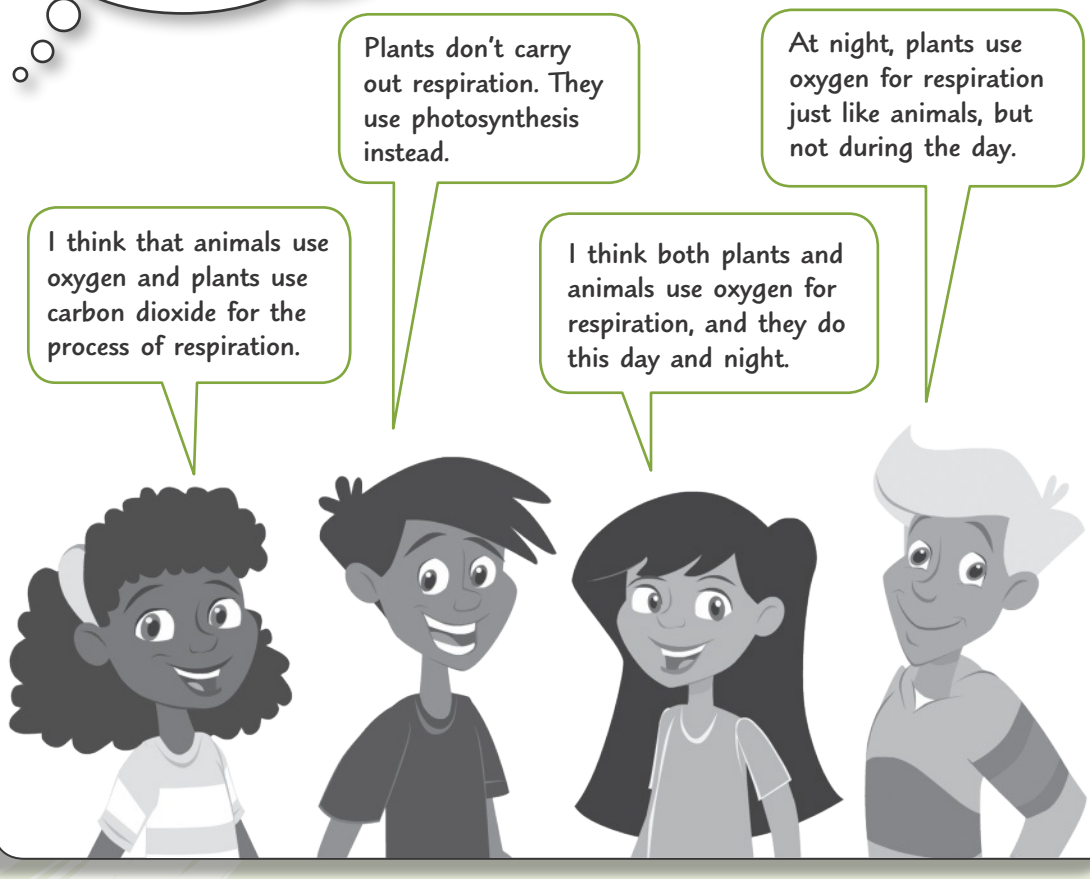
Homeostasis in Organisms

TOPIC 2

What do You Think?

Respiration and Photosynthesis



TOPIC 2

Homeostasis in Organisms

Vocabulary

AIDS
allergy
antibiotics
antibodies
antigen
ATP
bacteria
biochemical processes
catalyst
cellular respiration
chloroplast
disease
dynamic equilibrium
enzyme
feedback mechanism
fungi
gas exchange
glucose
guard cells
homeostasis
immune system
insulin
microbe
mitochondria
pancreas
parasite
pathogen
pH
photosynthesis
respiration
stimuli
synthesis
vaccine
virus

Topic Overview

All living things—from the simplest single-celled bacteria to the most complex multicellular animals—are organized biological systems. To stay alive, all organisms must keep their biological systems stable even though they live in a changing, and sometimes life-threatening, environment. To maintain this stability, organisms continually monitor and respond to changes in the environment. The internal stability that organisms maintain is known as **homeostasis.**

Homeostasis is the maintenance of internal conditions within a narrow range that varies only slightly over time. For example, your body temperature must stay within a specific temperature range (approximately 98.6°F, or 37°C) for you to survive. If you become too hot or too cold, the biochemical processes that keep you alive will begin to fail.

Digging Deeper

Homeostasis sometimes appears with the words *dynamic equilibrium* or *steady state*. These terms all involve the idea of "a constant balance." To picture this concept, it may help to think of a child learning to balance a bicycle. There may be some wobbling back and forth, but generally the rider remains upright.

Basic Biochemical Processes of Living Organisms

Biochemical processes are the chemical processes that occur in living things. All organisms need both energy and raw materials (atoms and molecules) to carry on the internal biochemical processes that are essential for their survival. Two of these enzyme-controlled biochemical processes are photosynthesis and respiration. **Photosynthesis** is the process by which energy is stored in chemical bonds of organic molecules such as carbohydrates. Plants, algae, and many single-celled organisms carry out photosynthesis. Recall that **respiration** is the process by which chemical energy stored in nutrients is released for use in cells. All living organisms carry out respiration.

Storing Energy: Photosynthesis

The energy for life comes primarily from the sun. In Figure 2-1, notice that photosynthesis is the connection between the energy released by the sun and the energy available to living systems.

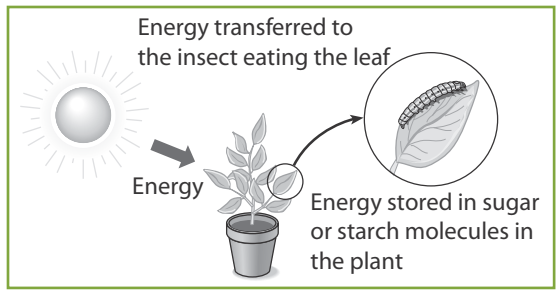


Figure 2-1. Energy transfer: The sun provides energy for most of the life on Earth.

The cells of organisms that carry out photosynthesis contain light-capturing molecules. In plant cells, these molecules are located in the **chloroplasts,** which are green-colored organelles where photosynthesis occurs. In Figure 2-2, the chloroplasts are the oval structures. You may have seen these green structures on microscope slides of cells prepared from plant leaves.

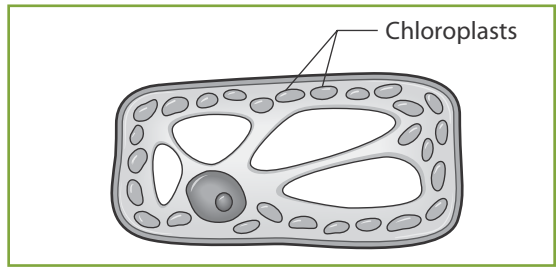


Figure 2-2. Chloroplasts in a typical plant cell: The chloroplasts capture light energy.

All plants, algae, and many one-celled organisms use solar energy to convert inorganic molecules (carbon dioxide and water) into any one of several energy-rich organic compounds. One such organic compound is the sugar **glucose**—a simple carbohydrate.

In the chemical reaction shown in Figure 2-3, notice that water and carbon dioxide from the environment are combined to make glucose. Oxygen gas, which is also formed in the process, is released into the environment.

light energy + water + carbon dioxide ⟶ glucose + oxygen

light energy + 6 H_2O + 6 CO_2 ⟶ $C_6H_{12}O_6$ + 6 O_2

Figure 2-3. Photosynthesis

What Happens to the Sugar Produced by Photosynthesis? Plant cells use the organic compounds (such as glucose) from photosynthesis in two ways. Their primary use is to generate ATP molecules during **cellular respiration,** which is the process of releasing the energy in chemical bonds. Glucose is also used as a raw material for building more complex molecules, such as those listed in Table 2-1.

Using Glucose to Produce ATP Molecules One way plants (and animals) use glucose is to generate high energy molecules known as **ATP.** This process occurs during cellular respiration. Energy stored in the chemical bonds of ATP molecules is the energy source for almost all life processes from obtaining, transforming, and transporting materials to eliminating wastes. Because cell processes actually "run" on ATP (rather than glucose), the transfer of energy from glucose to ATP is essential to both plants and the

Table 2-1. Complex Molecules and Their Functions

Molecule	Function
ATP	Supplies energy for cells to run on
DNA	Carries hereditary information
Carbohydrates	Acts as a food reserve molecule
Lipids (fats and oils)	Acts as a food reserve molecule
Protein	Makes up enzymes and many cell parts

MemoryJogger

Although glucose is the product of photosynthesis that is most frequently used in textbook examples, photosynthesis actually produces a variety of organic compounds.

organisms that consume them. All organisms—not just plants and animals—use organic food compounds to supply the ATP energy they need to live.

Using Glucose to Build Complex Molecules Cells also use glucose as the starting point for **synthesis** (chemical combining) that forms complex organic compounds. For example, plants store much of the glucose from photosynthesis as starch. Table 2-1 provides some examples of complex molecules and how they are used.

When animals eat plants or other animals, they digest the complex molecules into simpler molecules for their own cells to use. Some of these molecules provide energy for the organism. For example, starches from plants and fats from animals can both be digested and used right away for energy. If they are not all needed for energy, the molecules can be stored as fat to provide a food reserve for the animal.

Table 2-2. Summary of Photosynthesis

Energy	The energy comes from sunlight as solar energy and ends up in glucose molecules as chemical bond energy.
Materials used	Carbon dioxide gas and water are used; both molecules come from the environment.
Materials produced	Molecules made from the carbon dioxide and water include molecules of the sugar glucose (a simple carbohydrate) and oxygen gas. Oxygen is actually released as a byproduct of photosynthesis.
Time frame	Photosynthesis occurs in plant cells when light is available, which is generally during the daytime.
Location	Photosynthesis occurs in the chloroplasts of plant cells, algae, and some one-celled organisms when they are exposed to light.
Importance of photosynthesis	Organisms either (1) use glucose to synthesize other molecules they need or (2) break down the glucose to release its stored energy.
Relationship to respiration	The energy originally stored in glucose during photosynthesis is transferred to the chemical bonds of ATP. All cells "run" on the energy released from ATP.

Review Questions — Set 2.1

1. In a plant cell, the synthesis of sugar compounds from inorganic raw materials occurs in the

(1) cell membrane
(2) mitochondria
(3) nucleus
(4) chloroplasts

2. Which word equation represents the process of photosynthesis?

(1) glucose → alcohol + carbon dioxide
(2) carbon dioxide + water → glucose + oxygen
(3) chlorophyll + water → glucose + alcohol
(4) glucose + oxygen → carbon dioxide + water

3. Which factor *least* influences the rate of photosynthesis?

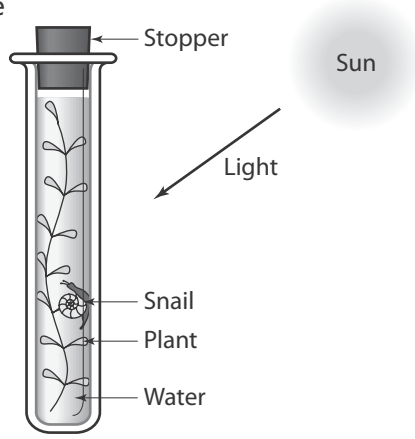
(1) atmospheric concentration of carbon dioxide
(2) time of day
(3) number of chloroplasts
(4) concentration of nitrogen in the air

4. The basic raw materials of photosynthesis are

(1) sugar and carbon dioxide
(2) oxygen and water
(3) water and carbon dioxide
(4) oxygen and sugar

5. Which compound is formed as a common product of the process of photosynthesis?
   (1) DNA
   (2) sugar
   (3) chlorophyll
   (4) carbon dioxide

6. In the test tube shown, what is produced by the snail that is used by the plant?
   (1) oxygen
   (2) carbon dioxide
   (3) food
   (4) egg cells



7. Which activity occurs during the process of photosynthesis?
   (1) Chemical energy from organic molecules is converted into light energy
   (2) Organic molecules are absorbed from the environment.
   (3) Organic molecules are converted into inorganic food molecules.
   (4) Light energy is stored as chemical energy in organic molecules.

8. Photosynthesis in plants requires chloroplasts and light energy.
   - Identify two raw materials plants also use in this process [1]
   - Explain why these two substances are needed [1]

Releasing Energy: Cell Respiration

All living things need energy to stay alive. Before the energy in the bonds of complex carbohydrates, such as starch, can be used, the molecules must be broken down (digested) into simpler ones, such as glucose.

Then, the glucose (or other simple molecules) must be broken down further. This process involves a series of chemical reactions controlled by **enzymes,** which are special proteins that affect the rate of chemical reactions.

In the final step, the chemical bonds of the glucose molecule are broken, and the energy in those bonds is released. This process of releasing the energy in chemical bonds is called cellular respiration.

In many organisms, cellular respiration requires oxygen, which must be brought into the organism from the environment. Obtaining oxygen from the environment and releasing carbon dioxide is called **gas exchange.**

During cellular respiration, cells capture much of the energy that is released from the glucose bonds. The captured energy is then used to form new bonds in high-energy molecules known as ATP. Figure 2-4 shows how ATP temporarily stores energy. Most of the energy that the cell fails to capture to make ATP is lost to the environment as heat.

MemoryJogger

Sometimes people use the term *respiration* when they really mean *breathing. Respiration* is the process that involves oxygen and breaks down food molecules to release energy. *Cellular respiration* refers specifically to the transfer of energy from simple organic molecules like glucose to ATP molecules within cells.

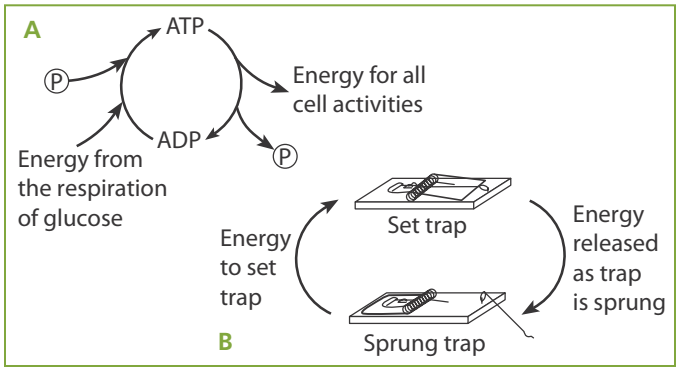


Figure 2-4. Energy storage in ATP molecules: (A) Chemical energy from the breakdown of glucose molecules is used to attach a phosphate (P) to a molecule of ADP. The result is called ATP. When the cell needs energy, the ATP is broken down into ADP. During that process, the phosphate (P), along with the energy that was stored in its chemical bond, is released. (B) A similar form of temporary energy storage occurs when a mousetrap is set. The mechanical energy that is put into the act of setting the trap is stored in the spring. When the trap is sprung, that energy is released.

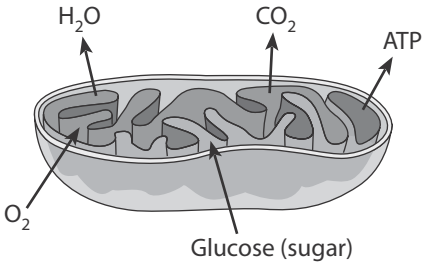


Figure 2-5. Cellular respiration in a mitochondrion: Partially broken down glucose molecules and oxygen (O_2) enter the organelle and are rearranged, with the help of enzymes. Water (H_2O) and carbon dioxide (CO_2) are released as waste products. The energy that was stored in the glucose is transferred to ATP molecules.

Cellular respiration in many organisms is completed in organelles called **mitochondria.** (See Figure 2-5.) Mitochondria are common in animal cells. Cells that require more energy contain more mitochondria. For example, muscles require more energy to complete their functions than skin cells do. Muscle cells usually contain mitochondria, which corresponds with their increased energy needs.

As they generate ATP, mitochondria release carbon dioxide and water molecules that come from fragments of molecules that were involved in the reactions. Most cellular processes use ATP as a direct source of energy. Basically, cells "run" on ATP.

Table 2-3. Summary of Cellular Respiration

Energy	Comes from the chemical bond energy of glucose molecules; ends up in the bonds of ATP where it can be utilized for cell activities
Materials used	Sugar or other energy-rich organic food compounds and oxygen gas from the environment • Food is obtained through photosynthesis in producers and by feeding in consumers. • Oxygen is obtained through gas exchange.
Materials produced	ATP molecules and two waste products— carbon dioxide gas and water. The release of carbon dioxide into the environment is part of the process of gas exchange.
Time frame	Cellular respiration occurs in all cells (including plant cells) 24 hours a day.
Location	Respiration occurs in the cells of all living things. In most organisms, cellular respiration is concluded in mitochondria.
Importance of respiration	All cells "run" on the energy released from ATP. Organisms can use the ATP they make as the source of energy to help them obtain raw materials and nutrients, to transform materials in chemical reactions, to transport materials (for example, active transport), and to eliminate wastes. ATP is essential for metabolic processes. The energy is also used to allow the organism to grow and to move from one place to another.

Digging Deeper

The D in ADP is for **Di**phosphate, or two phosphates. The T in ATP is for **Tri**phosphate, or three phosphates. ADP and ATP are converted back and forth as a phosphate is added or removed.

$$ADP + P = ATP$$
$$ATP - P = ADP$$

Review Questions Set 2.2

9. Energy for use in cells is stored in the form of
(1) chemical bond energy
(2) physical energy
(3) heat energy
(4) mechanical energy

10. In which process do organisms transfer the chemical bond energy in organic molecules to ATP molecules?
(1) excretion
(2) cellular respiration
(3) autotrophic nutrition
(4) photosynthesis

11. Energy released from the cellular respiration of glucose is
(1) first stored within ATP
(2) stored in the liver as fat
(3) turned into fat
(4) used directly for body activity

12. The process during which energy is released from digested foods is called
(1) cellular respiration
(2) chemical digestion
(3) photosynthesis
(4) excretion

13. As a direct result of the life process called cellular respiration in humans,

(1) liquid wastes are eliminated from the body
(2) food is digested and absorbed into the blood
(3) energy is released from digested food within the cells
(4) nutrients are transported within the cells

14. Which process involves the transfer of energy from carbohydrates to ATP molecules?

(1) photosynthesis (3) digestion
(2) respiration (4) circulation

15. During respiration, the energy within the bonds of a glucose molecule is released in small amounts in a step-by-step, enzyme-controlled reaction. In this process, the energy released is used to

(1) synthesize ATP
(2) control the process of diffusion
(3) synthesize more glucose
(4) produce oxygen molecules

16. Which statement best describes one of the events taking place in the chemical reaction represented below?

$$H_2O + ATP \xrightarrow{\text{enzymes}} ADP + P + \text{energy}$$

(1) Energy is being stored as a result of cellular respiration.
(2) Energy is being released for metabolic processes.
(3) Decomposition is taking place, resulting in the synthesis of ATP.
(4) Photosynthesis is taking place, resulting in the storage of energy.

17. Compare photosynthesis and respiration with regard to each of the following:

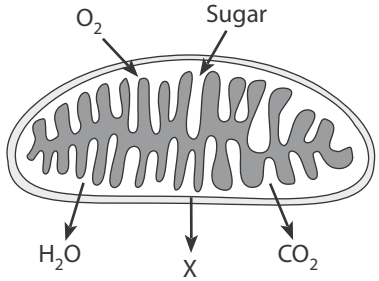
- source of energy [1]
- materials used by each process [1]
- location of each process in the cell [1]
- when each process occurs in plants and animals [1]

18. Which statement most accurately describes the process of respiration?

(1) It occurs only in plants during the daylight hours and usually involves the exchange of gases.
(2) It occurs only in plants during the daylight hours and involves the taking in of preformed organic molecules.
(3) It occurs continuously in the cells of all organisms and involves the synthesis of carbohydrate molecules.
(4) It occurs continuously in the cells of all organisms and often involves an exchange of gases.

19. During daylight hours green plants carry out photosynthesis. Do they also carry out respiration at this time? Support your answer. [1]

Base your answers to questions 20 through 22 on the diagram of a mitochondrion below and on your knowledge of biology.



20. The process represented in this diagram is

(1) respiration (3) photosynthesis
(2) coordination (4) immunity

21. What term would most appropriately be represented by the "X"?

(1) ATP (3) antibodies
(2) chlorophyll (4) glucose

22. What is present within the mitochondrion that allows the reaction to occur?

(1) enzymes (3) bacteria
(2) chlorophyll (4) carbon dioxide

Enzymes

A **catalyst** is any substance that can affect the rate of a chemical reaction without itself being changed or used up during the reaction. Because it is neither changed nor used up, the catalyst is capable of carrying out the same function again and again. Protein catalysts known as enzymes affect the chemical reactions in living things.

The Function of Enzymes Biochemical processes, such as digestion (breakdown), synthesis (building up), cellular respiration (energy release),

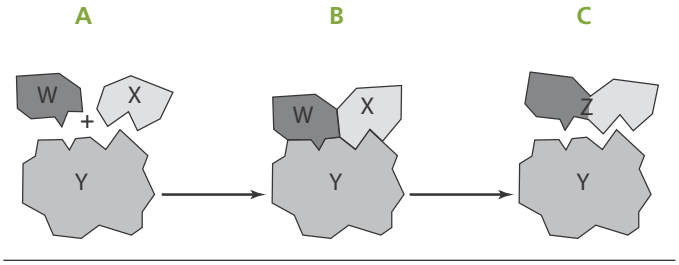


Figure 2-6. Enzymes interact with specific molecules: Enzyme interactions are determined by molecular shape. After the two molecules W and X collide with enzyme Y (A), the enzyme forms a temporary physical connection with them (B) and then separates after a reaction has occurred (C). As a result, the molecules W and X have chemically bonded for the synthesis of the new molecule Z. If the arrows in the illustration were reversed, the reaction would involve splitting molecule Z into two smaller molecules, W and X. This reverse process is digestion.

and photosynthesis (energy capture), are made possible in living things by enzymes.

All living organisms contain enzymes. Enzymes interact with other molecules when they collide. Chemical reactions in living organisms are regulated by many different enzymes that function best at whatever the normal "body" temperature is for the organism.

Importance of Molecular Shape Enzymes and several other molecules, such as hormones, antibodies, and receptor molecules on cell membranes, have specific shapes that influence both how they function and how they interact with other molecules. Many enzymes will interact with some substances, but not others. The enzyme salivary amylase, for example, acts on starches but not proteins. In Figure 2-6, notice how the shapes of W, X, and Y fit together precisely. If the shape of an enzyme is altered, it will not interact with other molecules the way it must to catalyze a reaction, and its function will be impaired.

Enzyme Reaction Rates

Several conditions, such as shape, temperature, and pH, can either speed up or slow down the rate of enzyme action.

Shape Enzymes are chain-like protein molecules that are folded into precise shapes. Each enzyme must have a specific shape to work correctly, and anything that alters that shape will affect the enzyme's ability to function properly. High temperatures and strong acids or bases can change the enzyme's shape either temporarily or permanently. When this happens, the enzyme cannot function, and the reaction rate will decrease in proportion to the number of enzyme molecules that are altered.

Temperature Most enzymes have an optimum temperature at which they function most efficiently and produce the highest reaction rate. For human enzymes, this temperature is typically 98.6°F (37°C). As the temperature of a cell or organism reaches its optimum level, enzymes and the molecules they are interacting with will move faster and collide more often, causing the reaction rate to increase. Beyond the optimum temperature, the rate falls rapidly because the fragile enzyme molecules begin to change shape or break apart. Trace the rise and fall of an enzyme reaction rate in Figure 2-7.

pH The **pH** of a substance is a measure of whether a substance is acidic, neutral, or basic. Placing enzymes in solutions of varying pH values affects their activity. Many enzymes work best in an optimum pH of about 7, which is neutral. This makes sense, since most body fluids and cells maintain a pH of near 7. However, some parts of organisms have typical pH values that are far from neutral. For example, the human stomach is acidic and has a pH of 2 or 3. The small intestine has a pH around 8. Enzymes in these locations typically have optimum rates that correspond to the pH of their environment, as shown in Figure 2-8.

MemoryJogger

A pH of about 7 is neutral, the same as pure water. A low pH, such as 1 or 2, indicates a strong acid. A high pH, such as 13 or 14, indicates a strong base. In a typical high school biology laboratory, pH is measured with pH paper treated with various indicator dyes.

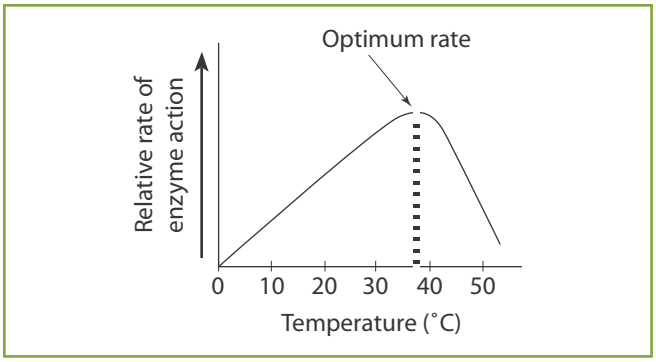


Figure 2-7. Enzymes and temperature: Note that the rate of enzyme action is fastest at about 37°C, which is typical of a human enzyme. The reason the rate declines so quickly beyond the optimum is that the higher temperature alters the shape of the enzyme. In this example, by the time the temperature reaches 55°C, all the enzyme molecules have been altered, and as a result, they no longer function.

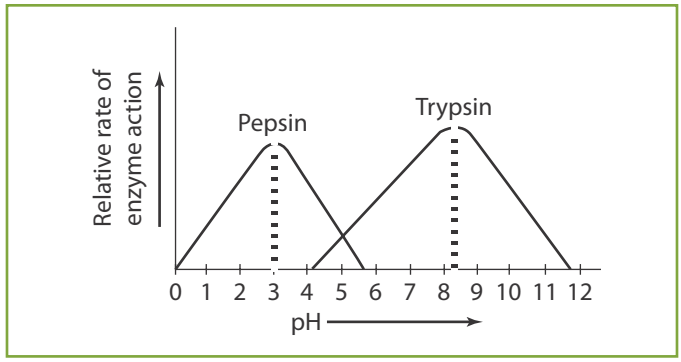


Figure 2-8. Enzymes and pH: Pepsin is found in the human stomach and has a pH that matches the acid environment found there. Trypsin is an enzyme located in the small intestine where the pH is close to 8. Notice that each enzyme is less effective if the pH is either raised or lowered from its optimum point.

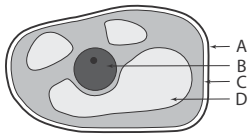
Review Questions — Set 2.3

23. Only small amounts of enzymes are required for reactions within cells because enzymes are

(1) fragile
(2) reused
(3) small molecules
(4) constantly synthesized

24. Which cell organelle indicated in the diagram below controls the synthesis of enzymes?

(1) A
(2) B
(3) C
(4) D



25. In order to survive, all organisms must carry out

(1) autotrophic nutrition
(2) heterotrophic nutrition
(3) enzyme-controlled reactions
(4) the process of reproduction

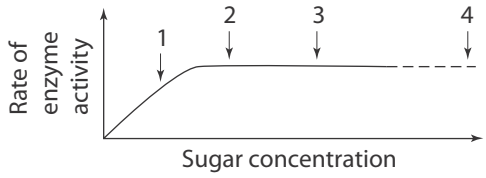
26. Which group of organic compounds includes the enzymes?

(1) proteins
(2) carbohydrates
(3) sugars
(4) fats

27. Luciferin is a molecule that, when broken down in fireflies, produces heat and light. The rate at which luciferin is broken down in cells is controlled by

(1) a carbohydrate
(2) a simple sugar
(3) an enzyme
(4) a complex fat

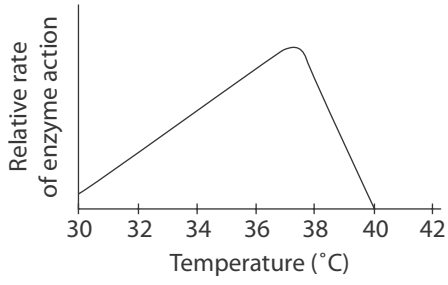
28. At which point on the graph below can the rate of enzyme activity be increased by increasing the concentration of sugar molecules?



(Enzyme concentration constant)

(1) 1
(2) 2
(3) 3
(4) either 2, 3, or 4

29. Which statement best describes the relationship between enzyme action and temperature shown in the graph below?

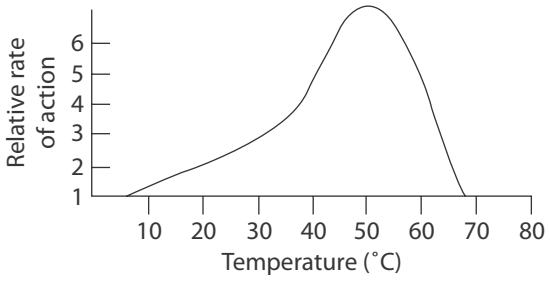


(1) Enzyme synthesis begins at 30°C.
(2) Enzyme activity constantly increases with increasing temperature.
(3) The pH has a greater effect on this enzyme than temperature does.
(4) Enzyme activity increases as the temperature increases from 32°C to 34°C.

30. The enzyme salivary amylase will act on starch but not on protein. This action illustrates that salivary amylase

(1) contains starch
(2) is chemically specific
(3) is not reusable
(4) lacks protein

31. The graph below shows the effect of temperature on the relative rate of action of enzyme X on a protein.



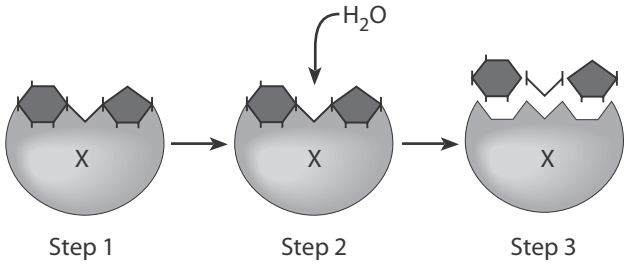
Which change would not affect the relative rate of action of enzyme X?

(1) the addition of cold water when the reaction is at 50°C
(2) an increase in temperature from 70°C to 80°C
(3) the removal of the protein when the reaction is at 30°C
(4) a decrease in temperature from 40°C to 10°C

32. Enzymes influence chemical reactions in living systems by

(1) becoming part of the product after the reactions occur
(2) combining with atmospheric gases to form waste products
(3) affecting the rate at which reactions occur
(4) absorbing water during synthesis and digestion

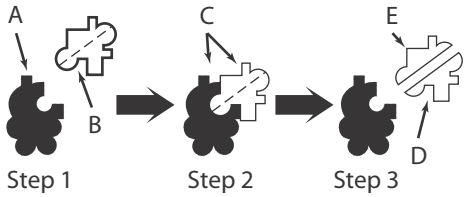
33. The diagram below represents three steps in the digestion of the sugar sucrose. In this diagram, structure X is most likely



(1) a molecule of oxygen
(2) the end product
(3) an enzyme molecule
(4) the sugar

Base your answers to questions 34 through 36 on the diagram of an enzyme-controlled reaction and on your knowledge of biology.

34. Explain what is happening during Steps 1-3 in the following diagram. Use the labels—A, B, C, D, and E—to help you with your explanation. As part of your answer, indicate which molecules represent the enzyme and the product.

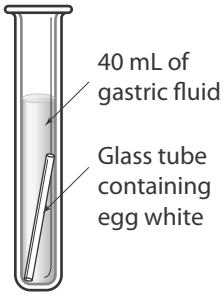


35. Is this reaction an illustration of synthesis or digestion? Support your answer. [1]

36. Explain why heating these molecules might *slow* the rate at which this reaction occurs? [1]

Base your answers to questions 37 through 41 on the diagram and data table below and on your knowledge of biology.

A student is studying the effect of temperature on the action of a protein-digesting enzyme that is contained in stomach fluid. An investigation is set up using five identical test tubes. Each test tube contains 40 milliliters of stomach fluid as well as a 20-millimeter glass tube filled with cooked egg white, as shown in the diagram. After 48 hours, the amount of egg white digested in each tube was measured. The data collected are shown in the following table.



Digestion at Different Temperatures

Tube	Temperature (°C)	Amount of Digestion After 48 Hours
1	4	0.0 mm
2	8	2.5 mm
3	21	4.0 mm
4	37	7.5 mm
5	100	0.0 mm

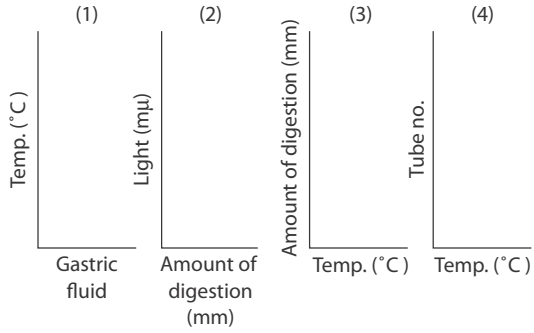
37. Identify the independent variable in this investigation.

(1) gastric fluid
(2) length of glass tubing
(3) temperature
(4) time

38. State the amount of digestion (in mm) that might be expected after 48 hours in a test tube that is identical to the other 5 test tubes, but at a temperature of 15°C.

(1) less than 2.5 mm
(2) between 2.5 and 4 mm
(3) between 4.0 and 7.5 mm
(4) more than 7.5 mm

39. The best graph of the results of this investigation would be made by plotting the data on which set of axes?



40. The student repeated this same experiment using a glass tube containing potato instead of egg white. After 48 hours, he found no evidence of any digestion.

Explain why no digestion occurred. [1]

41. During the winter, many fish eat very little. Some students thought this might be because less oxygen is dissolved in the cold winter water than in the same water during the warm summer months. The students tested the water and found that cold water holds more dissolved oxygen than warm water. They also discovered that the fish have nearly as much food available during the winter as in the summer.

Explain why the fish eat very little during the winter. [1]

Feedback and Homeostasis

Because an organism's external and internal environment is constantly changing, its homeostasis is constantly threatened. As a result, living things must monitor and respond to changes in the environment. Stability (homeostasis) results when the organism detects deviations (changes) in the environment and responds with an appropriate corrective action that returns the organism's systems to normal. If an organism's monitoring systems or control mechanisms fail, disease or even death can result.

As you go about your daily tasks, your body temperature readjusts, your heart and breathing rates alter slightly, and your blood flow increases or decreases. If your monitoring were to fail, these small adjustments would not be made. Soon, your body's homeostasis would begin to deteriorate. Under extreme conditions, you could become quite ill or even die. However, simple corrective actions usually take care of problems with your homeostasis and life goes on. Some examples of responses organisms have to changes they encounter are shown in Table 2-4.

Table 2-4. Responses to Environmental Change

Organism	Change (stimulus)	Response
Species of bacterium	Temperature falls below a certain point.	Bacterium produces a chemical that acts as an antifreeze.
Many plants	Air is hot and dry.	Leaf pores close to conserve water.
Monarch butterflies	Seasons change.	Butterflies migrate.
Human	Person hears a loud noise.	The person becomes alert; heart rate increases for "fight or flight."

Dynamic Equilibrium

Organisms have a variety of mechanisms that maintain the physical and chemical aspects of the internal environment within the narrow limits that are favorable for cell activities. The stability that results from these responses is called homeostasis or a "steady state." To many biologists, the phrase *steady state* suggests an

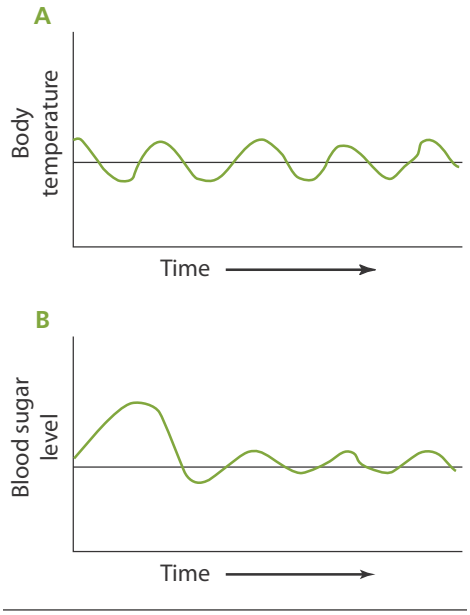


Figure 2-9. Dynamic equilibrium: (A) Temperature: Our body temperature shows a regular pattern of slight changes around a "normal" temperature of about 98.6°F (37°C). The graph represents the slight differences in temperature that are part of a daily cycle. Mechanisms such as shivering and sweating help maintain this range. (B) Blood sugar: Normal blood sugar levels show a rise in blood sugar after a meal, but blood sugar level is quickly restored to equilibrium as the hormone insulin prompts glucose to move from the blood to body cells.

unchanging condition. They prefer to use the term **dynamic equilibrium** to describe the constant small corrections that normally keep the internal environment within the limits needed for survival.

In Figure 2-9, notice that these small corrections include a normal range of variations. Certain microorganisms or diseases can interfere with dynamic equilibrium, and therefore with homeostasis. Organisms, including humans, have mechanisms to deal with such interference and restore the normal state. Homeostatic adjustments have their limits. They can operate only within certain set ranges.

Feedback Mechanisms

A **feedback mechanism** involves a cycle in which the output of a system "feeds back" to either modify or reinforce the action taken by the system. A variety of feedback mechanisms have evolved for helping organisms detect and respond to **stimuli** (changes in the environment). Multi-celled organisms detect and respond to change both at the cellular level and at the organism level. Their systems detect deviations from the normal state and take corrective actions to restore homeostasis.

Feedback responses can be simple or complex. A simple feedback response might involve a hormone that regulates a particular chemical process in a cell. A complex feedback response might be an elaborate behavior, such as bird migration.

Positive Feedback Feedback mechanisms can be either positive or negative. In positive feedback systems, a change prompts a response, which leads to a greater change and a greater response. Childbirth is an example of a positive feedback system. The first contractions push the baby's head against the base of the uterus, which causes stronger contractions in the muscles surrounding the uterus. This increases the pressure of the baby's head against the base of the uterus, which causes stronger contractions and so on. Eventually the baby is born, and the feedback cycle ends.

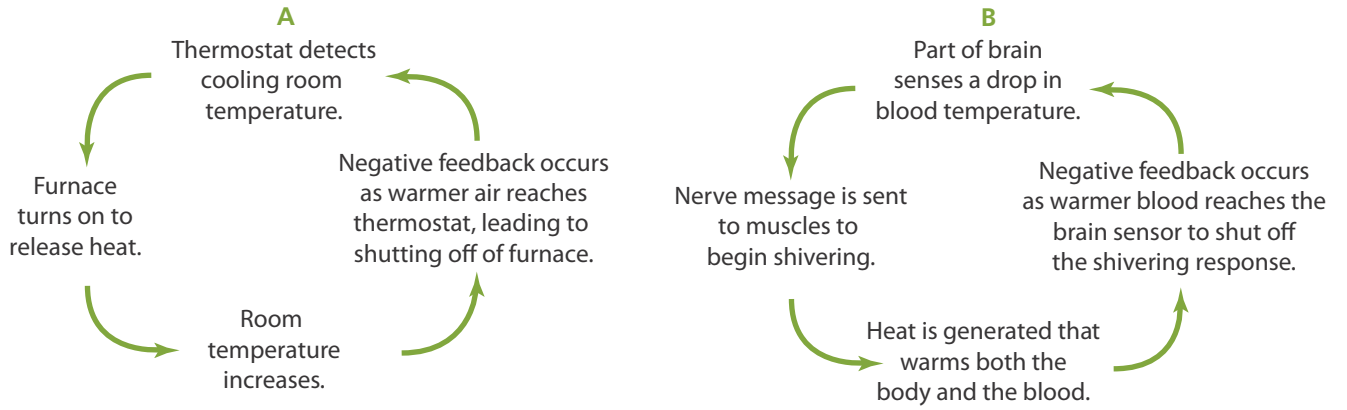


Figure 2-10. Negative feedback systems: (A) The furnace and thermostat in most houses are part of a negative feedback system. (B) Like the household heating system, the regulation of body temperature is a negative feedback system.

Negative Feedback Negative feedback systems are the most common. In this case, a change in the environment can prompt system 1 to send a message (often a hormone) to system 2, which responds by attempting to restore homeostasis. When system 1 detects that system 2 has acted, it stops signaling for further action.

A typical house heating system is an example of negative feedback. The furnace has a thermostat that is set to a specific temperature called the set point. When the room cools below the set point, the thermostat sends a message to turn on the furnace. When the room temperature rises above the set point, the thermostat stops sending the message, and the furnace shuts down. (See Figure 2-10.)

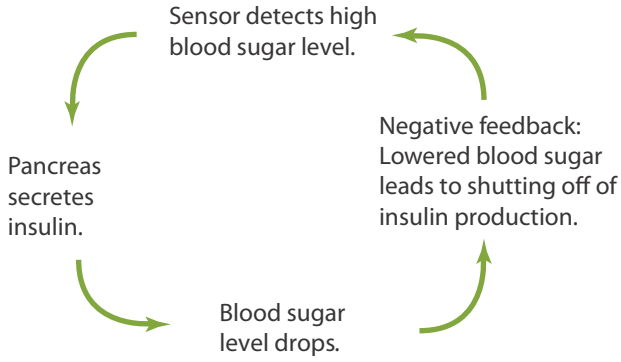


Figure 2-11. Negative feedback involving blood sugar level

Regulating human body temperature uses a similar system. A structure in the brain detects that the temperature of the blood is too low. This brain structure then sends a signal to muscles, causing them to contract and relax in rapid cycles. The result is shivering, which generates body heat. When shivering has sufficiently warmed the body and blood, sensors in the brain detect the change, and the signal to shiver stops.

Negative Feedback and Cell/Organ System Interaction

Maintaining dynamic equilibrium often involves interactions between cells and body organs or systems. For example, certain cells in the body monitor the level of glucose in the blood. When the glucose level is above normal limits, an endocrine organ called the **pancreas** secretes insulin. **Insulin** is a hormone that prompts glucose to move from the blood into body cells, resulting in a lower glucose level in the blood. Another hormone secreted by the pancreas works in the opposite way. When the glucose level in the blood is too low, this hormone prompts the release of glucose stored in the liver. The negative feedback process involving insulin is shown in Figure 2-11.

Other examples of cell/organ feedback interactions include:

- Increased muscle activity is often accompanied by an increase in heart rate and breathing rate. If this did not occur, the muscles would not receive the increase in blood flow and oxygen they need to continue working.
- When plant leaves detect a shortage of water, **guard cells**—specialized cells that surround pores on the surface of the leaf—change shape to close the pores and reduce evaporation. The process is shown in Figure 2-12.

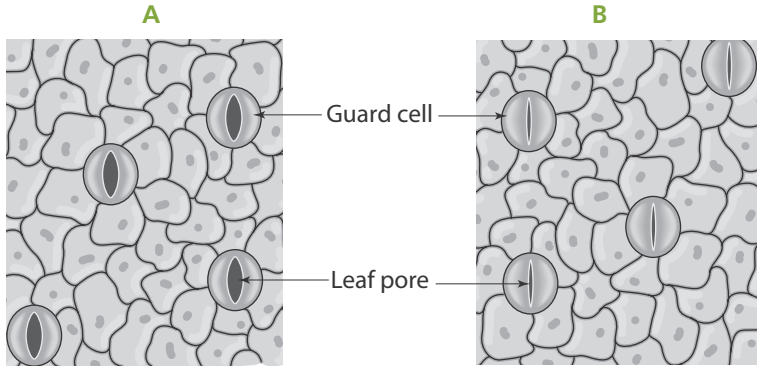


Figure 2-12. Guard cell activity on the surface of a leaf: (A) The guard cells have opened the pores in the leaf, allowing gas exchange between the leaf and the environment. Water can exit from the leaf, and CO_2 can enter. This situation commonly exists when the sun is shining, the air is warm, and water is available from the soil. (B) The guard cells have nearly closed the pores in the leaf, thus protecting the leaf from drying out. Under these conditions, gas exchange is limited. Photosynthesis slows down because little CO_2 is available. This situation commonly exists when the sun is shining, the air is hot and dry, and little water is available from the soil.

42. Some plants respond to light with a sudden enlargement of their leaf pores. This response is important because it enables the plant to increase its intake of

(1) carbon dioxide (3) oxygen
(2) soil (4) nitrogen

43. An increase in the blood's level of a thyroid gland hormone decreases the release of thyroid-stimulating hormone. This mechanism illustrates

(1) negative feedback
(2) enzyme action
(3) immune response
(4) positive feedback

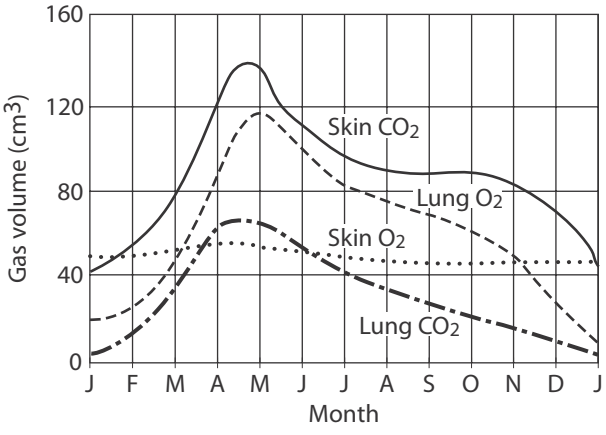
44. Maintenance of the pH of human blood within a certain range is an example of

(1) chemical digestion
(2) synthesis
(3) respiration
(4) dynamic equilibrium

45. Homeostasis is illustrated in the human body by the effects of insulin on the amount of

(1) proteins digested
(2) amino acids absorbed into the blood
(3) oxygen transport to the lungs
(4) glucose in the blood

46. The chart below shows the amount of oxygen and carbon dioxide exchanged through the skin and lungs of a frog for a period of one year.



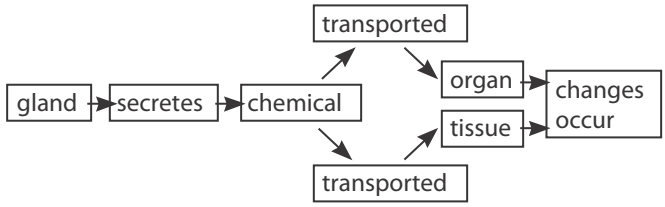
The lowest rate of gas exchange is most likely the result of

(1) increased mating activity
(2) elevated body temperature
(3) environmental conditions
(4) competition with other species

47. A student is frightened by a loud noise, which results in a hormone being released into the blood. The hormone causes the student's heart to beat rapidly. The two systems that work together to cause this reaction are the endocrine system that secretes the hormone and the

(1) nervous system (3) excretory system
(2) reproductive system (4) digestive system

48. Which important human process is represented in the diagram below?



(1) coordination (3) excretion
(2) digestion (4) cell respiration

49. Describe what normally happens to a person's blood sugar level soon after he or she eats a meal that contains carbohydrates. [1]

50. Describe the role of insulin in regulating blood sugar levels. [1]

51. On a sheet of graph paper, mark an X and a Y-axis, then draw a line representing the relative blood sugar levels for two individuals (Person A and Person B) over a 5-hour period after a meal. Both people ate the same foods. Person A produces a normal amount of insulin, and Person B does not.

Explain any differences in the lines representing Persons A and B. [1]

52. During hot weather and vigorous exercise, people sweat. As the water on their skin evaporates, the water molecules absorb heat energy.

Explain why this process is important to the individual. [1]

53. Many different feedback mechanisms have evolved over time. These mechanisms allow an organism to respond to changes in both its internal and external environment.

Select an organism from those you have learned about and describe how a specific feedback process works within that organism. Include how the feedback specifically helps the organism maintain homeostasis. [1]

Disease as a Failure of Homeostasis

Disease is any condition that prevents the body from working as it should. As a result, the body may fail to maintain homeostasis. Diseases in humans may result from foreign invader organisms, called **pathogens,** or from abnormal cells in the body that lead to cancer. Disease may also result from toxic substances, poor nutrition, organ malfunction, an inherited disorder, or risky personal behavior. All can lead to a disruption of the body's ability to function normally—that is, to maintain homeostasis.

Sometimes the onset of a disease becomes apparent right away, as in the case of some birth defects or poisoning. Sometimes, however, the disease may not show up for many years, as is the case with lung cancer caused by exposure to tobacco smoke. Some examples of these kinds of diseases are noted in Table 2-5.

Table 2-5. Causes of Disease

Cause of Disease	Examples
Inherited disorders	Down syndrome, cystic fibrosis, sickle cell disease
Exposure to toxins	Lead poisoning, radiation poisoning
Poor nutrition	Scurvy (vitamin C deficiency), goiter (iodine deficiency)
Organ malfunction	Heart attack, diabetes
High-risk behaviors	Lung cancer, drug addiction, skin cancer

Pathogens There are many potentially dangerous disease-causing organisms in the air, water, and food we take in every day. A variety of pathogens—viruses, bacteria, fungi, and other parasites—can interfere with our normal functioning and make us seriously ill. Plants and other animals can also be infected by these and similar organisms. Some examples of pathogens and the diseases they cause are shown in Table 2-6.

Cancer Certain genetic mutations in a cell can result in uncontrolled cell division called cancer. Exposing cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer. In this disease, genes that control and coordinate a cell's normal cycle of growth and division are altered by mutation. As a result, the cell begins to divide abnormally and uncontrollably. The result is a mass of abnormal cells referred to as a tumor.

Table 2-6. Pathogens and Disease

Pathogen	Description of Pathogen	Examples of Disease
Virus	**Viruses** are particles composed of nucleic acid and protein. They reproduce when they invade living cells.	Examples include the common cold, influenza, AIDS, and chicken pox. Immunizations have been developed to combat many viral diseases.
Bacterium	**Bacteria** are one-celled organisms.	Bacterial illnesses include strep throat, syphilis, and food poisoning. **Antibiotics**, drugs like penicillin that we get from microorganisms, are used to treat many bacterial diseases.
Fungus	**Fungi** are organisms made of either one or many cells. They include yeasts and molds. They eat by absorbing organic substances.	Examples include athlete's foot and ringworm. Fungicides and antibiotics are used to fight fungal diseases.
Parasites	Some animals and one-celled organisms are **parasites** that survive by living and feeding on other organisms.	Parasites include leeches and tapeworms. Malaria is a disease caused by a one-celled organism. It is transmitted to humans by mosquitoes. Heartworm is a parasitic worm that lives in dogs and cats. Medicines are available to treat some parasitic diseases. Avoiding exposure to the parasite is also effective.

Once they are identified, often by abnormal proteins on their surfaces, cancer cells may be attacked by the immune system and destroyed. If the immune system is unable to destroy the cancer cells, the disease may become life-threatening.

The Immune System

Humans have many ways of protecting themselves from danger and disease. For example:

- Our eyes, ears, and sense of smell help us detect danger.
- We release hormones that stimulate emergency responses to danger.
- Our muscles allow us to fight off some threats and to flee from others.
- Our skin—when unbroken—keeps out many foreign organisms that could be harmful.
- Our tears, saliva, and other body secretions trap and/or destroy invaders that come into contact with them.
- Our nervous system provides rapid coordination of many of our responses to danger.

Once invaded, however, the body needs an effective way to combat invaders or body cells that malfunction. The **immune system** is the body's primary defense against disease-causing pathogens.

Pathogens, foreign substances, or cancer cells that threaten our homeostasis can usually be identified by molecules on their outer surfaces or membranes. These molecules, called **antigens,** trigger a response from the immune system. Toxins, the poisonous wastes of certain pathogens, can also act as antigens.

All cells have potential antigens on their surfaces. However, the immune system can usually tell the difference between the molecules of "self" cells, which belong to the body, and "non-self" (foreign) cells, which come from outside the body. When cells of our immune system recognize foreign antigens, specialized white blood cells and antibodies attack them and the cells that display them.

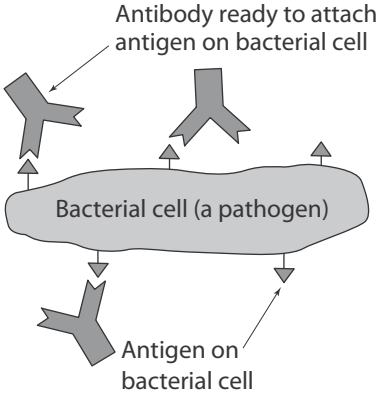


Figure 2-13. Certain white blood cells produce Y-shaped antibodies: The antibodies match the shape of certain antigens on pathogens or abnormal proteins on cancer cells. Note that the antibodies and antigens are not drawn to scale. They would be MUCH smaller than the pathogen cell.

White Blood Cells and Antibodies Some white blood cells are specialized to surround and engulf invading pathogens that are recognized as a threat. Others produce **antibodies**—proteins that either attack the invaders or mark them for killing. The marked invaders may then be destroyed by other white blood cells. In Figure 2-13, notice the Y-shaped antibodies that match the shape of antigens.

Most of the antibodies and white blood cells that attack an invader break down soon after they have defended the body. However, some specialized white blood cells will remain. These cells are capable of quickly dividing and producing more antibodies of the same kind to fight off later invasions of the same **microbes** (microscopic organisms). Antibodies are effective even against microbes that appear years later.

Vaccinations Scientists have discovered that weakened microbes (pathogens) or even parts of microbes can stimulate the immune system to react. The antigens found on the live pathogens are

usually present on the weakened or killed ones, too. As shown in Figure 2-14, **vaccines** are made using these weakened, killed, or parts of microbes (pathogens). When vaccines are injected into the body, the immune system responds just as if it had been invaded by a live pathogen. It produces antibodies. These antibodies can attack and destroy any of that pathogen that is still present in the body.

After a vaccination, the immune system "remembers" specific pathogens by leaving behind white blood cells that protect the body for years. The vaccinated body reacts as if it has already defeated the specific pathogen and responds faster in the future than it did when attacked the first time. The second response is so rapid that in most cases the disease will not even have time to develop before the immune system wipes it out.

Damage to the Immune System A person's immune system may weaken with age or other factors. Stress and fatigue, for example, can lower our resistance and make us more vulnerable to disease. Some viral diseases, such as **AIDS,** result from an attack on the immune system. Damage from the disease may leave the person with AIDS unable to deal with infections and cancerous cells. Their weakened immune system is one reason people with AIDS often die of infections that a healthy immune system would easily destroy.

Problems Associated with the Immune Response Although our immune system is essential for our survival, it creates problems for some people. These people have an **allergy**—a rapid immune system reaction to environmental substances that are normally harmless. Examples of such substances include certain foods, pollen, and chemicals from insect bites.

In people with allergies, the immune system reacts by releasing histamines. This leads to anything from a runny nose and sneezing to a rash and swelling. It is the swelling that makes some allergies dangerous: Occasionally, the throat swells, interfering with the victim's ability to breathe. People with allergies often use antihistamines to reduce the effects of the histamines and the symptoms they cause.

Sometimes the immune system fails to recognize the "self" molecules and attacks the body's own cells. For example, in some cases, the immune system attacks and destroys the pancreas cells that produce insulin. The result is one type of diabetes.

Since transplanted organs come from another person, they have foreign antigens on their cells. As a result, the immune system recognizes transplants as "invaders" and attacks them. To avoid "rejection" of their new organ, transplant patients receive injections of special drugs to reduce the effectiveness of their immune system. Of course, because the immune system's ability to protect the transplant patient from normal pathogens is reduced, the patient may become ill from a pathogen that normally would be no threat.

MemoryJogger

Remember germs? At one time *germ* was the word of choice for people who were talking about the tiny living things that cause disease. *Germ*, however, had two meanings in science, so the term *microbe* became the more accurate word choice. You still need to know that a microbe is any microscopic organism, but scientists now usually use the term *pathogen*. The reason is that the meaning of pathogen also includes viruses, those tiny "almost-organisms" that don't quite fit the description of a living thing.

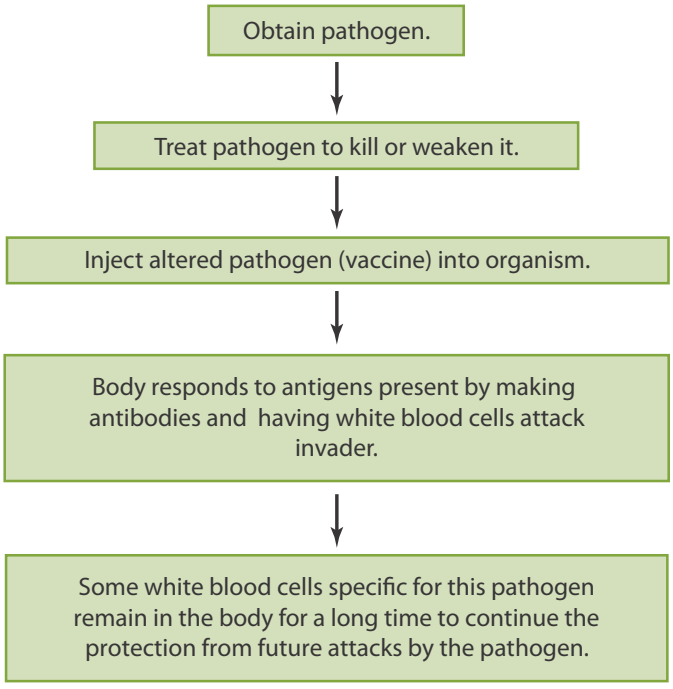


Figure 2-14. Preparation and use of a vaccine

Research and Progress Against Disease Biological research of diseases and their causes has generated a vast amount of knowledge that is used to find ways of diagnosing, preventing, controlling, or curing diseases of plants and animals. Some examples of how medical knowledge has developed are shown in Table 2-7.

Table 2-7. Biological Research of Diseases

Category of Research	Methods Developed
Diagnosing disease	• Culturing (growing) bacteria from the infected person to determine what specific pathogen is responsible for the illness • Using X-rays, CAT scans, ultrasound, blood pressure monitoring devices, and other methods to determine the cause or extent of the illness • Detecting genetic abnormalities that may be present in cells
Preventing and controlling disease	• Promoting improved sanitation measures, including frequent hand washing, safe garbage disposal, and sewage treatment • Sterilizing surgical instruments and treating wounds with antiseptics and other chemicals • Controlling populations of rats, flies, mosquitoes, and other disease-carrying organisms with pesticides or sanitation measures • Treating water, milk, and other foods to reduce the presence of pathogens • Vaccinating to promote the body's immune response to pathogens • Identifying the dangers of risky behaviors such as tobacco use
Treating and curing disease	• Developing antibiotics and other drugs to kill pathogens • Developing medical procedures, including surgical operations and laser techniques, to remove damaged or diseased tissue from the body

Review Questions — Set 2.5

54. When a person is suffering from an infection, such as strep throat or chicken pox, his blood usually shows a significant increase in the number of

(1) enzymes
(2) antibodies
(3) hormones
(4) sugars

55. When microscope slides are stained to show blood cells, the small red blood cells that appear on the slides are much more numerous than the large white blood cells. This supports the concept that

(1) the body's need for white blood cells is less than its need for red blood cells
(2) red cells are more numerous because they are smaller than white blood cells
(3) the nuclei of the white blood cells help them work more efficiently than the red blood cells, which lack nuclei
(4) each kind of cell is present in the numbers best suited to meet the needs of the body

56. Which response usually occurs after an individual receives a vaccination for the influenza virus?

(1) Hormones in the blood stop reproduction of the virus.
(2) Pathogens from the vaccine deactivate the virus.
(3) Enzymes released from antigens digest the virus.
(4) Antibodies against the virus are found in the blood.

57. A patient has just received an organ transplant. Which treatment would be most effective in preventing the patient's body from rejecting the organ?

(1) Treat the patient with medications that decrease the immune system's response.
(2) Treat the patient with antibiotics to fight off a possible viral infection.
(3) Restrict the patient's salt intake.
(4) Give the patient blood transfusions.

58. The body makes chemicals that can help to destroy harmful viruses and bacteria. These chemicals are called

(1) antibodies
(2) vaccines
(3) hormones
(4) antibiotics

59. A vaccine can protect you against a disease because it

(1) destroys toxic substances from bacteria before they can make you sick
(2) stimulates your immune system against the pathogen
(3) kills any pathogenic bacteria in your body
(4) changes pathogenic bacteria into harmless bacteria

60. The body is protected against harmful flu viruses by

(1) red blood cells and hormones
(2) white blood cells and antibodies
(3) white blood cells and enzymes
(4) red blood cells and antibodies

61. In some people, substances such as peanuts, eggs, and milk cause an immune response. This response to usually harmless substances is most similar to the

(1) action of the heart as the intensity of exercise increases
(2) mechanism that regulates the activity of guard cells
(3) action of white blood cells when certain bacteria enter the body
(4) mechanism that maintains the proper level of antibiotics in the blood

62. Parasitic strains of *E. coli* may produce poisonous chemicals that attack living tissue and cause disease in humans. These chemicals are called

(1) antibodies
(2) toxins
(3) viruses
(4) antibiotics

63. Uncontrolled cell division is known as

(1) meiosis
(2) cancer
(3) antibody production
(4) sexual reproduction

64. The resistance of the body to a pathogen is called

(1) immunity
(2) antigen
(3) cancer
(4) infection

65. Diseases can be caused by inherited disorders, exposure to toxic substances, organ malfunction and certain personal behaviors.

Choose *two* of the above causes and *for each one* give a specific example of an associated disease. [1]

66. Our immune system normally helps us resist infection and disease. Sometimes, however, it may actually work against us by attacking certain tissues or organs in the body.

State one example of the immune system attacking the body and explain how we try to counteract the problem. [1]

67. Vaccinations play a major role in medicine today. Explain the role of vaccines in the prevention of disease. Your answer must include at least:

- a description of the contents of a vaccine [1]
- a description of how a vaccine protects the body from disease [1]
- one specific reason certain vaccinations are required for students to attend public schools. [1]

Base your answer to question 68–70 on the information below and on your knowledge of biology.

Stem cells present in an embryo are responsible for the formation of various tissues and organs. Recent research suggests that it may be possible to replicate stem cells from sections of skin taken from adult mice, rather than having to use stem cells from the embryos of mice.

In the future, human stem cells may be used to replace human tissue damaged by diseases such as Parkinson's disease and multiple sclerosis.

68–70. Discuss why the use of stem cells taken from a patient to replace damaged tissues and organs may decrease the potential risk to a patient. In your answer, be sure to:

- identify the major problem that may occur when tissues and organs donated by another individual are used [1]
- explain why this problem may occur [1]
- explain why this problem will not occur if tissues and organs produced by stem cells from the patient are used [1]

Directions

Review the Test-Taking Strategies section of this book. Then answer the following questions. Read each question carefully and answer with a correct choice or response.

Part A

1 Most of the oxygen in our atmosphere comes from processes carried out
(1) in the soil
(2) by animals
(3) in factories
(4) by plants

2 Which organism releases oxygen into the atmosphere?
(1) mold
(2) bird
(3) fish
(4) tree

3 Plants provide food for animals through the process of
(1) respiration
(2) digestion
(3) photosynthesis
(4) excretion

4 Which word equation represents the process of photosynthesis?
(1) starch → many glucose molecules
(2) glucose + oxygen → carbon dioxide + water + energy
(3) carbon dioxide + water → glucose + oxygen
(4) fats → sugar molecules

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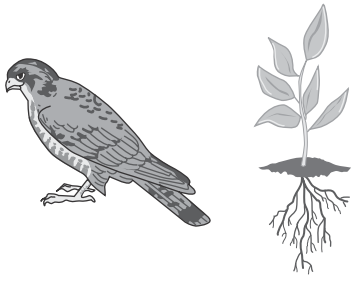
5 Which statement correctly relates the two organisms in the illustration below?



A B

(1) A carries out cell division, but B does not.
(2) B transports needed organic materials, but A does not.
(3) Both A and B carry out cellular respiration to release energy from organic molecules.
(4) Neither A nor B is able to use energy to combine carbon dioxide and water to make organic compounds.

6 A plant cell that lacks chloroplasts will not
(1) give off oxygen
(2) take in food
(3) give off carbon dioxide
(4) take in water

7 Which process removes carbon dioxide from the atmosphere rather than adding it?
(1) cellular respiration
(2) combustion of gasoline
(3) photosynthesis
(4) deforestation

8 Which process in plants produces carbon dioxide?
(1) respiration
(2) photosynthesis
(3) coordination
(4) digestion

9 The size of the openings in a leaf through which gases move in and out is controlled by the
(1) root cells
(2) chloroplasts
(3) chromosomes
(4) guard cells

10 What process does the word equation below represent?

$$\text{glucose} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{carbon dioxide} + \text{water} + \text{energy}$$

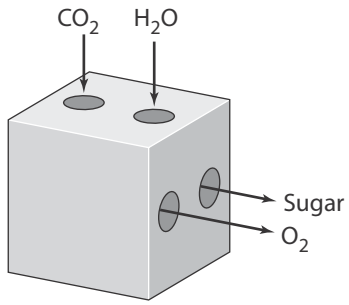
(1) photosynthesis
(2) breathing
(3) transport
(4) respiration

---

11 The major source of weight gain in a growing plant is
(1) sunlight
(2) carbon dioxide
(3) oxygen
(4) soil

12 Green plants do not release large amounts of CO_2 all the time because they use CO_2 in the process of
(1) photosynthesis
(2) respiration
(3) reproduction
(4) evolution

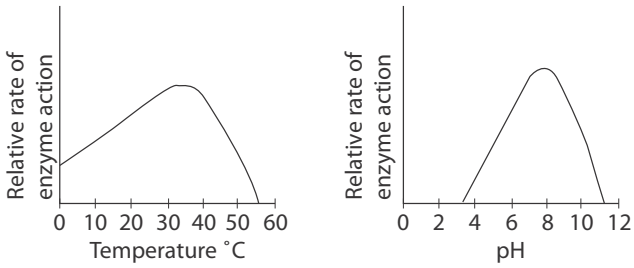
13 The diagram below represents some events that take place in a plant cell. With which organelle would these events be most closely associated?



(1) mitochondrion
(2) chloroplast
(3) ribosome
(4) vacuole

14 An enzyme that digests starch will not act upon the sugar sucrose. This fact is an indication that enzymes are
(1) specific
(2) synthetic
(3) starches
(4) generalized

15 Which statement best describes the enzyme represented in the graphs below?



(1) This enzyme works best at a temperature of 37°C and a pH of 8.
(2) This enzyme works best at a temperature of 55°C and a pH of 12.
(3) Temperature and pH have no effect on the action of this enzyme.
(4) This enzyme works best at a temperature near freezing and a pH above 4.

16 The body usually responds to foreign material by forming
(1) hormones
(2) antibodies
(3) vaccines
(4) antigens

17 A sudden increase in the number of white blood cells in a human may be an indication of
(1) growth
(2) color blindness
(3) mental retardation
(4) an infection

Part B

Base your answers to questions 18 and 19 on the equation below and on your knowledge of biology.

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow H_2O + 6\ CO_2 + 36\ ATP$$

(glucose) + (oxygen) → (water) + (carbon dioxide) + ATP

18 The equation represents the process of
(1) excretion
(2) photosynthesis
(3) respiration
(4) coordination

19 Explain the energy connection between the glucose and the formation of ATP in this process. [1]

Base your answers to questions 20 through 23 on the summary equations of two processes below and on your knowledge of biology.

Photosynthesis

$$\text{water + carbon dioxide} \xrightarrow{\text{enzymes}} \text{glucose + oxygen + water}$$

Respiration

$$\text{glucose + oxygen} \xrightarrow{\text{enzymes}} \text{water + carbon dioxide}$$

20 Choose one of the processes and identify the source of the energy in the process you chose. [1]

21 Identify where the energy ends up at the completion of that process. [1]

22 State one reason the processes of photosynthesis is important for living things.[1]

23 State one reason the processes of respiration is important for living things. [1]

Base your answers to questions 24 through 28 on the information and data table below and on your knowledge of biology.

The results of blood tests for two individuals are shown in the data table below. The blood glucose level before breakfast is normally 80–90 mg/100 mL of blood. A blood glucose level above 110 mg/100 mL of blood indicates a failure in a feedback mechanism.

Injection of chemical X, a chemical normally produced in the body, may be required to correct this problem.

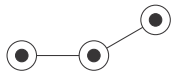
Data Table

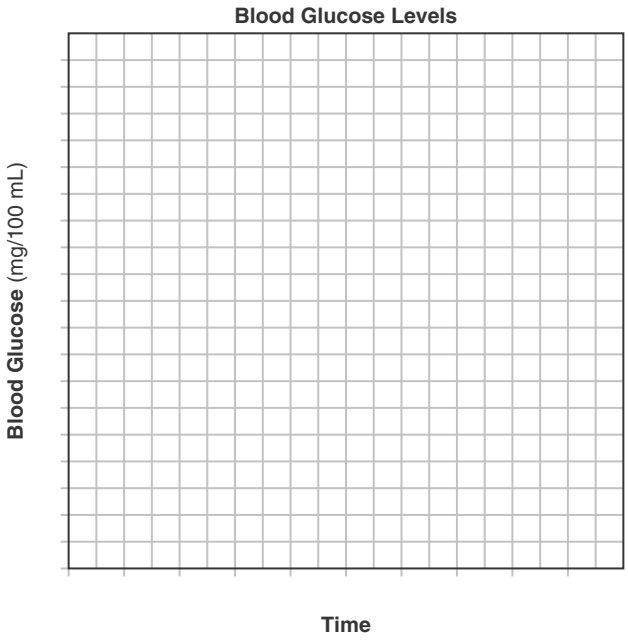
Time	Blood Glucose (mg/100 mL)	
	Individual 1	Individual 2
7:00 a.m.	90	150
7:30 a.m.	120	180
8:00 a.m.	140	220
8:30 a.m.	110	250
9:00 a.m.	90	240
9:30 a.m.	85	230
10:00 a.m.	90	210
10:30 a.m.	85	190
11:00 a.m.	90	170

Directions (24–25): Using the information in the data table, construct a line graph on the grid below, following the directions below.

24 Mark an appropriate scale, without any breaks in the data, on each labeled axis. [1]

25 Plot the blood glucose levels for the individual who will most likely need injections of chemical X. Connect the points and surround each point with a small circle.

Example: 



26 Identify chemical X. [1]

27 State one reason for the change in blood glucose level between 7:00 a.m. and 8:00 a.m. [1]

28 What term refers to the relatively constant level of blood glucose of individual 1 between 9:00 a.m. and 11:00 a.m.? [1]

---

29 Select one of the paired items below and describe how the first item in the pair regulates the second item for the maintenance of homeostasis. [1]

- insulin—blood sugar level
- CO_2 in blood—breathing rate

Base your answers to questions 31 through 34 on the passage below and on your knowledge of biology.

Lyme Disease

Since 1980, the number of reported cases of Lyme disease in New York State has been increasing. The vector (carrier) of Lyme disease is the black-legged tick, *Ixodes scapularis*. The disease is spread from infected animals to ticks that bite these animals. Humans bitten by these ticks may then become infected.

The symptoms of Lyme disease do not always occur immediately after a tick bite. An individual may develop a skin rash several days to weeks after being bitten by a tick. Flu-like symptoms, such as headaches, muscle aches, joint pain, and fever, may also develop. Generally, these symptoms clear up even if the individual does not seek medical help. In some cases, there may be no symptoms other than a sudden onset of arthritis. However, in a small number of cases, if the infection is not treated, it may lead to chronic arthritis, disorders of the heart and nervous system, or in a few cases, death. A blood test can help to confirm a diagnosis, and antibiotics are effective in treating the infection.

People may take preventive action by frequently checking themselves and their pets for ticks, tucking their pant legs into socks when walking through woods or high grass, wearing light-colored clothing to aid in spotting a tick, and using insect repellent.

30 Describe how Lyme disease is transmitted. [1]

31 State one way people might protect themselves from Lyme disease. [1]

32 State two symptoms that may occur if a person has Lyme disease. [2]

33 State one danger of ignoring any symptoms that may develop after a tick bite. [1]

Base your answers to questions 35 through 37 on the information and data table below and on your knowledge of biology.

Twenty-five geranium plants were placed in each of four closed containers and then exposed to the light conditions shown in the data table. All other environmental conditions were held constant for a period of two days. At the beginning of the investigation, the quantity of carbon dioxide (CO_2) present in each container was 250 cm^3 (cubic centimeters). The data table shows the amount of CO_2 remaining in each container at the end of two days.

Changes in CO_2 Levels

Container	Color of Light	CO_2 (cm^3) at Start	CO_2 (cm^3) After 2 Days
1	blue	250	50
2	red	250	75
3	green	250	200
4	orange	250	150

34 The independent variable in this investigation was the
(1) type of plant
(2) color of light
(3) amount of CO_2 in each container at the beginning of the investigation
(4) number of days needed to complete the investigation

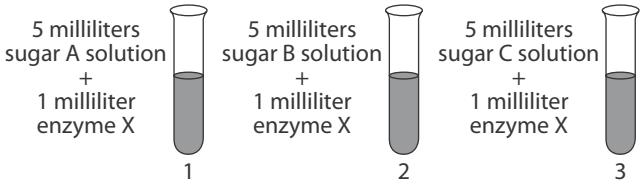
35 State the problem being investigated in this experiment. [1]

36 Identify the source of the carbon used in photosynthesis. [1]

Part C

Base your answers to questions 38 through 40 on the information below and on your knowledge of biology.

An investigation was performed to determine the effects of enzyme X on three different disaccharides (double sugars) at 37°C. Three test tubes were set up as shown in the diagram below.



At the end of 5 minutes, the solution in each test tube was tested for the presence of disaccharides (double sugars) and monosaccharides (simple sugars). The results of these tests are shown in the table below.

Result of Sugar Test

	Test Tube 1	Test Tube 2	Test Tube 3
Monosaccharide	not present	not present	present
Disaccharide	present	present	not present

37 What can be concluded about the activity of enzyme X from the data table? [1]

38 With only the materials list supplied below and common laboratory equipment, design an investigation that would show how a change in pH would affect the activity of enzyme X. Your design must include a *detailed procedure* and a *data table*. [3]

Materials
Enzyme *X*
Sugar *C* Solution
Indicators
Substances of various pH values —
vinegar (acidic)
water (neutral)
baking soda (basic)

39 State one safety precaution that should be used during the investigation. [1]

40 Enzyme molecules are affected by changes in conditions within organisms. Explain how a prolonged, excessively high body temperature during an illness could be fatal to humans. your answer must include:
- the role of enzymes in a human [1]
- the effect of this high body temperature on enzyme activity [1]
- the reason this high body temperature can result in death [1]

Base your answer to question 42–44 on the information below and on your knowledge of biology.

41–43 In order to enroll in most schools, students must be vaccinated against certain viral diseases, such as mumps. Even with these vaccinations, many students still suffer from other diseases. Discuss how a vaccination works and why some students still become infected with other diseases. In your answer, be sure to:
- identify what is present in a vaccine that stimulates an immune response [1]
- describe how a vaccine protects against disease [1]
- state why a student vaccinated against mumps can still be infected by the pathogens that cause other diseases, such as chicken pox [1]

44 State one way guard cells of a leaf help to maintain homeostasis in the plant? [1]