friend on the telephone. What parts of the brain are you using?

   The temporal lobes interpret sound, including language comprehension. The frontal lobes control the voluntary movements required to produce speech.

2. The following figure shows a map of the primary motor control area of the brain, found in the frontal lobes of the cerebrum. Why do think controlling the actions of body parts such as the hands and the lips requires such large portions of the brain? Why does controlling the back require only a small portion?

   The hands and lips are engaged in extremely fine movements when we manipulate objects and produce the sounds of speech, respectively. The back isn't required to perform fine movements.

3. Of the three types of neurons, sensory neurons, motor neurons, and interneurons, which type goes to your biceps muscle and tells you to bend your elbow? Which type transmits information from your feet as to whether they feel cold?

   A motor neuron goes to your biceps muscle and tells you to bend your elbow. A sensory neuron transmits information from your feet as to whether they feel cold.

4. Is a neuron that slows your heartbeat part of the somatic or autonomic nervous system? Is this neuron part of the sympathetic or parasympathetic division?

   A neuron that slows your heartbeat is part of the autonomic nervous system. It is part of the parasympathetic division.

5. What would happen if you artificially excited a neuron, producing an action potential in the middle of the axon? How and why is this different from how action potentials actually move along axons?

   The action potential would travel both forwards and backwards along the axon away from the spot where you artificially excited it. It travels backwards in addition to forwards, unlike a "real" action potential, because the area behind where the axon is stimulated has not just experienced an action potential, and so is able to be stimulated.

6. If the myelin sheath were removed from the axon of a neuron, what effect would that have on the neuron's action potential?

   The action potential would travel much more slowly along the axon, and not "jump" from one gap in the myelin sheath to the next.

7. Do neurotransmitters enter the target cell? If not, how do they have an effect on the target cell?

   Neurotransmitters do not enter the target cell. Instead, they have their effect by binding to receptors on the target cell, starting a sequence of events that results in the target cell's response to the neurotransmitter.

8. Do all neurotransmitters cause the target cell to fire?

   No, some stimulate the target cell, but not enough to cause it to fire, and others actually inhibit

the target cell from firing.

9. Why do a lot of nocturnal species have only rods in their retinas?

   Rods are more light sensitive than cones and are responsible for vision in dim light.

10. Are your rods or cones more important for reading a book?

    Your cones—cones are responsible for making out fine details, such as the letters in the words of the book we're reading.

11. In some people, the middle ear bones stiffen with age. This can result in deafness. Why?

    If the middle ear bones stiffen, they are less effective at transferring and amplifying sound vibrations from the outer ear to the inner ear, where "hearing" actually occurs.

12. How are the senses of smell and taste similar? How are they different?

    Both smell and taste rely on chemoreception, a process in which chemicals bind to receptors on the surface of special chemosensory cells. The binding causes ion channels to open and action potentials to happen. They differ in that smell detects odor molecules in the air, whereas taste detects chemical molecules inside the mouth. In addition, we have over 1000 different types of smell receptors but only five basic tastes.

13. Provide three examples of hormones that help maintain homeostasis in the body.

    Antidiuretic hormone helps regulate the amount of water in the body. Specifically, it helps the body conserve water by producing a more concentrated urine. Parathyroid hormone, which raises calcium levels in the blood, and calcitonin, which lowers calcium levels in the blood, help regulate calcium levels. Insulin and glucagons regulate the amount of glucose in the blood. Insulin lowers blood glucose levels by directing muscle and other cells to take in glucose and by stimulating the liver to convert glucose to the storage substance glycogen. Glucagon increases blood glucose levels by causing the liver to break down glycogen. (Other answers are possible.)

14. Suppose you know that the receptor for a hormone you are studying lies in the cytoplasm of cells. Can you tell whether the hormone is a protein or steroid hormone?

    It is a steroid hormone. Steroid hormones have receptors in the cytoplasm or nucleus, whereas protein hormones have receptors on the cell membrane.

15. Osteoporosis is a disease that primarily affects postmenopausal women, causing decreased bone density and brittle bones vulnerable to fracture. The hormone calcitonin is sometimes used to treat osteoporosis. Why? (*Hint*: It might be helpful to start by considering what parathyroid hormone does and how it has its effect.)

Parathyroid hormone raises calcium levels in the blood, partly by causing calcium to be released from bones. Calcitonin has the opposite effect—it lowers blood calcium levels by causing bones to take up calcium. This is why it is useful for treating osteoporosis. Calcitonin helps increase bone strength by increasing bone calcium.

16. On a brilliant, sunny day, you take a long hike through open country. You sweat a lot, losing a lot of water. What hormone does this cause you to produce? Why?

Antidiuretic hormone—this hormone helps you conserve water by producing a more concentrated urine.

17. How does meiosis in women differ from meiosis in men?

    Meiosis in women is unequal meiosis, with one of the four daughter cells—the future egg—getting the bulk of cytoplasm and nutrients. So, meiosis in women produces only a single egg. Meiosis in men is not unequal, and produces four functional sperm.

18. Vasectomy is a form of male sterilization in which a section of each vas deferens is removed. How does this cause sterility?

Sperm are unable to reach the ejaculate.

19. Tubal ligation is a form of female sterilization in which the oviduct is cut and the tubes tied. How does this cause sterility?

Sperm are unable to reach the unfertilized egg, which also cannot reach the uterus.

20. Does a fertilized human egg make anything other than the embryo?

The fertilized egg also makes the membranes that surround and protect the embryo, including the amnion and the embryonic contribution to the placenta.

21. Each time myosin heads pull on actin, the sarcomere contracts only 10 nanometers or so. Given that, how are we able to produce large motions?

In each of our muscles, there are many sarcomeres lined up end to end. If each of these contracts and shortens a tiny amount, the entire muscle shortens by a significant distance.

22. Can muscle contraction occur without the presence of calcium ions? Why or why not? Where are the calcium ions in a muscle cell stored, and what causes their release?

No, muscle contraction requires calcium. Calcium allows myosin to bind to actin. Calcium is stored in the endoplasmic reticulum of muscle cells. An action potential moving through the muscle cell causes the release of the ions.

23. Both the arrow poison curare and the nerve gas sarin affect the nerve-to-muscle connection. Do they work the same way? If not, how do they differ?

Both curare and sarin affect the nerve-to-muscle connection, and both cause death through asphyxiation. However, their precise mechanisms differ. Curare, an arrow poison used in the South American tropics for hunting, binds to acetylcholine receptors on muscle cells, preventing acetylcholine itself from binding. Curare causes paralysis and then death as the respiratory muscles become paralyzed. The powerful nerve gas sarin prevents acetylcholine from being broken down after muscles contract. Muscles are stimulated continuously and soon become exhausted. Again, death occurs through asphyxiation as the respiratory muscles stop working.

24. Write a letter to Grandma explaining how the new generation of antidepressants, selective serotonin reuptake inhibitors (SSRIs) such as Prozac and Zoloft, work. Explain to her how neurons signal each other and what SSRIs do to influence this process.

Some cases of depression are believed to be associated with the inability of signaling neurons to stimulate target neurons. Prozac, Paxil, and Zoloft are among a group of drugs known as selective serotonin reuptake inhibitors (SSRIs). SSRIs work by preventing signaling neurons from taking up ("reuptaking") the neurotransmitter serotonin once it has been released at synapses. That way, more serotonin remains to bind to and stimulate target neurons.

Solutions to Chapter 19 Problems

1. Action potentials travel at speeds anywhere between 0.5 and 120 meters/second, depending on factors such as temperature, the size of the axon, and whether the axon is myelinated. We have two different types of neurons that conduct pain signals from, say, our hand to our central nervous system. The slower type conducts signals at 0.5 meters/second. The faster type conducts signals at 25 meters/second. Let's say that the distance from your hand to your central nervous system is about 1 meter. Now, you touch a hot stove. Show that you become aware of the first type of pain in 0.04 seconds, but only become aware of the second type of pain after 2 seconds. (You may have noticed that when you do something like touch a hot stove, you feel a flash of sharp pain first, followed by a slow throbbing pain.)

   For the fast type, time distance/speed 1/25 0.04 seconds. For the slow type, time distance/speed 1/0.5 2 seconds.

2. The human retina has an area of about 1000 mm^2. If we have a total of 125 million rods and 6.5 million cones in each eye, show that we have about 131,500 sensory cells per square millimeter in the retina.

   We have a total of 125 6.5 131.5 million rods and cones.131,500,000/1000 mm^2 131,500 sensory cells per mm^2.

3. We have about 1000 different kinds of smell receptors. Each of these is a distinct protein coded for a specific gene. In Chapter 16, we learned that the Human Genome Project revealed that humans have a total of about 30,000 genes. Show that about 3.3 percent of our genes are dedicated to helping us smell.

   1000/30,000 0.033 or 3.3%

4. The egg is a large cell and contributes almost all the nutrients to the zygote (fertilized egg) created at fertilization. The sperm contributes little more than its set of chromosomes. Just how much bigger is a human egg than a human sperm? The human egg is about 100 micrometers in diameter. The head of a human sperm is about 4 micrometers in diameter. (And, in case you're curious, human sperm are about 50 micrometers long.) Show that the volume of a human egg is 15,625 times larger than the volume of a human sperm. Recall that the volume of a sphere is $4/3r^3$.

   Volume of a human egg $4/3r^3$ $4/3(50)^3$ 4/3(125,000)Volume of a human sperm $4/3r^3$ $4/3(2)^3$ 4/3(8)So, a human egg is 125,000/8 15,625 times bigger in volume than a human sperm.

Chapter 20: Human Biology II—Care and Maintenance

Answers to Chapter 20 Review Questions

1 Supplying the body with oxygen is a job that's split by two systems—the respiratory system bringsoxygen into the body, and the circulatory system distributes it to the tissues.

2 Getting rid of cellular wastes requires the coordinated efforts of the circulatory, respiratory, and excretory systems—the circulatory system collects wastes from the tissues, and the respiratory and excretory systems remove them from the body via exhalation and urine production, respectively.

3 Each heartbeat begins in a part of the right atrium called the *sinoatrial node,* or pacemaker. Thepacemaker initiates an action potential that sweeps quickly through the right and

left atria, whichcontract simultaneously. The signal also passes to the *atrioventricular node,* and from there to the twoventricles, which also contract simultaneously.

4 The atrioventricular node conducts action potentials slowly, producing a delay between the contraction of the atria and the contraction of the ventricles.

5 The sounds come from heart *valves* snapping shut after each contraction.

6 Capillaries allow materials to be exchanged between blood and tissues.

7 Valves in the veins help make sure the blood doesn't flow backwards.

8. Deoxygenated blood returning from the tissues flows from veins into the right atrium of the heart. The right atrium pumps it to the right ventricle. The right ventricle pumps it out arteries that go to the lungs. There, the blood picks up oxygen and drops off carbon dioxide—the blood is now oxygenated. This oxygenated blood flows back to the heart, along veins that lead to the left atrium. The left atrium pumps it to the left ventricle, which then pumps it out to arteries that go to tissues all over the body. After carrying oxygen to the tissues, the blood becomes deoxygenated again and returns to the heart via veins.

7 Red blood cells carry oxygen. White blood cells are part of the immune system and help our bodies

defend against disease. Platelets are involved in blood clotting.

7 As we inhale, air comes in through the nose or mouth. Air continues up the nasal passages. From the nasal passages, air passes through the *pharynx,* the part of the throat above the esophagus and respiratory tract. Then it proceeds through the *larynx,* or voice box, and down the *trachea,* or windpipe. The trachea branches into two tubes called *bronchi* that lead to the right and left lungs, and then into smaller and smaller tubules that finally dead-end at small sacs called *alveoli.*

7 Gas exchange occurs through diffusion—that is, gas molecules move from an area of greater concentration to an area of lower concentration. Both the alveolus and the surrounding capillaries have extremely thin walls, consisting of only a single flattened cell, to allow diffusion to proceed efficiently.

7 When we inhale, the diaphragm contracts. This causes it to flatten, increasing the volume of the thoracic cavity. Muscles between our ribs also contract, pulling the ribcage up and out from the chest and further increasing the volume of the thoracic cavity. So, the volume of the thoracic cavity increases, while the amount of air inside it remains constant. What happens? The air pressure in the thoracic cavity drops. Air is sucked into the lungs and fills the alveoli.

7 When we exhale, the diaphragm and rib muscles relax, decreasing the volume of the thoracic cavity. This increases the air pressure in the thoracic cavity and pushes air out of the lungs.

7 During digestion, food is broken down into organic molecules that can be absorbed and used by the body.

7 Our taste buds can only detect chemicals dissolved in liquid.

7 The *epiglottis*, a small flap of cartilage at the back of the tongue, covers the trachea during swallowing so that food can't get into it.

7 Swallowing begins as a voluntary activity—the muscles at the top of the esophagus are voluntary muscles. However, at a certain point, it becomes involuntary. The lower part of the esophagus is made of involuntary smooth muscle like that found in the rest of the digestive tract.

7 In the stomach, digestive enzymes and a muscular churning action combine to reduce food to a thick liquid called *chyme.*

7 In the *duodenum*, the first foot of the small intestine, digestion continues with the breakdown of proteins, fats, carbohydrates, and nucleic acids. Beyond the duodenum, the rest of the small intestine functions primarily in absorbing nutrients into the body.

7 Bile is an emulsifier—it breaks fats into tiny droplets that are more easily attacked by enzymes.

7 The small intestine has a huge surface area. It is covered with fingerlike projections called *villi,* each of which is covered with tiny little projections called *microvilli.*

7 In the large intestine, water and minerals such as sodium are absorbed into the body.

7 Humans are unable to make 8 of the 20 amino acids needed to build proteins. This is why it's important for us to eat a "complete protein"—one containing all the amino acids—

regularly.
7 Regular exercise reduces the risk of many health problems, including heart disease, high blood pressure, colon and breast cancer, osteoporosis, diabetes, and obesity.
7 Exercise improves the functioning of the heart and lungs, increasing oxygen consumption, the amount of blood the heart pumps, and lung capacity, while decreasing heart rate and blood pressure.
7 Each nephron in our kidneys is associated with a cluster of capillaries called the *glomerulus.* The glomerulus is surrounded by a cup-shaped structure called *Bowman's capsule,* part of the nephron. Blood pressure in the glomerulus pushes fluid out of the capillaries and into Bowman's capsule.
7 The loop of Henle functions in reabsorbing water from the filtrate.
7 Antidiuretic hormone causes the walls of the collecting duct to be permeable to water, allowing additional water to be reabsorbed.
7 The skin is a crucial barrier to pathogens, forming a tough outer layer that is nearly impenetrable when intact. The frequent shedding of skin cells also makes it harder for potential pathogens to establish a

foothold. In addition, hair follicles in the skin produce acidic secretions that help to kill bacteria and fungi.

1 Receptors of the innate immune system recognize carbohydrates, proteins, or nucleic acids that characterize many different pathogens.
2 When tissues are damaged, they release chemicals called *histamines.* Histamines increase blood flow to the site of the injury and cause local capillaries to leak fluid. This fluid causes swelling, which helps to isolate the injury from other body tissues. Histamines also attract innate immune system cells. Innate immune cells squeeze out of the capillaries, migrate to the site of the wound, and attack any microorganisms that have entered the body.
3 Each cell of the acquired immune system has receptors that respond to a single antigen—a molecule or part of a molecule belonging to a foreign pathogen. Most often, antigens are parts of foreign proteins.
4 When the receptor of a B cell binds to an antigen, the cell begins to divide, making many *clones,* or copies, of itself.
5 *Memory cells* remain in the body for a long time, years or even a lifetime. If the same antigen is encountered again, the memory cells initiate an immune response that is much faster and much more aggressive.

Answers to Chapter 20 Multiple-Choice Questions

1b, 2a, 3c, 4b, 5d, 6d, 7c, 8b, 9d, 10c

Answers to Chapter 20 Integrated Science Concepts

Chemistry: Hemoglobin

1 A molecule of hemoglobin consists of four subunits, each of which contains a component known as a heme group that includes an iron atom at its center. It is this iron atom that binds oxygen.

2 Lower blood pH (a more acidic environment) decreases hemoglobin's oxygen affinity.

3 An active, working tissue makes and uses more ATP and so releases more carbon dioxide during cellular respiration. Because carbon dioxide reacts with water in the blood to form carbonic acid, the presence of high carbon dioxide levels decreases blood pH. This acidity decreases the oxygen affinity of local hemoglobin molecules, making it easier for them to unload oxygen to the working tissue.

Physics and Chemistry: Low-Carb Versus Low-Cal Diets

1 How do you lose weight? The answer is simple—use up more calories than you take in. This forces your body to use stored energy, such as fat, to support its activities.

2 Studies have confirmed that, for many people, low-carb diets do produce weight loss more quickly and more consistently than low-calorie diets. This appears to be because many people find low-carb diets easier to stick to because of their permissive attitude towards fats. People on low-carb diets lose weight for the same reason that people on low-calorie diets lose weight—they consume fewer total calories. In addition, low-carb diets cause you to retain less water in the body, and this water is used during excretion to flush out the extra proteins consumed.

3 They tend to be high in saturated fats and cholesterol, which are associated with heart disease, and they tend to be short on whole grains and fruit, which are known to protect against many diseases. Finally, not a whole lot is known about potential long-term effects of low-carb diets. For example, water loss and the processing of large amounts of proteins may be hard on organs such as the liver and kidneys.

Answers to Chapter 20 Exercises

1. Several of our senses provide examples of how multiple body systems work together to accomplish important tasks. What body systems are involved in hearing? In smelling? In tasting?

   Hearing requires the functioning of our skin (makes up part of the eardrum) and skeleton (the cartilaginous outer ear as well as the middle ear bones). Smelling requires the functioning of the respirator system, which brings air in to be "sampled" by our sensory cells for smell. Tasting requires saliva, part of the digestive system, because molecules must be dissolved in liquid in order to be sensed.

2. How does reproduction require the integrated action of multiple organ systems?

   Aside from the organs of the reproductive system, mate-finding, wooing, and copulation require the work of our senses, our brains and nervous systems, and our muscles. Pregnancy requires the functioning of our endocrine, respiratory, and circulatory systems. (Other answers are possible.)

3. The pumping of the heart does the bulk of the work that is required to move blood around the body. What else contributes?

   The contractions of our voluntary muscles help move blood back toward the heart.

4. Why do you think the atria of the heart are less muscular than the ventricles? Why is the left ventricle more muscular than the right ventricle?

   The atria merely have to pump blood to the ventricles, whereas the ventricles have to pump blood to the lungs and body. The left ventricle has to pump blood to the body, so must generate more pressure than the right ventricle, which only has to pump blood to the lungs.

5. Where in the body is blood most oxygenated?

   Near the source of oxygen, by the alveoli.

6. How does the body control the amount of blood that different tissues receive?

   By controlling the diameters of arterioles that go to different parts of the body.

7. What bodily activities is the respiratory system involved in besides acquiring oxygen for the body?

   It contributes to our sense of smell by bringing chemical molecules in the air to the cells responsible for smelling. It also is involved in speech, which depends on air vibrating our vocal cords as we exhale.

8. Why shouldn't you talk with your mouth full (not just because it's impolite)?

   Talking with your mouth full can disrupt the functioning of the epiglottis, which covers the trachea to be sure food doesn't enter the respiratory tract. This disruption sometimes leads to choking.

9. What waste materials are produced in the process of making ATP, and what body systems are responsible for removing them from the body?

   Carbon dioxide and nitrogen-containing wastes (in the form of ammonia, which is then quickly converted to urea) are the waste products produced during cellular respiration. Carbon dioxide is removed from the body by the respiratory system. Nitrogenous wastes are removed by the excretory system.

10. The liver is an organ that plays important roles in multiple organ systems. What role does the liver have in digestion? In excretion?

The liver makes bile, which is important as an emulsifier for digestion. The liver also converts ammonia to the less toxic urea, an important function related to excretion.

11. How does the endocrine system interact with the excretory system? Give examples.

Antidiuretic hormone causes more water to be reabsorbed from the filtrate during excretion. Parathyroid hormone decreases calcium excretion. Mineralocorticoids help regulate water and salt balance in the body by affecting excretion of these substances. (Other answers are possible.)

12. Kangaroo rats, which live in dry desert habitats, have very long loops of Henle. Why might this be?

A long loop of Henle allows kangaroo rats to create a strong concentration gradient of solutes, which aids in water reabsorption. This is essential to surviving in a desert environment, where limited water is available.

13. What is the difference between elimination (feces) and excretion (urine)? What is the body getting rid of in each case?

Elimination is associated with the digestive system and excretion with the excretory system. Elimination eliminates substances in food that cannot be absorbed or used by the body. (Feces are composed primarily of living and dead bacteria and indigestible materials such as plant cellulose.) Excretion helps control the amount of many substances in the body, but it helps us get rid of urea in particular, which is a product of breaking down proteins during cellular respiration.

14. Why might eating a high-protein diet be particularly hard on the liver and kidneys?

Breaking down proteins to make ATP results in the production of ammonia. The liver is responsible for converting ammonia to urea, and the kidney is responsible for excreting urea. So both organs are particularly taxed when the body breaks down large amounts of protein.

15. Why is the innate immune system described as “nonspecific”? Why is the acquired immune system described as “specific”?

The innate immune system is described as nonspecific because its defenses work against a wide variety of potential pathogens. The acquired immune system is described as specific because the cells of this system recognize specific features of specific pathogens and take action only when these features are encountered.

16. What are some differences between the innate immune system and the acquired immune system?

The acquired immune system is specific in its response to pathogens and other foreign substances, whereas the innate immune system has defenses that work against a wide variety of potential pathogens. Each cell of the acquired immune system has receptors that respond to a single antigen, whereas innate immune receptors respond to features that characterize multiple pathogens. The acquired immune response is much slower than that of the innate immune system, usually taking between 3 and 5 days to reach full force; the innate immune response is immediate. The acquired immune system retains a “memory” of pathogens it has encountered in the past, so that subsequent responses to the same pathogen can be faster and more aggressive. The innate immune system has no such “memory.”

17. Allergies occur when the immune system is abnormally sensitive to particular substances. Why do people sometimes take antihistamines for their allergies?

Many of the symptoms of allergies result from an excessive inflammatory response to irritants. In order to trigger the inflammatory response of the innate immune system, injured tissues produce histamines. Antihistamines help to counter these histamines and reduce the redness and swelling that make up the inflammatory response.

18. How are the antigens B cells respond to different from the ones T cells respond to?

B cells respond to antigens in bodily fluids. T cells respond to antigens that infected body cells display (like SOS flags) on their surface.

19. A mother kisses her child's "owie." Do you think this might result in the child feeling less pain? Why or why not?

Perhaps it does, via the placebo effect.

20. Write a letter to Grandpa telling him about the trend toward low carb diets. Tell him why many people have been able to lose weight on low-carb diets, and explain some potential dangers of the diets as well.

Low-carb diets have become extremely popular, and it's easy to see why. Studies have confirmed that, for many people, low-carb diets do produce weight loss more quickly and more consistently than low-calorie diets. This appears to be because many people find low-carb diets easier to stick to because of their permissive attitude toward fats. People on low-carb diets lose weight for the same reason that people on low-calorie diets lose weight—they consume fewer total calories. In addition, low-carb diets cause you to retain less water in the body—this water is used during excretion to flush out the extra proteins consumed. Are there any problems with low-carb diets? Yes—they tend to be high in saturated fats and cholesterol, which are associated with heart disease, and they tend to be short on whole grains and fruit, which are known to protect against many diseases. Finally, not a whole lot is known about potential long-term effects of low-carb diets. For example, water loss and the processing of large amounts of proteins may be hard on organs such as the liver and kidneys.

Answers to Chapter 20 Problems

1. Show that the blood can carry as many as 3 10^{22} molecules of oxygen. Here's some information you may find useful: You have 25 trillion red blood cells. Each red blood cell contains 300 million molecules of hemoglobin. Each molecule of hemoglobin can carry four molecules of oxygen.

(25,000,000,000,000) (300,000,000) (4) 30,000,000,000,000,000,000,000 molecules of oxygen.

2. Because red blood cells have no nuclei and are therefore unable to make the proteins necessary to maintain themselves, they have a relatively short life span of about 120 days. Given that we have about 25 trillion red blood cells in all, show that more than 208 billion red blood cells die and are replaced each day. Also show that, in the 20 seconds it took you to read this problem, about 48 million red blood cells died and were replaced.

(25,000,000,000,000)/(120) 208,333,333,333 red blood cells per day. This is the same as 208,333,333,333/((24)(60)(60)) 2.4 million red blood cells per second. In other words, in the 20 seconds it took you to read the problem, about 48 million red blood cells died and were replaced.

3. A typical person has a heart rate of 70 beats per minute and takes 12 breaths in a minute. Show that her heart beats about 4200 times an hour, 100,800 times a day, and 36.8 million times a year. Show also that she takes about 720 breaths per hour, 17,280 breaths per day, and 6.3 million breaths per year.

For heartbeat:70 beats per minute (60 minutes per hour) 4200 beats per hour4200 beats per hour (24 hours per day) 100,800 beats per day100,800 beats per day (365 days per year) 36.8 million beats per yearFor breathing:12 breaths per minute (60 minutes per hour) 720 breaths per hour720 breaths per hour (24 hours per day) 17,280 breaths per day17,280 breaths per day (365 days per year) 6.3 million breaths per year

Chapter 21: Ecosystems and Environment **Answers to Chapter 21**

Review Questions

1 Ecology is the study of how organisms interact with their environments.

2 An organism's environment includes nonliving, or abiotic, features, such as temperature, sunlight, precipitation, rocks, ponds, and so forth. It also includes biotic features—that is, other living organisms.

3 A community consists of all the organisms that live within a given area. An ecosystem consists of all the organisms that live within a given area *and* all the abiotic features of their environment.

4 Food chain or food web.

5 A food chain begins with producers, species that live by making organic molecules out of inorganic
materials and energy.

6 Decomposers such as bacteria and fungi consume dead organic matter.

7 No two species in a community have exactly the same niche. Otherwise, the species that is better at
exploiting the resources eventually outcompetes the other and drives it to extinction—this is called the

competitive exclusion principle.

1 *Parasitism* benefits one member of the interaction and harms the other. Familiar examples include fleas, tapeworms, and other organisms that live on or in their hosts and obtain nutrients from them. Pathogens such as bacteria or viruses are parasites as well. A strikingly different form of parasitism is brood parasitism, in which the female of one species lays eggs in the nest of another species, causing individuals of the other species to raise her young.

2 *Commensalism* is a form of symbiosis that benefits one species of the interaction while having no effect on the other. *Mutualism* is a form of symbiosis that benefits both species.

3 For most ecosystems, energy comes ultimately from the sun.

4 Sunlight enters the biotic world when plants and other photosynthesizers use it to build organic molecules in the process of photosynthesis.

5 On average, only about 10% of the energy at one trophic level becomes available to the next level. What happens to the other 90%? First, not every organism at one trophic level is exploited by the next level—

for example, not every plant gets eaten by a herbivore. Second, when a consumer eats, the energy it receives from food goes into things other than building biomass—feces and maintenance, to be specific.

1 The flow of energy through trophic levels is sometimes diagrammed in an *energy pyramid.* The shape of the pyramid emphasizes the loss of energy as you go up trophic levels.

2 The type of biome found in a habitat is determined primarily by climatic variables, such as temperature, precipitation, and the presence or absence of distinct seasons.

3 Each biome is characterized by specific types of communities and, particularly, by specific types of plant life.

4 Because of the tremendous density and diversity of life, most of the nutrients present in tropical forests are being used by one or another living organism. As a result, the soil there tends to be poor. The soil of temperate forests is fertile, and these forests make good farmland. (Other answers are possible.)

5 Dry season fires help maintain savannas by preventing tree growth.

6 Desert plants typically have special adaptations for living in dry conditions, including

extensive root systems and the ability to store water when it is available.
7 Habitats close to the water surface and to shore are part of the *littoral zone.* The *limnetic zone* includes habitats that are close to the water surface but far from shore. The *profundal zone* describes deep water habitats in ponds and lakes.
8 Plankton, including diatoms and the larvae of animals such as clams, lobsters, and sea urchins, float wherever water currents take them. Unlike plankton, *nekton* such as fish and sea turtles actively swim through the water.
9 The intertidal zone, which is closest to shore, is periodically underwater and exposed to air as the tide moves in and out. Many species, including certain barnacles, sea anemones, starfish, and other species, are specialized for life in the intertidal zone.
10 *Primary succession* describes the colonization of bare land devoid of soil. *Secondary succession* occurs when a disturbance destroys existing life in a habitat, but leaves soil intact.
11 The activities of earlier waves of colonizers cause nutrients and organic matter to accumulate in the habitat, allowing later colonizers to thrive.
12 During the process of succession, the total biomass of the ecosystem typically increases, as does the number of species.
13 According to the *intermediate disturbance hypothesis,* regular disturbances, if not too extreme, actually contribute to biodiversity because different species make use of different habitats, and periodic disturbances guarantee that there will always be habitat at varying stages of recovery.
14 Exponential growth characterizes populations with unlimited resources.
15 Populations that occupy highly unstable environments, where resources are periodically plentiful and scarce, experience repeated cycles of exponential growth and crash. Good conditions trigger exponential growth. When resources run out, the population crashes. When another opportunity arises, the population explodes again, and so on.
16 At low population densities, logistic growth looks a lot like exponential growth. This is because resources are effectively unlimited when there are few or sparsely distributed individuals. At high population densities, however, growth slows as the population approaches the habitat's carrying capacity.
17 Organisms that make a lot of inexpensive offspring are described as *r-selected.* Organisms that make few expensive offspring are described as *K-selected.*

30. Type I organisms have low death rates early in life, with most individuals surviving until fairly late in life. Elephants are a good example of Type I survivorship, as are humans—most humans survive infancy and childhood and die late in life. Type III organisms have high death rates early in life, with few individuals surviving until late in life. Many invertebrates, including razor clams, have Type III survivorship. Type II organisms have a steady death rate that does not depend on age. Individuals are as likely to die early in life as late in life. Certain songbirds are good examples of Type II survivorship.
17 In the unstable environments of exponential growth, life and death are often chance events. By producing huge numbers of offspring (that is, by being *r*-selected), organisms are more likely to have one or two of these survive. In the stable environments of logistic growth, where many populations are at or near carrying capacity, an offspring that receives a lot of parental investment (such as in a *K*-selected species) is more likely to be able to compete and do well.
17 Exponentially.
17 No—in fact, carrying capacity has already increased twice in human history, once as agriculture spread through the world and again with the onset of the industrial revolution.
17 A population's age structure describes the distribution of people's ages within the population. We can learn something about how a population is growing from its *age structure.*

Answers to Chapter 21 Multiple-Choice Questions

1b, 2a, 3c, 4d, 5c, 6b, 7c, 8a, 9c, 10d

Answers to Chapter 21 Integrated Science Concepts

Physics: Energy Leaks Where Trophic Levels Meet

1 The Second Law of Thermodynamics states that natural systems tend to move from organized energy states to disorganized energy states; that is, useful energy dissipates to unusable energy. Specifically, any time energy is converted from one form to another—including in any chemical reaction—and some energy is lost to the environment as heat. Moving energy from one trophic level to another—such as by breaking down plant matter in the digestive tract of a rabbit, and then using the molecules to build more rabbit muscle—involves a long series of chemical reactions, one after another. So, the Second Law of Thermodynamics explains the reason for energy loss between trophic levels.

2 Yes. The chemical reaction for burning glucose is:

$C_6H_{12}O_6$ $6O_2$: $6CO_2$ $6H_2O$ 673 kcal/mole

That is, glucose and oxygen react to form carbon dioxide and water, releasing 673 kilocalories of energy per mole in the process. If this reaction were perfectly efficient in organisms, the entire 673 kilocalories per mole released would be captured as ATP. Is it? We know that about 38 molecules of ADP are converted to ATP as the result of burning a single glucose molecule. ATP then provides 7 kilocalories per mole when it is broken down into ADP and phosphate during cellular processes. But, 38 7 266, much less than 673. Clearly, a lot of energy is missing! What happened to it? It was lost as heat.

Earth Science: Materials Cycling in Ecosystems

1 The word “biogeochemical” emphasizes that substances cycle between living organisms (“bio”) and the Earth (“geo”)—in particular, Earth’s atmosphere, crust, and waters.

2 Carbon moves into the biotic world when plants and other producers convert carbon dioxide to glucose during photosynthesis. Carbon is returned to the environment by living organisms as carbon dioxide, a product of cellular respiration.

3 Legumes such as peas, beans, clover, and alfalfa have evolved a mutualistic symbiotic relationship with nitrogen-fixing bacteria. These bacteria live in nodules on legume roots and provide them with nitrogen.

Answers to Chapter 21 Exercises

1. A scientist studies how the number of coyotes in San Diego County has changed over the last decade. Is this a population-level study, a community-level study, or an ecosystem-level study?

   This is a population-level study, because it considers a group of individuals of a single species that occupies a given area.

2. Another scientist examines how the presence of a nonnative species, the starling, affects other species of birds in Alameda County. Is this a population-level study, a community-level study, or an ecosystem-level study?

   This is a community-level study, because it considers interactions between different species occupying the same area.

3. Are all producers autotrophs? Do all producers photosynthesize?

   Yes, all producers are autotrophs—they make their own food from inorganic substances. Not all producers photosynthesize; some are chemoautotrophs.

4. Cattle egrets live in close association with cows (hence, their name). They eat insects flushed out by the activity of the cows. Is their relationship with cows parasitism, commensalism, or mutualism?

   Commensalism—they benefit from the activity of the cows, but they do not affect the cows either positively or negatively.

5. Some flowering plants rely on insects to carry pollen from male flowers to female flowers. The insects receive nectar. Is this an example of parasitism, commensalism, or mutualism?

Mutualism—both species benefit. The insects receive food, and the plants are pollinated, a key step in their reproduction.

6. Give an example of an organism that is parasitic on humans. Give an example of an organism with which humans have a commensal relationship. Finally, give an example of an organism with which we have a mutualistic relationship. Explain.

   Many answers are possible. Human parasites include lice, disease-causing bacteria and viruses, fleas, bed bugs, and so forth. Human commensals include dust mites, pigeons, squirrels, and other species that live in human communities and receive food from humans without either benefiting or harming us. Species with which we have a mutualistic, mutually beneficial, relationship include dogs, cats, and so forth.

7. Why can't an ecosystem's energy pyramid be inverted (that is, upside-down)?

   Because, in all ecosystems, a huge amount of energy is lost as you go up the food chain. On average, only about 10% of the energy at one trophic level becomes available to the next level. First, not every organism at one trophic level is exploited by the next level—for example, not every plant gets eaten by a herbivore. Second, when a consumer eats, the energy it receives from food goes into things other than building biomass—feces and maintenance, to be specific. Feces contains organic materials that the consumer is unable to digest. Maintenance is the energy the consumer requires to live—the energy it takes to find and eat food, run, mate, breathe, and so on. During these activities, a lot of energy is also lost to the environment as heat. So, by the time feces and maintenance have taken their share, only about 10% is left for growth and reproduction—for building new biomass.

8. If you eat a pound of pasta, will you gain a pound of weight? Why not?

   No, much of the energy in that pound of pasta will go to feces and maintenance.

9. Was every carbon atom in your body once part of a plant? Why or why not?

   We heterotrophs get all our carbon from the food we eat. Ultimately, this all comes from producers such as photosynthesizing plants. As to whether every carbon atom in our body came ultimately from a plant, the answer is that *most* of the carbon in our bodies came to us via a plant. However, *some* may have come to us through diatoms or other oceanic plankton, seaweeds, and so forth.

10. Why do legumes grow better in nutrient-poor soil than many other plants?

    Legumes have a mutualistic relationship with nitrogen-fixing bacteria, which occupy the plants' root nodules. They obtain nitrogen from these bacteria.

11. Why do tropical forests typically have poor soil?

    Because of the tremendous density and diversity of life, most of the nutrients present in tropical forests are being used by one or another living organism—as a result, the soil tends to be poor.

12. What are the major factors that determine what kind of plant life, and therefore what kind of biome, is found in a habitat? Do living organisms ever affect the type of biome found in an area?

    The type of biome found in a habitat is determined primarily by climatic variables such as temperature, precipitation, and the presence or absence of distinct seasons. As a result, latitude and altitude are major influences on the distribution of biomes on Earth. Living organisms sometimes do affect the biome found in a particular area. For

example, organisms help maintain savanna habitats, preventing them from growing into tropical forest—elephants eat and kill trees, and humans burn forests for cropland.

13. Give an example of marine plankton and marine nekton. Give an example of a benthic species.

    Many answers are possible. Marine plankton include diatoms, dinoflagellates, and the larvae of many animals. Marine nekton include most fishes, whales, seals, penguins, and so forth. Benthic species include mussels, clams, marine worms, lobsters, and so forth.

14. Why do you think most of the early animal colonizers of Krakatoa were flying insects and birds?

    Flying insects and birds had the easiest time getting to the island.

15. Does primary succession or secondary succession occur more frequently?

    Secondary succession occurs more frequently—it is much more common for soil to remain intact than for bare rock to be revealed. Examples of the latter occur when volcanism creates new land or when glaciers retreat.

16. Once a habitat is occupied by its climax community, does its species composition continue to change? Why or why not?

    Yes, species composition changes when there are disturbances that remove climax community species from a patch of habitat. This patch of habitat then goes through succession.

17. Could a habitat that received regular, but not extreme, disturbances be more diverse than one that received no disturbances? How would it compare to a habitat that received regular, extreme disturbances?

    Yes. According to the intermediate disturbance hypothesis, regular disturbances, if not too extreme, actually contribute to biodiversity because different species make use of different habitats, and periodic disturbances guarantee that there will always be habitat at varying stages of recovery. However, a habitat that received regular, extreme disturbances would probably always be found in the early stages of succession and would probably be less diverse.

18. The graph below shows the growth of a *Paramecium* population in the lab. Does the population grow exponentially or logistically? Can you estimate the carrying capacity of the habitat?

    This is an *S*-shaped logistic curve. Carrying capacity appears to be around 900 individuals per milliliter.

19. Are humans *r*-selected or *K*-selected? What type of survivorship curve do we have? Which other correlates of *r*- or *K*-selection characterize humans?

    Humans are *K*-selected. We are described by Type I survivorship. Like other *K*-selected species, we have large body size, relatively few offspring, high investment in offspring (lots of parental care, for example), we reach sexual maturity slowly, and we have long life expectancy.

20. What is demographic transition? Provide an example of a country where demographic transition has occurred, and one where it has not.

    Demographic transition involves a shift from high birth and death rates to low birth and death rates. Most often, death rate decreases first, due to medical and public health advances such as better care, improved nutrition, and immunization. After some time, birth rate also declines. During the period between the fall in death rate and the fall in birth rate, the combination of low death rate and high birth rate causes the population to grow very rapidly. The United States has undergone demographic transition; Kenya has not completed it.

21. The following figure shows the age structure in Afghanistan in 2000. Are most people young or old? Do you think Afghanistan has a growing, stable, or declining population?

Most people are young. The population is growing rapidly.

22. The graph below shows survivorship curves for males and females in England and India in 1999, as well as for 17th century England. What differences do you see between England and India in 1999? What might explain these differences? How did survivorship in England change from the 17th century to 1999?

There is more infant and early mortality in India than in England in 1999. This is likely because poverty affects more people in India, and more people are unable to get proper medical care. There is a huge difference between 17th century survivorship curves in England and survivorship curves there in 1999. In fact, 17th century survivorship curves resemble Type III curves. This means that there were very high levels of infant and childhood mortality in 17th century England.

23. Write a letter to Grandma telling her about recent changes in the rate of human population growth. Be sure to tell her what it means that world human population is no longer growing exponentially. Also tell her about exponential and logistic growth, and explain which model describes human population growth over the last many thousand years.

Human population has grown exponentially for thousands of years. Exponential growth occurs when a population grows at a rate that is proportional to its size. Logistic growth occurs when population growth slows as it reaches the habitat's carrying capacity, that is, the maximum number of individuals or maximum population density the habitat can support. Interestingly, it has become evident in the last several decades that, although world population continues to grow rapidly, the *rate* of growth has slowed, so that growth is no longer exponential. In fact, scientists now believe that if present trends continue, the global human population will peak at around 10 billion soon after 2050.

Solutions to Chapter 21 Problems

1. A grassland supports 25 two-kilogram carnivores—they are secondary consumers in the community. Assuming that 10% of the energy available at each trophic level is captured by the next trophic level, how many kilograms of herbivores (primary consumers) does the grassland support? How many kilograms of grass and other producers?

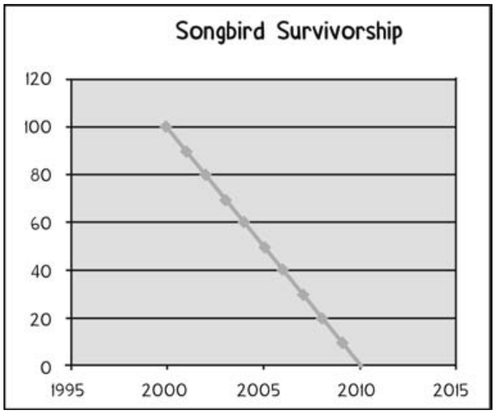
25 two-kilogram carnivores 50 kilograms of carnivoresThis means there were 500 kilograms of herbivores (since 10% of 500 50).And 5000 kilograms of grass and other producers (since 10% of 5000 500).

2. In a population of songbirds, 100 young are born in the year 2000. Each year, 10 individuals die. Make a table showing how many individuals are alive in each year from 2000 to 2010. Now draw a survivorship curve for the population. Does this songbird population have Type I, Type II, or Type III survivorship?

This is the table:

Year	Individuals Alive
2000	100
2001	90
2002	80

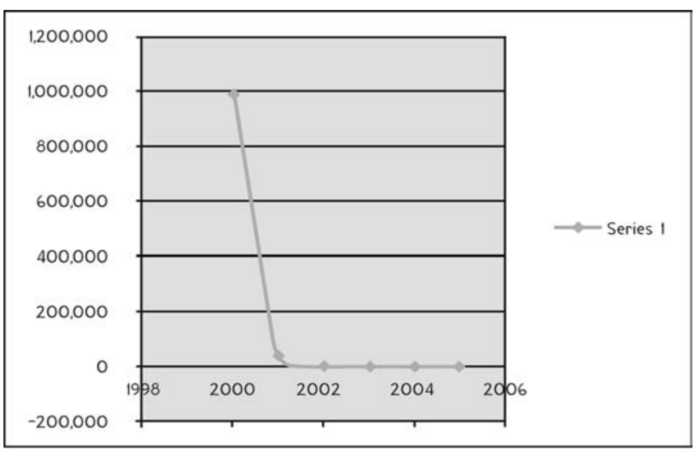
2003	**70**
2004	**60**
2005	**50**
2006	**40**
2007	**30**
2008	**20**
2009	**10**
2010	**0**



This is Type II survivorship.

3. In a population of insects, 1 million young are born in the year 2000. Each year, 95% of the living individuals die. Make a table showing how many individuals are alive in each year from 2000 to 2005 (round your answers as necessary). Now draw a survivorship curve for the population. Does this insect population have Type I, Type II, or Type III survivorship?

This is the table:Year Individuals Alive2000 1,000,0002001 50,0002002 2,5002003 1252004 62005 0



This is Type III survivorship.

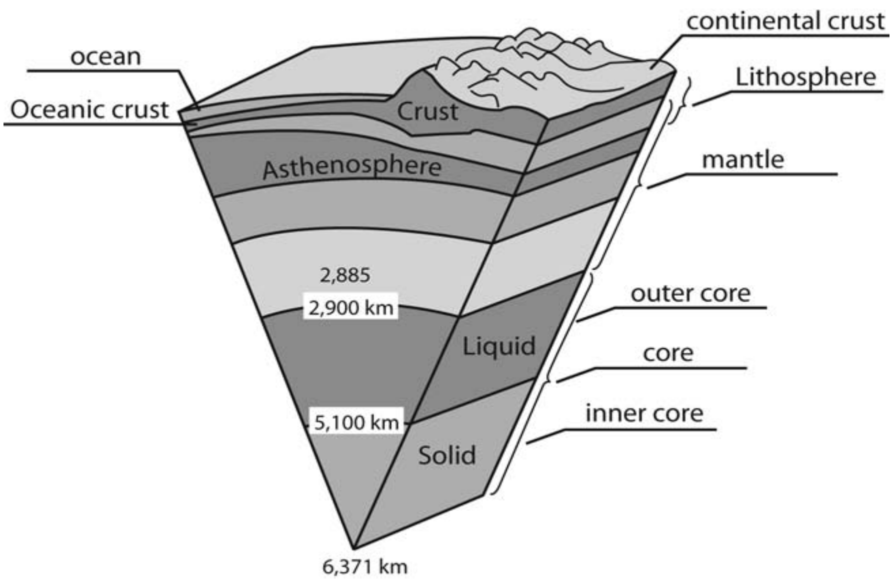
Chapter 22: Plate Tectonics **Answers to**

Chapter 22 Review Questions

1 False. Very little was known until seismology could be employed to investigate Earth's

interior.
2 Newton—portions of Earth's interior must be very dense; da Vinci—mountains are formed by compacted sediments that become rock and are uplifted; Hutton—the Principle of Uniformitarianism.
3 Crust, mantle, core.
4 S-waves cannot penetrate the earth at a certain depth; P-waves slow and refract at this same depth; P-waves and S-waves refract in such a way that their shadow regions indicate that there is a core that is part solid and part liquid.
5 The Mohoroviˇcic« discontinuity—the boundary between crust and mantle.
6 Layers of differing composition.
7 They showed the depth and the sharpness of the mantle–core boundary, that the outer core is liquid, and that the inner core is solid.
8 It is thin, rigid, and can crack.
9 Oceanic crust and continental crust. They are distinguished on the basis of the type (in particular, the
density) of rock found there.

10 Earth's crust is mainly made of granitic rocks.
11 Oceanic crust is mostly basalt.
12 The mantle.
13 The lithosphere is the relatively rigid layer of rock made up of crust and upper mantle.
14 The asthenosphere is the relatively plastic portion of the mantle.
15 Metals—mostly iron.
16 Estimates range from 7000¡F to 13,000¡F—about as hot as the surface of the sun.
17 P waves reflect and gain speed at the boundary, and S waves are able to travel there.



19. Continental drift is the hypothesis that the continents travel about the surface of the earth and are not fixed in one location.
1 The eastern shoreline of Africa and the western shoreline of South America fit together like pieces of a jigsaw puzzle. It looks as if the continents had been one landmass at one time and then tore apart along the matching edges and drifted apart to their present locations.
1 There was no known mechanism.
1 It happens too slowly relative to human lifetimes.
1 Hess confirmed that the seafloor was not flat as traditionally thought but had widely varying topography.

1 Along a divergent plate boundary, plates diverge as they are carried by convection in the asthenosphere. Lava oozes out of the spreading center, cools to form oceanic crust, and then moves outward from the spreading center to expand the seafloor.
1 Ocean trenches. Lithosphere is returned to the interior of the earth in the subduction zone that occurs at the trenches.
1 Seafloor spreading provided the missing mechanism—it explained that the continents move apart due to thermal convection in the plastically yielding asthenosphere.
1 The youngest rocks are located nearest the mid-ocean ridges. The rocks get progressively older away from the ridges, which is consistent with the idea that new lithosphere is generated at the ridges and then spreads outward on both sides of them.
1 Magnetic striping correlates bands of rock with eras of alternating magnetic polarity. The pattern of the bands shows that rock ages as it moves farther from the rifts.
1 Before Harry Hess measured depth variations in the seafloor, it was presumed to be flat because there was little geologic activity there. The uneven sea bottom suggests that the sea bottom undergoes geologic movement.
1 A mobile piece of lithosphere.
1 Estimates are that there are eight major plates with additional minor plates.
1 No; continents and oceanic crust as well ride atop the tectonic plates.
1 The site of lithospheric expansion at a divergent plate boundary.
1 Convergent; divergent; transform.
1 Different plates move with different speeds ranging from approximately 2 to 10 cm per year.
1 Seafloor spreading.
1 Continents tear apart.
1 New lithosphere.
1 Oceanic–oceanic; continental–continental; oceanic–continental.
1 The more-dense tectonic plate descends (subducts) below the less-dense plate. Material of the subducting plate that warms and softens in the high temperatures and pressures of earth’s interior can recycle into the mantle.
1 High mountain chains.
1 Plates move along beside one another scraping one another as they go.
1 Linear valleys can sometimes be found along transform boundaries. The valleys form from the grinding together of plates.
1 The San Andreas Fault is a transform boundary. The slice of California to the west of the fault is moving north relative to the rest of California. The sticking and slipping of the plates along the boundary create earthquakes.
1 Along plate boundaries.
1 Intraplate quakes.
2 A tsunami is a very large, fast-moving ocean wave generated by an earthquake, explosion, or other disturbance.
3 It is logarithmic to accommodate the wide variation in earthquake magnitudes.
4 10 times more; 10 times less.
5 A one-point increase in Richter magnitude corresponds approximately to a 30-fold increase in the earthquake’s energy.

Answers to Chapter 22 Multiple-Choice Questions

1a, 2b, 3a, 4a, 5c, 6a, 7b, 8c, 9b

Answers to Chapter 22 Integrated Science Concepts

Physics: Isostasy

1 Continental crust is less dense than oceanic crust, so it must sink further to achieve sufficient bouyant force to counter gravity.

2 Mountains have large portions of their mass sunk deep within the mantle—“roots”—to achieve isostatic balance.

Physics: What Forces Drive the Plates?

1 Heat transfer away from Earth’s extremely hot interior toward its surface, as required by the Second Law of Thermodynamics, is currently considered to be a main reason there is convection in the mantle and, thus, the reason there are moving plates.
2 Plates ride on convection cells as asthenosphere moves laterally at the top of a cell.
3 The core is like a spherical set of burners. There is convection in Earth’s interior just as there would be
convection in the water heating on the stove.

4 According to the Slab-pull model, cooler, denser edges of plates sink by gravity into the asthenosphere and then pull the rest of the plate gradually along. In the Ridge-push model, the inclined lithosphere at a mid-ocean ridge gravitationally pushes the previously formed, older lithosphere away from the spreading center.

Biology: Life in the Trenches

1 Zero light, extreme cold, and crushing pressure.
2 Bacteria consume minerals released at hydrothermal vents and produce oxygen as a by-product.
3 Hydrothermal vents are fissures created by the grinding action of the plates.

Physics: Anatomy of a Tsunami

1 Both are waves, but a ripple’s energy moves across a surface as it travels, whereas a tsunami’s energy
moves inside the body of water as it goes.

2 A massive underwater disturbance such as an earthquake.
3 A tsunami can be generated by subduction at a convergent boundary as the subducting plate “sticks” beneath the overriding plate. When the compressive force on the plates exceeds the force of friction between them, the plates jerk, which causes an earthquake. As rock snaps upward, it acts like a piston by pushing the water above it, generating a wave.

Answers to Chapter 22 Exercises

1. Is Earth’s inner core solid and the outer core liquid because the inner core is cooler than the outer core? Explain your answer.

   No—the inner core is solid and the outer core is liquid because the greater weight of overlying earth makes pressure greater at the core. The pressure packs the atoms of the inner core too tightly to allow them to be in the liquid state.

2. What is the principal difference between the theory of plate tectonics and the continental drift hypothesis?

   Plate tectonics incorporates the essential ideas of continental drift but goes on to explain that tectonic plates—pieces of lithosphere—are what actually move about on Earth’s surface, rather than just the continents.

3. How is magma generated at divergent plate boundaries?

   As plates pull apart, the weight of overlying crust on the asthenosphere is reduced. Under reduced pressure, rock in the asthenosphere partially melts to form magma.

4. What would happen if new lithosphere were created faster than it is destroyed?

The surface area of the Earth would increase.

5. What kinds of plate boundaries feature subduction zones?

   Oceanic–oceanic convergent boundaries and oceanic–continental convergent boundaries.

6. Why are earthquakes common in subduction zones?

   The subducting and overlying plate stick together, build up strain, then slip in a jarring motion that generates seismic waves.

7. Briefly describe how an island arc forms.

   An island arc, or arc-shaped region of volcanic islands, forms where there is oceanic–oceanic convergence of plates. The subducting plate partially melts as it descends, creating magma. This magma in addition to magma from partial melting of the overlying plate rises toward the surface and erupts. The erupted magma cools and accumulates to form a volcanic mountain. This process is repeated in various locations along the subduction zone so that a string of volcanic mountains forms.

8. Why are there so many expressions like “solid earth,” “old as the hills,” and “terra firma” that suggest the Earth is unchanging?

   The human perception of a stable Earth is based on our limited lifetimes.

9. How did seismic waves contribute to the discovery of Earth’s deep internal layers?

   The speed and direction of seismic waves depends on the density and physical state of the medium. The increases and decreases in speed of P waves and the inability of S waves to penetrate the outer core led scientists to deduce the presence of Earth’s layers.

10. Why does crust “float” on the mantle?

    Crust is less dense than mantle.

11. Briefly describe the fossil evidence that Wegener cited to support continental drift.

    Fossils of single species were found on facing edges of continents. It would be highly improbable for an organism to evolve in exactly the same way in two separate locations. And such organisms would have no way of swimming or otherwise transporting themselves across the intervening ocean.

12. Why are volcanic mountain ranges often found along oceanic–continental convergent boundaries?

    The denser subducting plate partially melts to create magma beneath the overlying continental crust. When the magma rises and erupts through the overlying continental crust, volcanoes form.

13. What is the evidence that tectonic plates move?

    The evidence comes largely from seafloor spreading, which is suggested by the ages of rocks, magnetic striping, and the existence of mid-ocean ridges, trenches, and other signs of underwater geological activity. Correlation of intense geologic activity along plate boundaries also supports the movement of plates. Finally, evidence for continental drift (the migration of ancient ice sheets, and the matching of fossils and rock formations on opposite sides of oceans, etc.) all support plate tectonics as well.

14. Why are most earthquakes generated near plate boundaries?

    Earthquakes are caused by the sticking and slipping of huge masses of Earth—this happens at plate boundaries.

15. Magnetic stripes that were laid down on the Pacific Ocean seafloor are wider than the magnetic stripes laid down over the same time period on the Atlantic Ocean seafoor. What does this tell you

about the rate of seafloor spreading of the Pacific Ocean compared to the Atlantic Ocean?

Sea floor spreading is faster in the Pacific.

16. Are continents a permanent feature of our planet? Discuss why or why not. Estimates are that up to 80% of Earth's surface is covered with volcanic rocks. Use what you know about plate tectonics to explain why this would be true.

No, continents can tear apart at divergent plate boundaries and water can fill the gap between them.

17. Could Los Angeles fall into the ocean, as is popularly thought? Why or why not?

It cannot. It is traveling northward with respect to the rest of California, not westward, into the ocean. Besides, isostasy would prevent this.

18. Is plate tectonics a theory based on integrated science? Why or why not?

Yes it is. Plate tectonics incorporates information from many scientific disciplines. For example, plate tectonics relies on geological information such as the types of rock found in the earth and on physics concepts such as heat transfer, gravity, and density. Fossil evidence (biology) provides evidence for the theory, and astronomical instruments (radio telescopes) are used to measure the actual motions of the plates.

19. Evidence of ancient ice sheets has been found in areas near the equator. Give two possible explanations for this.

Either the climate changed or the regions themselves have migrated away from the poles. As it turns out, explanation #2 is correct.

20. What is meant by magnetic pole reversals? What useful information do they provide about earth's history?

A magnetic pole reversal is the exchange of north and south magnetic poles. The switching of poles is recorded in the seafloor by magnetic striping. So the age and rate of spreading of the seafloor can be determined.

21. What is a very likely cause for the Earth's magnetic field?

The circulation of charges within the liquid outer core.

22. Relate the generation of magma to pressure changes at divergent plate boundaries.

At divergent plate boundaries, overlying weight of the earth and, thus, pressure are reduced. This allows asthenosphere rock to melt to the point of magma.

23. Cite one piece of evidence that suggests subduction once occurred off the West coast of the United States.

The Cascade mountain range is a coastal volcanic mountain range. This type of mountain range is formed when an oceanic plate subducts beneath a continental plate.

24. Where is the oldest oceanic crust? The youngest?

The oldest crust is the furthest from the seafloor spreading center and the youngest is at the rift valley.

25. Your friend who lives in Los Angeles says he is relieved when there are tiny earthquakes because that releases strain and prevents "the big one." Do you share his sense of relief? Why or why not?

Tiny quakes do not release enough strain to prevent major quakes. The Richter scale is logarithmic— quakes with low magnitude can have millions time less energy than large magnitude quakes, so they do not necessarily help significantly in releasing built-up strain in the rocks.

Solutions to Chapter 22 Problems

1 *t d*/*r* (600 km)/(3.5 cm/yr) (6 10^7 cm)/(3.5 cm/yr) 1.7 10^7 years about 17 million years.
2 *d rt* (3.5 cm/yr)(20 yr) 70 cm.
3 *t d*/*r* (2 10^2 km)/(14.2 cm/yr) 1.4 million years.

4. As the diagram shows, lithosphere at this divergent boundary moves 50 km away from where it originates in 3 million years. So, using *r d*/*t*, we see this new lithosphere moves at a rate of (50 km)/(3 10^6 years) 1.7 cm/year. However, the rate of seafloor spreading is double the rate at which new lithosphere moves from a central fissure. So the rate of seafloor spreading 2 1.7 cm/year
3.4 cm/yr.

Chapter 23: Rocks and Minerals

Answers to Chapter 23 Review Questions

1 Iron, oxygen, silicon, magnesium, nickel, calcium, aluminum, and sodium.
2 Both contain layers that are separated by differentiation.
3 Silicon and oxygen.
4 A naturally occurring solid material that has both a definite chemical composition and crystalline structure.

5 Every mineral has a crystalline structure—a repeating, orderly arrangement of its atoms or molecules.
6 They are polymorphs.
7 It cleaves along the planes of weakness—planes along which atoms that are held together by weak bonds.
8 The stronger the bonds within a mineral, the harder the mineral.
9 Because each mineral has a unique combination of crystal structure and composition.
10 (b) does not exhibit the crystal form of quartz, which is likely attributable to it having grown in a cramped environment.
11 When magma starts to cool, atoms in the hot liquid lose kinetic energy. Then, the attractive forces among them pull them into orderly crystal structures.
12 No, they revert to graphite when removed from high pressure conditions, though the process takes a billion years.
13 About 4000.
14 Silicates—they make up 92% of Earth's minerals.
15 Many ores are oxides.
16 An aggregate of minerals.
17 Formed by fire. Changed form.
18 Igneous rocks; Earth was covered by molten rock during the time of its formation. This molten rock slowly cooled to produce igneous rock.
19 Intrusive rocks are crystallized from magma below Earth's surface; extrusive rocks cool and solidify at the surface.
20 Due to increased temperature, decreased pressure, and added water.
21 30C for each kilometer of depth; geothermal gradient.
22 There are only three principal kinds of magma. Each of them produces many kinds of igneous rocks because rocks are composed of minerals, and minerals cystallize from magma according to their melting points.
23 Sediments making up detrital sedimentary rocks are particles weathered from other rocks. A chemical sedimentary rock is made up of sediments that originate as dissolved material.
24 Weathering; erosion; deposition; sedimentation.

25 Mechanical and chemical.
26 To become stable at new temperatures and pressures.

1 Foliated and nonfoliated.
2 When it melts.
3 The graphical representation of the processes of change that affect rock.
4 The conversion of sedimentary rock to sediment.
5 Hydrologic and atmospheric cycles, for example.

Answers to Chapter 23 Multiple-Choice Questions

1b, 2d, 3e, 4b, 5b, 6b, 7c, 8b

Answers to Chapter 23 Integrated Science Concepts

Chemistry: The Silicate Tetrahedron

1 Silicon and oxygen.
2 Silicon and oxygen form strong bonds to give each atom a full valence shell.
3 It has four unpaired electrons available for bonding.

Physics: The Texture of Igneous Rocks

1 The magma that produced the rock crystallized over a broad range of temperatures—the large crystals cooled slowly, but the small ones cooled quickly; porphyritic.
2 Crystals grow by adding on atoms to their exteriors. A slowly cooling crystal has plenty of time to grow large before it has to compete with its neighbors for space and available atoms. In other words, the rate of nucleation is slow compared to the rate of crystal growth. Possible examples: granite and gabbro.
3 Large numbers of small crystals form quickly in a fast-cooling magma as the atoms lose energy. They cannot grow large without bumping into neighboring crystals. Possible example: rhyolite.

4 The atoms lose energy so quickly that they freeze in place. Possible example: pumice or obsidian.
5 Large.

Biology: Coal

1 Photosynthesis.
2 The remains fall to the bottoms of oxygen-deficient swamps.
3 It is combusted.
4 Coal is the product of successive stages of development. At each stage, heat and pressure remove impurities (particulary volatiles) leaving energy-rich organic molecules behind.
5 It is made of plant remains rather than minerals.
6 Coal could not begin to form until land plants evolved. This occurred some 400 million years ago.

Answers to Chapter 23 Exercises

1. What does roundness tell us about sediment particles?

   They have been weathered.

2. What can we say about a rock that is composed of various sizes of sediments in a disorganized fashion?

   It is not well sorted; it hasn’t been transported far from its source.

3. Describe the process of crystallization.

   In crystallization, ions, molecules, or atoms solidify into orderly arrangements

characterized by a repeating basic structural unit. It is characterized by two steps: nucleation and crystal growth.

4. How does the atomic structure of glass differ from the atomic structure of the mineral calcite?

Calcite has a regular, repeating crystal structure, while the atoms of glass are randomly distributed.

5. Calcite is a nonsilicate mineral. Is it therefore rare?

No, it is actually very common, making up limestone, and so forth. It is the most abundant nonsilicate mineral.

6. The chemical formula for quartz is SiO_2. What is the chemical formula of coesite, a polymorph ofquartz?

SiO_2.

7. An impression—a type of fossil—is made by an organism that is buried quickly, before it can decompose. Is this impression of a fish contained in an igneous, sedimentary, or metamorphic rock? Why do you think so?

All fossils are contained in sedimentary rocks.

8. Your friend makes the following remark. Is he right or wrong? Defend your answer: "Minerals in Earth's crust generally do not contain oxygen because oxygen exists in the gaseous state at surface temperatures."

He is suffering from a few misconceptions. Pure oxygen is gaseous at surface temperatures but compounds of oxygen are not, necessarily. Countless millions of compounds containing oxygen are solid at surface temperatures—take iron oxide, or rust, just as one example. Oxygen is the second most abundant element in the crust and the silicates, which comprise 92% of minerals, all contain oxygen. Other classes of mineral such as the carbonates and oxides contain oxygen as well. Oxygen isn't just for breathing!

9. Retrograde metamorphosis is the process of a metamorphic rock returning to its original unmetamorphosed state. (a) What surface conditions encourage retrograde metamorphism to occur?

(b) Why don't rocks undergo retrograde metamorphism as easily as they undergo metamorphism?

(a) Decreasing temperature and pressure. (b) Retrograde metamorphism occurs when temperature and/or pressure are reduced. Chemical processes occur more slowly as temperature is decreased.

10. What is more plentiful on Earth—the group of minerals known as feldspars or the group of minerals known as silicates?

The feldspars are a subset of the nonferromagnesian silicates, so the silicates are more plentiful.

11. Does a mineral's stability depend on temperature and pressure? Explain.

Yes; added thermal energy can break apart bonds in a mineral, while added pressure can alter a crystal's geometry by squeezing positive and negative ions.

12. How does recrystallization produce a metamorphic rock?

New mineral crystals form at the expense of existing ones—a rock changes the minerals it contains without changing the atoms that are present.

13. Name a common intrusive igneous rock often found on the surface of mountains. Explain how this intrusive igneous rock, formed underground, is exposed at the surface.

Granite is exposed as layers of surface rock are eroded.

14. Describe the different conditions that produce the four different kinds of igneous rocks.

Fine-grained rocks form rapidly at the Earth's surface or within the upper crust; coarse-grained rocks cool slowly; porphyritic rocks form from minerals that cooled at different rates; glassy rocks are those that cooled almost instantly.

15. Why are metamorphic rocks created underground?

They are formed at high temperatures and/or pressures or from solutions associated with magma.

16. Cycles in nature, such as the rock cycle, can be viewed as consisting of materials and processes. What are the processes of change that take place in the rock cycle?

Crystallization; weathering, erosion, transportation, deposition, lithification, metamorphism, and melting.

17. Is rock conserved in the same sense that energy is conserved? Why or why not?
Rock is not conserved in the sense that energy is conserved. Rock can be created (by crystallization of magma) and destroyed (by melting), although the atoms rock is composed of cannot be created or destroyed (except by nuclear means).

18. Why does rock melt to form magma?

It melts because overlying pressure is reduced, because water is added and thereby lowers magma's melting point, and when it is heated by other magma flowing nearby.

19. How can one parent magma produce a variety of igneous rocks?

Minerals with high melting points crystallize out of a magma first; the remaining magma, therefore, has a different composition. Rocks form successively as different mixtures of minerals are produced from different magmas at different temperatures.

20. Why are coarse-grained igneous rocks generally intrusive igneous rocks? Why are extrusive igneous rocks usually fine-grained?

Coarse-grained rocks are formed by slow cooling; fine-grained rocks have small crystals and are, therefore, cooled quickly.

21. Would you expect to find any fossils in limestone? Why or why not?

Yes; limestone is a sedimentary rock formed from calcium carbonate which can be obtained from the hard body parts of animals.

22. What makes gold so soft while quartz and diamond are so much harder?

Hardness relates to the strengths of bonds in a crystal. Quartz and diamond have stronger internal bonds than gold.

23. The Earth's mineral resources are used in many ways. Many of these resources are plentiful, yet they are also nonrenewable. Once extracted and used, they do not grow back over the span of human lifetimes. What are some possible problems associated with the extraction of minerals?

High consumption of fossil fuels to supply the energy needed for processing minerals; disruption of ecosystems; erosion and landslides; toxic waste.

24. Many minerals can be identified by their physical properties, such as hardness, crystal form, cleavage, color, luster, and density (specific gravity). Why is identifying a mineral by its crystal form usually

difficult?

Well-shaped crystals occur only rarely in nature, because minerals typically grow in cramped spaces.

25. Can dikes and plutons be observed above ground? Can they form above ground? Explain.

Dikes and plutons are igneous rock intrusions, forming only below Earth's surface. They are visible only when overlying rock erodes.

26. Why is the ocean salty?

The ocean is salty due to sodium and potassium and sodium compounds which have been carried far from their source of weathering in solution.

27. Why is asbestos in drinking water much less harmful than asbestos in air?

Asbestos is primarily harmful to lung tissue when inhaled.

28. Is cleavage the same thing as crystal form? Why or why not?

No, the planar surfaces we see in cleavage are where a mineral breaks due to a weakness in crystal structure or bond strength. The planar surfaces in a crystal form are the external shape from the crystal's internal arrangement of atoms.

Solution to Chapter 23 Problem

Refer to the geothermal gradient. Does temperature change faster with increasing depth between 0 km and 10 km or between 40 km and 50 km? Can you offer an explanation?

Approximating the curve as a linear graph, the slope is about 30¡C per kilometer. Temperature changes faster near the surface because, deeper in the Earth, rock is surrounded by more insulating rock that slows heat loss.

Chapter 24: Earth's Surface—Land and Water

Answers to Chapter 24 Review Questions

1 71%.

2 Highest point is Mt. Everest at 8,848 meters; the Mariana Trench is the deepest point at 10,668 meters deep.

3 (a) *Compressional stress* is the pushing together of masses of rock; *tensional stress* is the pulling apart of rock; *shear stress* is produced by rock blocks sliding past one another. (b) Rock can deform plastically or elastically or fracture under stress.

4 Folding occurs when rock can flow and bend, which requires elevated temperature or pressure.

5 Reverse fault: the hanging wall and footwall are pushed together resulting in the rocks in the hanging wall being pushed above the footwall. Normal fault: rocks in the hanging wall and footwall are pulled apart, and rocks in the hanging wall drop down relative to the rocks in the footwall. Strike-slip fault: rock masses have side-to-side motion with respect to one another with no vertical displacement.

6 Most earthquakes are located along faults. Also, they provide clues about Earth's geologic history, affect the movement of groundwater, and indicate subsurface deposits of

resources, including fossil fuels.
7 Possible answers: (1) folded mountains—The Appalachians, Rockies, and Himalayas; (2) upwarped mountains—Black Hills of South Dakota and Adirondack Mountains; (3) fault-block mountains: Tetons in Wyoming and the Sierra Nevada in California; (4) Volcano—Mauna Loa, Mt Fuji, Sunset Crater.

8 They increase the plasticity of overlying rock so that it convects upward, melts under reduced pressure near the surface, and erupts as lava which accumulates to form a volcano.

9 In the Ring of Fire in the Pacific Ocean.
10 Mid-ocean ridges.
11 Most water is located in the oceans (97.6%); most freshwater is located in ice caps and glaciers.
12 (a) Water evaporates at the Earth's surface, enters the atmosphere as water vapor, condenses into clouds, precipitates (usually as rain or snow), and falls back to the surface, only to evaporate again and go through the cycle once again. (b) The portion of the water cycle that shapes landmasses most (not surprisingly) occurs when the water resides on Earth's surface, after precipitation and before evaporation.
13 Continental shelf—underwater extension of the continent; continental slope—sloping boundary between continental and oceanic crust; continental rise—a wedge of sediment built up at the base of the continental slope.
14 It is varied, featuring expansive flat areas (abyssal plains) but also towering seamounts and trenches that are even deeper than Mt. Everest, the world's tallest surface mountain.
15 About 80% of freshwater is frozen in ice caps and glaciers; about 20% is in groundwater; less 1 percent is in streams and lakes.
16 About 75% of it evaporates immediately; most of the rest soaks into the ground; whatever is left becomes runoff.
17 Yes; a watershed is the land that drains into a stream. Water where you live drains somewhere, so everyone lives in a watershed.
18 In the saturation zone.
19 It is not flat but roughly approximates surface contours.
20 Groundwater.
21 A large percentage of precipitation does not become runoff—it infiltrates into the ground and slowly moves until it empties into stream channels, which convey it to the surface.
22 (a) Water, wind, gravity, and glacial ice; (b) gravity; (c) running water—streams, in particular.
23 They no longer have enough energy to carry the sediments.

1 A delta.
2 Groundwater is removed which compacts sediments so that the land surface is lowered.
3 Agree; recharging can take hundreds or thousands of years.
4 Sinkholes and caves and caverns.
5 Wind has a weaker effect on the land surface. It lacks the eroding and carrying power of water and ice. Additionally, it's more intermittent and cannot cause chemical weathering.
6 Alpine glaciers are found in high mountainous valleys. Continental glaciers cover broad areas.
7 Plow: it scrapes and plucks up rock and sediment. Sled: it transports and deposits rocks and sediments.

Answers to Chapter 24 Multiple-Choice Questions

1d, 2b, 3a, 4c, 5c, 6a, 7d

Answers to Chapter 24 Integrated Science Concepts

Physics: Ocean Waves

1 They become too tall from the bunching of many waves.
2 Wind is the disturbance that creates waves.
3 Energy.
4 The bottom part of the orbital motion that characterizes an ocean wave is affected by the depth of the water. When the water's depth gets shallower and approaches half of the wave's wavelength, the bottom part of the wave slows due to friction between the wave and ocean bottom. Therefore, longer waves are slowed at depths that would not affect shorter waves.

Chemistry: Ocean Water

1 Only a few elements and compounds are present in abundance.
2 Just five: they are sodium chloride (NaCl); magnesium chloride ($MgCl_2$); sodium sulfate (Na_2SO_4);calcium chloride ($CaCl_2$); sodium fluoride (NaF).
3 The composition of seawater remains relatively constant.

Chemistry: Groundwater Contamination

1 Sewage, agricultural chemicals such as nitrate fertilizers, and pesticides.
2 Groundwater recharges very slowly, plus it is difficult to clean up because it is difficult to access.
3 Gas stations typically store MTBE in underground tanks. If a tank leaks, MTBE can infiltrate underground and pollute wells.

Answers to Chapter 24 Exercises

1. Relate plate tectonics to mountain building.

   Colliding tectonic plates produce compressive forces that deform rock plastically into folds. Folds on a large scale produce folded mountains and upwarped mountains. Volcanoes form where magma erupts and then accumulates—often where tectonic plates diverge. Fault-block mountains result where huge blocks of rock are subject to tension that occurs as tectonic plates move apart.

2. List five major landforms in the United States and describe them in as much geologic detail as you can.

   Answers will vary. Some possible answers include the Mississippi Delta, the Black Hills, the San Andreas Fault; the Great Plains; the Appalachian Mountains; and the Grand Canyon. Geologic details about all of these can be found in the chapter.

3. Where is the continental crust lower than it is under the ocean?

   Where it is below sea level—for example, on the shores of the Dead Sea, 400 meters below sea level.

4. Why must aquifers consist of material that has both high permeability and high porosity?

   Aquifers are regions in the saturation zone through which water can flow.

5. How did the development of groundwater resources lower the land elevation in certain regions of the Southwest?

   Extraction of groundwater caused subsidence.

6. How are a deep-sea fan and a continental rise similar? What is the relationship between them?

   They are both depositional bodies. Sea fans are bodies of deposited sediments that over time merge to create a continental rise.

7. Rain falls on land. What will happen to it?

Some will evaporate, some will become surface run-off; the rest will percolate underground.

8. Why does the area of the continental shelf change over geologic time?

When sea level rises, seas spill onto the shore, expanding the continental shelf.

9. What is the relationship between the level of the water table and the depth to which a well must be drilled?

A well must be drilled past the level of the water table.

1 What do sinkholes and caverns have in common?

2 Which of the three kinds of tectonic plate boundaries is most strongly associated with mountain building?

Convergent plate boundaries

12. In the formation of a river delta, why are large particles deposited first, followed by smaller particles further out? Defend your answer.

Large particles are deposited first, because it takes more energy to move them. As the stream slows as it moves toward the sea, it deposits smaller and smaller particles.

13. Which of the following three agents of transportation—wind, water, or ice—transports the largest boulders? Why?

Ice. Glaciers moving across a landscape loosen and lift up blocks of rock and incorporate them into the ice. They literally pick up everything in their paths. As the ice melts, the rock debris is deposited.

14. How do deposits from glacial ice differ from rocks deposited by rivers?

They are not as well sorted.

15. Can a stream erode land that lies below sea level? Explain.

No. Water flows downhill from higher elevations to the sea. So, it can't carry sediment up to sea level from where the land is below sea level.

16. Removal of groundwater can cause subsidence. If removal of groundwater is stopped, will the land likely rise again to its original level? Defend your answer.

If groundwater removal is stopped, land subsidence will stop. The ground, however, does not return to its original level. The weight of overlying sediments prevents the clays from expanding. Once the aquifer has been compacted, it cannot expand to its original level.

17. Is groundwater stored in underground rivers? What's your reasoning?

Underground rivers occur, but they are rare. Water typically moves through pore spaces, faults, and fractures and does not have large channels to move through.

18. How is surface water both a creator and a destroyer of sediments and sedimentary rocks?

Surface water creates sediments by weathering sedimentary rock; surface water destroys sedimentary rock for the same reason.

19. If you look at a map of any part of the world, you'll see that older cities are located beside rivers or where rivers existed when cities were built. What is your explanation?

Freshwater provides the sustenance for life. This includes water for drinking, agricultural uses, sanitation, and transportation.

20. The oceans consist of saltwater, yet evaporation over the ocean surface produces clouds that produce freshwater. Why no salt?

As evaporation occurs over the ocean surface, only the H_2O evaporates, the NaCl is left behind, thus making the seawater saltier. Although most of the NaCl is left behind, minute salt particles in the ocean spray can act as condensation nuclei, which aid in the formation of water vapor droplets. The amount of salt particles, however, is so small that precipitation is essentially freshwater.

21. Is the infiltration of water greatest on steep rocky slopes or on gentle sandy slopes? Defend your answer.

Infiltration is greater on gentle sandy slopes, because sandy materials have a high porosity, and because runoff is greater on steeper slopes.

22. If the water table at location X is lower than the water table at location Y, does groundwater flow from Xto Y or Y to X?

Groundwater flows from areas where the water table is high to where the water table is low. So groundwater would flow from Y to X.

Solutions to Chapter 24 Problems

1. The volume of solids in a sediment sample is 975 cm^3, and the volume of open space is 325 cm^3. What is the porosity of the sediment? Describe what the result of your calculation means in physical terms.

Porosity (volume of open space)/(volume of open space volume of solids) 325 cm^3/325 cm^3 975 cm^3 .25; the volume of open space is one-fourth the total volume of rock.

2. Show that freshwater is 2% of the water on Earth; Frozen water is 1.9%; and groundwater is 0.49% based on the data in Figure 24.9.

From Figure 24.16: freshwater is 2.4% of water on Earth. Frozen water is found in ice caps and glaciers and equals 1.9%. Groundwater is 0.49%.

3. Show that a mountain that can be approximated by a box 4 km 3 km 4 km would exist for about 329 million years.

Volume of the mountain = 4 km 3 km 4 km (4000 m) (3000 m) (4000 m) 4.8 10^{10} m^3. Assume the rate of erosion is about 146 m^3 per year as stated in the *Math Connection* example. Then the duration of the mountain (volume of mountain)/(rate of erosion) 3.29 10^8 years or 329 million years.

Chapter 25: Weather

Answers to Chapter 25 Review Questions

1 Weather is the state of the atmosphere at a particular time and place; climate is the general pattern of weather over a long period of years.

2 Atmospheric pressure; temperature; wind; precipitation; cloudiness; and humidity.

3 Rays of the Sun strike the poles at a steep angle with the result that solar radiation is less intense than nearer the equator, resulting in lowered temperature.

4 The tilt of Earth's axis produces the differences in solar intensity; this gives rise to seasons and affects the length of daylight.

1 Radiation emitted from Earth has a lower frequency than radiation emitted by the Sun.
2 Molecules of atmosphere absorb solar or terrestrial radiation which energizes them and sends them aloft.
3 Atmospheric pressure decreases with altitude.
4 The troposphere.
5 Temperature decreases steadily as density decreases. Fewer atmospheric molecules to trap terrestrial radiation.

6 Uneven heating of Earth's surface.
7 Warm air is characterized by low density and low air pressure, while cool air is characterized by high density and high pressure.
8 Local differences in surface heating give rise to small-scale convection cells and pressure gradients, and these create small-scale local winds which are changeable. Planet-scale temperature differences produce much larger convection cells and pressure gradients that give rise to prevailing winds, which are on a global scale and are relatively permanent.
9 An ocean current is a stream of water that moves relative to the larger ocean.
10 The Gulf Stream flows northward along the North American Coast warming Norway and Great Britain.
11 Increases.
12 It condenses.
13 Air rises, expands, and cools. As the air cools, water molecules move slower and condensation occurs. If there are larger and slower-moving particles or ions present in the air, water vapor condenses on these particles to create a cloud.
14 (a) They do sink. (b) However, as they fall, they are carried upward by rising air currents (updrafts).
15 A cold front develops as a colder, denser air mass advances into and displaces a stationary warm air mass; a warm front is air that moves into territory that had been occupied by a cold air mass.
16 They are associated with day-to-day weather variation.
17 (a) A hurricane is a cyclone—an area of low pressure that winds flow around and they occur in the warm moist conditions of the tropics; (b) latent heat released by large amounts of condensing water in warm, moist air.
18 A tornado is a rotating column of air extending from a thunderstorm to the ground.
19 (a) There is a strong observed correlation between the rise of carbon dioxide emissions from human activities and average global temperature increases. (b) When trees are cut down, the carbon dioxide they would have absorbed is released into the atmosphere.
20 Disagree—climatologists cannot predict the future climate in this much detail.

Answers to Chapter 25 Multiple-Choice Questions

1b, 2d, 3b, 4a, 5a, 6c, 7b, 8d, 9a

Answers to Chapter 25 Integrated Science Concepts

Chemistry: The Atmospheric "Ozone Hole"

1 Good ozone is the O_3 molecule when it is present in the stratosphere; bad ozone is O_3 found in the airwe breathe.
2 CFCs release chlorine atoms high up in the stratosphere, where they react with and destroy ozone molecules. Further, the chlorine atom catalyzes the ozone-destroying reaction so that one of them can destroy 100,000 or more ozone molecules.

Physics: The Coriolis Effect

1. The Coriolis influence winds as well as surface currents by causing them to rotate with respect to the
Earth from left to right (as viewed from above the Earth at the North Pole).

2. (a) A cyclone moves counterclockwise in the Northern hemisphere. (b) An anticyclone moves counter clockwise in the Southern hemisphere. Cyclones and anticyclones both rotate in the directions they do because of the Coriolis effect.

Physics: The Greenhouse Effect

1 Whitewash is sometimes applied to greenhouses to better reflect light, thus reducing the amount of
incoming solar radiation and subsequent indoor temperature.

2 Without the greenhouse effect, the Earth's average temperature would be a frigid 18¡C otherwise. An intensified greenhouse effect would be a bad thing, because it could lead to global warming.

Answers to Chapter 25 Exercises

1. In what direction does a sea breeze blow? Does it blow in the day or at night? What causes a sea breeze?

A sea breeze blows from the sea toward the shore and occurs mostly during the day. The reason is that land cools off faster than the ocean, so during the day, cooler, high-pressure air blows toward the land. At night, the cooler, high-pressure air forms over land, so it flows toward the area of lower pressure out to sea.

2. What are Hadley cells? Why are they important?

Hadley cells are the pairs of convection cells that comprise the prevailing winds. Winds as well as precipitation and air pressure vary according to the flow described by these convection cells.

3. What slows low-altitude winds relative to winds high in the troposphere?

Friction.

4. What kind of weather is associated with an approaching cold front? With an approaching warm front?

As a cold front approaches, cirrus clouds typically form, wind shifts direction, and temperature and air pressure drop. As a warm front approaches, cirrus clouds may form then thicken so that the sky becomes overcast. Winds usually pick up and snow or rain may fall.

5. After a day of skiing in the Rocky Mountains, you decide to go indoors and get a cup of hot cocoa. As you enter the ski lodge, your eyeglasses fog up. Why?

The change in environment from cold to warm. As we leave the cold outdoors the warm air inside comes into contact with the cold surface of the eyeglasses. As the air touching the glasses cools to its dew point, water vapor condenses onto the eyeglasses. Notice the similarity to Exercise 13—same physics, different situation.

6. Use what you learned about air pressure and barometers to analyze and explain how a straw works.

An old-fashioned mercury barometer works in a way similar to a straw: as the weight of the

atmosphere pushes the mercury in a dish down, the mercury rises in a low-pressure glass column. Similarly, when one sucks on a straw, one reduces the pressure in the straw and this allows the weight of the atmosphere to press the liquid up into the straw.

7. In some places, temperature inversions (areas where the air above is warmer than the air below) are common. Local air pollution can then become a serious problem. Why is that?

   The layer of cold air only allows minimal convection currents to occur.

8. Identify the clouds shown in the photo. How are they formed? What cloud group do they belong to?

   These clouds are cumulus clouds, which are clouds of vertical development. Like other clouds, these formed from water vapor in rising air that expanded, cooled, and condensed.

9. The Earth is closest to the Sun in January, but January is cold in the Northern Hemisphere. Explain.

   Seasonal temperatures are caused by solar intensity, solar radiation per area. In the winter in the Northern Hemisphere, the tilt of Earth's axis leads to solar radiation at the widest angle, reducing solar intensity to a minimum.

10. During a summer visit to Cancun, Mexico, you stay in an air-conditioned room. Getting ready to leave your room for the beach, you put on your sunglasses. The minute you step outside, your sunglasses fog up. Why?

    The change in environment from cold to warm. As you leave the air-conditioned room, the warm air outside comes into contact with the cold surface of the sunglasses. During contact, the cold surface cools the air by conduction, and the warm air's ability to hold water vapor decreases. As the air cools to its dew point, water vapor condenses onto the sunglasses.

11. Air is warmed and rises at the equator and then cools and sinks at the poles, as shown in the figure below. Is this an accurate picture of the global circulation of air? Explain why or why not.

    It is not accurate. Atmospheric circulation is broken up into six convection cells due to the influence of the Coriolis effect.

    The low cloud cover acts as an insulation blanket inhibiting the outflow of terrestrial radiation.

12. As an air mass moves first upslope and then downslope over a mountain, what happens to the air's moisture and heat content?

    As an air mass is pushed upward over a mountain, the rising air cools, and if the air is humid, clouds form and precipitation occurs. As the air mass moves down the other side of the mountain (the leeward slope), it warms. This descending air is dry, because most of its moisture was removed in the form of clouds and precipitation on the windward (upslope) side of the mountain.

13. Why are condensation and saturation more likely to occur on a cold day than on a warm day?

    Because cool air has slower moving molecules, and warm air can hold more water vapor than cold air.

14. How do fronts cause clouds and precipitation?

    When two air masses make contact, differences in temperature, moisture, and pressure can cause one air mass to ride over the other, forming clouds and causing precipitation.

15. Why does the surface temperature of the ground increase on a calm, clear night as low cloud cover moves overhead?

    The low cloud cover acts as an insulation blanket inhibiting the outflow of terrestrial radiation.

16. Why does dew form on the ground during clear, calm summer nights?

On a clear summer night, the ground cools as it radiates away heat absorbed during daytime and this has a cooling effect on surrounding air. As air temperature lowers, relative humidity increases. If leaves of grass or other surfaces cool below the cooled air's dew point, dew will form as the humid air comes into contact with them.

17. Why does warm, moist air blowing over cold water result in fog?

Warm air is able to hold more water vapor before becoming saturated than can cold air. As warm moist air blows over cold water, it cools, which causes the water vapor to condense into tiny droplets of fog.

18. Explain why your ears pop when you ascend to higher altitudes.

The air pressure at higher altitudes is less than at the surface. Time is required for your body to adjust to this new pressure, so the air inside your body pushes outward more than the atmosphere pushes inward, producing that popping feeling.

19. What role does the Sun play in ocean currents?

The Sun heats the ocean unevenly; equatorial waters are warmed more than parts of the ocean nearer the poles. Currents redistribute heat so that it is dispersed more evenly.

20. How does the ocean influence weather on land?

The ocean acts to (1) moderate the temperature of coastal lands; and (2) provide a reservoir for atmospheric moisture.

21. Why is it important that mountain climbers wear sunglasses and sunblock even when temperatures are below freezing?

At high altitudes, there is a higher concentration of UV radiation due to a decrease in the concentration of UV-absorbing atmospheric gases.

1 Why does the East Coast of the United States experience wider seasonal variation than the West Coast, even though both areas have oceans along their margins?

2 The aneroid barometer, which measures atmospheric pressure, is at the heart of the altimeters (devices that measure altitude) used in modern aviation. What's the connection between a barometer and an altimeter?

Because pressure decreases in a regular way with altitude, a device for measuring pressure can be used to measure altitude by recalibrating the scale.

24. What does convection in Earth's atmosphere produce? What does convection in the Earth's mantle produce?

Wind; plate tectonics.

25. What would be a good state for you to live in if you like extreme temperatures? If you like a moderate climate? Explain why your preferred area has the weather patterns it has.

People who prefer definite seasons prefer inland areas, while those who like more moderate climates would prefer to live in coastal areas, due to the moderating effect of large bodies of water on climate (due to water's high specific heat capacity).

26. While hiking, you survey the sky from a mountaintop. The sky is blue everywhere except for a puffy cloud directly over a mountain. Explain how orographic lifting caused this cloud to form.

This cloud apparently formed though orographic lifting. This means that a parcel of warm, moist air moved up the mountain's upward-sloping side. As the air lifted, it cooled and water vapor in it condensed to form a cloud.

27. How might you expect vegetation on the leeward side of a mountain to differ from the vegetation on

the windward side?

The leeward side of a mountain has a much drier climate than the windward side, so leeward vegetation would consist of plants adapted for dry climates—cacti and succulents, rather than ferns and conifers, for example.

Answers to Chapter 25 Problems

1. Consider a house at sea level that has 2000 square feet of floor area. What is the total force that the air inside this house exerts upward on the ceiling?

Standard atmospheric pressure 14.7 lb/in^2. Convert this to units of feet: (14.7 lb/in^2) (144 in^{2}ft^2), and we have atmospheric pressure 2100 lb/ft^2. Knowing that pressure is defined as force per area, we have *F* *P* *A*. So the total force that the air inside the house exerts upward on the ceiling is (2100 lb/ft^2) (2000 ft^2) 4.2 10^6 lb of force.

2. If a tornado passed next to the front of the house, the pressure there could easily drop by 15% in less than a second. Calculate the net force on the front door of a closed house if the outside pressure suddenly dropped by 15%.

The air inside the house is at standard atmospheric pressure; from Table 25.1 this is 14.7 lbs. per square inch. The outside air is at 85% of this pressure or (0.85)(14.7 lbs./in^2) 12.5 lbs./in^2. Thus, the net pressure pushing the door outward (14.7 lbs./in^2) (12.5 lbs./in^2) 2.2 lbs./in^2. The area of the door is 6.5 feet by 3 feet or (78 in)(36 in) 2,808 in^2. To find the outward force on the door, we use the relation Force Pressure Area. We have: Force (2.2 lbs./in^2)(2,808 in^2) 6178 lbs. Employing significant figures, the outward force on the door due to the tornado is 6200 lbs. It’s easy to see why the door will be flung far in the storm.

3. At 50¡C, the maximum amount of water vapor in the air is 9 g/m^3. If the relative humidity is 40%, what is the mass of water vapor in 1 m^3 of air?

Relative humidity [(water vapor content)/(water vapor capacity)] 100%. Rearrange to solve for the mass of water in 1 m^3 of air: water vapor content [(relative humidity)(water vapor capacity)]/100%. Then: water vapor content at 50¼C [(40%)(9 g/m^3)]/100% 3.6 g/m^3.

Chapter 26: Earth’s History

Answers to Chapter 26 Review Questions

1 Bacterial life: end of March; *Homo sapiens*: 11:50 December 31; recorded history 11:59 December 31.

2 The present is the key to the past; the natural laws of physics, chemistry, and biology that we know of today have been constant over the geologic past.

3 1) Original horizontality. Layers of sediment are deposited evenly, with each new layer laid down nearly horizontally over older sediment.

2) Superposition. In an undeformed sequence of sedimentary rocks, each layer is older than the one above and younger than the one below.

3) Crosscutting. An igneous intrusion or fault that cuts through preexisting rock is younger than the rock
through which it cuts.

4) Inclusion. Any inclusion is older than the rock containing it.

5) Faunal succession. Fossil organisms succeed one another in a definite, irreversible time sequence.

1 The collection of clues to Earth's past buried in its rocks.
2 An unconformity.
3 Eon.
4 About 4.5 billion years.
5 Almost 90%.
6 Hadean eon: A crust formed; Archaean eon: formation of oceans.
7 Cambrian, Ordovician, Silurian, Devonian, Carboniferous (Mississippian and Pennsylvanian), and Permian.
8 The Silurian brought the emergence of terrestrial life, the earliest known being terrestrial plants that had a well-developed circulatory system (vascular plants).
9 The Carboniferous.
10 The age of reptiles.
11 A worldwide rise in sea level occurred during the Cretaceous period, probably due to the breakup of Pangaea.
12 Only that of Europe and Asia has survived to the present time.
13 Tertiary: Paleocene, Eocene, Oligocene, Miocene, Pliocene. Quaternary: Pleistocene, Holocene.
14 Humans evolved during the Cenozoic era in the Quaternary period and Pleistocene epoch.
15 Warm, woolly coats.
16 A relatively warm, interglacial period.

Answers to Chapter 26 Multiple-Choice Questions
1c; 2d; 3b; 4a; 5c; 6b; 7c
Answers to Chapter 26 Integrated Science Concepts

Physics: Radiometric Dating of Rock

1 The half-life of uranium-238 is 4.5 billion years; potassium-40 has a half-life of 1.3 billion years;
carbon-14 has a half-life of 5730 years.

2 Uranium-238.
3 Carbon-14.

Biology, Chemistry: The Great Transformation of Earth's Atmosphere

1. (a) The early Earth atmosphere had a much higher concentration of carbon dioxide (perhaps 80%) compared to what it has today (only 1/10 of 1%).

   (b) Free oxygen was not present in appreciable amounts in the Earth's early atmosphere but is plentiful enough now to support air-breathing organisms.

1 The availability of free oxygen in the air allowed land animals to evolve.

2 Earth's atmosphere was drastically transformed by cyanobacteria that absorbed carbon dioxide and
produced free oxygen through photosynthesis.

Biology: The Permian Extinction

1 The Permian extinction caused the demise of about 90% of species living at the time.
2 A million-year-long volcanic eruption in Siberia; climate changes associated with the formation of
Panagaea.

Biology, Astronomy: The Cretaceous Extinction

1 The iridium layer in the rock record corresponding to the Cretaceous.
2 The Nemesis theory argues that Earth experiences a mass extinction approximately once every 26 million years and that this periodicity is due to a hypothetical star named Nemesis, binary to the Sun. Every 26 million years, proponents argue, Nemesis comes close enough to the solar system to disturb comets, which proceed to bombard the inner solar system. The alternative view that a meteorite triggered the Cretaceous extinction neither posits a Nemesis star nor holds that mass extinctions are periodic.

Answers to Chapter 26 Exercises

1. Suppose a certain type of sediment is deposited in all modern streams. On a geologic expedition into unknown territory, we find the same type of deposit in ancient rocks. What can we say about the ancient rocks? What assumption are we making?

   We can assume that the ancient rocks represent the location of an ancient stream. This is an application of the Principle of Uniformitarianism.

2. Why don't all rock formations show a continuous sequence from the beginning of time to the present?

   Weathering and erosion, crustal uplifts, and other geologic processes can interrupt the normal sequence of deposition (which gives rise to unconformities).

3. How are fossils used in determining geologic time?

   Fossils are used to establish the relative ages of rocks, because geologists have been able to arrange different groups of fossils—and the time periods they were associated with—in a chronological sequence.

4. In a sequence of sedimentary rock layers, the oldest layer is on the bottom, and the youngest layer is at the top. What relative dating principle applies here?

   Superposition.

5. What role did tectonic activity play in the formation of the San Andreas fault?

   The collision between the westward moving North American Plate and the Pacific Ridge system occurred about 30 million years ago, creating the San Andreas fault.

6. What kinds of mammals evolved to occupy niches left vacant by the extinction of many Mesozoic reptiles?

   Bats, some large land mammals, and marine animals such as whales and dolphins.

7. Did life exist on Earth in the Precambrian? If so, cite two or three examples.

Abundant microscopic life appeared at the end of the Precambrian.

8. If a sedimentary rock contains inclusions of metamorphic rock, which rock is older? Defend your answer.

Sedimentary rock is older by the principle of inclusion.

9. Which isotopes are most appropriate for dating rocks from the following ages? (a) Early Precambrian time. (b) The Mesozoic era. (c) The late Pleistocene epoch.

(a) Uranium-238 (or possibly Potassium-40, depending on how early). (b) Uranium-235 or Potassium-40 are best, but Uranium-238 will work too (but is not as precise). (c) Carbon-14.

10. Geologists often refer to the early Paleozoic era as the "Cambrian Explosion." What is meant by this phrase? What conditions prevailed at the time, allowing the "explosion"?

The Cambrian explosion was a time when Paleozoic invertebrates radiated to produce a great diversity of marine organisms; many low-elevation areas of the world were flooded at the time of the Cambrian explosion.

11. Suppose that, in an undeformed sequence of rocks, you find a trilobite embedded in shale layers at the bottom of the formation and fossil leaves embedded in shale at the top of the formation. From your observation, what can you say about the ages of the formation?

The fossil leaves must be older than the shale, but the shale is on top of the formation. Most of the rocks in the sequence are older than the fossil leaves. So we can say that the average age of the formation is younger than the trilobite and older than the fossil leaves. By average, we mean that the formation was deposited over some finite time period, and the age we get from the fossil brackets the beginning and end of that formation.

12. What key developments in life occurred during Precambrian time?

Appearance of cyanobacteria and transformation of Earth's atmosphere.

13. Coal beds are formed from the accumulation of plant material that has become trapped in swamp floors. Yet coal deposits are found on the continent of Antarctica, where no swamps or vegetation exist. What is your explanation?

At the time of deposition, the climate of Antarctica was mild enough to support swamps.

14. In what ways can sea level be lowered? What effect might the lowering of sea level have on existing life forms?

Rising temperatures can melt ice sheets and glaciers, which makes sea levels rise—potentially increasing habitat for marine organisms promoting radiation of new species as in the Cambrian. Conversely, lower temperatures promote glaciation, which causes sea levels to drop and can produce a surge in the rate of extinctions of shallow-water marine organisms.

15. What can cause a rise in sea level? Is this likely to happen in the future? Why or why not?

Melting of the polar ice caps, caused by global warming, for example. An increase in the rate of seafloor spreading could also make sea levels rise.

16. What general principle is used to make sense of what must be the processes that occurred throughout Earth's history?

The Principle of Unitarianism.

Solutions to Chapter 26 Problems

1. If fine muds were laid down at the rate of 1 cm per 1000 years, show that it would take 100 million years to accumulate a sequence 1 km thick.

By ratio and proportion, a 1-km thick sequence would accumulate in 100 million years.

2. How long has *Homo sapiens* existed? State your answer in terms of a percentage of Earth's history.

Homo sapiens **evolved 195,000 years ago; the Earth is approximately 4.5 billion years old. Humans have existed for 0.0043% of the Earth's history—a few thousandths of 1%.**

3. Chart the data given in "Science and Society: Extinction in the Modern Times" in pie graphs; one for each group of organisms: mammals, birds, reptiles, amphibians, fishes, insects, mollusks, mosses, ferns, and flowering plants.

Pie graphs should depict this data: 23% mammals, 12% birds, 61% reptiles, 31% amphibians, 46% fishes, 73% insects, 45% mollusks, 86% mosses, 67% ferns, and 73% flowering plants.

Chapter 27: The Solar System

Answers to Chapter 27 Review Questions

1 If Earth were the size of a grape, the Moon would be the size of a pea, and it would be about a foot (30 cm) away from Earth. The Sun would be the size of a Sumo wrestler and it would be 150 meters from Earth.

2 The planets revolve in the same direction (counterclockwise), orbit in the plane of the ecliptic (except Pluto), and mostly rotate in the same direction (counterclockwise).

3 Planets, moons, asteroids, comets, interplanetary medium of gas and dust particles.
4 (1) The orderly motions among large bodies of the solar system (2) the neat division of planets into two main types.
5 About 5 billion years.
6 Gravity; gas pressure.
7 The Sun loses mass. By $E \; mc^2$ the "lost" mass is converted to radiant energy. Some of this energy is intercepted by photosynthesizing organisms and used for life.

8 The core: comprises 10% of the Sun's total volume; hot—over 15,000,000¡C; dense; composed of hydrogen, helium, and minute quantities of other elements in the plasma state. Radiation zone: thick internal layer where atoms absorb and reradiate electromagnetic energy, slowly transferring it toward the Sun's surface. Convection zone: a turbulent layer consisting of low-density gases that are stirred by convection. Photosphere: The Sun's surface, a glowing, 6000-K plasma, about 100 kilometers thick. Chromosphere: transparent layer above photosphere, about 10,000 kilometers thick, composed of plasma. Corona: The Sun's outermost layer, composed of streamers and filaments of outward-moving, high-temperature plasmas curved by the Sun's magnetic field.
9 Solar wind: a whirl of high-speed protons and electrons. Sunspots: cooler and darker regions of photosphere caused by magnetic fields that impede hot gases from rising to the surface. Solar prominences: dense clouds of plasma pulled into looped and twisted shapes by the Sun's magnetic field.
10 Mercury, Venus, Earth, Mars.

11 They are much like Earth—small and rocky.
12 Two reasons: slow rotation of Mercury and its lack of atmosphere.
13 Mercury, Venus.
14 They are different from the inner planets in size, composition, and the way they were formed.
15 Jupiter, Saturn, Uranus, Neptune, Pluto.
16 They are much like Jupiter—large and gaseous (except Pluto).
17 Most likely it is a minor planet. Pluto is not a full planet, because it is quite small and has a highly eccentric, tipped orbit. Objects similar to Pluto have been discovered in the outer regions of the solar system so either they should be considered planets or Pluto should not be classified as a planet.
18 Too little mass to exert strong gravitational pull.
19 During a full moon, the Sun, Earth, and Moon are lined up, with Earth in between.
20. The Moon is between the Earth and the Sun at a new moon.
19 Solar eclipse: The Moon is in front of the Sun, so the Moon's shadow falls upon Earth. Lunar eclipse: the Moon and Sun are on opposite sides of Earth, and the shadow of Earth falls on the full Moon.
19 The Kuiper belt is a region of the sky beyond Neptune that is populated by many icy bodies and is a source of short-period comets. The Oort Cloud is a region beyond the Kuiper Belt that is populated by trillions of icy bodies—noted as a source of long-period comets.
19 A meteoroid is a piece of debris chipped off an asteroid or comet. Asteroids and rocky bodies usually orbit the Sun in the inner solar system; comets are icy bodies that generally inhabit the outer solar system.
19 The coma of a comet is produced when a comet gets close enough to the Sun to produce glowing vapors which surround its icy nucleus. The tail is produced when the solar wind pushes particles of the coma.
19 A meteor shower is produced, usually, when Earth passes through a stream of particles left behind by an orbiting comet.

Answers to Chapter 27 Multiple-Choice Questions

1a, 2a, 3c, 4a, 5d, 6a, 7b, 8d

Answers to Chapter 27 Integrated Science Concepts

Physics: The Solar Nebula Heats Up, Spins Faster, and Flattens

1 It spun faster and became flatter and hotter.
2 By conservation of angular momentum, it spun faster as it contracted.

Chemistry: The Chemical Composition of the Solar System

1 Astronomers call the elements heavier than hydrogen the "heavy elements." Elements form lithium
through iron are formed through thermonuclear fusion in stars. Elements heavier than iron are formed
by large-mass stars that supernovae.

2 The inner planets formed from materials that remained solid at high temperatures; the outer planets consist mainly of hydrogen and helium gas that coalesced in the cold regions of the solar system far away from the Sun.

Biology: What Makes a Planet Suitable for Life?

1 Scientists believe that most, perhaps all, life in the universe is based on carbon, because carbon can form four covalent bonds and therefore serve as the backbone for large biomolecules.
2 Liquids allow molecules to move around and react with one another.

Physics: Why One Side of the Moon Always Faces Us

1 The rates are the same.
2 They both tend to line up with their respective fields, gravitation for the moon, magnetic for the compass needle.
3 The fact we see one side is evidence that it rotates. If it didn't rotate, we'd only need to wait until it
completed a half orbit to see its opposite side.

Answers to Chapter 27 Exercises

1. Copy the diagram and label the planets.

   From left to right: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto.

2. Why aren't eclipses more common events?

   They occur only when the plane of the moon's orbit intersects the plane of the Earth's orbit about the Sun, which seldom occurs.

3. What causes comet tails to point away from the Sun?

Comet tails point away from the Sun because they are blown away from the Sun by the solar wind.

4. Cite as many of the features of the solar system as you can that are explained by the nebular theory.

   Features explained by the nebular theory include orderly motions among large bodies of the solar system; the neat division of planets into two main types—terrestrial and Jovian; existence of asteroids, comets, and moons; chemical compositions of the Sun and planets.

5. Is there evidence that Mars was at one time wetter than it presently is?

   Yes; the Martian poles are covered with ice, and the surface exhibits dry river beds or flood plains— surface features produced by flowing water.

6. We know that the Sun is much larger than the Moon, but both appear the same size in the sky. What is your explanation?

   Quite simply, the Sun is much farther away than the moon (as measured by Aristarchus in about 240 B.C.).

7. The giant impact theory is believed to explain the origin of the Moon. Does this mean that the nebular theory does not explain the Moon's formation? Explain.

   The giant impact theory is a subset of the nebular theory, so there is no contradiction between the nebular theory and Giant Impact Theory.

8. Why are there many more craters on the surface of the Moon than on the surface of Earth?

   Erosion hasn't occurred on the moon, so craters have not been covered up. Another way of saying the same thing is that the Moon wears no makeup.

9. Do star astronomers make stellar observations during the full Moon part of the month or during the new Moon part of the month? Does it make a difference?

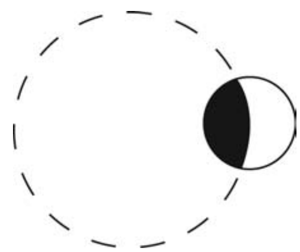
   Observations are made during the new moon part of the month, when the sky is moonless. It makes a difference, because moonlight is not there to be scattered and obscure a good view.

10. Nearly everyone has witnessed a lunar eclipse, but relatively few people have seen a solar eclipse. Why?

A lunar eclipse is in view of the whole hemisphere of the Earth facing the moon. But a solar eclipse is in view only on a small part of the hemisphere that faces the sun at that time, so few see it.

11. Because of Earth's shadow, a partially eclipsed Moon looks like a cookie with a bite taken out of it. Explain, with a sketch, how the curvature of the bite indicates the size of Earth relative to the size of the Moon. How does the tapering of the Sun's rays affect the curvature of the bite?

Extend the bite to complete a circle, and the patch of the Earth's shadow appears to be a circle with a diameter of 2.5 moon diameters. Does this mean the Earth's diameter is 2.5 moon diameters? No, because the Earth's shadow at the distance of the moon has tapered. How much? According to the tapering that is evident during a solar eclipse, by 1 moon diameter. So add that to the 2.5, and we find the Earth is 3.5 times wider than the moon.



12. Why is it not totally dark in the location where a total solar eclipse occurs?

Brightness of the solar corona somewhat lights up the Earth.

13. What energy processes make the Sun shine? In what sense can it be said that gravity is the prime source of solar energy?

The Sun's output of energy is that of thermonuclear fusion. Because fusion in the Sun is the result of gravitational pressure, we can say the prime source of solar energy is gravity. Without the strong gravity, fusion wouldn't occur.

14. A TV screen is normally light gray when it is not illuminated. How is the blackness of sunspots similar to the blackness in images on a TV screen?

Both look black due to the large contrast between the bright and dark parts.

15. When a contracting ball of hot gas spins into a disk shape, it cools. Why?

It has more surface area in the disk shape, which allows it to radiate more energy not re-radiated.

16. The greenhouse effect is very pronounced on Venus, but it doesn't exist on Mercury. Why?

Mercury is too small and too hot to hold any appreciable atmosphere.

17. Where are the elements heavier than hydrogen and helium formed?

In star interiors.

18. What is the cause of winds on Mars (and on almost every other planet, too)?

Unequal heating of the surface.

19. What is the major difference between the terrestrial and Jovian planets?

The Jovian planets are large gaseous low-density worlds and have rings. The terrestrial planets are rocky and have no rings.

20. What does Jupiter have in common with the Sun that the terrestrial planets don't? What differentiates Jupiter from a star?

Its composition resembles that of the Sun. It differs from a star in that nuclear fusion doesn't occur at its core.

21. Using the following mnemonic to state the order of the planets: *My very excellent mother just served us nine pizzas*, state the order of the planets.

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto.

22. Why are the seasons on Uranus different from the seasons on any other planet?

A planet like Earth rotates through an axis that is slightly nonperpendicular to the orbital plane. This means that the angle that the Sun's rays make with a given part of its surface depends on the time of the planet's year. A slight tilt results in slight changes of season. Uranus, however, is enormously tilted, with its polar axis nearly in the plane of its orbit. Its seasons are very exaggerated, so that when the polar axis is aligned with the Sun, a full summer is at one pole and a full winter at the opposite pole.

23. Why are meteorites so much more easily found on Antarctica than on the other continents?

Because so many are imbedded in ice. On regular ground, they are not so obvious. Being found on the surface of ice indicates they came from above.

24. Draw a comic strip illustrating the formation of the Sun.

Open ended.

25. A meteor is visible only once, but a comet may be visible at regular intervals throughout its lifetime. Why?

A comet continually orbits the sun.

26. Explain the connection between meteor showers and comets.

Meteor showers often occur when Earth passes through a stream of particles left behind by an orbiting comet.

27. Why are the inner planets rocky while the outer planets are gaseous?

The essential reason is the relative proximity of the inner planets to the Sun. Distance from the Sun deter-mines the temperature differences of the planets, which in turn accounts for differences in the planets chemical composition. The inner planets consist of materials that stay solid at the higher temperatures found nearest the Sun. The outer planets consist largely of hydrogen and helium gases that cohere under the influence of gravity in regions distant from the Sun, where gas pressure is lowered because the ther-mal energy of the gases is lower.

28. Chances are about 50/50 that, in any night sky, there is at least one visible comet that has not been discovered. This keeps amateur astronomers busy looking, night after night, because the discoverer of a comet receives the honor of having it named for him or her. With this high probability of comets being visible in the sky, why aren't more of them found?

Quite simply, the sky is big. A far-away comet occupies a pinpoint in the sky, and there are oodles of pinpoints!

Solutions to Chapter 27 Problems

1. How many Earth diameters fit between the Earth and the Moon?

The mean distance from the Earth to the Sun is defined as 1 AU 1.5 10^{8} km. From Table 27.1, the diameter of the Earth is 12,760 km. So the number of Earth diameters between the Earth and the Sun is

1.5 10^8 km/1.276 10^4 km 11,800. So, about 12,000 Earths would fit in the distance between Earth and Sun.

2. What is the diameter of the Earth–Moon system?

The diameter of the Earth–Moon system is twice the mean distance from Earth to the Moon, or (2)(384,401 km) 768,802 km. Note that the distance from the Earth to the Moon is stated in the Math Connection feature: *The Scale of the Solar System*.

3. To send a radio signal from Earth to Saturn, show that it would take about 71 minutes to arrive there. Then show that it would take about 321 minutes for a radio signal from Earth to reach Pluto.

Radio signals travel at the speed of light, 3 10^8 m/s 3 10^5 km/s. From Table 27.1, the distance from the Sun to Saturn is 9.54 AU so the distance from Saturn to the Earth is 9.54 AU 1 AU

8.54 AU. Convert this to kilometers: 8.54 AU (1.5 10^8 km/AU) 1.28 10^9 km. Using the dis-tance formula, we have *t* *d/r* (1.28 10^9 km)/(3 10^5 km/s) 0.4267 10^4 s 1.19 h or about 71 minutes. A similar calculation shows that the time required for the radio signal to reach Pluto is 5.4 h or about 321 minutes.

4. Show that it takes 8.3 minutes for visible light from the Sun to reach Earth. Infra-red radiation? Ultraviolet radiation?

The distance from the Sun to the Earth 1 AU 1.5 10^8 km. The distance formula shows that the time of travel for the radiation (whether in the IR, visible, or UV range) is *t* *d/r* (1.5 10^8 km)/ 3 (10^5 km/s) 500 s 8.33 minutes.

Chapter 28: The Universe

Answers to Chapter 28 Review

Questions

1 Groups of stars.
2 Seasonal variation of constellations is due to the fact that the night-side of the Earth faces different parts of the universe as it orbits the Sun; diurnal motion is a consequence of the daily rotation of the earth on its axis.
3 A light-year is a measurement distance.
4 Its temperature.
5 To avoid confusing brightness with energy output.
6. A plot of the luminosity vs. surface temperature of stars.
5 The main sequence.
5 Main sequence; red giants, supergiants, white dwarfs.
5 Thermonuclear fusion.
5 (a) Thermal pressure, (b) gravity, (c) outward thermal pressure balances inward gravitational pressure so that the star's size and mass stabilize.
5 Massive stars consume their fuel so fast that they die billions of years younger than smaller stars.
5 What will happen to the Sun in its old age? The supply of hydrogen fuel will diminish, the burned-out hydrogen core will contract due to gravity, its temperature will rise and launch *helium burning*—the fusion of helium to carbon—helium will fuse to carbon at the center, while hydrogen fuses to helium in a surrounding shell, energy output will soar, moving the Sun off the main sequence to become a red giant, carbon ash collects in its core, the Sun turns blue and moves to the left in the H-R diagram, the Sun will cease producing energy, become a planetary nebula, and finally a white dwarf.

5 No possibility of energy coming from fusion in an iron core.
5 A black hole is the remains of a supergiant star that has collapsed into itself.
5 Because a black hole is so dense and has such an intense gravitational field.
5 Spiral galaxy.
5 Galaxy clusters appear to be part of even larger clusters, the galaxy super clusters.
5 The beginning of both space and time for our universe.
5 The observed Doppler shift (red shift) of light emitted by stars shows that they are receding from Earth. The fact that all stars appear to be receding indicates the universe is expanding.
5 Hubble's Law: $v \;\; H \;\; d$ states that the universe is expanding at an accelerating rate and that it began at a certain point in time 8–16 billion years ago.
5 Particle accelerators are used to generate ultra high-speed collisions simulating conditions right after the Big Bang.
5 Perhaps, quasars are the cores of very distant spiral galaxies.
5 Current speculation is that quasars may be gigantic black holes that pull enormous amounts of material toward them. The resulting collisions may liberate the energy that characterizes quasars.

Answers to Chapter 28 Multiple-Choice Questions

1b, 2a, 3d, 4a, 5c, 6b, 7d, 8c

Answers to Chapter 28 Integrated Science Concepts

Physics: Radiation Curves of Stars

1 The hotter a star is, the shorter the wavelength of its peak frequency.
2 They are different temperatures.

Biology: The Search for Extraterrestrial Life

1 The SETI (Search for Extraterrestrial Intelligence) program is an effort to locate evidence of past or
present communicative civilizations in the universe, particularly within our own galaxy.

2 It would increase the value of F_l , the fraction of Earth-like planets where life develops by 1. This would, in turn, increase the all-important value of N, the number of civilizations with which we could possibly communicate.
3 Answers will vary.

Answers to Chapter 28 Exercises

1. Thomas Carlyle wrote, "Why did not somebody teach me the constellations and make me at home in the starry heavens, which are always overhead and which I don't half know to this day?" What besides the names of the constellations did Thomas Carlyle not know?

   He didn't know that the constellations are not always overhead in the sky, but vary with the Earth's motion around the Sun.

2. Why do we not see stars in the daytime?

   Stars aren't seen in daytime because their relatively dim light is overwhelmed by skylight.

3. Which figure in the chapter best shows that a constellation seen in the background of a solar eclipse is one that will be seen 6 months later in the night sky?

   Figure 28.2, which shows that the background of a solar eclipse is the nighttime sky normally viewed 6 months earlier or later.

4. We see the constellations as distinct groups of stars. Discuss why they would look entirely different from some other location in the universe, far distant from Earth.

Both near and faraway stars appear as if on the inner surface of one great sphere, with us at the center. Two stars that appear very close together are on the same line of sight, but may actually be an enormous distance apart, and would not appear close together at all when viewed from the side. Astronomers distinguish between double stars and binary stars. Double stars are on the same line of sight, yet are actually far apart. Binaries are stars that are both on the same line of sight and are in close interaction.

5. In what sense are we all made of stardust?

The nuclei of atoms that compose our bodies were once parts of stars. All nuclei beyond iron in atomic number were in fact manufactured in supernovae.

6. How is the gold in your mother's ring evidence of the existence of ancient stars that ran through their life cycles long before the solar system came into being?

The gold in any ring was made in the death throes of stars during supernovae explosions.

7. Would you expect metals to be more abundant in old stars or in new stars? Defend your answer.

Because all the heavy elements are manufactured in supernovae, the newer the star, the greater percentage of heavy elements available for its construction. Very old stars were made when heavy elements were less abundant.

8. Why is there a lower limit on the mass of a star? Why is there an upper limit to the mass of a star?

Too low a mass, and gravitational pressure in the inner core is insufficient to provoke thermonuclear fusion. No fusion, no star. There is an upper limit because stars with masses above 100 times the Sun's mass would undergo such furious nuclear fusion that gravity could not keep them collected—they would explode.

9. What keeps a main-sequence star from collapsing?

Thermonuclear fusion reactions produce an outward pressure that counteracts the inward pressure that would lead to collapse due to gravity.

10. How does the energy of a protostar differ from the energy that powers a star?

A protostar is not yet a star, and is made up of an aggregation of matter many times more massive than the Sun and much larger in size than the solar system. While a protostar derives its energy from the gravi-tational force acting on its particles, stars derive their energy principally through nuclear fission and fusion.

11. Why do nuclear fusion reactions not occur on the outer layers of stars?

Thermonuclear fusion is caused by gravitational pressure, wherein hydrogen nuclei are squashed

together. Gravitational pressures in the outer layers are insufficient to produce fusion.

12. Why are massive stars generally shorter lived than low-mass stars?

Massive stars burn at a greater rate and are the first to burn out.

13. With respect to stellar evolution, what is meant by the statement, "The bigger they are, the harder they fall"?

Bigger stars live faster, and collapse more energetically when they burn out.

14. Why will the Sun not be able to fuse carbon nuclei in its core?

There is insufficient gravitational pressure within the Sun to initiate carbon fusion, which requires greater squashing than hydrogen to fuse.

15. Some stars contain fewer heavy elements than our Sun contains. What does this indicate about the age of such stars relative to the age of our Sun?

Stars with fewer heavier elements formed at an earlier time than the Sun.

16. Which has the highest surface temperature: a red star, a white star, or a blue star?

Blue stars are hottest, red stars are coolest. White hot stars have surface temperatures in between.

17. A black hole is no more massive than the star from which it collapsed. Why, then, is gravitation so intense near a black hole?

You are simply closer to the center of gravity of the star, in accord with Newton's law of gravitation.

18. If the nucleus of our galaxy undergoes a gigantic explosion at this very moment, should we be concerned about its possible effects on us during our lifetime? Defend your answer.

The center of our galaxy is some 25,000 light years distant. An explosion there would take at least 25,000 years to reach the solar system. So no, we'd not notice any effect in our finite lifetimes.

19. Are there galaxies other than the Milky Way that can be seen with the unaided eye? Discuss.

Yes, the central bulge of the Andromeda Galaxy, which covers an area about five times that of the full moon, can be seen with the naked eye on a clear night. The Magellanic clouds are two galaxies visible to the naked eye in the Southern Hemisphere.

20. Quasars are the most distinct objects we know of in the universe. Why do we therefore say their existence goes back to the earliest times in the universe?

Because they are the most distant stellar objects detected—since the universe is expanding, the most distant objects are the oldest.

21. What is meant by saying that the universe does not exist in space? Change two words around to make the statement agree with the standard model of the universe.

Space exists in the universe, not the other way around.

22. Why are the long-wavelength microwaves that permeate the universe considered to be evidence of the Big Bang?

Radiation at the time of the Big Bang has been bouncing to and fro in the expanding universe, stretching out just as sound waves bouncing from a receding wall stretch out. The amount of stretch conforms to the Big Bang event some 15 billion years ago.

23. In your own opinion, do you have to be at the center of your class to be special? Does Earth have to be at the center of the universe to be special?

Both you and the Earth don't have to occupy a central location to be special. The Earth is certainly special among planets in the solar system in that it is the only one with abundant water and an atmosphere—and us.

24. How is the universe like a lump of rising raisin-bread dough?

The raisin-bread dough analogy is a popular conceptual model of the universe, because both expand outward, with the distance between points (stars or raisins) continually increasing. This is much like the ants-on-a-balloon model used in the text.

25. Why does the Big Dipper change its position in the night sky over the course of the evening but Polaris remains relatively fixed in its position?

Polaris lies on the axis of Earth's rotation, other stars do not. As Earth revolves on its axis, the celestial sphere seems to rotate.

26. Explain why, in terms of the life cycle of the Sun, Earth cannot last forever.

It will eventually consume its nuclear fuel and no longer be able to undergo thermonuclear fusion.

27. Elements heavier than iron are created in stars—are they formed in the same way as elements lighter than iron? Explain.

Elements heavier than iron are created by high-mass stars that supernova while elements lighter than iron are created by fusion in low- and medium-mass stars.

28. Will the Sun become a supernova? A black hole? Defend your answer.

The Sun has too little mass to become a supernova and therefore too little mass to become a black hole. Instead it will become a white dwarf.

29. What property of a star relates to the amount of energy it is producing?

Brightness relates to how much energy a star is producing.

30. How are neutrons and pulsars related to one another?

A pulsar *is* a neutron star—one that sends detectable pulses of radiation to Earth.

31. Why did ancient cultures study the constellations?

For some cultures, study of the constellations involved storytelling; to other cultures, they served as navigational aids for travelers and sailors; to other cultures, the constellations provided a guide for the planting and harvesting of crops, because constellations were seen to move in the sky in concert with the seasons.

32. Write a letter to Grandma telling her why we think the universe is 13.7 billion years old.

Letters to Grandma should discuss how Hubble's law can be used to determine the time of the Big Bang.

Solutions to Chapter 28 Problems

1. Suppose Star A is four times as luminous as Star B. If these stars are both 500 light years away from Earth, how will their apparent brightness compare? How will the apparent brightness of these stars compare if Star A is twice as far away as Star B?

If these stars were the same distance from Earth, apparent brightness would depend just on luminosity, and Star A appears four times as bright as Star B. However, if Star A were twice as far away as Star B, the stars would have equal apparent brightness, because apparent brightness is related to distance through the inverse-square law.

2. The brightest star in the sky, Sirius, is about 8 light-years from Earth. Show that if you could somehow travel there at jet-plane speed, 2000 kilometers per hour, the trip would take about 4.3 million years.

Use the distance formula: distance speed time and rearrange to solve for time: *t* *d*/*s*

(8 LY)/(2000 km/hr) $\frac{(8)(9.46 : 10^{12}\text{ km})}{2 : 10^{3}\text{ km/hr}}$ **3.8 : 10^{10} hr and**

1 day 1 yr

(3.8 : **10^{10} hr)**a ba b **4.3** : **10^{6} years**

24 hrs **365 days**