Assignments for Matt Q.

Math:

- Complete 1 lesson per day

English:

- Read Chapters 1-41
- Complete all questions in packet
- You may work at your own pace

Personal Finance

- Complete all worksheets
- Work at your own pace

Biology

- Read each section
- Answer all questions for each section

Government

- Read each biography
- Write facts for each President

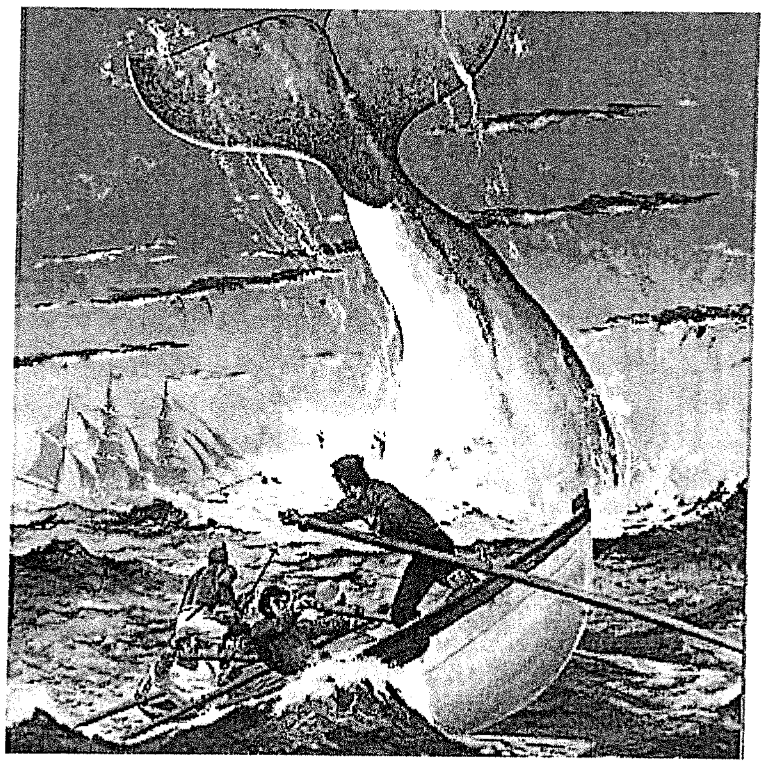
Social Studies

- Complete OGT practice tests
- Complete Citizenship tests

English

Moby Dick

By Herman Melville



Moby Dick
Pre-Reading Discussion

Directions: Discuss the following questions with a partner. Write down your thoughts as you both share your ideas. Be prepared to share your thoughts during class discussion time.

What do you know about whales? Have you ever seen one? Would you like to?

Have you ever been on a boat or ship? Describe your experience. If you haven't, what do you think being on a ship for a long time is like? Do you think you would enjoy it?

What could a whale symbolize in literature? What could the search for a whale symbolize?

Think about the characteristics of the ocean. What could the ocean symbolize in literature?

If you could go on an expedition, where would you go and what would you like to find out?

Moby Dick
Reading Guide

This reading guide is designed to help you focus on various themes and passages as you read Moby Dick. I suggest you pre-read the guide before you begin each section. The questions will help you focus your reading and formulate your own questions and thoughts in relation to the text.

Etymology and Extracts

- Why does Melville begin his novel with "Etymology"?
- How do you interpret the source of "Extracts"?
- Is there an overall pattern to the extracts?
- What assumptions does Melville make about his readers?

Chapters 1 – 3

- Who is the biblical Ishmael? How would you characterize Ishmael? Why does he go to sea?
- What is the symbolic relevance of the story of Narcissus?
- How does Ishmael characterize New Bedford?
- How does Ishmael describe the Spouter Inn?
- What is your first impression of Queequeg?
- What philosophical principles enable Ishmael to quell his fears before they go to sleep?

Chapters 4 – 6

- What is the symbolic significance of the Counterpane?
- How do you interpret Ishmael's dream and the supernatural hand?
- How do Ishmael's view of Queequeg change? Why?
- How would you characterize the whaling industry?

Chapters 7 – 9

- What is Ishmael's attitude toward religion and the afterlife?
- Does Ishmael want to believe in something divine? Why, or why not?
- In what ways does whaling pervade the discourse and religion in Mapple's church?
- How would you characterize Mapple's faith?
- What part of the story of Jonah does Mapple leave out? Why?

Chapters 10 – 15

- What effect does Queequeg have on Ishmael after the sermon?
- How does Ishmael respond to Mapple's sermon?
- How would you characterize Ishmael's and Queequeg's relationship?
- Where is Kokovoko?
- What does Ishmael mean when he says, "It's a joint-stock world"?

Chapters 16 – 18

- Why does Ishmael not heed the bad omens he sees?
- Why is Ishmael in charge of selecting the ship?
- What is distinctive about the ship, Pequod?
- Who was the biblical Ahab?
- How do you interpret Peleg's characterization of Ahab as a "grand, ungodly, god-like man"?
- What is the purpose of Queequeg's fasting?
- What is a Quohog?

Chapters 19 – 22

- What is the Biblical relationship between Elijah and Ahab?
- Does Ahab have a soul according to Elijah?
- Why does Ishmael pronounce Elijah "crazy" and then "in my heart, a humbug"?
- Why does Ishmael not treat the forebodings about Ahab seriously?
- How is Ishmael's second meeting with Elijah different from the first?

Chapters 23 – 32

- What is Bulkington's role in the novel? Why does Ishmael call him a "demigod"?
- What happens to Bulkington?
- How does Ishmael characterize the profession of whaling?
- Why is the whale-ship Ishmael's "Yale College and my Harvard"?
- What is Starbuck's flaw?
- Why is Stubb's pipe "a sort of disinfecting agent"?
- What is an Isolato?
- How is Ahab described? What does Ishmael think of him?

Chapters 33 – 36

- How do the mates proceed to supper? How do they disengage?
- Why is Flask "a butterless man"? Why does he always go hungry?
- What things do masthead standers look for?
- What happens to you while standing on the masthead?
- Why is Ishmael a lousy masthead stander?
- Why does the Platonist not spot any whales?
- How does Ahab attempt to win over Starbuck?
- How does Ahab win the men over? Why does Starbuck back down?

Chapters 37 – 41

- Why is Ahab "damned in the midst of Paradise"?
- What is Starbuck's predicament?
- Why does Ishmael go along with Ahab? Is he sympathetic to Ahab?

Social
Studies

WEEK 1 Day 1-5

OGT Coverage: PS.C.9.3.a, b, c, d, e, f, g

LESSON 10 Cultural Exchange

IT'S IMPORTANT:

- People from different cultures exchange cultural practices for a variety of reasons and in a variety of ways.
- Advances in communication and transportation have had an impact on globalization, cooperation and conflict, the environment, collective security, popular culture, political systems and religion.

The world has become smaller through mass communication and the ability to travel huge distances in a matter of hours. Because of this, the cultures of the world are more interconnected than ever before. Jet airplanes, high-speed trains, easy access to automobiles and advances in shipping practices have brought people from different cultures into ever closer contact. The Internet has connected us to a truly worldwide web of individuals. We come into contact with people who may share many of our interests, tastes and concerns, but who also have their own unique cultural practices. Cable and satellite television has allowed people from many different cultures to experience and exchange information about news, sports, art, language, education, politics, religion, the environment—and the list goes on.

In this lesson, you will learn how some of these technological advances have influenced the way people live, work and relate to each other.

Globalization

Globalization is a term that covers a lot in one word. It refers to the way the world's countries are increasingly interdependent on one another. This interdependence is largely economic. Goods, services and money flow across international borders as never before. Much of this flow is due to improvements in technology. As you will read in the following sections, transportation and communication improvements have been extremely important to the growth of globalization. Transportation technology carries things from place to place. Communication technology contributes to the flow of information across borders. When you can log onto the Internet to buy and download songs by a band from Sweden, that's globalization right in your own home. The flow of information also makes it possible for corporations to do business wherever and however they want. International investors can put their money to work anywhere, regardless of national borders.

In the industrial world, people have always moved to where the jobs are. This is still true to some extent today. However, in the global economy, jobs often move to where the people are. For example, American companies have moved some of their factories to Mexico or China, where people will work for less money. Even some high-tech jobs have been moved, or outsourced, to foreign countries. When you call a software company for technical support, you may be speaking to someone sitting in India. (This is another way in which communications improvements drive globalization.)

Critics of globalization say that it makes the world run by the rules of the richest countries. However, those who favor globalization say that participation in a global economy allows poorer countries their best chance to compete.

Quick Review 1: Globalization has changed the world economically and socially in the last 20 to 25 years. Which of the following statements best describes the changes brought about by globalization?

A. Globalization has given poorer countries an advantage over richer ones.

B. Globalization has led to the outsourcing of jobs from countries such as China to the United States.

C. Globalization has created a worldwide market for money, goods, services and information.

D. Globalization is responsible for the creation of the Internet as a method of delivering news and entertainment.

Transportation

Transportation improvements have made it possible for products to be manufactured far away from where they are used. Transportation has also affected the environment, leading to both conflict and cooperation between people and nations. From the steam engine to the jet engine, the process of globalization has been accelerated by advances in transportation.

TARIFFS, TRADE AND NAFTA

Countries used to place tariffs on imported goods. A tariff is a tax that raises the price of goods. When a tariff makes a foreign product more expensive, the same product made in the home country is more attractive to buy. In the 1990s, however, many of the world's countries lowered their tariffs or dropped them altogether. Free trade produces open markets in which all countries may participate on an equal basis. The North American Free Trade Agreement (NAFTA) between the United States, Canada and Mexico went into effect in 1994. NAFTA was intended to make North America into one big market, leading to lower prices for goods and higher profits for companies and countries, which in turn was supposed to lead to higher wages for workers. NAFTA has lived up to its promises in some ways, but not in others. Nevertheless, other NAFTA-style agreements are being proposed in other regions of the world. Free trade and open markets are important to the globalization of the economy.

OGT Coverage: PS.C.9.3.a, b, c, d, e, f, g.

The internal combustion engine

As you learned in Lesson 2, the steam engine changed industry, transportation and the environment all over the world in the 19th century. The average person, however, still walked to the market or rode a horse to the next town. Moving belongings from place to place required a horse-drawn cart. Steam engines were too large to drive wagons or small carts. They also needed a separate firebox to generate the heat to make steam.

The **internal combustion engine**, which produces power from fuel burned inside the engine itself, made the automobile possible. In turn, the automobile made it possible for the average person or family to go where they wanted, when they wanted. Workers no longer needed to live near factories or office buildings. They could move to any town within driving distance. Travel habits changed, too. Families drove instead of taking the train. Gas stations, restaurants and other tourist services sprouted along newly built highways.

One of the most serious effects of the automobile, however, has been environmental. Pollution caused by car and truck exhaust has made the air in places such as Los Angeles, California, and Mexico City, Mexico, dangerous to breathe. Road construction has destroyed sensitive wilderness. The commercial and residential development that follows road-building has destroyed even more.

Engines of war

In addition to its use in the automobile, the internal combustion engine was widely used for the first time during World War I. The use of trucks, planes and tanks changed the way war was waged. Motorized warfare increased the number of casualties and the destruction of property.

Use of vehicles in war also made quick surprise attacks much more likely. For example, the beginning of World War II would have been much different if Germany's troops had invaded Poland on horseback or on foot. Poland's army was well-trained. They would have known the Germans were coming. Instead, German planes and tanks took the war deep into Poland in just a few hours. Polish troops were defeated before they could mount a defense.

With the constant threat of sudden attack, the nations of the world entered an era of **collective security**. Collective security is a strategy under which a group of nations agree not to attack each other. They also agree to defend each other against an attack from one of the others. NATO (North Atlantic Treaty Organization) is an example of a collective security organization. The United Nations is another. With so many advances in military transportation and delivery systems over the past few decades, the role of collective security has become increasingly important for international cooperation and stability.

KEEP ON TRUCKIN'

Rudolf Diesel, a German engineer, wanted to make a heavy-duty engine that would allow small craftsmen to compete with large factories (which had huge steam engines). Diesel invented an internal-combustion engine that didn't need a spark to ignite the fuel (gasoline engines have spark plugs). Instead, his engine compressed air until it got so hot it burned the fuel. These engines used less fuel than gasoline engines, they could pull or lift much more weight than gasoline engines and the fuel was less expensive than gasoline.

Instead of changing the small shops of craftsmen, however, the **diesel engine** revolutionized large-scale transportation. Many trucks, railroad locomotives and ships (including submarines) still use diesel power.

Quick Review 2: The internal combustion engine affected transportation. Changes in transportation affected the way wars were fought. How did the internal combustion engine affect World War I?

A. It allowed attackers to move faster and permitted Germany to defeat Poland more easily.

B. More mobile weapons led to greater numbers of casualties and more property damage.

C. It improved the collective security of nations using motorized transportation.

D. Motorized transportation was less expensive than other forms of transportation.

The jet engine

One of the most influential advances for both the military and civilians was the invention of the **turbo-jet engine** in 1939. At first, the jet engine was used mostly in military fighter aircraft, but commercial airlines began jet-powered transatlantic service in 1958. Jets allowed many more people to travel to different continents and experience other cultures.

Jet engines also paved the way for rocket-powered space travel and the Cold War era "space race" between the United States and the Soviet Union. When the Soviet Union launched the world's first satellite, Sputnik I, into orbit around Earth in 1957, the United States worried about what kind of advantage this gave the Soviets over America. The United States feared that the Soviet Union might use satellites to spy on America, or even to deploy missiles. Because of these fears, the United States quickly responded by developing its own space program. The United States put the first man on the moon in 1969. The competition spawned by the jet engine was as much political as it was technological.

Since the end of the Cold War, however, the space race has been gradually replaced by increasing cooperation among nations that now share research and satellites.

SPACE TRAVEL AND POPULAR CULTURE

Space exploration fed the popular imagination and became a cultural symbol of the 1960s. Television and radio news often talked about space exploration, and advertisers used images and sounds of aliens and space suits to sell their products. Themes about space could be found in comic books, movies, music and television series. In Britain, the science fiction series *Dr. Who* became popular; in the United States, television viewers first watched *Star Trek* in 1966. Movies such as *Planet of the Apes* (1968) and *2001: A Space Odyssey* (1968) were huge box-office hits.

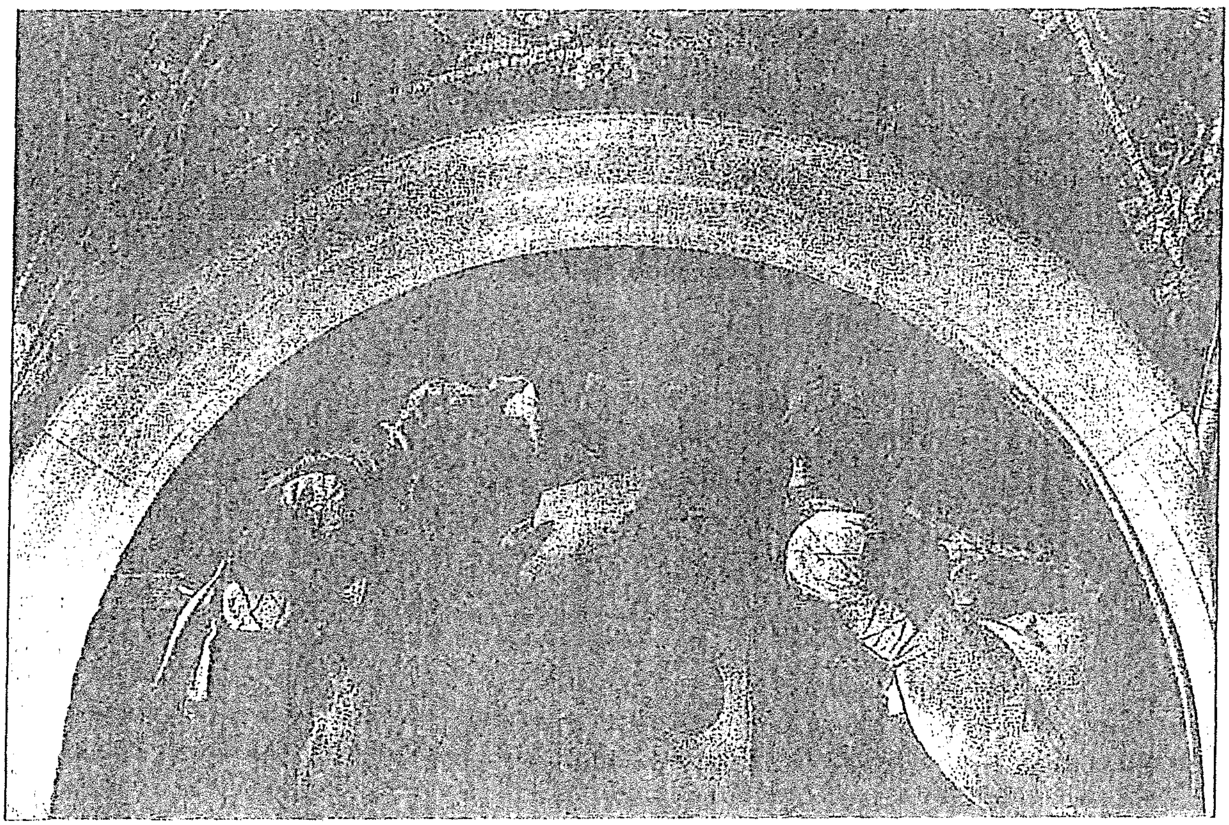
Quick Review 3: Imagine that a historian says, "The jet engine helped contribute to Cold War tensions between the United States and the Soviet Union." Explain why the historian's comment is correct.

OGT Coverage: PS.C.9.3.a, b, c, d, e, f, g

From the Printing Press to the Internet

Johannes Gutenberg was a 15th-century German goldsmith and craftsman who spent more than 17 years, most of it in secret, inventing the printing press. Before Gutenberg, books were copied by hand for monasteries or for wealthy nobles. These handmade books were beautiful but expensive. They also often contained errors made by scribes (the men who did the actual copying). Around 1455, Gutenberg printed his three-volume Latin Bible. About 40 copies of this first modern book still exist.

Gutenberg did not set out to invent mass publishing, however. He wanted to find a more convenient way to produce books for the Church that kept the beauty of the older, handmade versions. (His Bible even looked like the work of a scribe.) Instead, he invented the printing process that would be used until the 20th century. It would help bring the written word to millions of people. By doing so, the printing press helped pave the way to the Renaissance, the Enlightenment and modern mass education.



Above: *Gutenberg's printing press used movable type, consisting of small pieces of metal each engraved with a letter. He greatly improved the speed and efficiency of the printing process by developing a system to mass-produce movable type.*

Quick Review 4: How did Gutenberg's press affect the course of history?

A. By making it easier for monks to print books, it kept books in the monasteries.

B. The printing press was condemned by the Roman Catholic Church and had little effect outside Germany.

C. The printing press helped preserve the art of making and copying books by hand.

D. Books became accessible to millions of readers, which helped to spread knowledge.

Communications advances

Today, we can see pictures and live video from distant parts of the world on our TV sets or computers. We take that for granted now, but it wasn't always true. In 1963, when President Kennedy was assassinated in Dallas, Texas, film of events in the city had to be flown from Texas to TV studios in New York for broadcast. There was no other way to send video from place to place—but that was already changing. The previous year, 1962, the first communications satellite, *Telstar I*, had been launched into orbit around Earth. It was the beginning of the Information Age, a time of great leaps in technology that would directly affect millions of people.

Satellite broadcasting of news, sports and entertainment continues to change the way people see the world. Informational borders that were once tightly controlled in some nations are bypassed by people who have access to cable or satellite television and the Internet. The news coverage of the fall of the Berlin Wall and the resulting fall of communism in the rest of Eastern Europe was watched live by much of the world. Many believe that this instantaneous global news actually helped end the Cold War by inspiring people in Eastern Europe with images of mass protest in neighboring countries. Similarly, the 1991 Persian Gulf War and the Iraq War that began in 2003 were seen live, while they were happening.

The technology that sends pictures into our homes is only part of the story. Having a way to see the pictures is also important. Until 1980, there was relatively little time devoted to news on TV. Stations broadcast short news programs, mostly in the morning and evening, along with regular entertainment shows. In 1980, the **Cable News Network** (CNN) went on the air broadcasting news 24 hours a day, seven days a week. It showed live pictures of the Berlin Wall falling. CNN reporters were on the air live from Baghdad during the first air attacks of the Gulf War in 1991. Other 24-hour news channels, MSNBC and Fox News Channel, both went on the air in 1996. When the Iraq War began in 2003, military leaders permitted TV, radio and print reporters to accompany soldiers on missions. Viewers, listeners and readers got a closer view of war than ever before in history.

Not only has improved mass communication lessened the isolation of developing nations, it has also increased cultural awareness. It has contributed to globalization by helping people exchange cultural practices and products. People can learn about life in other cultures simply by watching television programs or movies (or visiting websites) from around the world.

OGT Coverage: PS.C.9.3.a, b, c, d, e, f, g

TECHNOLOGY AND RELIGION

The invention of the printing press had a huge impact on religion, especially Christianity and Judaism. It allowed people to read for the first time the Christian Bible and the Jewish text of religious studies, the Zohar, on their own. The printing press also contributed to the Reformation, the religious movement that broke away from Roman Catholicism and established the Protestant churches.

In the 20th century, radio and television changed the way religious thought and beliefs were communicated. In the United States, televangelism helped spread conservative Protestant beliefs to increasingly larger audiences. Beginning in the 1950s with a traditional format of church services usually restricted to Sunday mornings, televangelism today has 24-hour cable broadcasting with a wide range of formats, including news, entertainment and religious talk shows.

With the popularization of the Internet, online religion has reached even larger audiences. One of the biggest impacts is the Internet's ability to present a wide diversity of religious beliefs and practices. Every major religion has a site on the World Wide Web. The reading of religious texts such as the Torah, the Qur'an and the Bible has been made even more accessible through the innovation of electronic texts. The Internet has also inspired new religious activities, such as online prayer rooms that provide virtual holy sites for millions of people.

The globalization of the Internet

Although there was an Internet before 1993, most users were computer scientists and programmers in government, military and academic computer labs. Other types of scientists used the Internet as well. They could send e-mail to colleagues and run programs on computers across the country or around the world. The Internet of the 1970s and 1980s was difficult to use. Users had to know information about the computers to which they wished to connect, how to establish that connection and how to send their information.

In 1991, **Tim Berners-Lee**, a programmer at CERN, the European Center for Nuclear Research in Geneva, Switzerland, wrote the first **World Wide Web** program. His program allowed hundreds of scientists working on the same project to look at pages of notes, papers and simple diagrams on their computers. The program, which Berners-Lee called a "browser," took care of connecting the scientist's computer to the computers where the pages were located. The browser also determined how to display the pages, no matter what program had been used to make them. These early pages had "links" to click on, just as web pages do today.

In 1993, graduate students at the University of Illinois released the first browser that looks like the ones we use today. At first, only university professors, students and others who used the Internet for research used the browser. Soon, however, museums, libraries, newspapers and other institutions that owned information made that information accessible through web browsers. Businesses soon followed, and by the late 1990s the Internet was a place for recreation, learning, buying and selling.

With increasingly sophisticated software and browsers, companies were able to learn a lot about their Internet customers. They could then tailor their goods, production and marketing to appeal to individual tastes. Consumers were able to compare products and prices while sitting at their desks. It took minutes to make a purchase that previously might have taken a day or two driving from store to store. Internet commerce is dominated by large companies. However, it is possible for someone using the web in India to purchase custom-built furniture from a cabinetmaker in Maine. In addition, companies can keep more up-to-date records regarding the manufacture and sale of products by using the Internet.

Businesses also use the Internet to make many tasks of business operation easier. Electronic communication has made it easier for people in business to communicate. Using the Internet, it is possible for people in India to "attend" a meeting with people at an office in the United States. This is another way in which the Internet makes the world seem smaller. It permits more efficient operation of business because people no longer need to be located in the same place to work together.

Computer technology also contributes to the dissolving of barriers between people and nations. E-mail and the World Wide Web give up-to-the-minute information and access to capital needed for some global business ventures. In addition, Internet chat rooms and bulletin boards can connect people half a world apart.

Quick Review 5: How does the Internet contribute to the globalization of business?

A. by making it easier to sell goods and send or receive information over long distances

B. by making it possible for people to read documents for themselves

C. by requiring complicated computer programs that only large businesses can afford to create

D. by requiring scientists to keep improving the Internet so more people can use it

OGT Practice

1. Collective security agreements between countries have become more important as transportation technology has improved. Why has improved transportation made these agreements more important? In your answer, explain how such agreements protect countries. Write your answer on the lines below. (2 points)

2. Which of the following events began the space race between the United States and the Soviet Union?

   A. the *Apollo 11* mission to the moon

   B. the launching of the satellite *Sputnik I*

   C. the beginning of the Cold War

   D. the release of the film *2001:, A Space Odyssey*

3. The Internet was not widely used until the mid-1990s. However, its origins go back to the 1960s. Which group used the Internet the most during its earliest years?

   A. scientists

   B. school teachers

   C. businesspeople

   D. religious leaders

4. Communist governments in Eastern Europe rapidly fell during the late 1980s and early 1990s. Some historians claim that it couldn't have happened without the assistance of certain types of technology. Which of the following technological improvements is believed to have been a major factor in the fall of Communism in Eastern Europe?

   A. the Internet, because it permitted people in Communist countries to communicate and organize

   B. the printing press, because it made the spreading of knowledge easier than at any previous time in history

   C. satellite broadcasting, because it allowed people to see what was happening in other countries as it happened

   D. the internal combustion engine, because it gave people a way to escape from their Communist governments

5. In the early years of the Internet, American economist Paul Samuelson said, "Sooner or later the Internet will become profitable. It's an old story played before by canals, railroads and automobiles." Over the last 10 years, Samuelson's statement has proven true for many businesses around the world. Name and briefly explain two ways in which the Internet has contributed to the globalization of business. Write your answer on the lines below. (4 points)

American History WEEK 2 Day

United States Citizenship Test Questions

Applicants who wish to become United States citizens are asked to answer about twelve questions. The questions are asked by Immigration and Naturalization Service (INS) examiners. The examiners select the questions from the following 100 questions.

1. What are the colors of the flag?
2. How many stars are there in our flag?
3. What color are the stars on our flag?
4. What do the stars on the flag mean?
5. How many stripes are there in the flag?
6. What color are the stripes?
7. What do the stripes on the flag mean?
8. How many states are there in the union (United States)?
9. What is the 4th of July?
10. What is the date of Independence Day?
11. Independence from whom?
12. What country did we fight during the Revolutionary War?
13. Who was the first president of the United States?
14. Who is the president of the United States today?
15. Who is the vice president of the United States?
16. Who elects the president of the United States?
17. Who becomes president of the United States if the president should die?
18. For how long do we elect the president?
19. What is the Constitution?
20. Can the Constitution be changed?
21. What do we call a change to the Constitution?
22. How many changes or amendments are there to the Constitution?
23. How many branches are there in our government?
24. What are the three branches of our government?
25. What is the legislative branch of our government?
26. Who makes the laws in the United States?
27. What is Congress?
28. What are the duties of Congress?
29. Who elects Congress?
30. How many senators are there in Congress?
31. Can you name the two senators from your state?

CAN USE the Internet

330 *Appendix F: United States Citizenship Test Questions* *United States Government*

32. For how long do we elect each senator?
33. How many representatives are there in Congress?
34. For how long do we elect the representative?
35. What is the executive branch of our government?
36. What is the judicial branch of our government?
37. What are the duties of the Supreme Court?
38. What is the supreme law of the United States?
39. What is the Bill of Rights?
40. What is the capital of your state?
41. Who is the current governor of your state?
42. Who becomes president of the United States if the president and the vice president should die?
43. Who is the chief justice of the Supreme Court?
44. Can you name the 13 original states?
45. Who said, "Give me liberty or give me death"?
46. Which countries were our principal allies during World War II?
47. What is the 49th state of the Union (United States)?
48. How many terms can a president serve?
49. Who was Martin Luther King Jr.?
50. Who is the head of your local government?
51. According to the Constitution, a person must meet certain requirements in order to be eligible to become president. Name one of these requirements.
52. Why are there 100 senators in the Senate?
53. Who selects the Supreme Court justices?
54. How many Supreme Court justices are there?
55. Why did the Pilgrims come to America?
56. What is the head executive of a state government called?
57. What is the head executive of a city government called?
58. What holiday was celebrated for the first time by the American Colonists?
59. Who was the main writer of the Declaration of Independence?
60. When was the Declaration of Independence adopted?
61. What is the basic belief of the Declaration of Independence?
62. What is the national anthem of the United States?
63. Who wrote the Star-Spangled Banner?
64. Where does freedom of speech come from?
65. What is the minimum voting age in the United States?
66. Who signs bills into law?
67. What is the highest court in the United States?

United States Government *Appendix F: United States Citizenship Test Questions* **331**

68. Who was president during the Civil War?
69. What did the Emancipation Proclamation do?
70. What special group advises the president?
71. Which president is called the "father of our country"?
72. What is the 50th state of the Union (United States)?
73. Who helped the Pilgrims in America?
74. What is the name of the ship that brought the Pilgrims to America?
75. What were the 13 original states of the U.S. called?
76. Name three rights or freedoms guaranteed by the Bill of Rights.
77. Who has the power to declare war?
78. Name one amendment that guarantees or addresses voting rights.
79. Which president freed the slaves?
80. In what year was the Constitution written?
81. What are the first 10 amendments to the Constitution called?
82. Name one purpose of the United Nations.
83. Where does Congress meet?
84. Whose rights are guaranteed by the Constitution and the Bill of Rights?
85. What is the introduction to the Constitution called?
86. Name one benefit of being a citizen of the United States.
87. What is the most important right granted to U.S. citizens?
88. What is the United States Capitol (building)?
89. What is the White House?
90. Where is the White House located?
91. What is the name of the president's official home?
92. Name one right guaranteed by the First Amendment.
93. Who is the commander in chief of the U.S. military?
94. Which president was the first commander in chief of the U.S. military?
95. In what month do we vote for the president?
96. In what month is the new president inaugurated?
97. How many times may a senator be reelected?
98. How many times may a congressman be reelected?
99. What are the two major political parties in the United States today?
100. How many states are there in the United States?

332 *Appendix F: United States Citizenship Test Questions* *United States Government*

Biology

38

The Plant Body

Concept Outline

38.1 Meristems elaborate the plant body plan after germination.

Meristems. Growth occurs in the continually dividing cells that function like stem cells in animals.
Organization of the Plant Body. The plant body is a series of iterative units stacked above and below the ground.
Primary and Secondary Growth. Different meristems allow plants to grow in both height and circumference.

38.2 Plants have three basic tissues, each composed of several cell types.

Dermal Tissue. This tissue forms the "skin" of the plant body, protecting it and preventing water loss.
Ground Tissue. Much of a young plant is ground tissue, which supports the plant body and stores food and water.
Vascular Tissue. Special piping tissues conduct water and sugars through the plant body.

38.3 Root cells differentiate as they become distanced from the dividing root apical meristem.

Root Structure. Roots have a durable cap, behind which primary growth occurs.
Modified Roots. Roots can have specialized functions.

38.4 Stems are the backbone of the shoot, transporting nutrients and supporting the aerial plant organs.

Stem Structure. The stem supports the leaves and is anchored by the roots. Vascular tissues are organized within the stem in different ways.
Modified Stems. Specialized stems are adapted for storage and vegetative (asexual) propagation.

38.5 Leaves are adapted to support basic plant functions.

Leaf External Structure. Leaves have flattened blades and slender stalks.
Leaf Internal Structure. Leaves contain cells that carry out photosynthesis, gas exchange, and evaporation.
Modified Leaves. In some plants, leaf development has been modified to provide for a unique need.

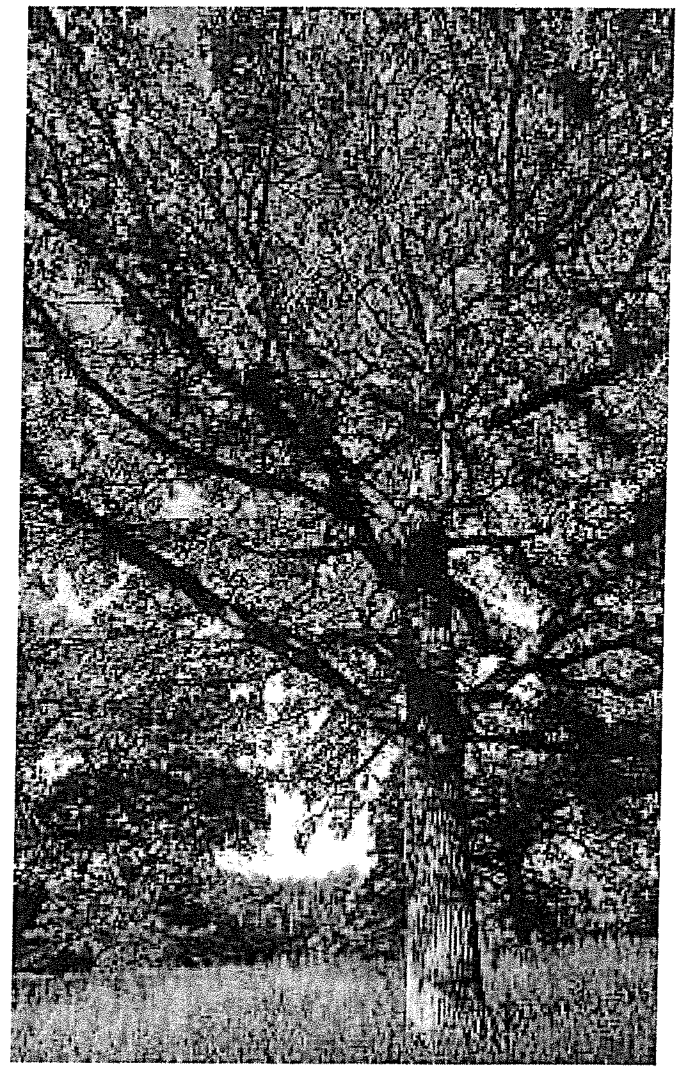


FIGURE 38.1
All vascular plants share certain characteristics. Vascular plan such as this tree require an elaborate system of support and fluid transport to grow this large. Smaller plants have similar (though simpler) structures. Much of this support system is actually underground in the form of extensive branching root systems.

Although the similarities between a cactus, an orchi plant, and a tree might not be obvious at first sigh most plants have a basic unity of structure (figure 38.1 This unity is reflected in how the plants are constructed; i the way they grow, manufacture, and transport their foo and in how their development is regulated. This chapt addresses the question of how a vascular plant is "built We will focus on the diversity of cell, tissue, and orga types that compose the adult body. The roots and shoo which give the adult plant its distinct above and belo ground architecture are the final product of a basic boc plan first established during embryogenesis, a process w will explore in detail in chapter 40.

38.1 Meristems elaborate the plant body plan after germination.

Meristems

The plant body that develops after germination depends on the activities of meristematic tissues. Meristematic tissues are lumps of small cells with dense cytoplasm and proportionately large nuclei that act like stem cells in animals. That is, one cell divides to give rise to two cells. One remains meristematic, while the other is free to differentiate and contribute to the plant body. In this way, the population of meristem cells is continually renewed. Molecular genetic evidence supports the hypothesis that stem cells and meristem cells may also share some common molecular mechanisms.

Elongation of both root and shoot takes place as a result of repeated cell divisions and subsequent elongation of the cells produced by the **apical meristems.** In some vascular plants, including shrubs and most trees, **lateral meristems** produce an increase in girth.

Apical Meristems

Apical meristems are located at the tips of stems (figure 38.2) and at the tips of roots (figure 38.3), just behind the root cap. The plant tissues that result from primary growth are called **primary tissues.** During periods of growth, the cells of apical meristems divide and continually add more cells to the tips of a seedling's body. Thus, the seedling lengthens. Primary growth in plants is brought about by the apical meristems. The elongation of the root and stem forms what is known as the **primary plant body,** which is made up of primary tissues. The primary plant body comprises the young, soft shoots and roots of a tree or shrub, or the entire plant body in some herbaceous plants.

Both root and shoot apical meristems are composed of delicate cells that need protection. The root apical meristem is protected from the time it emerges by the root cap. Root cap cells are produced by the root meristem and are sloughed off and replaced as the root moves through the soil. A variety of adaptive mechanisms protect shoot apical meristem during germination (figure 38.4). The epicotyl or hypocotyl ("stemlike" tissue above or below the cotyledons) may bend as the seedling emerges to minimize the force on the shoot tip. In the monocots (a late evolving group of angiosperms) there is often a coleoptile (sheath of tissue) that forms a protective tube around the emerging shoot. Later in development, the leaf primordia cover the shoot apical meristem which is particularly susceptible to desiccation.

The apical meristem gives rise to three types of embryonic tissue systems called **primary meristems.** Cell division continues in these partly differentiated tissues as they develop into the primary tissues of the plant body. The

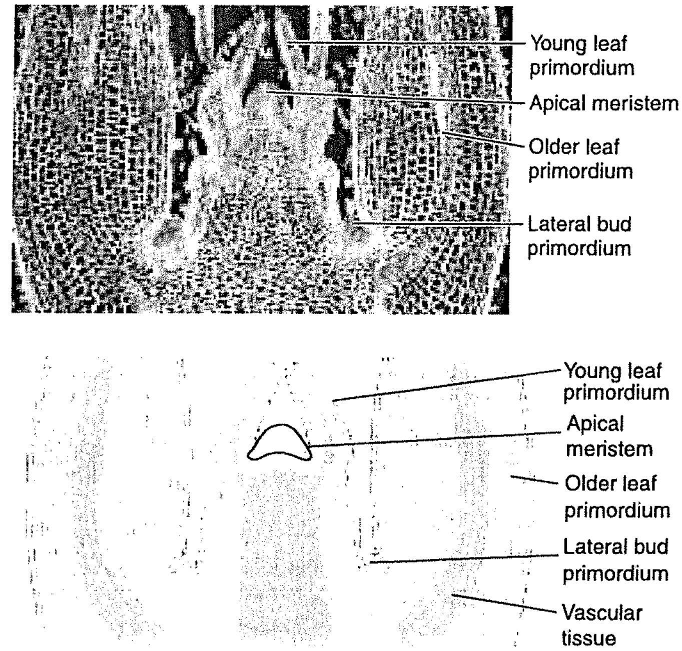


FIGURE 38.2
An apical shoot meristem. This longitudinal section through a shoot apex in *Coleus* shows the tip of a stem. Between the young leaf primordia is the apical meristem.

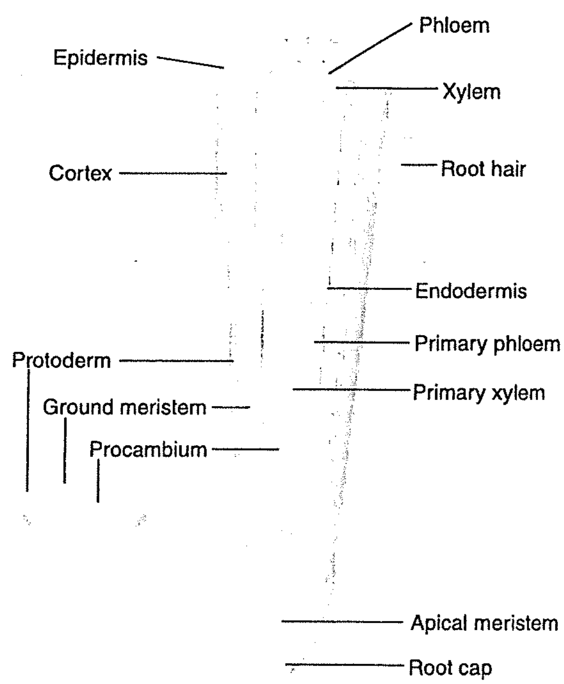
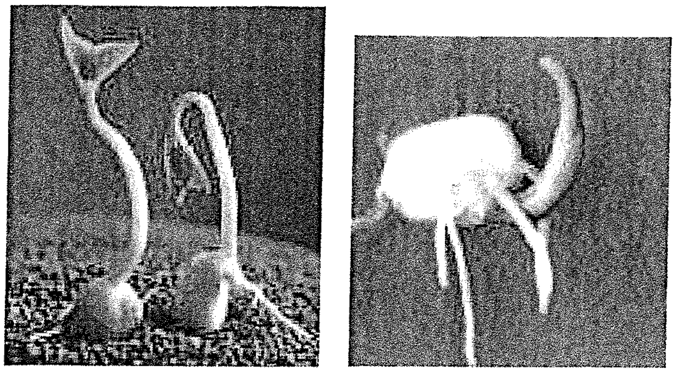


FIGURE 38.3
An apical root meristem. This diagram of meristems in the root shows their relation to the root tip.



(a) (b)

FIGURE 38.4
Developing seedling. Apical meristems are protected early in development. (*a*) In this soybean, a dicot, a bent epicotyl (stem above the cotyledons), rather than the shoot tip, pushes through the soil before straightening. (*b*) In corn, a monocot, a sleeve of tissue called the coleoptile sheaths the shoot tip until it has made it to daylight.

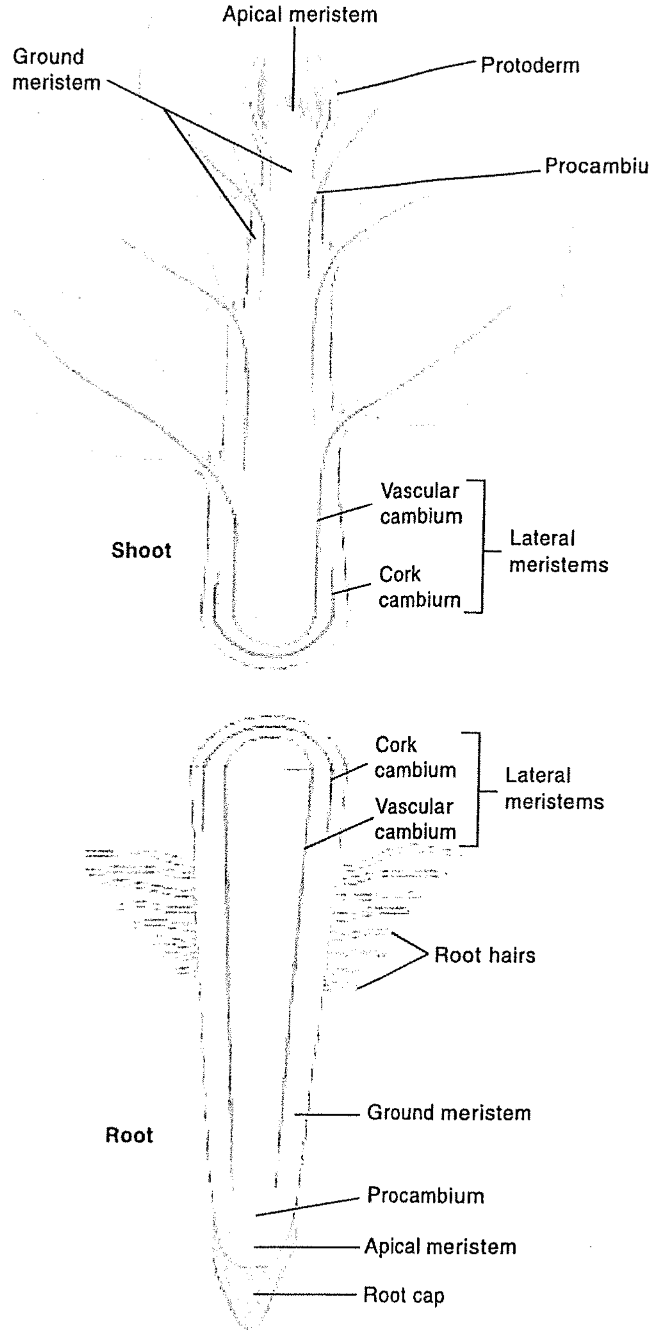


FIGURE 38.5
Apical and lateral meristems. Apical meristems produce primar growth, the elongation of the root and stem. In some plants, the lateral meristems produce an increase in the girth of a plant. Thi: type of growth is secondary because the meristems were not directly produced by apical meristems.

three primary meristems are the **protoderm,** which forms the epidermis; the **procambium,** which produces primary vascular tissues (primary xylem and primary phloem); and the **ground meristem,** which differentiates further into ground tissue, which is composed of parenchyma cells. In some plants, such as horsetails and corn, **intercalary meristems** arise in stem internodes, adding to the internode lengths. If you walk through a corn field (when the corn is about knee high) on a quiet summer night, you may hear a soft popping sound. This is caused by the rapid growth of intercalary meristems. The amount of stem elongation that occurs in a very short time is quite surprising.

Lateral Meristems

Many herbaceous plants exhibit only primary growth, but others also exhibit **secondary growth.** Most trees, shrubs, and some herbs have active **lateral meristems,** which are cylinders of meristematic tissue within the stems and roots (figure 38.5). Although secondary growth increases girth in many nonwoody plants, its effects are most dramatic in woody plants which have two lateral meristems. Within the bark of a woody stem is the **cork cambium,** a lateral meristem that produces the cork cells of the outer bark. Just beneath the bark is the **vascular cambium,** a lateral meristem that produces secondary vascular tissue. The vascular cambium forms between the xylem and phloem in vascular bundles, adding secondary vascular tissue on opposite sides of the vascular cambium. *Secondary xylem* is the main component of wood. *Secondary phloem* is very close to the outer surface of a woody stem. Removing the bark of a tree damages the phloem and may eventually kill the tree. Tissues formed from lateral meristems, which comprise most of the trunk, branches, and older roots of trees and shrubs, a known as **secondary tissues** and are collectively called th secondary plant body.

Meristems are actively dividing, embryonic tissues responsible for both primary and secondary growth.

Organization of the Plant Body

Coordination of primary and secondary meristematic growth produces the body of the adult sporophyte plant. Plant bodies do not have a fixed size. Parts such as leaves, roots, branches, and flowers all vary in size and number from plant to plant—even within a species. The development of the form and structure of plant parts may be relatively rigidly controlled, but some aspects of leaf, stem, and root development are quite flexible. As a plant grows, the number, location, size, and even structure of leaves and roots are often influenced by the environment.

A vascular plant consists of a **root system** and a **shoot system** (figure 38.6). The root system anchors the plant and penetrates the soil, from which it absorbs water and ions crucial to the plant's nutrition. The shoot system consists of the **stems** and their **leaves.** The stem serves as a framework for positioning the leaves, the principal sites of photosynthesis. The arrangement, size, and other features of the leaves are of critical importance in the plant's production of food. Flowers, other reproductive organs, and, ultimately, fruits and seeds are also formed on the shoot (see chapters 40 and 42). The reiterative unit of the vegetative shoot consists of the internode, node, leaf, and axillary buds. Axillary buds are apical meristems derived from the primary apical meristem that allow the plant to branch or replace the main shoot if it is munched by an herbivore. A vegetative axillary bud has the capacity to reiterate the development of the primary shoot. When the plant has transited to the reproductive phase of development (see chapter 41), these axillaries may produce flowers or floral shoots.

Three basic types of tissues exist in plants: *ground tissue, dermal,* and *vascular tissue.* Each of the three basic tissues has its own distinctive, functionally related cell types. Some of these cell types will be discussed later in this chapter. In plants limited to primary growth, the dermal system is composed of the **epidermis.** This tissue is one cell thick in most plants, and forms the outer protective covering of the plant. In young exposed parts of the plant, the epidermis is covered with a fatty **cutin** layer constituting the **cuticle;** in plants such as the desert succulents, a layer of wax may be added outside the cuticle. In plants with secondary growth, the bark forms the outer protective layer and is considered a part of the dermal tissue system.

Ground tissue consists primarily of thin-walled **parenchyma** cells that are initially (but briefly) more or less spherical. However, the cells, which have living protoplasts, push up against each other shortly after they are produced and assume other shapes, often ending up with 11 to 17 sides. Parenchyma cells may live for many years; they function in storage, photosynthesis, and secretion.

Vascular tissue includes two kinds of conducting tissues: (1) **xylem,** which conducts water and dissolved minerals; and (2) **phloem,** which conducts carbohydrates—mainly sucrose—used by plants for food. The phloem also transports hormones, amino acids, and other substances that are necessary for plant growth. Xylem and phloem differ in structure as well as in function.

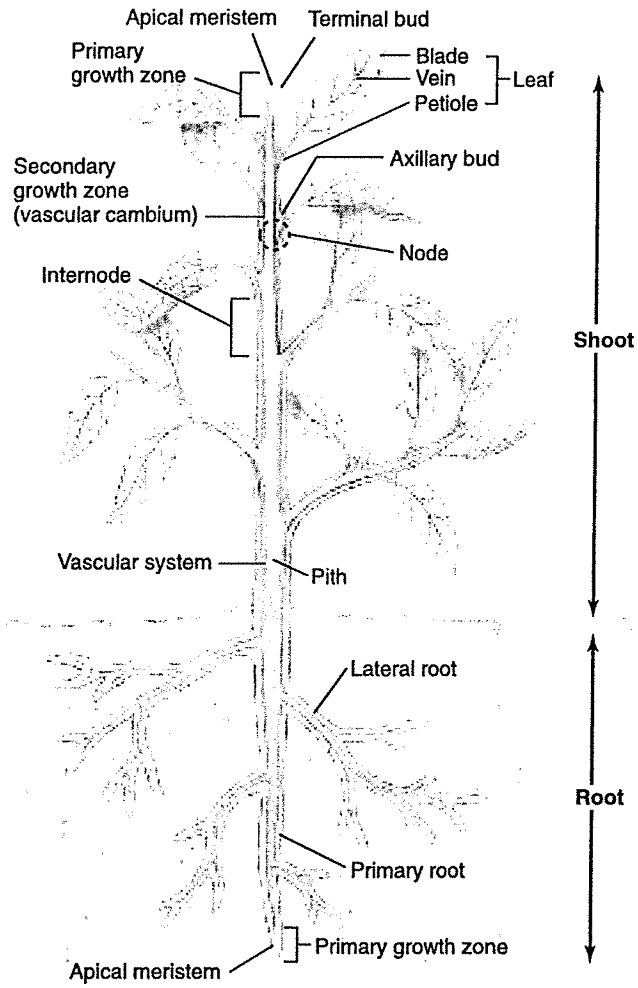


FIGURE 38.6
Diagram of a plant body. Branching in both the root and shoot system increases the number of apical meristems. A significant increase in stem/root circumference and the formation of bark can only occur if there is secondary growth initiated by vascular and cork cambium (secondary meristems). The lime green areas are zones of active elongation; secondary growth occurs in the lavender areas.

Root and shoot meristems give rise to a plant body with an extensive underground, branching root system and aboveground shoot system with reiterative units of advantageously placed leaves joined at the node of the plant, internode, and axillary buds.

Primary and Secondary Growth

Primary and secondary growth play important roles in establishing the basic body plan of the organism. Here we will look at how these meristems give rise to highly differentiated tissues that support the growing plant body. In the earliest vascular plants, the vascular tissues produced by primary meristems played the same conducting roles as they do in contemporary vascular plants. There was no differentiation of the plant body into stems, leaves, and roots. The presence of these three kinds of organs is a property of most modern plants. It reflects increasing specialization in relation to the demands of a terrestrial existence.

With the evolution of secondary growth, vascular plants could develop thick trunks and become treelike (figure 38.7). This evolutionary advance in the sporophyte generation made possible the development of forests and the domination of the land by plants. As discussed in chapter 37, reproductive constraints would have made secondary growth and increased height nonadaptive if it had occurred in the gametophyte generation. Judging from the fossil record, secondary growth evolved independently in several groups of vascular plants by the middle of the Devonian period 380 million years ago.

There were two types of conducting systems in the earliest plants—systems that have become characteristic of vascular plants as a group. *Sieve-tube members* conduct carbohydrates away from areas where they are manufactured or stored. *Vessel members* and *tracheids* are thick-walled cells that transport water and dissolved minerals up from the roots. Both kinds of cells are elongated and occur in linked strands making tubes. Sieve-tube members are characteristic of phloem tissue; vessel members and tracheids are characteristic of xylem tissue. In primary tissues, which result from primary growth, these two types of tissue are typically associated with each other in the same vascular strands. In secondary growth, the phloem is found on the periphery, while a very thick xylem core develops more centrally. You will see that roots and shoots of many vascular plants have different patterns of vascular tissue and secondary growth. Keep in mind that water and nutrients travel between the most distant tip of a redwood root and the tip of the shoot. For the system to work, these tissues connect, which they do in the transition zone between the root and the shoot. In the next section, we will consider the three tissue systems that are present in all plant organs, whether the plant has secondary growth or not.

Plants grow from the division of meristematic tissue. Primary growth results from cell division at the apical meristem at the tip of the plant, making the shoot longer. Secondary growth results from cell division at the lateral meristem in a cylinder encasing the shoot, and increases the shoot's girth.

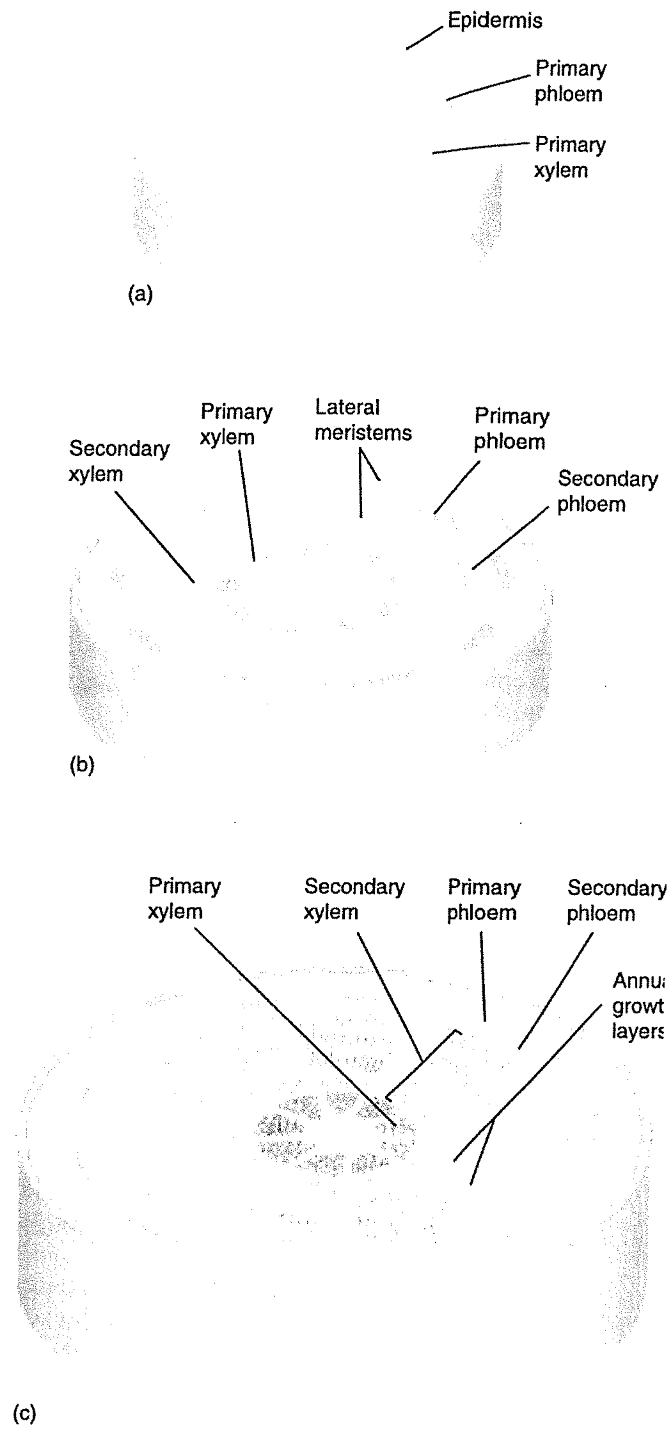


FIGURE 38.7
Secondary growth. (*a*) Before secondary growth begins, primary tissues continue to elongate as the apical meristems produce primary growth. (*b*) As secondary growth begins, the lateral meristems produce secondary tissues, and the stem's girth increases. (*c*) In this three-year-old stem, the secondary tissues continue to widen, and the trunk has become thick and woody. Note that the lateral meristems form cylinders that run axially in roots and shoots that have them.

38.2 Plants have three basic tissues, each composed of several cell types.

Dermal Tissue

Epidermal cells, which originate from the protoderm, cover all parts of the primary plant body. This is probably the earliest tissue system to appear in embryogenesis. The exposed outer walls have a cuticle that varies in thickness, depending on the species and environmental conditions. A number of types of specialized cells occur in the epidermis, including **guard cells, trichomes,** and **root hairs.**

Guard cells are paired sausage- or dumbbell-shaped cells flanking a **stoma** (plural, **stomata**), a mouth-shaped epidermal opening. Guard cells, unlike other epidermal cells, contain chloroplasts. Stomata occur in the epidermis of leaves (figure 38.8), and sometimes on other parts of the plant, such as stems or fruits. The passage of oxygen and carbon dioxide, as well as diffusion of water in vapor form, takes place almost exclusively through the stomata. There are between 1000 to more than 1 million stomata per square centimeter of leaf surface. In many plants, stomata are more numerous on the lower epidermis than on the upper epidermis of the leaf. Some plants have stomata only on the lower epidermis, and a few, such as water lilies, have them only on the upper epidermis.

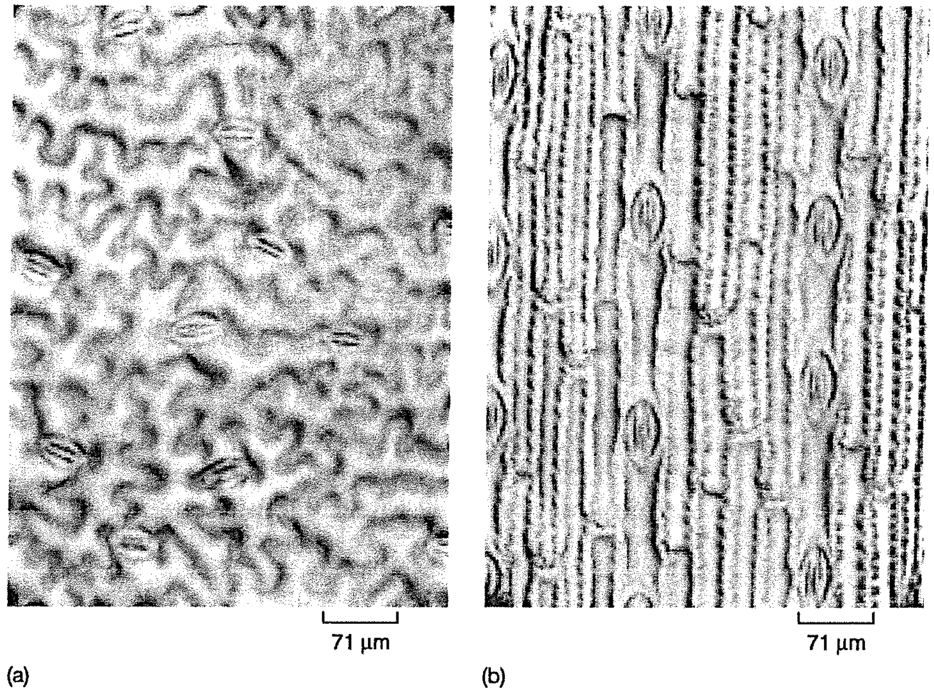


FIGURE 38.8
Epidermis of a dicot and monocot leaf (250×). Stomata are evenly distributed over the epidermis of monocots and dicots, but the patterning is quite different. (*a*) A pea (dicot) leaf with a random arrangement of stomata. (*b*) A corn leaf with stomata evenly spaced in rows. These photos also show the variety of cell shapes in plants. Some plant cells are boxlike, as seen in corn (*b*), while others are irregularly shaped, as seen in peas (*a*).

Guard cell formation is the result of an asymmetrical cell division just like we saw in the first cell division in an algal and angiosperm zygote. The patterning of these asymmetrical divisions resulting in stomatal distribution has intrigued developmental biologists. Research on mutants that get "confused" about where to position stomata are providing information on the timing of stomatal initiation and the kind of intercellular communication that triggers guard cell formation. For example, the *too many mouths* mutation may be caused by a failure of developing stomata to suppress stomatal formation in neighboring cells (figure 38.9).

The stomata open and shut in response to external factors such as light, temperature, and availability of water. During periods of active photosynthesis, the stomata are open, allowing the free passage of carbon dioxide into and oxygen out of the leaf. We will consider the mechanism that governs such movements in chapter 39.

Trichomes are hairlike outgrowths of the epidermis (figure 38.10). They occur frequently on stems, leaves, and reproductive organs. A "fuzzy" or "woolly" leaf is covered with trichomes that can be seen clearly with a microscope

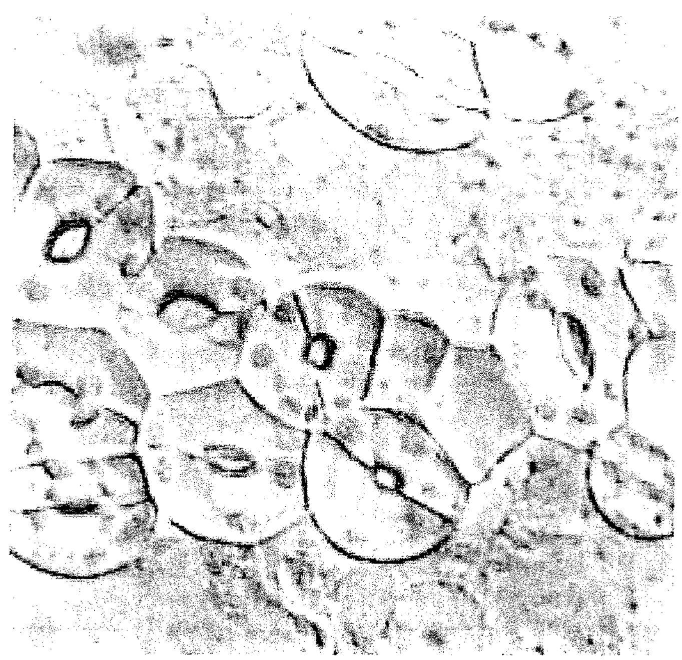


FIGURE 38.9
The *too many mouths* stomatal mutant. This *Arabidopsis* plant lacks an essential signal for spacing guard cells.

under low magnification. Trichomes play an important role in keeping the leaf surface cool and in reducing the rate of evaporation. Trichomes vary greatly in form in different kinds of plants; some consist of a single cell, while others may consist of several cells. Some are glandular, often secreting sticky or toxic substances to deter herbivory.

Trichome development has been investigated extensively in *Arabidopsis.* Four genes are needed to specify the site of trichome formation and initiate it (figure 38.11). Next, eight genes are necessary for extension growth. Loss of function of any one of these genes results in a trichome with a distorted root hair. This is an example of taking a very simple system and trying to genetically dissect all the component parts. Understanding the formation of more complex plant parts is a major challenge.

Root hairs, which are tubular extensions of individual epidermal cells, occur in a zone just behind the tips of young, growing roots (see figure 38.3). Because a root hair is simply an extension and not a separate cell, there is no crosswall isolating it from the epidermal cell. Root hairs keep the root in intimate contact with the surrounding soil particles and greatly increase the root's surface area and the efficiency of absorption. As the root grows, the extent of the root hair zone remains roughly constant as root hairs at the older end slough off while new ones are produced at the other end. Most of the absorption of water and minerals occurs through root hairs, especially in herbaceous plants. Root hairs should not be confused with lateral roots which are multicellular and have their origins deep within the root.

In the case of secondary growth, the cork cambium (discussed in the section on stems in this chapter) produces the bark of a tree trunk or root. This replaces the epidermis which gets stretched and broken with the radial expansion of the axis. Epidermal cells generally lack the plasticity of other cells, but in some cases, they can fuse to the epidermal cells of another organ or organelle and dedifferentiate.

Some epidermal cells are specialized for protection, others for absorption. Spacing of these specialized cells within the epidermis maximizes their function and is an intriguing developmental puzzle.

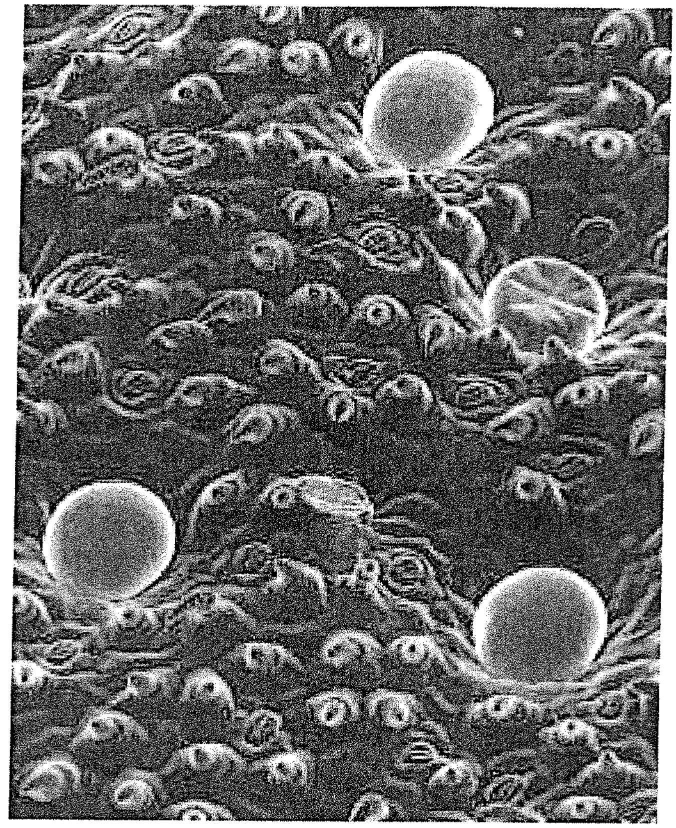


FIGURE 38.10
Trichomes. A covering of trichomes, teardrop-shaped blue structures above, creates a layer of more humid air near the leaf surface, enabling the plant to conserve available water supplies.

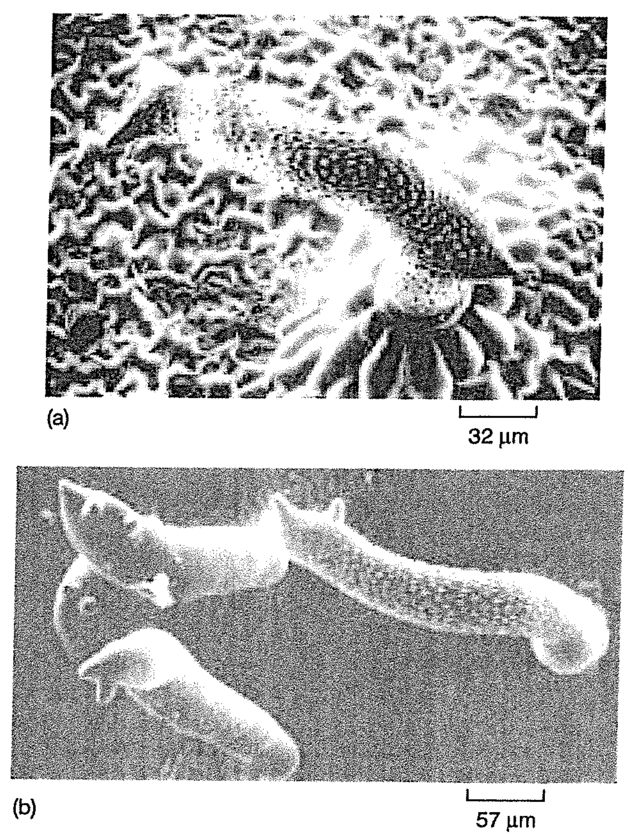


FIGURE 38.11
Trichome mutations. Mutants have revealed genes involved in a signal transduction pathway that regulates the spacing and development of trichomes. These include (*a*) *DISTORTED1* (*DIS1*) and (*b*) *DIS2* mutants in which trichomes are swollen and twisted.

Ground Tissue

Parenchyma

Parenchyma cells, which have large vacuoles, thin walls, and an average of 14 sides at maturity, are the most common type of plant cell. They are the most abundant cells of primary tissues and may also occur, to a much lesser extent, in secondary tissues (figure 38.12*a*). Most parenchyma cells have only primary walls, which are walls laid down while the cells are still maturing. Parenchyma are less specialized than other plant cells, although there are many variations that do have special functions such as nectar and resin secretion, or storage of latex, proteins, and metabolic wastes.

Parenchyma cells, which have functional nuclei and are capable of dividing, commonly also store food and water, and usually remain alive after they mature; in some plants (for example, cacti), they may live to be over 100 years old. The majority of cells in fruits such as apples are parenchyma. Some parenchyma contain chloroplasts, especially in leaves and in the outer parts of herbaceous stems. Such photosynthetic parenchyma tissue is called *chlorenchyma*.

Collenchyma

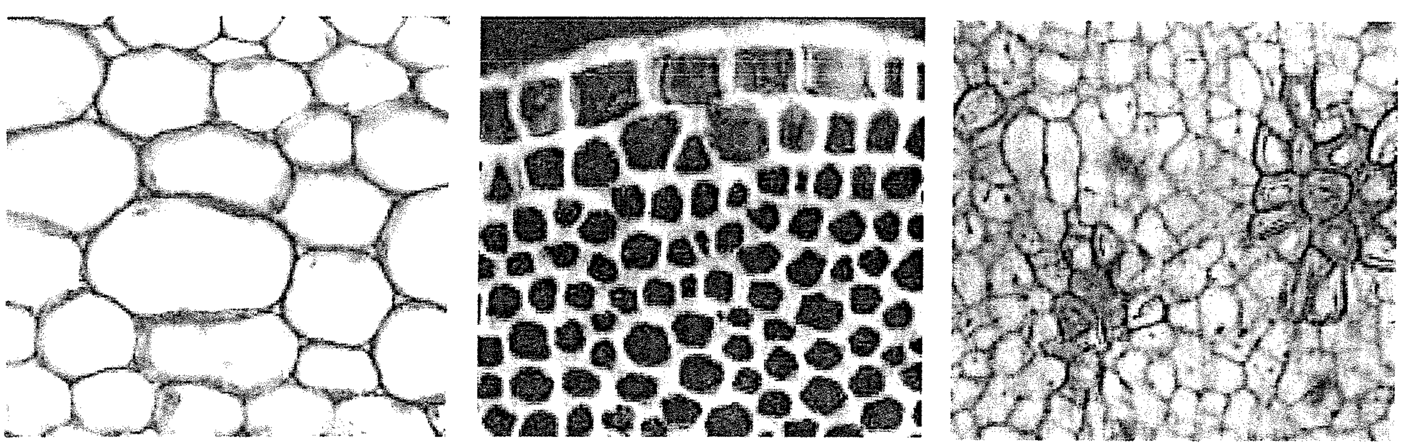
Collenchyma cells, like parenchyma cells, have living protoplasts and may live for many years. The cells, which are usually a little longer than wide, have walls that vary in thickness (figure 38.12*b*). Collenchyma cells, which are relatively flexible, provide support for plant organs, allowing them to bend without breaking. They often form strands or continuous cylinders beneath the epidermis of stems or leaf petioles (stalks) and along the veins in leaves. Strands of collenchyma provide much of the support for stems in which secondary growth has not taken place. The parts of celery that we eat (petioles, or leaf stalks), have "strings" that consist mainly of collenchyma and vascular bundles (conducting tissues).

Sclerenchyma

Sclerenchyma cells have tough, thick walls; they usually lack living protoplasts when they are mature. Their secondary cell walls are often impregnated with **lignin,** a highly branched polymer that makes cell walls more rigid. Cell walls containing lignin are said to be **lignified.** Lignin is common in the walls of plant cells that have a supporting or mechanical function. Some kinds of cells have lignin deposited in primary as well as secondary cell walls.

There are two types of sclerenchyma: fibers and sclereids. **Fibers** are long, slender cells that are usually grouped together in strands. Linen, for example, is woven from strands of sclerenchyma fibers that occur in the phloem of flax. **Sclereids** are variable in shape but often branched. They may occur singly or in groups; they are not elongated, but may have various forms, including that of a star. The gritty texture of a pear is caused by groups of sclereids that occur throughout the soft flesh of the fruit (figure 38.12*c*). Both of these tough, thick-walled cell types serve to strengthen the tissues in which they occur.

Parenchyma cells are the most common type of plant cells and have various functions. Collenchyma cells provide much of the support in young stems and leaves. Sclerenchyma cells strengthen plant tissues and may be nonliving at maturity.



(a) (b) (c)

FIGURE 38.12
The three types of ground tissue. (*a*) Parenchyma cells. Only primary cell walls are seen in this cross-section of parenchyma cells from grass. (*b*) Collenchyma cells. Thickened side walls are seen in this cross-section of collenchyma cells from a young branch of elderberry (*Sambucus*). In other kinds of collenchyma cells, the thickened areas may occur at the corners of the cells or in other kinds of strips. (*c*) Sclereids. Clusters of sclereids ("stone cells"), stained red in this preparation, in the pulp of a pear. The surrounding thin-walled cells, stained light blue, are *parenchyma.* These sclereid clusters give pears their gritty texture.

Vascular Tissue

Xylem

Xylem, the principal water-conducting tissues of plants, usually contains a combination of **vessels,** which are continuous tubes formed from dead, hollow, cylindrical cells **(vessel members)** arranged end to end, and **tracheids,** which are dead cells that taper at the ends and overlap one another (figure 38.13). In some plants, such as gymnosperms, tracheids are the only water-conducting cells present; water passes in an unbroken stream through the xylem from the roots up through the shoot and into the leaves. When the water reaches the leaves, much of it passes into a film of water on the outside of the parenchyma cells, and then it diffuses in the form of water vapor into the intercellular spaces and out of the leaves into the surrounding air, mainly through the stomata. This diffusion of water vapor from a plant is known as **transpiration.** In addition to conducting water, dissolved minerals, and inorganic ions such as nitrates and phosphates throughout the plant, xylem supplies support for the plant body.

Primary xylem is derived from the procambium, which comes from the apical meristem. *Secondary xylem* is formed by the vascular cambium, a lateral meristem that develops later. Wood consists of accumulated secondary xylem.

Vessel members are found almost exclusively in angiosperms. In primitive angiosperms, vessel members tend to resemble fibers and are relatively long. In more advanced angiosperms, vessel members tend to be shorter and wider, resembling microscopic, squat coffee cans with both ends removed. Both vessel members and tracheids have thick, lignified secondary walls and no living protoplasts at maturity. Lignin is produced by the cell and secreted to strengthen the cellulose cell walls before the protoplast dies, leaving only the cell wall. When the continuo stream of water in a plant flows through tracheids, it pass through **pits,** which are small, mostly rounded-to-ellipti areas where no secondary wall material has been deposite The pits of adjacent cells occur opposite one another. I contrast, vessel members, which are joined end to end, ma be almost completely open or may have bars or strips wall material across the open ends.

Vessels appear to conduct water more efficiently than d the overlapping strands of tracheids. We know this part because vessel members have evolved from tracheids inde pendently in several groups of plants, suggesting that the are favored by natural selection. It is also probable th some types of fibers have evolved from tracheids, becomin specialized for strengthening rather than conducting. Som ancient flowering plants have only tracheids, but virtual all modern angiosperms have vessels. Plants, with a muta tion that prevents the differentiation of xylem, but does n affect tracheids, wilt soon after germination and are unab to transport water efficiently.

In addition to conducting cells, xylem typically includ fibers and parenchyma cells (ground tissue cells). Th parenchyma cells, which are usually produced in horizont rows called **rays** by special *ray initials* of the vascular cam bium, function in lateral conduction and food storage. A initial is another term for a meristematic cell. It divides produce another initial and a cell that differentiates into ray cell. In cross-sections of woody stems and roots, th rays can be seen radiating out from the center of the xyle like the spokes of a wheel. Fibers are abundant in som kinds of wood, such as oak (*Quercus*), and the wood is co respondingly dense and heavy. The arrangements of the and other kinds of cells in the xylem make it possible identify most plant genera and many species from the wood alone. These fibers are a major component in mo ern paper. Earlier paper was made from fibers in phloem.

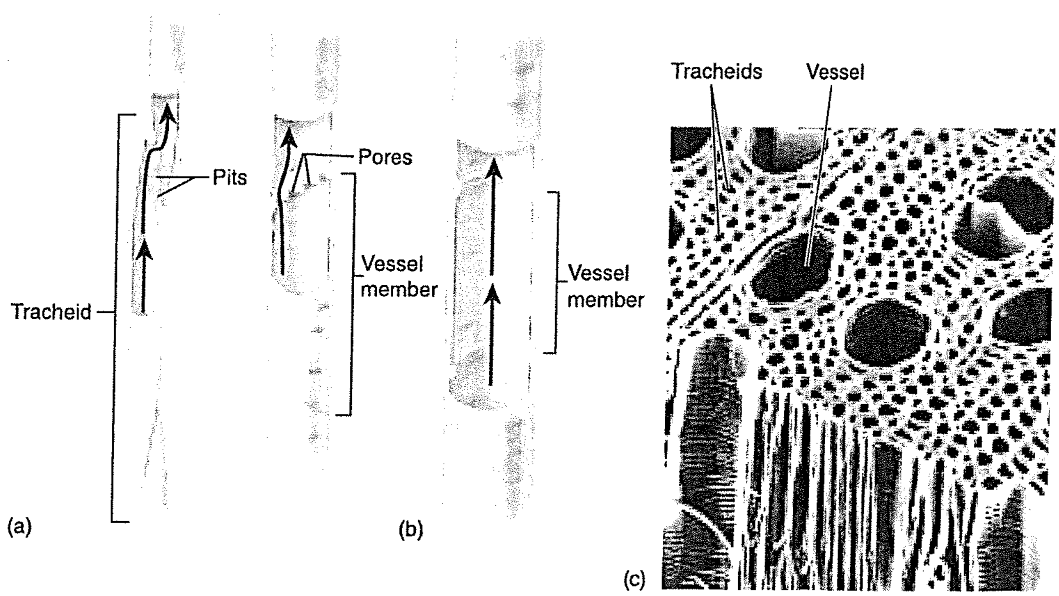


FIGURE 38.13
Comparison between vessel members and tracheids. (*a*) In tracheids, the water passes from cell to cell by means of pits, (*b*) while in vessel members, it moves by way of perforation plates or between bars of wall material. In gymnosperm wood, tracheids both conduct water and provide support; in most kinds of angiosperms, vessels are present in addition to tracheids, or present exclusively. These two types of cells conduct the water, and fibers provide additional support. (*c*) Scanning micrograph of the wood of red maple, *Acer rubrum* (350×).

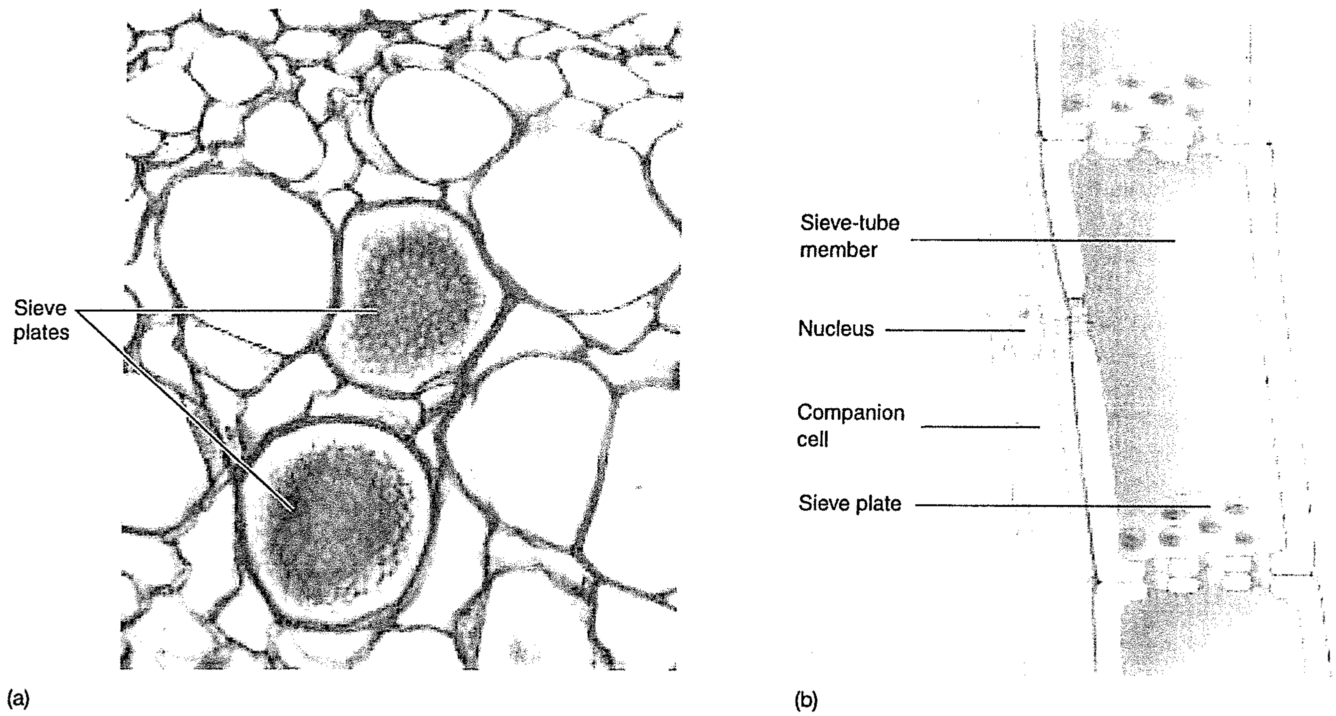


FIGURE 38.14
A sieve-tube member. (*a*) Looking down into sieve plates in squash phloem reveals the perforations sucrose and hormones move through. (*b*) Sieve-tube member cells are stacked with the sieve plates forming the connection. The narrow cell with the nucleus at the left of the sieve-tube member is a companion cell. This cell nourishes the sieve-tube members, which have plasma membranes, but no nuclei.

Phloem

Phloem, which is located toward the outer part of roots and stems, is the principal food-conducting tissue in vascular plants. If a plant is *girdled* (by removing a substantial strip of bark down to the vascular cambium), the plant eventually dies from starvation of the roots.

Food conduction in phloem is carried out through two kinds of elongated cells: **sieve cells** and **sieve-tube members** (figure 38.14). Seedless vascular plants and gymnosperms have only sieve cells; most angiosperms have sieve-tube members. Both types of cells have clusters of pores known as **sieve areas.** Sieve areas are more abundant on the overlapping ends of the cells and connect the protoplasts of adjoining sieve cells and sieve-tube members. Both of these types of cells are living, but most sieve cells and all sieve-tube members lack a nucleus at maturity. This type of cell differentiation has parallels to the differentiation of human red blood cells which also lack a nucleus at maturity.

In sieve-tube members, some sieve areas have larger pores and are called **sieve plates.** Sieve-tube members occur end to end, forming longitudinal series called **sieve tubes.** Sieve cells are less specialized than sieve-tube members, and the pores in all of their sieve areas are roughly of the same diameter. In an evolutionary sense, sieve-tube members are more advanced, more specialized, and, presumably, more efficient.

Each sieve-tube member is associated with an adjacent specialized parenchyma cell known as a **companion cell.** Companion cells apparently carry out some of the metabolic functions that are needed to maintain the associated sieve-tube member. In angiosperms, a common initial cell divides asymmetrically to produce a sieve-tube member cell and its companion cell. Companion cells have all of the components of normal parenchyma cells, including nuclei, and their numerous **plasmodesmata** (cytoplasmic connections between adjacent cells) connect their cytoplasm with that of the associated sieve-tube members. Fibers and parenchyma cells are often abundant in phloem.

Xylem conducts water and dissolved minerals from the roots to the shoots and the leaves. Phloem carries organic materials from one part of the plant to another.

38.3 Root cells differentiate as they become distanced from the dividing root apical meristem.

Root Structure

The three tissue systems are found in the three kinds of vegetative organs in plants: **roots, stems,** and **leaves.** Roots have a simpler pattern of organization and development than stems, and we will consider them first. Four zones or regions are commonly recognized in developing roots. The zones are called the **root cap,** the **zone of cell division,** the **zone of elongation,** and the **zone of maturation** (figure 38.15). In three of the zones, the boundaries are not clearly defined. When apical initials divide, daughter cells that end up on the tip end of the root become root cap cells. Cells that divide in the opposite direction pass through the three other zones before they finish differentiating. As you consider the different zones, visualize the tip of the root moving away from the soil surface by growth. This will counter the static image of a root that diagrams and photos convey.

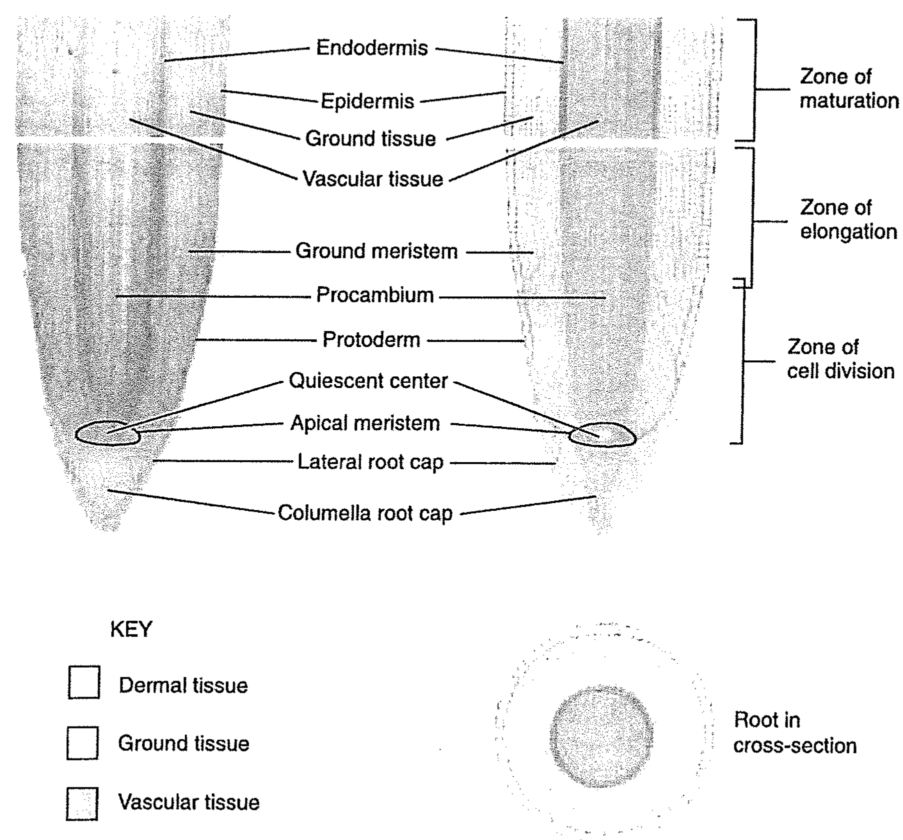


FIGURE 38.15
Root structure. A root tip in corn, *Zea mays.* This longitudinal section of a root shows the root cap, apical meristem, procambium, protoderm, epidermis, and ground meristem.

The Root Cap

The root cap has no equivalent in stems. It is composed (two types of cells, the inner columella (they look lik columns) cells and the outer, lateral root cap cells that a continuously replenished by the root apical meristem. I some plants with larger roots it is quite obvious. Its mo obvious function is to protect the delicate tissues behind as growth extends the root through mostly abrasive so particles. Golgi bodies in the outer root cap cells secre and release a slimy substance that passes through the ce walls to the outside. The cells, which have an average life (less than a week, are constantly being replaced from the ir side, forming a mucilaginous lubricant that eases the ro through the soil. The slimy mass also provides a mediu for the growth of beneficial nitrogen-fixing bacteria in th roots of some plants such as legumes.

A new root cap is produced when an existing one is a tificially or accidentally removed from a root. The ro cap also functions in the *perception* *gravity.* The columella cells are highl specialized with the endoplasmic retic ulum in the periphery and the nucle located at either the middle or the to of the cell. There are no large vacuole Columella cells contain amyloplas (plastids with starch grains) that colle on the sides of cells facing the pull (gravity. When a potted plant is place on its side, the amyloplasts drift c tumble down to the side nearest th source of gravity, and the root bends i that direction. Lasers have been used t ablate (kill) individual columella cells i *Arabidopsis.* It turns out that only two (the columella cells are essential fc gravity sensing! The precise nature (the gravitational response is nc known, but some evidence indicat that calcium ions in the amyloplasts ir fluence the distribution of growth ho mones (auxin in this case) in the cell There may be multiple signaling mech anisms because bending has been ol served in the absence of auxin. A cu rent hypothesis is that an electric signal moves from the columella cell t cells in the distal region of the elong tion zone (the region closest to th zone of cell division).

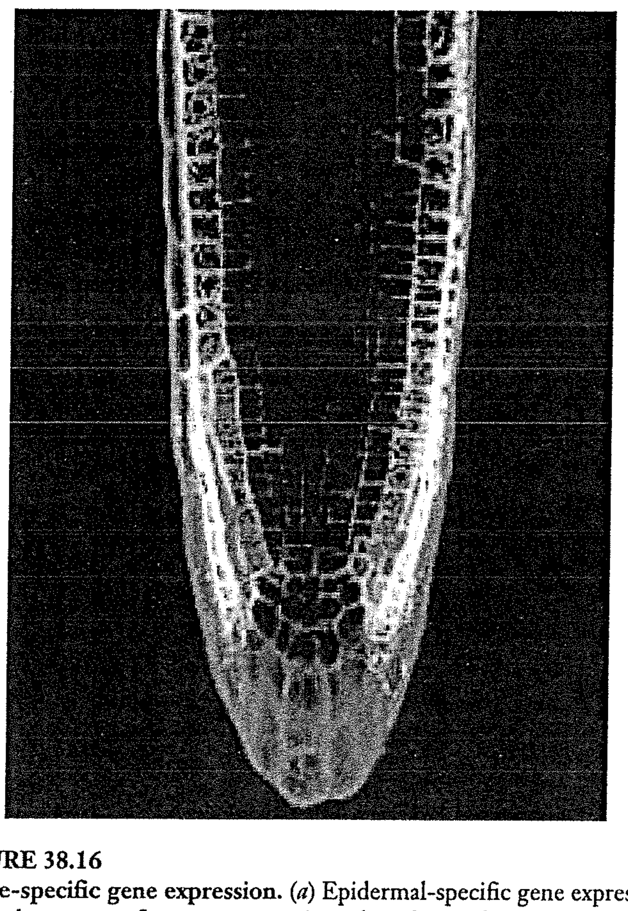
The Zone of Cell Division

The apical meristem is shaped like an inverted, concave dome of cells and is located in the center of the root tip in the area protected by the root cap. Most of the activity in this *zone of cell division* takes place toward the edges of the dome, where the cells divide every 12 to 36 hours, often rhythmically, reaching a peak of division once or twice a day. Most of the cells are essentially cuboidal with small vacuoles and proportionately large, centrally located nuclei. These rapidly dividing cells are daughter cells of the apical meristem. The *quiescent center* is a group of cells in the center of the root apical meristem. They divide very infrequently. This makes sense if you think about a solid ball expanding. The outer surface would have to increase far more rapidly than the very center.

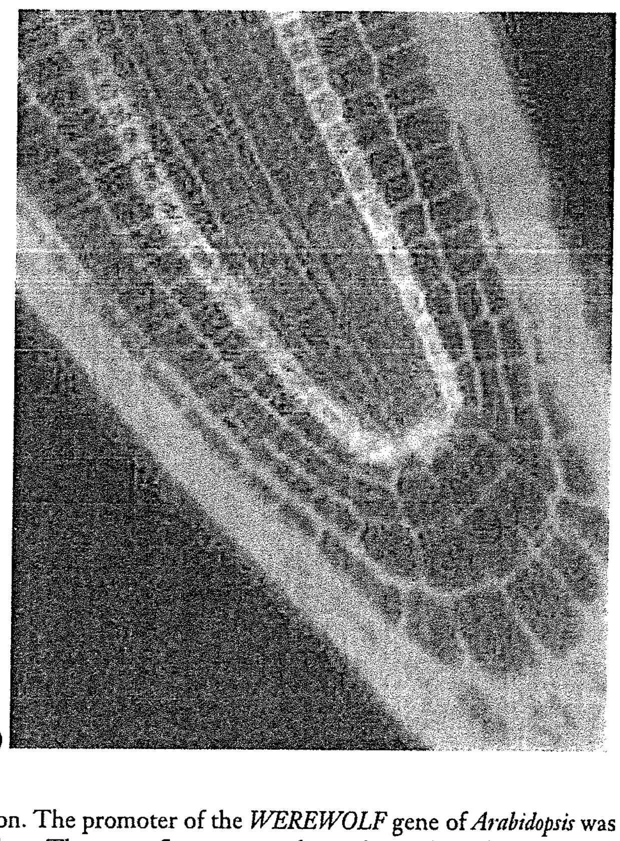
The apical meristem daughter cells soon subdivide into the three primary tissue systems previously discussed: *protoderm, procambium,* and *ground meristem.* Genes have been identified in the relatively simple root of *Arabidopsis* that regulate the patterning of these tissue systems. The patterning of these cells begins in this zone, but it is not until the cells reach the zone of maturation that the anatomical and morphological expression of this patterning is fully revealed. *WEREWOLF*, for example, is required for the patterning of the two root epidermal cell types, those with and without root hairs (figure 38.16*a*). The *SCARECROW* gene is important in ground cell differentiation (figure 38.16*b*). It is necessary for an asymmetric cell division that gives rise to two cylinders of cells from one. The outer cell layer becomes ground tissue and serves a storage function. The inner cell layer forms the endodermis which regulates the intercellular flow of water and solutes into the vascular core of the root. Cells in this region develop according to their position. If that position changes because of a mistake in cell division or the ablation of another cell, the cell develops according to its new position.

The Zone of Elongation

In the *zone of elongation*, the cells produced by the primary meristems become several times longer than wide, and their width also increases slightly. The small vacuoles present merge and grow until they occupy 90% or more of the volume of each cell. No further increase in cell size occurs above the zone of elongation, and the mature parts of the root, except for an increase in girth, remain stationary for the life of the plant.



(a)



(b)

FIGURE 38.16
Tissue-specific gene expression. (*a*) Epidermal-specific gene expression. The promoter of the *WEREWOLF* gene of *Arabidopsis* was attached to a green fluorescent protein and used to make a transgenic plant. The green fluorescence shows the epidermal cells where the gene is expressed. The red was used to visually indicate cell boundaries. (*b*) Ground tissue-specific gene expression. The *SCARECROW* gene is needed for an asymmetric cell division allowing for the formation of side-by-side ground tissue and endodermal cells. These two layers are blue in wild-type, but in the mutant, only one cell layer is blue because the asymmetric cell division does not occur.

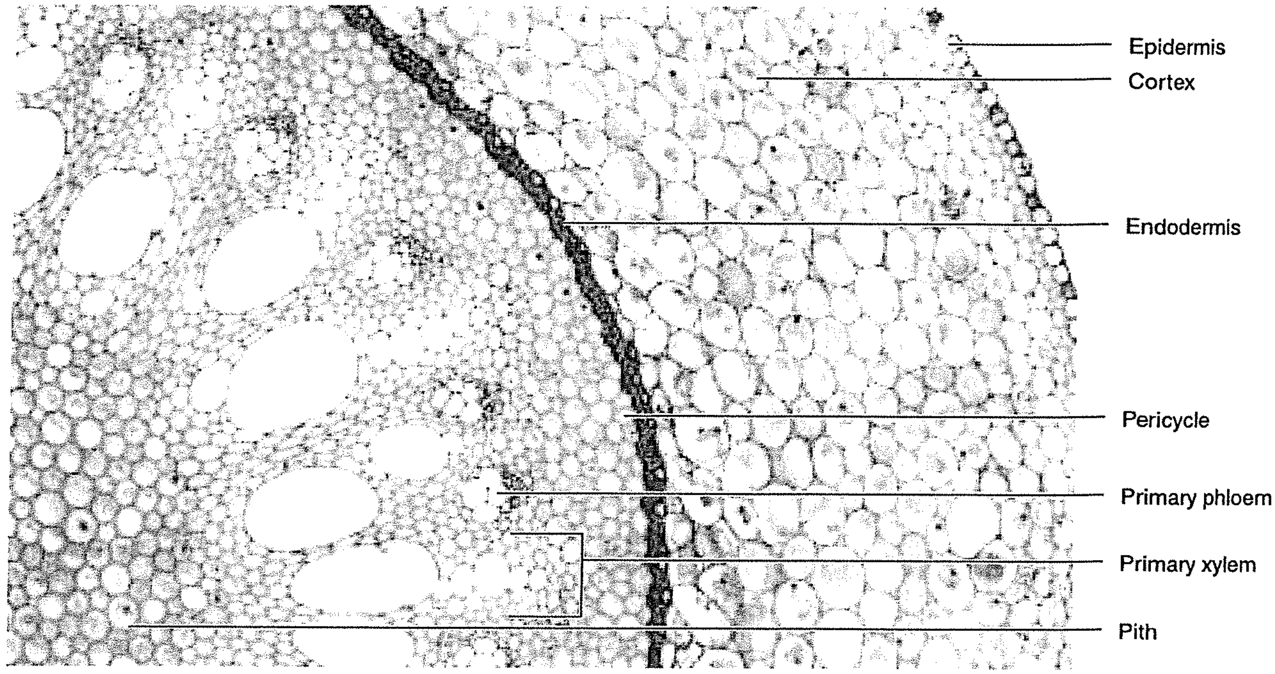


FIGURE 38.17
Cross-section of the zone of maturation of a young monocot root. Greenbrier (*Smilax*), a monocot (100×).

The Zone of Maturation

The cells that have elongated in the zone of elongation become differentiated into specific cell types in the *zone of maturation.* The cells of the root surface cylinder mature into *epidermal cells,* which have a very thin cuticle. Many of the epidermal cells each develop a **root hair;** the protuberance is not separated by a crosswall from the main part of the cell and the nucleus may move into it. Root hairs, which can number over 35,000 per square centimeter of root surface and many billions per plant, greatly increase the surface area and therefore the absorptive capacity of the root. The root hairs usually are alive and functional for only a few days before they are sloughed off at the older part of the zone of maturation, while new ones are being produced toward the zone of elongation. Symbiotic bacteria that fix atmospheric nitrogen into a form usable by legumes enter the plant via root hairs and "instruct" the plant to create a nodule around it.

Parenchyma cells are produced by the ground meristem immediately to the interior of the epidermis. This tissue, called the **cortex,** may be many cells wide and functions in food storage. The inner boundary of the cortex differentiates into a single-layered cylinder of **endodermis** (figure 38.17), whose primary walls are impregnated with **suberin,** a fatty substance that is impervious to water. The suberin is produced in bands, called **Casparian strips** that surround each adjacent endodermal cell wall perpendicular to the root's surface (figure 38.18). This blocks transport between cells. The two surfaces that are parallel to the root surface are the only way into th core of the root and the cell membranes control wh passes through.

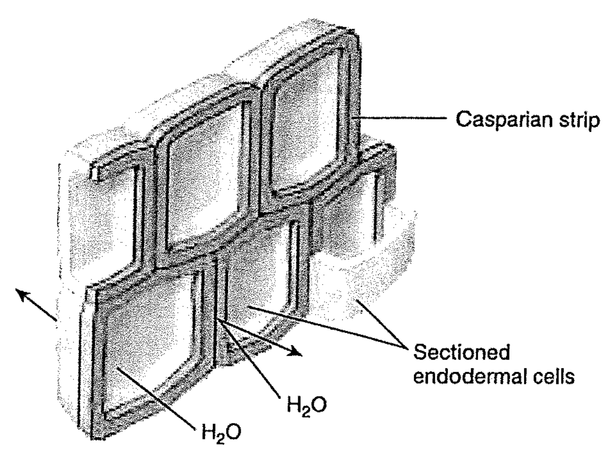
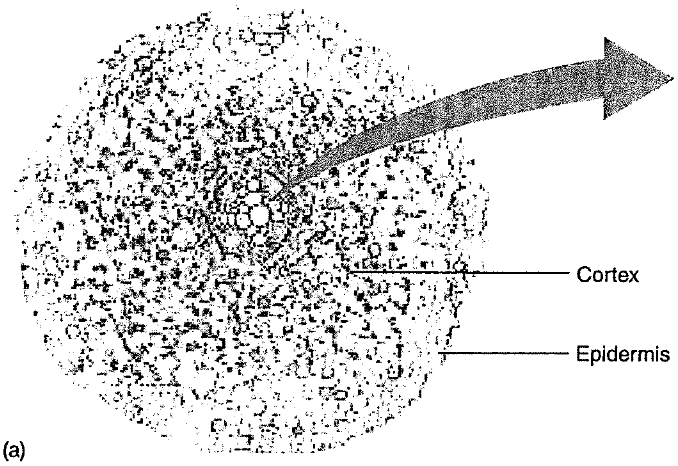


FIGURE 38.18
Casparian strip. The Casparian strip is a water-proofing band that protects cells inside the endodermis from flooding.

All the tissues interior to the endodermis are collective referred to as the **stele.** Immediately adjacent and interic to the endodermis is a cylinder of parenchyma cells know as the **pericycle.** Pericycle cells can divide, even after the mature. They can give rise to *lateral* (branch) *roots* or, in d cots, to part of the *vascular cambium.*



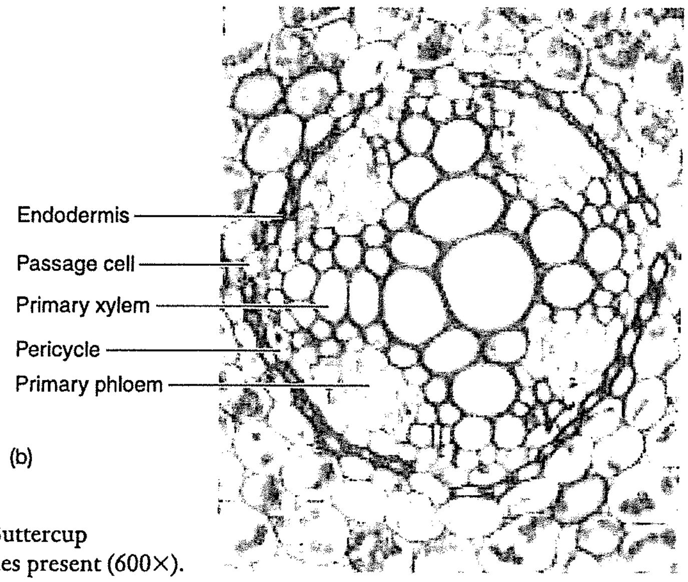


FIGURE 38.19
Cross-section of the zone of maturation of a young dicot root. (*a*) Buttercup (*Ranunculus*), a dicot (40×). (*b*) The enlargement shows the various tissues present (600×).

The water-conducting cells of the *primary xylem* are differentiated as a solid core in the center of young dicot roots. In a cross-section of a dicot root, the central core of primary xylem often is somewhat star-shaped, with one or two to several radiating arms that point toward the pericycle (figure 38.19). In monocot (and a few dicot) roots, the primary xylem is in discrete **vascular bundles** arranged in a ring, which surrounds parenchyma cells, called **pith,** at the very center of the root. **Primary phloem,** composed of cells involved in food conduction, is differentiated in discrete groups of cells between the arms of the xylem in both dicot and monocot roots.

In dicots and other plants with **secondary growth,** part of the pericycle and the parenchyma cells between the phloem patches and the xylem arms become the root vascular cambium, which starts producing **secondary xylem** to the inside and **secondary phloem** to the outside (figure 38.20). Eventually, the secondary tissues acquire the form of concentric cylinders. The primary phloem, cortex, and epidermis become crushed and are sloughed off as more secondary tissues are added. In the pericycle of woody plants, the cork cambium produces bark which will be discussed in the section on stems (see figure 38.26). In the case of secondary growth in dicot roots, everything outside the stele is lost and replaced with bark.

Root apical meristems produce a root cap at the tip and root tissue on the opposite side. Cells mature as the root cap and meristem grows away from them. Transport systems, external barriers, and a branching root system develop from the primary root as it matures.

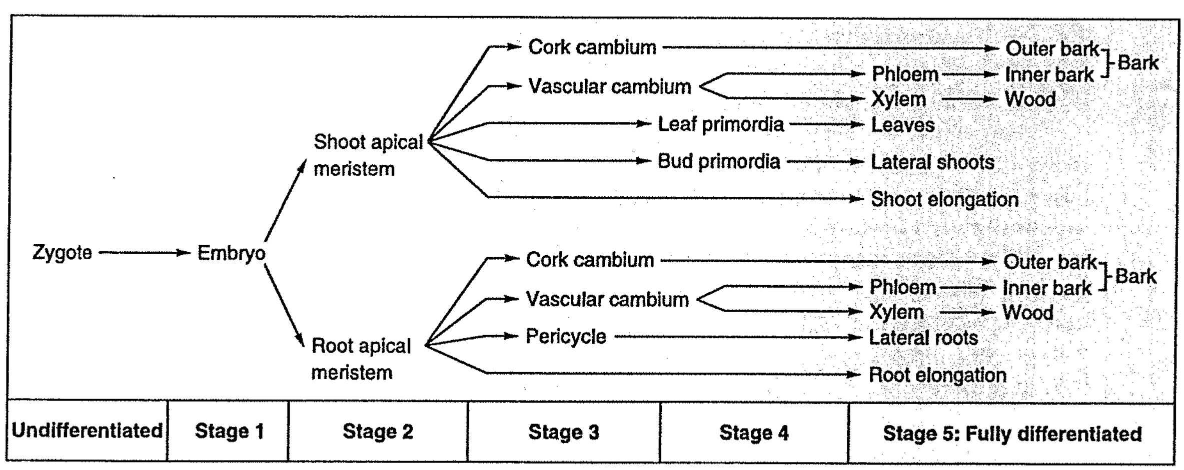
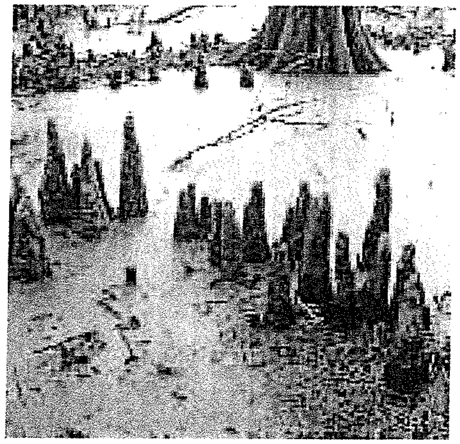


FIGURE 38.20
Stages in the differentiation of plant tissues.

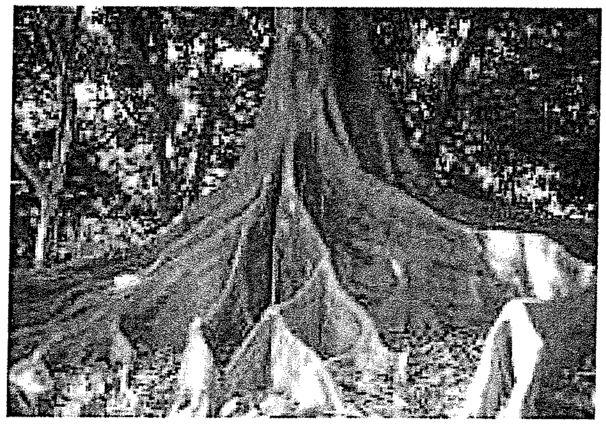
Modified Roots

Most plants produce either a **taproot system** in which there is a single large root with smaller branch roots, or a **fibrous root system** in which there are many smaller roots of similar diameter. Some plants, however, have intriguing root modifications with specific functions in addition to those of anchorage and absorption.



(a)

(b)



(c)

FIGURE 38.21
Three types of modified roots. (*a*) Pneumatophores (foreground) are spongy outgrowths from the roots below. (*b*) A water storage root weighing over 25 kilograms (60 pounds). (*c*) Buttress roots of a tropical fig tree.

Aerial roots. Some plants, such as epiphytic orchids (orchids that are attached to tree branches and grow unconnected to the ground without being parasitic in any way) have roots that extend out into the air. Some aerial roots have an epidermis that is several cells thick, an adaptation to reduce water loss. These aerial roots may also be green and photosynthetic, as in the vanilla orchid. Some monocots, such as corn, produce thick roots from the lower parts of the stem; these *prop roots* grow down to the ground and brace the plants against wind. Climbing plants such as ivy also produce roots from their stems; these anchor the stems to tree trunks or a brick wall. Any root that arises along a stem or in some place other than the root of the plant is called an *adventitious root.* Adventitious root formation in ivy depends on the developmental stage of the shoot. When the shoot transitions to the adult phase of development, it is no longer capable of initiating these roots.

Pneumatophores. Some plants that grow in swamps and other wet places may produce spongy outgrowths called *pneumatophores* from their underwater roots (figure 38.21*a*). The pneumatophores commonly extend several centimeters above water, facilitating the oxygen supply to the roots beneath.

Contractile roots. The roots from the bulbs of lilies and of several other plants such as dandelions contract by spiraling to pull the plant a little deeper into the soil each year until they reach an area of relatively stable temperatures. The roots may contract to a third of their original length as they spiral like a corkscrew due to cellular thickening and constricting.

Parasitic roots. The stems of certain plants that lack chlorophyll, such as dodder (*Cuscuta*), produce peglike roots called *haustoria* that penetrate the host plan around which they are twined. The haustoria establis contact with the conducting tissues of the host and e fectively parasitize their host.

Food storage roots. The xylem of branch roots (sweet potatoes and similar plants produce at interva many extra parenchyma cells that store large quantiti of carbohydrates. Carrots, beets, parsnips, radishes, an turnips have combinations of stem and root that als function in food storage. Cross sections of these roo reveal multiple rings of secondary growth.

Water storage roots. Some members of the pumpki family (Cucurbitaceae), especially those that grow in ari regions, may produce water-storage roots weighing 5 or more kilograms (figure 38.21*b*).

Buttress roots. Certain species of fig and other tropic trees produce huge buttress roots toward the base of th trunk, which provide considerable stability (figure 38.21*c*

Some plants have modified roots that carry out photosynthesis, gather oxygen, parasitize other plants, store food or water, or support the stem.

38.4 Stems are the backbone of the shoot, transporting nutrients and supporting the aerial plant organs.

Stem Structure

External Form

The shoot apical meristem initiates stem tissue and intermittently produces bulges (**primordia**) that will develop into leaves, other shoots, or even flowers (figure 38.22). The stem is an axis from which organs grow. Leaves may be arranged in a spiral around the stem, or they may be in pairs opposite one another; they also may occur in *whorls* (circles) of three or more. Spirals are the most common and, for reasons still not understood, sequential leaves tend to be placed 137.5° apart. This angle relates to the golden mean, a mathematical ratio, that is found in nature (the angle of coiling in some shells, for example), classical architecture (the Parthenon wall dimensions), and even modern art (Mondrian). The pattern of leaf arrangement is called **phyllotaxy** and may optimize exposure of leaves to the sun.

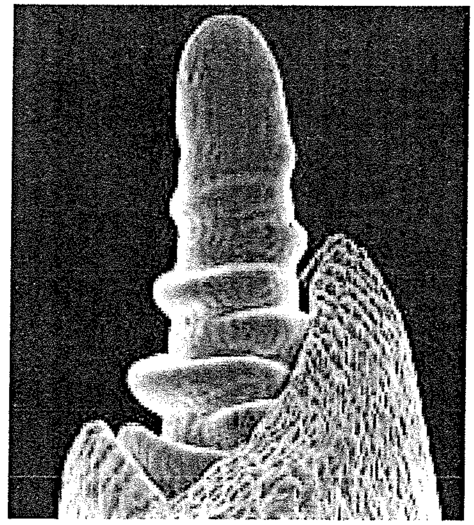


FIGURE 38.22
A shoot apex (200×). Scanning electron micrograph of the apical meristem of wheat (*Triticum*).

The *region* or *area* (no structure is involved) of leaf attachment is called a **node;** the area of stem between two nodes is called an **internode.** A leaf usually has a flattened **blade** and sometimes a **petiole** (stalk). When the petiole is missing, the leaf is then said to be **sessile.** Note that the word *sessile* as applied to plants has a different meaning than it does when applied to animals (probably obvious, as plants don't get up and move around!); in plants, it means *immobile* or *attached.* The space between a petiole (or blade) and the stem is called an axil. An **axillary bud** is produced in each axil. This bud is a product of the primary shoot apical meristem, which, with its associated leaf primordia, is called a **terminal bud.** Axillary buds frequently develop into branches or may form meristems that will develop into flowers. (Refer back to figure 38.6 to review these terms.)

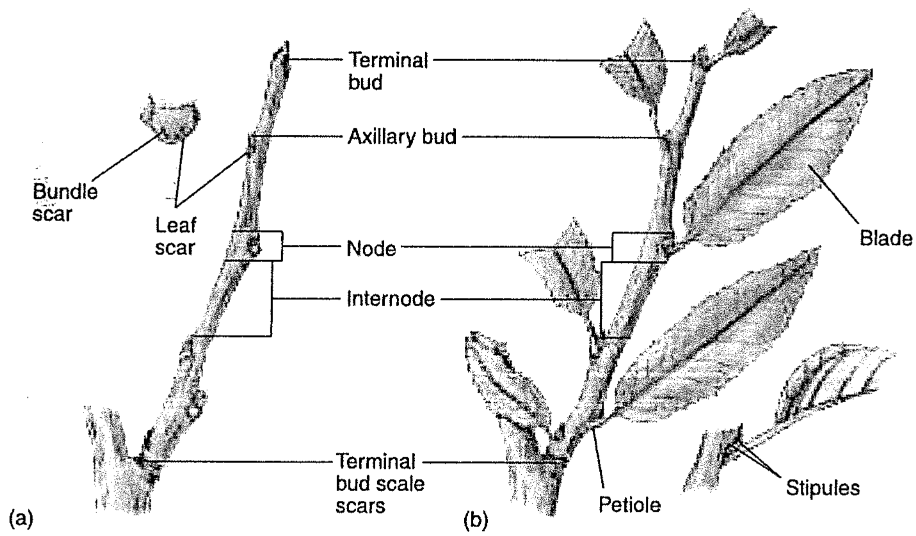


FIGURE 38.23
A woody twig. (*a*) In winter. (*b*) In summer.

Herbaceous stems do not produce a cork cambium. The stems are usually green and photosynthetic, with at least the outer cells of the cortex containing chloroplasts. Herbaceous stems commonly have stomata, and may have various types of trichomes (hairs).

Woody stems can persist over a number of years and develop distinctive markings in addition to the original organs that form. Terminal buds usually extend the length of the shoot during the growing season. Some buds, such as those of geraniums, are unprotected, but most buds of woody plants have protective winter *bud scales* that drop off, leaving tiny *bud scars* as the buds expand. Some twigs have tiny scars of a different origin. A pair of butterfly-like appendages called **stipules** (part of the leaf) develop at the base of some leaves. The stipules can fall off and leave *stipule scars.* When leaves of deciduous trees drop in the fall, they leave *leaf scars* with tiny *bundle scars*, marking where vascular connections were. The shapes, sizes, and other features of leaf scars can be distinctive enough to identify the plants in winter (figure 38.23).

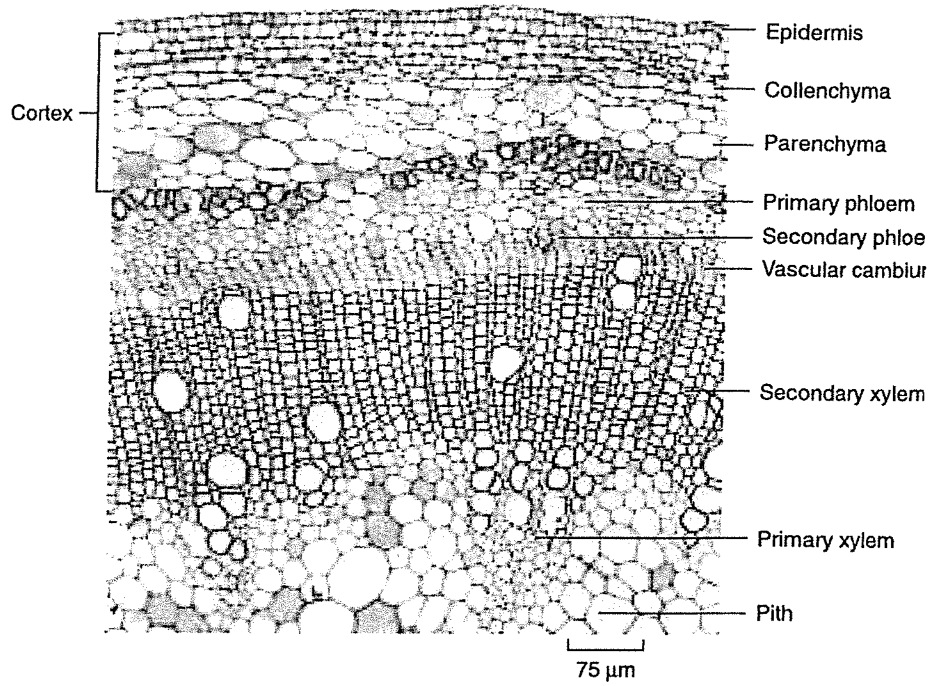


FIGURE 38.24
Early stage in differentiation of vascular cambium in the castor bean, *Ricirus* (25x). The outer part of the cortex consists of collenchyma, and the inner part of parenchyma.

Internal Form

As in roots, there is an *apical meristem* at the tip of each stem, which produces *primary tissues* that contribute to the stem's increases in length. Three primary meristems develop from the apical meristem. The *protoderm* gives rise to the *epidermis.* The *ground meristem* produces parenchyma cells. Parenchyma cells in the center of the stem constitute the *pith;* parenchyma cells away from the center constitute the *cortex.* The *procambium* produces cylinders of *primary xylem* and *primary phloem,* which are surrounded by ground tissue.

A strand of xylem and phloem, called a *trace,* branch off from the main cylinder of xylem and phloem and ente the developing leaf, flower, or shoot. These spaces in th main cylinder of conducting tissues are called **gaps.** In d cots, a **vascular cambium** develops between the prima xylem and primary phloem (figure 38.24). In many way this is a connect-the-dots game where the vascular cam bium connects the ring of primary vascular bundles. I monocots, these bundles are scattered throughout th ground tissue (figure 38.25) and there is no logical way t connect them that would allow a uniform increase in girt This is why monocots do not have secondary growth.

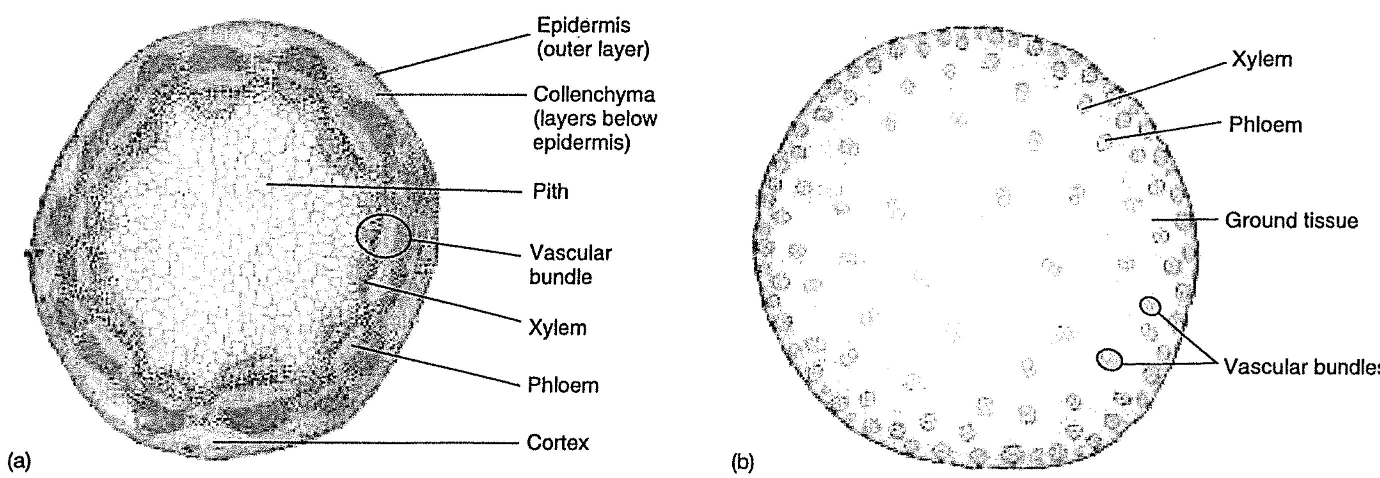


FIGURE 38.25
Stems. Transverse sections of a young stem in *(a)* a dicot, the common sunflower, *Helianthus annuus,* in which the vascular bundles are arranged around the outside of the stem (10×); and *(b)* a monocot, corn, *Zea mays,* with the scattered vascular bundles characteristic of the class (5×).

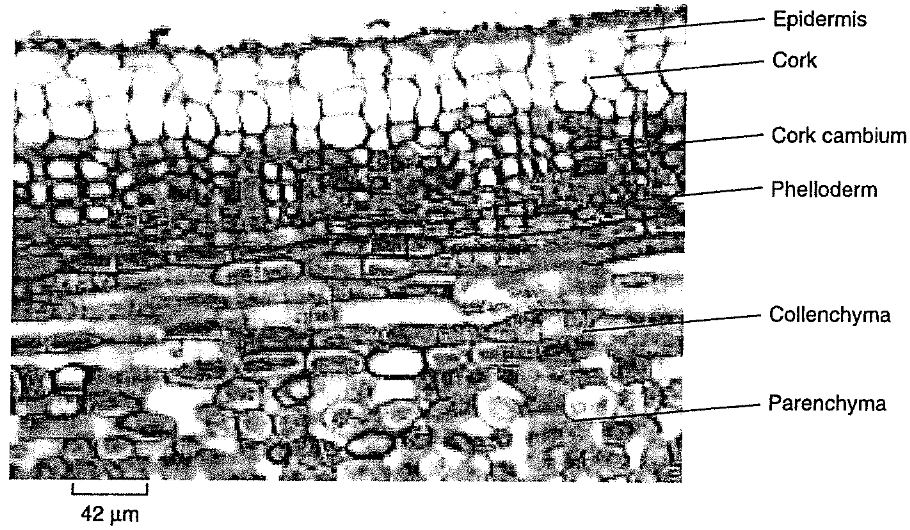
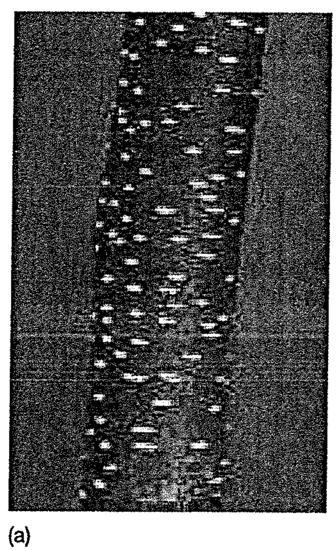


FIGURE 38.26
Section of periderm (50×). An early stage in the development of periderm in cottonwood (*Populus* sp.).

The cells of the vascular cambium divide indefinitely, producing **secondary tissues** (mainly *secondary xylem* and *secondary phloem*). The production of xylem is extensive in trees and is called wood. Rings in the stump of a tree reveal annual patterns of growth; cell size varies depending on growth conditions. In woody dicots, a second cambium, the *cork cambium*, arises in the outer cortex (occasionally in the epidermis or phloem) and produces box-like *cork cells* to the outside and also may produce parenchyma-like *phelloderm* cells to the inside; the cork cambium, cork, and phelloderm are collectively referred to as the *periderm* (figure 38.26). Cork tissues, whose cells become impregnated with *suberin* shortly after they are formed and then die, constitute the **outer bark.** The cork tissue, whose suberin is impervious to moisture, cuts off water and food to the epidermis, which dies and sloughs off. In young stems, gas exchange between stem tissues and the air takes place through stomata, but as the cork cambium produces cork, it also produces patches of unsuberized cells beneath the stomata. These unsuberized cells, which permit gas exchange to continue, are called **lenticels** (figure 38.27).

The stem results from the dynamic growth of the shoot apical meristem which initiates stem tissue and organs including leaves. Shoot apical meristems initiate new apical meristems at the junction of leaf and stem. These meristems can form buds which reiterate the growth pattern of the terminal bud or they can make flowers directly.



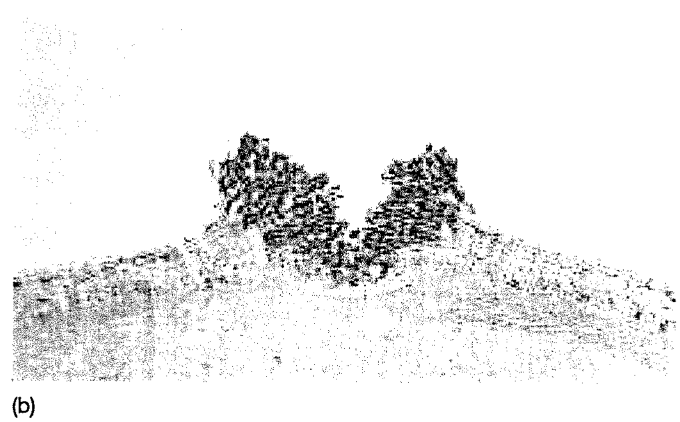


FIGURE 38.27
Lenticels. (*a*) Lenticels, the numerous, small, pale, raised areas shown here on cherry tree bark (*Prunus cerasifera*), allow gas exchange between the external atmosphere and the living tissues immediately beneath the bark of woody plants. Highly variable in form in different species, lenticels are an aid to the identification of deciduous trees and shrubs in winter. (*b*) Transverse section through a lenticel (extruding area) in a stem of elderberry, *Sambucus canadensis* (30×).

Modified Stems

Although most stems grow erect, there are some modifications that serve special purposes, including that of natural *vegetative propagation*. In fact, the widespread artificial vegetative propagation of plants, both commercial and private, frequently involves the cutting of modified stems into segments, which are then planted and produce new plants. As you become acquainted with the following modified stems, keep in mind that stems have *leaves* at *nodes*, with *internodes* between the nodes, and *buds* in the *axils* of the leaves, while roots have no leaves, nodes, or axillary buds.

Bulbs. Onions, lilies, and tulips have swollen underground stems that are really large buds with adventitious roots at the base (figure 38.28*a*). Most of a *bulb* consists of fleshy leaves attached to a small, knoblike stem. In onions, the fleshy leaves are surrounded by papery, scalelike leaf bases of the long, green aboveground leaves.

Corms. Crocuses, gladioluses, and other popular garden plants produce *corms* that superficially resemble bulbs. Cutting a corm in half, however, reveals no fleshy leaves. Instead, almost all of a corm consists of stem, with a few papery, brown nonfunctional leaves on the outside, and adventitious roots below.

Rhizomes. Perennial grasses, ferns, irises, and many other plants produce *rhizomes*, which typically are horizontal stems that grow underground, often close to the surface (figure 38.28*b*). Each node has an inconspicuous scalelike leaf with an axillary bud; much larger photosynthetic leaves may be produced at the rhizome tip. Adventitious roots are produced throughout the length of the rhizome, mainly on the lower surface.

Runners and stolons. Strawberry plants produce horizontal stems with long internodes, which, unlike rhizomes, usually grow along the surface of the ground. Several *runners* may radiate out from a single plant (figure 38.28*c*). Some botanists use the term *stolon* synonymously with runner; others reserve the term stolon for a stem with long internodes that grows underground, as seen in Irish (white) potato plants. An Irish potato itself, however, is another type of modified stem—a *tuber*.

Tubers. In Irish potato plants, carbohydrates may accumulate at the tips of stolons, which swell, becoming *tubers;* the stolons die after the tubers mature (figure 38.28*d*). The "eyes" of a potato are axillary buds formed in the axils of scalelike leaves. The scalelike leaves, which are present when the potato is starting to form, soon drop off; the tiny ridge adjacent to each "eye" of a mature potato is a leaf scar.

Tendrils. Many climbing plants, such as grapes and Boston ivy, produce modified stems knows as *tendrils*, which twine around supports and aid in climbing (figure 38.28*e*). Some tendrils, such as those of peas and pumpkins, are actually modified leaves or leaflets.

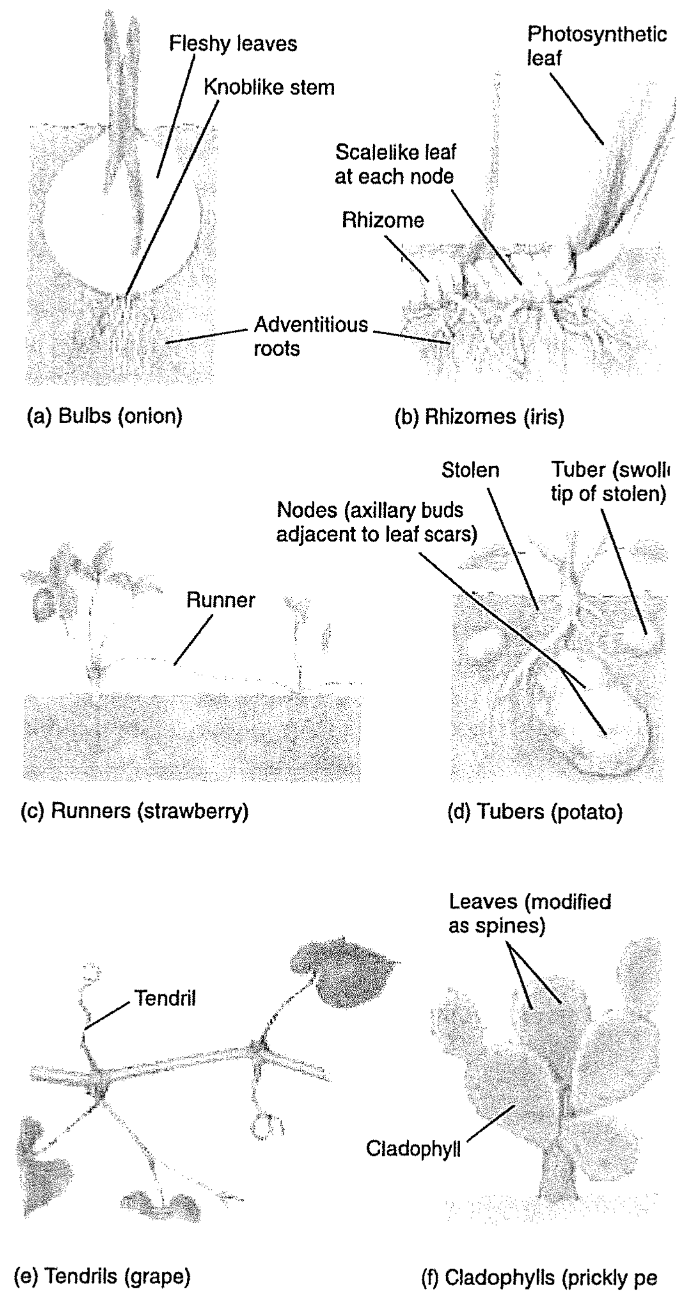


FIGURE 38.28
Types of modified stems.

Cladophylls. Cacti and several other plants produc flattened, photosynthetic stems called *cladophylls* that r semble leaves (figure 38.28*f*). In cacti, the real leaves a modified as spines.

Some plants possess modified stems that serve special purposes including food storage, support, or vegetative propagation.

38.5 Leaves are adapted to support basic plant functions.

Leaf External Structure

Leaves, which are initiated as *primordia* by the apical meristems (see figure 38.2), are vital to life as we know it. They are the principal sites of photosynthesis on land. Leaves expand primarily by cell enlargement and some cell division. Like our arms and legs, they are determinate structures which means growth stops at maturity. Because leaves are crucial to a plant, features such as their arrangement, form, size, and internal structure are highly significant and can differ greatly. Different patterns have adaptive value in different environments.

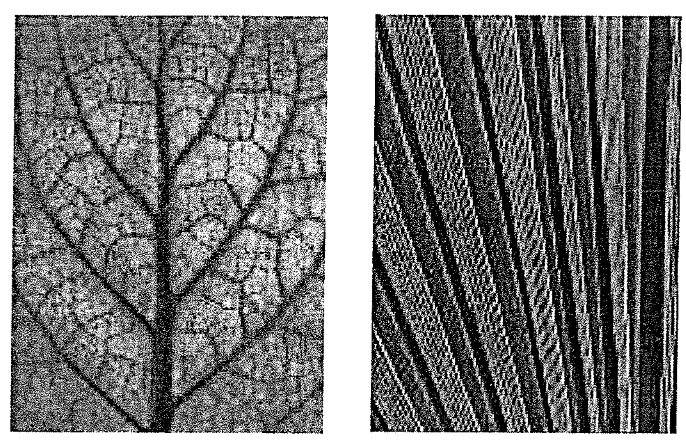
Leaves are really an extension of the shoot apical meristem and stem development. Leaves first emerge as primordia as discussed in the section on stems. At that point, they are not committed to be leaves. Experiments where very young leaf primordia in fern and in coleus are isolated and grown in culture demonstrate this. If the primordia are young enough, they will form an entire shoot rather than a leaf. So, positioning the primordia and beginning the initial cell divisions occurs before those cells are committed to the leaf developmental pathway.

Leaves fall into two different morphological groups which may reflect differences in evolutionary origin. A *microphyll* is a leaf with one vein that does not leave a gap when it branches from the vascular cylinder of the stem; microphylls are mostly small and are associated primarily with the phylum Lycophyta (see chapter 37). Most plants have leaves called *megaphylls,* which have several to many veins; a megaphyll's conducting tissue leaves a gap in the stem's vascular cylinder as it branches from it.

Most dicot leaves have a flattened *blade,* and a slender stalk, the *petiole.* The flattening of the leaf blade reflects a shift from radial symmetry to dorsal-ventral (top-bottom) symmetry. We're just beginning to understand how this shift occurs by analyzing mutants like *phantastica* which prevents this transition (figure 38.29). In addition, a pair of *stipules* may be present at the base of the petiole. The stipules, which may be leaflike or modified as *spines* (as in the black locust—*Robinia pseudo-acacia*) or *glands* (as in cherry trees—*Prunus cerasifera*), vary considerably in size from microscopic to almost half the size of the leaf blade. Development of stipules appears to be independent of development of the rest of the leaf.

Grasses and other monocot leaves usually lack a petiole and tend to sheathe the stem toward the base. **Veins** (a term used for the vascular bundles in leaves), consisting of both xylem and phloem, are distributed throughout the leaf blades. The main veins are parallel in most monocot leaves; the veins of dicots, on the other hand, form an often intricate network (figure 38.30).

FIGURE 38.29
The *phantastica* mutant in snapdragon. Snapdragon leaves are usually flattened with a top and bottom side (plant on *left*). In the *phantastica* mutant (plant on *right*), the leaf never flattens but persists as a radially symmetrical bulge.

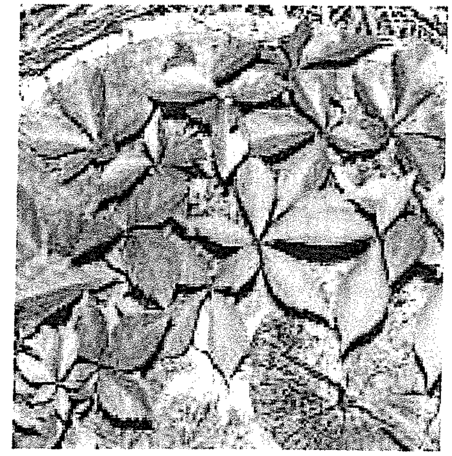


(a) (b)

FIGURE 38.30
Dicot and monocot leaves. The leaves of dicots, such as this (*a*) African violet relative from Sri Lanka, have netted, or reticulate, veins; (*b*) those of monocots, like this cabbage palmetto, have parallel veins. The dicot leaf has been cleared with chemicals and stained with a red dye to make the veins show up more clearly.

(a)

(b)



(c)

FIGURE 38.31
Simple versus compound leaves. (*a*) A simple leaf, its margin deeply lobed, from the tulip tree (*Liriodendron tulipifera*). (*b*) A pinnately compound leaf, from a mountain ash (*Sorbus* sp.) A compound leaf is associated with a single lateral bud, located where the petiole is attached to the stem. (*c*) Palmately compound leaves of a Virginia creeper (*Parthenocissus quinquefolia*).

Leaf blades come in a variety of forms from oval to deeply lobed to having separate leaflets. In **simple leaves** (figure 38.31*a*), such as those of lilacs or birch trees, the blades are undivided, but simple leaves may have teeth, indentations, or lobes of various sizes, as in the leaves of maples and oaks. In **compound leaves**, such as those of ashes, box elders, and walnuts, the blade is divided into **leaflets.** The relationship between the development of compound and simple leaves is an open question. Two explanations are being debated: (1) a compound leaf is a highly lobed simple leaf, or (2) a compound leaf utilizes a shoot development program. There are single mutations that convert compound leaves to simple leaves which are being used to address this debate. If the leaflets are arranged in pairs along a common axis (the axis is called a *rachis*—the equivalent of the main central vein, or *midrib*, in simple leaves), the leaf is **pinnately compound** (figure 38.31*b*). If, however, the leaflets radiate out from a common point at the blade end of the petiole, the leaf is **palmately compound** (figure 38.31*c*). Palmately compound leaves occur in buckeyes (*Aesculus* spp.) and Virginia creeper (*Parthenocissus quinquefolia*). The leaf blades themselves may have similar arrangements of their veins, and are said to be **pinnately** or **palmately** veined.

Leaves, regardless of whether they are simple or compound, may be **alternately** arranged (alternate leaves usually spiral around a shoot) or they may be in **opposite** pairs. Less often, three or more leaves may be in a **whorl**, a circle of leaves at the same level at a node (figure 38.32).

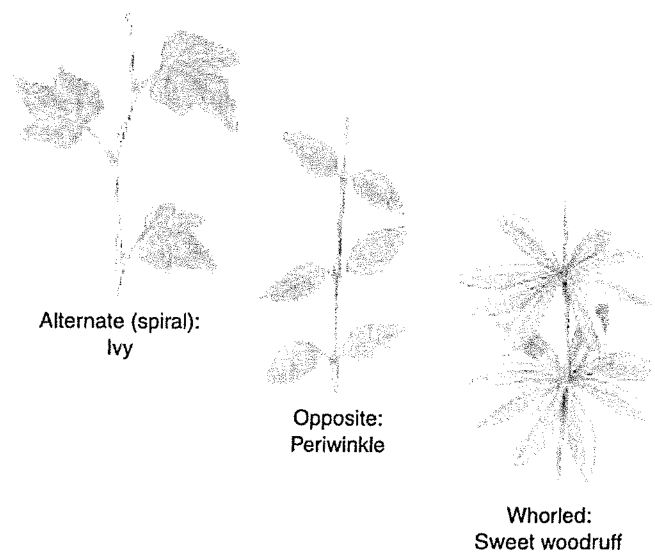


FIGURE 38.32
Types of leaf arrangements. The three common types of leaf arrangements are alternate, opposite, and whorled.

Leaves are the principal sites of photosynthesis. Their blades may be arranged in a variety of ways. In simple leaves the blades are undivided, while in compound leaves the leaf is composed of two or more leaflets.

Leaf Internal Structure

The entire surface of a leaf is covered by a transparent epidermis, most of whose cells have no chloroplasts. The epidermis itself has a waxy *cuticle* of variable thickness, and may have different types of glands and trichomes (hairs) present. The lower epidermis (and occasionally the upper epidermis) of most leaves contains numerous slit-like or mouth-shaped *stomata* (figure 38.33). Stomata, as discussed earlier, are flanked by *guard cells* and function in gas exchange and regulation of water movement through the plant.

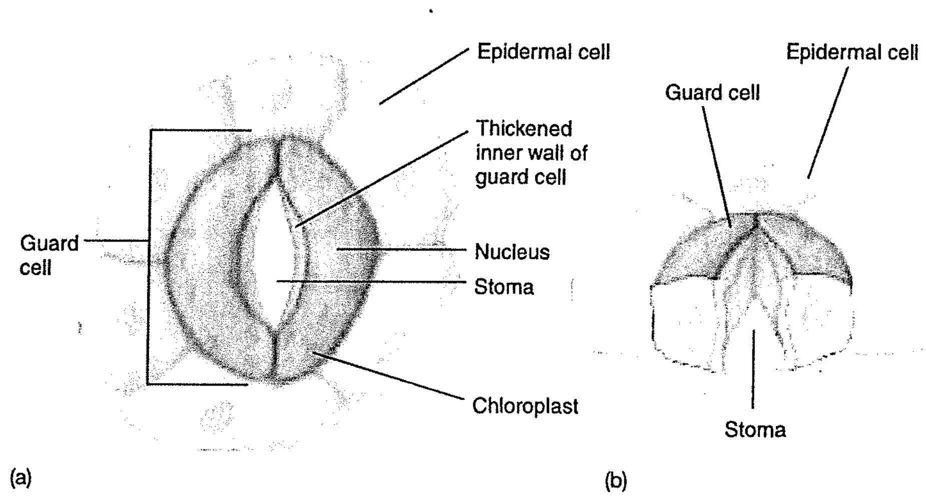


FIGURE 38.33
A stoma. (*a*) Surface view. (*b*) View in cross-section.

The tissue between the upper and lower epidermis is called **mesophyll.** Mesophyll is interspersed with veins (vascular bundles) of various sizes. In most dicot leaves, there are two distinct types of mesophyll. Closest to the upper epidermis are one to several (usually two) rows of tightly packed, barrel-shaped to cylindrical *chlorenchyma* cells (parenchyma with chloroplasts) that constitute the **palisade mesophyll** (figure 38.34). Some plants, including species of *Eucalyptus,* have leaves that hang down, rather than extending horizontally. They have palisade parenchyma on both sides of the leaf, and there is, in effect, no upper side. In nearly all leaves there are loosely arranged **spongy mesophyll** cells between the palisade mesophyll and the lower epidermis, with many air spaces throughout the tissue. The interconnected intercellular spaces, along with the stomata, function in gas exchange and the passage of water vapor from the leaves. The mesophyll of monocot leaves is not differentiated into palisade and spongy layers and there is often little distinction between the upper and lower epidermis. This anatomical difference often correlates with a modified photosynthetic pathway that maximizes the amount of CO_2 relative to O_2 to reduce energy loss through photorespiration (refer to chapter 10). Leaf anatomy directly relates to its juggling act to balance water loss, gas exchange, and transport of photosynthetic products to the rest of the plant.

Leaves are basically flattened bags of epidermis containing vascular tissue and tightly packed palisade mesophyll rich in chloroplasts and loosely packed spongy mesophyll with many interconnected air spaces that function in gas and water vapor exchange.

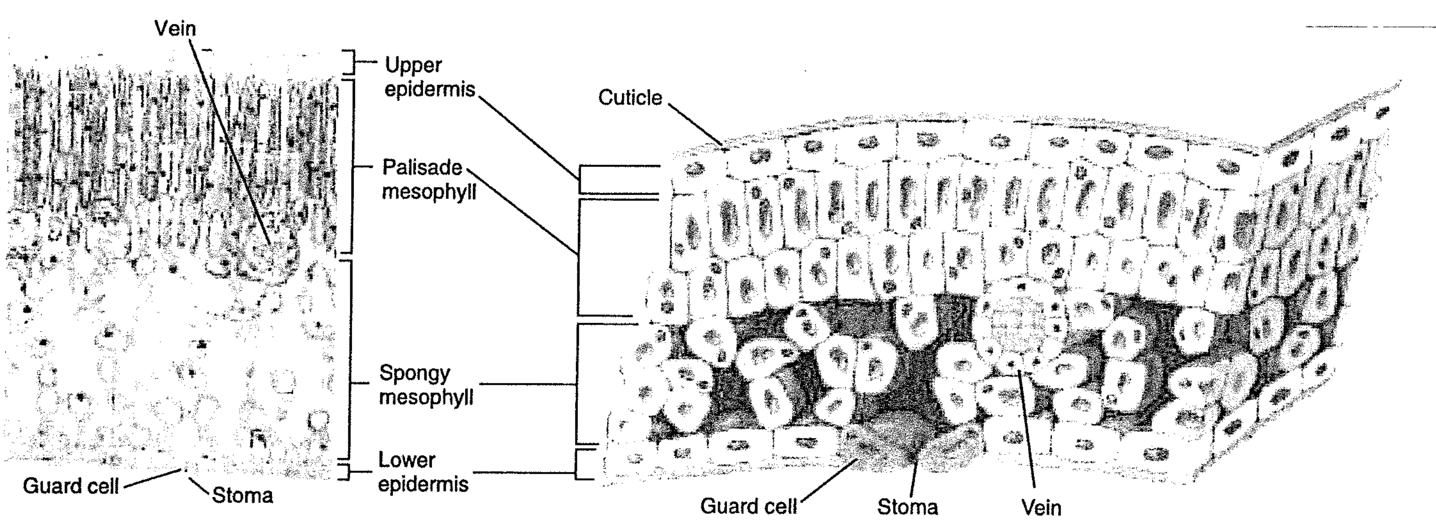


FIGURE 38.34
A leaf in cross-section. Transection of a leaf showing the arrangement of palisade and spongy mesophyll, a vascular bundle or vein, and the epidermis with paired guard cells flanking the stoma.

Modified Leaves

As plants colonized a wide variety of environments, from deserts to lakes to tropical rain forests, modifications of plant organs that would adapt the plants to their specific habitats arose. Leaves, in particular, have evolved some remarkable adaptations. A brief discussion of a few of these modifications follows.

Floral leaves (bracts). Poinsettias and dogwoods have relatively inconspicuous, small, greenish-yellow flowers. However, both plants produce large modified leaves, called **bracts** (mostly colored red in poinsettias and white or pink in dogwoods). These bracts surround the true flowers and perform the same function as showy petals (figure 38.35). It should be noted, however, that bracts can also be quite small and not as conspicuous as those of the examples mentioned.

Spines. The leaves of many cacti, barberries, and other plants are modified as **spines** (see figure 38.28*f*). In the case of cacti, the reduction of leaf surface reduces water loss and also may deter predators. Spines should not be confused with *thorns*, such as those on honey locust (*Gleditsia triacanthos*), which are modified stems, or with the *prickles* on raspberries and rose bushes, which are simply outgrowths from the epidermis or the cortex just beneath it.

Reproductive leaves. Several plants, notably *Kalanchoë*, produce tiny but complete plantlets along their margins. Each plantlet, when separated from the leaf, is capable of growing independently into a full-sized plant. The walking fern (*Asplenium rhizophyllum*) produces new plantlets at the tips of its fronds. While leaf tissue isolated from many species will regenerate a whole plant, this in vivo regeneration is unique among just a few species.

Window leaves. Several genera of plants growing in arid regions produce succulent, cone-shaped leaves with transparent tips. The leaves often become mostly buried in sand blown by the wind, but the transparent tips, which have a thick epidermis and cuticle, admit light to the hollow interiors. This allows photosynthesis to take place beneath the surface of the ground.

Shade leaves. Leaves produced where they receive significant amounts of shade tend to be larger in surface area, but thinner and with less mesophyll than leaves on the same tree receiving more direct light. This plasticity in development is remarkable, as both types of leaves on the plant have exactly the same genes. Environmental signals can have a major effect on development.

Insectivorous leaves. Almost 200 species of flowering plants are known to have leaves that trap insects, with some digesting their soft parts. Plants with insectivorous leaves often grow in acid swamps deficient in needed elements, or containing elements in forms not readily available to the plants; this inhibits the plants' capacities

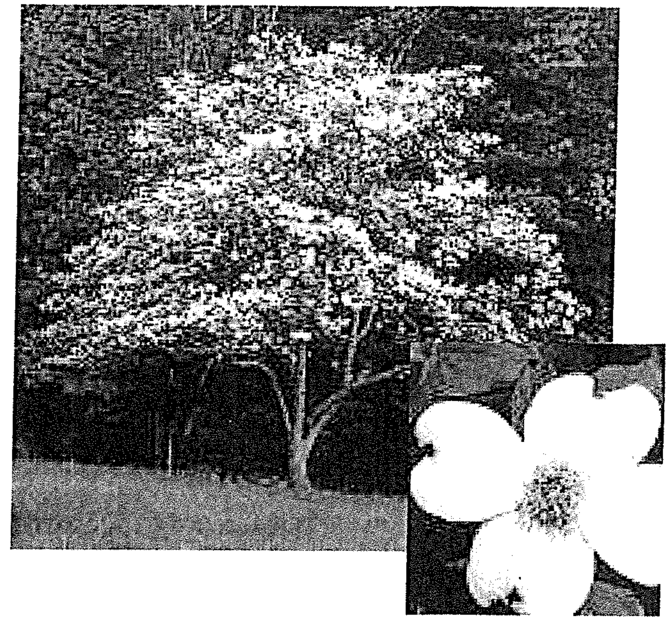


FIGURE 38.35
Modified leaves. In this dogwood "flower," the white-colored bracts (modified leaves) surround the several true flowers withou petals in the center.

to maintain metabolic processes sufficient to meet the growth requirements. Their needs are, however, met b the supplementary absorption of nutrients from the an mal kingdom.

Pitcher plants (for example, *Sarracenia*, *Darlingtoni*, *Nepenthes*) have cone-shaped leaves in which rainwat can accumulate. The insides of the leaves are ve smooth, but there are stiff, downward-pointing hairs : the rim. An insect falling into such a leaf finds it ve difficult to escape and eventually drowns. The nutrien released when bacteria, and in most species digestive e zymes, decompose the insect bodies are absorbed in the leaf. Other plants, such as sundews (*Drosera*), hav glands that secrete sticky mucilage that trap insect which are then digested by enzymes. The Venus flytra (*Dionaea muscipula*) produces leaves that look hinged : the midrib. When tiny trigger hairs on the leaf blade a stimulated by a moving insect, the two halves of the le snap shut, and digestive enzymes break down the so parts of the trapped insect into nutrients that can be al sorbed through the leaf surface. Nitrogen is the mo common nutrient needed. Curiously, the Venus flytra will not survive in a nitrogen-rich environment, perha a trade-off made in the intricate evolutionary proce that resulted in its ability to capture and digest insects.

The leaves of plants exhibit a variety of adaptations, including spines, vegetative reproduction, and even leaves that are carnivorous.

Chapter 38

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Summary / *Questions* / *Media Resources*

38.1 Meristems elaborate the plant body plan after germination.

- A plant body is basically an axis that includes two parts: root and shoot—with associated leaves. There are four basic types of tissues in plants: meristems, ground tissue, epidermis, and vascular tissue.

1. What are the three major tissue systems in plants? What are their functions?

- Art Activity: Plant Body Organization
- Art Activity: Stem Tip Structure
- Art Activity: Primary Meristem Structure
- Characteristics of Plants
- Meristems
- Cambia

38.2 Plants have three basic tissues, each composed of several cell types.

- Ground tissue supports the plant and stores food and water.
- Epidermis forms an outer protective covering for the plant.
- Vascular tissue conducts water, carbohydrates, and dissolved minerals to different parts of the plant. Xylem conducts water and minerals from the roots to shoots and leaves, and phloem conducts food molecules from sources to all parts of the plant.

2. What is the function of xylem? How do primary and secondary xylem differ in origin? What are the two types of conducting cells within xylem?

3. What is the function of phloem? How do the two types of conducting cells in phloem differ?

- Effect of Water on Leaves
- Girth Increase in Woody Dicots
- Vascular System of Plants
- Activity: Vascular Tissue
- Ground Tissue
- Dermal Tissue
- Vascular Tissue
- Student Research: Leaf Structure Wetness

38.3 Root cells differentiate as they become distanced from the dividing root apical meristem.

- Roots have four growth zones: the root cap, zone of cell division, zone of elongation, and zone of maturation.
- Some plants have modified roots, adapted for photosynthesis, food or water storage, structural support, or parasitism.

4. Compare monocot and dicot roots. How does the arrangement of the tissues differ?

5. How are lateral branches of roots formed?

- Art Activity: Dicot Root Structure
- Roots

38.4 Stems are the backbone of the shoot, transporting nutrients and supporting the aerial plant organs.

- Plants branch by means of buds derived from the primary apical meristem. They are found in the junction between the leaf and the stem.
- The vascular cambium is a cylinder of dividing cells found in both roots and shoots. As a result of their activity, the girth of a plant increases.

6. What types of cells are produced when the vascular cambium divides outwardly, inwardly, or laterally?

7. Why don't monocots have secondary growth?

- Art Activity: Dicot Stem Structure
- Art Activity: Secondary Growth
- Art Activity: Herbaceous Dicot Stem Anatomy
- Activity: Cambium
- Stems

38.5 Leaves are adapted to support basic plant functions.

- Leaves emerge as bulges on the meristem in a variety of patterns, but most form a spiral around the stem. The bulge lengthens and loses its radial symmetry as it flattens.
- Photosynthesis occurs in the ground tissue system which is called mesophyll in the leaf. Vascular tissue forms the venation patterns in the leaves, serving as the endpoint for water conduction and often the starting point for the transport of photosynthetically produced sugars.

8. How do simple and compound leaves differ from each other? Name and describe the three common types of leaf growth patterns.

- Art Activity: Plant Anatomy
- Art Activity: Leaf Structure
- Leaves

39

Nutrition and Transport in Plants

Concept Outline

39.1 Plants require a variety of nutrients in addition to the direct products of photosynthesis.

Plant Nutrients. Plants require a few macronutrients in large amounts and several micronutrients in trace amounts.
Soil. Plant growth is significantly influenced by the nature of the soil.

39.2 Some plants have novel strategies for obtaining nutrients.

Nutritional Adaptations. Venus flytraps and other carnivorous plants lure and capture insects and then digest them to obtain energy and nutrients. Some plants entice bacteria to produce organic nitrogen for them. These bacteria may be free-living or form a symbiotic relationship with a host plant. About 90% of all vascular plants rely on fungal associations to gather essential nutrients, especially phosphorus.

39.3 Water and minerals move upward through the xylem.

Overview of Water and Mineral Movement through Plants. The bulk movement of water and dissolved minerals is the result of movement between cells, across cell membranes, and through tubes of xylem.
Water and Mineral Absorption. Water and minerals enter the plant through the roots.
Water and Mineral Movement. A combination of the properties of water, structure of xylem, and transpiration of water through the leaves results in the passive movement of water to incredible heights. Water leaves the plant through openings in the leaves called stomata. Too much water is harmful to a plant, although many plants have adaptations that make them tolerant of flooding.

39.4 Dissolved sugars and hormones are transported in the phloem.

Phloem Transport Is Bidirectional. Sucrose and hormones can move from shoot to root or root to shoot in the phloem. Phloem transport requires energy to load and unload sieve tubes.

FIGURE 39.1
A carnivorous plant. Most plants absorb water and essential nutrients from the soil, but carnivorous plants are able to obtain some nutrients directly from small animals.

Vast energy inputs are required for the ongoing cor struction of a plant such as described in chapter 38. I this chapter, we address two major questions: (1) what ir puts, besides energy from the sun, does a plant need to su vive? and (2) how do all parts of the complex plant boc share the essentials of life? Plants, like animals, need variou nutrients to remain alive and healthy. Lack of an importar nutrient may slow a plant's growth or make the plant mo susceptible to disease or even death. Plants acquire the nutrients through photosynthesis and from the soi although some take a more direct approach (figure 39.1 Carbohydrates produced in leaves must be carried throug out the plant, and minerals and water absorbed from th ground must be transported up to the leaves and other par of the plant. As discussed in chapter 38, these two types o transport take place in specialized tissues, xylem an phloem.

39.1 Plants require a variety of nutrients in addition to the direct products of photosynthesis.

Plant Nutrients

The major source of plant nutrition is the fixation of atmospheric CO_2 into simple sugar using the energy of the sun. CO_2 enters through the stomata. O_2 is a product of photosynthesis and atmospheric component that also moves through the stomata. It is used in cellular respiration to release energy from the chemical bonds in the sugar to support growth and maintenance in the plant. However, CO_2 and light energy are not sufficient for the synthesis of all the molecules a plant needs. Plants require a number of inorganic nutrients (table 39.1). Some of these are macronutrients, which the plants need in relatively large amounts, and others are micronutrients, which are required in trace amounts. There are nine macronutrients: carbon, hydrogen, and oxygen—the three elements found in all organic compounds—as well as nitrogen (essential for amino acids), potassium, calcium, phosphorus, magnesium (the center of the chlorophyll molecule), and sulfur. Each of these nutrients approaches or, as in the case with carbon, may greatly exceed 1% of the dry weight of a healthy plant. The seven micronutrient elements—iron, chlorine, copper, manganese, zinc, molybdenum, and boron—constitute from less than one to several hundred parts per million in most plants (figure 39.2). The macronutrients were generally discovered in the last century, but the micronutrients have been detected much more recently as technology developed to identify and work with such small quantities.

Nutritional requirements are assessed in hydroponic cultures; the plants roots are suspended in aerated water containing nutrients. The solutions contain all the necessary nutrients in the right proportions but with certain known or suspected nutrients left out. The plants are then

Table 39.1 Essential Nutrients in Plants

Elements	Principal Form in which Element Is Absorbed	Approximate Percent of Dry Weight	Examples of Important Functions
MACRONUTRIENTS			
Carbon	(CO_2)	44	Major component of organic molecules
Oxygen	(O_2, H_2O)	44	Major component of organic molecules
Hydrogen	(H_2O)	6	Major component of organic molecules
Nitrogen	(NO_3^-, NH_4^+)	1–4	Component of amino acids, proteins, nucleotides, nucleic acids, chlorophyll, coenzymes, enzymes
Potassium	(K^+)	0.5–6	Protein synthesis, operation of stomata
Calcium	(Ca^{++})	0.2–3.5	Component of cell walls, maintenance of membrane structure and permeability, activates some enzymes
Magnesium	(Mg^{++})	0.1–0.8	Component of chlorophyll molecule, activates many enzymes
Phosphorus	($H_2PO_4^-$, $HPO_4^=$)	0.1–0.8	Component of ADP and ATP, nucleic acids, phospholipids, several coenzymes
Sulfur	($SO_4^=$)	0.05–1	Components of some amino acids and proteins, coenzyme A
MICRONUTRIENTS (CONCENTRATIONS IN PPM)			
Chlorine	(Cl^-)	100–10,000	Osmosis and ionic balance
Iron	(Fe^{++}, Fe^{+++})	25–300	Chlorophyll synthesis, cytochromes, nitrogenase
Manganese	(Mn^{++})	15–800	Activator of certain enzymes
Zinc	(Zn^{++})	15–100	Activator of many enzymes, active in formation of chlorophyll
Boron	(BO_3^- or $B_4O_7^=$)	5–75	Possibly involved in carbohydrate transport, nucleic acid synthesis
Copper	(Cu^{++})	4–30	Activator or component of certain enzymes
Molybdenum	($MoO_4^=$)	0.1–5	Nitrogen fixation, nitrate reduction

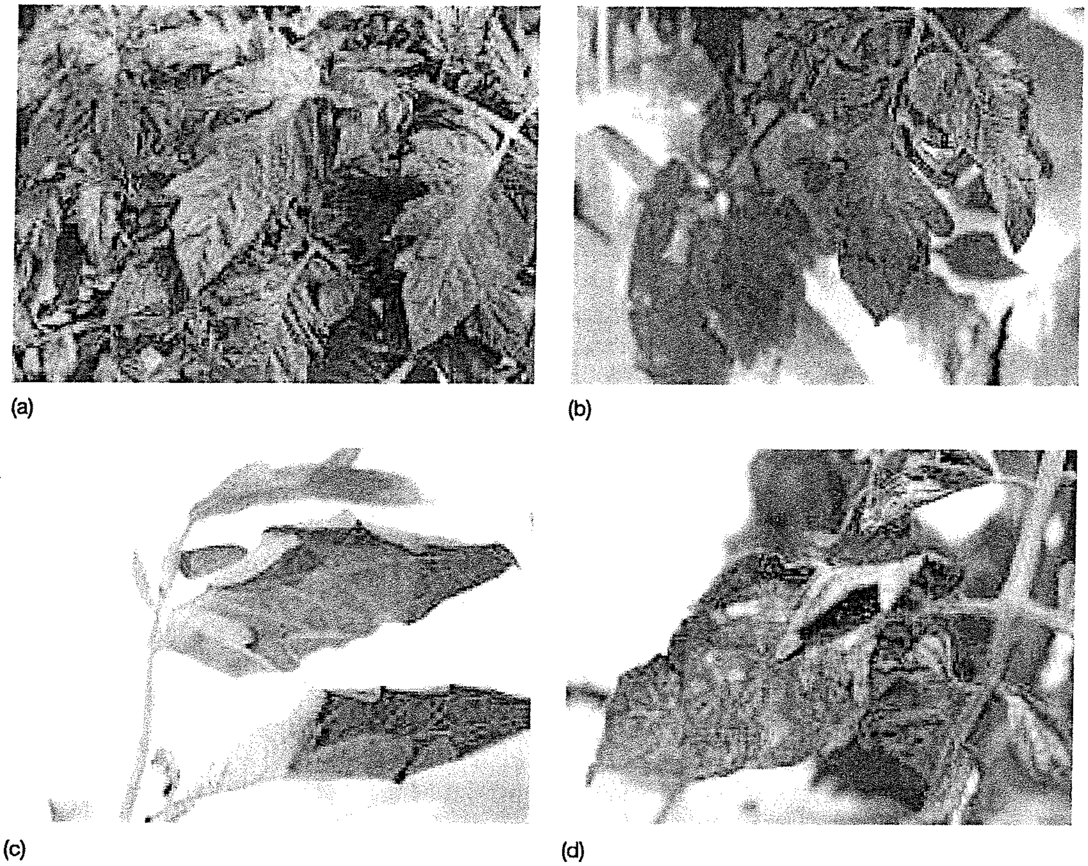


FIGURE 39.2
Mineral deficiencies in plants. (*a*) Leaves of a healthy Marglobe tomato (*Lycopersicon esculentum*) plant. (*b*) Chlorine-deficient plant with necrotic leaves (leaves with patches of dead tissue). (*c*) Copper-deficient plant with blue-green, curled leaves. (*d*) Zinc-deficient plant with small, necrotic leaves. (f) Manganese-deficient plant with chlorosis (yellowing) between the veins. The agricultural implications of deficiencies such as these are obvious; a trained observer can determine the nutrient deficiencies that are affecting a plant simply by inspecting it.

allowed to grow and are studied for the presence of abnormal symptoms that might indicate a need for the missing element (figure 39.3). However, the water or vessels used often contain enough micronutrients to allow the plants to grow normally, even though these substances were not added deliberately to the solutions. To give an idea of how small the quantities of micronutrients may be, the standard dose of molybdenum added to seriously deficient soils in Australia amounts to about 34 grams (about one handful) per hectare, once every 10 years! Most plants grow satisfactorily in hydroponic culture, and the method, although expensive, is occasionally practical for commercial purposes. Analytical chemistry has made it much easier to take plant material and test for levels of different molecules. One application has been the investigation of elevated levels of CO_2 (a result of global warming) on plant growth. With increasing levels of CO_2, the leaves of some plants increase in size, but the amount of nitrogen decreases relative to carbon. This decreases the nutritional value of the leaves to herbivores.

The plant macronutrients carbon, oxygen, and hydrogen constitute about 94% of a plant's dry weight; the other macronutrients—nitrogen, potassium, calcium, phosphorus, magnesium, and sulfur—each approach or exceed 1% of a plant's dry weight.

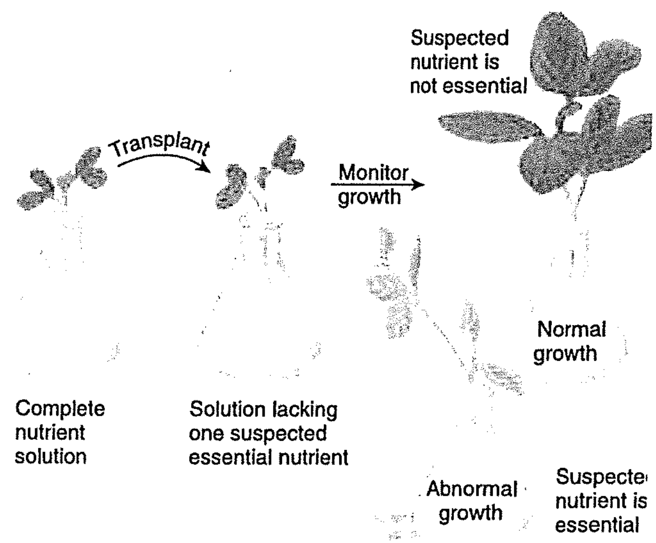


FIGURE 39.3
Identifying nutritional requirements of plants. A seedling is first grown in a complete nutrient solution. The seedling is then transplanted to solution that lacks one suspected essential nutrien The growth of the seedling is then studied for the presence of abnormal symptoms, such as discolored leaves and stunted growtl If the seedling's growth is normal, the nutrient that was left out may not be essential; if the seedling's growth is abnormal, the lacking nutrient is essential for growth.

Soil

Plant growth is affected by soil composition. Soil is the highly weathered outer layer of the earth's crust. It is composed of a mixture of ingredients, which may include sand, rocks of various sizes, clay, silt, humus, and various other forms of mineral and organic matter; pore spaces containing water and air occur between the particles. The mineral fraction of soils varies according to the composition of the rocks. The crust includes about 92 naturally occurring elements; table 2.1 in chapter 2 lists the most common of these elements and their percentage of the earth's crust by weight. Most elements are combined as inorganic compounds called **minerals;** most rocks consist of several different minerals. The soil is also full of microorganisms that break down and recycle organic debris. About 5 metric tons of carbon is tied up in the organisms that are present in the soil under a hectare (0.06 mile^2) of wheat land in England, an amount that approximately equals the weight of 100 sheep!

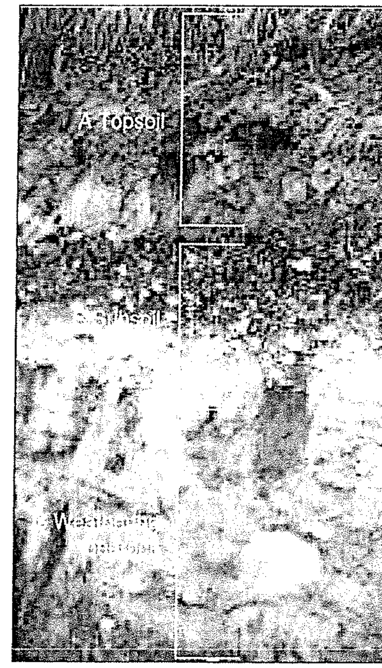


FIGURE 39.4
Most roots occur in topsoil. The uppermost layer in soil is called topsoil, and it contains organic matter, such as roots, small animals, and humus, and mineral particles of various sizes. Subsoil lies underneath the topsoil and contains larger mineral particles and relatively little organic matter. Beneath the subsoil are layers of bedrock, the raw material from which soil is formed over time and weathering.

Most roots are found in **topsoil** (figure 39.4), which is a mixture of mineral particles of varying size (most less than 2 mm thick), living organisms, and **humus.** Humus consists of partly decayed organic material. When topsoil is lost because of erosion or poor landscaping, both the water-holding capacity and the nutrient relationships of the soil are adversely affected.

About half of the total soil volume is occupied by spaces or pores, which may be filled with air or water, depending on moisture conditions. Some of the soil water, because of its properties described below, is unavailable to plants. Due to gravity, some of the water that reaches a given soil will drain through it immediately. Another fraction of the water is held in small soil pores, which are generally less than about 50 micrometers in diameter. This water is readily available to plants. When it is depleted through evaporation or root uptake, the plant will wilt and eventually die unless more water is added to the soil.

Cultivation

In natural communities, nutrients are recycled and made available to organisms on a continuous basis. When these communities are replaced by cultivated crops, the situation changes drastically: the soil is much more exposed to erosion and the loss of nutrients. For this reason, cultivated crops and garden plants usually must be supplied with additional mineral nutrients.

One solution to this is **crop rotation**. For example, a farmer might grow corn in a field one year and soybeans the next year. Both crops remove nutrients from the soil, but the plants have different nutritional requirements, and therefore the soil does not lose the same nutrients two years in a row. Soybean plants even add nitrogen compounds to the soil, released by nitrogen-fixing bacteria growing in nodules on their roots. Sometimes farmers allow a field to lie fallow—that is, they do not grow a crop in the field for a year or two. This allows natural processes to rebuild the field's store of nutrients.

Other farming practices that help maintain soil fertility involve plowing under plant material left in fields. You can do the same thing in a lawn or garden by leaving grass clippings and dead leaves. Decomposers in the soil do the rest, turning the plant material into humus.

Fertilizers are also used to replace nutrients lost in cultivated fields. The most important mineral nutrients that need to be added to soils are nitrogen (N), phosphorus (P), and potassium (K). All of these elements are needed in large quantities (see table 39.1) and are the most likely to become deficient in the soil. Both chemical and organic fertilizers are often added in large quantities and can be significant sources of pollution in certain situations (see chapter 30). Organic fertilizers were widely used long before chemical fertilizers were available. Substances such as manure or the remains of dead animals have traditionally been applied to crops, and plants are often plowed under to increase the soil's fertility. There is no basis for believing that organic fertilizers supply any element to plants that inorganic fertilizers cannot provide and they can. However, organic fertilizers build up the humus content of the soil, which often enhances its water- and nutrient-retaining properties. For this reason, nutrient availability to plants at different times of the year may be improved, under certain circumstances, with organic fertilizers.

Soils contain organic matter and various minerals and nutrients. Farming practices like crop rotation, plowing crops under, and fertilization are often necessary to maintain soil fertility.

39.2 Some plants have novel strategies for obtaining nutrients.

Nutritional Adaptations

Carnivorous Plants

Some plants are able to obtain nitrogen directly from other organisms, just as animals do. These carnivorous plants often grow in acidic soils, such as bogs that lack organic nitrogen. By capturing and digesting small animals directly, such plants obtain adequate nitrogen supplies and thus are able to grow in these seemingly unfavorable environments. Carnivorous plants have modified leaves adapted to lure and trap insects and other small animals (figure 39.5). The plants digest their prey with enzymes secreted from various types of glands.

The Venus flytrap *(Dionaea muscipula)*, which grows in the bogs of coastal North and South Carolina, has three sensitive hairs on each side of each leaf, which, when touched, trigger the two halves of the leaf to snap together (see figure 39.1). Once the Venus flytrap enfolds a prey item within a leaf, enzymes secreted from the leaf surfaces digest the prey. These flytraps actually shut and open by a growth mechanism. They have a limited number of times they can open and close as a result. In the sundews, the glandular trichomes secrete both sticky mucilage, which traps small animals, and digestive enzymes. Unlike Venus flytraps they do not close rapidly and it is possible that the two share a common ancestor.

Pitcher plants attract insects by the bright, flowerlike colors within their pitcher-shaped leaves and perhaps also by sugar-rich secretions. Once inside the pitchers, insects slide down into the cavity of the leaf, which is filled with water and digestive enzymes.

Bladderworts, *Utricularia*, are aquatic. They sweep small animals into their bladderlike leaves by the rapid action of a springlike trapdoor, and then they digest these animals.

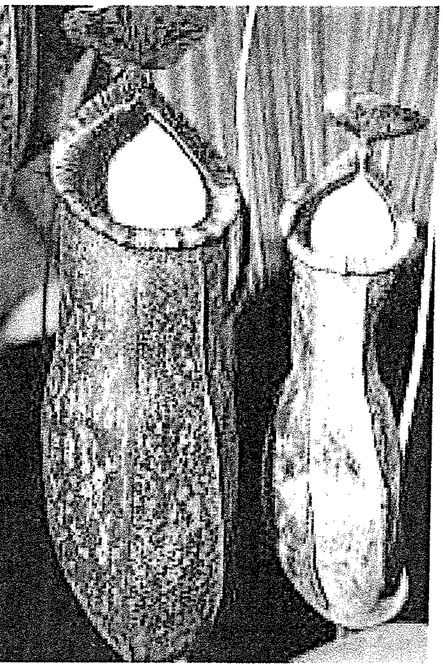


FIGURE 39.5
A carnivorous plant. A tropical Asian pitcher plant, *Nepenthes*. Insects enter the pitchers and are trapped and digested. Complex communities of invertebrate animals and protists inhabit the pitchers.

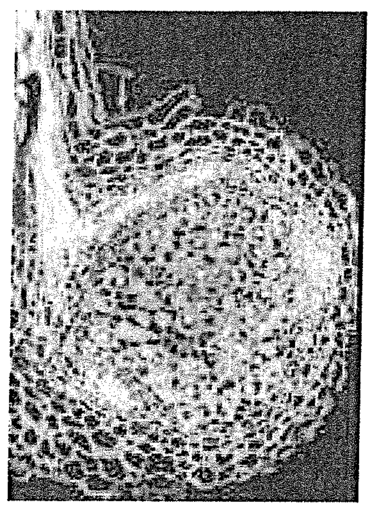


FIGURE 39.6
Nitrogen-fixing nodule. A root hair of alfalfa is invaded by *Rhizobium*, a bacterium (yellow structures) that fixes nitrogen. Through a series of exchanges of chemical signals, the plant cells divide to create a nodule for the bacteria which differentiate and begin producing ammonia.

Nitrogen-Fixing Bacteria

Plants need ammonia (NH_3) to buil amino acids, but most of the nitroge is in the atmosphere in the form (N_2. Plants lack the biochemic: pathways (including the enzyme n trogenase) necessary to conve gaseous nitrogen to ammonia, bı some bacteria have this capacit Some of these bacteria live in clo: association with the roots of plant Others go through an intricate danc and end up being housed in plant ti: sues created especially for them calle nodules (figure 39.6). Only legum are capable of forming root nodul and there is a very specific recogn tion required by a bacteria speci and its host. Hosting these bacter: costs the plant in terms of energy, bı is well worth it when there is litt ammonia in the soil. An energy cor servation mechanism has evolved i the legumes so that the root hairs wi not respond to bacterial signals whe nitrogen levels are high.

Mycorrhizae

While symbiotic relationships wit nitrogen-fixing bacteria are rare, syn biotic associations with mycorrhiz: fungi are found in about 90% of tl vascular plants. These fungi hav been described in detail in chapter 3 In terms of plant nutrition, it is in portant to recognize the significa role these organisms play in enhan ing phosphorus transfer to the plan The uptake of some of the microni trients is also enhanced. Functionall the mycorrhizae extend the surfa area of nutrient uptake substantially

Carnivorous plants obtain nutrients, especially nitrogen, directly by capturing and digesting insects and other organisms. Nitrogen can also be obtained from bacteria living in close association with the roots. Fungi help plants obtain phosphorus and other nutrients from the soil.

39.3 Water and minerals move upward through the xylem.

Overview of Water and Mineral Movement through Plants

Local Changes Result in the Long-Distance, Upward Movement of Water

Most of the nutrients and water discussed above enter the plant through the roots and move upward in the xylem. It is not unusual for a large tree to have leaves more than 10 stories off the ground (figure 39.7). Did you ever wonder how water gets from the roots to the top of a tree that high? Water moves through the spaces between the protoplasts of cells, through plasmodesmata (membrane connections between cells), through cell membranes and through the continuous tubing system in the xylem. We know that there are interconnected, water-conducting xylem elements extending throughout a plant. We also know that water first enters the roots and then moves to the xylem. After that, however, water rises through the xylem because of a combination of factors and some exits through the stomata in the leaves.

While most of our focus will be on the mechanics of water transport through xylem, the movement of water at the cellular level plays a significant role in bulk water transport in the plant as well, although over much shorter distances. You know that the Casparian strip in the root forces water to move through cells. In the case of parenchyma cells it turns out that most water also moves across membranes rather than in the intercellular spaces. For a long time, it was believed that water moved across cell membranes only by osmosis through the lipid bilayer. We now know that osmosis is enhanced by water channels called **aquaporins**. These transport channels are found in both plants and animals. In plants they exist in vacuole and plasma membranes. There at least 30 different genes coding for aquaporin-like proteins in *Arabidopsis*. Some aquaporins only appear or open during drought stress. Aquaporins allow for faster water movement between cells than osmosis. They are important not only in maintaining water balance within a cell, but in getting water between many plant cells and the xylem. The greatest distances traveled by water molecules and dissolved minerals are in the xylem.

Once water enters the xylem, it can move upward 100 m in the redwoods. Some "pushing" from the pressure of water entering the roots is involved. However, most of the force is "pulling" caused by water evaporating (**transpiration**) through the stomata on the leaves and other plant surfaces. This works because water molecules stick to themselves with hydrogen bonds (cohesion) and to the walls of the tracheid or xylem vessel (adhesion). The result is an unusually stable column of liquid reaching great heights.

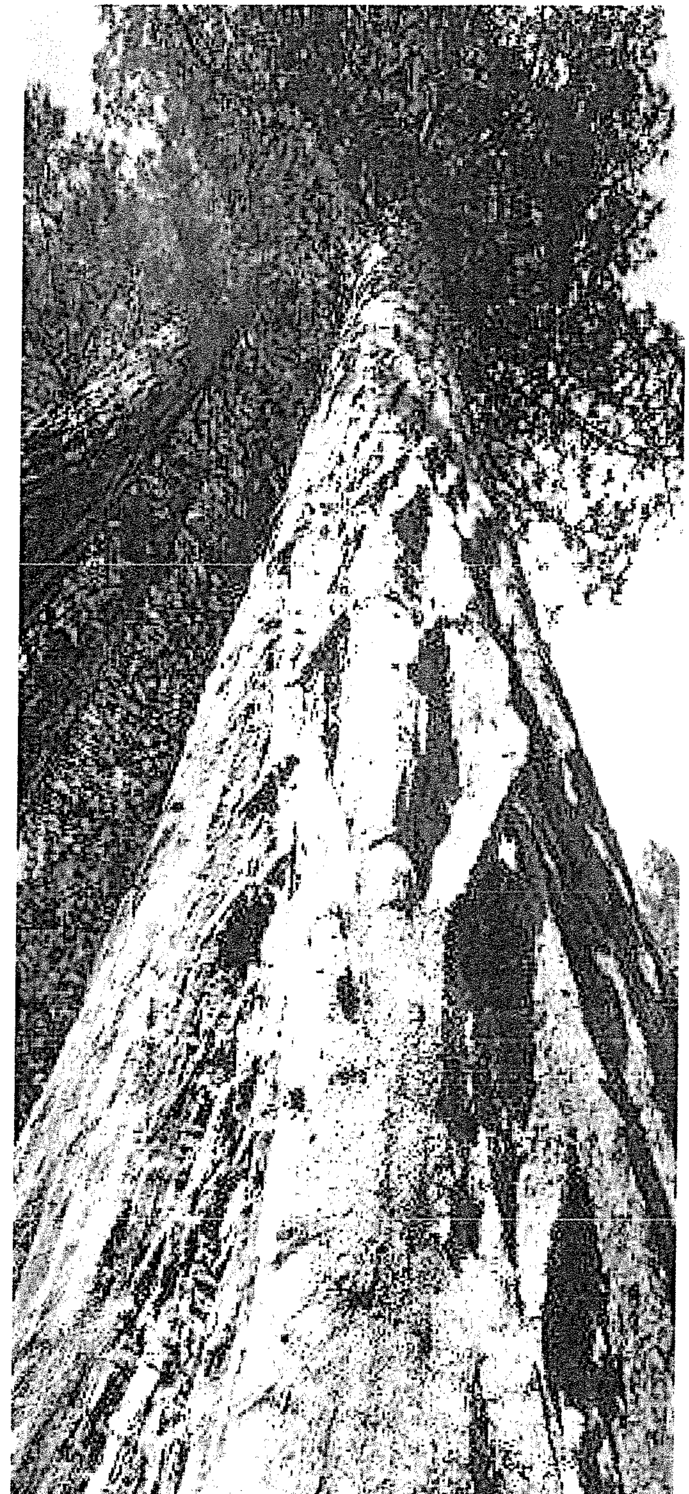


FIGURE 39.7
How does water get to the top of this tree? We would expect gravity to make such a tall column of water too heavy to be maintained by capillary action. What pulls the water up?

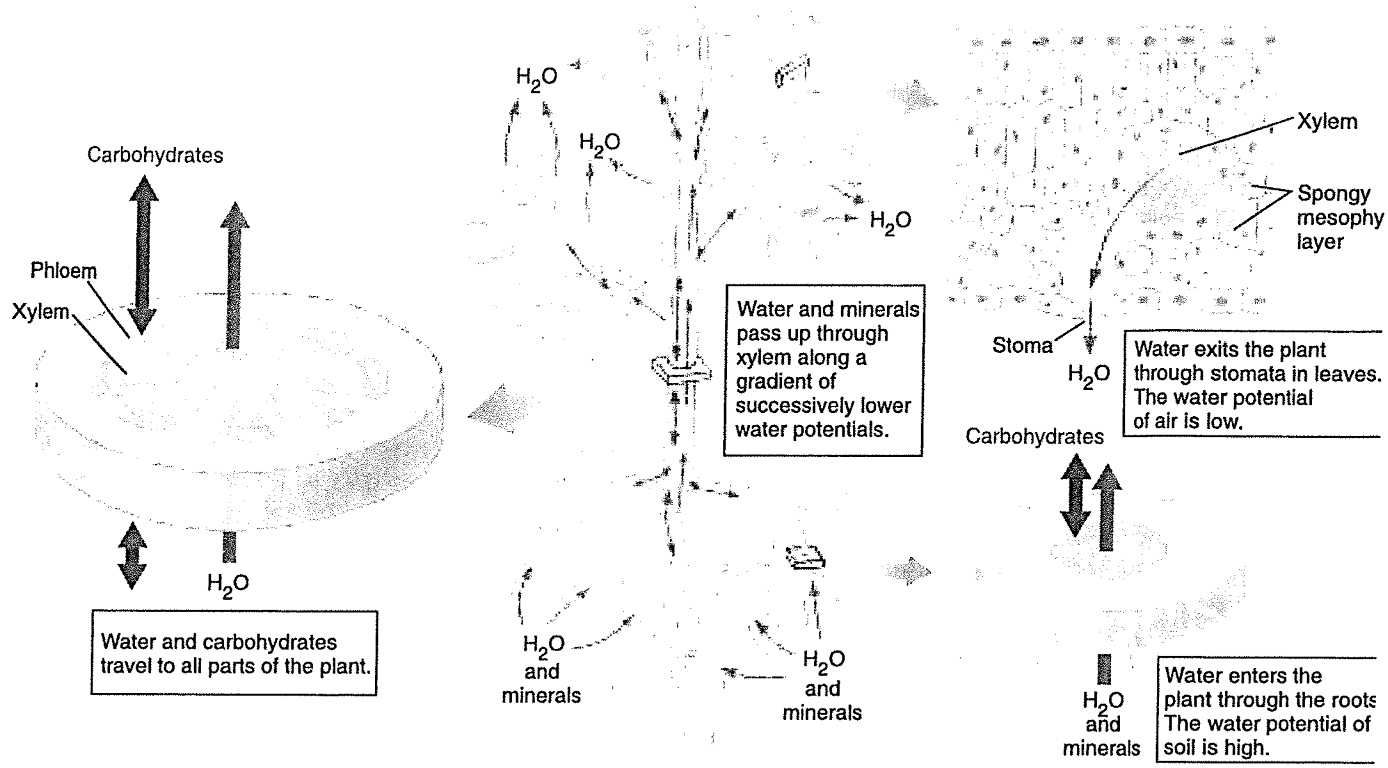


FIGURE 39.8
Water movement through a plant. This diagram illustrates the path of water and inorganic materials as they move into, through, and out of the plant body.

Water Potential

Plant biologists often discuss the forces that act on water within a plant in terms of **potentials.** The *turgor pressure,* which is a physical pressure that results as water enters the cell vacuoles, is referred to as **pressure potential.** Water coming through a garden hose is an example of physical pressure. There is also a potential caused by an uneven distribution of a solute on either side of a membrane, which will result in osmosis (movement of water to the side with the greater concentration of solute). By applying pressure (on the side that has the greater concentration of solute), it is possible to prevent osmosis from taking place. The smallest amount of pressure needed to stop osmosis is referred to as the **solute** (or **osmotic) potential** of the solution. Water will enter a cell osmotically until it is stopped by the pressure potential caused by the cell wall. The **water potential** of a plant cell is, in essence, the combination of its pressure potential and solute potential; it represents the total potential energy of the water in a plant. If two adjacent cells have different water potentials, water will move from the cell with the higher water potential to the cell with the lower water potential. Water in a plant moves along a gradient between the relatively high water potential i the soil to successively lower water potentials in th roots, stems, leaves, and atmosphere.

Water potential in a plant regulates movement (water. At the roots there is a positive water potential (e: cept in the case of severe drought). On the surface (leaves and other organs, water loss called **transpiratio** creates a negative pressure. It depends on its osmotic al sorption by the roots and the negative pressures create by water loss from the leaves and other plant surfaces (fiş ure 39.8). The negative pressure generated by transpir: tion is largely responsible for the upward movement (water in xylem.

Aquaporins enhance water transport at the cellular level, which ultimately affects bulk water transport. The loss of water from the leaf surface, called transpiration, literally pulls water up the stem from the roots which have the greater water potential. This works because of the strong cohesive forces between molecules of water that allow them to stay "stuck" together in a liquid column and adhesion to walls of tracheids and vessels.

Water and Mineral Absorption

Most of the water absorbed by the plant comes in through root hairs, which collectively have an enormous surface area (figure 39.8). Root hairs are almost always turgid because their solute potential is greater than that of the surrounding soil due to mineral ions being actively pumped into the cells. Because the mineral ion concentration in the soil water is usually much lower than it is in the plant, an expenditure of energy (supplied by ATP) is required for the accumulation of such ions in root cells. The plasma membranes of root hair cells contain a variety of protein transport channels, through which *proton pumps* (see page 120) transport specific ions against even large concentration gradients. Once in the roots, the ions, which are plant nutrients, are transported via the xylem throughout the plant.

The ions may follow the cell walls and the spaces between them or more often go directly through the plasma membranes and the protoplasm of adjacent cells (figure 39.9). When mineral ions pass between the cell walls, they do so nonselectively. Eventually, on their journey inward, they reach the endodermis and any further passage through the cell walls is blocked by the Casparian strips. Water and ions must pass through the plasma membranes and protoplasts of the endodermal cells to reach the xylem. However, transport through the cells of the endodermis is selective. The endodermis, with its unique structure, along with the cortex and epidermis, controls which ions reach the xylem.

Transpiration from the leaves (figure 39.10), which creates a pull on the water columns, indirectly plays a role in helping water, with its dissolved ions, enter the root cells. However, at night, when the relative humidity may approach 100%, there may be no transpiration. Under these circumstances, the negative pressure component of water potential becomes small or nonexistent.

Active transport of ions into the roots still continues to take place under these circumstances. This results in an increasingly high ion concentration with the cells, which causes more water to enter the root hair cells by osmosis. In terms of water potential, we say that active transport increases the solute potential of the roots. The result is movement of water into the plant and up the xylem columns despite the absence of transpiration. This phenomenon is called **root pressure,** which in reality is an osmotic phenomenon.

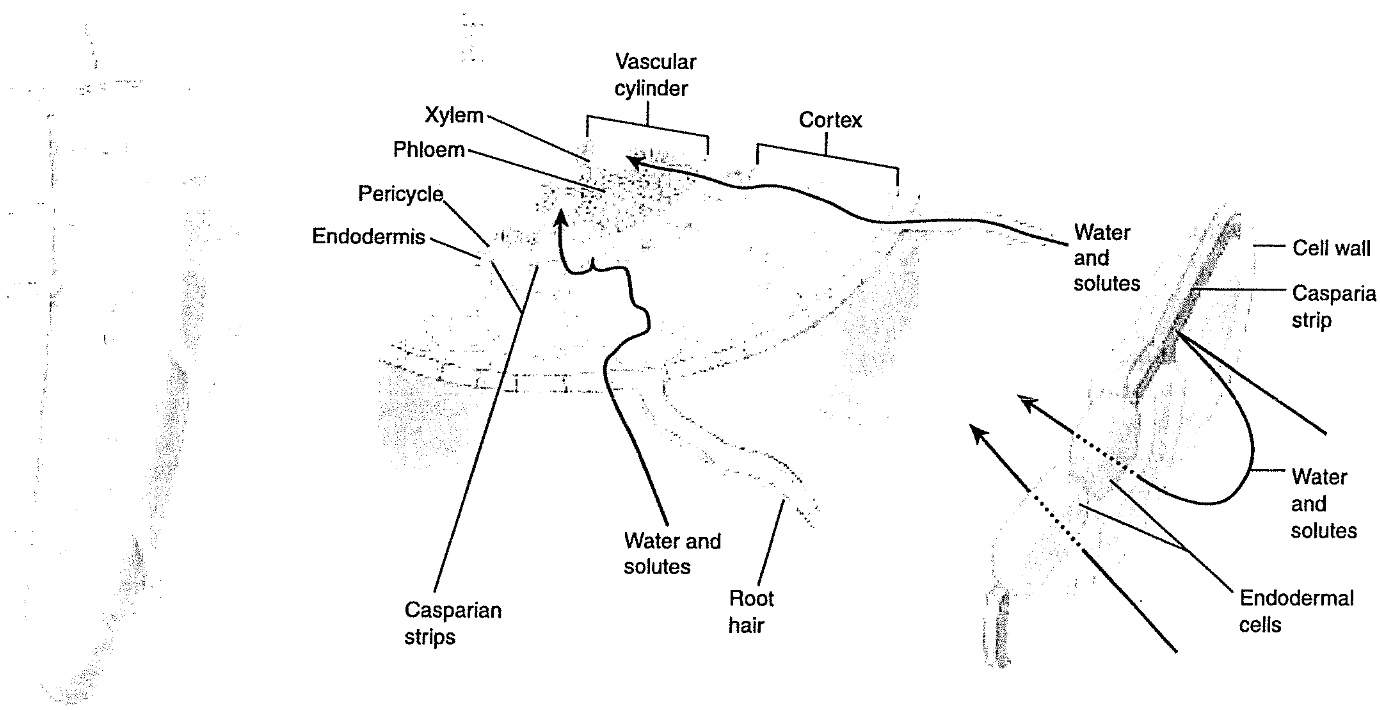


FIGURE 39.9
The pathways of mineral transport in roots. Minerals are absorbed at the surface of the root, mainly by the root hairs. In passing through the cortex, they must either follow the cell walls and the spaces between them or go directly through the plasma membranes and the protoplasts of the cells, passing from one cell to the next by way of the plasmodesmata. When they reach the endodermis, however, their further passage through the cell walls is blocked by the Casparian strips, and they must pass through the membrane and protoplast of an endodermal cell before they can reach the xylem.

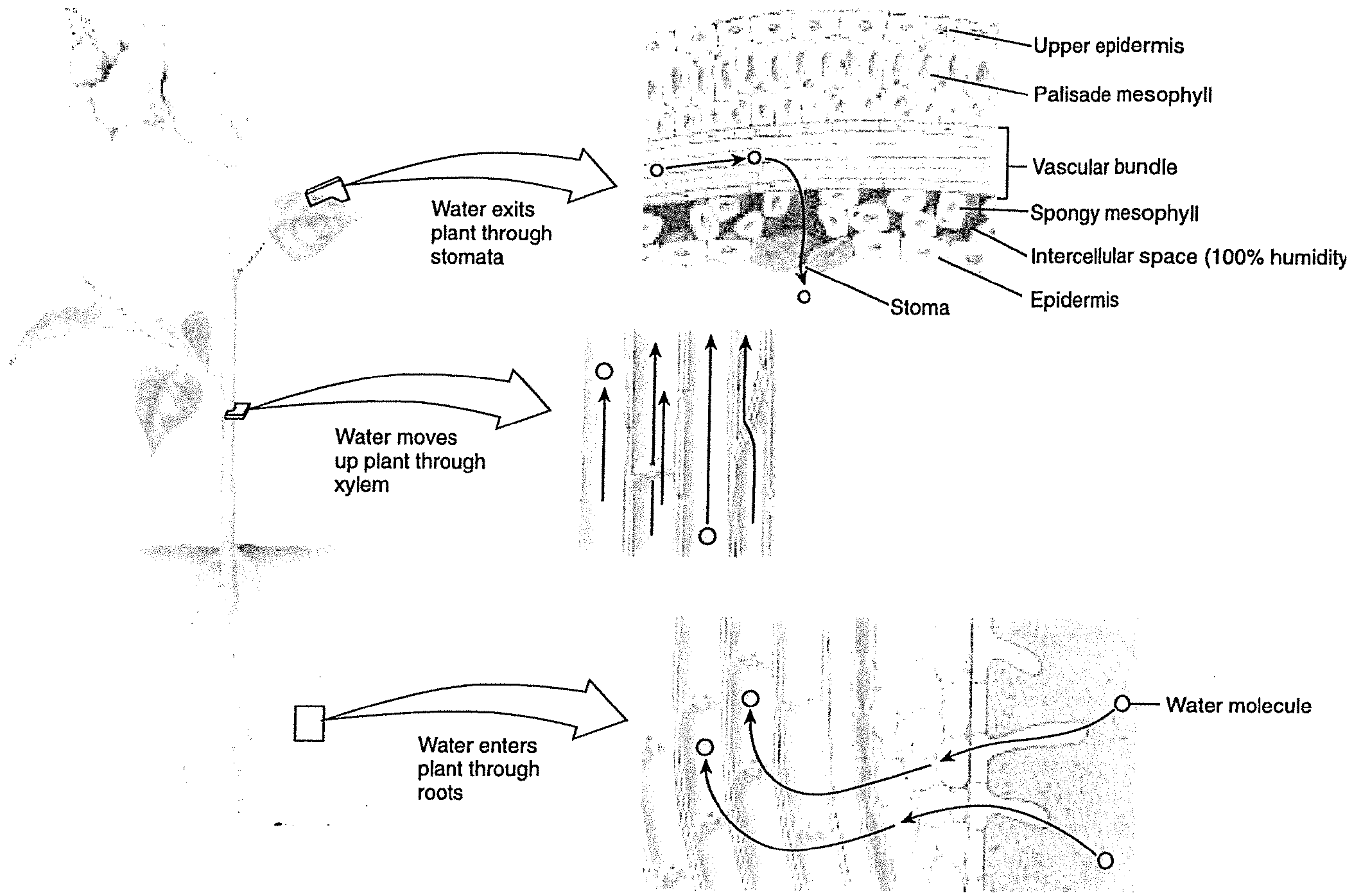


FIGURE 39.10
Transpiration. Water evaporating from the leaves through the stomata causes the movement of water upward in the xylem and the entrance of water through the roots.

Under certain circumstances, root pressure is so strong that water will ooze out of a cut plant stem for hours or even days. When root pressure is very high, it can force water up to the leaves, where it may be lost in a liquid form through a process known as **guttation** (figure 39.11). Guttation does not take place through the stomata, but instead occurs through special groups of cells located near the ends of small veins that function only in this process. Root pressure is never sufficient to push water up great distances.

Water enters the plant by osmosis. Transport of minerals (ions) across the endodermis is selective. Root pressure, which often occurs at night, is caused by the continued, active accumulation of ions in the roots at times when transpiration from the leaves is very low or absent.

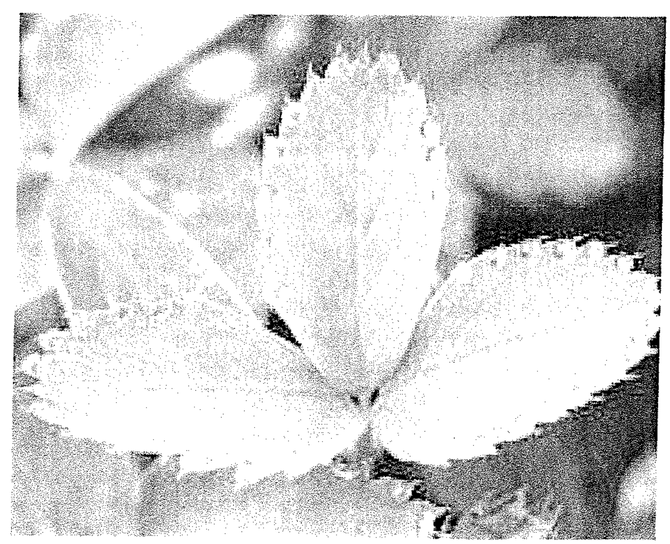


FIGURE 39.11
Guttation. In herbaceous plants, water passes through specialize groups of cells at the edges of the leaves; it is visible here as small droplets around the edge of the leaf in this strawberry plant (*Fragaria ananassa*).

Water and Mineral Movement

Water and Mineral Movement through the Xylem

It is clear that root pressure is insufficient to push water to the top of a tall tree, although it can help. So, what does work? Otto Renner proposed the solution in Germany in 1911. Passage of air across leaf surfaces results in loss of water by evaporation, creating a pull at the open upper end of the "tube." Evaporation from the leaves produces a tension on the entire water column that extends all the way down to the roots. Water has an inherent tensile strength that arises from the cohesion of its molecules, their tendency to form hydrogen bonds with one another. The tensile strength of a column of water varies inversely with the diameter of the column; that is, the smaller the diameter of the column, the greater the tensile strength. Because plants have transporting vessels of very narrow diameter, the cohesive forces in them are strong. The water molecules also adhere to the sides of the tracheid or xylem vessels, further stabilizing the long column of water.

The water column would fail if air bubbles were inserted (visualize a tower of blocks and then pull one out in the middle). Anatomical adaptations decrease the probability of this. Individual tracheids and vessel members are connected by one of more *pits* (cavities) in their walls. Air bubbles are generally larger than the openings, so they cannot pass through them. Furthermore, the cohesive force of water is so great that the bubbles are forced into rigid spheres that have no plasticity and therefore cannot squeeze through the openings. Deformed cells or freezing can cause small bubbles of air to form within xylem cells. Any bubbles that do form are limited to the xylem elements where they originate, and water may continue to rise in parallel columns. This is more likely to occur with seasonal temperature changes. As a result, most of the active xylem in woody plants occurs peripherally, toward the vascular cambium.

Most minerals the plant needs enter the root through active transport. Ultimately, they are removed from the roots and relocated through the xylem to other metabolically active parts of the plant. Phosphorus, potassium, nitrogen, and sometimes iron may be abundant in the xylem during certain seasons. In many plants, such a pattern of ionic concentration helps to conserve these essential nutrients, which may move from mature deciduous parts such as leaves and twigs to areas of active growth. Keep in mind that minerals that are relocated via the xylem must move with the generally upward flow through the xylem. Not all minerals can re-enter the xylem conduit. Calcium, an essential nutrient, cannot be transported elsewhere once it has been deposited in plant parts.

Transpiration of Water from Leaves

More than 90% of the water taken in by the roots of a plant is ultimately lost to the atmosphere through transpiration from the leaves. Water moves into the pockets of air in the leaf from the moist surfaces of the walls of the mesophyll cells. As you saw in chapter 38, these intercellular spaces are in contact with the air outside of the leaf by way of the stomata. Water that evaporates from the surfaces of the mesophyll cells leaves the stomata as vapor. This water is continuously replenished from the tips of the veinlets in the leaves.

Water is essential for plant metabolism, but is continuously being lost to the atmosphere through the stomata. Photosynthesis requires a supply of CO_2 entering the stomata from the atmosphere. This results in two somewhat conflicting requirements: the need to minimize the loss of water to the atmosphere and the need to admit carbon dioxide. Structural features such as stomata and the cuticle have evolved in response to one or both of these requirements.

The rate of transpiration depends on weather conditions like humidity and the time of day. After the sun sets, transpiration from the leaves decreases. The sun is the ultimate source of potential energy for water movement. The water potential that is responsible for water movement is largely the product of negative pressure generated by transpiration, which is driven by the warming effects of sunlight.

The Regulation of Transpiration Rate. On a short-term basis, closing the stomata can control water loss. This occurs in many plants when they are subjected to water stress. However, the stomata must be open at least part of the time so that CO_2 can enter. As CO_2 enters the intercellular spaces, it dissolves in water before entering the plant's cells. The gas dissolves mainly in water on the walls of the intercellular spaces below the stomata. The continuous stream of water that reaches the leaves from the roots keeps these walls moist. A plant must respond both to the need to conserve water and to the need to admit CO_2.

Stomata open and close because of changes in the turgor pressure of their guard cells. The sausage- or dumbbell-shaped guard cells stand out from other epidermal cells not only because of their shape, but also because they are the only epidermal cells containing chloroplasts. Their distinctive wall construction, which is thicker on the inside and thinner elsewhere, results in a bulging out and bowing when they become turgid. You can make a model of this for yourself by taking two elongated balloons, tying the closed ends together, and inflating both balloons slightly. When you hold the two open ends together, there should be very little space between the two balloons. Now place

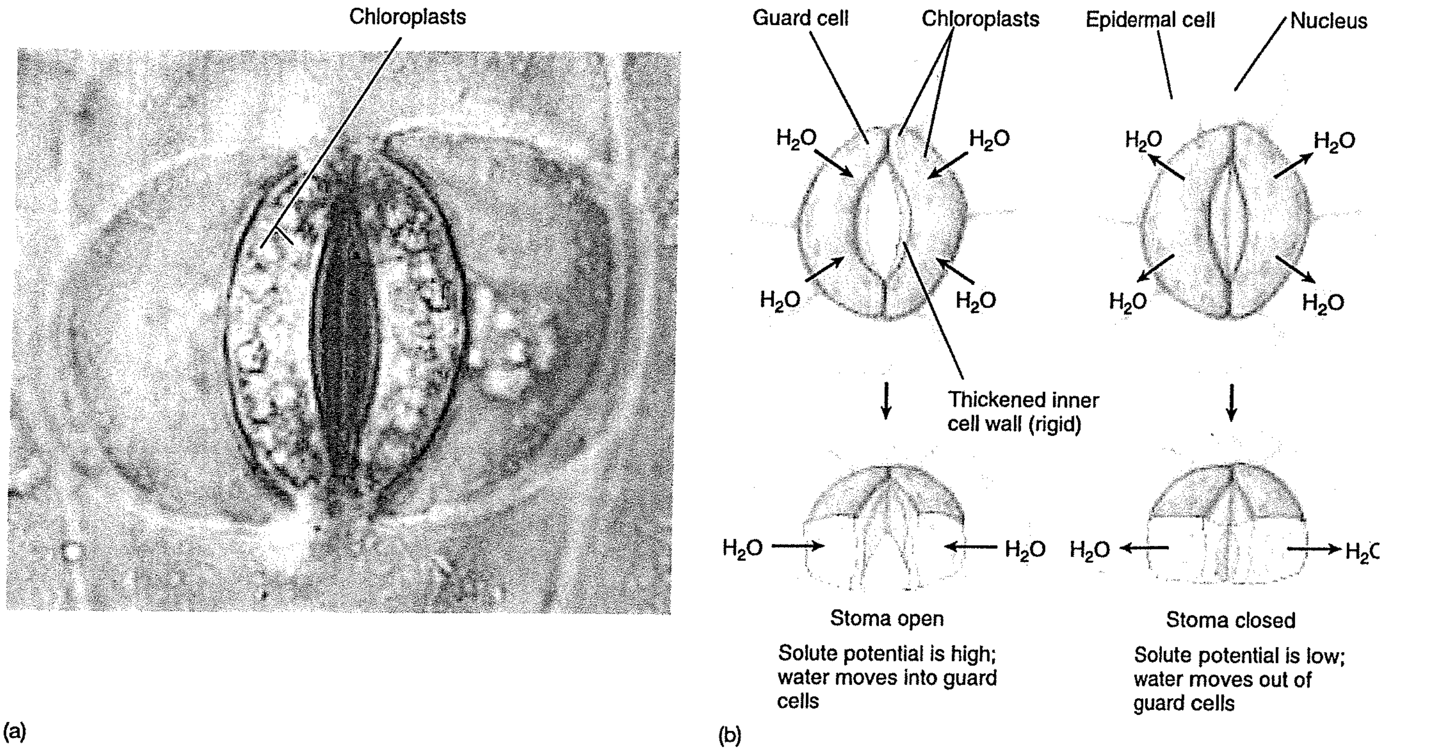


FIGURE 39.12
How a stoma opens and closes. (*a*) When potassium ions from surrounding cells are pumped into guard cells, the guard cell turgor pressure increases as water enters by osmosis. The increased turgor pressure causes the guard cells to bulge, with the thick walls on the inner side of each guard cell bowing outward, thereby opening the stoma. (*b*) When the potassium ions leave the guard cells and their solute potential becomes low, they lose water and turgor, and the stoma closes.

duct tape on the inside edge of both balloons and inflate each one a bit more. Hold the open ends together. You should now be holding a doughnut-shaped pair of "guard cells" with a "stoma" in the middle. Real guard cells rely on the influx and efflux of water, rather than air, to open and shut.

Loss of turgor in guard cells causes the uptake of potassium (K^+) ions through ATP-powered ion transport channels in their plasma membranes. This creates a solute potential within the guard cells that causes water to enter osmotically. As a result, these cells accumulate water and become turgid, opening the stomata (figure 39.12*a*). Keeping the stomata open requires a constant expenditure of ATP, and the guard cells remain turgid only as long as ions are pumped into the cells. When stomata close, sucrose, rather than K^+, leaves the cell through sucrose transporters. Water then leaves the guard cells, which lose turgor, and the stomata close (figure 39.12*b*). Why closing depends on sucrose transport out of the cell and opening on K^+ uptake is an open question. Experimental evidence is consistent with several pathways regulating stomatal opening and closing.

Photosynthesis in the guard cells apparently provides an immediate source of ATP, which drives the active transport of K^+ by way of a specific K^+ channel; this K^+ channel h: now been isolated and studied. In some species, Cl^- accon panies the K^+ in and out of the guard cells, thus maintair ing electrical neutrality. In most species, both Cl^- an malate^{2-} move in the opposite direction of K^+.

When a whole plant wilts because there is insufficiei water available, the guard cells may also lose turgor, and : a result, the stomata may close. The guard cells of mar plant species regularly become turgid in the morning, whe photosynthesis occurs, and lose turgor in the evening, r gardless of the availability of water. When they are turgi the stomata open, and CO_2 enters freely; when they a flaccid, CO_2 is largely excluded, but water loss is also r tarded.

Abscisic acid, a plant hormone discussed in chapter 4 plays a primary role in allowing K^+ to pass rapidly out (guard cells, causing the stomata to close in response t drought. This hormone is released from chloroplasts an produced in leaves. It binds to specific receptor sites in tł plasma membranes of guard cells. Plants likely control tł duration of stomatal opening through the integration (several stimuli, including blue light. In the next chapter, w will explore the interactions between the environment an the plant in more detail.

Other Factors Regulating Transpiration. Factors such as CO_2 concentration, light, and temperature can also affect stomatal opening. When CO_2 concentrations are high, guard cells of many plant species lose turgor, and their stomata close. Additional CO_2 is not needed at such times, and water is conserved when the guard cells are closed. The stomata also close when the temperature exceeds 30° to 34°C when transpiration would increase substantially. In the dark, stomata will open at low concentrations of CO_2. In chapter 10, we mentioned CAM photosynthesis, which occurs in some succulent like cacti. In this process, CO_2 is taken in at night and fixed during the day. CAM photosynthesis conserves water in dry environments where succulent plants grow.

Many mechanisms to regulate the rate of water loss have evolved in plants. One involves dormancy during dry times of the year; another involves loss of leaves. Deciduous plants are common in areas that periodically experience a severe drought. Plants are often deciduous in regions with severe winters, when water is locked up in ice and snow and thus unavailable to them. In a general sense, annual plants conserve water when conditions are unfavorable, simply by going into dormancy as seeds.

Thick, hard leaves, often with relatively few stomata—and frequently with stomata only on the lower side of the leaf—lose water far more slowly than large, pliable leaves with abundant stomata. Temperatures are significantly reduced in leaves covered with masses of woolly-looking trichomes. These trichomes also increase humidity at the leaf surface. Plants in arid or semiarid habitats often have their stomata in crypts or pits in the leaf surface. Within these depressions the water vapor content of the air may be high, reducing the rate of water loss.

Plant Responses to Flooding

Plants can also receive too much water, and ultimately "drown." Flooding rapidly depletes available oxygen in the soil and interferes with the transport of minerals and carbohydrates in the roots. Abnormal growth often results. Hormone levels change in flooded plants—ethylene (the only hormone that is a gas) increases, while gibberellins and cytokinins usually decrease. Hormonal changes contribute to the abnormal growth patterns.

Oxygen-deprivation is among the most significant problems. Standing water has much less oxygen than moving water. Generally, standing water flooding is more harmful to a plant (riptides excluded). Flooding that occurs when a plant is dormant is much less harmful than flooding when it is growing actively.

Physical changes that occur in the roots as a result of oxygen deprivation may halt the flow of water through the plant. Paradoxically, even though the roots of a plant may be standing in water, its leaves may be drying out. One adaptive solution is that stomata of flooded plants often close to maintain leaf turgor.

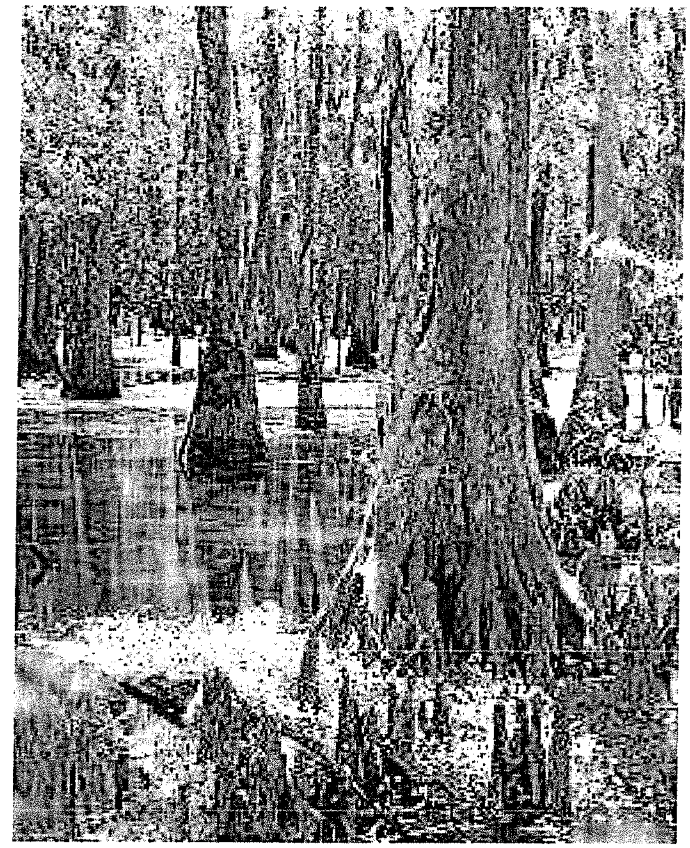


FIGURE 39.13
Adaptation to flooded conditions. The "knees" of the bald cypress (*Taxodium*) form whenever it grows in wet conditions, increasing its ability to take in oxygen.

Adapting to Life in Fresh Water. Algal ancestors of plants adapted to a freshwater environment from a saltwater environment before the "move" onto land. This involved a major change in controlling salt balance. Since that time, many have "moved" back into fresh water and grow in places that are often or always flooded naturally; they have adapted to these conditions during the course of their evolution (figure 39.13). One of the most frequent adaptations among such plants is the formation of **aerenchyma,** loose parenchymal tissue with large air spaces in it (figure 39.14). Aerenchyma is very prominent in water lilies and many other aquatic plants. Oxygen may be transported from the parts of the plant above water to those below by way of passages in the aerenchyma. This supply of oxygen allows oxidative respiration to take place even in the submerged portions of the plant.

Some plants normally form aerenchyma, whereas others, subject to periodic flooding, can form it when necessary. In corn, ethylene, which becomes abundant under the anaerobic conditions of flooding, induces aerenchyma formation. Plants also respond to flooded conditions by forming larger lenticels (which facilitate gas exchange) and additional adventitious roots.

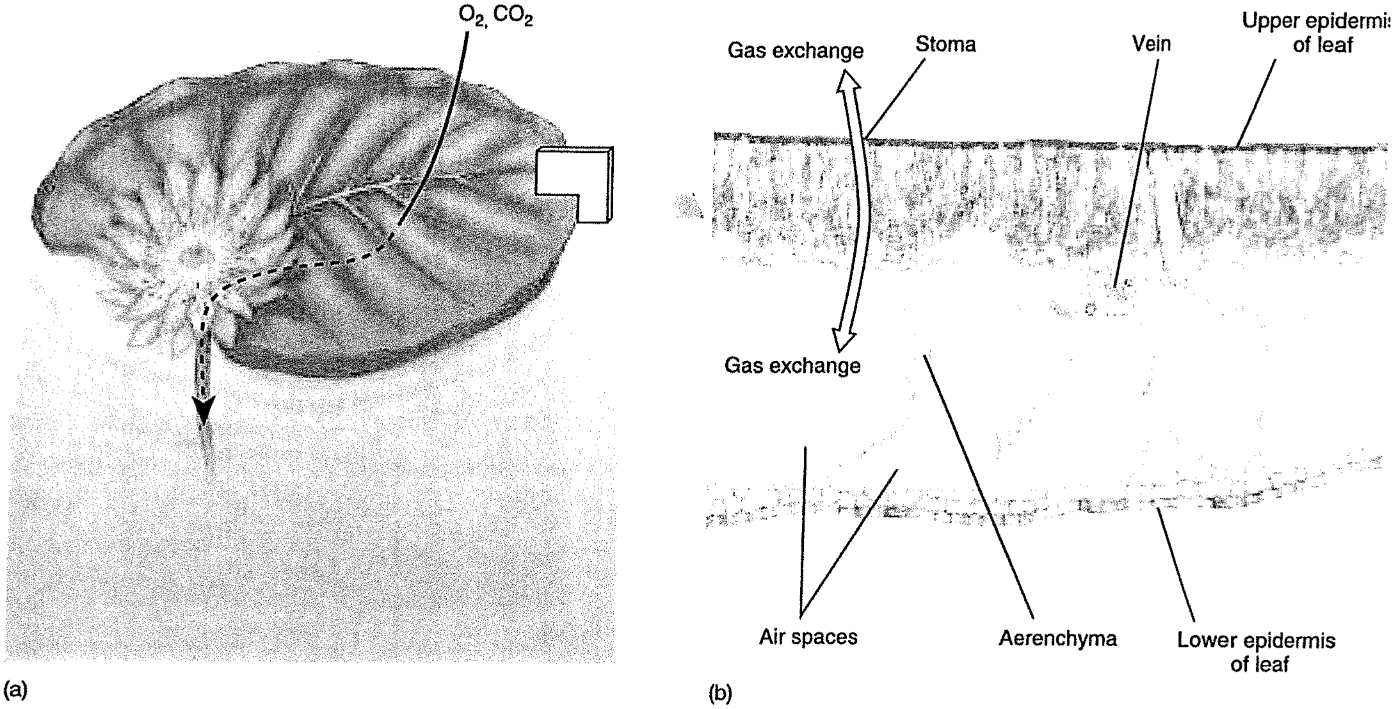


FIGURE 39.14
Aerenchyma tissue. Gas exchange in aquatic plants. (*a*) Water lilies float on the surface of ponds where oxygen is collected and transported to submerged portions of the plant. (*b*) Large air spaces in the leaves add buoyancy. The specialized parenchyma tissue that forms these open spaces is called aerenchyma. Gas exchange occurs through stomata found only on the upper surface of the leaf.

Adapting to Life in Salt Water. Plants such as mangroves that are normally flooded with salt water must not only provide a supply of oxygen for their submerged parts, but also control their salt balance. The salt must be excluded, actively secreted, or diluted as it enters. The arching silt roots of mangroves are connected to long, spongy, air-filled roots that emerge above the mud. These roots, called pneumatophores (see chapter 38), have large lenticels on their above-water portions through which oxygen enters; it is then transported to the submerged roots (figure 39.15). In addition, the succulent leaves of mangroves contain large quantities of water, which dilute the salt that reaches them. Many plants that grow in such conditions also secrete large quantities of salt.

Transpiration from leaves pulls water and minerals up the xylem. This works because of the physical properties of water and the narrow diameters of the conducting tubes. Stomata open when their guard cells become turgid. Opening and closing of stomata is osmotically regulated. Biochemical, anatomical, and morphological adaptations have evolved to reduce water loss through transpiration. Plants are harmed by excess water. However, plants can survive flooded conditions, and even thrive in them, if they can deliver oxygen to their submerged parts.

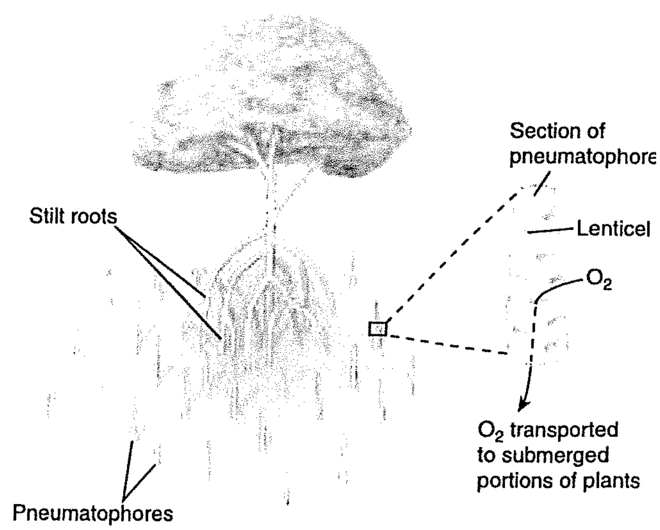


FIGURE 39.15
How mangroves get oxygen to their submerged part. Mangrove plants grow in areas that are commonly flooded, and much of each plant is usually submerged. However, modified roots called pneumatophores supply the submerged portions of the plant with oxygen because these roots emerge above the wate and have large lenticels. Oxygen can enter the roots through the lenticels, pass into the abundant aerenchyma, and move to the re of the plant.

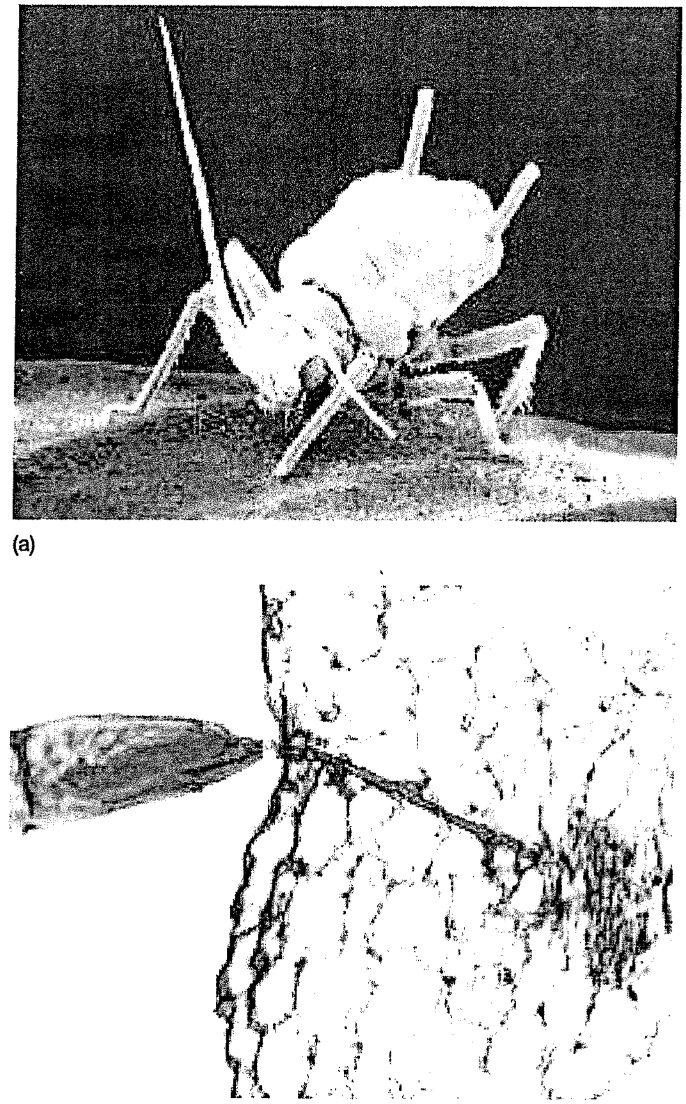
39.4 Dissolved sugars and hormones are transported in the phloem.

Phloem Transport Is Bidirectional

Most carbohydrates manufactured in leaves and other green parts are distributed through the phloem to the rest of the plant. This process, known as **translocation,** is responsible for the availability of suitable carbohydrate building blocks in roots and other actively growing regions of the plant. Carbohydrates concentrated in storage organs such as tubers, often in the form of starch, are also converted into transportable molecules, such as sucrose, and moved through the phloem. The pathway that sugars and other substances travel within the plant has been demonstrated precisely by using radioactive tracers, despite the fact that living phloem is delicate and the process of transport within it is easily disturbed. Radioactive carbon dioxide ($^{14}CO_2$) gets incorporated into glucose as a result of photosynthesis. The glucose is used to make sucrose, which is transported in the phloem. Such studies have shown that sucrose moves both up and down in the phloem.

Aphids, a group of insects that extract plant sap for food, have been valuable tools in understanding translocation. Aphids thrust their *stylets* (piercing mouthparts) into phloem cells of leaves and stems to obtain abundant sugars there. When a feeding aphid is removed by cutting its stylet, the liquid from the phloem continues to flow through the detached mouthpart and is thus available in pure form for analysis (figure 39.16). The liquid in the phloem contains 10 to 25% dry matter, almost all of which is sucrose. Using aphids to obtain the critical samples and radioactive tracers to mark them, it has been demonstrated that movement of substances in phloem can be remarkably fast; rates of 50 to 100 centimeters per hour have been measured.

While the primary focus of this chapter is on nutrient and water transport, it is important to note that phloem also transports plant hormones. As we will explore in the next chapter, environmental signals can result in the rapid translocation of hormones in the plant.



(a)

(a)

FIGURE 39.16
Feeding on phloem. (*a*) Aphids, like this individual of *Macrosiphon rosae* shown here on the edge of a rose leaf, feed on the food-rich contents of the phloem, which they extract through their piercing mouthparts (*b*), called stylets. When an aphid is separated from its stylet and the cut stylet is left in the plant, the phloem fluid oozes out of it and can then be collected and analyzed.

Energy Requirements for Phloem Transport

The most widely accepted model of how carbohydrates in solution move through the phloem has been called the **mass-flow hypothesis, pressure flow hypothesis,** or **bulk flow hypothesis.** Experimental evidence supports much of this model. Dissolved carbohydrates flow from a **source** and are released at a **sink** where they are utilized. Carbohydrate sources include photosynthetic tissues, such as the mesophyll of leaves, and food-storage tissues, such as the cortex of roots. Sinks occur primarily at the growing tips of roots and stems and in developing fruits.

In a process known as *phloem loading,* carbohydrates (mostly sucrose) enter the sieve tubes in the smallest veinlets at the source. This is an energy-requiring step, as active transport is needed. Companion cells and parenchyma cells adjacent to the sieve tubes provide the ATP energy to drive this transport. Then, because of the

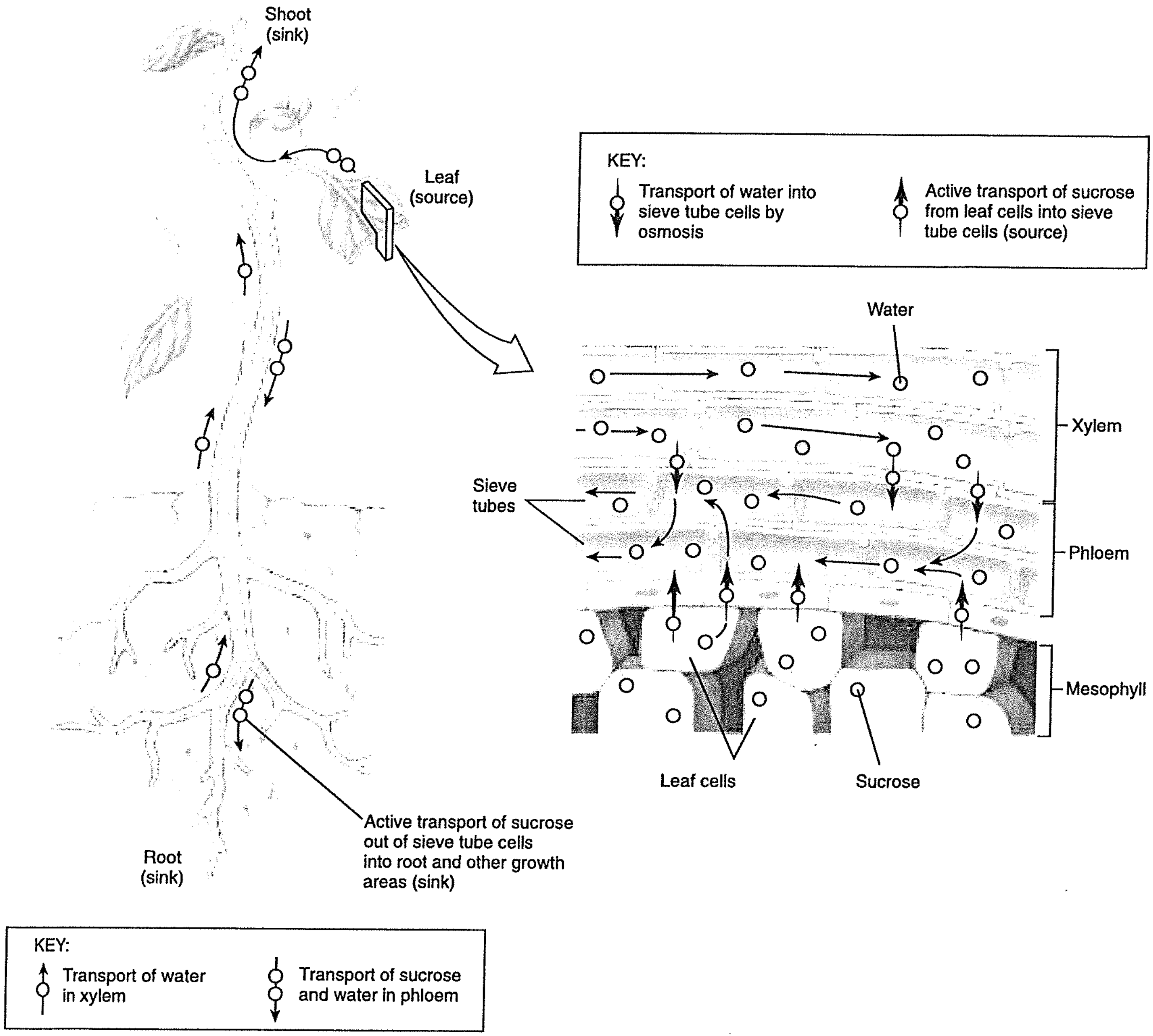


FIGURE 39.17
Diagram of mass flow. In this diagram, red dots represent sucrose molecules, and blue dots symbolize water molecules. Moving from th mesophyll cells of a leaf or another part of the plant into the conducting cells of the phloem, the sucrose molecules are then transported t other parts of the plant by mass flow and unloaded where they are required.

difference between the water potentials in the sieve tubes and in the nearby xylem cells, water flows into the sieve tubes by osmosis. Turgor pressure in the sieve tubes increases. The increased turgor pressure drives the fluid throughout the plant's system of sieve tubes. At the sink, carbohydrates are actively removed. Water moves from the sieve tubes by osmosis and the turgor pressure there drops, causing a mass flow from the higher pressure at the source to the lower pressure sink (figure 39.17). Most of the water at the sink diffuses then back into the xylen where it may either be recirculated or lost throug transpiration.

Transport of sucrose and other carbohydrates through sieve tubes does not require energy. The loading and unloading of these substances from the sieve tubes does.

Chapter 39

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Summary

Questions

Media Resources

39.1 Plants require a variety of nutrients in addition to the direct products of photosynthesis.

- Plants require a few macronutrients in large amounts and several micronutrients in trace amounts. Most of these are obtained from the soil through the roots.
- Plant growth is significantly influenced by the nature of the soil. Soils vary in terms of nutrient composition and water-holding capacity.

1. What is the difference between a macronutrient and a micronutrient? Explain how a plant would utilize each of the macronutrients.

- Nutrients
- Soil

39.2 Some plants have novel strategies for obtaining nutrients.

- Some plants entice bacteria to produce organic nitrogen for them. These bacteria may be free-living or form a symbiotic relationship with a host plant.
- About 90% of all vascular plants rely on fungal associations to gather essential nutrients.

2. The atmosphere is full of nitrogen yet it is inaccessible to most plants. Why is that? What solution has evolved in legumes?

39.3 Water and minerals move upward through the xylem.

- Water and minerals enter the plant through the roots. Energy is required for active transport.
- The bulk movement of water and minerals is the result of movement between cells, across cell membranes, and through tubes of xylem. Aquaporins are water channels that enhance osmosis.
- A combination of the properties of water, structure of xylem, and transpiration of water through the leaves results in the passive movement of water to incredible heights. The ultimate energy source for pulling water through xylem vessels and tracheids is the sun.
- Water leaves the plant through openings in the leaves called stomata. Stomata open when their guard cells are turgid and bulge, causing the thickened inner walls of these cells to bow away from the opening.
- Plants can tolerate long submersion in water, if they can deliver oxygen to their submerged tissues.

3. What is pressure potential? How does it differ from solute potential? How do these pressures cause water to rise in a plant?

4. What proportion of water that enters a plant leaves it via transpiration?

5. Why are root hairs usually turgid? Does the accumulation of minerals within a plant root require the expenditure of energy? Why or why not?

6. Under what environmental condition is water transport through the xylem reduced to near zero? How much transpiration occurs under these circumstances?

7. Does stomatal control require energy? Explain.

- Activity: Water Movement
- Uptake by Roots
- Water Movement

- Student Research: Heavy Metal Uptake

39.4 Dissolved sugars and hormones are transported in the phloem.

- Sucrose and hormones can move up and down in the phloem between sources and sinks.
- The movement of water containing dissolved sucrose and other substances in the phloem requires energy. Sucrose is loaded into the phloem near sites of synthesis, or sources, using energy supplied by the companion cells or other nearby parenchyma cells.

8. What is translocation? What is the driving force behind translocation?

9. Describe the movement of carbohydrates through a plant, beginning with the source and ending with the sink. Is this process active or passive?

Algebra 2

Algebra 2

Name Date Period

Functions as Ordered Pairs

EXAMPLE Is this set of ordered pairs a function?
(5, 4), (7, 2), (9, 0), (11, −2)
The set of ordered pairs is a function because no *x*-coordinates have been repeated.

Directions Tell whether the sets of ordered pairs are functions or not. Write *yes* or *no* and explain your answer.

1. (1, 0), (4, 2), (7, 4), (10, 6) __________

2. (5, −2), (5, −1), (5, 0), (5, 1) __________

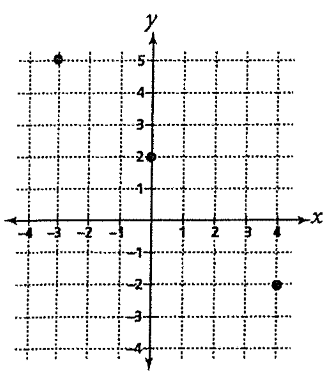
3. (−3, 3), (−2, 2), (−1, 1), (0, 0) __________

4. (9, −2), (8, 1), (7, 4), (6, 7) __________

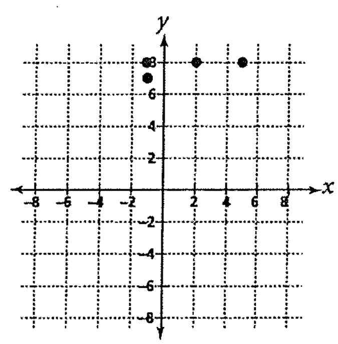
5. (0, 0), (−1, 2), (1, 0), (1, 2) __________

Directions If a vertical line passes through two or more points of a graph, the graph does not represent a function. Use this vertical line test to determine if the graph is a function or not. Write *yes* or *no*.

6.



7.



EXAMPLE Write the domain and range of this function.
(7, −2), (1, 4), (3, 6), (−4, −1)
The domain is 7, 1, 3, −4. The range is −2, 4, 6, −1.

Directions Write the domain and range for each function below.

8. (1, −2), (0, 2), (−1, 6), (−2, 10) ________

9. (5, 0), (3, −2), (1, −4), (−1, −6) ________

10. (0, 4), (2, −1), (4, −6), (−2, 8) ________

Name Date Period

Workbook Activity 13
Chapter 2, Lesson 2

Functions as a Rule

EXAMPLE Calculate $f(x)$ for the given domain values.
$f(x) = 3x$; $x = 1, 3, 8, 10, 100$
$f(x) = 3, 9, 24, 30, 300$ for the given domain values.

Directions Calculate $f(x)$ for the given domain values.

1. $f(x) = 5x; x = 4, 6, 8, 10, 20$
2. $f(x) = -3x; x = 0, -1, -2, -3, -4$
3. $f(x) = \frac{1}{6}x; x = 6, 12, -12, -42, 60$
4. $f(x) = 5x + 2; x = 0, 1, 2, 3, 4$
5. $f(x) = 7x - 11; x = 3, 6, 9, 12, 15$
6. $f(x) = \frac{1}{2}x - 5; x = 0, 4, 10, 50, -100$
7. $f(x) = 4x + 8; x = 1, 11, 21, 31, 101$
8. $f(x) = -2x - 14; x = -1, -5, -10, -15, 12$
9. $f(x) = \frac{1}{3}x + 22; x = 9, 6, 3, 0, -3$
10. $f(x) = \frac{7}{8}x - 12; x = 16, 24, 48, -8, -64$

EXAMPLE Choose any number; then multiply it by 7.

$f(x) = 7x$ is a rule in function notation for the example above.
The reason that it is a function is that each x has one and only one $7x$.

Directions Write a rule using function notation, $f(x) =$ ______.
Then give a reason why it is a function.

11. Choose any number; then divide it by 6. ______
12. Choose any number; then multiply it by 4. ______
13. Choose any number; multiply it by 3, then add 15. ______
14. Choose any number; then subtract 9. ______
15. Choose any number; then divide it by −2. ______
16. Choose any number; then multiply it by −5. ______
17. Choose any number; multiply it by −8, then subtract 7. ______
18. Choose any number; divide it by 3, then add 13. ______
19. Choose any number; multiply it by 4, then subtract 52. ______

Directions Solve the problem.

20. Each month Daisy shoots eight rolls of film. Write a rule that shows how many rolls of film she shoots for a given number of months. Write the rule in function notation.

Name ______ Date ______ Period ______

Workbook Activity 14

Chapter 2, Lesson 3

Zeros of a Function

EXAMPLE $f(x) = 3x - 6$ Find the zeros of $f(x)$.

Let $f(x) = 0$ and solve for x.

$0 = 3x - 6$
$6 = 3x$
$2 = x$

Check: $f(2) = 3(2) - 6$
$f(2) = 6 - 6$
$f(2) = 0$

Directions Find the zeros of $f(x)$.

1. $f(x) = -2x + 12$ ______
2. $f(x) = \frac{2}{5}x - 10$ ______
3. $f(x) = 4x - 4$ ______
4. $f(x) = \frac{1}{3}x - 9$ ______
5. $f(x) = x + 8$ ______
6. $f(x) = x^2 - 64$ ______
7. $f(x) = \frac{1}{4}x + 3$ ______
8. $f(x) = 5x - 10$ ______
9. $f(x) = -x - 8$ ______
10. $f(x) = 6x + 42$ ______
11. $f(x) = 9x - 9$ ______
12. $f(x) = 7x - 3$ ______
13. $f(x) = \frac{3}{8}x - 1$ ______
14. $f(x) = x^2 - 81$ ______
15. $f(x) = 8x + 4$ ______
16. $f(x) = \frac{2}{7}x - 4$ ______
17. $f(x) = x^3 - 125$ ______
18. $f(x) = \frac{3}{4}x + 12$ ______
19. $f(x) = 10x + 25$ ______
20. $f(x) = x^3 - 27$ ______
21. $f(x) = 2x + 10$ ______
22. $f(x) = \frac{1}{10}x + 100$ ______
23. $f(x) = 7x + 91$ ______
24. $f(x) = 6x + 15$ ______
25. $f(x) = \frac{10}{21}x - 1$ ______
26. $f(x) = 30x - 450$ ______
27. $f(x) = x^4 - 81$ ______
28. $f(x) = \frac{1}{6}x + 2$ ______
29. $f(x) = 15x + 75$ ______
30. $f(x) = x^5 - 32$ ______

Name Date Period

Workbook Activity **15**

Chapter 2, Lesson 4

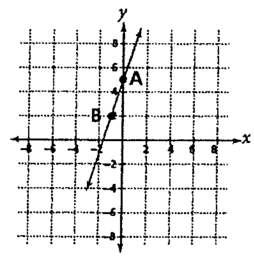
Graphs of Linear Functions

EXAMPLE Graph $f(x) = 3x + 5$.

Step 1 Let $x = 0$.
$f(0) = 3(0) + 5 = 5 \rightarrow (0, 5)$ is point A.
$y = 5$ is the y-intercept.

Step 2 Let $x = -1$.
$f(-1) = 3(-1) + 5 = 2 \rightarrow (-1, 2)$ is point B.

Step 3 Graph the two points; then draw the line $y = f(x) = 3x + 5$.



Directions Graph each linear function and label the y-intercept. (Use graph paper. Label the x- and y-axes first.)

1. $f(x) = 2x$
2. $f(x) = 3x + 2$
3. $f(x) = -4x$
4. $f(x) = 2x - 4$
5. $f(x) = 5x + 1$
6. $f(x) = \frac{1}{4}x$
7. $f(x) = -3x - 8$
8. $f(x) = 2x + 7$
9. $f(x) = \frac{3}{8}x + 2$
10. $f(x) = 5x - 2$
11. $f(x) = \frac{2}{7}x$
12. $f(x) = 4x - 5$
13. $f(x) = -\frac{1}{5}x + 3$
14. $f(x) = x + 10$
15. $f(x) = \frac{1}{4}x - 6$
16. $f(x) = 6x + 6$
17. $f(x) = \frac{7}{10}x$
18. $f(x) = 10x - 8$
19. $f(x) = \frac{1}{5}x + 2$
20. $f(x) = 8x + 8$

Name Date Period

Workbook Activity 16
Chapter 2, Lesson 5

The Slope of a Line, Parallel Lines

EXAMPLE Calculate the slope of $f(x) = 3x + 4$.

Step 1 Find two points.

$f(1) = 3(1) + 4 = 7 \rightarrow (1, 7)$ is point 1.
$f(0) = 4(0) + 4 = 4 \rightarrow (0, 4)$ is point 2.

Step 2 Calculate $m = \frac{(y_1 - y_2)}{(x_1 - x_2)}$.

$m = \frac{(7 - 4)}{(1 - 0)} = \frac{3}{1} = 3$

$m = 3$

Directions Calculate the slope of each line. Remember, $m = \frac{(y_1 - y_2)}{(x_1 - x_2)}$.

1. $f(x) = x + 5$ ______

2. $f(x) = 4x - 2$ ______

3. $f(x) = -3x$ ______

4. $f(x) = 5x$ ______

5. $f(x) = -2x - 7$ ______

6. $f(x) = \frac{1}{2}x$ ______

7. $f(x) = \frac{3}{7}x + 5$ ______

8. $f(x) = -7x - 2$ ______

9. $f(x) = -\frac{2}{9}x + 1$ ______

10. $f(x) = x - 6$ ______

11. $f(x) = \frac{2}{5}x + 1$ ______

12. $f(x) = 2\frac{1}{2}x + 6$ ______

13. $f(x) = -4x - 9$ ______

14. $f(x) = -\frac{1}{15}x + 3$ ______

15. $f(x) = 10x - 1$ ______

16. $f(x) = -15x - 25$ ______

17. $f(x) = \frac{2}{15}x + 8$ ______

18. $f(x) = -4x - 11$ ______

19. $f(x) = -\frac{8}{11}x + 5$ ______

20. $f(x) = 18x + 1$ ______

EXAMPLE Given $f(x) = 5x$ and $g(x) = 5x - 4$, show that the lines are parallel by showing that their slopes are equal.

$f(1) = 5(1) = 5 \rightarrow (1, 5)$ is point 1.
$f(0) = 5(0) = 0 \rightarrow (0, 0)$ is point 2.

$m = \frac{(5 - 0)}{(1 - 0)} = \frac{5}{1}$

$m = 5$

$g(1) = 5(1) - 4 = 1 \rightarrow (1, 1)$ is point 1.
$g(0) = 5(0) - 4 = -4 \rightarrow (0, -4)$ is point 2.

$m = \frac{(1 + 4)}{(1 - 0)} = \frac{5}{1}$

$m = 5$

Directions Show that the lines are parallel by showing that their slopes are equal.

21. $f(x) = 2x + 5$ and $g(x) = 2x$ ______

22. $f(x) = -6x$ and $g(x) = -6x + 7$ ______

23. $f(x) = \frac{1}{3}x - 4$ and $g(x) = \frac{1}{3}x + 4$ ______

24. $f(x) = -x + 100$ and $g(x) = -x - 8$ ______

Directions Solve the problem.

25. A hill has a height of 450 feet. The horizontal distance covered between the bottom of the hill and the top is 1,800 feet. Find the slope of the hill.

The Formula $f(x) = y = mx + b$

EXAMPLE

$5x + y = 2$

Change to $y = mx + b$. Give m and b.

Solution: Subtract $5x$ from both sides. $y = -5x + 2$

$m = -5$, y-intercept $= 2$

Directions Change the given equation to the form $y = mx + b$. Give the value of m and b.

1. $2x + 4y = 8$ __________
2. $-2x + y = 1$ __________
3. $-4x + 4y = 4$ __________
4. $-x + 3y = 9$ __________
5. $3x + y = -7$ __________
6. $-2x + 2y = 2$ __________
7. $x - 4y = 2$ __________
8. $-3x + 6y = 12$ __________
9. $4x + 8 = y$ __________
10. $-6x + 10 = y$ __________
11. $-6x - 3y = 9$ __________
12. $-\frac{1}{3}x + 6y = 2$ __________
13. $\frac{2}{5}x + \frac{1}{5}y = 5$ __________
14. $-x + \frac{1}{3}y = 4$ __________
15. $-3x + \frac{1}{5}y = -4$ __________
16. $2x + \frac{1}{5}y = 0$ __________
17. $x - \frac{1}{10}y = 1$ __________
18. $\frac{1}{5}x + 2y = 8$ __________
19. $-10x + 8 = 5y - 2$ __________
20. $\frac{1}{3}x + 9 = \frac{1}{3}y + 6$ __________
21. $-x + \frac{3}{4}y = -2$ __________
22. $-6x + 9y = 3$ __________
23. $x + \frac{1}{8}y = -4$ __________
24. $-3x - y = 6$ __________
25. $\frac{1}{2}x + 2y = 8 - 2y$ __________
26. $x + \frac{1}{6}y = 6$ __________
27. $-\frac{1}{10}x + y = 10$ __________
28. $-12x - 4y = 2y + 3$ __________
29. $-x + y = 0$ __________
30. $-x + y = 2$ __________

Name Date Period

Workbook Activity 22
Chapter 3, Lesson 1

The Distributive Law—Multiplication

EXAMPLE $6(x - y) = 6x - 6y$

Directions Multiply, using the distributive law.

1. $3(8 + 2)$ ____________
2. $6(x + y)$ ____________
3. $a(b + c)$ ____________
4. $x(a + b - c)$ ____________
5. $x(3x + 9)$ ____________
6. $y(x + y^3)$ ____________
7. $x(a - b - c)$ ____________
8. $x^2(x^3 + y^3)$ ____________
9. $x^4(x + z - y)$ ____________
10. $x^3(5x^3 + x^2)$ ____________

EXAMPLE $(2 + 7)(y - x) = 2y - 2x + 7y - 7x$
$= 9y - 9x$

Directions Multiply, using the distributive law twice. Simplify by adding like terms.

11. $(6 + 4)(a - b)$ ____________
12. $(a - 2)(a + 4)$ ____________
13. $(x + y)(a - b)$ ____________
14. $(x + 3)(x + 5)$ ____________
15. $(y + 4)(y - 4)$ ____________
16. $(2a + 4)(a + 5)$ ____________
17. $(x - y)(y - x)$ ____________
18. $(a + 2b)(4a + b)$ ____________
19. $(a + b)(a - b)$ ____________
20. $(x - y)(3x + 3y)$ ____________

EXAMPLE $(x + 3)(x - y + 8) =$
$x^2 - xy + 8x + 3x - 3y + 24 =$
$x^2 - xy + 11x - 3y + 24$

Directions Multiply.

21. $(x - 5)(x - y + 4)$ ____________
22. $(x + y)(6x + y - z)$ ____________
23. $(x + y)(3x^2 + 4y + 7)$ ____________
24. $(x - 4)(4x + y + z)$ ____________
25. $(a - b)(3a + 6b + ab)$ ____________
26. $(a + b)(a^3 - b^2 + 1)$ ____________
27. $(a - b)(a + 2b - 4ab)$ ____________
28. $(x + 3)(3x - y + 8)$ ____________
29. $(x + 4y)(x - y + xy)$ ____________
30. $(x + y)(x + y - 10)$ ____________

Name Date Period

The Distributive Law—Factoring

EXAMPLES $rb + rc = r(b + c)$

$3yx^2 + 6yx - 9y^2 = 3y(x^2 + 2x - 3y)$

Directions Factor the expressions by finding the common factor(s) first.

1. $kl + kj$ ____________

2. $9x + 6y$ ____________

3. $x^2 - xy - x$ ____________

4. $xb - xc + xd$ ____________

5. $2x^2 - 6xy + 4x$ ____________

6. $ab - ac + a^3$ ____________

7. $axy - xy^2$ ____________

8. $5xy + 10xya$ ____________

9. $4x^2y + 12xy + 10y^2$ ____________

10. $g^2 + g^3$ ____________

EXAMPLE Factor $x^2 + 6x + 9$.

Step 1 $x^2 + 6x + 9 = (x + \_\_\_)(x + \_\_\_)$

Step 2 The factors of 9 are 3 and 3; 1 and 9; −3 and −3; and −1 and −9. So the possible factors for $x^2 + 6x + 9$ include $(x + 3)(x + 3)$; $(x + 1)(x + 9)$; $(x - 3)(x - 3)$; and $(x - 1)(x - 9)$.

Step 3 Substitute each set of factors in the product and check.

$$\begin{aligned} x^2 + 6x + 9 &= (x - 1)(x - 9) \\ &= x(x - 9) - 1(x - 9) \\ &= x^2 - 9x - x + 9 \\ &= x^2 - 10x + 9 \quad \text{Incorrect.} \end{aligned}$$

$$\begin{aligned} x^2 + 6x + 9 &= (x + 3)(x + 3) \\ &= x(x + 3) + 3(x + 3) \\ &= x^2 + 3x + 3x + 9 \\ &= x^2 + 6x + 9 \quad \text{Correct.} \end{aligned}$$

Directions Factor, using the model $(x + \_\_\_)(x + \_\_\_)$. Check by multiplying.

11. $x^2 + 7x + 6$ ____________

12. $x^2 + x - 6$ ____________

13. $x^2 + 8x + 15$ ____________

14. $x^2 - 2x - 15$ ____________

15. $x^2 + 2x - 8$ ____________

16. $x^2 + 3x - 18$ ____________

17. $x^2 - 25$ ____________

18. $x^2 + 6x + 5$ ____________

19. $x^2 + 6x - 7$ ____________

20. $x^2 - 10x + 25$ ____________

Name Date Period

Workbook Activity 24
Chapter 3, Lesson 3

Solutions to $ax^2 + bx = 0$

EXAMPLE Solve for x and check: $2x^2 + 8x = 0$.

Step 1 Factor: $2x^2 + 8x = 0 \rightarrow 2x(x + 4) = 0$

Step 2 Set each factor equal to 0 and solve for x:
$2x = 0$ or $x + 4 = 0$
$x = 0$ or $x = -4$

Check:
$x = 0$, $2x^2 + 8x = 0 \rightarrow 2(0)^2 + 8(0) = 0 + 0 = 0$
$x = -4$, $2x^2 + 8x = 0 \rightarrow 2(-4)^2 + 8(-4) = 32 - 32 = 0$

Directions Solve for x and check.

1. $x^2 + 12x = 0$ ______
2. $x^2 - 3x = 0$ ______
3. $x^2 - 10x = 0$ ______
4. $x^2 + 25x = 0$ ______
5. $x^2 - 13x = 0$ ______
6. $x^2 - 7x = 0$ ______
7. $x^2 - 19x = 0$ ______
8. $x^2 + 23x = 0$ ______
9. $x^2 + 36x = 0$ ______
10. $x^2 - 45x = 0$ ______
11. $2x^2 - 8x = 0$ ______
12. $3x^2 - 15x = 0$ ______
13. $4x^2 + 4x = 0$ ______
14. $10x^2 - 25x = 0$ ______
15. $8x^2 + 16x = 0$ ______
16. $6x^2 - 21x = 0$ ______
17. $2x^2 + 40x = 0$ ______
18. $3x^2 + 30x = 0$ ______
19. $4x^2 - 36x = 0$ ______
20. $5x^2 - 45x = 0$ ______
21. $2x^2 + 48x = 0$ ______
22. $3x^2 + 48x = 0$ ______
23. $4x^2 - 52x = 0$ ______
24. $5x^2 + 75x = 0$ ______
25. $6x^2 - 90x = 0$ ______
26. $12x^2 - 6x = 0$ ______
27. $20x^2 + 4x = 0$ ______
28. $15x^2 - 3x = 0$ ______
29. $24x^2 + 6x = 0$ ______
30. $35x^2 + 7x = 0$ ______

Name ______ Date ______ Period ______

Workbook Activity 25
Chapter 3, Lesson 4

Solutions to $x^2 + bx + c = 0$ by Factoring

EXAMPLE Solve for x by factoring $x^2 + 7x + 10 = 0$. Then check.

Step 1 Factor: $x^2 + 7x + 10 = 0$
$(x + \_\_)(x + \_\_) = 0$ Think: Factors of 10 are 2, 5, 1, 10.
$(x + 2)(x + 5) = 0$

Step 2 Set each factor equal to 0: $x + 2 = 0$ or $x + 5 = 0$
Solve for x: $x = -2$ or $x = -5$

Check:
$x = -2$, $x^2 + 7x + 10 = 0 \rightarrow (-2)^2 + 7(-2) + 10 = 4 - 14 + 10 = 0$
$x = -5$, $x^2 + 7x + 10 = 0 \rightarrow (-5)^2 + 7(-5) + 10 = 25 - 35 + 10 = 0$

Directions Solve for x by factoring. Check your answers.

1. $x^2 + 2x - 8 = 0$ ______
2. $x^2 + 2x - 15 = 0$ ______
3. $x^2 - 6x + 9 = 0$ ______
4. $x^2 + 3x - 18 = 0$ ______
5. $x^2 + 4x - 21 = 0$ ______
6. $x^2 - 10x + 25 = 0$ ______
7. $x^2 + 9x + 14 = 0$ ______
8. $x^2 + 3x - 10 = 0$ ______
9. $x^2 + 5x - 6 = 0$ ______
10. $x^2 + 6x - 27 = 0$ ______
11. $x^2 + 11x - 26 = 0$ ______
12. $x^2 + 12x + 35 = 0$ ______
13. $x^2 + 14x + 45 = 0$ ______
14. $x^2 + 2x - 80 = 0$ ______
15. $x^2 + 20x + 100 = 0$ ______
16. $x^2 - 6x - 55 = 0$ ______
17. $x^2 - 8x - 33 = 0$ ______
18. $x^2 + 8x - 65 = 0$ ______
19. $x^2 - 13x + 36 = 0$ ______
20. $x^2 - 14x + 40 = 0$ ______
21. $x^2 + 30x + 29 = 0$ ______
22. $x^2 - 9x - 52 = 0$ ______
23. $x^2 + 16x + 64 = 0$ ______
24. $x^2 + 19x + 84 = 0$ ______
25. $x^2 - 20x - 69 = 0$ ______
26. $x^2 + 3x - 70 = 0$ ______
27. $x^2 + 17x + 30 = 0$ ______
28. $x^2 - x - 56 = 0$ ______
29. $x^2 - x - 72 = 0$ ______
30. $x^2 - 3x - 108 = 0$ ______

Government

Kaple

Blizzard Bag Assignment – American Government/Economics

After reading each presidential biography pick 3 significant things about each president and write a paragraph on each.

Ronald Reagan

1.

2.

3.

George H.W. Bush

1

2.

3.

Bill Clinton

1.

2.

3.

George W. Bush

1.

2.

3.

Barack Obama

1.

2.

3.

1981 – 1989

Ronald Reagan

After two troubled decades, Americans sought a president to restore confidence in themselves and the country – and Ronald Reagan delivered

The plot of the 1967 film *In Like Flint* involves an imposter replacing the president of the United States. Secret agent Derek Flint, played by James Coburn, uncovers the truth that a nefarious stand-in has been playing the part of the leader of the free world. "An actor? As president?" Flint gasps in astonished incredulity.

Barely 13 years later, the US voted for Ronald Reagan, a former Hollywood star and TV performer, as the 40th president of the country. It was an unlikely previous occupation for a resident of the White House, yet he proved to be an extraordinary leader.

Born in Tampico, Illinois in 1911, Ronald Wilson Reagan's immediate family consisted of alcoholic father John (known as Jack), older brother Neil, and nurturing, compassionate mother Nelle. She taught her boys not to blame their father as alcoholism was a disease. It impacted upon everyone, however, in that the Reagan family had to move frequently for Jack to find work. They finally settled in Dixon, Illinois in 1920, where Reagan's father sold shoes.

> Taking office just 17 days before his 70th birthday, Reagan remains the oldest man to become US president

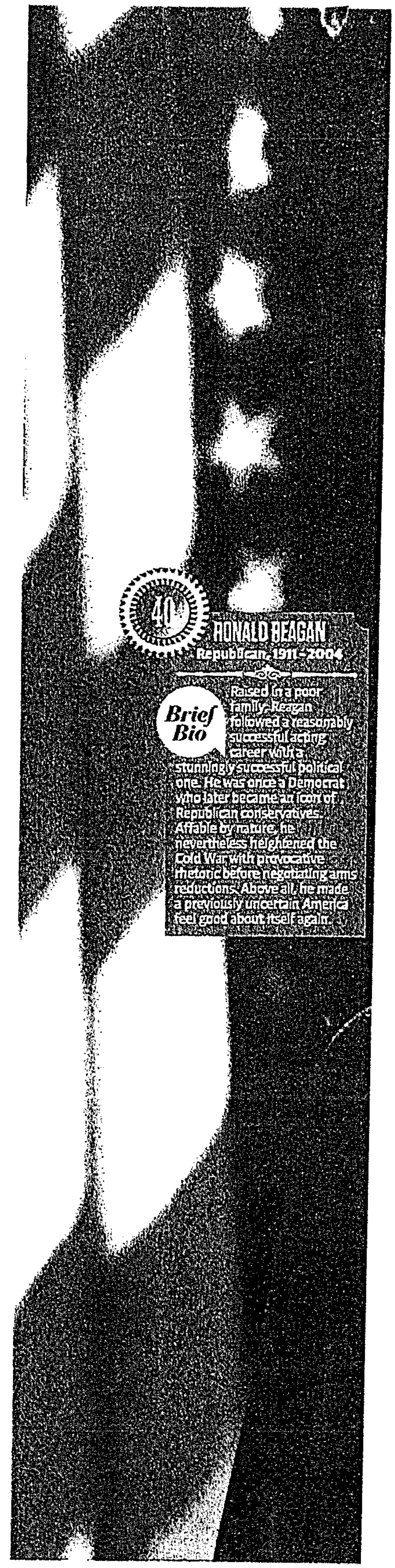
Following high school graduation, Jack's youngest enrolled in Eureka College, Illinois. He majored in economics and sociology, and while only average academically, he excelled in sport and drama. Tellingly perhaps, he was elected class president in his senior year.

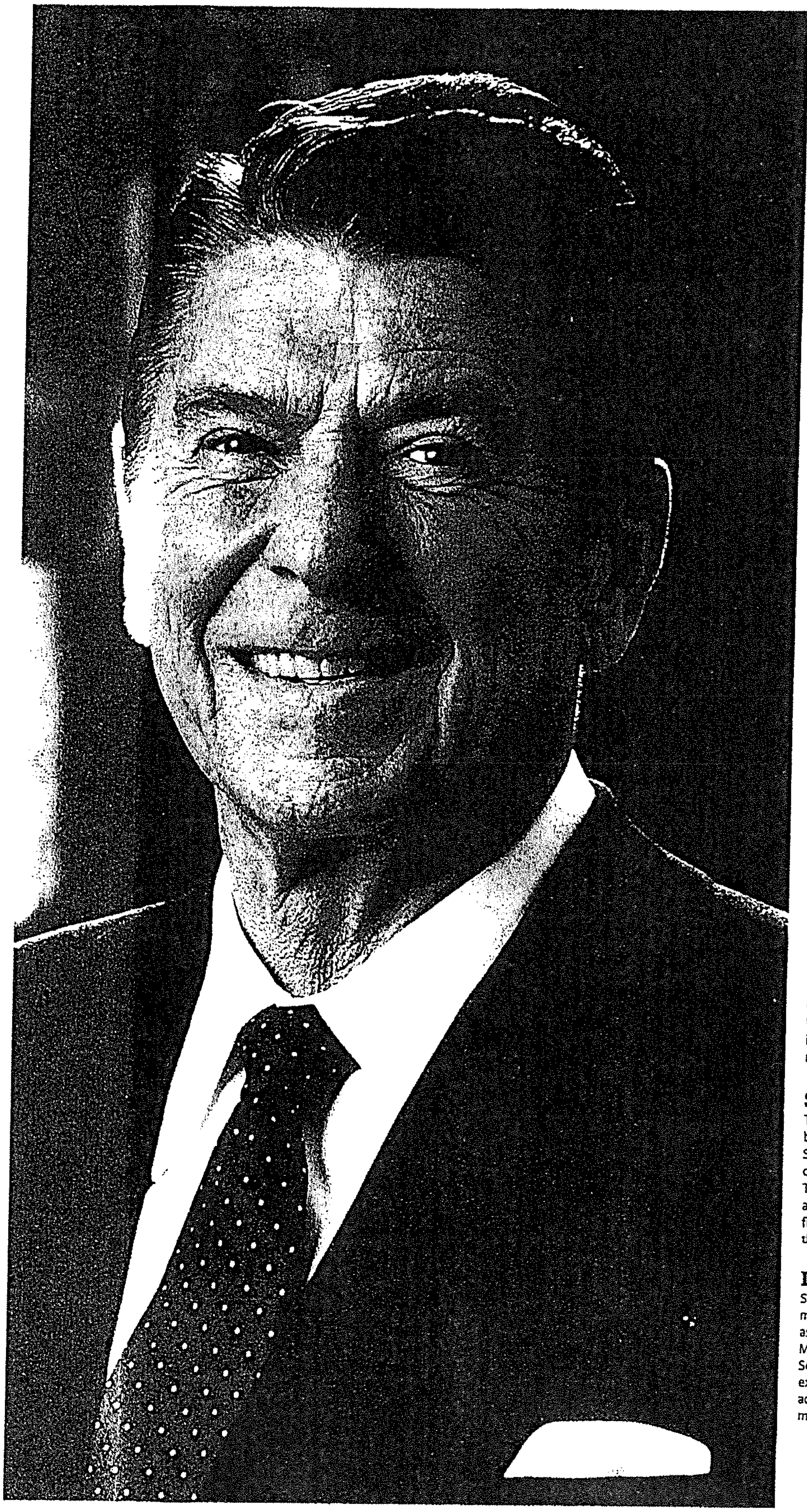
Reagan first found work as a radio sports reporter in Davenport, Iowa, soon progressing to a similar post with larger station, WHO, in Des Moines. His coverage of the Chicago Cubs baseball team proved popular in the state – and also kick-started his acting career.

In 1937, while following the Cubs to a training camp in California, the budding reporter also arranged to make a screen test at Warner Brothers studios. Tall, athletic, good-looking, and with an impressive speaking voice, Reagan landed a $200 per week contract.

He appeared mostly in films regarded not as features but as B-movies. Frequently he played wholesome, easy-going 'good guy' characters who were, many have noted, rather like himself. In the relaxed, self-mocking manner that served him so well in his political career, Reagan later explained the studio "didn't want the films good, they wanted them Thursday."

Critics and himself regarded his best film as *King's Row*. Yet any hopes Reagan had of building on that 1942 release were curtailed by the war. A US Army cavalry reserve since the 1930s, in the wake of Japan's attack on Pearl Harbor, Reagan was called to active service. Eyesight problems meant he wasn't suitable for combat duty but his talents were put to use in the military's first motion picture unit narrating training films and appearing in patriotic movies to aid the war effort. He had married actress Jane Wyman by then, too. Their first child, Maureen, was born in 1941, and a second, Michael, was adopted in 1945, but the marriage ended in divorce four years later.





Nancy and Ronald Reagan aboard a boat in California in 1964

Life in the time of Ronald Reagan

Cue VT

With the words, "Ladies and gentlemen, rock and roll," MTV was launched on 1 August 1981, kick-starting a revolution in the music industry. The first music video shown on the channel was 'Video Killed The Radio Star', by British recording duo The Buggles.

Car wars

The DeLorean gull-winged sports car launched on the American market in the early 1980s – with the car industry in its biggest slump for decades. The company went bankrupt in 1982, though the car later featured as a time machine in the Back To The Future trilogy.

Armageddon almost by accident

The world came dangerously close to destruction in 1983. With Cold War tensions high, US and NATO forces began a wargame exercise called Able Archer '83. The Soviet Union, fearing a a surprise attack might be instigated under such a premise, mobilised its nuclear forces and came close to launching.

Sport and politics

The Moscow Olympics in 1980 were boycotted by many countries included the United States. Four years later, the Soviet Union and others boycotted the Los Angeles Olympics. The Goodwill Games, introduced in 1986, attempted to break the cycle. Moscow hosted first, Seattle four years later, and there were three further tournaments.

Disaster in the skies

Space Shuttle Challenger began its tenth mission in January 1986. Among its seven astronauts was school teacher Christa McAuliffe, due to give lessons from space. Seconds into the mission, the Shuttle exploded, killing all on board. Reagan addressed the nation that evening to pay a moving tribute to the lost astronauts.

Making nuclear weapons obsolete

Rather than trust that the volume of nuclear weapons of both superpowers would prevent war because of mutually assured destruction, Reagan seized on the notion of a Strategic Defence Initiative. He charged the scientific community with creating a system largely deployed in space to shoot down missiles launched at the United States. Research and development costs would be enormous, while such a system risked breaching existing weapons control treaties and instigating a new arms race.
The economy of the Soviet Union, meanwhile, was in a parlous state, particularly after the price of its main export oil plummeted. Soviet leader Mikhail Gorbachev was introducing reforms promising greater freedom and sought negotiations with Reagan. The two leaders met four times.

The second summit in Iceland began with low expectations but progressed rapidly, Gorbachev eventually offering to eliminate all nuclear weapons within a decade if the Americans would confine SDI research to laboratories. Reagan, however, would not give up on SDI and such an historic agreement was never made, even though a later summit produced a treaty eliminating intermediate-range nuclear forces. Years later, with SDI as originally conceived proving difficult to achieve, defence systems were downgraded to earth-based theatre, not national, levels.


Reagan and Soviet Union leader Mikhail Gorbachev sign the Intermediate-Rang Nuclear Forces Treaty in 1987

Reagan was first elected president of the Screen Actors Guild, the union for film and television performers, in 1947. He served as its leader for a further five years. They were turbulent times in the movie industry because of investigations by the House of Un-American Activities Committee into left-wing politics in Hollywood. Strongly anti-communist, Reagan fought other movie unions he felt were under communist influence, testified as a friendly witness to the HUAC, and was an FBI informant on suspected Hollywood leftist sympathisers. The blacklist of performers, writers and directors prevented from working for major studios because of their political views subsequently numbered more than 300.

During this period, Reagan's own politics were shifting. He had been a liberal, Democratic Roosevelt supporter but was becoming more conservative. Meeting actress Nancy Davis, who had views similar to her right-wing adoptive father, only accelerated the process. The pair married in 1952.

The movie offers were drying up, but in 1954 Reagan landed a TV job as presenter and occasional performer for General Electric Theatre, a drama series which became a staple of Sunday night viewing. Part of his role was to visit the sponsor company's plants, giving talks to its employees. Over the years, this exposure to 'business America' convinced the actor that big government hindered rather than helped enterprise, pushing him further towards the political right, while the talks helped hone his speech construction and delivery skills.

> During his second term as governor of California, Reagan granted country singer Merle Haggard a full pardon from his past crimes

Reagan's acting career was a success, but few predicted he would eventually land the presidency

After campaigning with Democrats-for-Eisenhower to vote the Republican to the White House in 1952 and 1956, Reagan supported the Grand Old Party's Richard Nixon against John F Kennedy, finally registering as a Republican in 1962. As such, he championed the party's 1964 conservative presidential candidate, Barry Goldwater. In the last week of the campaign, Reagan presented "A Time for Choosing," a 30-minute nationally televised address, considered to be one of the finest political endorsements ever made.

Although Goldwater lost, Reagan rocketed to pre-eminence on the Republican right.

The next move was to seek office himself. Against Democrat incumbent 'Pat' Brown, Reagan ran for governor of California in 1966. Brown tried discrediting his opponent as an inexperienced lightweight, but Reagan flipped the accusations, arguing he was an ordinary citizen fed up with

Defining moment

A true soulmate
4 March 1952

After numerous film appearances, and a divorce, Reagan marries actress Nancy Davis. She claims her life only really begins after her marriage, which produces two children, Patricia and Ronald. The couple are devoted to each other, remaining deeply in love for the rest of their lives. Reagan's personal politics have begun to shift, in part through Nancy, in part due to his position as president of the Screen Actors Guild, and in part because of his exposure to the business world brought about by his role as presenter of TV's General Electric Theatre

Timeline

1911

- **Humble Beginnings** Reagan is born in Tampico, Illinois. When the family settle in Dixon, his alcoholic father becomes a shoe salesman. **6 February 1911**
- **Hollywood Beckons** Reagan begins working as a radio sports reporter and is soon broadcasting on Chicago Cubs baseball games. Covering the team takes him to California, where he makes a successful screen test. **1932-1937**

- **New career** A nationwide TV appearance endorsing Republican presidential candidate Barry Goldwater brings in $1 million worth of support. Goldwater loses, but Reagan's profile as a prominent politician is firmly established. **27 October 1964**
- **Time to govern** Reagan is elected governor of California, serving two terms. Untypically, he sanctions record tax increases to tackle a budget deficit and achieves some notable environmental success. Controversially uses the National Guard to quell student unrest. **1796**
- **Out of office** Reagan bides his time giving speeches and writing a weekly newspaper column before announcing he wishes to seek the Republican Party presidential nomination. He comfortably secures it. **13 November 1979**
- **The White House beckons** He is sworn in as the 40th president following a resounding election victory the previous November over Jimmy Carter. He advocates supply-side economic reform which quickly become know as 'Reagonomics'. **20 January 1981**

remote and inefficient state government. This appealed to voters, who also warmed to Reagan's affable personality. He won convincingly, securing a second term four years later.

A half-hearted tilt at the Republican presidential nomination failed in 1968. A more serious challenge to Gerald Ford - president after Nixon's resignation - followed eight years later. That failed too, but when Ford lost to Jimmy Carter, Reagan was the obvious choice to secure the GOP nomination in 1980. He resoundingly defeated President Carter, confidently asserting that he could rebuild the nation's economy and spirit - badly tarnished after Vietnam, the Watergate scandal, and the Iran hostage crisis - with sweeping tax cuts, increased defence spending, less government interference, and a balanced federal budget.

The American hostages in Iran were released the day Reagan was inaugurated, but that auspicious start was abruptly halted when John Hinckley Jr attempted to assassinate the new President in early 1981. With a bullet lodged in Reagan's body just millimetres from his heart, he was rushed to hospital. When Nancy arrived, her husband told her, "Honey, I forgot to duck." Just before undergoing surgery, he removed his oxygen mask, enquiring of the staff, "I hope you are all Republicans." Reagan's survival of the attack and his endearing quips made his popularity soar.

His language was hawkishly tough, however, when confronting the Soviet Union. Reagan dubbed it "an evil empire", escalating the Cold War with his increased military spending. A further step came in 1983 when the president announced the country would develop the Strategic Defence Initiative. Labelled "Star Wars" by critics, the system called for space-based technologies to intercept and destroy nuclear missiles launched at the United States.

Some contended this was a dangerous escalation of the arms race that would create a black hole in the military budget. In later years, however, others say pressures created by the SDI helped end the Cold War and pushed the Soviet Union into collapse, as its increasingly unstable economy was incapable of competing with such US military expansion.

With the economy booming again, a landslide second election victory was achieved in 1984. After Brezhnev, Andropov and Chernenko, a fourth Soviet leader, Mikhail Gorbachev, came to power during Reagan's presidency. Unlike the previous three, Gorbachev signalled he was prepared to negotiate with the US President, whose bellicose language began to soften during his second term. From a position of strength following military expansion, Reagan's discussions with Gorbachev on limiting the nuclear arsenal of both super powers bore fruit. Historic agreements on strategic arms reductions were signed, though some contend more could have been achieved had Reagan not been so steadfastly wedded to SDI.

> In his 1984 re-election, Reagan won more electoral college votes - 525 out of 538 - than any other president in history

While the economy continued expanding during Reagan's second term, there were increases to the budget deficit and the national debt, yet neither harmed his popularity. What did was the Iran-Contra Affair. American hostages were being held in Lebanon by groups friendly to Iran. Despite a policy of not dealing with terrorists, between 1985 and 1986, arms were shipped to Iran in exchange for hostage releases and payments. Later, some of the payments were diverted to the Contras of Nicaragua who were fighting to overthrow the country's socialist government, even though such funding was outlawed by Congress. It remains unclear how much the president knew about the Affair, but he did apologise to the nation for it, tarnishing his image. Nevertheless, on leaving office, Reagan had the highest presidential approval ratings since Roosevelt.

Five years after exiting the White House, Reagan was diagnosed with Alzheimer's disease. Despite periods in his last years in office when he appeared confused, with Nancy occasionally stepping forward to prompt his answers before the press, his doctors insisted he did not have the illness when serving.

The degenerative disease curtailed his public appearances in later life. He died aged 93 in 2004. Although the image of a rider-less horse following the carriage carrying his coffin, with Reagan's own riding boots reversed in the stirrups, seemed pure Hollywood for the former actor, it has been seen at state funerals for other former Presidents who were, like Ronald Reagan, venerated by the nation.

> "Reagan dubbed the Soviet Union an 'evil empire', escalating the Cold War"

Defining moment

Assassination attempt
30 March 1981

Leaving the Washington Hilton Hotel, the president and three others are hit by a hail of bullets fired by John Hinckley Jr. Reagan is rushed to hospital and undergoes emergency surgery. He survives, the first president to do so after being shot in an assassination attempt. His popularity skyrockets. Hinckley, obsessed with the actress Jodie Foster, sought to impress her by emulating a character from her film *Taxi Driver* who makes an assassination attempt. Charged with attempting to assassinate the president, Hinckley is found not guilty by reason of insanity and is confined to a psychiatric institution

Defining moment

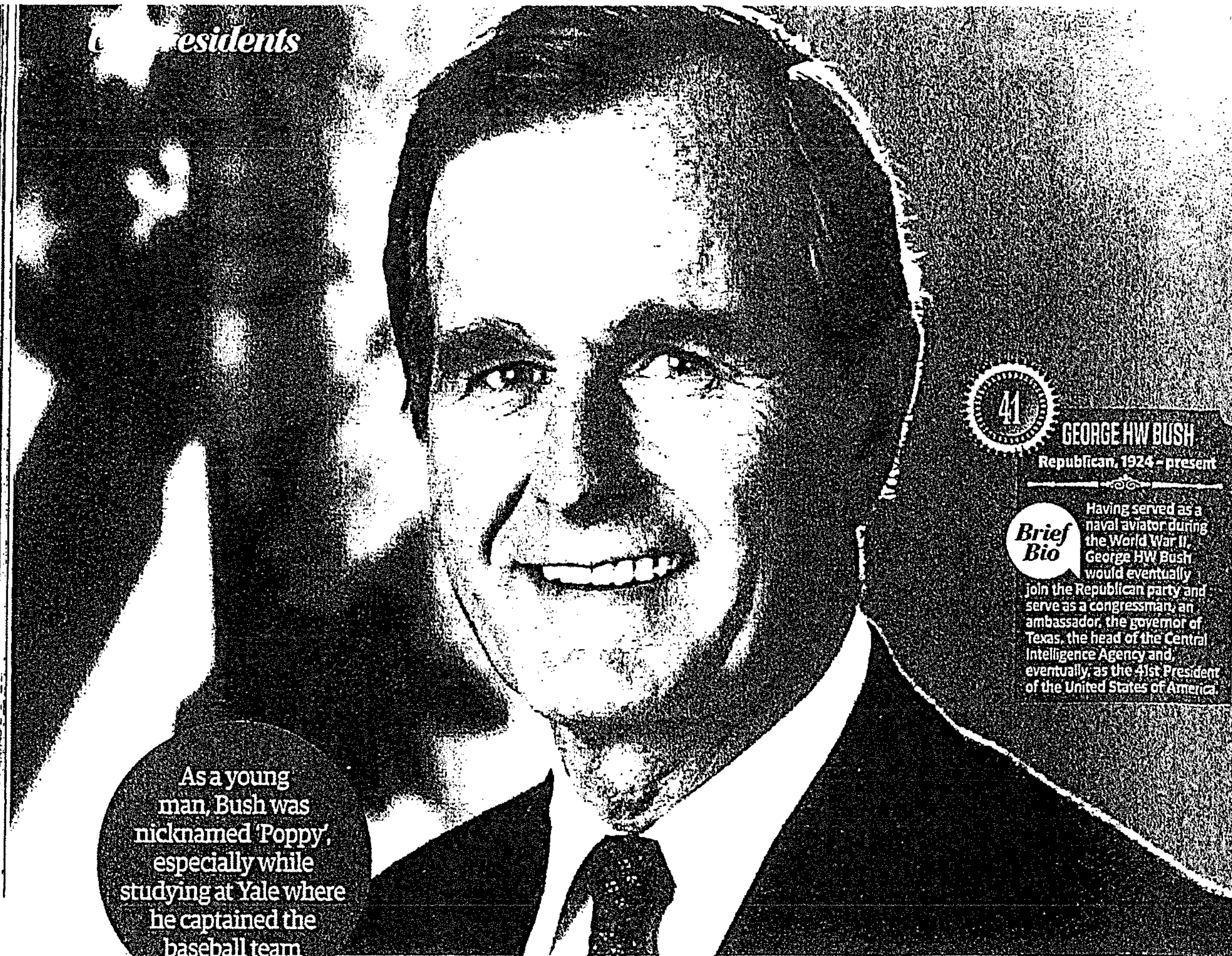
Last day
20 January 1989

Reagan retires from the White House. Four successful summits with Soviet leader Gorbachev have paved the way for a peaceful resolution to the Cold War. Not all foreign policy ventures have been successful, though. The Iran-Contra Affair in particular has been shambolic, even down to how much the president knew or didn't know about it. At home, there are mixed economic outcomes too. Inflation is down and under control and there has been extensive growth, yet the budget deficit has deepened while the national debt has soared. Without doubt, however, the president leaves office a popular and highly regarded figure

Reagan delivers his famous speech in front of the Brandenburg Gate in Berlin, in which he appealed to Gorbachev to "tear down this wall"

2004

- **Reach for the stars**
  Reagan unveils his proposal for a Strategic Defence Initiative to protect the US from attack by nuclear missiles with space-based systems. Critics call it "Star Wars" and claim it is unfeasible.
  23 March 1983
- **Four more years**
  After declaring it was "Morning again in America" during the campaign because of the resurgent economy, he secures a second term as president with the largest ever electoral college victory.
  4 November 1984
- **Iconic speech**
  Reagan visits the Berlin Wall's Brandenburg Gate. Superpower summits have been productive but he challenges the Soviet Union to go further with reforms, urging, "Mr Gorbachev, tear down this wall!"
  12 June 1987
- **No Sir!**
  Reagan is awarded an honorary knighthood by Queen Elizabeth II. It is the highest honour Britain can bestow upon a foreign national, though he cannot be referred to as Sir.
  14 June 1989
- **Incurable illness**
  After appearing in public for the last time at Richard Nixon's funeral earlier in the year, Reagan discloses in an open letter to the American people that he has Alzheimer's disease.
  5 November 1994
- **The curtain comes down**
  At the age of 93, Reagan dies of pneumonia complicated by Alzheimer's at his Bel Air home in California.
  5 June 2004



41 GEORGE HW BUSH
Republican, 1924 – present

Brief Bio Having served as a naval aviator during the World War II, George HW Bush would eventually join the Republican party and serve as a congressman, an ambassador, the governor of Texas, the head of the Central Intelligence Agency and, eventually, as the 41st President of the United States of America.

As a young man, Bush was nicknamed 'Poppy', especially while studying at Yale where he captained the baseball team

1989 – 1993

George HW Bush

The last living president to have served during WWII, George HW Bush is the elder statesman at the head of one of the US's most influential political familie[s]

Born into a wealthy family on 12 June 1924, George Herbert Walker Bush was already a part of legacy well versed in the minutia of military service and politics. His father, Prescott Bush, had served as a captain during World War I and had gone on to serve as a US senator. The second of five children, the young Bush attended the super-elite preparatory school Phillips Academy where he excelled both socially and academically, captaining varsity teams and holding a variety of leadership positions.

It was here, in 1941, that Bush met a young Barbara Pierce, the woman who would remain at his side for decades to come. A year later, on his 18th birthday, Bush followed in his father's footsteps a joined the military, opting for the US Navy. He became the youngest ever naval aviator at the time, and flew a total of 58 combat missions during World War II.

After the war, Bush married his fiancée Barbara, graduated from Yale with a degree in economics and moved to Texas (with son, and future president, George Jr in tow) where he made his mark in oil refinery. However, his attention soon turned to politics. He became chairman of the Harris County Republican Party by 1963, but failed in his attempts to gain a seat in the Senate on behalf of Texas. This knockback, and the one that followed the year after, didn't dissuade him and he eventually earned a seat in the House of Representatives in 1966.

His political career then began to bloom. His no-nonsense and direct demeanour, mixed with his family name, his experience as a war veteran and his influence as a former oil magnate made him a formidable force as he served as the US ambassador to the United Nations and headed up the Republican National Committee during President Nixon's Watergate scandal. His political ascendance even saw him assume the post of director of the CIA in 1976.

But by the end of the 1970s, Bush's attention had moved to the highest office of all: the presidency. His attempt to win the Republican nomination in 1980 wasn't to be, losing out to charismatic former Hollywood star Ronald Reagan, but his campaign made a big impact and Reagan selected him as vice president. The pairing proved successful and Bush served two full terms as vice president.

> As well as flying 58 combat missions, Bush was awarded three Air Medals and the Distinguished Flying Cross

His own presidential campaign (1987-1988), took a far more proactive and aggressive tone than his previous effort, and his renewed vigour ultimately struck a chord – although Bush's victory wasn't a landslide, with the Republican taking 54.4% of the popular vote. Slim margin or not, Bush was in and he became the first serving vice president to be elected president since Martin Van Buren in 1836, and the first president to succeed someone from his own party since Herbert Hoover in 1929.

Sworn into office on 20 January 1989, Bush assumed the presidency at a time of dramatic change for the Western world, most notably the destabilisation of the Soviet Union. The Cold War that had silently raged for decades had petered out and Soviet states were finally transforming into democratic territories once more. In the face of such events, it's no surprise that Bush's administration would focus a great deal of its attention on foreign policy and the United States' relationship with the changing world.

Bush began a dialogue with liberal Soviet leader Mikhail Gorbachev, and between them Russo-American relations improved significantly. The two would form something of a political power couple on the global stage and the signing of the Soviet Arms Reduction Treaty in July 1991 typified this new strategy of cooperation.

Another significant factor that defined Bush's time in office was the Gulf War. When the Iraqi military invaded Kuwait in January 1991, it thrust the world's oil resources into crisis. With infamous Iraqi leader Saddam Hussein now in control of these oil fields illegally, Bush and his administration had to act. Shortly after, Congress sanctioned the use of military force. Operations Desert Shield and Desert Storm saw US forces drive out the Iraqi occupation and liberate Kuwait.

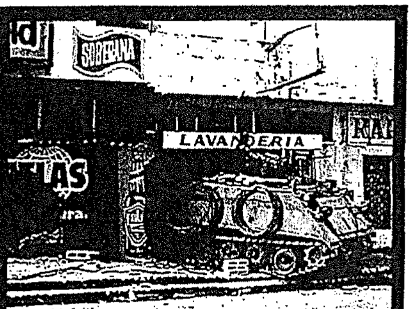
The liberation of Kuwait (and, of course, its precious oil reserves) sent Bush's approval ratings through the roof - but for all his successes in foreign policy, his domestic administration brought him no end of ridicule. The United States' economy was in recession, mainly due to sluggish job recovery across the nation, and while this economic downturn wasn't necessarily the fault of the Bush administration, it still left a significant proportion of the American population feeling vulnerable and disillusioned.

When Bush actively raised taxes (after, rather ironically, using the slogan, "Read my lips: no new taxes," as one of the tenets of his presidential campaign) in order to deal with the worsening budget deficit, his popularity ultimately plummeted. Even his successes overseas couldn't repair the damage and Bush lost his seat in the 1993 presidential elections to the popular Democrat Bill Clinton.

After serving a single term as president, Bush proudly watched his son George W Bush assume the presidency in 2000, while his other son Jeb became governor of Florida between 1999 and 2007. Now in his nineties and still going strong, the elder Bush continues his philanthropy, working with charities across the US to raise money for countless good causes.

The US invasion of Panama

During the 1980s, Panamanian leader Manuel Noriega (who had previously been openly pro-US) had been smuggling drugs from his nation into the US. When a democratic election ousted him from power he nullified the vote and reassumed control. In response, Bush sent 2,000 American troops into Panama (Operation Just Cause) to settle the growing unrest under Noriega's de facto government. The leader had been an issue for Reagan's administration, but the Republican president had been unable to find a solution. Under Bush's presidency, Noriega was removed from office and power was granted back to the rightful winner of the election, Guillermo Endara.



Bush's long list of political appointments, including being director of the CIA, made him a popular candidate for the presidency

Life in the time of George HW Bush

Somali strife

In the early 1990s African state Somalia descended into a devastating civil war, which plunged the country towards a humanitarian crisis. In April 1994, the United Nations attempted to aid the situation, but the mission failed. The war continued through Bush's administration and into Bill Clinton's.

Into the light

Bush established the Point Of Light Award, an affectation of the Points Of Light movement, which aimed to promote the spirit of volunteerism in local communities. The award itself was created to recognise those that went above and beyond in the name of helping their fellow Americans. In 2013, the 5,000th award was granted.

Berlin united

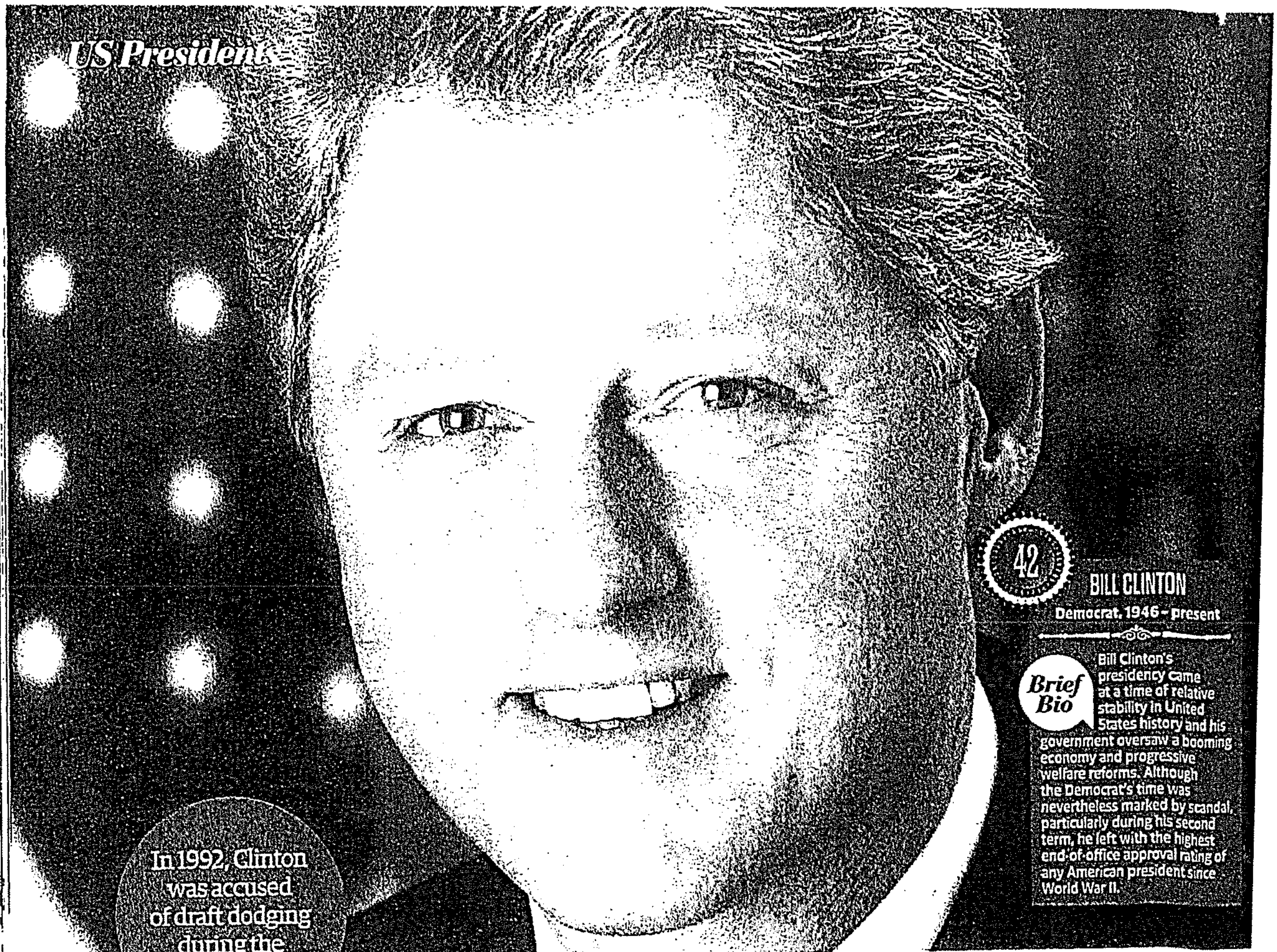
In the same year Bush finally ascended to the office of the president, the world around his new administration was changing drastically. The crumbling of the Soviet Union saw East and West Berlin – divided for over three decades – united as one.

Soviet Union disbanded

In December 1991, the prime and first ministers of Russia, Ukraine and Belarus signed the Belavezha Accords which deemed the Soviet Union dissolved. A Commonwealth of Independent States (CIS) was established in its place.

Flood damage

Between April and October 1993, the United States suffered its worst recorded flooding in the history of the country. It occurred in the American Midwest along the Mississippi and Missouri rivers and caused a staggering $15 billion in damages across agriculture, property and more.



42 BILL CLINTON
Democrat, 1946 – present

Brief Bio Bill Clinton's presidency came at a time of relative stability in United States history and his government oversaw a booming economy and progressive welfare reforms. Although the Democrat's time was nevertheless marked by scandal, particularly during his second term, he left with the highest end-of-office approval rating of any American president since World War II.

In 1992, Clinton was accused of draft dodging during the Vietnam War

1993 – 2001

Bill Clinton

Calling himself 'The Comeback Kid', Bill Clinton's reign was tainted by scandal but it was impossible to keep him down

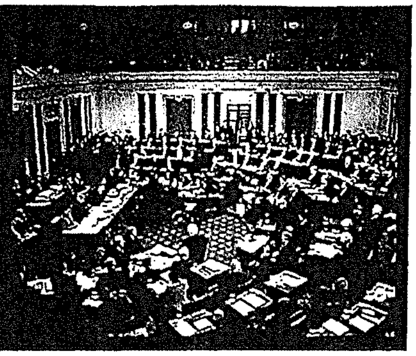
With the phrase, "It's the economy, stupid," ringing in the ears of the American electorate, Bill Clinton found himself the victor in the 1992 presidential campaign against President George HW Bush. The phrase hammered home the message that the economy was the most important electoral issue and, during Clinton's subsequent term, the United States' economy prospered. But it was to be just one of a number of things that would mark his eight roller-coaster years in office.

Bill Clinton was born William Jefferson Blythe in the tiny town of Hope, Arkansas, on 19 August 1946. He was raised alone by his mother, Virginia Cassidy Blythe; his father had died in a car crash three months before Clinton was born. With his mother studying for a nursing degree in New Orleans, the young boy was raised by his grandparents Eldridge and Edith Cassidy. His mother married Roger Clinton in 1950 and although the used car salesman was a gambler and an alcoholic prone to violence, the future president nevertheless officially adopted his stepfather's surname at the age of 15.

During his formative years, Clinton had shown deep intelligence. He graduated from Georgetown University, won a Rhodes Scholarship to Oxford

The Lewinsky scandal

When former Arkansas state employee Paula Jones sued Clinton for sexual harassment, her lawyers went on to subpoena White House intern Monica Lewinsky, another woman with whom Clinton was suspected of having an affair. Clinton denied a sexual relationship twice in January 1998 saying, "I did not have sexual relations with that woman". But Lewinsky, who also initially said the accusations were false, testified before the Starr commission and admitted nine encounters. Clinton, meanwhile, denied the affair under oath. It led to an impeachment trial in the Senate in December 1998 but in February the following year he was found not guilty on the charges of perjury and obstruction of justice.



University and studied law at Yale until 1973. But controversially, he was also questioned about his drug use at Oxford, responding infamously: "When I was in England, I experimented with marijuana a time or two, and didn't like it. I didn't inhale, and I didn't try it again." On the positive side, he met an ambitious, smart woman called Hillary Rodham at Yale and the couple married in 1975.

By the time the couple had a daughter, Chelsea, in 1980, the Democratic Party member had already served two years - from 3 January 1977 to 9 January 1979 - as the 50th attorney general of Arkansas. He had only just begun his first of two split terms as the 40th and 42nd governor of Arkansas too, the second of which ended on 12 December 1992.

But Clinton was destined for greater things and his reputation was growing. He followed a progressive brand of politics, which was part and parcel of a New Democrat centrist faction ideology that had emerged following George HW Bush's victory in 1988. He firmly believed in the need to improve the quality of public education. In 1992, he had won his party's nomination, running for president on a promise of welfare reform, a tax cut for the middle classes and an expansion of the Earned Income Tax Credit for the working poor.

His campaign was marred by claims of an affair by nightclub singer Gennifer Flowers yet with Clinton and his running mate Al Gore successfully in the White House, public attention turned firmly to politics. Clinton focused his work on economic reforms that would drag the US out of the recession that had blighted Bush's later years.

There were some positive standout moments including the so-called 'Don't ask, don't tell' law in 1993 which replaced an outright ban on gay people serving in the military and prohibited discrimination. That same year, Israel's prime minister Yitzhak Rabin shook hands with the Palestine Liberation Organisation's Yasser Arafat following the signing of the Oslo Accords. An agreement was also ratified in 1994 by the US, Canada and Mexico which created a trade bloc and eliminated barriers to investment.

But reform of the US healthcare system had to be scrapped and it was a bitter blow. First lady Hillary Clinton had been put in charge of spearheading the proposal - unofficially nicknamed Hillarycare - and the president had hoped to see it through. He yearned for universal health care and made it part of his presidential campaign but strong opposition and red tape strangled it. Following that, the midterm elections in 1994 saw the Republican Party make a net gain of 54 seats in the House of Representatives and pick up eight seats in the Senate. The Republican Revolution saw the party win both houses of Congress.

> **Jazz fan**
> Clinton began to play the saxophone aged nine and would play for 12 hours a day

It did not prevent Clinton from winning re-election in 1996. He became the first Democrat since Franklin D Roosevelt to win a second term, beating Republican Party nominee Bob Dole. Applauded for raising the national minimum wage, he clamped down on crime and became the first serving US president to visit Northern Ireland, telling his hosts the two countries were "partners for security, partners for prosperity, and most [importantly], partners for peace." Unemployment also fell to its lowest levels and the economy boomed. Yet further trouble brewed in his personal life and his second term was marked by the scandal involving White House intern Monica Lewinsky. It led to the president's impeachment (and later acquittal), which blemished his reputation.

His final years of presidency saw a rise in his popularity with the signing of tax-relief plans, tax credits for children and college tuition, and the announcement of a $70 billion budget surplus. But world tensions began to simmer and he oversaw a United States-led, two-month NATO bombardment of Serbia in support of the Albanians. He also warned in 1998 that Iraq was pursuing nuclear weapons, prompting four days of concentrated air attacks on Iraqi military installations. He may have taken office after the end of the Cold War but the United States' brief time of peace was coming to an end. Clinton left office on 20 January 2001.

Clinton meets with President Jimmy Carter during his time as governor of Arkansas

Life in the time of Bill Clinton

A changing Europe

Although the Cold War was over, many European borders were being redrawn in the east, particularly due to the Yugoslav Wars, the Kosovo War and the Bosnian War. Many countries were also shifting away from the influence of the former Soviet Union. The political landscape was shifting and the United States' standing was strengthened.

Prosperous times in the US

The American economy was flourishing in the Nineties, experiencing the longest period of peacetime economic expansion in its history. The US had more than overcome the recession at the turn of the decade and the Welfare Reform Act also succeeded in reducing poverty from 1996.

Dawn of the Internet

Around 1995, the Internet really began to take off, three years after the first photo on the World Wide Web was published by its inventor, English scientist Tim Berners-Lee (he had also written the first web browser in 1990). The Internet was proving to be revolutionary with email a popular form of communication.

Blair's rise to power

It is said that the progressive politics of Bill Clinton were mimicked by Tony Blair who became prime minister of the United Kingdom in 1997, following a landslide victory against the previously ruling Conservative Party. The UK and Ireland signed the Good Friday peace agreement in 1998.

Booming entertainment and high-profile cases

The 1990s saw the release of the first *Star Wars* prequel while animation moved up a notch with the debut of *Toy Story*. Punk rock flourished in California and nu metal became influential. Footballer and actor OJ Simpson fell from grace, accused of the double-murder of his ex-wife Nicole Brown Simpson and her friend Ronald Goldman.

2001 – 2009

George W Bush

Bush's time in office was marked by the terrorist attacks on the United States which led to the global War on Terror

It is video footage which has been seen many times over and yet it still manages to stay in the minds of those who view it. On the day Al-Qaeda terrorists flew two hijacked aeroplanes into the World Trade Center in New York, the White House chief of staff, Andrew Card, was filmed whispering into the ear of George W Bush in front of schoolchildren. That day also saw another plane blasted into the Pentagon and control of United Airlines Flight 93 seized - both were acts by Al-Qaeda - only for Flight 93 to crash in a field in Pennsylvania after its brave passengers attempted to overcome the terrorists.

The president listened intently for the few seconds it took for the message to be delivered, his face barely flickering as the news cameras focused upon him. He was reading a book to schoolchildren in Florida and, after the news was delivered, he continued to read for a few more minutes, stood up, apologised and left. But for those brief moments, he was a picture of calm on an otherwise hectic and uncertain day.

September 11 is the day which would define the 43rd president's time in office. He had only been leader for eight months when 9/11 - as it became known - happened in 2001, and he barely had the opportunity to make his mark. But from that moment on, he led the global War on Terror. He positioned himself as the head of the coalition of the willing - a group of allied countries uniting against terrorism - and he formed the Department of Homeland Security. The US was plunged into two long military campaigns in Afghanistan and Iraq, which split the opinion of its citizens. There was no denying Bush's impact.

Bush was born on 6 July 1946 in New Haven, Connecticut, the son of Barbara Bush and the future President George HW Bush, who made his fortune in oil. It was a relatively happy childhood albeit tinged with great sadness following the death of his younger sister, Pauline, of leukaemia aged just three. Bush was seven at the time and it was an event which dominated and shaped his early years as he battled to come to terms with his grief. A report in the *Washington Post* in 1999 said that Bush repeatedly questioned why no one had told him she had been dying. It was an event which defined him, ensuring his life would be driven by chance and humour.

Bush and wife Laura were instrumental in setting up PEPFAR, which helps save the lives of HIV and AIDS sufferers in Africa

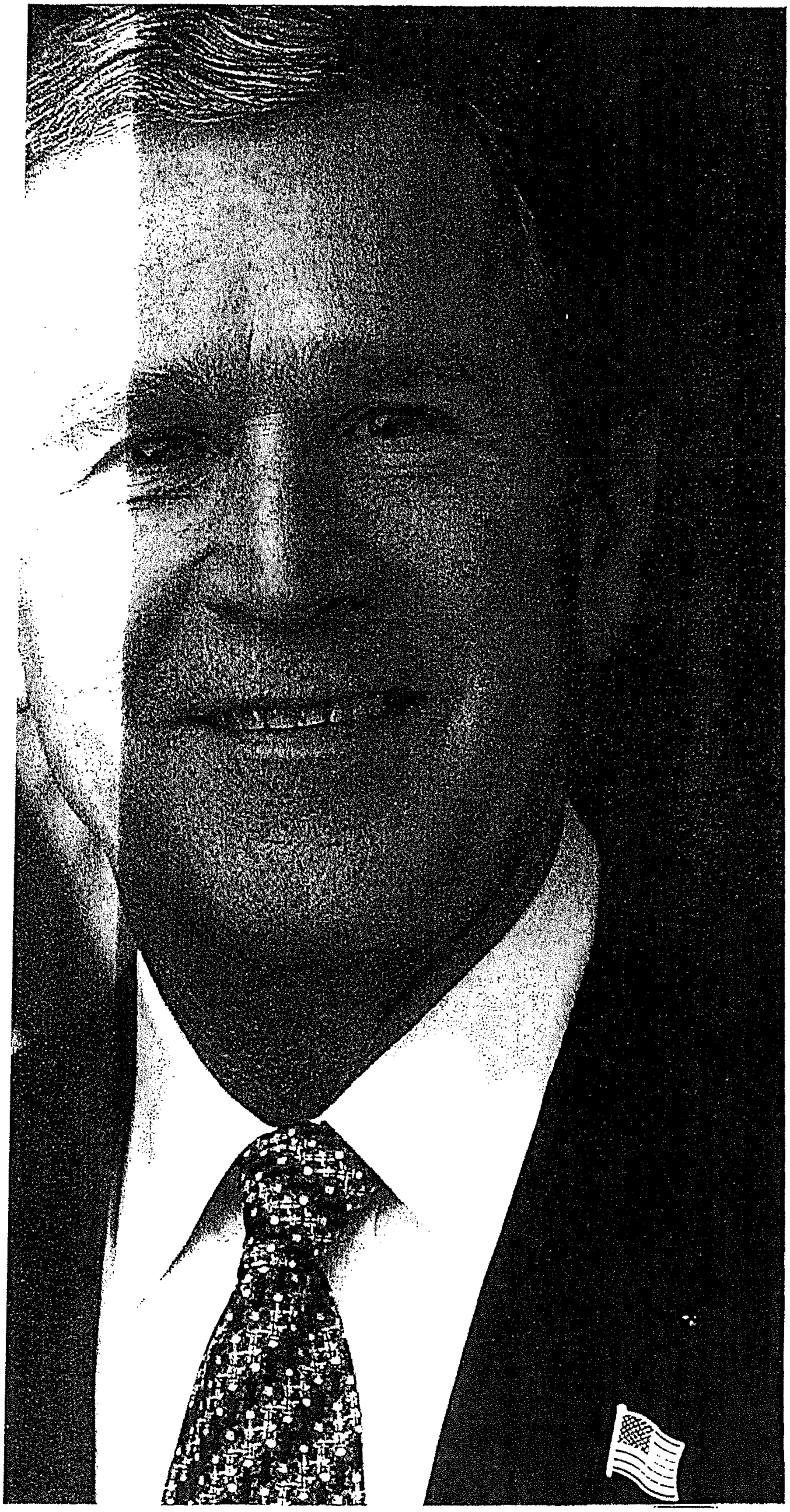
This was evident during his time reading history at Yale University. He was a member of the privileged Skull and Bones society and he spent more time socialising and drinking than studying. "To the C students, I say, 'You too can be president of the United States,'" he quipped in 2001 at Yale's 300th commencement. Even so, he was - literally - a high flier after graduation: until 1972, he served as an F-102 fighter pilot in the Texas Air National Guard during the Vietnam War. He went on to receive a Master of Business Administration from Harvard Business School in 1975.

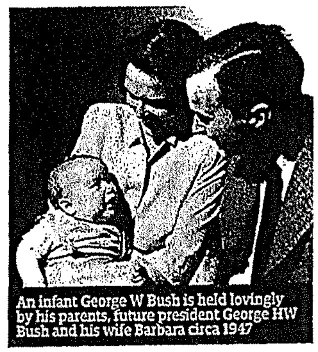
43

GEORGE W BUSH
Republican, 1946 – present

Brief Bio

George W Bush was the son of another president – George HW Bush, and his earlier life had alternated between forays in politics and business. After becoming governor of Texas, he was elected as the 43rd president, only to bear the brunt of the terrorist atrocities of September 11 in 2001, which went on to define both of the terms he eventually served.





An infant George W Bush is held lovingly by his parents, future president George HW Bush and his wife Barbara circa 1947

Life in the time of George W Bush

The War on Terror

September 11 changed everything for the first decade of the 21st century. Al-Qaeda terrorists would strike in Madrid, London and Mumbai, while Iraq and Afghanistan dominated political thinking. There were mass protests against war, rising fears of further attacks and concern over Iran's nuclear ambitions.

Religious awareness rises

The world became less ignorant of other religions and began to learn and understand more about Islam, in particular. Meanwhile, Pope John Paul II died on 2 April 2005. Two years earlier, he had sent Cardinal Pio Laghi to meet Bush, asking him to reconsider invading Iraq. He wouldn't.

The rise of Apple

More people began to invest in technology, in part, because of the phoenix-like revival of Apple spearheaded by founder Steve Jobs who had returned to the company in 1997. The iPod was released in 2001 and revolutionised the way that people bought and listened to music and the iPhone in 2007 ushered in the smartphone era.

Slower air travel

Concorde was retired in 2003 following its only crash in 2000. It was also a victim of the terrorist attacks of September 11 which had caused a general downturn in air travel numbers, and it heralded the end of supersonic transport and fast travel between the United States and Europe.

Superheroes dominate Hollywood films

With wars, climate change worries and disasters such as Hurricane Katrina, the world needed superheroes, it seemed. The box office was awash with *X-Men, Fantastic Four, Iron Man, Watchmen, Batman* and *Spider-Man* movies, and fantasy films such as *The Lord of the Rings* were also popular.

Bush was only the second president after John Quincy Adams to be the son of a president

His success, experience and responsibilities did not curb his fondness for alcohol, though. In 1976, he was caught drink-driving and arrested. He continued drinking for another ten years, only giving up alcohol in 1986, just two years before he became a paid campaign advisor on his father's successful presidential bid. During that time he had married Laura Welch, joined the United Methodist Church, run a failed campaign for the House of Representatives from Texas' 19th congressional district against Kent Hance, created Arbusto Energy which became Bush Exploration and fathered two children: twin daughters Barbara and Jenna.

In 1994, two years after being campaign advisor for his father's failed re-election campaign, Bush won governorship of Texas and served two terms. It led to him becoming the Republican presidential nominee for the 2000 elections. This had put him up against Al Gore, vice president of the United States under President Bill Clinton.

The election was mired in controversy as scores of voters said they had accidentally voted for the wrong candidate because the ballot was not entirely clear. A recount was triggered in Florida where Bush's victory of margin was just 537. Disappointed voters had rows over hand recounts and punch card ballots where so-called 'chads' were hanging from the papers and were not registering votes. In the end, Bush was declared the winner even though Gore had won the popular vote by 48.4 per cent to Bush's 47.9 per cent.

When Bush was seeking election, he had promised to overhaul Medicare, Social Security and public education. He wanted to put to bed the Clinton-esque scandals of the last office and he rode a wave of principled policies. Newspapers spoke of his desire to cut taxes and help the poor with health insurance tax credits. He wanted investment in the military too.

In his first term Bush achieved tax cuts, and he made strides in the education sector but on September 11 everything would change. Bush's priorities needed to shift in line with the expectations he laid out on the evening of that day.

Having been fully briefed on the terrorist attacks and their likely motivation, Bush's attention fixed on foreign rather than domestic policy. Analysts believed the United States could become an isolationist country but instead the US went all-out, seeking retribution. "The search is underway for those who were behind these evil acts," he told the nation as Osama Bin Laden quickly became identified as the enemy's leader and targets started to be identified.

Bush had, after all, said that "we will make no distinction between the terrorists who committed these acts and those who harbour them" and so the army and air force were sent to bombard Afghanistan and drive out the ruling Taliban. In 2003, attention switched to Saddam Hussein, the president of Iraq and a man who Bush's father had fought in the Gulf War between 2 August 1990 and 28 February 1991. Hussein

Defining moment

Bush graduates from Yale University 1968

Bush arrives at Yale in 1964, at the same time his father is in the running for the Texas United States Senate election against Democrat Ralph Yarborough. He studies history but it is not known what his grades were, quite possibly because he was not viewed as an exceptional student, rather someone who liked to drink, party and have fun. On one occasion he is arrested for disorderly conduct for taking a Christmas wreath from a shop door but the charges are dropped. On 1 January 1967, a notice in the Houston Chronicle says Bush is engaged to Cathryn Lee Wolfman. The wedding is later called off.

Defining moment

Bush elected governor of Texas 1994

Bush defeats the popular incumbent Ann Richards and governs Texas for five years, having won a second term in 1998 - the first Texas governor to have done so. He proves to be popular, winning 68.6 per cent of the vote the second time around. Bush is improves public schools, cuts taxes and encourages growth in business, but there is condemnation from human rights activists throughout his time in charge. By the time he leaves office, he has presided over 152 executions - more than any other governor in the state's history at that time.

Timeline

1946

- **George W Bush is born**
  Bush is born in New Haven, Connecticut and is the first child of Barbara and George HW Bush. His parents would later give him three younger brothers - Jeb, Neil and Marvin - and two sisters - Dorothy and Robin.
  6 July 1946
- **The Bush family relocate to West Texas**
  Bush's father decides to move the family to West Texas in order to pursue a new career in the oil industry. This is where the young Bush grows up, later attending The Kinkaid School in Houston.
  1948
- **Death of his sister**
  Just a few weeks after the birth of Barbara Bush's second son, Jeb, daughter Pauline Robinson Bush - nicknamed Robin - is diagnosed with leukaemia and dies six months later. The young George is understandably devastated.
  11 October 1953
- **Bush marries Laura Welch in Texas**
  Less than a year after meeting, Bush, who is now 31, marries Laura Welch, aged 33, at the First United Methodist Church in Midland, Texas. They go on to have twin daughters called Barbara and Jenna.
  5 November 1977
- **Bush enters politics**
  Bush runs for the House of Representatives from Texas' 19th congressional district but loses. He decides to pursue a business career in oil and becomes highly successful. He also buys the Texas Rangers.
  1978
- **Bush wins the presidential election**
  After one of the most controversial elections ever, Bush becomes the 43rd president of the United States and he resigns as governor of Texas. He is inaugurated on 20 January 2001.
  2000

"Bush's slow response to Katrina rankled with the American people"

was identified as supporting terrorist groups and he was captured in December 2003.

Key to Bush's efforts to remove Hussein from power and cause change in Iraq was a litany of supposed evidence that Iraq was actively pursuing nuclear weapons. He was claimed to have a stash of chemicals earmarked for warfare and was said to be a threat to world peace. The words 'weapons of mass destruction', or WMD, became widely used but searches in Iraq found nothing at the time of invasion and no caches have ever been discovered since. The whole affair was ultimately highly embarrassing and controversial.

Bush was accused of misleading the American people, an allegation he has strenuously denied. He also risked becoming tarnished by a war that seemingly had no end point in sight. Some sections of the US and the press often held him to ridicule and he was the victim of hoaxes falsely claiming him to have the lowest IQ of any US president over the preceding 50 years. 'Bushisms' became a term given to his frequent verbal slip-ups. "Our enemies are innovative and resourceful, and so are we," he said in August 2004. "They never stop thinking about new ways to harm our country and our people, and neither do we." That year, though, he ran for re-election and won, defeating the Democratic Party's challenger, John Kerry with 50.7 per cent of the popular vote and a margin of 286 to 252 electoral votes.

Certain policies - while controversial around the world - did not seem to affect him. Bush's administration had approved the Guantanamo Bay detention camp in 2002 which held 779 men and boys in harsh conditions. At that time, Bush had the highest approval rating of any president during a mid-term congressional since Dwight D Eisenhower. His second term saw his popularity dip, though. His standing deteriorated in 2005 when Hurricane Katrina struck the Gulf Coast in the summer, killing more than 1,000 people and causing $100 billion of damage.

Bush was on vacation in the 1,600-acre Prairie Chapel Ranch in Crawford, Texas, and he did not immediately cut it short. Bush's slow response to Katrina rankled with the American people as news reports continued to show the extreme devastation. Even when he did end his holiday two days earlier than intended, he did not visit the area straight away. It was widely seen as the event which caused the United States to lose confidence in him. His approval rating dropped to 40 per cent in 2006.

By 2008 it had dropped further, to an astonishing 22 per cent according to one poll. By this time the United States was suffering a financial crisis that was also engulfing the world. The Economic Stimulus Act of 2008 sought to stimulate the economy but the global recession was in full force. Amid growing discontentment, Bush had come to the end of his second term but there was no appetite for four more years of Republican policies. It paved the way for a Democratic Party victory as Barack Obama defeated John McCain to spark a new era in American history.

Defining moment

Terrorists strike the United States 11 September 2001

No timeline of George W Bush could be complete without mention of September 11 since it would go on to define his entire presidency and overshadow everything else he achieved. Bush is informed of the multiple terrorist attacks on US soil while be is reading *The Pet Goat* to children at the Emma E Booker School in Sarasota, Florida. He gives a short press conference at 9.30am that morning before he is moved to a secure location on board Air Force One. He returns to the White House and begins work on a more long-term response.

Bush oversaw the construction of a brand new stadium in Arlington

Bush the sports fan

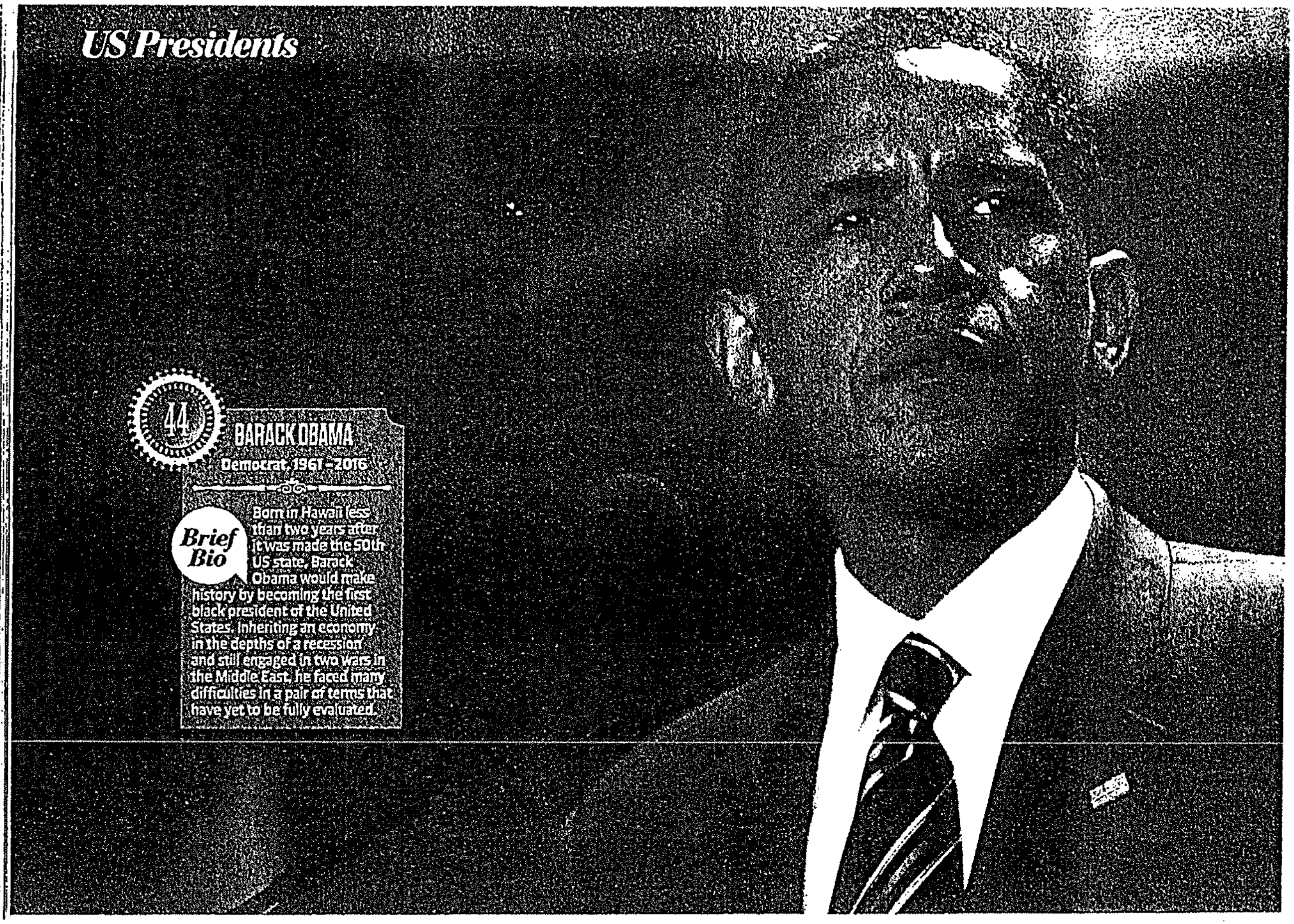
Bush was a keen sportsman and he played rugby union during his high school and Yale years. Having learned in 1988 that the Texas Rangers were being put up for sale, he headed a group the following April which invested $89 million and took a controlling stake in the franchise.

Under Bush's watch - and in conjunction with the city of Arlington - a new stadium was built for the team costing $193 million. It was financed through a half-cent sales tax increase for Arlington residents. The move boosted attendances, pushing them beyond two million for the first time in franchise history.

Bush continued to buy more shares and he eventually took his personal financial investment to $606,302. But attorney Glenn Sodd sued the Rangers on behalf of two families whose property had been seized for stadium parking space. They argued that they had received only a fraction of its value.

The new Ballpark eventually opened in 1994 and achieved average crowds of 40,374 but when Bush was elected governor, he decided to step down as managing general partner. In 1998, the franchise was eventually sold to Tom Hicks for $250 million, a sum which netted Bush a cool $14.9 million. Bush remains a huge fan of the Texas Rangers and he is often seen at the games.

- **Education reform introduced**
  Bush pushed through the No Child Left Behind Act which introduced the standardised testing of children to close the achievement gap between the advantaged and disadvantaged.
  2002
- **A busy year**
  As well as declaring war on Iraq - ensuring that it joined Afghanistan in being part of the War on Terror, Bush brings in laws encouraging business growth, better health systems and he also signs the HIV/AIDS act.
  2003
- **Bush is inaugurated again**
  Having beaten senator John F Kerry in the presidential race of 2004, Bush assumes a second term, but the destruction in New Orleans brought about by Hurricane Katrina severely dents his popularity ratings and leaves him with a public relations mountain to climb.
  2005
- **Sealing the borders**
  The Secure Fence Act of 2006 was signed in a bid to halt the rise of illegal entry, drug trafficking and security threats in the United States. A fence 700 miles long was built on the Mexico-US border to boost security.
  26 October 2006
- **More activity in Iraq**
  Further US troops are committed to Iraq in order to secure Baghdad and the adjascent Al Anbar province. Former Iraq president Saddam Hussein was finally executed by the United States the year before.
  2007
- 2008
  Second term ends
  Bush draws his second term of office to a close and Democrat Barack Obama is elected the 44th president of the United States. Bush publishes his memoirs in 2010 and he becomes a grandparent for the first time in 2013.
  26 October 2008



44

BARACK OBAMA

Democrat, 1961 – 2016

Brief Bio Born in Hawaii less than two years after it was made the 50th US state, Barack Obama would make history by becoming the first black president of the United States. Inheriting an economy in the depths of a recession and still engaged in two wars in the Middle East, he faced many difficulties in a pair of terms that have yet to be fully evaluated.

2009 – 2017

Barack Obama

Barack Obama's inauguration generated unprecedented excitement and clamour. He largely delivered on his promises to restore the country's shattered reputation abroad and resurrect it from the doldrums of the Great Recession

On 20 January 2009, downtown Washington DC was swamped with millions of supporters, generating the largest inauguration crowds since Lyndon Johnson's re-election in 1965. The man they had come to see: President Barack Obama. Elected to the nation's highest office at the tender age of 47, his only political experience consisting of one term in the Senate, Obama was a sensation.

Obama's upbringing was atypical, yet emblematic of the American dream that came to underscore his political story. Born in Honolulu to a mother from Kansas and a father from Kenya, he lived in Indonesia and Hawaii, splitting time between his mother and grandparents. He was unsettled as a teen, and admitted to smoking marijuana and experimenting with cocaine to fit in. He was rigorously home-schooled for much of his childhood by his mother, and he credited this occasionally stern upbringing with instilling in him the values that would allow him to succeed. He gained national attention in 1991 when he was elected the first black president of the Harvard Law Review. He also began writing a book on race relations that would become his bestselling memoir, *Dreams From My Father*. Obama began teaching at the University of Chicago Law School, lecturing on constitutional law, and working as a community organiser. During his political career, he would often return to the measured, patient tones that he honed teaching law.

Later political opponents mocked Obama's days as a community organiser and point to his associations with unsavoury characters that he cultivated, but his work with black churches in Chicago helped bolster his image as a man of the people, rather than an elite and disconnected Ivy League scholar.

During his candidacy for the Illinois Senate, Obama gained notoriety with his bitter opposition to Bush's invasion of Iraq. At the 2004 Democratic National Convention, he electrified his party with the keynote speech, rising from obscurity to a genuine party leader. Despite a fruitful first term as Senator, Obama was a political neophyte, so few expected him to pose a serious challenge to Hillary Clinton in the lead up to the 2008 presidential election. However, Obama's accessible, tech-savvy campaign harnessed an engaged new cadre of young voters and small fundraisers. He was an excellent orator, charismatic, and rode a wave of adulation and excitement to the White House, defeating John McCain in a landslide victory.

The country was in a bad state, suffering from the wounds inflicted by a runaway Wall Street, and dealing with the worst recession since the Great Depression. Obama embraced a radical spending plan, rejecting the austerity that many European nations opted for. His stimulus plan was his most lasting and resounding success, as the country recovered quickly from the recession and unemployment decreased steadily over his two terms.

When Obama was inaugurated, the US was also embroiled in two unpopular wars in Iraq and Afghanistan. He had promised to end both wars, and when he was re-elected in 2012, he campaigned on his successes in the Middle East, having ostensibly ended the Iraq War in 2011. However, as tensions boiled over in Syria and Iraq, Obama sent troops back in – and he never did withdraw troops from Afghanistan altogether.

His presidency was characterised throughout by battles with a stubborn Congress – the Democrats had a majority in both Houses in his first term, but that didn't last. He failed to follow through on his campaign pledge to close the notorious Guantanamo Bay detention facility when Congress refused to cooperate, but supporters will wonder if he could have done more. His lingering achievement was his Affordable Care Act, dubbed ObamaCare, which, although neutered somewhat in Congress, was a genuine and lasting effort to make basic healthcare available to all Americans. His efforts at working with Republicans on landmark legislation foundered, and he repeatedly faced the threat of government shutdowns from an increasingly fractious Republican House critical of his excessive spending. In the wake of the Sandy Hook school shooting, Obama reiterated his desire to pass gun-control legislation, but was again thwarted.

Obama will be remembered for his deep commitment to progressive ideals. He repealed the 'Don't ask, don't tell' policy, allowing openly gay men and women to serve in the military. And in 2015, a Supreme Court featuring two of his appointed justices made same-sex marriage federally legal. He considered himself an arbitrator of racial disputes, and often intervened in police matters (notably issuing statements on the killings of Michael Brown and Trayvon Martin), yet towards the end of his second term it became clear that racial tensions in the US were worse than ever before.

Obama's two terms featured notable foreign policy successes, the highlights being the rapprochement with Cuba, the killing of Osama Bin Laden, and the successful negotiations with Iran over its nuclear program. However, those were overshadowed by his failure to deal with ISIS, his sluggish action in Syria, an inability to control the security environment in Iraq, a bombing campaign in Libya that left it a failed state, frosty relations with Israel, the debacle in Benghazi, backtracking on a warning to Bashar al-Assad over chemical weapons use, and repeated humiliation at the hands of Vladimir Putin and Russia. Critics will find similarities in the foreign policy of Obama and his predecessor, as he continued Bush's extra-judicial drone strikes in dozens of countries, and stepped up a mass surveillance plan through the National Security Agency. Obama swept in on a platform of hope, and to his credit delivered on many domestic items, salvaged the economy, and did much to restore the United States' reputation abroad, yet he failed to realise many of his promises and was widely seen as indecisive when it mattered most.

Obama worked in Baskin Robbins as a teenager and as a result can't stand ice cream

The Affordable Care Act

Obama's most lasting achievement was healthcare reform, which he pushed through in 2010 with the Patient Protection and Affordable Care Acts. Despite serious opposition from the right-wing Tea Party movement and virtually every Republican in Congress, the act carried and was reaffirmed by the Supreme Court in 2012. Despite a slow roll-out of government-sponsored healthcare plans, and subsequent opposition by state governors, the Act has made affordable healthcare available to working-class Americans, and granted the consumer protection from predatory insurance company practices.

Obama won a Grammy in 2006 for the audiobook reading of his memoir

Life in the time of Barack Obama

The Great Recession

A sub-prime mortgage crisis, a shady default swaps market, and the bundling of exotic financial instruments combined with deregulation of Wall Street in the 1990s and 2000s led to a total collapse of the financial system and the housing market in 2007. Obama creditably resurrected the car industry, regulated the banks, and restored the economy over his two terms.

The Iraq War 'ends'

In early 2009, Obama announced that he would end the Iraq War within 18 months. The US public was upset with the fraudulent entry into the war and the subsequent failure of nation-building. Obama kept his word. However, when the Islamic State shrugged off the American-trained and American-supported Iraqi army, captured Mosul and carried out ethnic cleansing campaigns in 2014, thousands of US troops re-entered Iraq.

Osama meets his watery grave

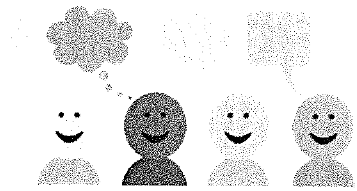
In May 2011, CIA intelligence revealed that Osama Bin Laden was living in Abbottabad, Pakistan. Obama rejected a plan to bomb the compound, opting instead for a raid by Navy Seals. The raid was successful, and Bin Laden was shot and buried at sea. Though he was no longer actively involved in Al-Qaeda, the raid was considered a strategic and moral victory for the US and bolstered Obama's popularity.

Spying among friends

When Edward Snowden revealed the NSA's overreach in collecting data, the US faced a stern backlash abroad. German Chancellor Angela Merkel was particularly enraged that US intelligence was listening to her mobile phone calls. The NSA agreed to stop the overeager collection of data but Obama's popularity dipped.

A thin red line

When Syrian dictator Bashar al-Assad used sarin gas, a chemical weapon outlawed by the Geneva Convention, to murder thousands of innocent civilians in Damascus, Obama faced a conundrum. He had called the use of such weapons a red line not to be crossed, at the threat of immediate military reprisal. Yet Obama backed down from his threat and Putin mediated the situation instead, humiliating him.



A note from your child's speech therapist

Hello!

Here are some ways to encourage your student's communication while school is experiencing a prolonged spring break.

Best regards to your family,

Ms. Nancy

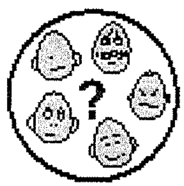
- When watching television shows and movies, encourage conversations about the words and actions of the characters (ex., "How are the other characters feeling?" "What social rule is being broken/followed?" "What size thoughts are the other characters having?") (See Size-of-Thoughts visual attached)
- Friendly conversations are a good way to practice social skills. Encourage your student to ask you questions about your thoughts on a topic. Take turns selecting topics so your student can continue to practice engaging on topics not of their choosing.

SMALL thoughts/feelings

Most of the time. we have very small thoughts about each other.

We barely notice people if they are doing behaviors that are expected across different situations.

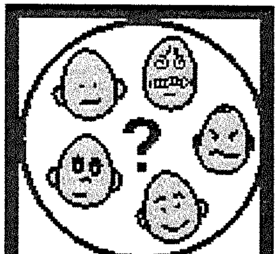
MEDIUM thoughts/feelings



When people's behavior attracts our attention. it is often because they are doing something that is unusual for the situation.

They can do something that is really good or they can do something that is really unexpected in a negative way for the situation.

LARGE thoughts/feelings



When people do something that is very unexpected, we have strong uncomfortable thoughts and strong negative emotions about that person.