SCIENCE AND SOCIETY IN THE TWENTIETH CENTURY

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For Brynne and Cameron
— W.S.

For Wendi and Darci
— T.K.

Contents

Preface

When we designed this book, we were thinking of our students. We teach teachers, both those who are in training and those who are in schools. Having taught a course on integrating science and social studies topics in the middle grades level (grades 4–9 in Ohio), we noticed that some of our students were initially resistant to the idea that the two school subjects could be integrated. These students seemed to feel that scientific discoveries or technological advancements occur independently of society's influence, or that historic events could have no scientific phenomena associated with them.

We wanted our students to think differently. National education standards in both science (National Research Council, 1996) and social studies (National Council for the Social Studies, 1994) require as much. The pursuit of scientific understanding and technological innovation is a human endeavor tied to the society in which it takes place. It is important that science and social studies teachers understand this and help their students realize this.

This book addresses the link between science and social studies in a practical way, primarily for the benefit of middle and secondary level teachers and students. Many of the entries link topics that routinely occur in biology, chemistry, physics, earth science, and history curricula. In working with our students, we noticed that even the majority who recognized the connectedness of science and society were often at a loss as to how to combine topics from very different courses of study. We hope this book can serve as a reference for opening up possibilities for such combinations.

Throughout the book, we have tried to be creative in linking societal events to scientific topics. We know that middle and high school students are often interested in topics which are related by a thematic context. It seems perfectly reasonable and natural to us that a science teacher who is introducing the properties of sound may want to present the history of rock-and-roll to spark students' interest and attention. Conversely, a social studies teacher who is describing the Spanish flu pandemic may want to use the occasion to reinforce students' understanding of the science of emerging disease. We have tried to combine realism with creativity in order to link topics that have natural connections and will be useful background material for teachers of various school subjects (occasionally we mention topics which can be found in courses on art, music, mathematics, or literature as well).

This book covers a century of human history in a limited number of pages. To enhance the usefulness of this work as a reference for teachers, we chose to focus on delivering breadth of topics rather than depth of coverage. Each entry provides suggestions on where to look for more information, since our discussion can be only a brief introduction to an event and related concepts.

The entries in this book represent a collection of hors d'oeuvres, so to speak. They are meant to whet the appetite, to spark creative thinking and perhaps cross-disciplinary collaboration among teachers who may normally reside on opposite ends of the hallway. We hope to succeed in making our students—and our students' students—hungry for more.

Wendy and Trish

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Introduction

Science and technology shaped life in the United States during the twentieth century in far-reaching and unprecedented ways. Battles against human disease were fought and won. The widespread availability of automobiles and the advent of airplanes helped ensure that the nation and the world would be accessible in ways previous generations could only imagine. The electronic age has allowed machines to work for people in amazingly diverse applications. Engineers and architects once designed buildings that reached for the heavens; now, space stations exist there. Throughout the century, the practices of science, which constitute a systematic way of understanding the natural environment, continued to inform the development of technologies designed to modify that environment.

At the same time, science is a human endeavor always influenced by society. Where society takes interest in the natural world, scientists find their work supported. New technologies often reflect the needs or desires of industry, or agriculture, or the military, or even artists and entertainers. Societal values, economic realities, demographic situations, and other human factors help determine whether a technology makes a lasting impact upon the world or fizzles into oblivion.

Despite this powerful connection, many Americans remain uninformed about basic scientific concepts and principles, and about the way this knowledge of the world is used during daily life. One reason for this may be that science and social studies are presented in schools and in our culture at large as distinct subjects, unrelated to one another. In contrast, this book is an attempt to link various historical events of the twentieth century to scientific ideas related to them. For example, what causes the emergence of diseases such as the deadly influenza pandemic of 1918–1919, or of polio? How do computers communicate through the use of on–off electrical signals? How does the Hoover Dam produce electricity? Is interstellar travel, as seen on the TV series *Star Trek*, really possible? *Science and Society in the Twenti-*

eth Century addresses questions such as these, in addition to outlining the impact that these events had on society during the twentieth century.

This book could serve as a resource for social studies or science teachers who would like to place more emphasis on the science–society connection in classroom lessons. It will also prove interesting to anyone who desires to become scientifically literate about familiar societal practices. The chapters of this book are organized by decades of the twentieth century. Within each decade, entries are listed under the subheadings Architecture & Engineering; Arts & Entertainment; Communication; Defense & Diplomacy; Environment; Food & Agriculture; Medicine & Health; and Transportation. In addition, each chapter begins with a brief overview of the societal context for the decade being discussed, and ends with a discussion of advancements in human knowledge: scholarly ideas and concepts that were introduced in the natural and social sciences during the decade. It is possible to use the book for information about a specific event, or about a collection of events that appeared at one period during the twentieth century; or to follow developments in a particular area of human social life (such as Arts & Entertainment or Transportation) throughout the entire century.

Each entry in this work gives a brief description of a historic event, and discusses scientific concepts and principles related to the event. The events are primarily those which impacted the United States during the twentieth century. Entries are generally placed in the era during which they occurred, but occasionally entries that describe inventions are located within a decade in which they had a greater impact. Scientific discoveries and technological innovations are necessarily cumulative endeavors and are linked to prior work in a way that cannot be fully acknowledged in a reference work of this type. Still, whenever possible, attention is given to the historical development and future ramifications of an event which transcends the boundary created by placing it in a certain decade.

Finally, although science and society are interrelated, it is important to recognize that in general, scientific inquiry alone is not suited to answering questions that arise about societal values. In other words, the findings of scientists tell us *how* the world works, but cannot answer the question of *what should be done* with that knowledge. Are medical tests on animals justifiable? Do the benefits of harnessing nuclear power outweigh the risks? What responsibility does the United States have for the impact of its nuclear weapons testing programs in the South Pacific? Science cannot provide the answers, but it is imperative that decision makers be accurately informed about the scientific knowledge that underlies questions such as these. It could be said that acquiring scientific literacy is one of the most important duties of a democratic participant in modern America. Knowing the limits of science as well as its accomplishments provides us with the ultimate perspective on the interplay between science and society.

Chapter 1

THE DAWN OF A NEW CENTURY

SOCIETAL CONTEXT: UNREST AT THE TURN OF THE CENTURY

The first decade of the twentieth century was ushered in by significant turmoil, as unrest was felt around the world. On September 6, 1901, U.S. President William McKinley was fatally shot and his assertive, young vice president, Theodore Roosevelt, was sworn into office. Russians were engaged in a revolution, conflict between Dutch settlers and the British raged in South Africa, China's most ancient monarchy was toppled, the Young Turks revolted against the Ottoman Empire, and uprisings ensued in the Adriatic and Balkan provinces. Even nature added to the turbulence of the time when the San Francisco earthquake hit in 1906, reaching 8.3 on the Richter scale and causing fires that burned for three days. Twenty-eight wooden buildings were toppled, and over half of San Francisco's 400,000 residents were left homeless.

Society in the United States at the turn of the twentieth century looked very different than it does today. In 1900, 42 percent of workers in the United States were farmers; by 1990, farmers made up only 3 percent of the workforce. At the dawn of the twentieth century, industrial workers logged an average of 52 hours per week, compared with an average workweek of just less than 39 hours by the end of the century. The makeup of the population changed dramatically during the twentieth century, and particularly in the first decade, when immigration was at its highest levels. The peak was reached in 1907, when more than 1.2 million people, mostly of southern and eastern European descent, arrived—meeting poor living conditions and resentment by immigrants of earlier decades.

The industrial revolution and the advent of giant corporations also changed the nature of American society in the twentieth century. Business barons such as John D. Rockefeller, J. P. Morgan, and Andrew Carnegie formed trusts to manage and con-

Figure 1.1. Immigrants arriving at Ellis Island, 1907. Courtesy of Library of Congress.

trol the manufacturing of and markets for steel, cars, railroads, oil, and coal on a grand economic scale. As these corporations assumed more prominent roles in the economy, reformers argued for checks and balances on the power of business. President Theodore Roosevelt aligned with the Progressive political movement in promoting the radical view that the federal government had a right to interfere with business in order to guard the public interest, and proceeded to take on the railroad trusts in 1902. Throughout the first decade of the twentieth century, the federal government ruled on over forty other cases, using the Sherman Antitrust Law of 1890 to break up monopolies and reinstate competition among businesses.

But government officials weren't fighting the battle alone. During this time period, the corruption of lofty trusts, as well as other social injustices, became a target for investigative journalists, or "muckrakers." Ida Tarbell, Lincoln Steffens, and Ray Stannard Baker changed the nature of journalism and sought to awaken the ire of middle-class Americans. Upton Sinclair's novel *The Jungle* portrayed life—and death—in a turn-of-the-century American meatpacking factory. This grim indictment detailed the unhealthy practices of the meat industry and prompted Congress to pass the Pure Food and Drug Act on June 30, 1906, only six months after the novel was published.

Throughout the twentieth century, art forms were used to disturb, to question, to provoke, and to transgress societal standards. The arts became a forum for revolt, and in a quest to break through conventional values, twentieth-century artists found an ally in science. Technology introduced art forms such as gramophone recordings, the Brownie camera, and the premier art form of the century, the cinema. At the turn of the century, technology also afforded advancements in flight, cars for the working class, the birth of radio transmission, and the creation of plastics. Conversely, innovations from the second decade of the 1900s fostered the expansion of unrest as World War I delivered mass destruction and chemical warfare.

ARCHITECTURE & ENGINEERING

Air-conditioning Improves Our Lives

Although we think of air conditioners as devices that cool the air for us, the basic ideas behind the system we use today were initially developed to control humidity in the indoor environment. Willis Haviland Carrier, an engineering graduate of Cornell University, designed and built this first system in 1902 for a printing company. In the company's production rooms, variations in the air's moisture content caused paper to stretch or shrink, resulting in poor quality printings. Printing designs on the paper required four successive layers of colored ink to be applied, and when the size of the paper changed, the designs were misaligned, thus spoiling the patterns. Carrier's air-conditioning system secured a given humidity level that made the printing process error-free, and Carrier received a patent for the "apparatus for treating air" (U.S. Pat# 808897) in 1906.

After the success of the printing company system, Carrier installed air conditioners in southern U.S. textile mills. Without proper moisture in the air, excess static electricity would cause cotton fibers to become fuzzy and hard to weave. Silk mills in Japan requested a system to control static by regulating the temperature and humidity in the plant. The air conditioner was able to answer all of these needs.

It wasn't long before people realized that Carrier's system for controlling the humidity of an indoor environment allowed for temperature control as well. Soon after the first installation in 1902, large department stores such as J.L. Hudson in Detroit, and cinemas like the Rivoli in New York City, recognized that this creature comfort could significantly increase business, so they installed and heavily advertised their new amenity. Other businesses and churches followed the trend. Trains, cars, and buses made use of the invention to add to the comfort of travelers on long journeys. Home air-conditioning units hit the market by 1928, when Carrier introduced the "Weathermaker" model for residences. Although the Great Depression and World War II slowed sales considerably, by the end of the twentieth century, about two-thirds of homes in the United States possessed some version of Carrier's invention.

How do air conditioners work? Air conditioners work according to the same scientific principles as the refrigerator, which depend on the relationships between heat, molecular motion, and phases of matter. The compressor squeezes a cool gas. When gas molecules move closer together, they bump into each other, increasing the temperature of the gas. This hot gas flows through a length of coils so that the heat can be released, and the gas can condense into a liquid as it cools. The heat is released to the outside of the building. The liquid runs through an expansion valve, allowing it to evaporate into a cold, low-pressure gas again. This cold gas runs through a set of coils that allow the gas to absorb heat from air inside a building, therefore cooling the room. Fans are used to pass warm, moist room air over the cool coils. This cools the room's air.

Cool air holds less moisture, so as the room air passes over the cool coils, moisture from the air condenses onto the outside of the coils and drips through a channel to flow outside of the building. This reduces the humidity in the room. Similarly, excess humidity from a car's air conditioner often forms a puddle on a garage floor. The heating and cooling of the gas cycles constantly as a room is air-conditioned. Ammonia gas is no longer used inside the coils. It was replaced by what was thought to be a safer gas, Freon.

There are two sides to every coin. Anyone who has been in an air-conditioned room during hot humid days would not want to give it up; the comfort is refreshing. Productivity rates in offices, factories, schools, and businesses are estimated to improve by 40 percent as a result of air-conditioning. The fabric, meat, and produce industries rely on air-conditioning to control the quality of their products. Museums depend upon air-conditioning to preserve rare books and precious works of art affected by fluctuations in temperature and humidity. Computers, too, are sensitive to hot environmental conditions.

The impact of air conditioners isn't a total success story, however. In the 1980s scientists discovered that gases used in refrigeration systems such as Freon, a chlorofluorocarbon (CFC), are harmful to the ozone layer. CFCs are broken apart by ultraviolet (UV) radiation in the stratosphere to form chlorine atoms. These atoms then react with ozone in a chain reaction to produce oxygen. This chain reaction can convert as many as 10,000 ozone molecules into oxygen. The reaction itself is not harmful, but it depletes the ozone layer, which blocks UV radiation from the earth's surface. Too much UV radiation increases the possibility of skin cancer, cataracts, and immune system disorders. Many governments have agreed to closely regulate the use of CFCs, and scientists have recently found chlorine-free gas substitutes for cooling units.

The invention of air-conditioning also changed the American landscape. In the past, home architectural styles were specific to regions of the country, in large part because of climate. Southern homes with high ceilings or adobe homes in the Southwest were designed to provide families with maximum comfort in hot months. With the advent of air-conditioning, home builders had many more options. While some people have enjoyed the opportunity to experiment with architectural styles, other social commentators have lamented a loss of characteristic regional flavor that has come with the widespread availability of air-conditioning. From printing production rooms to our family homes, the air conditioner changed American life in the twentieth century.

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Steel and Construction of the Skyscraper

Location, location, location. As communities expanded and prime locations became limited, architects often began to consider building upward as a reasonable option. High-rise buildings have defined our skylines since the pyramids were painstakingly constructed thousands of years ago. Religions have inspired architects to reach for the heavens. Cathedrals, castles, and towers on just about every continent are cherished for their beauty, and societies through the ages have marveled at the ingenuity it took to build them.

Until the late 1800s, the height of a building was limited mainly by building materials, creativity, and particularly gravity. Most structures were limited to eight to ten stories. When technology presented new options for building, metropolitan areas such as Chicago, New York City, and Cleveland rallied for innovative structures that provided more office and living space while using a relatively small amount of land.

How are gravity and steel related? Gravity was the main barrier to building taller structures. Gravity is the attraction of the earth for a given object, the downward pull toward the earth. This downward pull puts ever-increasing stress on the foundation as each floor is added to the height of a building. The principle also applies to the way in which acrobats build a human pyramid. One person can hold another up, but if a third person climbs on top of the second, the bottom person will most likely be unable to support the other two. However, if there are more people at the bottom over whom to distribute the weight of those on top, the human pyramid is feasible.

The masonry arch distributed weight and was used quite often in older architectural designs, but it had its weight limits. The only apparent answer to building taller structures was to increase the thickness of the foundation, but that decreased the usable space on the lower levels. To reach upward, something new was needed. Eventually, architects discovered new ways of building upward, in spite of gravity, when new, stronger building materials emerged.

In the early 1900s steel replaced cast iron and masonry block as a common construction material. Using steel expanded the architectural limitations of modern

Figure 1.2.
Blast furnace in a steel mill, Massillon, Ohio, ca. 1920. Courtesy of Library of Congress.

buildings. Like clay, cast iron would shatter under stress, but steel was more pliable, malleable (easily shaped), and lighter than cast iron. Additionally, steel was a much stronger building material than stone, cast iron, or timber. Long beams of relatively lightweight steel were anchored with rivets to form grids. This grid formation became the skeleton of the building, and materials such as masonry and glass formed the skin.

Inexpensive, high-quality steel was made possible through the work of the Englishman Henry Bessemer. He discovered that when iron ore is heated in a furnace with coke (carbon) and limestone, the iron oxide is reduced (oxygen is removed) and molten iron metal is produced. Combining this with small amounts of coke forms pig iron, or cast iron. If all of the carbon and impurities are removed and a specific amount of carbon is reinserted (or a specified amount of carbon is left in when removing the impurities), steel is produced. The amount of carbon left in the end product determines the quality of the steel. Bessemer invented the furnace that could force steam or a blast of air through the molten pig iron to cleanse it from impurities and excess carbon producing high-quality, inexpensive steel.

What has steel construction contributed to society? The numerous skyscrapers and homes like the one Frank Lloyd Wright built in Chicago for Frederick Robie in 1909 epitomized the architectural revolution engendered by steel. A proliferation of bridges, railways, cars, and skyscrapers cover our countryside and cities due to the abundance and attributes of steel. The U.S. economy grew as a result of increased commerce afforded by steel. Steel increased travel for vacations and family visits as people drove steel cars over steel bridges instead of around bodies of water. Refrigerators and washing machines were made of steel frames, and steel tanks and trucks would play a major part in the upcoming war.

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ARTS & ENTERTAINMENT

Caruso's Gramophone Recording

At the turn of the century, Enrico Caruso, a famous Italian tenor, was encouraged by Fred Gaisberg to record his vocal talent. Gaisberg reasoned with Caruso that by selling the recordings before his London and New York debuts, Caruso would entice a potential audience with his talents in advance of the actual performance. Caruso's trust in Gaisberg paid off with a large volume of gramophone disk sales and instant acceptance from the audience. His 1902 disk recording became the first high-quality, successful disk made. Gaisberg was a master at recognizing genius, and his business sense and technical knowledge helped him generate positive reputations for promising international musical talents.

Gramophones are more commonly known today as phonographs or record players, and disks are called records. Early, acoustically recorded sounds had serious technical limitations, since the range of frequencies could reach only from 164 to 2,088 vibrations per second. This prohibited the use of certain musical instruments, especially string instruments that had musical sound ranges from about 6,000 to 8,000 vibrations per second. Electrically recorded disks, which greatly improved on this range, were not available until 1925.

How are recordings made? The earliest recordings were made using purely mechanical parts. Caruso's recording worked this way. The system produced sound waves by directly connecting a needle to a diaphragm that freely vibrated, just the way the throat does when a person is speaking. The vibrating needle scratched grooves onto a tin foil cylinder. The depth of the groove corresponded to the loudness of the sound, and the roughness of the groove depended on the pitch or frequency of the sound that produced it.

Copies of the original recordings were then made, using a wax cylinder and electrolysis to form a "negative" copper copy. Using heat and pressure, copies could be molded from the copper record, using celluloid and a hard wax top on the cylinders. Later, flat disks and records with thin shellac laminated surfaces replaced these cylinders.

In 1925 the first electrically recorded disk was produced for sale. The signals or grooves read by the needle were amplified electronically, and a speakerlike device drove the needle. The electrical version read the wiggles of the grooves horizontally rather than vertically (as the mechanical version had done). This produced better sound even if the grooves were filled with dust, and soon the demand for this invention surpassed that for Thomas Edison's mechanical recording device. Within a few decades, magnetic tape, digital recordings, videotapes, and compact discs using laser technology would replace the records of Caruso's day. Each new invention brought with it better quality, longer playing time, and longer life for the disk.

The societal impact of recording devices. Throughout the twentieth century, recordings would impact our history, politics, education, and family life as well as the entertainment industry. Hearing speeches from the late President Kennedy inspires many of us to "ask not what our country can do for us but what we can do for our country." The Watergate tapes changed the history of the United States as we watched President Nixon resign, having been forced to acknowledge recordings of conversations he had about illicit activities. Songs, speeches, and stories captured on tapes and CDs bring pleasure to daily life in modern society. Listening to a book on tape during a long drive passes the time quickly, or helps a visually impaired student review information for an assignment. Relaxing to a favorite song gives us a healthier outlook, even if only for a short period of time. Audio recordings guarantee we don't miss a telemarketer's message. Digital recordings are used worldwide to store financial information for banks and the IRS as well as for all computer users. Clearly, recording devices have colored the way we lived in the twentieth century.

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COMMUNICATION

First Radio Transmission Across the Atlantic

Who perfected radio transmission? At the age of twenty-one, the Italian inventor Guglielmo Marconi was already immersed in conducting experiments and refining equipment to study the transmission of electrical signals through air. In 1894 he transmitted and received signals across his room, and by December 12, 1901, he had substantially increased the distance between the transmitter and the receiver. He heard the Morse code letter *s* at a receiving station at St. John's, Newfoundland, that had been sent 1,800 miles across the Atlantic from a station he built at Poldhu, on the southwest tip of England.

Marconi's commitment to careful data collection and endless trials and revisions led to the development of wireless telegraphy, or radio. His tuning equipment guaranteed simultaneous communications between several stations without interference. He continued to perfect the transmission of radio waves, and received the Nobel Prize for physics in 1909.

The accomplishment of transatlantic communication. Heinrich Hertz had discovered radio waves in 1887, working with periodic (regularly repeating) electrical currents at very high frequencies. This demonstrated the existence of electromagnetic waves and furthered scientists' understanding of the connection between light and electromagnetic action. But it was Marconi who produced the equipment that proved electromagnetic waves could travel long distances through air and still preserve their precise characteristics.

Most scientists at the time believed that electromagnetic waves could be transmitted only in a straight line with no obstacles to deflect them. It was thought that over large distances the curvature of the earth would interfere with the transmission. Marconi's transatlantic experiment proved differently. Marconi discovered that by connecting an antenna to the oscillator and grounding it, he could increase the power, and therefore the distance, of his transmission. He also discovered that solar radiation had harmful effects on the transmission.

How does a radio work? Electromagnetic waves travel at the speed of light and can pass through air as well as walls and mountains. Some waves are absorbed, but enough pass through to complete the transmission. The waves travel in all directions from the place they begin, similar to waves from a pebble thrown in water or the light from a candle shining in all directions. The vibration or oscillation of alternating electric current produces the waves. The alternating current sets up a cycle as the direction changes at a given rate or cycle.

Radio waves vibrate at a frequency of about 550,000 to 1.5 million cycles per second. A frequency of 1 million cycles per second would make the wavelength—the size of a wave measured across one "peak" and one "valley"—about 300 meters. A desired wavelength can be achieved by manipulating the frequency of transmitted radio waves. These waves serve as carrier waves. Although a radio antenna receives radio waves of all frequencies, a listener will hear only the radio frequency that matches the single point tuned on the radio dial.

In order to send voice or music, the sound waves from the broadcasting studio are changed into an electrical pattern. A modulator shapes this pattern so that it will fit onto the carrier waves as a coded message. In amplitude modulation (AM), the amplitude or height of the carrier wave is changed to match the pattern of the sound. In frequency modulation (FM) the frequency is changed to carry the sound pattern, but the amplitude remains the same. To keep radio stations from interfering with each other, each station transmits only one carrier wave at its assigned frequency.

In moving from place to place, AM waves reflect off the ionosphere, a region of the atmosphere lying about 80–600 km above the surface of the earth. This ionized section of the earth's atmosphere acts like a mirror and reflects the carrier waves back to Earth. Therefore the reflected signals can be "bounced" around, and received at very long distances from the station. On the other hand, FM radio uses a very high frequency wave that goes right through the ionosphere and is not reflected. As a result, FM signals can be received only if the transmitter and receiver are in a straight line and not blocked by the earth. This is why an AM radio station often cuts out under a bridge and an FM station does not. Marconi probably unknowingly had the help of the ionosphere in 1901.

Impact of the radio. The impact of radio is far-reaching and includes effects on entertainment, family, politics, business, and education as well as health and safety. Until World War I, radio enthusiasts used airwaves to communicate with each other, with little concern from outsiders. With the realization that radio communications could help the war efforts on the ground, in the air, and at sea, most radio stations were refocused toward military use. It also became obvious that newspaper coverage and personal appearances were not the only ways to convey a political point of view, and politicians began to use radio as a major campaign tool. The medium was efficient, since more people could be reached in a smaller amount of time.

Businesses also realized the marketing and advertising value of radio. With this in mind, commercial firms such as RCA, GE, and Westinghouse lobbied heavily for restrictions on privately owned radio stations. These regulations dramatically changed

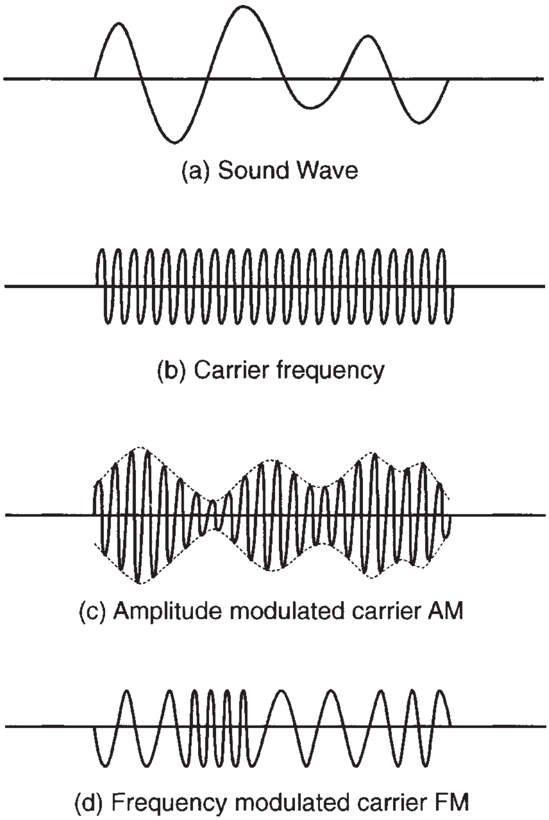

Figure 1.3.
Sound patterns modulated by amplitude or frequency on a carrier wave.

the vision Marconi and others had of radio as an open forum for public interests rather than private entrepreneurship.

Entertainment flourished on the radio, with opera, comedy, and dramas being broadcast regularly. Family gatherings often centered on listening to the next segment of their favorite broadcast. Concern was raised about the lack of interpersonal communications as radio absorbed more family time. And as with other technologies such as TV, radio was often used to occupy children while adults attended to chores or entertained friends.

Informing and educating people is extremely important in a democratic society. News was more quickly obtained by radio than by reading the newspapers the next day, and for the illiterate, public radio was essential. The Coast Guard, police, and firefighters regularly used radios to bring people to safety, as did amateur radio operators during floods, earthquakes, and hurricanes when the phone lines were down. Today we still capitalize on the multiple uses of radio, and it has developed further into technologies involving radar, television, and cell phones, to name just a few modern applications.

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DEFENSE & DIPLOMACY

Second International Peace Conference of 1907 (Second Hague Conference)

In 1907 the Russian government called for a second assembly of several nations to achieve a reduction in armament. The first peace conference also had met in The Hague, Netherlands, in 1899. Neither conference achieved the goal of limiting arms, but several laws of war were endorsed and later ratified by the participants. The first conference established the Permanent Court of Arbitration, which helped to promote understanding across cultures. It was more successful with laws protecting noncombatants and rights of neutral shipping than with laws restricting armament use. At the second Hague Conference the United States proposed the establishment of a world court, but efforts were blocked. The second conference was also ineffective in curbing the use of aerial bombardment, submarine mines, and poison gas even though fifty-six articles were ratified. These methods of mass destruction unfortunately were all too prevalent during World War I.

Science, technology, and war. In part, the Second Hague Conference was about the ethics of using technology in warfare. Although science and technology are complex human undertakings, in general we can characterize the difference between them in terms of their purposes. Science, defined simply, is a systematic way of studying the natural world that is used to derive general laws and principles about the patterned, orderly behavior of the components of that world. Technology, on the other hand, can be described as an effort to make use of the behavior of the natural world to serve some human purpose. So, for example, a new technology could be designed to heat or cool a room for human comfort. In general, technologies are based on scientific knowledge; in the example of heating or cooling, the invention would make use of the scientific laws of thermodynamics.

The twentieth century saw amazing advances in our scientific understanding of the natural world and our ability to manipulate that world. Yet, as early as the turn of the century, before the majority of these advances had been conceived, some people were asking what limits should be placed on our desire to control the world around us. The potential and actual use of scientific knowledge and technological design for purposes of war loomed large over the leaders of this century. The Hague conferences represent an early attempt to come to terms with one set of ethical questions surrounding our desire to control our world. The efforts of conference delegates speak to a concern for the preservation of humanity, in light of the advancing technologies that could more and more easily devastate and exterminate. The moral questions raised by the use of science and technology to alter the environment by acts of aggression and domination remain with us today.

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ENVIRONMENT

Oil Exploration

Forms of petroleum (oil) have been used for thousands of years. Just as we use asphalt for roofs and roadways, the ancient Babylonians paved their streets with pitch. Egyptians coated mummies with pitch, and Noah built his Ark using a solid form of pitch. The Chinese used petroleum as a fuel as early as 200 BC. The frontiersman Kit Carson sold axle grease for covered wagons. However, it was not until the mid-1800s, when Abraham Gesner, a Canadian geologist, discovered kerosene for burning in lamps that the value of oil rapidly increased.

At the turn of the century, electric lights were phasing out the use of kerosene. Nevertheless, the search for oil fields continued. In 1901, Spindletop, the largest gusher in North America, was discovered in Beaumont, Texas. The 200-foot-high fountain spilled over 100,000 barrels of oil before it was capped. As it happened, technology had a use for all of this surplus oil—the Model T Ford. Prior to the automobile industry, gasoline was considered a useless by-product of kerosene and was often dumped into waterways; later, the demand for kerosene plummeted as an enormous thirst for gasoline commenced in the early 1900s. Petroleum products were also in demand as heating oil, and as fuel to power ships and railways.

What is petroleum? The word "petroleum" is derived from the Latin words for rock (*petra*) and oil (*oleum*.) Although its origin is not completely understood, most geologists believe that the basic form of petroleum, crude oil, comes from decayed marine life buried in sediments millions of years ago. Bacterial action helped the decay process. Heat and pressure increased as the sediments were buried deeper and deeper and this process repeated itself, forming sedimentary rock. The weight of the upper layers of rock squeezed the petroleum into cracks and pockets in the rocks. This organic theory is substantiated by the presence in crude oil of certain carbon substances that are found only in living or dead organisms. In addition, this process produces natural gas, which is often found coexisting in oil fields.

Crude oil is a dark, slippery mixture consisting of volatile and involatile organic compounds. The volatile compounds are responsible for crude oil's strong, distinctive odor. The complex molecular structure of crude oil consists mainly of hydrocarbons: compounds of carbon and hydrogen derived from organic (once-living) material. Carbon is a unique element in that it can bond with itself, making long chains. Crude oil is a mixture of hydrocarbons that have anywhere from five to more than twenty-five carbons linked together. The smaller the number of carbons, the lower the boiling point and the more likely the hydrocarbon is to be a gas such as methane. The higher the number of carbon bonds, the higher the boiling point and the more likely it is to be a solid form such as grease or pitch. Most hydrocarbons are in liquid form such as fuel oil, gasoline, and kerosene with six to ten carbon-to-carbon bonds. Crude oil seldom can be used directly as it comes from the ground. It must be refined into separate products.

How is the mixture of hydrocarbons separated? Fractional distillation, the process of separating a mixture of liquids having different boiling points, is the initial process used to refine crude oil. The crude oil is heated under pressure to keep the oil from becoming a vapor. The oil flows into a fractionating tower where the pressure is reduced, allowing the liquid oil to become a vapor. The vapors separate onto shelves where they condense as individual compounds. This separation occurs because vapors with the lowest boiling point rise the highest in the tower. The higher the boiling point, the lower it rises in the tower and, in this case, condenses on a lower shelf. For a better separation the process is repeated. The different hydrocarbons separate out in the following order, from lightest to most dense: gasoline, kerosene, fuel oil, lubricating oil, and asphalt. As stated above, the more carbon atoms a compound contains, the higher the temperature needed for it to boil. Gasoline has six to ten carbon atoms, whereas asphalt contains twenty-six to sixty carbon atoms.

The many uses of petroleum. Because of its complicated molecular structure, petroleum has a greater variety of uses than most other substances. Petroleum fuels such as gasoline, diesel, and jet fuel or kerosene ignite and burn easily. Relative to their weight they produce a great amount of heat and power, and are much easier to store and transport than fuels such as coal or wood. Petroleum fuels used for heating homes and businesses are light oils. Heavier, residual oils provide energy for larger factories and electric utility companies.

Petroleum products are widely used in cleaning products, such as paint solvents, and in the production of synthetic fabrics and plastics. They still lubricate gears and grease axles, as they did during the pioneer days. Petroleum derivatives play an important part in cosmetics and medicines. The uses of petroleum products are seemingly endless.

Petroleum products and the environment. As the century progressed and people became more reliant on all energy forms, the production, transportation, and use of petroleum created serious environmental concerns. Offshore drilling and tanker accidents such as the 1989 *Exxon Valdez* grounding in Alaska have polluted waters, damaged beaches, and destroyed wildlife. Fuels burned by motor vehicles, power plants, and factories produce air pollution in most cities. Gasoline, diesel fuels, and utility boiler fuels emit particulates and hydrocarbons. However, the Clean Air Act, passed by Congress in 1990, set standards to reduce air pollution from all energy sources in the United States. For example, particulate and smoke emissions have decreased by a factor of twenty, to near zero levels, for home heating. Industry has been required to develop techniques and products to minimize pollution. To reduce pollutants in automobile exhaust, oil companies phased out the use of leaded gasoline and automakers now install catalytic converters to stop engine knock. Having polluted the environment with petroleum products for over a century, people will need to enact serious cleanup efforts in order to remedy the problems this energy source has created.

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FOOD & AGRICULTURE

Upton Sinclair's *The Jungle*

Sinclair's meaty contribution. Upton Sinclair's literary contributions are best known for their political purpose. Born in 1878 in Baltimore, Maryland, to an upper-class family, Sinclair was a dedicated advocate of socialism. He knew that writing could be used as a political tool to advance his cause of exposing man's inhumanity to man. Research for a book took him undercover to Chicago's slaughterhouses. There he found facts more horrific than fiction. In his book *The Jungle*, Sinclair wrote about a Lithuanian family of immigrants who endured severe hardships after mov-

Figure 1.4.
A lamb being slaughtered, ca. 1913. Courtesy of Library of Congress.

ing to Chicago to find the Promised Land in America. Sinclair realistically revealed social injustices such as the consequences of poor wages, miserable living conditions, unsafe workplaces, and business and governmental corruption.

Sinclair's portrayal of the family's hardships and the unhealthy conditions in the meatpacking industry made this book an instant success. Public outcry expedited the passage of the federal Pure Food and Drug Act of 1906. And the Meat Inspection Act of 1906 was a direct result of *The Jungle*. Sinclair's book raised major concerns about unsanitary conditions in the food industry and was an accurate picture of how capitalism promoted greed at the expense of the poor working class. Sinclair felt that the grotesque treatment of the animals in his book was analogous to the treatment of the immigrants in capitalist America.

Food safety a century later. Prior to the Pure Food and Drug Act of 1906 and the Meat Inspection Act of 1906, food was often sold that contained diseases and organisms that were fatal, especially to infants and the frail elderly. There were no regulations as to what constituted wholesome meat.

Ironically, the federal food safety laws have not changed in nearly a century. Current inspections are still mostly by the sight, smell, and touch method that dates back to 1906. Microbial pathogens cannot always be detected in this manner. Scientific tests using microscopes are necessary to check for pathogens that pose major health risks to all who eat the products. In 1995 the U.S. Department of Agriculture (USDA) estimated that 15 percent of meat and poultry carcasses were contaminated with bacteria that cause health risks.

The conventional inspection methods have not stopped food poisoning from microorganisms like *Salmonella* and *E. coli*. Although reports have estimated that the number of inspections has steadily increased to about forty chicken carcasses per minute, contaminated meat still reaches the consumer. One possible scientific method of significantly decreasing harmful bacteria is to irradiate the meat at different phases of the processing. However, there is controversy over the long-term effects of eating irradiated meat. There is also much debate over regulations that allow meat with scabs, sores, cancer, glandular swelling, and other defects to be sold to the consumer.

The major bacterial food-borne diseases are caused by *Campylobacter*, *E. coli* O157: H7, and *Listeria monocytogenes*. *Campylobacter* is the number-one cause of food poisoning and is found mostly in raw chicken. It causes diarrhea, cramping, nausea, fever, headache, and muscle pain. *E. coli* O157: H7 is estimated to cause over 70,000 cases of illness and about sixty deaths a year in the United States. It is found mostly in ground beef products that are undercooked. The symptoms that accompany this food illness are severe abdominal pain, watery and bloody diarrhea, and vomiting. *Listeria monocytogenes* poisoning occurs less frequently, about 1,000 cases per year. About 20 percent of those who contract the bacteria, which is found in raw meat, cheeses, and raw vegetables, die from the serious symptoms of a persistent high fever, vomiting, and diarrhea. Several other bacteria cause similar food poisoning symptoms, but less frequently. However, they are just as fatal.

Preventing food poisoning at home. Scientists have determined that the growth of bacteria is significantly slowed at 5° C (41° F) or less. Below −18° C (0° F), bacterial growth stops. Neither temperature kills the bacteria that are present but it will decrease the spread. Therefore it is important to regulate refrigerator and freezer temperatures in grocery stores, restaurants, and homes. Meat should be cooked to an internal temperature of at least 71° C (160° F). This corresponds to a medium-well to well-done steak (no pink is left and the juices are clear). People who prefer rare-cooked meat put themselves at risk. Hot foods should be refrigerated within two hours after cooking or the warmth can become breeding places for bacteria. After food has been stored properly, it should be kept for a maximum of five days in the refrigerator to ensure that safe limits of bacteria growth are not exceeded.

Microwaved food should be cooked according to directions on the packages. More important, the food should stand for a few minutes so that the heat is evenly distributed throughout any meat before consumption. Last, cutting boards and countertops need to be cleaned after each use with soap and water, followed by a mild bleach to kill any bacteria that linger on the moist cutting board.

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MEDICINE & HEALTH

The Royal Disease

The "royal disease"—otherwise known as hemophilia—received its name from the number of people of nobility afflicted by the disorder. The genetic bleeding disorder was passed on to descendants of Queen Victoria (queen of England 1837–1901), a carrier of the disease, during an era when intermarriage among royals was both accepted and encouraged for political reasons. Alexandra, Victoria's granddaughter, married Nicholas, the czar of Russia, and passed hemophilia to their first son, Alexei.

Overwhelmed with grief, Alexandra sent for a self-proclaimed "holy man" to cure her son. Using hypnosis, Grigory Yefimovich Rasputin stopped many of Alexei's bleeding episodes, thus gaining favor with the royal family. Rasputin quickly took advantage of the situation and had his friends appointed to influential positions at the royal court. With Russia already in political turmoil and Czar Nicholas preoccupied with his son's illness, it was easy for Rasputin to manipulate power in his own favor and alienate the people. By siding with Rasputin the royal family increased the tension that eventually led to the Russian Revolution. Rasputin was murdered by a group of political leaders in 1916.

What is hemophilia? Hemophilia is a genetic bleeding disorder that is primarily found in males but the gene is often carried by females. In the disease, which afflicts approximately 1 in every 5,000 males, one of two blood clotting factors is either missing or not present in sufficient amounts. Without the blood's ability to clot, cuts can hemorrhage and internal injuries do not heal properly, many times leading to death if immediate medical attention is not secured. There is no known cure for the disease, making it imperative that care be taken in all aspects of life from playing sports, to careers, to simple medical procedures being performed.

From bloodletting to blood typing. Prior to Karl Landsteiner, an Austrian immunologist, discovering that not all blood was alike, transfusions during operations were often lethal. Physicians did not know that one person's blood might not be compatible with another person's blood. At the beginning of the 1900s, it was thought that disease was caused by "bad blood." To treat many illnesses, doctors or barbers (who treated a lot of illness during the 1800s) commonly performed bloodletting. A vein in the arm would be opened in order to drain the "bad blood." Fresh human blood, animal blood, and other liquids were used to replenish the body fluids, often killing the patient.

In 1900, Landsteiner discovered there were three human blood groups. He called them A, B, and O. The AB blood type was realized by two of his colleagues, Decastello and Sturle, in 1902. This same system of A, B, O, and AB typing is used today. While working in the Vienna Pathological Institute, Landsteiner performed thousands of autopsies. He noticed that two distinctly different molecules were present on the surface of the red blood cells. He identified one as A and the other as B. It is known today that he was observing two types of glycoproteins present in the red blood cells. If A-type glycoproteins are present, a person has group A blood. If B-type glycoproteins are present, a person has group B blood. If both A and B are present, a person has group AB blood, and if neither is present, this person is classified as being O.

Why is it important to know your blood group? Glycoproteins function as antigens that stimulate the production of antibodies. When antibodies are formed, a reaction occurs in which the red cells agglutinate, or clump together. If this clumping occurs in the blood vessels, it could cause a fatal situation. People with group O blood are universal donors because the recipient of O blood does not have to fear this agglutination reaction, since neither A nor B glycoprotein antigens are present. People with AB blood are considered universal recipients because they can function with either glycoprotein present in their bloodstream since they do not produce the anti-A or anti-B antibodies.

Understanding the mechanism of how these reactions work saves lives in an emergency situation. If different types are matched inappropriately, the patient could die. If, in an emergency, physicians don't know a person's blood type, type O is most likely accepted. Type A can be donated to a person with type A or AB. Type B can be donated to a person with type B or AB. Type AB can be donated only to a person with AB. Type O is the universal donor and can be given to anyone.

Reuben Ottenberg, a physician who noticed the Mendelian inheritance of blood groups and recognized the importance of group O as a universal donor, performed the first cross matching of donor and recipient in 1907 in New York.

There's more to the story: Rh factor. Landsteiner received the Nobel Prize for medicine in 1930 for his work on blood typing, as it proved to be essential knowledge for saving lives during World War I. A few years later he discovered the Rh factor. This attribute of blood was labeled Rh after the rhesus monkeys used in scientific research that led to this discovery.

The Rh factor represents the presence or absence of another protein found on the surface of the red blood cell. About 85 percent of people bear this protein and therefore are labeled Rh+. The remaining 15 percent of people who do not carry this protein are considered Rh–. It was found that expectant mothers are at a potential risk if they don't know their Rh factor. When a baby inherits the positive Rh factor from its father and the mother is Rh-negative, the mother's Rh– blood could attack the baby's blood. If this happens, a transfusion can be used to exchange the baby's blood for the Rh-type that matches the mother's.

However, another problem might arise. If the baby's Rh+ blood cells enter the mother's circulatory system, the mother's immune system will form anti-Rh antibodies. These anti-Rh antibodies could interfere with a future pregnancy. The antibodies would destroy the red blood cells of any Rh– baby born to this mother. To reconcile this situation, it was determined that an injection of anti-Rh antibodies could be given to the mother shortly after the birth of each Rh+ child, thus preventing the mother's immune system from forming its own antibodies.

Looking at the total story. The two Rh factors and four blood groups form eight different combinations of blood type. For example, a person can be AB–, having both the A and B glycoproteins but not the Rh antigen. It is recommended that your blood type be determined and that you carry a card with your blood type in case of an emergency. Also, in a massive crisis, organizations are more likely to use your blood if your type is already documented and they don't need to take the time to test it. Blood type O+ is the most common, and therefore the most needed at blood banks. Blood type O– is the type given in emergency cases when a blood type is not known.

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TRANSPORTATION

Wright Brothers' Flight

Before Orville and Wilbur Wright, the possibility of a controlled, human-powered flight seemed unattainable. On December 17, 1903, Orville Wright manned the *Flyer I* for the first flight in history in which an aircraft raised itself by its own power, cruised forward without reduction of speed, and landed at a place as high as where the plane had started. The key to the Wright brothers' success was their persistence and systematic engineering that had gone beyond the trial-and-error methods of their more formally educated contemporaries.

Figure 1.5.
Orville Wright flying in Virginia, June 29, 1909. Courtesy of Library of Congress.

Early interests. The Wright brothers owned a custom bicycle shop in Dayton, Ohio, where their mechanical abilities and interest in aerodynamics flourished. As young men they were fascinated by gliders and kites, and studied glider data from other scientists such as Otto Lilienthal of Germany. Their first flying machine was a wood, cloth, and wire kite with a 5-foot wingspan. The construction of this machine convinced Wilbur that he could build an aircraft capable of sustaining a person in the air. Two years later, Orville and Wilbur demonstrated that their 1902 glider design could remain stable. In fact, the Wright brothers felt confident that careful readings from their 1902 glider flights were accurate enough for them to work on a general design of a new plane propelled with a motor. They constructed the motor themselves with numerous short tests, accurate measurements, and a tomato can as a carburetor. The simple internal combustion engine drove propellers that converted engine torque (turning force) into thrust.

Discussions and tests. With their 1902 glider experiences combined with data figures from air pressure calculations, the Wright brothers determined the thrust necessary to sustain *Flyer I* in flight. Knowing that thrust is the force exerted on the plane by the exhaust gases, and power is the product of this force times velocity, the Wrights needed to design a new propeller that would produce enough thrust with the power provided by their motor. Of course neither data on propellers nor theoretical formulas were available.

The Wright brothers approached the problem by assuming that a propeller was simply an airplane traveling in a spiral course. They could calculate the effect of an airplane traveling in a straight line, but calculations for a spiral course were more complex. It was hard to decide from which variable to start the study, for neither the propeller nor the medium in which it acts stands still. The thrust depends upon the speed of the airplane when it is traveling forward and the angle at which the blade strikes the air. However, the angle is constantly changing with propeller speed, and thrust is determined by the speed at which the air is slipping backward. The slip of the air backward depends upon the thrust exerted by the propeller and the amount of air acted upon. When any one variable changes, it changes all variables, because they are all interdependent.

Many months were spent in intense discussions and study before Orville and Wilbur determined that the only way to test the efficiency of the propeller would be to try it. To best replicate conditions experienced in the field, the Wright brothers designed a wind tunnel. Through these many experiments, they were the first to understand how the lift from the airfoil changes in flight, and the first to design propellers in the form of an airfoil. An airfoil is the curved shape of a propeller or wing. As the curved wing passes through the air, the air going above the wing travels farther, and therefore faster, than the air traveling below the wing. This faster-moving air has a lower pressure than the slower-moving air below the wing. This difference in pressure forces the slower air toward the lower pressure, causing the wing to lift.

What other technologies did the Wright brothers invent? The Wright brothers designed their plane with two propellers to secure a reaction against a greater quantity of air; by having the propellers turn in opposite directions, the twisting effect of one would neutralize that of the other. They improvised skids, similar to runners on sleds, to prevent the airplane from rolling over if it tilted too much in one direction. The brothers, determined how to move the aircraft freely up and down on a cushion of air, built a forward elevator to control the pitch of their craft, and designed a pair of rudders in back to control its tendency to sway from side to side. In addition, they assembled a pulley system that warped the shape of the wings during flight, to turn the plane and to stop it from rolling in air.

First flights at Kitty Hawk. Orville and Wilbur Wright left Dayton on September 23, 1903, and arrived at their camp at Kill Devil Hill, North Carolina, to find the building they were to use to assemble the *Flyer I* had been blown over by a storm. In the subsequent months they built a new workshop, assembled the plane, calculated, experimented, and readjusted parts so that *Flyer I* was ready for trial in early December. They tossed a coin to decide who should have the first trial. Wilbur won the toss, but the trial run ended when several minor parts of the plane broke. However, the trial determined that their launching method was safe. On December 17, 1903, it was Orville's turn to attempt the flight. Several members of the Kill Devil Life Saving Station were there to witness the first flight. The wind, measured with a handheld anemometer, showed velocities of 11 to 12 meters per second, or 24 to 27 miles per hour. Years later Orville recounted the "audacity it took in attempting this flight in such high winds," but faith in their calculations and design were based on many years of careful and accurate laboratory work. With Orville at the controls, *Flyer 1* lifted shakily off from Kitty Hawk and flew 120 feet in 12 seconds. By the fourth and last flight of that day, Wilbur had increased the flight time and distance to 59 seconds and 852 feet.

Airplanes change the world. In the years that followed, the technology of flight developed rapidly. The airplane revolutionized both peacetime and wartime. The embrace of the airplane as a military vehicle and weapon started in World War I, and it has continued to be a major player in wars and terrorism by making international warfare an obvious reality. In contrast, the airplane also brings families together during vacation travel. Today, people can visit the birthplace of their ancestors or meet new friends around the world. The Wright brothers created one of the greatest cultural forces that effectively brought people, languages, ideas, and values together. Flight ushered in an age of globalization where international trade and understanding of human diversity become accessible to all peoples. Air travel opens up isolated countries and extends communication of democratic goals around the world. Of equal importance is the reality that aircraft are the foundation to travel beyond the earth's atmosphere.

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Model T Ford

Henry Ford invented neither the automobile nor the assembly line but diligently worked at a dream to perfect a process to build a low-cost, quality automobile the common laborer could afford. Growing up on a farm in Dearborn, Michigan, Ford had a propensity for designing machines that would ease menial labor. Leaving home at sixteen with only a sixth-grade education, he started working as a mechanic and later became chief engineer at the Edison Illuminating Company. He was an avid car racer by hobby but spent many of his nonworking hours in his backyard, designing and building an affordable car with an internal combustion engine. His efforts would eventually revolutionize life in the twentieth century.

Why did the car have a significant impact on American society? At the time Henry Ford was ready to promote his Model T, other automobile manufacturers were selling cars for about $5,000. The average salary of working Americans was about $600 per year when Ford introduced the first Model T in 1908, selling for $825. Ford was able to offer a low-cost automobile for many reasons. By using a "push" moving assembly line and interchangeable parts, and instituting effective labor practices, the company consistently made a good profit on the manufacturing and sale of its cars. Throughout the history of the Model T production, Ford increased benefits in order to keep workers. He provided a school where foreign-born employees could learn to read, write, and speak English. In addition, he paid all his workers a fair wage, often double what other employers offered, and provided medical care, bonuses, and generous benefits.

By providing such good working conditions, Ford helped to decrease child labor, since more families could support themselves with one breadwinner. As wages increased, more families bought cars, which made it necessary to produce even more cars. This lowered the manufacturing cost per car and raised profits.

In addition, the Model T gave Americans a mobility not previously known. Families visited friends and relatives, vacationed farther from home, and witnessed a cultural awakening as they traveled to other parts of the United States. By providing the opportunity for every family to own a car, Ford increased the incentive for people to better understand the workings of a car and technology in general.

Ford also studied materials in great detail, determining which afforded the most quality and were most cost-effective. While examining a French race car after it had been in a wreck, he noticed that the parts were made of stronger but lighter steel. Ford hired a metallurgist, who determined that the French steel was a vanadium alloy that was not available in the United States. This vanadium alloy had about three times the tensile strength of ordinary steel. It was much more pliable and lighter, easier to work, and safer in an accident. To produce this special steel, Ford had a mill built close to his manufacturing operations in the United States.

The first Model T car weighed about 1,200 pounds, light compared to most other cars of that time. The car was equipped with a relatively powerful 4-cylinder, 20-horsepower engine and had a two-speed manual transmission. Its design included simple lines, and the only color available was black. It had no options, but the low price and sturdy construction made it appealing. By the end of its production, 10 million Model T Fords had been produced.

Although Henry Ford is touted as being a genius and social reformer, some critics questioned his excessive use of repetitive movements and the fast pace for assembly line workers. He was accused of "slave driving," turning employees into unthinking automatons, and taking the skill out of work. He rebutted these claims by stating, "We have put a higher skill into planning, management, and tool building, and the results of that skill are enjoyed by the man who is not skilled." Nevertheless, Henry Ford's contributions to technology and society literally set the world into motion.

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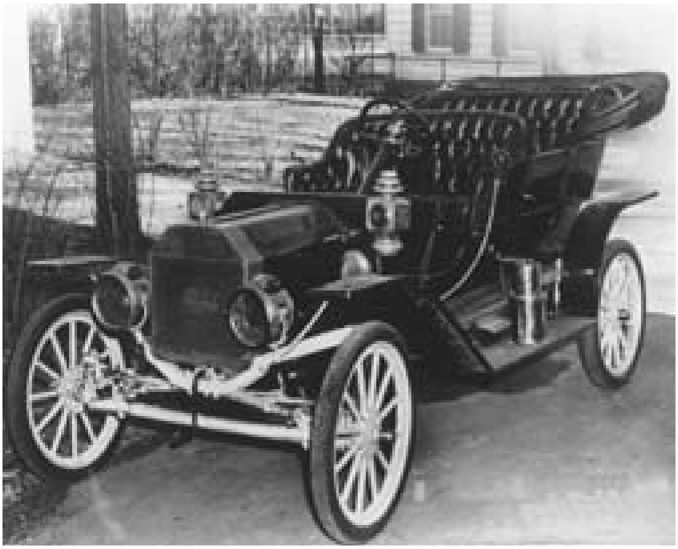

Figure 1.6.
Ford's four-cylinder Model T, built in 1908. Courtesy of Library of Congress.

HUMAN KNOWLEDGE

In the first decade of the twentieth century, revolution seemed the norm rather than the exception, in our understanding of the natural world. From the smallest bits of matter to the mysteries of space, scientists seemed to be shattering old views of the world at a breathtaking pace.

In biology, William Bayliss and Ernest Starling showed that messages can be sent through the human body along a pathway other than the nervous system. They demonstrated that hormones provided for the chemical regulation of digestion, even when access to the nervous system was prohibited. The importance of hormones to body function was thus just beginning to be understood. Later in the same decade, work done by Wilhelm Johannsen and Thomas Hunt Morgan would contribute to the burgeoning science of genetics and inheritance. Johannsen named "genes" and recognized them as the fundamental units of inheritance in organisms. Morgan studied the patterns of specific traits found in successive generations of fruit flies, and was able to verify the chromosome theory of inheritance though his work.

Midway through the first decade of the twentieth century, Albert Einstein published three papers which established his reputation for genius. One paper explained the phenomenon of Brownian motion, which had puzzled scientists for years. Through his explanation, Einstein practically confirmed the existence of atoms as the "building blocks" of all matter. Although such an insight seems trivial today, it is illustrative to appreciate that at the start of the twentieth century, many members of the scientific community were still unconvinced that atoms did indeed exist.

Einstein's other papers had similar impact. He published an explanation of the photoelectric effect, theorizing that light is emitted and absorbed in discrete packets called quanta. And finally, Einstein's special theory of relativity forced physicists to reverse some of their most familiar assumptions about the universe. Through the advent of special relativity, the scientific community began to accept that space and time were not absolute quantities, but relative or changeable ones. Einstein described the way in which the length and mass of an object would change as it traveled at extremely high speeds, and theorized ways to slow down or speed up the passage of time. Scientists in the 1900s were continually being challenged to think differently.

Sigmund Freud's Psychoanalysis

Born in 1856 in Moravia, Sigmund Freud, the pioneer of psychoanalysis, was the first to develop a systematic way to study unconscious mental activity. His controversial writings eloquently described the human condition and opened new possibilities in understanding that good and evil reside in man. His theory of human nature was first described in his book *The Interpretation of Dreams*, published in 1900. In this book Freud characterized his most important psychoanalytic study about why dreams are significant, where they originate, and what they mean. *The Interpretation of Dreams* unlocked the world's imagination as to how the unconscious element of the mind engages and influences our lives, and liberates us from dull routine activity through fantasies and nightmares.

In studying the development of thought, Freud pointed out how the mind creates vivid stories and roles that one plays only in one's unconscious self. He claimed that everyone dreams, both the healthy and the insane, and that interpretations were valuable for all, not just the mentally ill. His writings commenced the study of general psychology.

Freud was both a research scientist and a medical doctor who studied physiology and the anatomy of the brain. He believed that scientific knowledge would cure the ills of the world. Basing his theories strictly on naturalistic observations, Freud inductively developed theory starting with data. He felt theory should be formulated from well-defined concepts that represent observations and relations among the observations. He practiced the belief that science advances knowledge only if one collects data to describe phenomena that will be used to prove, classify, and correlate ideas. Relating these well-organized ideas to empirical material helped formulate and prove a theory. Freud felt confident to change his theory if sufficient data were collected to further refine or dispute the interrelationships among the data he had already used.

Freud's work ethic was very strong, and he often saw patients for 10 to 12 hours a day. Since he felt that taking notes during sessions was interruptive, he would write his data down after the sessions were completed at the end of the day. This practice produced much criticism on the accuracy of his notes for individual patients. Many believed that selective or biased memories might have played a part in what appeared to surface as major concerns of his clients. Nevertheless, Freud's influence can be felt even today with many of his analysis interpretations mirrored in the present understanding of psychological therapy.

What were Freud's theories? Freud felt that the emotions are linked to a situation or complex series of situations. He concluded that human reactions were "suffering mainly from reminiscence." When he first started his psychoanalysis, he used hypnosis. Soon he began just to listen as he applied a mild, soothing pressure to the brow of his patients to relax them as they talked. Later he relied on free association as a means of analysis. He mostly listened as the patient talked his way through his own problems, referring to memories and dreams, and creating his own "talking cure." Freud discovered that the most important point of the analysis was that someone listened to the patient day after day, month after month, year after year. That is, someone showed that they cared. He suggested and practiced that there is cure through love.

Freud determined that sexuality often was a major theme in a patient's discussion. He claimed that one repeated characteristic of many of his patients was childhood seduction. He came to believe that much of this was fantasizing on the part of his patients. He theorized that females had hidden sexual fantasies about their fathers and sons fantasized about their mothers. Sons were therefore jealous of their fathers and daughters were jealous of their mothers. This Oedipus complex, and Electra complex, written by Sophocles centuries ago, was a foundation for Freudian belief. Historians claim that Freud's own unusual family circumstances influenced him. His father was considerably older than his mother, and perhaps Freud found the age difference unsuitable. Although he believed that everyone is bisexual and that women suffer from "penis envy," he is credited with elevating the status of women more than his contemporaries did. He was the first to treat analysis of women more equally and to accept women's sexuality in its own right.

Freud's emphasis on the relationship between sexuality and neuroses brought ridicule and isolation from colleagues and at professional meetings. Even though he was considered a crackpot, he held fast to his beliefs. In this period of detachment he began extensive self-analysis that greatly influenced revisions in his theories. He spoke of sexuality during a time when such discussion was taboo. His theories were not well received in a puritanical period where normal sexual desires were silenced.

Freud articulated that repressed childhood desires turned into neurotic symptoms. These buried cravings surfaced in altered forms that caused what society would observe as bizarre behaviors. Freud theorized that each person struggles with three elements of his or her personality: the id, the unconscious, unaware instinct; the ego, the conscious, deliberate thinking mind; and the superego, the awareness of prohibitions, restraints, and the forbidden. However, modern analysts do not maintain such absolute divisions within the psychology of the mind. Freud's deterministic philosophy stressed how past situations bind us to particular behaviors. For example, our animal instincts or parental biases determine our personalities.

What is the relevance of Freud today? In the late 1990s the exhibit "Sigmund Freud: Conflict and Culture" was presented by the Library of Congress. And according to the American Psychoanalytic Association, whose membership includes over 3,000 psychoanalysts, Freud's spirit remains alive and well. As with most theories, parts of Freud's ideas have been refined or abandoned, but two of his profound breakthroughs endure. First, a person's behaviors, thoughts, and feelings are influenced by outside, unconscious factors. And second, a person's childhood experiences have a significant influence on the development, disposition, and character of that individual.

Much of the language and definitions used to communicate psychological concepts were coined and developed by Freud. Words like repression, Freudian slip, free association, id, and ego are commonplace in the twentieth century. Furthermore, the general idea of therapists being good listeners and using a form of talk therapy, originating from Freud, shows his continual influence.

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North Pole Exploration

The challenge to be the first. With a shrinking number of landmasses to explore and with flight in its infancy, many explorers accepted the challenge of conquering the earth's poles. Personal as well as nationalistic pride motivated explorers to be the first to reach a geographic pole on one end of the planet. Although many explorers, such as Frederick Cook, claimed to have reached the North Pole first, Robert Edwin Peary is given credit for this feat. There is still controversy as to whether or not he and his team actually reached the center of the North Pole. Most historians agree that he was the first person to come within 1 degree, or about 60 miles, of the center.

Scientific data in question. Without doubt Peary was one of the most outstanding explorers to lead expeditions to Greenland and other Arctic areas for over thirty years. His meteorological studies brought him honors, but his passion to reach the North Pole brought him fame. Funded by the National Geographic Society, fifty-two-year-old Peary and his team left Ellesmere Island, headed for the North Pole, in February 1909. Matthew Henson, an excellent dog driver, joined Peary and four Eskimos on this grueling venture. A seventh team member, Robert Barlett, was asked to stay behind. Peary's rationale was that the extra weight of the supplies would be hard on the dogs. Unfortunately, it was Barlett who could have verified the latitude and longitude, and perhaps lessened the doubt as to whether or not Peary actually reached the exact location of the North Pole. None of the other members of the team knew trigonometry, nor could they accurately read a sextant. Other discrepancies cloud the honor. The trip records show that Peary averaged over 25 miles per day for the 5 days, but in his previous explorations his best time was an average just over 15 miles per day. Even at the close of the twentieth century controversy looms as to who was the first or even second explorer to reach the center of the North Pole.

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Chapter 2

THE TEENS

SOCIETAL CONTEXT: EQUALITY, JUSTICE, AND WAR

The decade from 1910 to 1919 was fraught with contradiction for Americans. Progressive ideals mixed with traditional sentiments. The country prospered economically, and the roots of consumerism began to take hold. While America's love affair with glamour and glitz was taking shape, her shameful exploitation of human labor was also being exposed. Carefree lifestyles were placed on hold during the years of involvement in World War I, as sacrifice and patriotism became widespread expectations. Many historians locate this decade of contrast as the "end of innocence" in America.

In the 1910s, Henry Ford's new and efficient means of mass production made automobiles a reality for mainstream America. Ford was not the first to realize the benefits of assembly-line production, but he recognized that these benefits could change the rules of the consumer game by making an item previously available only to the wealthiest individuals a virtual household fixture. His aim was to make the automobile affordable and desirable, and in achieving this he changed the course of life in the twentieth century.

Although Ford went against convention by paying his employees impressive wages and considering their welfare, many workers of the 1910s found themselves laboring in unsafe environments under exploitative conditions. Six- and seven-day workweeks and up to 12-hour workdays were commonplace, as were pitifully low wages. Women and children were often more severely exploited than their male counterparts. Labor unions gained some headway during the decade in promoting fair wages and safer work conditions, although progress was usually gradual. Unfortunately, it

Figure 2.1.
Suffrage marchers on their way to Washington, D.C., February 10, 1913. Courtesy of Library of Congress.

often took sensational or tragic events, such as the Triangle Shirtwaist fire of 1911, to garner the public support needed for change.

Social roles began to change during the decade as well. Women's suffrage became a hotly contested issue, and throughout the 1910s, women gradually wore away the traditional resolve to keep them out of the voting booth. By decade's end, the Nineteenth Amendment to the Constitution of the United States provided women the same voting rights as their male counterparts. But where women's rights advanced, ethnic groups felt the sting of increasing hate crimes, as Americans struggled to come to terms with the realities of a heterogeneous society. The huge waves of immigrants who had landed in the United States during the first decade of the twentieth century were often viewed with mistrust and suspicion in the second decade, especially during the nationalistic fervor induced by World War I.

The definitive move away from "innocence" came with the U.S. involvement in World War I. Although President Wilson tried to remain neutral throughout the conflict, he finally conceded the impracticality of that position, and famously urged the United States to enter the Great War in order to "make the world safe for democracy." By the end of the war, and the decade, America was poised to live the twentieth century as one of the most powerful nations on earth.

ARCHITECTURE & ENGINEERING

Panama Canal Opens

Since at least the sixteenth century, civilizations had been seeking a convenient route of transport between the Atlantic and Pacific oceans. On August 15, 1914, this route was realized as the SS *Ancon* became the first ship to officially pass through the 51-mile-long Panama Canal, literally sailing right through a continent. After a failed attempt by a French company and ten years of American-backed construction efforts, building a canal across the Panamanian Isthmus proved no small feat. However, although it served as a marvel of engineering, the canal also provided the United States with an awkward reminder of its still-developing diplomatic presence in the world.

Canal history. During the nineteenth century, as the United States became larger and more prosperous, interest in efficient routes of transport grew. Connecting the Atlantic and Pacific oceans via an artificial waterway was a broad goal, and specific plans centered on Panama and Nicaragua as viable construction sites. In 1876 and 1901, two separate government-sponsored commissions under U.S. Presidents Grant and McKinley studied the sites and recommended that Nicaragua be home to the transoceanic waterway. Meanwhile, however, France negotiated a treaty in 1878 that would allow for building a canal on the Isthmus of Panama. The French crew was not prepared to handle the challenging terrain and unfamiliar diseases that faced them in Panama. These problems, along with a lack of financial support, led the French to abandon the canal project in 1889.

The U.S.-backed Panama Canal project began under the encouragement of President Theodore Roosevelt in 1903. At the time, the United States was prepared to develop plans for a Nicaraguan canal, but the representatives of the failed French project convinced Roosevelt to buy their holdings instead. Though the United States did purchase the French assets in Panama, it was unable to negotiate a canal treaty with Colombia, which controlled the Isthmus of Panama at the time. Frustrated by Colombia's reluctance, Roosevelt took drastic measures to secure the eventual Canal Zone. Despite potential damage to foreign relations, he decided to help Panama gain its independence from Colombia in order to virtually assure a canal treaty for the United States. In early November 1903, the United States provided military enforcement for the autonomy of Panama in opposition to the Colombian army. Within a few weeks, a treaty was drawn with the new nation of Panama allowing the United States to build the canal and have sovereign nation rights in the Canal Zone.

A formidable challenge. Construction of the Panama Canal provided a formidable challenge for the Americans. Disease—particularly malaria and yellow fever—had been a severe problem for the French workers. In addition, the physical challenge of cutting through mountainous terrain and thick jungle in the tropical climate would prove a monumental task. In the end, the competent administrative styles of John F. Stevens and later Col. George Washington Goethels, informed by scientific and technical understandings, helped make the decade-long project a success.

New understandings of disease were proliferating at the turn of the century. Although Walter Reed's work in Cuba at the time seemed to provide proof that mosquitoes were responsible for the spread of yellow fever and malaria, many people remained skeptical. Even Chief Engineer Stevens was unconvinced, but he deferred to the expertise of his chief sanitary officer, Dr. William Crawford Gorgas, who took action against the mosquito population around the canal site. Gorgas screened windows and doorways, cleared surrounding vegetation, bred natural predators, and poisoned mosquito breeding grounds. Although costly, the measures undoubtedly saved human lives: yellow fever was eliminated on the Isthmus in 1905, and deaths from malaria dwindled considerably after the treatment.

The geology of the Isthmus of Panama presented problems for the construction of a canal. The land is composed of alternating deposits of soft and hard rock, in irregular layers and formations. A significant consequence of the mixture of soft and hard rock was that rock slides were a real danger in the Canal Zone. Two kinds of slides occurred during the excavation: structural break slides and gravity slides. Structural break slides occurred when unstable surfaces simply crumbled—often, looser, soft rock gave way under the weight of a hard, heavy rock layer. Explosives used as a routine part of the excavation process caused some surfaces to become unstable and thus susceptible to such slides. Gravity slides occurred when a loose upper layer of rocks and soil was saturated by rain, causing it to slip over a harder underlying rocky surface. The first slide that took place during American construction efforts was at Cucaracha in 1907, when heavy rains caused half a million cubic yards of material to slide into the cutaway areas.

Undoubtedly, the successful American efforts at the Panama Canal were critically influenced by the French failures. Whereas the French had been set on carving out a waterway at sea level, the U.S. project settled on a system of locks and reservoirs to carry ships across the land. Chief Engineer Stevens again made a crucial decision in abandoning the idea of a sea-level canal, based upon the careful examination of technical and engineering possibilities. From the Atlantic side of the canal, a ship is raised 85 feet by three locks before it sails across Gatun Lake. Then the ship is lowered by a series of locks to the Pacific. An incredible 52 million gallons of water is needed each time a ship travels through the lock system.

The U.S.-backed canal project was strengthened by an investment in massive, timesaving technologies. In addition to using explosives to loosen the earth and steam shovels to assist in excavating the land, the Americans employed unloaders, spreaders, and track shifters in their efforts. The Panama Railroad, running relatively parallel to the dig, was incorporated into the effort with huge success. Tracks were constructed on various levels, and the railroad traffic was coordinated with the excavation needs. Track shifters were huge machines that uprooted and replanted large sections of track as needed, so that train routes could be relocated as excavation needs dictated. Train cars moved huge amounts of earth from the dig sites, while giant unloaders emptied the trains and spreaders smoothed the unloaded soil and rock. Each unloader and spreader could do the work of hundreds or even thousands of humans. The magnitude of the task is somewhat incomprehensible; in all, about 184 million cubic meters (240 million cubic yards) of earth were moved for the canal.

"The greatest liberty." A British politician of the era observed that the construction of the Panama Canal was "the greatest liberty man has ever taken with nature." Although the canal stood as a testament to modern engineering prowess, it also exemplified an attitude of dominance over the natural and political world that was slowly coming into question.

Although President Theodore Roosevelt had touted the canal project as a great testament to human ingenuity and a service to the world, others were dismayed at the way in which he secured the rights to building it by helping stage a Panamanian coup. The United States' seemingly brash statement of imposed will troubled people at home and abroad. Later, President Woodrow Wilson, who held office at the time of the canal opening, proposed that a $25 million payment be made to Colombia for reparations. Roosevelt voiced his outrage at Wilson's proposal, and reparations were postponed until after Roosevelt's death. The Panama Canal project exemplified the tension that often exists in the United States between a desire for security and a willingness to trust political alliances enough to remain uninvolved in the domestic affairs of other nations.

The benefits of an American presence in Panama were strong enough to convince U.S. leaders throughout the twentieth century to retain control of the Canal Zone and maintain military bases there. By the mid-twentieth century, however, the United States began to feel more pressure to withdraw from the region. In 1977, President Jimmy Carter signed a treaty that called for the gradual dismantling of U.S. military bases and return of the Canal Zone to Panama. Two years later, another treaty assured the neutrality of the Panama Canal.

On December 31, 1999, the United States left the Canal Zone, and Panama took control. New challenges seem to await the Panamanians in the twenty-first century. As traffic increases on the canal, so does the need for water. However, deforestation in Panama is drastically reducing the available freshwater, as runoff from the cutaway areas flows into the oceans rather than the locks of the canal. Panama's government has answered these challenges by developing an impressive and ambitious plan to help protect the area by promoting ecologically friendly tourism (itineraries that keep people away from ecosystems that are at risk of being destroyed) and using profits from such tourism to improve and maintain the current canal site.

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Triangle Shirtwaist Fire

Often throughout history, tragic events have prompted social reforms. One such tragedy was the Triangle Shirtwaist fire of 1911. Poor factory design and lack of emergency policies contributed to the loss of many lives during the incident, and became important targets for improvements in work conditions for future generations.

The fire. On March 25, 1911, employees of the Triangle Shirtwaist Company in New York City were about to leave work for the day when fire suddenly broke out and trapped many of them inside the factory. In less than half an hour, three floors of the building had burned and 146 workers were dead.

At the time of the fire, the Triangle Shirtwaist Company employed mostly girls and women between the ages of thirteen and twenty-three to operate rows of sewing machines. As in many other factories of the day, little thought was given to workers' rights or safety, and work conditions were often quite dismal. Although the Triangle Shirtwaist factory was located in a building that was considered fireproof, the cotton and linen fabric that was used to produce shirtwaists was certainly flammable, and it was hanging from the ceiling over the rows of workers and lying in scrap piles all along the floors. Once the fire started in the factory, there was little protection for those working inside.

Other poor safety conditions made it relatively easy for the Triangle Shirtwaist fire to become deadly. For one, the employees had only twenty-seven buckets of water to fight the fire. Another problem was that exits were not accessible, either because they were kept locked or because the doors opened inward, and could not open against the force of dozens of people trying to get out of the building. Although a fire truck arrived outside the building during the fire, the ladders couldn't reach the floor on which the factory was located. In addition, fire blankets could not hold the weight of all of the girls and women jumping to escape the inferno, some of whom died trying to save themselves. Others chose to leap to their deaths rather than be consumed in the flames. The average age of the dead was nineteen years old.

Figure 2.2.
At work in the garment industry. Courtesy of Library of Congress.

Combustion chemistry. Much of the material used by the Triangle Shirtwaist Company was cotton, a material made of plant cellulose. Cellulose can be thought of as the "skeletal substance" of plant cells. It is a carbohydrate, which means it is composed of the chemical elements carbon, hydrogen, and oxygen. In addition, cellulose is a polymer, a chemical that consists of a long chain of smaller molecular pieces. In this case, the long chains are of glucose (sugar) molecules; therefore, cellulose is also known as a polysaccharide. Compounds made of carbon, hydrogen, and oxygen are flammable. In the presence of oxygen, such compounds generally burn and are converted into carbon dioxide and water. This reaction occurs rapidly, and a flame is usually seen.

The basic principle in fighting fires is to attempt to remove one of three elements that are vital to the life of a fire: fuel, heat, or oxygen. The Triangle Shirtwaist fire would be classified by modern fire safety experts as a class A fire, one that was fueled by ordinary combustible material, such as wood, cloth, or paper. Other types of fires include class B, which is fueled by flammable liquids (such as oils or gasoline); class C, which is an electrical fire originating from electrical wiring, fuse boxes, or electric appliances; and class D, which has its source in combustible metals. Firefighters need to determine the type of fire before attempting to contain and extinguish it; for example, water will help stop a type A fire, but will increase dangers if used against class B or C fires. Unfortunately, at the time of the Triangle Shirtwaist fire there were no regulations that employees must be trained in basic fire safety procedures, and many lives were lost in fires as a result.

The Triangle Shirtwaist legacy. The owners of the Triangle Shirtwaist Company were brought to trial for the deaths of their workers, but they were acquitted because no laws existed in the 1910s that required worker safety and protection. Labor unions, which were already gaining in strength at the time, were seen in a more sympathetic light after the Triangle Shirtwaist fire, as the public began to recognize the poor conditions in which many workers were expected to exist. After the fire, as many as 100,000 people marched in support of the Ladies Garment Workers Union to convince the New York legislature that the time for government regulation of business had arrived.

Today in the United States, employee safety is regulated by the Occupational Safety and Health Administration (OSHA) under the Department of Labor. Escape routes are to be planned and published, and multiple, unblocked paths to safety are to exist. Fire extinguishers and sometimes sprinkler systems are required to be kept in working order on company premises. Hazardous materials must be properly controlled, stored, and maintained. In addition, employers are required to provide safety training for their employees.

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ARTS & ENTERTAINMENT

Edison's Talking Movies

Talking pictures could be found in American movie theaters from 1913 to 1915, when a large-scale version of Thomas Edison's earlier Kinetophone was made available for use. However, Edison's invention never enjoyed widespread popularity, and "talkies"—movies with recorded pictures as well as sound—would become popular only over a decade later when *The Jazz Singer* captured audiences' attention and interest. The story of the failed Kinetophone involves both scientific-technical difficulties and societal perspectives that ran counter to the invention's potential for change.

Two kinds of waves. One of the difficulties of working with both sound and pictures to produce images has to do with the fundamental difference between sound and light. Both can be described as forms of energy transported by waves, but the nature of these waves is quite different. Sound waves are mechanical waves that result from the vibrations of solid, liquid, or gaseous matter. In other words, sound travels through a substance when vibrations are passed along its molecules. We hear a sound when the vibrations of air molecules reach our ears, where the motion is then converted into electrical impulses that the brain can interpret as sound. This generally happens very quickly, since sound travels at a speed of approximately 350 meters per second (or about 1,150 feet per second) in air at room temperature.

Light waves, on the other hand, can be thought of as oscillations of electric and magnetic fields. When a charged particle is accelerated by a force, it creates waves of electrical and magnetic fields. These fields exchange energy as the wave propagates, or moves through space. The energy in these waves can be transferred to matter when molecules absorb the waves. Unlike sound waves, electromagnetic waves can travel through empty space. These waves can also travel through a medium (like light through glass), but the medium can affect the way the wave propagates (e.g., by changing its wavelength or absorbing some of its energy). Electromagnetic light waves travel much faster than mechanical sound waves; in a vacuum (empty space) this speed is a constant 300 million meters (984 million feet) per second. The speed changes when light travels through matter.

Our body's sensory receptors regularly perceive sound (via our ears) and light (via our eyes), and our brains translate these signals into information about the surrounding world. Our experience tells us that objects close enough to us to be emitting audible sounds can be seen and heard "simultaneously," even though the light waves actually reach us first, and sound waves afterward. An exception in our experience is what happens during a thunderstorm, when our eyes often see a flash of lightning before our ears are able to hear the resulting thunderclap. In that case, the distance that light and sound must travel to be perceived is large enough that the difference in the travel times between light and sound becomes significant. In the case of talking pictures, it is not a long distance but technical problems that can cause us to see and hear events in a movie at slightly different times. When the purpose of a movie is to make us believe that we are witnessing a real event, the production of light and sound must be synchronized in such a way that the "signals" reach our senses at the same time, or closely enough to ensure that our brain can't process a discrepancy.

Technical difficulties. As we might expect, capturing and recording light (photographs) and sound also works differently. To capture light, film is held still and exposed to patterns of light and dark which are then chemically developed into images we see. It is, in essence, a static process. Of course, movies are possible because many photographs are shown in rapid succession, and our brain is tricked into thinking that the pictures are actually moving, since one image hasn't entirely disappeared before the next one appears to our brain. On the other hand, when sound is captured by a recording device, the medium on which it is captured is in continual motion;

it is a dynamic process. Sound recordings capture the continuous vibration of matter, and when played back, they re-create these vibrations in a continuous manner.

Because of these differences in recording procedures, early attempts to combine motion pictures and sound consisted of attempts to synchronize two different kinds of recorded media. For example, Edison's early Kinetophone was a Kinetoscope movie-viewing machine connected to a record player through a belt mechanism, so that the two devices would operate simultaneously. The 1913 adaptation of the Kinetophone was a large-scale version in which a large-screen movie projector was connected to a celluloid cylinder player in another part of the theater by a long pulley system. Although ingenious, the system's practical problems prevented it from selling audiences on its possibilities. Often projectionists were not trained in the proper operation of the Kinetophone equipment, and audiences were left feeling that their sight and hearing were out of synch.

Eventually, technology would make it possible to record both sound and light on the same film. Both 16mm and 35mm movie films have one perforated side to allow for the film to be pulled through the camera, and one side free of perforations for recording a sound track. On the actual roll of film, sound is recorded ahead of the light to allow the different capture processes to remain static and dynamic. When such film is edited (cut and spliced), it is often difficult to align the sound track and pictures. Therefore, many professional filmmakers record photos and sound separately, and the two are synchronized by later aligning pulses that have been embedded on each film.

Hollywood or bust? Some media historians blame forces other than technical problems for Edison's failure to spark the public's interest in talking pictures. Edison was fiercely protective of his media patents and was known for suing those who would use his inventions without his permission. In fact, some believe that Hollywood became the eventual favorite location for movie production because so many competing filmmakers attempted to get as far away from Edison's New York–based lawyers as possible. After competitors' complaints, the federal government intervened in 1915 and dissolved Edison's Motion Picture Patent Corporation, which essentially stifled the continuation of projects such as the Kinetophone.

Others also note that Edison's company didn't have its finger on the pulse of America's cinematic tastes. While other moviemakers wowed audiences with longer and longer feature films, Edison's nineteen talking pictures produced from 1913 to 1915 were essentially short stories. While Edison relied on his technological ingenuity as a means to advance the industry, others saw that audiences were evidently attracted instead to charismatic on-screen personalities and to the reputations of talented directors. It was only a matter of time before Hollywood business became the business of "star power."

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COMMUNICATION

Hello, San Francisco? It's New York Calling

In 1915, the first telephone call connected one end of the nation to the other, as technological innovations changed the nature of transcontinental communications forever. Prior to this coast-to-coast conversation, telephone connections were limited in range because the signal would lose strength at appreciable distances.

Triodes and feedback. The ability to conduct cross-country phone conversations was the result of a massive undertaking of engineering and problem solving. The transcontinental phone line between New York and San Francisco consisted of almost 3,000 tons of cables stretched over 13,000 poles. It was the longest telephone line in the world.

But the problem that had made coast-to-coast telephone service heretofore unheard-of was not a matter of construction but one of transmission. The telephone works by converting vibrations from the sound of a caller's voice into electrical signals, which are then transported along wires and converted back into vibrations, or sound waves, on the listener's end. The basic dilemma for long-distance transmission was that strength would be lost as the electrical signals traveled along the wire, until essentially no signal was left. Before 1915, the extent of the phone service connection was New York to Denver, and one historian notes that such a connection required shouting in order for the parties to be understood.

Telephone signal amplification became possible because of the invention of the three-element vacuum tube (or triode) and the development of the feedback amplification process. Lee De Forest is credited with inventing the triode in 1906, although he admitted not knowing what its applications might be at the time. Eventually, the American Telephone and Telegraph Company (AT&T) bought the rights to De Forest's invention and devised a way to use it as a signal amplifier. Doing so meant taking advantage of Edwin Armstrong's circuit design, which allowed for a signal to be repeatedly fed back into the device, amplifying it more each time until it reached the desired strength.

The triode vacuum tube can also be called a thermionic valve—"thermionic" because one piece of it gives off electrons when heated, and "valve" because it is effectively a one-way street for charge flow. The triode consists of an evacuated tube with three elements inside: a cathode (or filament), a positively charged plate, and a control grid. When heated, the cathode acquires an excess of electrons, which are attracted to the positively charged plate at the other end of the tube. In the middle is the control grid, which is connected to the telephone signal. As the signal from the telephone changes, the grid controls the path of the electrons between the filament and the plate, so that the plate receives the signal corresponding to the caller's original message. However, the signals emanating from the plate are at a higher voltage and thus of greater strength than those sent into the control grid. Thus, the signals can be carried over a longer distance without fear of loss. Allowing for the original signal to be part of a feedback loop means that it is repeatedly sent through the tube and is amplified to an even greater degree; thus, even greater transmission is possible.

Ceremony and consequences. The first transcontinental phone call was a ceremonious occasion that took place on January 25, 1915. Alexander Graham Bell and Thomas A. Watson reenacted their original telephone call that had taken place in 1876, with Bell on the East Coast telling Watson on the West Coast, "Mr. Watson, come here. I want you." Of course, now the pair was over 2,500 miles apart instead of two floors away in the same building.

Although Lee De Forest was not present at the time of the transcontinental conversation, others were listening in. The phone call was interrupted by the president of AT&T, who was in New Jersey at the time, and by President Woodrow Wilson, from Washington, D.C. The possibilities this new technology opened for modern communication seemed quite promising.

Indeed, telephones began to become commonplace in American society and culture. By the end of the decade, there were twelve phones available for every 100 people. By the end of the century, there would be more than sixty phone lines available for every 100 residents of the United States. Telephone communication would also play a critical role in the late twentieth-century dawn of the "Information Age," and innovations such as fiber optic cable and satellite networks seemed destined to extend the reach of telephones to virtually any corner of the globe. It should be noted, however, that by the end of the century, not everyone on the planet enjoyed the access to telephone communication that Americans did. Countries such as Afghanistan, Cambodia, and Chad could claim only one telephone line per 1,000 people, and many citizens of developing countries would still never come in contact with the technology. Some say this discrepancy adds to the "digital divide" in modern global society—the gap between individuals with access to information and those without—

Figure 2.3.
An early telephone, ca. 1915–1925. Courtesy of Library of Congress.

and many social critics fear that such a gap perpetuates the inequality in wealth and power that is likely to have caused it in the first place. Certainly, a formidable but worthy challenge of the twenty-first century could be to ensure that access to modern communications technology is enjoyed by all.

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DEFENSE & DIPLOMACY

A New Poison

World War I was known to its contemporaries as the "War to End All Wars." It is often thought to have essentially ended the "innocence" of twentieth-century societies. One of the consequences of the improved transportation and communication systems of the time was that people could learn about the horrors of war more rapidly, and in more graphic detail, than ever before. Although many new military tactics and weapons were employed by all sides on the battlefields, perhaps the most frightening were the various kinds of poison gases brought into play. Tear gas, chlorine gas, phosgene, and mustard gas were emblematic of how far the warring countries were willing to go to inflict pain and fear upon their enemies.

Uses during battle. The French were actually the first to use gas during battle in World War I, employing tear gas grenades in August 1914. However, it was the German army that was the most aggressive in studying and deploying gas as a weapon in the war. During the second battle of Ypres (Belgium) in April 1915, French and Algerian troops found themselves staring into an advancing greenish-yellow cloud. Confused and expecting a German attack, the soldiers began choking violently as the chlorine gas they came into contact with reacted with moisture in eyes and respiratory tracts, forming caustic hydrochloric acid.

During the war, other kinds of poison gases were used in battle. Phosgene (or carbonyl chloride) had effects similar to those of chlorine, but was potent in much smaller concentrations and was known for producing a delayed attack on those who were in contact with it. Mustard gas (or dichloroethylsulfide) was a particularly feared weapon that caused serious blisters on contact with human tissue. It would remain in the soil after an attack, so that capturing trenches could prove quite uncomfortable, or even deadly.

Clouds of poison. All three chemical weapons mentioned above had damaging effects on the respiratory systems of those who were unfortunate enough to have inhaled them. Chlorine and phosgene both produce hydrochloric acid when they react with moisture. When in contact with the upper respiratory system (nose, mouth, throat), the acid can irritate tissue and cause sneezing and coughing. However, in each of these cases, it is not the hydrochloric acid but the remaining product of the chemical reaction that does the most damage to human tissue. In the case of the chlorine–water reaction, the dangerous by-products are single oxygen atoms; for phosgene–water reactions, a resulting free carbonyl group (carbon and oxygen atom acting together) does the damage. Both of these chemicals attack the alveoli, or air sacs, in the victim's lungs. The alveoli serve a critical function in the respiratory system; they are the site of oxygen–carbon dioxide exchange between the lungs and the circulatory system. Inhaling phosgene or chlorine causes destruction of the alveoli cell walls, resulting in their swelling and blocking this vital respiratory exchange. If large enough concentrations are taken in, victims can eventually suffocate.

Mustard gas, when inhaled, can have an effect similar to those of chlorine and phosgene. It, too, damages alveoli and blocks the body's access to oxygen. Further, doctors have found that those who have inhaled mustard gas have an increased risk of developing lung cancer later in life. Mustard gas that was accidentally swallowed could cause burns in the intestinal tract and result in internal bleeding. And upon contact with the skin, mustard gas caused redness, itching, and eventual blistering. Severe scarring could often result from such exposure. Throughout the war, but particularly when they were first introduced on the battlefield, chemical weapons and their gruesome effects were generally acknowledged to have scarred the psyches of the exposed soldiers along with their bodies.

Lasting effects. Although estimates indicate that more than 90,000 soldiers died as a result of poison gas use during World War I, the results were not as absolutely devastating as some had feared. In each participating country, much effort was put into preventing gas from becoming a problem for fighters. Early in the war, soldiers were trained in how to use their clothing to make emergency masks to protect against a gas attack; by the end of the war, gas masks had become standard issue equipment.

Many experts feel that the psychological effects of gas use during World War I were at least as damaging as the physiological ones. On the large scale, many people abhorred the use of poison gas, and the publicity surrounding the Germans' use of chlorine at Ypres turned many people in otherwise ambivalent countries away from sympathizing with Germany. Although other armies set out to retaliate, and did indeed employ gas weaponry for their own purposes, Germany's image never really recovered. Fearful of acquiring such a negative public image, British military commanders insisted that Special Forces who worked with gas weapons should be forbidden to refer to it by name. So absolute was the public's repulsion for gas weapons that although nations continued to develop the technology, various treaties and disarmament talks have consistently aimed to ban such warfare (although some leaders have chosen to ignore such agreements: Italy used gas in Ethiopia in the 1930s and Iraq used chemical weapons in its late-twentieth-century war with Iran).

Nevertheless, individuals suffered the psychological effects of this brutal war. Trapped in trenches, waiting to be bombarded by artillery, and wearing heavy, stifling gas masks, many soldiers eventually developed what became known as "shell shock"—a traumatic condition that effectively brought persons to a psychological

Figure 2.4.
Gas masks used in World War I, 1920. Courtesy of Library of Congress.

standstill. Whether on the side of the victors or the defeated, many soldiers knew their lives would never be the same again after the War to End All Wars.

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ENVIRONMENT

National Park Service Founded

During the nineteenth century, many thinkers began to worry about the impact that humans were having on the natural environment, as societies placed increasing demands on Earth's natural resources in order to meet the needs of a rapidly changing lifestyle. In 1864, Congress answered this concern by declaring that Yosemite Valley in California was to be preserved as a state park, and eight years later, the Yellowstone area in Wyoming and Montana territories was also to be preserved for "the enjoyment of people." As the country grew, so did the government's acquisition of "national treasures"—including parks and monuments of historic or cultural significance. However, the Department of the Interior, although technically responsible for the areas, had no real way of managing them, and the effectiveness of preservation of national parks and monuments was accomplished in a very unsystematic way.

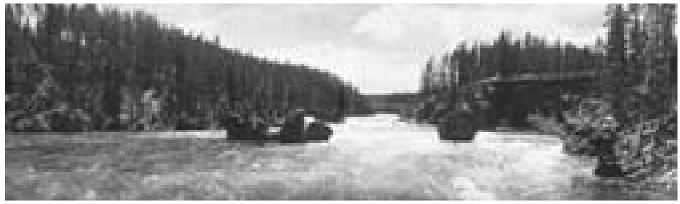
In 1913, an argument over damming the Tuolumne River in the Hetch Hetchy Valley area of California focused attention on this growing area of debate. Those concerned with preserving the Earth's resources (leaving them untouched) were opposed by others who argued for utilitarian conservation of resources (managed, sustainable use of lands). The government sided with those who favored using the resources and voted to allow building of the dam, which angered preservationists. But President Woodrow Wilson and other government officials realized that a more balanced and systemic approach would be necessary in order to keep our designated national treasures safely intact. On August 25, 1916, the United States National Park Service was created to oversee national parks and monuments at the federal level and to ensure such a balance for future generations.

The human role in ecology. Ecology is the study of the relationships between and among living things and their environments. Ecology-minded individuals who argued for preservation of lands in the nineteenth century were reacting to the apparent lack of regard that many modern societies seemed to have for their relationship to other living species and environmental resources. They felt that humans were using nature to serve their own purposes by gobbling up living and nonliving resources in excess of needs, and considering only short-term (if any) effects of their actions. In their view, setting aside key areas of land and preventing the use of such lands by humans was the only way to protect nature from misuse and destruction.

In time, others began to argue that the preservation idea was not in harmony with natural cycles and relationships. They pointed out that in nature, balance between living things is ever-changing, and that trying to set aside land for the sake of keeping it forever in the same condition was an unnatural expectation. A better solution, thought the utilitarian conservationists, would be to manage human interaction with the environment so that it obeys the laws of nature as much as possible; that what is taken, is given back in some way; and that human actions don't alter the balance of natural interactions too drastically.

Today, the National Park Service operates to manage human interaction with national parks in just this way. It allows humans to interact with park areas, primarily for recreational purposes, and acts as a watchdog for potential problems in these interactions. Some ways in which humans act to destroy the environment may be obvious, such as littering or killing off particular species, but other problems can be more subtle. For example, although it is desirable that people visit and appreciate national park areas, too much traffic can cause trouble, since increasing traffic through the parks increases the chance for vehicle–wildlife accidents and adds to air and noise pollution. Another problem is the introduction of invasive species into park areas;

Figure 2.5.
The Yellowstone River, 1908. Courtesy of Library of Congress.



these are species which do not normally inhabit an area, but proliferate widely upon being introduced, often to the detriment of natural inhabitants of an area.

Continuing challenges. Over the years, those who have served as National Park Service director have taken different approaches to emphasizing maintaining the status quo and expanding areas under Park Service control, and at times the equilibrium between preserving and using natural resources necessarily shifts. But one thing that remains the same is the need to strike a balance between human activity and the natural environment of the parks. As lifestyles change even more and new technologies develop, the problem of weighing human societal needs against the need to sustain our national treasures will always pose a challenge to the National Park Service.

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FOOD & AGRICULTURE

The Prohibition Movement

America's love–hate relationship with alcohol reached a crescendo in the 1910s, leading to the ratification of the Eighteenth Amendment in 1919. This amendment to the Constitution of the United States banned the production, selling, or transporting (though not the consumption) of "intoxicating liquors," and became known simply as "Prohibition." The amendment enjoyed great popular support at the time it went into effect, as decades of work by temperance groups came to fruition. The reasons for eschewing alcohol seemed many and varied, from its apparent link to society's declining moral fiber to a patriotic desire to support the United States in World War I.

Despite this popular support, during the next few years many people chose to ignore the Prohibition laws by frequenting speakeasies, where alcohol flowed freely, counter to the intended restrictions. Others took their chances by brewing their own moonshine. Organized crime flourished in the void left by formerly legal alcohol-related establishments. By the time Prohibition was repealed under President Franklin D. Roosevelt's administration in 1933, most people conceded that this grand experiment in improving morality had been a failed effort.

What is alcohol? "Alcohol" refers to a class of organic compounds; that is, a chemical containing carbon as the primary element. Alcohols are compounds of carbon and hydrogen which include a hydroxyl group (an oxygen and a hydrogen atom connected together) somewhere in the molecule. There are many kinds of alcohol, and all are poisonous to humans when ingested. However, ethanol (C_2H_5OH), or "drinking alcohol," can be consumed in small quantities. Alcohol generally acts to depress the central nervous system, and its effects can range from impairment of muscle control, vision, and speech, to the eventual loss of consciousness and respiratory function, and death.

There are two basic steps in the production of alcohol for human consumption: fermentation and distillation. Fermentation involves the conversion of sugar into alcohol by yeast. Yeast consists of tiny, single-celled microorganisms. When combined with sugar and other nutrients and allowed access to free oxygen, yeast cells rapidly multiply until a large colony forms. However, after a while, the oxygen supply becomes depleted, and yeast cells begin to decompose sugar molecules in order to obtain the oxygen they need. This chemical reaction results in sugar being converted into alcohol and carbon dioxide. The same reaction occurs when yeast makes bread dough rise; the carbon dioxide gas bubbles allow the dough to expand. However, when bread dough is baked, the alcohol is burned off, whereas in brewing, the alcohol is purposely separated from the rest of the mixture by distillation.

Distillation is a technique used to separate components of a mixture of liquids. A mixture is a conglomeration of substances that are joined together but retain their individual distinct properties. For example, if some iron filings were stirred together with crystals of table salt, each would still be recognizable as iron and salt. The physical properties of each substance could be used to separate the mixture; in this case, a magnet could be passed over the mixture in order to attract and pull out the iron filings. Distillation works because different liquids boil (change from the liquid phase to the gaseous phase) at different temperatures. When a mixture is distilled, it is heated slowly until one component (that with the lowest boiling point) begins to vaporize. When it turns into a gas, it rises through a set of tubes, where it is directed away from the original mixture, then cooled so that it returns to a liquid state before being collected in a separate container. In this way, the various types of liquids present in a mixture can be carefully sorted from one another and used or discarded, as appropriate.

Wet versus dry America. The Prohibition movement gained momentum in the later part of the nineteenth century in the United States as people reacted to what they saw as "declining morals" and a "culture of drink" affecting society. For some, this attitude was related closely to fundamental religious (usually Christian) beliefs. For others, it was tied to anti-German sentiment that bubbled up during World War I. Since descendants of German immigrants were largely responsible for the successful brewery operations in the United States at the time, many people felt that supporting the enterprise was "un-American." The issue was also frequently tied to women's rights; male drunkenness was seen as leading to family disarray and myriad other problems for the women who had to contend with such men.

Effectively latching on to popular sentiments of the time, groups such as the Anti-Saloon League and the Woman's Christian Temperance Union first targeted local communities and then moved their cause to the national spotlight. Working through local churches throughout the United States, temperance groups had succeeded in getting nine states to enact Prohibition laws by 1913. So many local laws concerning Prohibition were in effect at the time (in thirty-one other states) that effectively half the population of the United States was under some kind of Prohibition in that year. By the time Congress passed the Eighteenth Amendment in 1917, it took less than two years for the required number of states to ratify it.

However, by the time the Twenty-first Amendment, repealing Prohibition, was sent to the states for ratification in 1933, it took less than a year to be accepted (with only North Carolina and South Carolina voting against it). What made public perception shift so dramatically in the years between 1917 and 1933?

Most experts concur that although Prohibition tried to limit the supply of alcoholic beverages, it never eliminated the public's demand for them. Instead, the liquor establishment went underground, and organized crime rings often flourished by offering people access to what they still apparently wanted. While temperance groups had argued that society's moral fiber would improve after Prohibition, violent crimes and other "immoral" activities became more sensationalized than ever.

The attitudes of Americans changed over the course of the Prohibition years. Whereas World War I had brought a spirit of sacrifice and patriotism, the postwar years were marked by a desire for glamour, glitz, and excess. After the stock market crash in 1929, Americans became demoralized, and Prohibition seemed to represent just one more aspect of life being denied to otherwise hardworking and honest folks.

Figure 2.6.
Stills nabbed by Prohibition agent. Courtesy of Library of Congress.

Whatever the complex set of reasons, Prohibition turned out to be a relatively short-lived experiment in legislating morality.

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MEDICINE & HEALTH

The Influenza Pandemic of 1918–1919

Between March 1918 and August 1919, a deadly strain of influenza virus infected populations across the planet and killed between 20 million and 40 million people. The story of this "Spanish flu" pandemic provides a powerful example of the precarious relationship between human society and infectious diseases.

Although often called a flu "epidemic," the outbreak of 1918 was actually a *pan-*

demic, an epidemic of larger (or global) proportions. Even though the first outbreaks occurred in military camps in the United States in March and April 1918 (Camp Funston, Kansas, is cited as the first area known to have been affected), the disease was named "Spanish flu" after a particularly deadly outbreak of the virus took hold in Spain in May of the same year. The disease quickly spread along major transportation and trade routes, and eventually affected one-fifth of the world's population. In the United States, approximately 20 million cases were reported, and between 500,000 and 1 million people died.

What is influenza? Influenza is the name for both a common disease and the viral agent that causes it. Typical "flu" symptoms include fever, cough, sore throat, runny or stuffy nose, muscle aches, headaches, and fatigue. A common misconception about influenza infections is that they necessarily involve nausea, vomiting, or other gastrointestinal maladies. This latter list of symptoms, while more common in children, is not generally recognized as a routine result of influenza in adults. An influenza infection usually lasts 1 to 2 weeks; however, occasionally, and especially among children and the elderly, more serious secondary infections such as pneumonia can develop. According to the Centers for Disease Control, currently an average of 100,000 people are hospitalized each year for influenza-related complications, and approximately 20,000 deaths are reported in the United States.

The influenza virus is known to have a distinctive "enveloped" structure. Like all viruses, influenza contains genetic material surrounded by a protective coating, or capsid. However, in the influenza virus, the capsid is enclosed in a lipid material, which is covered with protein "spikes." The spikes allow the virus to attach itself to living host cells and begin its reproduction cycle. Viruses cannot reproduce on their own, but instead must enter a living cell, force the cell to manufacture copies of its own viral parts, assemble the parts, and release the new copies of the virus to attack new cells.

The "spikes" on the influenza virus envelope are made of two kinds of proteins, hemagglutinin (H) and neuraminidase (N). Different strains of influenza contain different forms and combinations of these two kinds of protein spikes. There are three general kinds of influenza viruses: type A, type B, and type C. Only types A and B infect humans. Within the type A or type B influenza viruses, subtle chemical differences in the H and N protein spikes give rise to even more variation in viral strains, so that many combinations, and therefore many different influenza viruses, are possible.

When an influenza virus enters a human, the H and N chemicals act as antigens—in other words, they signal the body's immune system that something is wrong, and the body gears up to fight the intruding substance. The body produces chemical antibodies in response to the particular antigens. When a person recovers from a viral infection, the antibodies that were created to fight the disease are still present, so that if the same kind of virus should invade the body again, the antibodies can "attack" very quickly, and the person is said to be immune to the virus.

What causes influenza epidemics and pandemics? There are both scientific and sociological reasons why influenza outbreaks—both epidemic and pandemic—are quite common, and are likely to continue to occur on a regular basis.

Outbreaks of influenza occur in a regular cycle (for example, the well-known yearly "flu season") and also in more sudden and problematic episodes (such as the deadly "Spanish flu"). These outbreaks result from two kinds of changes that occur in influenza viruses, antigen drift and antigen shift. Antigen *drift* is a gradual change in the chemical makeup of the H and N protein spikes on the influenza virus. It occurs because of small mutations in the genetic code that happen each time the virus replicates—after a while, the small changes build up to be a recognizable difference in the strain of flu. Yearly "flu seasons" happen because of this slight change to flu viruses that circulate among people every year. Antigen *shift*, on the other hand, is a sudden change in the strain of flu virus (in the makeup of the H and N proteins). Antigen shift occurs when two or more different influenza viruses exist in a living body, and "mix" their parts when they recombine to reproduce. This mixing of flu viruses can occur in humans, but often it occurs in animals such as birds or pigs, which may not be adversely affected and can have many different kinds of flu viruses in their bodies at the same time. The viruses still take over cells and replicate, but if several try to replicate at the same time, a very new virus can emerge. Because the new virus is so different from others in circulation among the human population, its virulence (or potential deadliness) is greatly increased, and an epidemic or pandemic can result.

Social factors also contribute to the spread of influenza viruses. Since the virus is airborne, it is spread through close interaction between noninfected people and infected people who may be coughing and sneezing, therefore communicating the disease. Especially in places such as the United States, where people may feel an obligation to be at work or school even though they may be suffering from flu symptoms, the disease is likely to spread. Also, more options for cheaper and faster travel mean that the potential for infectious diseases to reach many populations quickly is increased. Human agricultural practices can also contribute to the spread of the disease—for example, farming practices that place animals such as pigs and ducks in close proximity create a greater likelihood that those animals' bodies can become "mixing vessels" for antigen shift in influenza.

What happened in 1918? Because scientists at the time of the Spanish flu pandemic were still learning about the nature of viruses, the virus responsible for its outbreak was not isolated during the pandemic. In the late 1990s, scientists were able to isolate some genetic material from three people who died during the 1918 pandemic, and use the material to determine the structure of the hemagglutinin and neuraminidase spikes on the flu virus culprit. Scientists speculate that the Spanish flu virus was dormant in either humans or pigs for several years before it broke out in 1918.

Those who have looked at the historical events surrounding the Spanish flu epidemic note the significance of World War I to the story. Without doubt, the rapid and widespread movement of soldiers during the last months of World War I contributed to the spread of the disease. When the war ended, many soldiers carried the disease home with them and exposed new and vulnerable populations. Even seemingly innocent events such as end-of-war celebrations in which people gathered in the streets to revel in victory had the tragic effect of bringing people into close proximity and increasing the rate of infection.

Ironically, though, the simultaneous context of World War I also probably had the effect of helping control and contain the disease. During the outbreak, many city health and other government officials occasionally had to restrict people's normal freedoms in order to stop the disease from spreading; for example, people were asked to wear gauze masks in public, limit funerals to 15 minutes, and certify their health before entering a new town. Because this happened during the war, some historians speculate that people were already in a mind-set of "personal sacrifice for the common good," and thus instituting restrictive public health measures wasn't as difficult as it might otherwise have been. In fact, at the time of the 1918 pandemic, many allies believed that the Germans had released the virus as a weapon of war, and so were willing to fight it as a matter of national pride.

Could a flu pandemic of similar proportions ever happen again? Epidemics and pandemics of influenza have occurred before and since the Spanish flu of the early twentieth century (for example, less deadly epidemics occurred in 1957 and 1968). Most definitely the potential exists for an influenza pandemic similar to the one of 1918 to occur again. Especially in some locations in Asia, where common farming practices place ducks and pigs in close proximity to each other, the development of new and potentially deadly strains of influenza is always a possibility.

Currently, experts agree that the best answer to the threat of a new influenza pandemic is careful monitoring and prevention strategies. The Centers for Disease Control and the World Health Organization continually monitor the development of new strains of influenza and yearly produce vaccines, or flu shots, to guard against potential outbreaks. Because the vaccines must be prepared and tested well in advance of flu season, the vaccines are speculative—they represent the "best guess" of health officials as to what strains will be prevalent during any particular year. People can also do much to control influenza outbreaks by taking commonsense sanitation measures and being wary of actions that might lead to the further spread of the disease.

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TRANSPORTATION

The *Titanic* Sinks

In one of history's most famous tragedies, the luxury passenger ship *Titanic* sank on its maiden voyage between Southampton, England and New York City on April 14 and 15, 1912. Only around 700 of the more than 2,200 passengers on board the ship survived the sinking. Prior to its launch, the *Titanic* was touted as "indestructible," and news of its demise was met with disbelief by people on both sides of the Atlantic.

The fated voyage. The *Titanic* was meant to bring new elegance and luxury to travel on the Atlantic ferry route. During the late nineteenth and early twentieth centuries, travel between Europe and North America flourished. One reason for the traffic was the demand created by waves of immigrants desiring to start over in the New World. However, ships eventually began catering as well to the tastes of wealthy individuals, who perhaps enjoyed the "royal treatment" they received on such luxury liners at least as much as the holiday time spent on the other side of the Atlantic.

The *Titanic* was built and advertised to be bigger and more opulent than its competitors, and it was with great fanfare that it set out on its initial voyage in April 1912. Members of wealthy and well-known families from Britain, Europe, and the United States were among the passengers, as well as "second-class" travelers who crowded into the ship under more spartan conditions, in the hopes of reaching America for a chance at a new life.

After five days at sea—just before midnight on April 14—the *Titanic* struck an iceberg in the waters off Newfoundland. The iceberg tore at the ship's steel exterior, producing a series of gashes and causing the cold, brittle metal to fracture and separate. Water poured into the ship, and within three hours it had sunk into the icy Atlantic Ocean.

Titanic *science.* The scientific principle that describes how ships float is known as Archimedes' principle. In basic terms, the weight of whatever volume of water is dis-

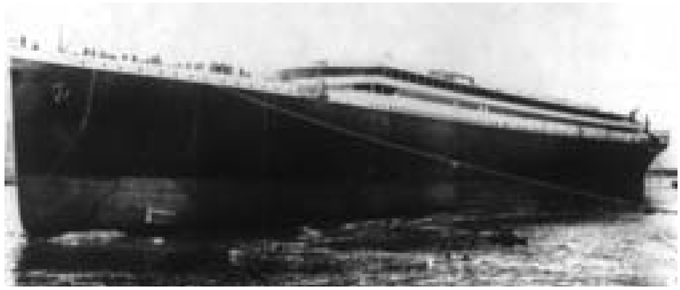

Figure 2.7.
The *Titanic,* 1911. Courtesy of Library of Congress.

placed by a floating object equals the weight of the object. The weight of the volume of water displaced depends upon the size of the surface touching the water. Ships spread their weight over a large surface area, and so displace a large amount of water—enough to support their own weight. Compare that with the design of something like an anchor, which does not float because its weight is packed into a small surface area. It displaces a small amount of water, which is not enough to hold it afloat.

Ship designers must also plan for the eventuality that a collision could puncture the boat, letting water inside. This would obviously change the weight of the boat, so designers allow for a "cushion" in their plans, in case such an event takes place. The ship's body is subdivided into compartments, and each compartment is sealed from the surrounding ones in a watertight fashion. To be seaworthy, ships are required to meet a "one-compartment" standard, which means that one compartment could flood and the ship would still stay afloat. The *Titanic* was designed to exceed this criterion, and in fact boasted a "two-compartment" standard. However, the iceberg that tore the ship apart on its maiden voyage caused at least five compartments to fill with water. It is actually a comment on the effectiveness of its watertight seals between compartments that the ship took nearly three hours to sink.

The story lives on. The story of the *Titanic* has proven quite alluring throughout modern history. There are several reasons that seem to contribute to the public's fascination with the tragedy. Public interest in lifestyles of glamour and wealth most certainly played a part. In addition, the *Titanic* story in many ways became emblematic of the struggle between wealth and poverty, for the scores of low-fare passengers on the *Titanic* were never told of the impending disaster nor given a real chance to escape. Tales of individual strength and courage—displayed by those who lived or died—captured public imagination. Stories such as the tale of the "Unsinkable Molly Brown," or the dance band that heroically continued playing while the ship went down became sustenance for future artistic endeavors, including musicals, songs, and movies. The recovery of the wreck in 1985 also rekindled the public's interest in this slice of history.

Another reason the *Titanic* story has been so compelling may be that people have always been drawn to the helplessness of its tragedy. In hindsight, much of the disaster was preventable, had basic safety procedures and equipment been in place. The *Titanic* crew either did not receive warning messages about the iceberg in its path or ignored them. The *Californian*, a ship which had been close enough to assist the fated *Titanic*, had missed her distress call because its radio operator was off-duty at the time of the tragedy. In addition, the *Titanic* had lifeboat space for only a little more than half of its passengers. Because of these failings, new safety regulations were adopted for maritime travel, and the International Ice Patrol was created so that ships could be told of potential dangers in their navigation routes. The legacy of the *Titanic*—pragmatic and romantic—lives on.

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HUMAN KNOWLEDGE

During the second decade of the twentieth century, scientific and technological advancements would lead to profound changes in future thinking and living. Besides the development of atomic theory and the introduction of the theory of continental drift, the decade saw the foundations laid for significant progress in understanding other aspects of nature.

Explorers of various stripes continued to canvass the globe in the 1910s. Roald Amundsen, disappointed to have been denied his dream of becoming the first to reach the North Pole, became the first to reach the South Pole in 1911. Tragically, a competing expedition led by Robert Falcon Scott arrived a little over a month after Amundsen, and later was wiped out by exposure and starvation. On another kind of expedition, Yale Professor Hiram Bingham climbed the Andes Mountains and introduced the academic world to the mysterious ruins of Machu Picchu, a pre-Colombian city with thousands of steps linking houses and garden terraces.

Several discoveries and inventions of the decade pointed toward exciting future possibilities for research and technology. In 1912, the Polish biochemist Casimir Funk discovered vitamins B1, B2, C, and D, and postulated a deficiency theory of disease that explained an important link between nutrition and health. George Washington Carver announced the results of his work with peanuts and sweet potatoes, detailing the many products which could be derived from these plants. Heike Kamerlingh Onnes discovered low-temperature superconductivity by demonstrating that at temperatures approaching absolute zero, some substances exhibit virtually no resistance to an electric current. Robert Goddard filed patents for a liquid-fuel rocket propulsion system and a multistage rocket design in 1914.

Logic was paramount in some significant advances of the 1910s. Bertrand Russell and Alfred North Whitehead published *Principia Mathematica*, which was a comprehensive treatise on the logical foundations of mathematics. And Albert Einstein's method of conducting logical "thought experiments" to derive theoretical knowledge about the world led to the development of his general theory of relativity, published in 1916.

The Quantum Atomic Model Is Born

At the turn of the twentieth century, scientists were still coming to terms with the implications of an atomic world. Einstein's paper on Brownian motion, which definitively confirmed the existence of atoms, was only a few years old when Ernest Rutherford discovered atomic nuclei. At the time, scientists knew that atoms contained electrically charged negative particles, but the arrangement of these particles within an atom was not known. A plausible design had been suggested by J. J. Thomson, whose "plum pudding" model of the atom conceived of tiny negatively charged particles embedded in some sort of positively charged amorphous matter.

Rutherford designed a famous experiment that would reveal startling evidence about the structure of atoms. In previous work, he had noted that when he sent radioactive alpha particles through a thin film of mica, the particles seemed to spread out; the sharp beam of alpha particles going into the mica was a fuzzy beam of particles after having passed through the substance. He decided to measure the scattering of alpha particles that had been sent through a very thin film of gold foil. To his surprise, some of the alpha particles were deflected nearly completely backward upon hitting the gold foil. Because the alpha particles were traveling at extremely high speeds and were simply aimed at a very thin piece of foil, no one expected that they could be repelled so strongly. To put this observation in perspective, Rutherford commented that it was like firing a huge naval shell at a piece of tissue paper and having it bounce back.

Rutherford pondered the results of the gold foil experiment, and determined that an explanation for the alpha particles' behavior must lie in the structure of the gold atoms. Since alpha particles were positively charged bits of radiation, Rutherford reasoned that they could be sent backward if they came into contact with an extremely powerful positive charge, since substances with the same electric charge will repel one another. In 1911, he revised the "plum pudding" atomic model: instead of the positive charge of an atom being spread throughout an amorphous, gel-like substance, Rutherford hypothesized that all of the positive charge of a particular atom was contained in an extremely tiny, dense, central space he called the *nucleus* of the atom. Rutherford saw the negatively charged particles as orbiting the positive nucleus, similar to the way that planets orbit our sun. This explained the gold foil experimental results: most of the alpha particles passed through the empty spaces between the electrons, though a reasonable number of them were deflected slightly because they would be affected by an attraction to the negative particles they passed on their way through the foil. Every now and then, however, one of the alpha particles would be aimed directly at a tiny gold nucleus with a large positive charge—and in this instance, the repulsive force would send the alpha particle careening backward.

Bohr quantizes the atom. Scientists were excited about the discovery of the atomic nucleus, but they were puzzled as well. If atoms truly existed the way Rutherford described them, then they should be extremely unstable. Scientists knew that whenever a charged particle accelerates, it gives off radiation, or energy. They also knew that it would take energy to hold negative and positive charges apart. If tiny negatively charged particles were orbiting the atomic nucleus, then they should be emitting radiation on a constant basis, which would make them lose energy. These particles would be less and less able to remain in orbit some distance away from the positive charges, and with continual movement and continual energy loss, should eventually spiral closer and closer to the nucleus.

Niels Bohr solved the problem of atomic structure in 1913 by combining Rutherford's planetary model with the emerging ideas of quantum mechanics. He hypothesized that the negatively charged particles, or electrons, orbited the nucleus in fixed trajectories. A number of orbits existed at various distances from the nucleus, and each corresponded to a certain amount of energy that would be necessary to hold an electron in place. Thus, the various electron orbits surrounding a nucleus became known as energy levels.

Bohr claimed that as long as an electron remained in its fixed orbit, it would not lose energy. However, if it were to "jump" to a higher energy level or "fall" to a lower one, it would need to acquire or emit a certain amount of energy, so that its total energy would be what was necessary for the particular level. Bohr reasoned that these energy jumps consisted of discrete amounts of energy, or *quanta*.

The Bohr model of the atom was a revolutionary achievement. Still, it did not fully account for the quantum behavior of subatomic particles. Later, scientists would use mathematical models which treated electrons as waves (rather than particles) to come up with more elaborate schemes of quantum atomic design. For all its shortcomings, however, the Bohr model is quite powerful as a basic representation of atomic structure. It allowed scientists to see a submicroscopic, atomic universe in an entirely new way.

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Wegener Proposes the Theory of Continental Drift

In 1912, the German meteorologist Alfred Wegener offered an explanation for why the Atlantic coastlines of the western and eastern hemispheres appear to fit together as the pieces of a jigsaw puzzle might. He claimed that the continents were once joined in a single, huge landmass known as *Pangaea*. According to Wegener, over millions of years the continents had drifted to the locations in which we know them today.

Evidence for Wegener's theory existed in the fossil record as well as in knowledge of living species. Several species which were found in South America and South Africa would seem to indicate the possibility that these two continents were once not separated by an ocean. In addition, layers of rock across the Atlantic can be matched up; for example, rocks in Scotland can be paired to similar formations in North America. Wegener also pointed to the way in which transatlantic mountain ranges can be fitted together like puzzle pieces.

Despite these observations, most scientists discounted Wegener's theory at the time he proposed it. Having long believed that the landmasses covering the earth were stationary, not many scientists were willing to accept such a revolutionary idea. In fact, Wegener was the target of public ridicule until his death in 1930. A major problem was that despite evidence for continental motion, Wegener was unable to postulate a mechanism for how these massive continents could drift across the planet.

Wegener's legacy was vindicated in the 1950s and 1960s, when geologists were finally able to propose such a mechanism. Evidence suggested that the outermost region of the earth—the lithosphere—is made of rocky matter that is broken into large, distinct regions known as plates. The layer of the earth directly under the lithosphere is a molten, fluidlike layer known as the asthenosphere. Convection currents cause the earth's plates to "float" along the asthenosphere, carrying the continents with them. Although this process—as articulated in the theory of plate tectonics—is extremely slow, over vast expanses of time its effects can be profound. The areas along plate boundaries are geologically active and produce features such as mountain ranges, volcanoes, and earthquakes.

Although Alfred Wegener never knew it, his ideas were eventually appreciated for their groundbreaking insight. Earth scientists today continue to study and develop the concepts and principles behind continental drift and plate tectonics.

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Chapter 3

THE TWENTIES

SOCIETAL CONTEXT: THE ROARING TWENTIES

In the United States, the 1920s were characterized by a fast yet carefree pace. The pulse of the time was quick, as radio coverage conveyed the news instantaneously to interested parties. Listeners heard that Warren G. Harding defeated James M. Cox in the 1920 presidential election hours before newspapers could publish the victory. Play-by-play radio coverage of the World Series brought even more popularity to a game that was already dear to Americans and others across the world. Even printed news was being presented in a new format, in order to keep busy people up-to-date. First published in 1923, *Time* magazine became popular because of its compressed design for reporting the news.

Historians also recognize the 1920s as the birth of popular culture. Mass production of items such as cars, mass media via the radio, and mass consumption of entertainment and material goods were responsible for assisting a large population in sharing experiences and goals. The first paid radio commercial was aired on New York City's radio station WEAF in 1922. Technology brought to people of the 1920s a buying power and craving for material goods never before seen.

The 1920s were bursting with social and political changes. President Woodrow Wilson's dream of an international body working toward collaboration and cooperation was begun in the League of Nations, even though the United States never held membership during the 26 years of the League's existence. At the same time, activist groups hoped to cure the ills of society by curbing the manufacture, sale, and consumption of alcohol through Prohibition. Instead, the Eighteenth Amendment opened the doors for organized crime, speakeasies, and bootlegged spirits, as many Americans broke the law in order to have the freedom to consume alcohol.

Figure 3.1.
Flappers do "The Charleston" in the nation's capital, ca. 1920–1930. Courtesy of Library of Congress.

Women won the right to vote when the Nineteenth Amendment was passed. And for the first time, African-American art forms were being exhibited as genius when African-American jazz musicians such as Louis Armstrong played in nightclubs in New York City, Chicago, and Kansas City. The rich as well as common workers frequented these nightclubs in appreciation of talent suppressed and ignored in past generations.

Despite the optimistic note on which the decade began, it ended with turmoil and disaster. Gambling, prostitution, drinking, and corruption were all on the rise, and the stock market crash on October 29, 1929, initiated the depression that would characterize life in the decade to follow.

ARCHITECTURE & ENGINEERING

Holland Tunnel Constructed

Completed in 1927, the Holland Tunnel became a marvel of modern architecture. It was the world's first lengthy underwater tunnel designed with a mechanical ventilation system to flush out noxious gases created by the multitude of vehicles that traveled through it daily.

Disconnected. With its growing population, the island of Manhattan found it more and more difficult to bring in supplies to meet the needs of its populace at the beginning of the century. By the end of World War I, ferries across the Hudson River could not keep up with the growing number of vehicles traveling back and forth between New York City and New Jersey. In 1913, a proposal to build a bridge was quickly rejected because a bridge high enough to clear the harbor shipping required the purchase of costly land. Instead, it was proposed that a tunnel be considered to meet the needs and conditions of life in Manhattan.

Six years later, Clifford Holland, a civil engineer, was given the job of designing and drilling a highway tunnel under the Hudson River. Construction of the tunnel began on October 12, 1920. Holland sagely anticipated that the tunnel must be constructed with a capacity to allow for a huge volume of daily traffic, and that the resulting large amount of carbon monoxide gas had to be cleared from the tunnel safely.

The art of construction. In order to make the tunnel easily accessible to as many travelers as possible, Holland positioned it between two major highways. Digging the tunnel required a slow, almost blind maneuvering of machinery and men beneath the riverbed. Crews drilled holes, blasted with dynamite, excavated the pathways, and reinforced the walls, then started over again for the next section. The north tube would be 8,557 feet long and the south tube measured 8,371 feet, each with an inside diameter of 29.5 feet. In order to prevent water from filling the tunnel, compressed air was forced into the heading of the tunnel to offset the water pressure surrounding the newly formed empty space.

Despite these impressive statistics, it was the unprecedented ventilation system that gave the tunnel its fame. Designed by Ole Singstad with the help of scientists from Yale University, the University of Illinois, and the U.S. Bureau of Mines, it exchanged 4 million cubic feet of exhaust gases for fresh air every minute. It would have required a 75-mile-per-hour wind pushing air directly through the tunnel to match the efficiency of the ventilation design. Instead, a transverse-flow system was designed to draw fresh air through one of four ventilation buildings, using blowers and exhaust fans of 6,000 total horsepower to move the air.

Figure 3.2.
The tunnel pump room in Holland Tunnel North, 1927. Courtesy of Library of Congress.

Fresh air enters the tunnel through narrow openings just above the curb, spaced 15 feet apart. Exhaust fans pull the polluted air through openings located above the ceiling tiles and discharge it into the open air through the rooftops of the four ventilation buildings. Fresh air can be completely exchanged in the tunnel every 90 seconds when the fans are running at top speed. Engineers and medical personnel worked together to design instruments that monitor the carbon monoxide levels of the tunnel air and simultaneously change the speed of the ventilation system fans as needed.

Why the need for ventilation? Carbon monoxide (CO) is an odorless, colorless gas produced as a by-product of the incomplete burning of hydrocarbon fuels such as gas, oil, and kerosene. Incomplete combustion occurs when there is a shortage of oxygen. The resulting products are carbon monoxide, water, and energy. The following equation demonstrates the reaction: $2\ CH_4 + 3\ O_2 \rightarrow 2\ CO + 4\ H_2O$ + energy. Carbon monoxide gas is emitted from the tailpipes of cars, and the amount produced increases in cold weather, when the engine is not tuned properly, and when cars' engines are left idling. Hundreds of people die accidentally every year from CO poisoning caused by idling cars.

Breathing carbon monoxide can cause permanent tissue damage and even death. The gas combines with hemoglobin molecules of red blood cells more readily than does oxygen, leaving fewer cells available to carry the necessary oxygen to parts of the body that need it. People with moderate carbon monoxide poisoning show symptoms such as severe headache, dizziness, confusion, and nausea. Since many of these symptoms are similar to those of the flu or food poisoning, CO poisoning may not always be readily identifiable. However, recognizing the effects of carbon monoxide inhalation is critical, since at high levels of intake, death can occur.

The tunnel through the century. After seven years of construction, the tunnel opened to the public. On November 13, 1927, the first day of operation, a toll of 50 cents was charged for the 8-minute drive through the tunnel. That day over 51,000 vehicles passed through the longest underwater ventilated structure in the world. The total cost of the tunnel was $48 million, equivalent to about $1.5 billion today. Unfortunately, Holland never saw his plan come to fruition. In 1924, he suffered from exhaustion and was admitted to a sanitarium, where he died of a heart attack at age forty-one. Ole Singstad served as chief engineer for the opening ceremony.

On May 13, 1949, a truck accident on the New Jersey side of the tunnel caused major damage. The truck carried carbon disulfide, an explosive material, which burst into flames. The wall and ceiling slabs were demolished, and although there were sixty-six injuries, no one died. The fire caused approximately $600,000 in damages, and resulted in the establishing of new standards for transportation of explosives.

In 1984, the Holland Tunnel received special status as a National Civil Engineering Landmark by the American Society of Civil Engineers. In 1992, a complete renovation of the entire toll plaza and administration building was completed, and by the end of the following year, investment in the tunnel was more than $272.5 million. Presently, about 100,000 cars drive through the tunnel each day.

Lasting impact. The Holland Tunnel has had a notable and lasting impact on American society, especially where transportation and engineering are concerned. The tunnel created easier access between New Jersey and New York City, thus promoting more vehicle travel, creating more jobs, and allowing New York City to sustain even more growth. The design and construction of the Holland Tunnel serve as a model for other major structures, tunnels, and bridges. The Holland Tunnel is one of the few engineering feats named after the designing engineer, and admirers often called it the eighth wonder of the world.

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ARTS & ENTERTAINMENT

Golden Age of Amusement Parks

The 1920s was a decade of indulgence. The rise of the roller-coaster industry paralleled the rise of an easygoing and fun-loving society. Americans were seeking leisure time enjoyment, daring obstacles, and big thrills. Nowhere could all three of these desires be met more quickly than at an amusement park, aboard a roller coaster.

Rise of the roller coaster. In the postwar years, Americans delighted in financial security, a shorter workday, and lifestyle changes brought about by a variety of modern conveniences. The stock market was booming in paper wealth, and credit was widely available to those who wanted it. Working Americans found themselves with 12 extra hours of time during a regular workweek: instead of 60 hours, the week was now 48 hours. For the first time in history, many Americans viewed play as more important than work. This increase in free-time hours, coupled with the convenience appliances found in most homes, led Americans to seek out various forms of entertainment. They wanted to play, spend money, and experience life as they never had before.

Luckily for thrill-seeking Americans, John Miller was paving the way for an exciting new pastime by building "death-defying" roller coasters. These fast coasters incorporated scientific and technological advancements that pushed the limits of this fast-growing industry. Miller himself patented over fifty inventions, many during the first two decades of the twentieth century. One very prominent patent was the "Anti Roll Back Safety Dog" that prevented coaster cars from rolling backward while being pulled up a hill. This device, which is still used on present-day roller coasters, produces a clanking sound as the car moves up the hill. Miller also developed and patented the locking bars that keep riders in their seats while experiencing negative gravitational forces, or "negative g's." Another notable patent credited to John Miller is the friction wheels which lock the coaster trains to their tracks. Without a doubt, Miller paved the way for more daring roller-coaster designs.

Harry Traver advanced his own coaster ideas, using Miller's patents. He designed roller coasters with structural technology different from anything used before. Traver applied Miller's ideas to a new type of coaster, made of steel. Until this time, coasters were constructed of wood, but throughout the 1920s Traver began working on steel coasters that he believed would prove stronger and more resistant to wear than their wooden counterparts. Traver's coasters were almost always constructed near or on a beach, and two were built on piers stretching into the water. Traver was quite successful, and his engineering company became the world's largest amusement ride manufacturer. It produced over 2,000 rides, including many coasters, from 1919 to 1932.

How did inventors use science to build a better coaster? Roller coasters (as well as most amusement park rides) use the principles of physics to create excitement and the illusion of danger, although the rides themselves are carefully calculated and built for safety. A motor and attached chain pull the riders to the top of the first hill, and from there, gravity takes over. The relationship between the height of the first hill and the speed of the coaster is the basic principle of this thrill ride. In any ordinary physical system, forms of energy (heat, light, motion, sound, etc.) are conserved;

in other words, they are neither created nor destroyed, but changed from one form to another. In roller coasters, the force of gravity pulling on the coaster from the top of the first hill provides the coaster's speed: the gravitational potential energy it has due to its height at the beginning is converted into kinetic energy by the time the coaster reaches the bottom of the hill.

Once the coaster train is in motion, Isaac Newton's first law of motion applies—a body in motion stays in motion until acted upon by another force. This force could be friction from applying brakes or wind resistance. Each time a force like this acts, the coaster cars lose kinetic energy, which is subsequently converted to heat or sound energy. This loss of kinetic energy results in a loss of speed. If, however, during the ride additional energy is transferred to the coaster from a motor or another large hill, speed is maintained.

Roller-coaster designs also aid in their effectiveness. Three different types of wheels keep the ride smooth and safe. Running wheels navigate the coaster on the track, friction wheels control the car motion from side to side, and the third set of wheels keeps the coaster on the track even in an inverted loop. The shape of each hill on a roller-coaster course determines how fast the coaster can safely travel and stay on the track. The path out of each hill or loop needs to be designed so that the coaster maintains its excitement yet provides a safe transition to the next section of the ride. Speed is directly related to the height of the hill or loop just finished. In order to continue the feeling of high speed at the end of the ride, designers add sharper curves to take advantage of whatever speed remains after the last hill.

Roller coasters' popularity takes a downhill turn. America's fascination with leisure and amusement parks during the 1920s temporarily ended during the Great Depression. Americans found themselves out of work, out of money, and out of hope. The decade of indulgence had come to an end, and there was no longer a place for the roller coaster in the discouraging economic climate. Following the Great Depression, the amusement park industry experienced a revival, only to be hampered once again by World War II. After the war, Americans were introduced to the television set, and a growing number of families chose to be entertained in their own homes. By the end of the twentieth century, the demand for roller coasters had again increased. Like the first productions, current coaster designs test the limits of science, technology, and human nature. Thanks to inventors like Miller and Traver, modern designers are able to create higher, faster, and more dangerous coasters than ever before.

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COMMUNICATION

The Birth of Television

Although the groundwork for television was laid in earlier decades and its popularity would not come until later, the invention underwent some of its most significant advances during the 1920s. In many aspects, the story of the development and eventual success of television illustrates how science, technology, and society invariably shape and are shaped by one another.

Who invented television? As with many inventions, no one person is given full credit for the conception and invention of television. Rather, a long line of inventors generated a web of ideas that improved upon each other's contributions to create what we now know as television. The first television sets scanned and transmitted images in a mechanical fashion, using a rotating disk; however, by the end of the 1920s, television systems were electronic devices built around a cathode ray tube (CRT) unit.

Mechanical television. Most historians identify a German engineering student, Paul Gottlieb Nipkow, as the first person to fashion a mechanical television system in 1884. He conceived a scanning system that analyzed the intensity of light coming from small portions of an image. Nipkow incorporated a rotating disk with numerous holes arranged in a spiral pattern around the edge. These holes produced a scanning pattern that could later be translated into electrical signals. Nipkow's rotating disk was placed between the setting and the chemical element selenium. Eleven years prior to Nipkow's work it had been discovered that selenium's electrical conductivity varied with the amount of illumination it received. Nipkow used this photoelectric property of selenium in his design to generate an electrical signal to transmit the image or to produce the image at the receiver. The number of holes in the disk corresponded to the eighteen scanned lines it successively transmitted to a receiver. However, eighteen lines of resolution seriously limited brightness, smoothness, and details in the picture.

John Logie Baird, a Scottish inventor, improved Nipkow's system. He used arrays of transparent rods to send the first television transmission. He produced thirty lines of resolution, but the image, of a ventriloquist's dummy, was still barely recognizable. In 1925, Baird presented the first televised objects in motion and furthered the practicality of television by succeeding in broadcasting a transatlantic transmission in 1928.

During this same decade, Charles Francis Jenkins invented another mechanical television system predicated on a mechanical scanning drum. This system was basically a radio capable of receiving sound, but it included a special attachment to receive video. The images, though cloudy, were produced using forty to forty-eight lines of resolution and were projected onto a 6-square-inch mirror. Jenkins appropriately called his device a radiovisor.

Electronic television. As other inventors were making improvements on mechanical television, a fourteen-year-old American high school student named Philo Farnsworth shared his vision of an electronic version of television with his science teacher. At the time, mechanical television projected uneven images due to the relatively slow speed of the rotating disk. Farnsworth reasoned that the great speed of electrons could produce smooth, lifelike images to the human eye. He proposed using the principles behind the cathode ray tube (CRT) to improve television: an electron beam could scan pictures and transmit them onto a screen.

How does the television tube work? In 1875 Sir William Crookes, a British scientist, discovered that electric current traveled better in low-pressure gases. He continued his investigation by sealing a wire electrode at each end of a glass tube and removing the air from the tube with a pump. He observed an arc created by the electricity jumping from one end to the other until the whole tube glowed with a pale pink light. The lower the pressure, the longer the arc. However, when the pressure in the tube approached a vacuum, the glow disappeared. Crookes noticed a glow at the negative electrode, the cathode. This glow is actually a stream of electrons. The stream of electrons can be guided up or down, left or right, by magnetic or electric forces surrounding the beam, since the negatively charged electrons are either attracted to or repelled by the forces. The beam can also be directed at a chemically coated screen that will glow when hit by the electrons. These principles underlie the functioning of a cathode ray tube.

The television tube Farnsworth invented was a form of the CRT. The thin electronic beam swept back and forth across the end of the television tube like a paintbrush, making thousands of strokes in one second. The stronger the beam used, the brighter the picture that was created. In a broadcast, the strength of the beam is controlled by the radio waves received by the television's antenna. The waves are adjusted or modulated to produce light and dark patterns of the setting being televised.

Farnsworth is said to have dreamed up the idea of television as a teen, while plowing fields on the family farm in Idaho. Looking at the field, he thought about the possibility of having electrons scan and subsequently transmit pictures in horizontal rows. Several years later, Farnsworth developed a working "image dissector" system that incorporated these ideas. Essentially he used a spray of electrons emitted from an "anode finger," controlled the location of the electrons with magnetic coils, and then used a CRT and a fluorescent screen to reproduce the image. In 1927, he applied for a patent of his device.

Farnsworth's system was superior to the mechanical ones that preceded it because his device was capable of transmitting twenty pictures every second. Humans can't detect changes in images that occur faster than twenty-five or thirty times per second, so Farnsworth's device delivered images that were very close to appearing as smooth as events in real time.

The legal battle over television. Farnsworth was applying for a patent on this new idea when another inventor claimed the rights to television with a patent request. In 1923, Vladimir Zworykin, a Russian inventor working for the Radio Corporation of America (RCA), invented what he called an "iconoscope." The iconoscope used a specially treated vacuum-tube camera. Zworykin was given the patent for his invention in 1925, prior to completing a working model. Farnsworth contested the patent, noting that he had the idea and a working model before Zworykin. Sketches and drawings that Farnsworth had shared with his high school teacher and the working model he had previously demonstrated for news reporters helped him win the 15-year-long legal battle for the rights to the electronic television. RCA appealed the decision, but eventually bought the patent from Farnsworth. RCA would later win the public relations game, publicizing television as Zworykin's invention and perfecting the technology. Sales of television sets exploded in the late 1940s and continued through the end of the century, when most families owned more than one set.

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ENVIRONMENT

The Battle of Blair Mountain

In the 1920s, society was largely dependent on coal for fueling industrial, transportation, and heating systems. Coal consumption reached its peak in the United States in 1927. Unfortunately, the laborers who mined coal were often exploited financially and forced to work in extremely unsafe conditions. In southern West Virginia in the summer of 1921, tensions reached a crescendo when thousands of miners marched to Blair Mountain in what turned out to be a bloody and symbolic battle between labor and management.

Coal was the fuel of choice. In the mid-1800s, the popularity of coal as a fuel began to increase. The industrial revolution brought with it a rise in the use of steam engines, which were powered by coal. American business was expanding, and railroads kept pace as they were built to crisscross the nation. Not only did this allow for more efficient transportation of coal and other goods, but it also required consumption of a large amount of coal. By the turn of the century, coal was the fuel of choice.

What is coal? Coal is one of the three fossil fuels, along with petroleum and natural gas. Geologists believe that coal formed in thick layers as lush vegetation died and decayed. Layer after layer of soil, rock, and decaying vegetation built up and caused enormous pressure on the lower layers. This pressure and the heat from the earth's interior slowly converted the plant remains into coal. Four forms of coal (from softest to hardest) are peat, lignite, bituminous, and anthracite. Peat contains the most moisture and the least carbon. Anthracite contains the least moisture and has the greatest carbon content, about 80 percent. The high concentration of carbon makes it an excellent fuel source.

Coal played a significant role in meeting society's needs because it is so easy to obtain and use. It can be distilled to make a variety of other products, such as coal gas, coal tar, coke, and ammonia. Coal gas is a mixture of hydrogen, methane, and carbon monoxide, all of which are flammable. Coal tar is used to make chemicals such as benzene, toluene, and naphthalene. Coke is a fuel used in industrial processes, and ammonia is converted into ammonium sulfate for use in fertilizers.

However, the use of coal has negative effects on the environment that weren't fully realized until the latter half of the century. Burning coal is a dirty process, as coal leaves more soot than other fossil fuels. Coal also contains about 7 percent sulfur, which when burned is converted into air pollutants, SO2 and SO3. In addition, a coal-fired power plant can give a radiation exposure hundreds of times greater than is obtained from a normally operating nuclear plant. Coal contains trace amounts of radium, uranium, and thorium, which are vented into the air and settle in the communities near coal-burning power plants. According to the Environmental Protection Agency (EPA), a person living within 50 kilometers of a coal-burning power plant is likely to receive 50 to 380 millirems of radiation per year, depending upon the type of coal. This dose is surprising, but not dangerous—a chest X-ray dose to the bone marrow is about 50 millirems and the chest X-ray dose to the skin is about 1,500 millirems. Coal mined in the western states is generally more radioactive than that mined in the east.

Dangers for the miners. As society's need for coal increased, skilled miners were asked to find techniques to increase production and maximize the efficiency of the mining process. Not only did this necessitate advances in mining technologies, it also meant more coal had to be found. By the 1860s, some coal mines in Pennsylvania reached depths of 1,500 feet. The "engineers" called upon to solve the many safety concerns were not as much engineers as they were experienced coal workers. The result was increasingly unsafe mining environments.

Two of the most vexing problems related to mine safety were the inability to drain water from the mines and the tendency of the highly flammable methane gas that collected in the mines to catch fire and explode. To alleviate the flooding problem, steam-powered pump systems were installed. However, a broken pump would lead to a major flood of a mine. The issue of mine explosions was by far the most serious of all safety issues. The most common solution to this problem was the use of furnaces at the end of mine shafts to create drafts, which would allow ventilation to clear the air of methane. This system was usually effective but still carried a dangerous consequence if the system were to malfunction. If the furnace ignited deep within the mine shaft, the wooden support beams and other timber in the mine often caught fire. This fire depleted the oxygen and suffocated workers trapped in the mine's underground chambers. By 1902, at least 35,000 mine workers had been killed or injured in Pennsylvania mine explosions alone.

Problems between labor and management. In addition to the physical dangers they faced, miners were often exploited by their employers. Miners commonly earned a meager $1.50 for a 12-hour day. Because families were so large and wages so paltry, young boys often went to work before they had finished primary school. The houses provided by the companies were often small shanties that housed as many as twenty people. Furthermore, employees were often paid in "scrip," which was money redeemable only at a company store where high prices were common.

Not surprisingly, the growth of industry and coal use was paralleled by the development of the labor movement. Starting with trade guilds, laborers began forming organizations to promote workers' rights. However, the most widespread and effective activity of labor unions occurred after workers gained the right to form unions in 1825. The United Mine Workers of America (UMWA) was formed from the merger of smaller unions in 1890.

The West Virginia coal mine wars. West Virginia's many coal miners were slow to join the UMWA. This was largely due to pressure from mine owners, who forced their employees to sign "ironclad" or "yellow-dog" contracts that forbade them to organize or strike. Workers were fired or evicted from company housing if they were found to have associated with union members. Local politicians in West Virginia were supportive of the mine owners' concerns about unions, and often assisted in preventing workers from organizing.

During World War I, efforts to recruit more miners for the unions were stalled. However, by 1919, the UMWA launched renewed efforts to organize areas in the southern part of the state. In Logan County, Sheriff Don "Boss" Chafin was sympathetic to mine owners and often used his police force to obstruct miners' efforts to organize. However, in the town of Matewan, Police Chief Sid Hatfield was supportive of miners, and in 1920 he and a group of armed miners ambushed some company-hired detectives who were evicting miners with union ties. Ten people died in the "Matewan Massacre," but Hatfield became a folk hero to miners in the area.

The next summer, Hatfield was found innocent of wrongdoing, but was assassinated shortly afterward. Union leaders saw the event as an opportunity to unite miners, finally face Boss Chafin, and potentially win the right to organize. In late August, 5,000 to 10,000 miners assembled at Lens Creek Mountain and marched to Blair Mountain, wearing red bandanas around their necks as a symbol of their support for the union. The conflict is often referred to as "the Red Neck War." News of the coal mine wars in West Virginia led outsiders to investigate work conditions, and the political climate began to change to favor workers' rights. The National Industrial Recovery Act, passed in 1933, protected the rights of miners everywhere to organize.

Lasting changes. Eventually, major changes took place in the safety and work conditions of coal mines. By 1947, electricity was commonly used in mines to create a safer, less physically demanding workplace. Conveyor belts transported coal and people, air compressors helped operate machinery, and surface and underground fans were used to improve ventilation. In the 1940s, strip mining provided a safer work environment, allowed for more complete recovery of coal deposits, and reduced production costs. Employee wages also saw a steady increase. In 1969, President Nixon signed the Coal Mines and Safety Act, protecting miners from their harsh working environment.

While working conditions improved, the negative effects of mining on the environment became a focus of attention in the latter part of the twentieth century. Strip mining, especially mountaintop removal strip mining practices, have left permanent scars on the landscape in certain areas of the United States. However, the effectiveness of unionists in the 1920s can be measured by the fact that most serious and controversial topics in mining today deal with reclamation of abandoned mines and their environmental impact, not the health and safety of miners.

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FOOD & AGRICULTURE

Mechanical Food Preservation

In the early 1600s Lord Francis Bacon stuffed a hen with snow to test the idea that cold would preserve food, but he died before he was able to share the results of his experiment. Two centuries later, scientists discovered that harmful bacteria which contribute to food decay cannot flourish and multiply in temperatures less than 10° Celsius. It was also discovered that cold food storage had limits: foods such as lettuce could be damaged if kept below freezing. Until the 1920s, there was no practical way of incorporating these findings into methods for storing food for everyday use.

What was used to cool food before the invention of the mechanical refrigerator? Before the mechanical refrigeration unit was invented, huge ice blocks were collected from northern lakes and stored in insulated warehouses. Families bought this ice and stored it and their food in an ice chest, lowered the food and ice blocks into wells, or kept the ice in cool caverns or cellars. At times chemicals were used to lower the temperature. In fact, by the eighteenth century there were about fifteen different combinations of chemicals that made it possible to keep objects cold. But in reality most families did not use cold storage to preserve foods because of its inefficiency and limited practicality.

The science of keeping food cool. In 1748, William Cullen of the University of Glasgow made the earliest demonstration of man-made production of "cold" when he evaporated ether in a partial vacuum. As the ether evaporated, it absorbed the heat from its surroundings, giving them a cold feeling. Nearly a century later, in 1844, a machine for cooling was invented. John Gorrie of Apalachicola, Florida, invented a machine for cool storage in hospitals. Patented in 1851, Gorrie's machine was produced in New Orleans and shipped to kitchens of wealthy families. However, the machine was not without problems—it was small, leaky, and noisy, and it often iced-up uncontrollably.

In the early 1900s, Willis Carrier improved on the basic mechanical unit by designing a system that could better control the humidity in the atmosphere. But it was not until 1923 that Frigidaire, a division of General Motors, engineered a chest that enclosed both the refrigeration unit and the components of the cooling system to make a relatively quiet and compact device. As assembly-line manufacturing took hold, prices dropped, and more families bought the mechanical refrigerator (or, as it was named for decades, the "icebox").

How does a refrigerator work? In refrigerators, a small electric motor compresses a gas such as ammonia, methyl chloride, sulfur dioxide, or a compound such as Freon.

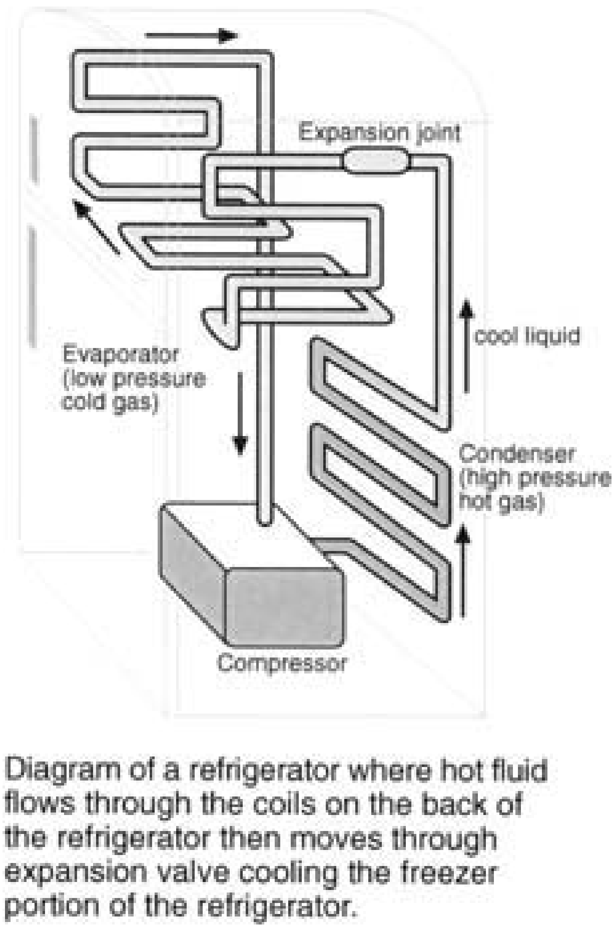

Figure 3.3.
Diagram of a refrigerator.

The compressed gas goes to a condenser, where it is cooled by water or air, and liquefies. It is then passed through pipes to the freezer coil inside the refrigerator, where it changes back to a gas, using up much heat in the process. It soaks up this heat from inside the refrigerator, making the refrigerator cooler. The gas then returns to the compressor to start the cycle over again. This heat is carried away in the condenser and is often felt coming from the bottom of a refrigerator.

More than a convenience. Over the century, the invention of mechanical refrigeration impacted families in several ways. Because most homes were wired with electricity, the 1923 Frigidaire, like the Model T Ford, brought amenities even to working-class families, raising the standard of living across the country. Before the refrigeration unit, it was not possible to keep fresh meat, dairy products, and vegetables for an extended period of time. By storing food cool or frozen, it could suddenly be held two to five times longer than it could otherwise be kept. This reduced the number of trips to buy fresh food and, more important, provided for the transport and availability of a variety of foods. Fresh meats, fish, fruits, and vegetables could be shipped across the country in refrigerator units. This increased the number and variety of vitamins and minerals available to consumers. It also extended the time in which families could enjoy a given food. By the end of the century, fresh foods were available to consumers practically year-round. The availability of the mechanical refrigerator made increased health and better food choices possible for many Americans.

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MEDICINE & HEALTH

The Power of Penicillin

In the first few decades of the 1900s, placing a person's life in the hands of a physician was seldom cause to be optimistic about his or her survival. Often, little could be done to heal a person who had been cut or scraped, or who had contracted pneumonia or a cold. The average adult could expect to live to about forty-eight to fifty years of age. Children often died before the age of five, since many strains of infection had no cure. A single cut could open the door for bacteria to enter the body and poison a person's bloodstream. The discovery of penicillin and related drugs dramatically improved life expectancy in the twentieth century.

The discovery. Alexander Fleming entered St. Mary's Hospital Medical School in London in 1901. After completing his medical studies, he was offered a position as junior assistant in the inoculation department of the hospital. Over time, he came to enjoy the study of bacteria. After observing the ineffectiveness of antiseptics in treating wounds during World War I, Fleming was convinced that a better way of fighting infections within the body must exist. In 1922, he observed that the human

Figure 3.4.
A child afflicted with spinal tuberculosis, 1939. Courtesy of Library of Congress.

teardrop contained a chemical that quickly destroyed bacteria. Unfortunately, the type of bacteria that was destroyed was not a microorganism harmful to humans. After six more years of investigation, Fleming accidentally discovered that a substance produced by mold could destroy colonies of staphylococcus bacteria—a much more dangerous species. Fleming isolated the liquid the mold produced and named it penicillin. Luckily, he had failed to clean the special dishes he was using in his experiments before going on vacation, or he might never have observed the interaction between the mold and the bacteria.

How does penicillin work? Animal and plant cells do not have the same structure as bacteria. Bacteria cells have a special outer membrane, called the peptidoglycan, which exists in addition to the cellular membrane common to other living cells. This outer wall is a rigid sugar net that gives the bacteria cell its shape and helps protect the cell from perforating in hostile environments. Penicillin disrupts this cell wall, making the bacteria susceptible to harm. This process is called selective toxicity—the ability of the drug to damage or kill bacteria without harming the host (in this case, human) tissue. Penicillin kills only bacteria because it attacks the special cell wall present only in bacterial cells.

Developing a practical medicine. Fleming wrote that penicillin was a substance that could "strengthen the body's defenses against bacteria and other microorganisms and kill them while leaving the cells of the body unharmed." On January 9, 1929, Stuart Craddock became the first of Fleming's patients to receive penicillin. His sinus infection cleared up immediately. However, a second attempt to use penicillin, on a woman injured in a car accident, failed. Fleming soon realized that in order for penicillin to be effective, it must be purified and concentrated. In addition, penicillin would need to maintain its potency, and be able to be preserved and to be mass-produced. Although Fleming knew about these problems, he needed the assistance of a qualified chemist to realize solutions for them. Two chemists attempted to purify and concentrate penicillin, but both failed in their attempts. This lack of success led to a skeptical reaction to the discovery by some of the most respected and distinguished researchers of Fleming's day. The absence of enthusiasm, along with the continued failures to purify and concentrate penicillin, resulted in the abandonment of the project in 1932.

In 1935, two Oxford scientists stumbled over Fleming's penicillin research notes. Excited by what they read, Ernst Chain and Howard Florey decided to pick up where Fleming and others had left off. Using a new method to synthesize the drug, Chain created a powder form of penicillin. This newly purified substance was successfully tested on mice. In a famous study, Chain and Florey injected fifty mice with deadly amounts of streptococcus. Half were then injected with this new form of penicillin every 3 hours for the next 2 days, while the other half were not given any penicillin. Within just 16 hours, all twenty-five nonpenicillin mice were dead. After the full 2 days, twenty-four of the twenty-five mice receiving penicillin had fully recovered. Florey and Chain released their findings, which attracted the attention not only of Fleming but also of the rest of the world. In 1941, the first human received this "new" penicillin. In the first few days the patient improved. However, Florey and Chain had no idea how long the patient would need to take the medication; unfortunately, the supply ran out and the patient died. The next crucial step was to find a way to mass-produce this critical drug.

In that same year a small factory in Oxford started producing penicillin, and by the end of the year a factory to produce this newfound drug was being built in the United States. After the famous D-Day invasion, 95 percent of the wounded soldiers treated with penicillin survived. By November 1944, the largest penicillin factory was up and running in Great Britain, and by 1945, penicillin had become widely available to the general population.

The post-penicillin years. Penicillin has proven to be a monumental discovery. It has given the world more than 50 years of relief from worrying about the possibility of death from a simple cut or scrape. Since its initial discovery, over sixty antibiotics have been developed. In the latter half of the twentieth century, bronchitis, strep throat, tetanus, Lyme disease, and a number of sexually transmitted diseases have been treated with penicillin and other antibiotics. Although side effects ranging from a mild rash or fever to shock and shortness of breath may occur, very few cases result in death unless the patient is highly allergic to penicillin.

Penicillin, along with many other medical and technological discoveries, has led to a current life expectancy of about seventy-eight years. However, the misuse of drugs such as penicillin can have potentially serious consequences. Two problems are common: patients take antibiotics to fight diseases other than those caused by bacteria; or patients do not take the required dose of antibiotic. In the first instance, people often think penicillin or other antibiotic "miracle drugs" cure all diseases, when in fact viral infections are unaffected by this medicine. Viruses do not contain the peptidoglycan cell covering attacked by penicillin. In the second case, patients may begin to feel better after a few days of medication, and therefore fail to complete their prescribed dosage. The problem is that the stronger bacteria which survive an initial dose of the medicine will be able to propagate and eventually lead to drug-resistant strains.

Although the discovery of penicillin's effects caused understandable excitement, the miracle of antibiotic therapy has turned out to be a double-edged sword. World health care agencies urge people to complete their dosages, and not to save and take antibiotics indiscriminately. Doctors are urged not to overprescribe or improperly prescribe antibiotics. Educating the population about proper use of antibiotics will be imperative to sustaining their future effectiveness.

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TRANSPORTATION

Traffic Lights Patented

Before the invention of the automobile, there was little need to control the flow of traffic on America's roadways. After cars became the popular mode of transportation, however, streets in metropolitan areas became too chaotic for traffic patrol officers to handle. Accidents between cars and horses and buggies, street signs, and pedestrians were commonplace. It became obvious that some sort of system was desperately needed to regulate traffic.

A historical perspective. Some versions of traffic lights were developed and used before the automobile was common. The first light was developed in 1868 in London, where pedestrians, buggies, and wagons had caused traffic problems. The device used gas to illuminate the lights and was hand-operated by a lever at its base so the appropriate light faced traffic. This particular traffic light lasted only about 6 months; in January 1869 it exploded, injuring the policeman operating it.

For 50 more years, several different models were tried until a viable traffic control system was developed. A police officer in Michigan named William Potts designed the first electric traffic light; it used red, amber, and green railroad lights and about $37 worth of electrical controls. This system was installed in 1920 on the corner of Woodward and Michigan avenues in Detroit.

Other inventors tackled the problem of dangers at intersections, causing controversy over when and who actually invented the traffic light. While Potts was developing his version of the traffic light in Detroit, Garrett Morgan created a similar version to control the flow of traffic in Cleveland, Ohio. After witnessing a collision between an automobile and a horse-drawn carriage, Morgan was convinced something had to be done to improve traffic safety. He eventually received credit for inventing the traffic light because he was the only man who patented a system. Morgan was also credited with inventing the gas mask, which was used during World War I.

How did Morgan's traffic signal work? Morgan developed a system consisting of a T-shaped pole with three positions: Stop, Go, and All Direction Stop. The traffic device was hand-operated, using gears and levers to change the position of the T arms as needed. Two directions were labeled Go and two were labeled Stop. A patrol officer rotated the sign as needed. A four-way stop could be formed by raising the two arms of the T. This third position allowed pedestrians to cross the street safely. Morgan's light was used in North America until it was replaced by the red, yellow, and green electric lights currently used around the world.

How has the design of traffic lights changed over time? Today traffic lights are even more important on roads that are crowded with automobiles. Traffic lights are controlled either by a timer or by a sensor buried in the road. There is a simple but very effective logic to traffic lights. Lights are programmed for a basic timing cycle—a set number of seconds green followed by a set number of seconds red—or they use a variable schedule determined by the time of day. These more advanced lights also change their timing according to input from a sensor. New, "smart" traffic control systems change their timing schedules continuously to reflect traffic flow rather than following a predetermined set of rules. These systems are extremely effective for school traffic; nighttime, when little traffic is detected; or when emergency vehicles are nearing an intersection. Today, more than ever, there is a need for an organized method to sustain the flow of traffic as safely as possible.

Figure 3.5.
Traffic signals arrive on Washington streets, 1925. Courtesy of Library of Congress.

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Antifreeze Keeps Motorists Moving

In the 1920s, automobile use was severely limited during cold weather. Most car owners stored their cars for the winter and drove them only in warm weather. The development of antifreeze in 1926 changed this reality, making the automobile a practical way to travel year-round.

The need for antifreeze. Car engines produce heat during their operation, and must be cooled considerably in order to prevent damage. Water's ability to absorb and hold heat makes it a useful liquid for this purpose. However, the relatively high freezing point and low boiling point of water place a severe limitation on its ability to cool an automobile engine. Automobile makers realized that the life of a car could be prolonged if the engine could be cooled by a substance that would not freeze or boil as quickly as pure water.

Some of the first antifreeze solutions contained mixtures of alcohol, methanol, and glycerin. Others tried using honey, moonshine, glucose, cooking oil, and kerosene. Eventually, chemists recognized the benefits of ethylene glycol as a nonvolatile solute added to water. In a car's cooling system, the water-ethylene glycol solution was successful in preventing damage to the moving parts of the engine. Ethylene glycol has a very high boiling point and at the same time lowers the freezing point of water to prevent freezing. The fact that it doesn't evaporate makes it an ideal "permanent antifreeze solution."

How does antifreeze work? A solution consists of a solvent (material present in greater quantity) and solute (material dissolved in the solvent). When a solution is made, the physical properties of the solution are often different from the physical properties of the pure solvent. An attractive force exists between particles of the solvent and of the solute. This attractive force changes the physical properties of the solvent, such as boiling point and freezing point. These properties are called colligative properties and depend upon the number of particles dissolved in the solvent. The degree of the physical changes in a solution is proportional to the quantity of solute particles in a given amount of solution. In solutions, the boiling point of the original substance is elevated so that it boils at a higher temperature. The freezing point of the solvent is depressed, so that the solution freezes at a lower temperature than the pure substance would.

The boiling point of a substance is the temperature at which a substance changes from liquid to gaseous form. Microscopically, the boiling point is also the temperature at which the vapor pressure of the liquid phase of a substance equals the external pressure on the surface of the liquid, or atmospheric pressure. By adding a nonvolatile solute such as antifreeze to a liquid solvent, the vapor pressure of the solvent is decreased. By decreasing the vapor pressure, additional kinetic energy must be added (a higher temperature is necessary) to raise the vapor pressure of the liquid phase of the solution to atmospheric pressure. This makes the boiling point of the solution higher than the boiling point of the pure solvent. It takes kinetic energy for the particles of the solvent to break the attractive force that keeps them in the liquid. When the antifreeze particles are added to a solvent, they, too, occupy space at the surface of the solution. Since proportionally fewer solvent particles come in contact with the surface, fewer leave the solution. Therefore the presence of the antifreeze lowers the vapor pressure and thereby elevates the boiling point of the solvent.

A similar mechanism affects the freezing point of a solution. When antifreeze is added to water, which normally freezes at 0°C, the antifreeze lowers the freezing point of water several degrees. In other words, the solution remains liquid at 0°C. Antifreeze can decrease the freezing point of water to as much as −17°C. As water freezes, the particles align themselves in an orderly pattern. The presence of the antifreeze interferes with the formation of the crystalline lattice of water molecules. Therefore, more energy must be taken from the solution than would have been taken from pure water to freeze the solution. This same process occurs when rock salt is spread on icy roads. The salt interferes with water molecules' attempts to freeze. Depending upon the amount of salt used, the water may not freeze until the temperature drops as low as −10°C.

Why was antifreeze's formulation important in the twenties? The 1920s were a very prosperous time for industry, and antifreeze played a large role in the automobile boom. During the 1920s, Ford Motor Company was producing nearly half of all of the automobiles in the world and the United States controlled 90 percent of the global market. The popularity of the year-round automobile contributed greatly to the changing society in the Roaring Twenties. Having a car gave most Americans a freedom of movement that had never before been experienced on such a large scale. More and more people were able to travel and spend money in cities other than their own. The highway system was improved, creating more jobs to keep the economy spinning. Year-round driving enabled families to move farther from the cities, starting the creation and expansion of what we now know as suburbs.

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HUMAN KNOWLEDGE

Culture in the 1920s was shaped by World War I. Taking life too seriously was taboo as people celebrated the end of the war. Victorian restraints were gladly shed as science and technology lured everyone to new forms of pleasure, including amusement parks, joy rides, talking pictures, and television. Mass media blended cultures in ways never before seen. Art, music, fashion, literature, and the routines of everyday life became subject to welcome outside influences. Science and technology contributed to the changes of the 1920s in many ways besides those already described. The 1920s saw the first Band-Aid, the first robot built, and the first 3-D movie. In 1920 Hermann Staudinger, a German chemist, revealed a theory now used as the basis for polymer chemistry, which later led to the manufacturing of nylon and plastics. Insulin was isolated by the Canadian Frederick Banting and first administered to diabetics in 1922. In 1923, Jean Piaget published his theory of how children learn, and it significantly influenced education throughout the century. The Frenchman Louis-Victor de Broglie (1924) algebraically laid the foundation for the new field of wave mechanics explaining how subatomic matter and energy are interchangeable. Meanwhile, in Germany, Werner Heisenberg (1925) was explaining energy shifts (quantum theory). Hermann Muller discovered that X-rays caused mutations, and contributed to the understanding of how genes reshuffle in sexual reproduction. Interest in nutrition was increasing, as Hungarian biochemists isolated vitamin C in 1928.

Indeed, significant contributions to human knowledge were made during this decade that would have profound impacts on the world. Discoveries such as King Tut's tomb gave humans an unprecedented look into past civilizations, while the Big Bang theory helped explain the beginnings of the natural world more fully than ever before. Also during this period, the very conception of science was further defined: science can be thought of as the accumulation of the questions that get asked, the processes followed, and the skepticism applied before accepting "the answers." For the scientific community, Margaret Mead's *Coming of Age in Samoa* revealed a new way to engage in such a process.

The Tomb of King Tutankhamen

In November 1922, Howard Carter accidentally uncovered an amazing find: the tomb of King Tutankhamen, untouched by vandals or thieves. The discovery provided archaeologists with one of the most significant glimpses into human civilization of the past.

Why is archaeology so often associated with Egypt? Archaeologists have explored Egypt ever since it was known that ancient Egyptians buried many records and artifacts with their dead. In addition, the climate of the region tends to safeguard and preserve buried objects unlike those located in damper areas of the globe. For centuries people have heard stories of the glory of Greek, Roman, and Egyptian civilizations, and are continually intrigued to find objects of worth and beauty. Scholars, too, are inspired with hopes of learning what the world was like in the distant past. Perhaps more than any other find, the tomb of King Tutankhamen captured the world's attention.

What is the history of "King Tut"? In mid-1300s BC a young noble married the king's third daughter in the city of Tel el-Amarna. When he succeeded to the throne, he moved the capital to Thebes, and in honor of his sun god, Amon, he changed his

Figure 3.6.
The death mask of King Tutankhamen. Courtesy of Library of Congress.

name to Tutankhamen. He died at the age of eighteen, having ruled for approximately nine years. Upon his death, he was wrapped in layers of linen with gold jewelry between them, and his mummy was placed in a nest of coffins. His tomb consisted of four rooms full of furniture, household goods, agricultural tools, paintings, and written records, among other treasures. Tutankhamen's wife cleverly had his tomb concealed to prevent pillage.

How was the tomb discovered? The archaeologist Howard Carter had been digging for over fifteen frustrating years when he stumbled upon his amazing find. Carter and his financial partner were often among over fifty scientific expeditions working in the relatively small area of the Valley of the Kings. However, King Tutankhamen's tomb had remained hidden for over 3,000 years, since another tomb had unknowingly been built over it in the mid-1100s BC. In November 1922, Carter accidentally discovered stairs that led to "King Tut's" tomb.

Carter's find was of particular importance because the contents were untouched by robbers. Three coffins were found in the tomb, and the inner one was made of solid gold. In addition, over 400 statues of servants, complete with baskets and tools, were in the tomb. The most famous object found was a golden mask that covered King Tutankhamen's head. This gold and inlaid glass mask weighed several pounds and was meant to grant King Tut immortality. Today, the artifacts from Tutankhamen's tomb can be found in the Cairo Museum.

What do the finds contribute? Each unearthed find adds to the growing body of knowledge that helps an archaeologist put together a jigsaw puzzle to gain a better picture of the past. For example, a young, economically struggling nation with a primitive government and lifestyle will produce crude tools and rough pottery demonstrating few accomplished skills. However, as the nation develops, skills, products, and artistry increase. Artifacts from tombs such as King Tut's help archaeologists understand more about society's development.

Often, an archaeological find can confirm or contradict hypotheses about how an ancient society lived. In the case of ancient, defunct civilizations, knowledge of history may provide crucial economic, political, or ecological lessons applicable to today's societies.

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Mead Pens *Coming of Age in Samoa*

Margaret Mead's anthropological writings in the 1920s changed the social sciences for years to come. Her work became the focal point for discussions of previously taboo subjects. Furthermore, her methods of conducting scientific investigations sparked debate that would affect the ways some sciences were eventually understood and practiced.

A book of influence. In *Coming of Age in Samoa*, Margaret Mead detailed her travel to the American Samoan village of Ta'u, where she studied the culture, and more specifically adolescent females as they experienced cultural demands and expectations.

A twenty-four-year-old graduate student of anthropology, Mead investigated the customs of primitive people, observed their behaviors, interviewed members of the culture, and then reported her findings and conclusions. She focused on the sexual habits of the villagers and compared her observations with the sexual habits of North Americans.

Mead concluded that female sexuality is more determined by the culture than by the biological nature of gender. She wrote of the sexual freedoms of Samoan females, stating that she spent "six months accumulating an intimate and detailed knowledge of all adolescent girls in the community." She "spoke their language and ate their food." She detailed the lack of neurotic behaviors and frigidity due to an open attitude toward sexuality, including homosexuality and masturbation. Mead concluded that much of the turmoil felt by adolescent girls and boys in North America was the direct result of cultural confinements and not of the biological changes in development from child to adult. The book was widely read and groundbreaking. In the 1920s, sexuality was seldom a topic of conversation beyond the medical field, let alone published with such openness to what most Westerners would consider private matters. The fact that it was a study with thick, rich descriptions increased its credibility in scientific fields.

Why was the book so influential? Mead's book was influential during the twenties for several reasons. The growing field of psychology was beginning to look for reasons why adolescents rebel and appear maladjusted. Educators were becoming "child-centered," and questioned the inflexibility of most classrooms as more students were being educated. The decade of the twenties was a more relaxed, carefree society than past times, and the society was more accepting of such talk of sexual freedom. The women's movement was also gaining momentum, and this was the first major recognizable study about females.

Mead's book also impacted social science generally. As a discipline, anthropology was in its infancy and most anthropologists were males studying males. Topics centered more on artifacts and history than on present cultures. Margaret Mead was opening a new field of social anthropology at a time ripe for disciplinary restructuring and reorganization. This widely believed book caused people inside academe and out to reflect more deeply upon their culture and society.

What do the critics say of her work? Many anthropologists have criticized Mead's book, both then and now. Her field notes and published works sometimes contradict each other. Other researchers questioned whether she actually conversed in the Samoan language, since all her field notes were in English. Her lack of fluency in the language could result in misinterpretations of beliefs. In addition, many claim the time needed to carefully collect the data was too short for the amount of data she produced. But most important, many critics viewed Mead as a cultural determinist, one who maintains that an individual's culture determines his or her behavior. Many felt that her strong "nurture over nature" beliefs, held prior to her travels, perhaps biased her observations and conclusions.

Criticisms of Mead's work opened up discussions of ethnographic research and scientific methods. The success of her work allowed anthropologists to resist the "quantification" of scientific research that was taking place in psychology and sociology. Quantitative research looks for relationships among variables, using numbers and statistics, whereas Mead was more interested in describing insights about people's beliefs and feelings, which cannot be easily evaluated with numbers. Later generations of social scientists would return to Mead's work in redefining their own disciplines in the latter half of the century.

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Big Bang Theory

Throughout history humans have contemplated the universe and wondered how it all began. For thousands of years, religion provided some answers to these questions, and scientists have sought verifiable information about the beginning of time. From simple gazing at the vast, starry sky to the building of the space shuttle, humans have been drawn to the mysteries of the heavens. Throughout the years many hypotheses and observations have been made about the universe, but few ideas have shaken the scientific world as much as the Big Bang theory.

Theoretical foundations. The foundation for the Big Bang theory was established in 1916, when Albert Einstein developed his general theory of relativity. Einstein proposed that gravity no longer be described as a "gravitational field," but as a distortion of space and time. Many had serious doubts about the theory at the time, but, in 1919, observations of the apparent shifting of star positions due to the sun's gravity during an eclipse provided the first evidence that Einstein's theory was correct.

In 1922, a Soviet meteorologist and mathematician, Alexandre Friedmann, used Einstein's theory to devise the idea that the universe is a never-ending, expanding space. In 1927, an unknown Belgian clergyman and physics teacher, Georges Lemaitre, continued Friedmann's studies and proposed that the universe began with the explosion of a tiny, incredibly dense "cosmic egg" or "primeval atom." As the egg collapsed in upon itself from its own gravitational pull, Lemaitre hypothesized, the high temperature and small volume created an enormous explosion that resulted in the formation of the universe. In 1929, Edwin Hubble made several important astronomical observations to help confirm Lemaitre's theory. Hubble found that distant galaxies are traveling away from Earth in every direction at speeds proportional to their distance from Earth. Then in 1948, the Russian-American physicist George Gamow refined and modified Lemaitre's theory of the cosmic egg into the Big Bang theory of the origin of the universe.

What is the Big Bang theory? The Big Bang theory states that the universe began approximately 13 billion years ago as an extremely dense and tiny (as much as 20 orders of magnitude smaller than a proton!) "bubble" of space-time and energy. The enormous energy of the tiny bubble caused it to expand at a fantastically rapid rate, creating space as it expanded. Eventually it cooled and formed the universe as we know it: galaxies, stars, planets, and the vast spaces between them. The Big Bang theory predicts that all large objects, such as galaxies, should be moving away from each other as the universe expands and space is created. This was exactly what Hubble observed and thus was one piece of strong evidence to support the theory.

In the first few minutes of the expansion, the extremely high temperature and density of the universe formed 99 percent of all elements present in the universe today. This reaction was made possible through a process called *nucleosynthesis*, which created mostly hydrogen and helium atoms, and is similar in nature to the nuclear reactions that occur in the hot, dense centers of stars. During the first billion years of the universe, the hydrogen and helium that were formed in nucleosynthesis cooled and condensed into stars and galaxies, and this process continues today.

The Big Bang theory has had a huge impact on the scientific community. This theory changed the thinking of many scientists who had previously supported the steady-state model of the universe—the idea that the universe has always been and always will be in place. Scientific evidence collected during the twentieth century, such as the relative abundance of the elements and the presence of cosmic microwave background radiation, continues to strongly support the Big Bang theory and refute the steady-state model.

Why is the theory significant? The Big Bang theory has created controversy in our society, mainly because it is seen to conflict with some people's beliefs about the creation of the universe. For example, some religious groups are not able to reconcile the idea of the Big Bang and Judeo-Christian creationism. Lawsuits have resulted from teaching the Big Bang theory in public schools. The controversy over the Big Bang will continue as long as science and religion disagree on answers to questions about the creation of the universe.

The Big Bang theory has changed the content of many science textbooks and the way many teachers teach science. On a larger scale, it has changed the way science looks at the world. It may also have contributed to a sense of the questions that can—and can't—be answered by science. Science seeks objectively verifiable explanations of the natural world, while religion addresses the spiritual aspects of our existence.

As long as the Big Bang theory is seen to involve both, it will continue to cause controversy and interest.

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Chapter 4

THE THIRTIES

SOCIETAL CONTEXT: THE GREAT DEPRESSION AND GOVERNMENT CONTROL

The stock market crash of 1929 changed life in the United States forever. During the 1930s, an economic depression affected countries around the entire globe. In the United States, bread lines stretched along city streets and malnutrition was a desperate problem. Many people lost their jobs and homes. Social life changed as well, as people delayed marriage and family life for lack of financial stability. Suicide and abandonment rates increased dramatically. Often, populations were in transition as people moved from town to town in search of a better life.

Many citizens, out of work and out of hope, turned to their national governments for help. Although the federal government of the United States had historically taken a "hands off" approach to many societal problems, the unique context of the Great Depression provided an impetus for change. After his election as president in 1932, Franklin Delano Roosevelt quickly instituted major economic and social reform policies, and shifted the responsibility for fixing many of society's ills from the local to the national level. The New Deal changed the shape of American politics and American society.

In other parts of the world, governments assumed even more control. In Italy, Germany, and Russia, the move toward totalitarian governments was an ominous mark of society during the 1930s. Conservative totalitarian regimes, such as Mussolini's Fascists and Hitler's Nazis, rose to power by promising a life of glory and supremacy for their country's people. At the opposite end of the political spectrum, Stalin's Soviet Union promised an eventual egalitarian life for the proletariat, through initial dictatorship. All three leaders capitalized upon the fear and despair caused by the trying times of the decade. Across the globe, other countries watched and waited, suspecting that eventually, as two ends of the political spectrum pulled harder to advance their causes, something would have to give.

ARCHITECTURE & ENGINEERING

The Tennessee Valley Authority Formed

The reforms instituted in the United States as part of President Franklin Delano Roosevelt's New Deal were undeniably revolutionary. The days of rugged individualism and government noninvolvement had come to an end. One of the most unusual and comprehensive government projects of the era was the Tennessee Valley Authority.

The mission. Roosevelt's conception of the Tennessee Valley Authority (TVA), created in 1933, was a novel idea. In his words, it would be "a corporation clothed with the power of government but possessing the flexibility and initiative of a private enterprise." The TVA employed many residents of the Tennessee Valley area, which was ravaged by the effects of the Great Depression. TVA employees built dams, hydroelectric plants, and artificial waterways for the region, and brought electricity, job security, sound agriculture, and industry to long-suffering Appalachia.

The TVA was responsible for the development and resource management of an entire geographic region, and thus was an original idea in the history of the United States. The organization prided itself on its integrated approach to problem solving and its emphasis on sustainable development practices—in other words, ensuring that programs, projects, and technologies did as much as possible take into account future as well as present societal needs rather than apply a "quick fix." The TVA has been criticized by environmental groups, especially in regard to its Tellico Dam project and nuclear power program; however, it remains a relatively active site of research and dissemination of information on environmental issues.

How does a power plant deliver electricity? A modern electric power plant operates through the use of generators, which convert mechanical energy into electrical energy. A fuel source—often coal—is burned to heat water into highly pressurized steam. The steam is forced over turbines, spinning them and initiating the turning in the generator as well. In the generator, a spinning magnet creates electricity in the copper wires surrounding it—this is due to the fact that a moving magnetic field induces (creates) an electric field in a conductor. In a typical power station, the electromagnets may spin at speeds of around 3,000 revolutions per minute, creating electric currents of 10,000 amperes.

When it leaves the power station, electricity is carried on a network (called a grid) of high-voltage wires. When electricity travels in a conductor with a specific resistance, the amounts of current and voltage are inversely proportional to one another;

that is, as current is increased, voltage decreases, and vice versa. If cables in the electric grid carry large amounts of current, they will heat up and lose much of their efficiency. Therefore, transformers are used to change the amount of current and voltage so that the wires carry electricity with a high voltage and a low current. When the electricity reaches a point where it is brought into a home or other building, another set of transformers changes the current and voltage to the U.S. standard: 110 volts. In the United States, life today is largely dependent on the availability and versatility of electrical power. In the 1930s, arguably the most significant accomplishment of the TVA was its success in bringing electricity to the rural areas of the Tennessee Valley.

What is the status of the TVA today? Since its charter in 1933, the TVA has continued to grow and develop. In the 1940s, it participated in a large-scale hydropower construction effort. In the 1950s, the TVA began the shift to financial independence, which is complete today. In the 1960s, it upgraded several existing power plants and made plans to develop nuclear power facilities. The energy crisis of the 1970s and 1980s caused the TVA to cancel some projects, but it remains regionally vital today. It is still among the largest energy suppliers in the country, and continues to provide recreational, educational, and environmental programs and resources to area residents.

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Hoover Dam Constructed

The Hoover Dam project began in 1931 and was completed in 1936. The dam is located on the Arizona–Nevada border, on the Colorado River. At the time it was completed, it was an architectural marvel, creating Lake Mead and standing as the world's tallest dam.

History of the Hoover Dam project. The Hoover Dam project was part of a larger initiative known as the Boulder Canyon Project Act, which was authorized by Pres-

Figure 4.1.
The Hoover Dam stretches across the Colorado River. Courtesy of Library of Congress.

ident Herbert Hoover in 1928. The southwest had been wrestling with the Colorado River for decades, and a particularly damaging flood in the 1920s created renewed public pressure for help in controlling irrigation in the area. The Hoover Dam was planned as a way to harness the power of the river in order to provide water for farmland, and it would also serve to generate electricity to the region.

The dimensions of the Hoover Dam were unprecedented. It is 726 feet high and 1,244 feet wide. The structure is thicker at the bottom (1,660 feet) than at the top (45 feet). Weighing approximately 5.5 million tons, the dam contains just under 90 million cubic feet of concrete. Beyond the staggering dimensions, the dam was unique in the way it was built. Special cooling tubes allowed the concrete to set faster, and newly developed machinery contributed to the efficiency of the building process. Some sources have estimated that construction of the Hoover Dam would have taken centuries without these technologies.

How do dams produce electricity? Dams use hydroelectric generators as an alternative to fossil fuel combustion. They rely on falling water—instead of burning fuel and producing steam—to move the turbines that power the electric generators. The quantity of power generated by a dam depends on the amount (volume) of water flowing through the system, and the distance it falls. The more water and the greater the distance it falls, the greater the amount of power that can be produced. Many hydroelectric generators take advantage of natural waterfalls; for example, when water flows over mountainous regions, its energy can generally be harnessed quite efficiently. However, when the vertical drop is less than about 65 feet, concrete dams must be constructed so that water can be contained, and the volume and drop consequently increased.

Hydroelectric generators do not produce the pollution associated with power plants that burn fossil fuels. In addition, hydroelectric dams do not deplete a nonrenewable resource. However, large dams are often criticized because they can disrupt the natural environment and lead to problems for wildlife. Many communities today elect to build smaller dams that, although they meet the needs of fewer people, have less potential for negatively impacting the environment.

What has been the impact of the Hoover Dam? The Hoover Dam became an example of how a large-scale works project could address societal needs on several levels. Today, the dam furnishes water to 18 million people, and irrigates over 1.5 million acres of land in the southwestern United States as well as Mexico. Seventeen generators provide electricity for 16 million people. Lake Mead National Recreation Area is available for use by residents and tourists. However, one unique legacy of the dam relates to the societal context of its creation. Some have argued that the architectural feat became a rallying point and source of pride for Americans during the trying years of the Great Depression and into World War II. The project renewed hope in American ingenuity and spirit.

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ARTS & ENTERTAINMENT

The "Golden Era" of Radio

During the 1930s, record numbers of Americans turned on the radio as a source of news and entertainment. What started as a fascination for inventors and hobbyists soon grew to be a giant commercial industry and a source of entertainment, information, and comfort for millions of people. Perhaps as at no other time in history, radio was a part of everyday life in the United States during the 1930s—the "Golden Era" of radio.

A popular medium. In the early years of radio, the medium was primarily an outlet for inventors and amateur scientists. The most popular radio receivers were kits that had to be put together by the customer. That soon changed, as completed units were sold to the public by companies like Zenith and RCA, and the industry became increasingly commercialized. During the 1930s, people bought radios as never before. By 1934, approximately 600 stations were broadcasting to 20 million homes. In 1935, a million radios were sold to American consumers. One year later, 8 million radio units were sold, and three-fourths of American households had a radio in them.

Another major change that occurred during the 1930s was the securing of radio as a commercial industry. David Sarnoff of RCA was largely responsible for changing radio from a forum for inventors to a full-fledged business enterprise. In these formative years, decisions made in the United States would distinguish its radio industry from that in places like Britain, where a government-run agency (the British Broadcasting Corporation, or BBC) was responsible for presenting information free from politics and commercialization. In the United States, free enterprise and commercialization governed radio broadcasting, largely due to entrepreneurs like Sarnoff. Government influence was not totally absent, as is evidenced by the creation of the Federal Communications Commission (FCC) in 1934. However, the FCC's responsibilities were primarily for licensing and monitoring distribution, and it was not significantly involved in controlling content.

Technological advances in radio. During the 1930s, several technological advances in radio paved the way for popularization of the medium. In 1935, frequency modulation (FM) was introduced as a means of transmitting radio signals. In contrast to carrying information via the *amplitude* of radio waves (AM transmission), FM signals modified the *frequency* of signals as a way of sending information. This greatly reduced the amount of static interruption to radio broadcasts and improved the clarity tremendously. In addition, advances in volume control at both the transmission and the reception ends of radio were made during the 1930s. Cathode ray–based "magic eye" radio tuners were a huge hit with the public when they were introduced in 1937.

The radio culture. The cultural impact of radio in 1930s America is undeniable. During this decade, radio broadcasts were a source of news and entertainment. In fact, the two genres were still closely related, since newscasts during this period were generally dramatizations of the day's events performed by actors (a precursor of the movie newsreels popular in the 1950s). Politicians, especially Franklin Roosevelt, found radio to be a way of reaching many people with great efficiency. Roosevelt's "fireside chats" were a popular and stabilizing influence during the anxious times that marked his presidency. Radio entertainment was also extremely popular—music shows and dramas provided people with an inexpensive way to enjoy life during the economic hard times of the Great Depression.

Radio also contributed to a growing sense of popular culture that was distinctly American. People tuned in to find information in common. Events such as Herb

Morrison's broadcast of the *Hindenburg* disaster in 1937, or Howard Hughes's broadcast of his around-the-world flight in 1938, riveted the nation and gave people something to talk about. Reports of increasingly ominous events in Europe galvanized the nation. If anyone doubted it, the power and influence of radio was certainly evident by the time Orson Welles broadcast his infamous *War of the Worlds* play the night before Halloween in 1938. Though Welles was reading a scripted drama, persons tuning in believed his descriptions of a Martian invasion were "the real thing," and many rushed into the streets in a panic. Radio had become the true connecting link for an increasingly diverse America.

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Electric Guitars Appear on the Musical Scene

Throughout the course of the twentieth century, the electric guitar became distinctly embedded in American popular culture. The electric guitar was invented and perfected by musicians during the first part of the century, and indelibly shaped music in the second.

Experimenting and inventing. Various styles of electric guitars have simultaneously been in existence since the early twentieth century. Adolph Rickenbacker is credited with developing an early model, the frying pan electric guitar, which was a small, rounded steel guitar marketed in the 1930s. Other jazz and blues guitarists of the same time put microphones on their guitars in order to amplify the sound. Into the mid-twentieth century, Les Paul and Leo Fender were particularly successful with their innovative electric guitar designs.

Technically, the electric guitar is an electroacoustic instrument—the sound is not *produced* electronically, but is *amplified* that way. The electronic part of the electric guitar is a device known as a pickup. The pickup transmits the sound vibrations to an amplifier, which increases their volume. The Frying Pan guitar incorporated two curved pickups on either side of the strings to amplify the sound. Other models of electric guitar, known as hollow-body or electric-acoustic guitars, amplified the sound by placing pickups inside a regular acoustic Spanish-style guitar. The modern solid-body electric guitar uses pickups placed under the strings to amplify the sound.

Today, there are many electric guitar styles that allow musicians to achieve distinct sounds. For example, there are guitars with single, double, and triple pickup systems, each of which produces a slightly different sound. The guitar's sound can also be modified by adding special effects boxes that distort the electronic signal. A very basic difference exists between hollow-body and solid-body electric guitars: in the hollow body, the pickup transmits vibrations from the strings and the body of the guitar, whereas in the solid-body style, the pickup receives vibrations from the strings only.

An American instrument. During the "Jazz Age" of the 1920s, musicians experimented with music and sounds in very new ways. Performers often found new ways to spotlight a particular instrument—for example, the piano, saxophone, or clarinet. Focusing on the guitar as a solo instrument was difficult, primarily because of its soft volume. Musicians experimented with ways to bring the guitar front and center in an arrangement—for example, by changing the materials of the instrument (perhaps using steel strings) or by changing the shape of the instrument. However, attempts to make the guitar a more powerful solo instrument were generally modestly successful until the instrument was electrified.

Perhaps the most American of musical instruments, the electric guitar has been a popular instrument with performers and fans alike. Country and jazz musicians were among the first to use electric guitars in musical performances of the 1930s. Today, hollow-body electric guitars are still often used in arrangements of those genres. But without doubt, the solid body electric guitar became symbolic of American rock-and-roll, and later rock music during the last half of the twentieth century. Although rock performers of the 1950s and 1960s primarily sought ways to produce clear guitar sounds with admirable volume, rock musicians approaching the twenty-first century experimented with distortion and other special effects to create unique identities for their instruments. As musicians experimented with techniques and manufacturers experimented with styles, the instrument and music evolved simultaneously.

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COMMUNICATION

Signals from Space

In 1933, the *New York Times* published news of a startling discovery: Karl Jansky, a scientist at Bell Laboratories, had discovered radio waves emanating from outer space. The finding opened new doors for astronomers to learn about the universe, and eventually captured the imaginations of a few scientists as well as the public at large.

A serendipitous discovery. In the late 1920s, Karl Jansky had been hired by Bell Laboratories to determine possible sources of interference in radio wave transmission. The company was interested in improving the burgeoning field of radio communications. Jansky built a unique, rotating antenna to capture a wide range of radio waves, and worked diligently on identifying the sources of the signals received.

After reviewing his data, Jansky determined that his antenna was detecting three kinds of static signals. One kind of static was caused by nearby thunderstorms and a second type was generated by distant thunderstorms. However, the third, faint type of static was more puzzling. It seemed to occur in regular, daily cycles, but its source was not immediately clear.

Upon careful study, Jansky noted that the peaks for reception occurred every 23 hours and 56 minutes. He recognized that this time represented a sidereal day, the time it takes for a particular star to reappear in the sky. Jansky inferred that the third type of static was indeed originating from outer space.

Scientific applications. Although some astronomers were intrigued by Jansky's findings, most fiscal resources were directed to more practical scientific pursuits during this time of economic hardship. Although Jansky was interested in learning more about cosmic radiation, Bell Laboratories did not fund further experiments. Instead, a scientist living in Chicago, Gröte Reber, used his personal resources to build a radio telescope in his backyard. By the end of the decade, others renewed their interest in radio astronomy, based on some of Reber's work.

As scientists, astronomers are limited to making *observations* of the phenomena they study, rather than learning through *controlled experiments*. Therefore, new ways of making observations and gathering data about the universe often allow for significant additions to the knowledge base. The radio telescope was just such a device, allowing astronomers to make observations about the universe in a much greater range than had previously been available.

The radio telescope is basically a movable dish designed to reflect incoming radio waves toward a receiving antenna. Scientists know that when electric charges accelerate, they emit electromagnetic (EM) radiation. Radio waves are one kind of EM radiation. When radio telescopes pick up such signals from outer space, astronomers can make inferences about how the signals were produced, and thus construct a better picture of the universe. Over the course of the century, radio astronomy continued to develop and led to significant advances in our understanding of the life cycle of stars and the origins of the universe.

Communicating with space. Eventually, radio telescopes came to be seen as devices with the potential to communicate with other intelligent beings in the universe. By 1959, in an article published in the journal *Nature*, Cornell scientists Giuseppe Cocconi and Philip Morrison argued that astronomers should strive to separate natural from unnatural radio signals picked up by telescopes, and analyze "unnatural" signals for evidence of intelligent life elsewhere in the universe. Simultaneously, Frank Drake was experimenting with a radio telescope in Green Bank, West Virginia, attempting to do just that. America's SETI program—the Search for Extra-Terrestrial Intelligence—had begun.

Drake held the first international SETI meeting in 1961. In the decades following, under the leadership of Bernard Oliver, NASA became involved in the SETI effort. Yet by 1993, the U.S. Congress banned government-sponsored SETI projects. Drake's organization continued the effort, however, establishing Project Phoenix—a massive effort to gather data from 1,000 nearby stars—in 1995.

Today, many experts recognize that a major problem with SETI research is that the data are overwhelming. Huge receivers are constantly bombarded with radiation from space, and the task of sifting through it to determine whether the information is from natural or unnatural sources is tremendous. By the end of the twentieth century, the University of California at Berkeley developed a way for amateur astronomers to participate in SETI efforts. By downloading some free software, anyone with Internet access could receive data from the world's largest radio telescope, at Arecibo, Puerto Rico, and analyze data on a home computer.

The advent of radio astronomy techniques in the 1930s allowed researchers to "see" farther out into space than with light telescopes. Our picture of the universe has become much more complete as a result. Additionally, some scientists hope that radio astronomy may someday give us the answer to another intriguing question—Are we, in fact, alone in the vast universe?

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DEFENSE & DIPLOMACY

Jet Engine Developed

World War I had introduced military organizations across the globe to the power and possibility of aircraft in battle. In the 1930s, as events in Europe pointed more and more toward a second great war, military strategists looked to the skies to develop potential battle plans. During this same time period, two young engineers independently tested and developed designs for jet engines that would revolutionize aviation and defense.

The time line of invention. During the 1930s, two jet engine models were developed independently by Sir Frank Whittle in England and Dr. Hans von Ohain in Germany. Whittle applied for a patent for his idea to use a gas turbine engine to run an aircraft in 1930, when he was only twenty-three years old. After some initial trouble securing interest in and backing for his project, he was allowed to begin developing his ideas in a military-industry partnership in 1936. After a test run of an engine described by Whittle as "frightening" in 1937, various aspects of the engine design were tweaked and improved until a model with ten combustion chambers was approved by the Air Ministry in 1939. Work soon commenced on an aircraft that would incorporate Whittle's engine.

Meanwhile, Ohain became intrigued by the possibility of a jet engine while a doctoral student in Germany in the early 1930s. In 1935, he developed a test engine and approached the German aircraft industry to support further development. Aircraft manufacturer Ernst Heinkel agreed to back the project. By early 1937, Ohain's test engine was producing promising results, and Heinkel was ready to support the development of a jet-powered aircraft.

On August 27, 1939, Ohain's jet engine was used to successfully power an aircraft, the He-178, for the first time. A British aircraft followed soon after; the Gloster E28/39 took flight on May 15, 1941.

How does a jet engine work? The jet engine is based on the scientific principle of Newton's Third Law of Motion and the technological design of a gas turbine. In simplest form, the engine consists of three basic parts: a compressor, a combustion chamber, and a turbine. The compressor draws air into the engine and reduces the air's volume, therefore increasing its pressure (a scientific principle known as Boyle's Law). This high-pressure gas is forced into a combustion chamber, where it is mixed with a spray of fuel, and ignited. The burning fuel heats the air, which rapidly expands and pushes its way out of the back of the engine. As it does, some of the kinetic energy of the moving air spins a turbine, which connects back to the compressor, turning it and pulling more air into the compressor to repeat the process.

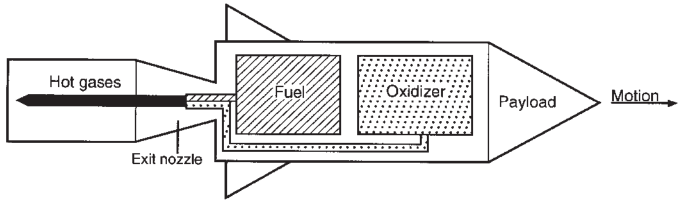

Figure 4.2.
Rocket engine application of Newton's Third Law of Motion.

Newton's Third Law of Motion is often simplified as the "action–reaction" principle: "for each action, there is an equal and opposite reaction." A more precise way to think about it is that when object A exerts a force on object B, object B exerts an equal and opposite force on object A. The "action–reaction" name seems to imply that one event occurs before the other in time, but in fact the forces described by Newton's Third Law are at all times simultaneous and of equal strength. When a jet engine produces the force that pushes the air out of the engine, the air exerts an equal and opposite force on the engine. Thus, the air travels backward, and the jet is pushed forward (this force is known as thrust).

Application of jet engines. The jet engine was immediately heralded for its potential application to the development of aircraft technology. Jet engines would improve the speed and efficiency of aircraft in dramatic ways and open new possibilities that early military strategists could not have imagined. By 1944, German and British combat jets took part in the battles of World War II. The Germans used jet technology to develop guided missiles, which they used with fearsome results, primarily on London.

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Radar Technology Put in Place

The foundations for the use of radar, a system for *ra*dio *d*etection *a*nd *r*anging, were laid in the 1880s, when experiments with radio waves commenced. In World War I and previous conflicts, reconnaissance was limited to observations made by human

Figure 4.3.
Radar in operation during World War II. Courtesy of Library of Congress.

eyes and ears. In the 1930s, the practical development of radar paved the way for future wars to be waged quite differently.

How does it work? The possibility of tracking an object with radio waves was conceived by the latter part of the nineteenth century. Henrich Hertz noted in his experiments with radio waves that such waves could be reflected off an object, and therefore give an idea of its location. When radio became popularized as a communications medium, and planes were increasingly used for transportation, it was only a matter of time until the two technologies were used in tandem. In the mid-1930s, England began constructing a network of radio towers for tracking the location of aircraft, based on the designs of Sir Robert Watson-Watt. Germany built a similar tracking infrastructure a few years later.

Early radar systems made use of transmission and reception towers built on the earth's surface. The transmission towers emitted radio signals which were sent toward an object, reflected off the object, and collected at the receiver. The energy of the reflected signals was measured to determine the intercepted object's position and/or velocity. By 1939, British scientists Henry Boot and John Randall determined that microwaves could be employed in the transmission and reception process, with much more powerful and precise results. Microwave radar technology also led to the development during World War II of air-based systems, eliminating the need for radio tower systems.

Effects and applications. As a military technology, radar proved invaluable during World War II. Targets in places of low visibility could still be attacked. Advance warning of an impending attack was possible, and preparations could be made. When

British and American scientists developed airplane-based radar systems before the Axis forces could, they enjoyed a huge military advantage. Allied bombers could locate and bomb submarines with the aid of small radar systems incorporated into the planes' noses.

Today, radar applications are used not only for military purposes but also in civilian and scientific pursuits. Computer power and satellite technology have enhanced the basic concept of radar to provide many powerful and essential navigational systems. Computer-controlled systems are used to guide and monitor traffic systems on land, in the air, and at sea. Radar, especially Doppler radar technology, has become an invaluable tool for detecting and tracking weather events.

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ENVIRONMENT

Concerns over Air Pollution

Although air pollution was not a new phenomenon in the 1930s, it was a problem of which the public was becoming increasingly aware. As a result of the country's westward expansion, continued industrialization, and increased automobile traffic, air pollution became a significant environmental issue.

What is smog? The major air-pollution problem of the early twentieth century was smog. The term was introduced in 1905 by H. A. Des Voix, as a description of the hazy, dirty atmosphere; the word is a combination of the words "smoke" and "fog." Smog results from large amounts of particulate matter and chemicals being trapped in the atmosphere. By the 1930s, Americans in some cities had come to expect smog as part of their "normal" environment.

Smog was an international phenomenon. Especially in European cities which boomed during the industrial revolution, smog was frequent and even deadly. In 1930, pollution became trapped in the Meuse River valley in Belgium, causing 63 people to die and 600 additional people to become ill. Even earlier, smog in London had killed 700 (in 1873) and over 1,100 (in 1911).

How does smog form? The type of smog common in London and other industrial cities results from stagnant, moist air mixing with pollutants. Coal smoke, which releases sulfur dioxide (SO_2), is a major contributor to this kind of smog. The sulfur dioxide can react with water vapor in the air to produce sulfuric acid, a key contributor to the acid rain problem. The combination of air pollutants and temperature inversions can be deadly. Normally, air temperature decreases with altitude; occasionally, however, an inversion occurs, and in a particular layer of the atmosphere, the temperature increases with altitude. When this happens, pollutants become trapped near the ground, and the air takes on a sooty, grimy appearance.

Another type of smog, common today in cities such as Los Angeles, is photochemical smog. In this type of smog, nitrogen oxides (which are by-products of both automobiles and industrial processes) combine with reactive organic gases (primarily from unburned gasoline) in the presence of sunlight. The chemical reaction produces ozone (O_3) and nitrogen dioxide (NO_2). Both chemicals are hazardous to humans, and can cause respiratory problems and even death.

Efforts at control. The first major effort to survey air pollution in the United States was in Salt Lake City, Utah, in 1926. In the next several years, eastern cities were surveyed, and the data collected in New York City showed that sunlight was cut by as much as 20 to 50 percent in that city by the end of the 1920s. Additional surveys in New York in 1937 and a serious smog incident in St. Louis in 1939 convinced many that the problem was getting worse.

Further smog problems in the 1940s and 1950s would finally motivate stricter controls on air pollution. In the late nineteenth and early twentieth centuries, air pollution was considered a local problem. However, people soon realized that problems with air could not be localized—one city's pollution became another city's nightmare. Thus, action was eventually taken at the federal level. A precursor to the Clean Air Act was passed in 1955; however, the legislation with the most impact has definitely been the Clean Air Act, passed in 1970 and revised in 1977 and 1990. It established allowable levels of chemical pollutants in the air, and required industry to comply with regulations and restrictions on the production of pollutants. Overall, the act is considered to have been successful at reducing pollution problems, though without doubt such issues still challenge us today.

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FOOD & AGRICULTURE

The Dust Bowl

On April 15, 1935, Associated Press reporter Robert Geiger described the aftermath of a horrible dirt and dust storm known as Black Sunday. As he put it, "Three little words . . . rule life in the dust bowl of the continent: 'if it rains.' " During the 1930s, farmers in parts of Kansas, Colorado, Oklahoma, Texas, and New Mexico endured trying times. The combination of drought, severe weather, and economic hardship left an indelible mark on the region that has come to be known by Geiger's characterization, the Dust Bowl.

Trying times. Beginning in 1931, farmers in the Great Plains region of the United States suffered eight years of drought that ruined land and lives. Frequent storms blew the dry soil violently enough to send it traveling hundreds of miles—for example, from Kansas and Oklahoma to New York and Washington, D.C. Clouds of dirt blackened the skies so dramatically that trains missed stopping at stations. Dust covered and entered buildings, ruining furniture and food. People suffered from respiratory problems—children playing outside in dust storms were even smothered.

During the Dust Bowl years, many farms failed. In the postwar 1920s, farming was a prosperous enterprise. Yields were high, prices were good, and new technologies for farming made life easier and more productive. The troubles for farmers in the 1930s actually started before the drought, with a bumper crop in 1931. That year there was so much excess wheat that prices fell to less than half of their value the year before (from 68 cents per bushel to 25 cents per bushel). Farmers who were already behind on mortgages and loans fell even further behind when severe weather conditions made farming next to impossible in the years to come. In the Great Plains farming towns, small businesses were dependent on farmers as customers, so many businesses felt the effects of the farmers' plight. It didn't help that the rest of the United States was simultaneously wallowing in economic depression, with close to 30 percent of people unemployed across the country.

Faced with such adversity, many farmers left their farms and their lives behind. In fact, events of the Dust Bowl caused the largest migration in the history of America, with 25 percent of farmers, 2.5 million people, relocating over the course of the decade. Many Plains families went to California, where they found jobs as migrant workers and struggled under grueling work and living conditions. John Steinbeck's famous novel *The Grapes of Wrath* details the lives of one such migrant family and the hardships they endured. Likewise, folk musician Woody Guthrie recorded the stories of everyday citizens on his landmark album *Dust Bowl Ballads*. Remarkably, three-quarters of families committed to staying in the Dust Bowl, and their amazing

Figure 4.4.
A farm occupied during the Dust Bowl era in Texas, 1938. Courtesy of Library of Congress.

experiences and sense of resolve are captured in many stories, songs, and works of art from the decade.

What were the reasons for the dust storms? Certainly, the extended dry period and high winds were directly responsible for the dust storms that ravaged the Plains during the thirties. However, the conditions were made worse by the shortsighted farming practices used in the decades before the drought. In times of prosperity, farmers who had moved to the Great Plains from the east employed techniques that had worked there, but were not appropriate for this new breadbasket.

In the 1920s, many Plains farmers planted more and more land without any conservation practices. They removed grasses and natural plant cover that had served to anchor the soil against the high winds of the Plains. Farmers encroached onto poorer-quality land in an effort to produce more crops, but the soil was quickly depleted of its fertility and left unplanted. Lands were overgrazed, and farmers did not rotate crops, so that repeated stresses were placed on the land without a chance for it to be replenished. Other imprudent land and resource management practices, such as the often unchecked westward expansion of the railroads and the division of inappropriate lands for farmers, also hurt this region.

Lessons learned. During the 1930s, the federal government helped with the recovery of the Dust Bowl region, both economically and physically. Realizing how essential the Plains were to the entire country, President Roosevelt and his "brain trust" New Deal advisers made recovery of this area a priority. One estimate is that the government provided as much as $1 million (in 1930s value) to the region for recovery purposes.

Government plans for the recovery of the Dust Bowl area included not only farm supplies but also financial and medical help. In addition, government-sponsored programs helped farmers rethink some of the practices that had magnified the region's problems. Soil conservation practices were emphasized, and farmers were encouraged to improve irrigation systems and to diversify their crops and techniques. Morale improved, as did the weather—by the early 1940s, many Plains farmers were ready to put the Dust Bowl behind them.

Although the recovery and education systems were considered highly successful, events of the 1940s led to a small relapse. With the U.S. involvement in World War II, money that had been earmarked for supporting farmers was redirected to the war effort. In addition, many men left work on farms to fight in the war. Although some farming families returned to the hazardous practices of neglecting soil and irrigation needs, in general the new practices were maintained, and in fact were responsible for seeing the region through another drought period in the 1950s. Today, efforts to maintain the land in an environmentally responsible way remain strong, and the legends and lessons of the Dust Bowl years live on.

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MEDICINE & HEALTH

Electron Microscope Invented

By the early twentieth century, the microscope had become an indispensable tool for biologists, yet few advancements had been made in the tool itself since the compound microscope was invented over two centuries earlier. Because of the explosion of quantum physics at the beginning of the twentieth century, scientists were able to build a new and more powerful type of microscope by the 1930s.

A quantum background. During the quantum mechanics revolution in physics, seemingly commonsense ideas about nature were often questioned and even revised. One example was the debate over the nature of visible light. Since at least the time of Isaac Newton and Christiaan Huygens, scientists had debated whether rays of light were streams of tiny particles (often called "corpuscles" in early theories) or were actually wave phenomena, which acted in a way similar to water waves. One reason the debate was never fully resolved was that different experiments seemed to indicate different answers to the question—some results supported the wave theory of light, and others supported the particle theory of light. Eventually, the debate was abandoned altogether, based on the work of (among others) Max Planck and Albert Einstein: instead of supposing that light was either one or the other, scientists adopted the stance that light had a dual nature, and indeed was capable of acting as *both* a particle and a wave.

In 1924, Louie de Broglie applied the idea of a particle–wave duality to matter. He claimed that particles of matter could act like waves, and under the right conditions, this wavelike nature could be observed. This principle underlies the operation of the electron microscope.

How does the electron microscope work? The transmission electron microscope developed in the 1930s works by using electrons instead of light to bring a small object into view. Electrons are very tiny subatomic particles with a negative electric charge. In an electron microscope, a beam of electrons is sent through a small sample of material. Where the specimen is thin, the electrons pass through to a fluorescent screen on the other side. Where the specimen is thicker, the electrons are deflected or absorbed. Thus, a picture of the object is obtained on the screen—brighter spots represent thinner areas of the specimen, where more electrons pass through, and darker areas indicate where the specimen is thicker.

The electron microscope works because the electron beam acts similarly to the way visible light would in a simple or compound light microscope. Besides de Broglie's insight that particles could act like waves, the electron microscope makes use of the findings of Hans Busch, who demonstrated the way in which electron beams can be focused by manipulating electric and magnetic fields around them. Because electrons are negatively charged, they are attracted to or repelled by magnetic and electric fields. In an electron microscope, these magnetic and electric fields are used to focus the electron beam in the same way the knobs on a light microscope are used to move the lenses and bring the light into focus.

The electron microscope advantage. The two primary functions of any microscope are to magnify an object and to improve the resolution with which it can be viewed. Magnification is the ratio of the actual size of the object to the size of the image. Resolution is the ability to distinguish between two different objects. The advantage of the electron microscope over the light microscope is that it vastly improves the resolution with which tiny objects can be seen. This is because light in the visible range has a particular wavelength, around 500 nanometers (nm) in size. Therefore, no matter how powerful the light microscope, it is always limited to being used

Figure 4.5.
RCA electron microscope with its inventors, Dr. V. K. Zworykin and Dr. James Hillier. Courtesy of Library of Congress.

for objects larger than 500 nm; if it is smaller, light passes over the object and can't detect it. In contrast, electrons exhibit a wavelength of five-thousandths of a nanometer (0.005 nm)—much smaller than visible light. These smaller wavelengths allow the electron microscope to resolve minute objects that a light microscope could not detect.

German scientists Max Knoll and Ernst Ruska inadvertently built the first transmission electron microscope in 1931, while attempting to produce a device to measure the fluctuations of high-voltage power lines. In North America, James Hillier and Albert Prebus developed the first commercial electron microscope. Today, most electron microscopes can magnify objects to between 100 and 500,000 times their actual size.

The electron microscope allowed humans to see things they had never seen before, including the inner structure of cells and tiny viruses. This had powerful implications for the field of medicine, since for the first time, scientists could carefully study and theorize how cells worked and how viruses could be fought. The field of cell biology has made extremely important contributions to the advancement of medicine in the twentieth century.

Since the development of the transmission electron microscope, other advances have been made. The scanning electron microscope allows for a three-dimensional image of an object to be obtained, and has an even greater power of magnification than the transmission model. Used together, the transmission and scanning electron microscopes could give scientists a much more complete picture of the microscopic world.

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The Eugenics Program

Published in 1932, Aldous Huxley's dark novel *Brave New World* foretold a future society in which humans were engineered to their life purpose through the "science" of eugenics. In truth, the eugenics movement of the early twentieth century was built on ideals about the improvement and genetic refinement of the human race that were misinformed at best, and shockingly evil at worst. Though for the most part they would not come to fruition as their proponents planned, these ideals would have lasting impacts on society far into the future.

What is eugenics? The eugenics movement represents a philosophy at the extreme of the nature–nurture debate about human characteristics that was popularized in the twentieth century. Believing in strict biological determinism (i.e., that human characteristics are solely the result of their biological makeup, rather than of their environment), eugenicists argued that only certain people who possessed desirable characteristics should be allowed to reproduce. In other words, eugenicists believed in selective breeding of humans, in order to "improve" future generations of people and future societies.

This type of attitude is also known as social Darwinism—the idea that society could evolve through an artificial sort of "natural selection." In reality, the eugenics movement and similar ideas about controlling human development are based on incomplete and skewed understandings of biological concepts of heredity, race, and evolution. Although the most familiar manifestation of the eugenics movement is probably the Nazi program of race purification, eugenicists were found among intellectuals everywhere in the early twentieth (and late nineteenth) century.

Where did the ideas come from? In the late nineteenth century, Francis Galton studied the heritage of British societal leaders and determined that they were linked through their ancestry more often than should be the case if such leadership were based on pure chance. Galton concluded that these many distantly related leaders must be endowed with superior biological traits which predetermined their leadership capabilities. He reasoned that these superior traits could be bred into human society and devised a plan for selectively breeding the citizenry to enhance the quality of human society. Galton named this program "eugenics."

Eugenicists' ideas were influenced by the work of Gregor Mendel, Carolus Linnaeus, and Charles Darwin. Mendel's breeding experiments with pea plants were popularized at the turn of the century, even before scientists really grasped the concept of genetic inheritance. Mendel kept careful records of the mathematical ratios of pea plant offspring endowed with parental traits over the course of several generations. Eugenicists used Mendel's work as a model, and predicted the occurrence of human traits in successive generations with a fierce certainty. Proponents of eugenics simply associated Mendel's inheritance ratios with complex human characteristics such as poverty, sexual promiscuity, laziness, and alcoholism. Although critics argued that environmental rather than biological factors were most responsible for traits such as these, eugenicists firmly believed in their inheritability.

Another, more indirect influence on the eugenics movement was the Swedish biologist Carolus Linnaeus (born Carl von Linné), who spent an entire career building classification systems for living things, including humans. Linnaeus officially separated humans into races, and provided descriptions of what he deemed to be their defining characteristics. However, many of Linnaeus's descriptions were based on value judgments and ethnocentric beliefs rather than on any sort of scientific evidence. For example, he labeled Native Americans as "obstinate, content, and free"; Asiatic peoples as "melancholy, rigid, haughty, and covetous"; Africans as "crafty, indolent, and negligent"; and Europeans as "gentle, acute, and inventive." Linnaeus's status and other classification accomplishments led many to accept his racial characteristics as fact, a legacy that unfortunately haunts some groups of people today. Many eugenicists believed in or sought similar notions about the ties between race and behavior or personality traits.

Eugenicists also appropriated Darwin's writings on evolution and natural selection in ways that justified a program of social control. Many of them believed that human civilization and technological prowess had interfered with the natural processes which should govern population control. These eugenicists argued that nature would have destroyed less "fit" members of human society, had it not been for modern sanitation, medicine, and other progress; and they believed that, as a result, societal leaders would have to take action to control population artificially. For some advocates of eugenics, this meant taking action to control birth rates by ensuring that "weak" persons did not reproduce and that "fit" individuals did. For others, however, the task was even more chilling—deciding which persons would be subject to "mercy killings" or outright murder in order to save the larger society.

What actions did eugenicists take? In the United States, eugenicists pushed for limiting immigration, education on selective breeding, and forced isolation or even sterilization of criminals and people with "undesirable" mental, physical, or social characteristics. The movement was very much part of the intellectual atmosphere in the early twentieth century, as policy makers, professors, and activists debated how to handle pressing social issues. It was very common during this time to segregate members of the population who were judged to be criminally insane, alcoholic, sexually promiscuous, or "feebleminded." Sometimes the intent of separation was to change individuals' behavior or skills so that they would be more socially acceptable; however, many eugenicists felt that the best option was to keep such individuals from reproducing and passing along their undesirable characteristics to future generations. In 1927, the U.S. Supreme Court upheld this position, ruling that forced sterilization of developmentally or mentally disabled individuals was constitutional.

Although some eugenicists believed their cause to be noble or even humane, others certainly saw an opportunity to act on the fear and racism rampant in an increasingly diverse society. In the United States, for example, the Galton Society was committed to exploring the relationship between race and human characteristics, and to exploiting seeming evidence of white superiority. However, the best-known and undeniably most malevolent example of a program of racial eugenics took place in Nazi Germany, and was directed by Heinrich Himmler with the sanction of Adolf Hitler. Himmler's plan for the purification of the Aryan race included *Lebensborn* homes, where desirable women would be paired with "pure" Aryan males in order to produce children who would become future Aryan leaders. Conversely, those who were deemed "undesirable"—those who suffered from blindness, deafness, manic depression, schizophrenia, epilepsy, alcoholism, or "feeblemindedness"—were sterilized (approximately 300,000 to 450,000 people were affected by this program), or even euthanized. Eventually, the Nazi fascination with creating a superior race led to a systematic effort to kill persons of Jewish heritage. Officially beginning with the Nuremberg Laws enacted in 1935, the Nazi regime systematically arrested, enslaved, and murdered at least 6 million people because of their "impure" Jewish blood.

Could something like this happen today? Certainly the science of genetics is much better understood at the dawn of the twenty-first century, and few educated persons would associate characteristics such as "laziness" or "poverty" with hereditary traits. Most people understand that a complex interaction of nature and nurture plays a role in deciding human characteristics. However, as scientists learn more about the qualities that do seem to be a part of the human genome, some bioethicists fear that our increasing capability for genetic engineering could easily become a modern-day program of eugenics. Will parents of the twenty-first century request that certain traits be engineered into their offspring, creating a new program of selective breeding? Could insurance companies be the source of social control in the future, deciding on coverage and resources for clients based on genetic propensity for diseases? Time will tell what society will deem ethical and appropriate, and whether society has indeed learned from the dark eugenics lessons of the past.

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TRANSPORTATION

The *Hindenburg* Crashes

In the 1930s, wealthy individuals had the opportunity to travel in a relatively novel way; Germany offered high-profile zeppelin flights between Europe and the United States. The crash of the *Hindenburg* airship is generally believed to have led to the end of the development of this unique form of passenger transportation. On May 6, 1937, the luxury passenger ship *Hindenburg* was attempting to dock at the U.S. naval base at Lakehurst, New Jersey, when it suddenly burst into flames, killing 35 people.

How do airships work? Airships are lighter-than-air craft that can be controlled through steering mechanisms. Like balloons, they float above the Earth's surface because they contain a gas (usually helium) that is less dense than the atmosphere. However, unlike balloons, airships can be steered, or piloted (which is the meaning of the French term, dirigeable). Generally, airships are controlled by means of an engine and propeller, and a rudder.

There are three kinds of airships, rigid, semi-rigid, and nonrigid. The rigid airships have a lightweight frame or skeleton beneath the outer covering (fabric or metal), called the envelope. Inside the envelope are cells of gas called ballonets. The *Hindenburg*, and similar zeppelins common in the 1920s and 1930s, were rigid airships. In contrast, nonrigid ships maintain their outer envelope shape not with a skeleton frame but by using the pressure from the gas inside. Modern craft such as the Goodyear Blimp are nonrigid airships. The semi-rigid incorporates both design ideas, using gas pressure to maintain the envelope, but also employing a rigid keel.

The* Hindenburg *story. The *Hindenburg* was a German zeppelin—a commercial airship derived from the innovative designs of Count Ferdinand von Zeppelin. It was a rigid airship with sixteen ballonets and four small diesel engines. Hydrogen, the

Figure 4.6.
The airship *Hindenburg* is engulfed in flames, 1937. Courtesy of Library of Congress.

lightest element found on Earth, was used in the ballonets to provide the lift necessary for travel. At 804 feet long and 135 feet tall, the craft was about four times the size of the modern Goodyear Blimp.

The *Hindenburg* was a luxury liner purchased by the German Nazi Party as a public relations tool. During its initial 1936 season, it carried over 1,000 passengers on ten flights between Europe and the United States. For a $400 one-way ticket, passengers could enjoy fine food and music while they relaxed in common spaces or in private cabins. Although travel was slow by the standards of today's jet planes (the *Hindenburg* averaged about 80 miles per hour on its fateful flight), the trip was notably shorter than taking a ship across the Atlantic.

On its final flight, the *Hindenburg* took off from Germany on May 3, 1937. On the evening of May 6, as it prepared to land in Lakehurst, New Jersey, it suddenly ignited and quickly was consumed by fire. Thirty-five people lost their lives in the accident.

Those who have tried to explain the cause of the *Hindenburg* disaster have proposed three theories. Some people originally believed that the ship was sabotaged by enemies of the Nazis. Others argued that a spark of atmospheric electricity probably ignited the hydrogen in the ship's envelope, causing the disaster. A lesser-known explanation was that the ship's envelope fabric, and not the hydrogen gas, was the flammable material that initiated the *Hindenburg*'s demise. Today, scientists believe the third theory is the most likely explanation for the disaster. No credible evidence of sabotage on the *Hindenburg* has been found. Although the hydrogen explosion theory has traditionally been the accepted explanation for the disaster, careful study of records and reconstruction of the events surrounding the crash now point to flammable envelope fabric as the probable culprit.

The aftermath of the* Hindenburg *disaster. By 1940, the last of the German zeppelins were dismantled, and the reign of the airship as a means of passenger transportation had come to an end. Although the tragedy was considerable, the worst loss of human life associated with the crash of an airship had occurred four years earlier. In 1933, the U.S. Navy airship *Akron* crashed in a storm off the east coast, killing seventy-three people. However, the high-profile *Hindenburg* crash was probably the reason why it is usually associated with the demise of passenger travel on airships.

The widespread impact of the *Hindenburg* crash was largely due to the description given by radio reporter Herb Morrison. At the scene of the *Hindenburg* disaster, Morrison, a reporter from Chicago radio station WLS, had waited to record the docking of the airship for a story to be broadcast later. Instead, he watched the huge craft burst into flames and stood witness to a tragic loss of human life.

Radio listeners heard Morrison's feverish words as he bore witness to the fiery scene in front of him: "Get out of the way! Get this, Charley! Get out of the way, please. She's bursting into flames! This is terrible! This is one of the worst catastrophes in the world. The flames are shooting 500 feet up in the sky. It is a terrific crash, ladies and gentlemen. It is in smoke and flames now. Oh, the humanity! Those passengers! I can't talk, ladies and gentlemen. . . ."

In these formative days of radio news, reporters were trained to take the perspective of detached, outside observers. Objectivity was expected. Morrison's broadcast was notable because he let his emotions show in his famous report, and audiences found his account riveting. Some wonder whether Morrison's tone played the decisive role in the demise of passenger airships. Had the reporter or his producers changed the report of the *Hindenburg* tragedy by editing out the emotional reaction and nonobjective tone, would we be crossing the oceans in luxury airships today? While we cannot know for sure, it is certain that the *Hindenburg* crash and the broadcast that announced it to the world remain indelibly etched in history.

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HUMAN KNOWLEDGE

The 1930s were a time of increased reliance upon human knowledge of the natural world to guide societal development. Scientists pushed to explore aspects of nature that had previously been out of reach—from the subatomic to the vast reaches of outer space. Especially in the United States, society's dependence on technology and scientific study was progressively being established. During this time, aside from the technological developments discussed above, Vannevar Bush built the first modern analog computer in 1930, and Alan Turing conceived of its digital counterpart seven years later. Wallace H. Carothers, a chemist for DuPont, developed nylon (1934), and his colleague Roy J. Plunkett synthesized Teflon (1938), two substances that would markedly change everyday life in American society in the years to come. The pesticide dichlorodiphenyltrichloroethane, or DDT, was used for the first time in 1939—another example of a chemical that would alter not only society but living systems in general. Other inventions that appeared during the 1930s would become indispensable and even taken-for-granted features of home and office life in the future: copy machines, ballpoint pens, and Scotch Tape all appeared during this time.

Significant contributions to our scientific understanding of the world were made during the 1930s. In biology, a young professor named Theodosius Dobzhansky provided a crucial theoretical link between theories of evolution and genetics. And in physics, scientists around the world continued to delve deeper into the structure of the atom, and began to unlock its mysterious secrets.

Dobzhansky's Theories of Biology

Theodosius Dobzhansky is perhaps best known to science teachers and students for his observation that "Nothing in biology makes sense except in light of evolution." Born in 1900 in Russia, he was still a teenager when he read Darwin's work on evolution and natural selection, and decided on a career in biology. By the late 1920s, he had moved to the United States to study at Columbia University. In 1937, his book *Genetics and the Origin of Species* was groundbreaking in its attempt to integrate genetics and evolutionary biology.

In the early twentieth century, biologists' ideas about evolution, from Darwin's writings, and about heredity, from the work of Mendel, were related only indirectly. Dobzhansky's work changed that picture dramatically. Studying the characteristics of successive generations of fruit flies, he proposed ideas about how broader evolutionary changes in populations of organisms come about.

Dobzhansky argued for the importance of genetic diversity for species survival. He observed that in any given population of a species, there are traits which seem to be unnecessary for the species to survive. However, transformations in the natural environment could render these same traits necessary, even crucial, to the continued existence of a species. Therefore, Dobzhansky argued, the more genetic diversity is contained in a particular population, the more chance that population has to survive environmental change.

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Exploring the Subatomic

Physicists in the 1930s continued to chip away at the mysteries of the atom. In 1930, Ernest Lawrence provided a crucial tool for doing just that when he introduced his "cyclotron" particle accelerator. This laboratory apparatus employed a magnetic field acting over a spiral tunnel to speed up small particles to extremely high velocities. The high-speed particles, used as "atom-smashers," were sent crashing into atoms in order for physicists to study the resulting collisions.

In 1932, James Chadwick confirmed the existence of neutrons—small, neutrally charged subatomic particles that had been theorized to exist in the atomic nucleus but had never previously been isolated. Later the same year, physicists established the existence of "antimatter," which had similarly been predicted but never detected.

Perhaps the decade's most ominous scientific advances centered on the beginning of our understanding of nuclear reactions. In 1932, Ernest Walton and John Cockroft shot high-speed particles at lithium atoms, which broke into two smaller pieces and released a large amount of energy. This artificially induced nuclear reaction created much interest in the possibility of a new and efficient energy source. Later, the Germans Otto Hahn and Fritz Strassmann bombarded unstable uranium-235 atoms with high-speed neutrons, and observed the splitting of uranium-235 into two smaller atoms, with a resulting release of energy. Hahn and Strassmann's associate, Lise Meitner, named the nuclear reaction "fission."

Scientists eventually recognized the possibility of a self-sustaining chain reaction of uranium atoms: one split nucleus released neutrons, which could split more nuclei and release more neutrons, splitting more nuclei, and so on. Although open information and shared knowledge is an understood value of scientific practitioners throughout the world, the dark realities of life in late 1930s Europe scared many scientists into secrecy with regard to this threatening nuclear development. With Hitler's increased military presence throughout Europe, thoughts were focused on impending conflict, and suddenly the possibility of using a chain reaction as a weapon of war was a looming reality. In a letter dated August 2, 1939, a small group of prominent scientists urged President Roosevelt to keep abreast of the situation, noting the potential significance of the achievement of an artificially produced fission reaction. Little did some of these scientists know how deadly accurate their premonition was to be.

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Chapter 5

THE FORTIES

SOCIETAL CONTEXT: DEVASTATION OF GLOBAL WAR

By the early 1940s, the world's geopolitical boundaries were changing rapidly. The expansionist efforts of the Axis countries—Germany, Italy, and Japan—had allowed them to dominate most of Europe and large portions of China, the rest of Asia, and northern Africa. The Allied powers of France, Poland, and the United Kingdom tried to halt the Axis aggression by waging battles on land, on sea, and in the air. Originally neutral, the Soviet Union employed its massive Red Army to relentlessly hammer the German infantry after being attacked by Germany in mid-1941. The United States remained a noncombatant until the Japanese attacked Pearl Harbor on December 7, 1941. The new war, World War II, was truly a *world* war, involving more countries across the globe than had World War I.

In the 1940s, war permeated all aspects of life and influenced manufacturing and business endeavors. Engineers now worked on defense radar, weaponry design, and military transportation. Pfizer risked all of its assets by curtailing its normal pharmaceutical production and taking up the government's call to focus on a new fermentation process to mass-produce penicillin for injured soldiers. The first freeze-dried orange juice crystals were supplied to the U.S. Army in 1941. Silk production was slow and costly, but new, synthetic nylon could be manufactured cheaply and on a massive scale. As a result, the newest fashion in leg wear, nylon stockings, suddenly became scarce as nylon fabric was being used for military parachutes to aid the Allied war effort.

World War II gave rise to unprecedented forms of technical sophistication in weaponry. Napalm, a chemical designed to start fires, was developed by U.S. military scientists at Harvard University. In 1944, the Nazis launched the first rocket-propelled missile against London. Radar was first utilized in the World War II efforts to locate battleships and detect enemy bombers and fighter planes. The invention of atomic weapons changed the world's concept of defense forever when the Japanese cities of Hiroshima and Nagasaki were bombed by the United States in 1945. With their surreal, devastating effects, the atomic bombs ended the war in the Pacific.

The development of electronic technologies for the war effort would prove to have a lasting impact on society at large. In 1943 British scientists at Bletchley Park developed Colossus, an electronic decoder that processed 25,000 letters per second and deciphered German Army communications across Europe. The U.S. War Department commissioned electrical engineers John Presper Eckert and John Mauchly at the University of Pennsylvania to develop a digital electronic computer. The ENIAC, an electronic numerical integrator and computer, filled an entire room, weighed 30 tons, and used a series of more than 17,000 vacuum tubes and miles of wire. It was designed to perform complex ballistic calculations for the military to improve the aim and percentage of targets hit by missiles.

After World War II, a weary planet began to rebuild. The Information Age—in its infancy—crawled forward. Although television broadcasting had begun to take hold in the early 1940s, it was suspended during the war. However, the first postwar Olympic Games, held in London, were viewed by thousands of families worldwide via television, signaling the beginnings of a media revolution. Computer technology advanced further as mechanical parts were replaced with nonmoving electrical parts to speed up calculations in machines such as the IBM Mark I, the first large-scale automatic calculator. In fact, by the end of the decade, the rate of computer processing had increased to thousands of calculations per second.

It is tempting to think that because technical breakthroughs kept pace after the war, life was back to normal. In fact, the emotional scars of global battle ran deep. For many, the faith in scientific progress and technological innovation which had carried Americans through the war years had become a substitute for faith in the human character. The resulting politics and ideologies would see the advent of a new type of war in the decade to come: the Cold War.

ARCHITECTURE & ENGINEERING

Tacoma Narrows Bridge Disaster

Suspension bridges are among modern society's oldest structural achievements, and they acquired a renewed importance as the automobile created an increased need for roads and bridges in the twentieth century. Suspension bridges are easier to build and more economical than other bridge designs. Thus, they became a popular model to incorporate into America's expanding network of roadways.

A large majority of the suspension bridges built in the United States were constructed during the last half of the 1800s and were modeled after those built in Europe. Historical records detail the lessons learned from the collapsing of many European suspension bridges built in the early 1800s. However, through the next century, risks were escalated as the spans of newly constructed suspension bridges slowly grew longer. As each successful bridge was built, confidence rose. Soon the girder construction became less rigid and lighter to appeal to artistic considerations rather than engineered soundness of design, and the lessons of the previous century went unheeded. The Tacoma Narrows Bridge failure could be attributed to this trend toward sleek aesthetics at the expense of structural stability.

Suspension bridge design. Suspension bridges have four main components: the anchorage, the towers, the cables, and the roadbed. First, two towers must be built high enough to hold cables that stretch across a river, canyon, or other obstacle. Each end of each main cable is secured to an anchorage or a block located behind the towers to provide tension. Attached to the main cables are suspender ropes that hang down and are connected to the roadway. This system of cables and suspender ropes holds up the roadway. As simple as this design might seem, there are many complex forces that come into play when considering the stability of suspension bridges.

Bridge history. On July 1, 1940, the Tacoma Narrows Bridge was opened to traffic crossing Puget Sound in Washington. It was 2,800 feet long and 39 feet wide, with 8-foot-tall steel girders for stiffening. At its opening the bridge was the world's third largest suspension bridge. It was fashioned by Leon Moisseiff, the design engineer, to be graceful and sleek. Its deck was considerably more slender than those of the George Washington Bridge and the Golden Gate Bridge.

Suspension bridges around the world have been known for their swaying motion. In some cases, it actually became common for residents to take visiting relatives to watch a local suspension bridge sway and vibrate during a windstorm. Before it was opened to the public, the Tacoma Bridge was nicknamed "Galloping Gertie" by workers constructing it. Even in light winds, the bridge oscillated and fluttered. A number of remedial measures were completed before and after the opening of the bridge to try and stabilize it. Inclined stay cables, tie-down cables, and dynamic dampers were all added, but none provided any significant improvement.

The oscillating vertical motion seemed relatively harmless, and motorists were able to use the bridge for four months until November 7, 1940. Early that morning the wind velocity was 40 to 45 miles per hour, somewhat stronger than previous winds but nothing of great concern. However, by 9 A.M. the bridge was closed to traffic as the amplitude (crest to trough) of the wave motion on the roadway reached about 5 feet and the frequency of waves was 12 to 14 vibrations per minute. About 10 A.M. a very strong torsional (twisting) movement suddenly occurred on the bridge, and the frequency quickly changed. As it swayed, the bridge floor rotated about 45 degrees in each direction. The rotating movement of the bridge made one sidewalk 28 feet higher than the other side of the bridge. By 11 A.M., the center span—measuring 600 feet long—had dropped into Puget Sound.

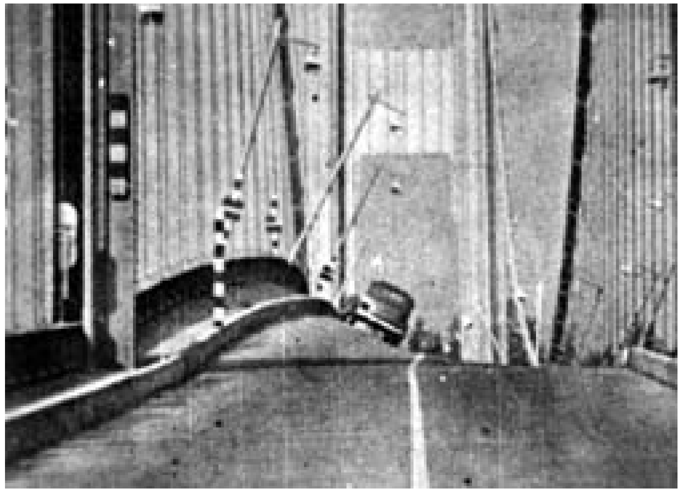

Figure 5.1.
The twisting Tacoma Narrows Bridge, 1940. Courtesy of Library of Congress.

The collapse of the bridge is noteworthy in itself, but the fact that engineers such as F. B. Farquharson were able to record significant data as the bridge began to undulate and twist itself apart has resulted in much research in torsional and vertical oscillation. Using details from movies of the collapse, still shots, and descriptions from observers, scientists eventually pieced together possible explanations for the demise of the bridge.

Why did the bridge collapse? According to its specifications, the Tacoma Narrows Bridge should not have collapsed. The span was designed to withstand winds of approximately 100 miles per hour, more than double the 45-mile-per-hour winds that took it down. It was also calculated to withstand a lateral sway of about 6 meters, yet on the morning of its collapse it was just 6 decimeters out of alignment—a mere one-tenth of the deflection it should have endured. A commission that was formed to study the collapse of the bridge concluded that the bridge was built sturdily enough to withstand static forces. It also verified that the materials and workmanship were of high order.

So why did the bridge fail? In answer, the commission acknowledged the engineering community's fundamental lack of awareness of the dynamic effects of wind on suspension bridges. Without drawing any definite conclusions, they explored three possible explanations of dynamic action: aerodynamic instability (negative damping that produces self-induced vibrations); possible periodic eddy formations; and random fluctuations in the velocity and direction of the wind. Most current science textbooks blame the failure of the bridge on *resonance*.

What is resonance? Resonance is the ability of anything to vibrate by absorbing energy at its own natural frequency. The number of times an object vibrates per second is referred to as the object's frequency. An object will vibrate best at only one frequency—its natural frequency. You can hear the natural sound of an object by striking it. When an object is vibrating at its natural frequency, it is said to be resonating. When an object resonates, it becomes louder than normal. For example, if you sing a tone in front of a piano, you can hear the piano "reply" in the same tone. Only those strings with vibration rates identical to the singing tones will resonate loudly enough to be heard.

A more concrete illustration of resonance is given by the example of a child on a swing. A swing has a natural frequency related to the length of its ropes (which is much slower than that of the musical notes in the example above). If the child tries to pump her legs back and forth in a random way, the swing will not move very high. Instead, it will move in random wiggles. Once the child learns to time the pumping motion to the tempo of the swing, each pump adds energy to the previous one. Each additional pumping action adds energy at the right time to make the swing go higher and higher. The same amount of random energy that caused a jerky motion for the child will produce a cohesive, cumulative motion when pumped in a more rhythmic fashion in step with the swing's natural frequency.

The wind blowing on the Tacoma Narrows Bridge worked in much the same way as the child's pumping on the swing. It was blowing in a periodic manner; in other words, wind gusts varied regularly with respect to time. The wind started the bridge oscillating until it reached its natural frequency, which increased the vibrations enough to twist it apart. When resonance occurred, the relatively small wind speed of 40 to 45 miles per hour added to the vibrating energy of the bridge and produced large deflections. This pulled the bridge apart.

Bridge rebuilt. Much of the knowledge learned from the Tacoma misfortune was not immediately used to modify and correct faulty designs. The demands of World War II pulled engineers' efforts in other directions. As a result, sensors to measure wind and seismic motion were not added to bridges until after 1945, at the conclusion of World War II. The Tacoma Narrows Bridge was rebuilt at the end of the 1940s—this time, with the benefit of the research on dynamic wind motion.

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ARTS & ENTERTAINMENT

Fire at the Cocoanut Grove Nightclub

A devastating fire at the Cocoanut Grove nightclub in Boston shattered the lives of over a thousand partygoers the night of November 28, 1942. Many of the patrons were there to celebrate the outcome of a football game between Boston College and Holy Cross, while others were saying last goodbyes to friends who had enlisted in the military and were soon departing for Europe. The largest and most popular Boston nightclub had exceeded its capacity by over 400 people when the fire started at the basement level, in the Melody Lounge. It is reported that a sixteen-year-old busboy lit a match when he couldn't find the light socket in a darkened room so he could replace a lightbulb. Unfortunately, some flammable decorations caught fire, and within seconds, flames spread to curtains and moved throughout the basement.

People on the main floor continued to dance, not knowing of the terror below. Within minutes panic enveloped the crowd as flames shot up through the floor from the basement. People raced to the exits, trampling and clawing at each other. To complicate matters, the fire burned through the insulation of the electrical wires, causing the fuses to shut off the electric lights within 3 minutes of the start of the fire. Few could escape the smoke-filled inferno because the side exit doors opened inward. The main exit, a revolving door, had been jolted off its axis, blocking most of the 6-foot exit. Another door had a panic lock that should have opened under pressure, but was reportedly welded shut to discourage customers from leaving without paying their tabs.

Treating burn victims: One patient every eleven seconds. As the Boston hospitals went into disaster mode, it was reported in the *Boston Globe* that an emergency room physician recalled receiving "one patient every 11 seconds." Typically, about 5 percent of patients hospitalized with serious burns die, and another 50 percent perish from asphyxiation or carbon monoxide poisoning caused by smoke inhalation. Despite the incredible number of patients and the dismal odds, the Cocoanut Grove fire has been credited with improving medical care for burn victims. In fact, important research on how to better treat burn victims came about as a result of the fire.

The skin is the largest organ of the human body. It performs many functions, including protecting an individual from bacteria and foreign bodies, insulating against dramatic changes in body temperature, assisting in the process of perspiration, promoting hair growth, and retaining fluids. Skin is composed of two layers: a thin outer layer called the epidermis, and a strong, stretchy inner layer called the dermis.

Burns are classified as first, second, third, or fourth degree. Although the measurement is subjective, the degree of a burn is determined by an estimation of how deeply the burn damage has penetrated the layers of skin. First-degree burns are the mildest and can usually be described as similar to a serious sunburn. The upper layer of the skin, the epidermis, is affected. Second-degree burns involve the lower layer of the skin, the dermis. Blisters form and the area burned is very painful. When the damage goes deep enough to include the fat layer underneath the two layers of skin, it is considered a third-degree burn. Third-degree burns do not heal on their own, and extensive medical attention is needed. The skin at first is numb and feels hard or waxy. Fourth-degree burns go even deeper. Bones, muscles, and tendons below the skin are damaged. Although the degree of a burn is important in determining treatment, the amount of area damaged is often a more significant consideration.

Medical treatment of a burn starts with cleaning the area of dead tissue and foreign matter. Antibiotics are used to fight or prevent infection. Second-degree or more serious burns impair the skin's infection-fighting ability, so intravenous antibiotics may be administered in addition to topical ones. In fact, the use of penicillin to treat the victims of the Cocoanut Grove fire helped to popularize the drug. Upon seeing the results, everyone wanted access to the miracle drug.

To heal large areas of damaged skin, doctors perform skin grafts. Healthy new skin, consisting of the epidermis and the top portion of the dermis, is removed from an unaffected area of the patient's body and placed over whatever dermis is left on the damaged area. The transplanted section of skin will heal over time, as will the area from which the healthy skin was harvested. Reconstructive surgery is usually necessary after the areas heal. The physical damage from serious burns is devastating, but the excruciating pain and psychological trauma due to disfigurement and multiple surgeries can be even more difficult to treat.

Regulation changes in the aftermath of the fire. In total, 492 people died, and hundreds of others were severely burned or otherwise injured in the Cocoanut Grove fire, having sustained both physical and psychological injuries. The disaster prompted authorities to adopt and enforce stricter building and occupancy codes. Immediately after the fire, nightclubs were required to install emergency lighting and occupancy placards. Lights indicating exits and exterior doors that open outward were now dictated on commercial and public buildings. A law was also passed that prohibited the use of flammable materials in decorations.

For the first time in history, prosecutors brought criminal charges against owners and landlords who violated construction and safety codes. The owner of the nightclub was found guilty of manslaughter when it was proven that he had previously locked club doors and operated the lounge without approval from the city's building inspector. The legal precedent of this case has helped convict many other owners throughout the years. Safety and building codes are taken more seriously now that they are upheld by legal measures established by this tragedy. Ironically, a smoke alarm had been invented and was available, but was not installed at the Cocoanut Grove Lounge.

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COMMUNICATION

Transistors Change the World of Communications

The early 1900s brought telephone communication to most people, although the capability to connect across long distances was not available until later. Two inventors who made long-distance conversations a reality were J. Ambrose Fleming and Lee De Forest. In 1904 Fleming developed a diode tube, which was followed by De Forest's invention of the triode tube two years later. These devices could amplify small electrical signals and permit weak circuits to control strong circuits. The tubes consisted of red-hot filaments that would burn out upon contact with air. Therefore, the air was pumped out of the tube, leaving a vacuum inside. This was the beginning of vacuum tube technology.

Using De Forest's vacuum tube, scientists from the research laboratories of American Telephone and Telegraph (AT&T) devised a way to carry telephone signals over long distances. The signals were amplified at regular intervals from one switch box to the next across deserts and plains. As long as there were amplifiers along the line, the message went through loud and clear. This structure was used for the first half of the 1900s, but proved to be notably unreliable. Vacuum tubes were large and consumed a great deal of electrical power. Much of that power was converted into heat, which shortened the life of the tube.

In order to make further advances in communications capabilities, a new technology would be needed. During the 1930s, William Shockley, a scientist for Bell Laboratories, explored solid-state physics as a potential source of insight for developing a replacement for the vacuum tube. Over ten years later, he developed a theoretical device that would use semiconducting material to amplify signals, rather than the vacuum tube filament design. Shockley had devised a plan for the first transistor.

In 1945, Walter Brattain and John Bardeen joined Shockley to work on the engineering and development of the transistor. Bardeen developed theory while Brattain built the necessary equipment and conducted experiments; often they worked as rivals rather than colleagues with Shockley. On December 16, 1947, Brattain and Bardeen built the first working point-contact transistor. Not to be outdone, Shockley feverishly worked out another advancement to the theory. Although the research and design process was sometimes marred by personal egos and competitive secrecy, the realization of the solid-state transistor was a brilliant scientific and technological feat. The three men were honored with the Nobel Prize in 1956 for their contribution to its development.

What is a transistor? The function of a transistor is very similar to that of a vacuum tube, but it is faster, much smaller, and considerably more energy-efficient than its ancestor. Much of the input energy of the vacuum tube was converted into heat. However, excess heat production does not occur in a transistor, so it can be made smaller and can be placed closer to other components in the circuit.

The main function of a transistor is to regulate current; for example, it might amplify an electrical signal or turn the electric current on or off. Transistors have three wires. Two of the wires are connected in the circuit so that electrons come in by one wire and leave by the other. The emitter is the incoming wire, and the collector is where the charge is collected so that it can leave. The third wire is the control wire. Small voltage changes on the control wire regulate the flow of electrons in the other two wires. This can be accomplished through the design of the transistor, which relies on the special properties of materials known as semiconductors.

What is a semiconductor? Semiconductors are substances that exhibit the properties of both metals and nonmetals. As a result, they have some unique characteristics that lend themselves to interesting technological applications. For example, metals are electrical conductors that can permit an electrical current to flow through them; nonmetals are insulators that do not carry a current. Semiconductors, on the other hand, have a range of potential conductivity, which makes them useful for technologies in which a goal is to control electric current in some fashion.

Metals typically conduct electricity because of the arrangement of the electrons they exhibit at the atomic level. In general, atoms with eight electrons in an outer shell, or energy level, have a stable electron configuration. Metal atoms have only a few electrons in their outermost energy level: generally one, two, or three. As a result, these electrons are loosely bound and therefore can be easily removed to "drift" during the application of voltage: this electron drift is electric current. On the other hand, *nonmetals* generally have all but a few electrons present in their outer shell (usually six or seven). These electrons are more tightly held, and do not tend to drift in the presence of a voltage. Thus, nonmetals are nonconductors, or insulators, of electric current.

Semiconductors are elements that fall between these two groups and exhibit both metallic and nonmetallic characteristics. Silicon, gallium, and germanium are such elements. Each of these has four free electrons in its outer shell. Pure germanium or silicon is generally a nonconductor and may be considered a good insulator. However, with the addition of a certain impurity in carefully controlled amounts, the conductivity of the material is altered. In addition, the choice of the impurity can change the direction of the conductivity through a crystal. Some impurities increase conductivity to positive voltages while others increase the conductivity to negative voltages. In other words, semiconductors conduct electricity better than insulators but less well than conductors, and when they are contaminated with atoms of other elements, their properties of conductivity change drastically.

The mechanism of conduction in semiconductors is different from that in metallic conductors. In semiconductors both negatively charged electrons and positively charged particles exist. The positively charged particles are called holes, and behave as though they had a positive electrical charge equal in magnitude to the negative electron charge. The process of adding contaminated atoms to a crystal of semiconductor material is called "doping." In doping, some of the pure silicon, gallium, or germanium atoms are replaced by such atoms as arsenic or boron. Doping with an arsenic atom, which has five electrons in its outer shell (compared to the four electrons in the adjoining silicon atoms), leaves the extra electron from the arsenic atom free to move around. The opposite is accomplished when doping with boron. Boron, with only three electrons in its outer shell, is used to replace a silicon atom, thus creating a receptor for an electron. The electrons drift differently in each case; thus the current flow can be controlled.

In the transistor there are three different regions of semiconductors. Each wire is located in a different region. When the voltage along the control wire changes, it can change the connection between the emitter and the collector from conducting to nonconducting. Depending on the voltage on the control wire, the conduction in the circuit may be minimal or full tilt.

Transistors change lives beyond the imagination. Shortly after the invention of the transistor it was obvious that the impact of its creation was monumental. The invention truly marked the beginning of the current age of electronics. Replacing vacuum tube technology with one that was more reliable, consumed less energy, produced less heat, cost considerably less to manufacture, and was minute in comparative size, allowed the development of new—and especially miniature—kinds of electronic equipment to flourish. For example, the first electronic computer, ENIAC (Electronic Numerical Integrator and Computer), which relied on vacuum tube technology, occupied 2,000 square feet of floor space—an area comparable to a room 100 feet long and 20 feet wide. It contained 18,000 vacuum tubes that produced so much heat the room needed air-conditioning year round. If the ENIAC had been built with transistors, it would have occupied a space the size of a credit card. The transistor and the tiny electronic devices born from it led the way to the improvement or creation of transistor radios, television sets, calcu-

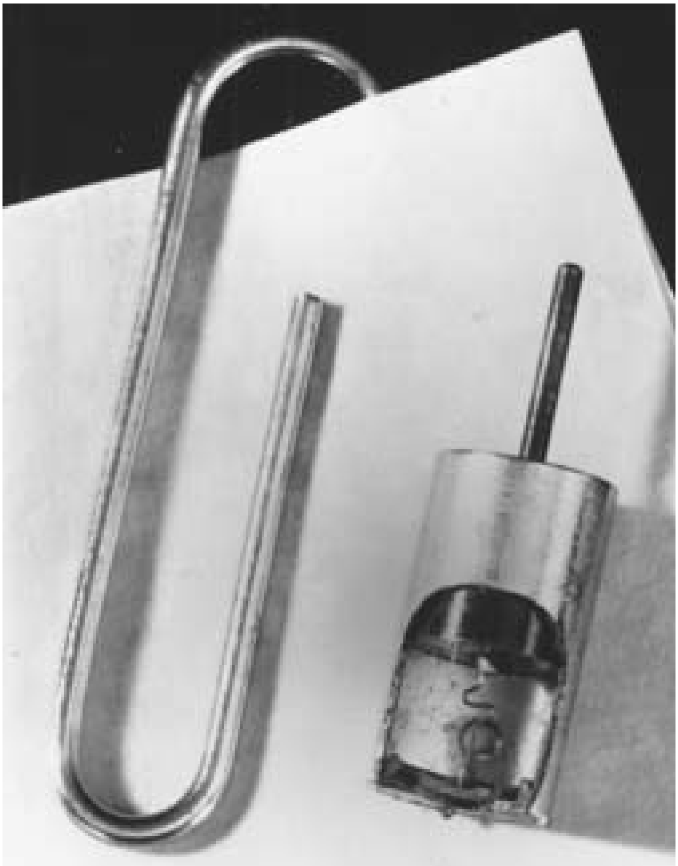

Figure 5.2.
A transistor, shown in comparison to a paper clip. Courtesy of Library of Congress.

lators, movie cameras, and the many electronic items familiar to Americans in the twenty-first century.

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DEFENSE & DIPLOMACY

The Manhattan Project

The saying "Necessity is the mother of invention" could be used to describe the motivation and purpose of the U.S. effort to develop the first atomic bomb during World War II. Under the code name "the Manhattan Project," the United States recruited the country's best scientists and engineers to work around the clock to develop technology that could be used to harness the energy created from a newly discovered, extremely powerful type of reaction called nuclear fission. Yet, many were unprepared for the formidable reality this weapon would create.

On August 6, 1945, the "Little Boy" atomic bomb was dropped on the city of Hiroshima, Japan. As the bomb detonated 1,900 feet above the ground, Hiroshima was vaporized. Temperatures near the center of the explosion were estimated to have reached 7,000° F. About 90,000 Japanese citizens died instantly and another 140,000 died later from the effects of radiation exposure. Over 90 percent of the city's 76,000 buildings were destroyed. The impact of atomic weaponry was unparalleled in history, and it changed the course of life in the twentieth century.

Why did the United States want to create a new bomb? In the late 1930s, many distinguished European scientists who had fled Nazi persecution to the shelter of the United States described how Germany was experimenting with the energy produced by fission to create a powerful new explosive device. These scientists were cognizant of the devastating consequences to Allied nations if the Germans were to succeed in building the first nuclear bomb, and so many of them worked to bring their concerns to the attention of the president of the United States. In a letter to Franklin D. Roosevelt, the famous physicist Albert Einstein described how newly discovered chain reactions of the element uranium give off enormous amounts of energy that could be used to construct an extremely powerful bomb. Einstein recommended that the U.S. government develop a partnership with the group of American scientists who were working on the chain reactions to help to speed up experimental work with uranium. British scientists, who also were aware of the impending German atomic bomb development, urged the United States to press forward with its own research. These realities, combined with the bombing of Pearl Harbor by the Japanese, provided the United States with the motivation to dedicate the resources necessary to build an atomic weapon.

In early 1942, research for the project was housed in the Manhattan Engineer District in New York, and thus the secretive project was dubbed the Manhattan Project. Some experimental work for the Manhattan Project was done at the University of Chicago, where research on fission chain reactions was already taking place. The American physicist Arthur Compton was chosen to head up the research in Chicago with help from immigrant physicists Enrico Fermi, Leo Szilard, and Eugene Wigner. These four scientists performed groundbreaking research on methods of controlling fission, which allowed a viable bomb to be constructed.

What is fission? Nuclear fission is a kind of reaction in which the core of an atom is broken into smaller pieces, with a large amount of energy being given off in the process. Fission was discovered by accident, but because of its tendency to self-propagate as a chain reaction, it was quickly recognized as a potential way to produce a massive release of energy.

To understand fission, it is important to understand the structure and design of the atom. Atoms are made up of smaller particles known as protons, neutrons, and electrons. The tiny, dense core—or nucleus—of an atom contains the protons, which have a positive charge, and the neutrons, which are neutral (have no electric charge on them). Electrons are not part of the nucleus, but are found in cloudlike regions of space surrounding it. In a normal chemical reaction, atoms either combine to form molecules, or molecules break apart to form atoms, or both. However, in these ordinary chemical reactions, the electron clouds are the site where bonds between atoms are broken and re-formed; the nuclei of the atoms involved remain unchanged. A fission reaction is different. In fission, the nucleus itself undergoes a transformation, as an atom is literally split apart to create new kinds of atoms.

The amounts and kinds of subatomic particles in a particular atom give it its unique characteristics. A chemical element is identified by its *atomic number*, the number of protons it has in the nucleus of one of its atoms. For example, an atom of carbon has six protons in its nucleus. A carbon atom can also have six neutrons and six electrons, but these numbers can vary without changing the identity of the element. An atom with six protons and seven neutrons, for instance, is still carbon. An atom with six protons and six neutrons is known as carbon-12. The "12" indicates the *mass* of the atom, which is obtained by adding the number of protons and the number of neutrons in the nucleus. A carbon atom with seven neutrons would be known as carbon-13; carbon-14 would have eight neutrons in its nucleus. Atoms of the same element that have different numbers of neutrons in their nuclei are known as *isotopes*.

Atomic nuclei are held together by a powerful force. However, certain combinations of protons and neutrons in a nucleus are somewhat unstable, and over time a nucleus that has one of these unstable configurations will undergo a spontaneous transformation in order to become more stable. This process is called radioactive decay. When a nucleus undergoes radioactive decay, it can change into a different kind of element, by losing or gaining protons. The French physicist Antoine-Henri Becquerel discovered radioactivity in 1896. Later, Marie Curie classified three forms of radiation as alpha, beta, and gamma.

In 1938, the German scientists Otto Hahn and Fritz Strassman were trying to create isotopes by bombarding uranium with neutrons. After the experiment, they noticed that the uranium sample now contained atoms of barium. Later, Lise Meitner determined that hitting the uranium atoms (which have ninety-two protons) with fast-moving neutrons had caused some of them to split into atoms of barium (fifty-six protons) and krypton (thirty-six protons). Uranium-235 has an unstable nucleus, and so will readily undergo a rearrangement when struck by a neutron in this way. This process became known as nuclear fission.

In order to initiate fission in a sample of uranium-235, it is first bombarded with neutrons. The uranium may split into barium and krypton, or it may split into other kinds of atoms. As the nucleus divides, it releases a few neutrons, which are ejected into the surroundings. These neutrons can then hit other uranium-235 nuclei, which split and release more neutrons, and so on. Because the reaction can sustain itself in this way, it is known as a chain reaction. Each time a nucleus splits, it releases a great deal of energy in the form of gamma radiation and heat.

Taming nuclear fission. In order to incorporate a fission reaction into an explosive device, scientists and engineers who worked on the Manhattan Project knew that they would have to be able to control the fission reaction. This control is a matter of having a *critical mass* of uranium-235. When there are too few uranium-235 atoms in a fission sample, or when these atoms are not densely concentrated enough, the chain reaction will die out because the neutrons that are released cannot hit new nuclei to keep the reaction going. This is why the uranium-235 that is found naturally on Earth does not spontaneously undergo a fission reaction—there is not a sufficient concentration of it to sustain a reaction when one nucleus decays and releases more neutrons into the surroundings. A critical mass of uranium-235, or any fissionable material, is the amount and concentration needed to keep a chain reaction going.

When fission reactions are used to produce energy in nuclear reactors, it is necessary to have a critical mass of fissionable material such as uranium-235. Scientists manipulate the composition of the fuel source to maintain a steady rate of reaction. Atoms of fissionable materials such as uranium-235 and plutonium-239 are interspersed throughout atoms of uranium-238, which does not break apart when bombarded by neutrons. In addition, water and graphite serve as moderators, and are used to slow down the neutrons that are released during fission. Other substances, such as cadmium and boron steel rods, are used to absorb excess neutrons. When more neutrons are absorbed than are released by the fission process, the reaction can be slowed down. Therefore, the reaction rate can be changed by moving the control rods in and out. When the concentration of fissionable substances reaches a *subcritical mass* (concentration is less than the critical value), the reaction will come to a stop.

To make an atomic bomb, scientists needed to find a way to allow a *supercritical mass* (concentration is greater than the critical value) of fissionable material to react. With a supercritical mass, fission would not proceed steadily; instead, it would produce a chain reaction that accelerated quickly to create a virtually instantaneous, enormous burst of energy. Of course, while stored in the bomb before detonation, the fissionable atoms must be kept at a subcritical mass, to keep the dangerous reaction from occurring prematurely. The challenge for bomb designers, then, was to devise a safe way to quickly turn a subcritical mass of fissionable substance into a supercritical one. One design allowed for a subcritical mass of uranium to be shot into a second subcritical mass during detonation, producing a supercritical mass and a large chain reaction. A second design used an implosion on detonation to push subcritical masses together into a supercritical one.

What were other obstacles to building the bomb? The stumbling blocks for the Manhattan Project went beyond those of controlling the fission reaction rate. Another problem was finding and obtaining an acceptable and plentiful source of fissionable material to serve as fuel for the bomb. Uranium occurs naturally on the Earth's surface in the form of uranium ore. As it is mined, uranium ore consists of two main isotopes, uranium-238 and uranium-235. Only uranium-235 can be used to produce chain reactions, but it constitutes merely 1 percent of the uranium found in naturally occurring ore. In order to create a critical mass of the substance, the two isotopes had to be separated, and then recombined in the appropriate ratio.

Scientists at the Oak Ridge laboratory focused on separating out uranium-235 atoms in preparation for making fission fuel. Known methods used to separate the isotopes included magnetic separation, gaseous diffusion, and centrifuging; all of which could be relatively difficult to perform. In 1941, a new element with an atomic number of 94 was discovered. This element—plutonium—was also capable of sustaining the chain reactions needed to fuel an atomic bomb. Scientists found that plutonium-239, the most fissionable plutonium isotope, could be made by leaving readily available uranium-238 in a nuclear reactor for long periods of time, which made it relatively easy to acquire for use in the bomb. To supply the Manhattan Project with enough plutonium to fuel an atomic bomb, four new production reactors modeled after Fermi's reactor at the University of Chicago were slated to be built.

Where were the bombs created? Manhattan Project officials determined that construction of the nuclear bomb was to take place at a central weapons facility. The new laboratory would require a climate that permitted year-round construction, and it must offer safety from enemy attack, ease of transportation, and access to power, water, and fuel. It would also have to provide an adequate testing ground and, for reasons of safety and security, should be in a sparsely populated area. Finally, after much searching, the new laboratory was located in a remote part of the New Mexico desert called Los Alamos.

By 1943, the Los Alamos facility, headed by the physicist J. Robert Oppenheimer, was operating at full capacity. Three bombs were built. The first bomb, "Gadget," was a test model of the plutonium bomb. The second bomb, "Little Boy," named for its appearance, was a uranium bomb. The third bomb, "Fat Man," was another plutonium bomb.

On July 16, 1945, the world's first atomic bomb was detonated at the Trinity Test Site, located in a valley between the Rio Grande River and the Sierra Oscura Mountains in the New Mexico desert. More powerful than originally expected, the explosion of "Gadget" was equivalent to about 20,000 tons of TNT. After inspection of the test site, the half-mile radius from the center of detonation became known as the "vaporization point." Everything located in this area was missing or burned beyond recognition. Items located within a mile radius suffered severe blast damage. Up to a three-mile radius, severe fire and wind damage was apparent.

A grave decision. Because of the complete destructive powers of the atomic bomb, the decision to use it in wartime was fervently debated. Germany had surrendered in May 1945, and was no longer a threat to the United States. However, war with Japan raged on.

In July 1945, the leaders of the United States, Great Britain, and the Soviet Union met in Potsdam, Germany, to discuss options for ending the war with Japan. Harry Truman, Winston Churchill, and Joseph Stalin called for Japan's unconditional surrender in a document known as the Potsdam Declaration. Japan refused to comply, and it was decided that the use of the atomic bomb could bring about a quick end to war.

On August 6, 1945, "Little Boy" exploded above Hiroshima with devastating consequences. Three days later, the powerful "Fat Man" bomb was dropped on Nagasaki. This new weapon left an indelible and frightening impression upon the world. Not knowing how many similar bombings might be in store for his country should the war continue, Emperor Hirohito announced Japan's surrender on August 14, 1945.

Guilt and devastation beyond belief. Many of the scientists who created the bomb were horrified by the effects of the bombs dropped on Hiroshima and Nagasaki. Some worried about the future of the world. In the ensuing years, many of these scientists openly and actively opposed the development of more bombs. Robert Oppenheimer was stripped of his security clearance and was even considered a dissident.

Debate over the decision to use nuclear force against Japan continues into the twenty-first century. One criticism has been that the bombs were dropped on civilian, rather than military, targets. Another is that the bombs should not have been used until the full range of their effects was known. However, supporters of the decision believe that it saved the lives of many soldiers who would have died if the Allies had had to invade Japan to force its surrender.

Some historians have argued that the bombing of Hiroshima and Nagasaki left an impression upon the world which was horrific enough to deter the use of nuclear weapons throughout the rest of the twentieth century. Although the weapons have not been used in an act of war since, many nations have sought to add fission (and eventually fusion) bombs to their military stockpiles. However the events of August 1945 are viewed, it cannot be denied that the development of nuclear bombs marked a new era for life on Earth. The products of the Manhattan Project gave us a means to literally destroy the world. At the start of the twenty-first century, humans have yet to come to terms with containing this possibility.

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ENVIRONMENT

Rubber Shortages

Once it became deeply embroiled in World War II, the United States utilized every resource available to ensure victory against Germany and Japan. The efforts necessary to support the war effort taxed the supply of commodities upon which the nation had come to depend. The availability of items such as tin, paper, vegetable oil, and rubber had once been taken for granted, but this was no longer the case. Regional sources of many metals and the domestic initiatives to produce other resources helped lessen the impact of some of the supply crunch. However, the United States had few local sources of natural rubber, and this shortage was felt most profoundly. From tires to raincoats, bathing caps to gloves, many common, everyday goods were made of rubber. With a military need for rubber items like tires, hoses, insulation, and shoes, domestic applications were in scarce supply.

Aware of the escalating need for rubber, the U.S. government initiated several programs in the attempt to supply at least the nation's military and essential civilian requirements. To jump-start the effort to bolster the nation's rubber supply, Congress passed the Emergency Rubber Project Act to establish large-scale domestic sources of natural rubber. In addition, more programs were developed to fund research into synthetic rubber production. Finally, scrap rubber drives were organized in which civilians "did their part" for the national war effort by collecting scrap rubber products to be reclaimed and recycled for further use.

What is rubber, and where does it come from? The discovery of natural rubber was in Central and South America, where the sap that flowed from the bark of certain trees was captured, condensed, and used by indigenous people. This substance was called caoutchouc, meaning "weeping tree," and was used to create waterproof clothing and cooking vessels. In 1736, French explorers observed this process and brought the knowledge back to their home country; consequently, the first rubber factory in the world was built near Paris in 1803. In 1770, the English chemist Joseph Priestly realized the substance could rub out lead pencil marks, and thus coined the name "rubber." This new, waterproof, highly resilient substance was used to make effective raincoats as well as other waterproof commodities. However, it was soon discovered that on hot days the substance became dreadfully sticky, and on cold days it became stiff as a door.

In 1839, during one of his many experiments with rubber, Charles Goodyear observed that when mixed with elemental sulfur and heated to a specific temperature for a specific period of time, rubber acquired enhanced physical properties. This allowed the substance to sustain larger temperature ranges, giving it an even greater usefulness. This process, termed *vulcanization*, or curing, is used today to give rubber products such as shoes, clothing, fire hoses, sporting goods, and many other specialized products greater function and utility.

During the nineteenth century, nearly all rubber originated from the jungles of Brazil. Exponential growth in the demand for rubber led to the development of rubber plantations in other regions of the world. To accommodate its substantial rubber consumption, industrialized England began establishing rubber plantations in British-ruled Asia. By the beginning of World War II, 90 percent of the world's natural rubber was produced in Asia.

How did the war cause rubber shortages? Prior to World War II it was estimated that the United States consumed around 600,000 tons of rubber annually. While the war against Germany had intensified the nation's reliance on rubber, the country had begun accumulating and stockpiling excess rubber supplies. However, within six weeks of the bombing of Pearl Harbor, the United States had less than a six-month supply of rubber. After the nation's rubber reserves had been exhausted, the country's ability to support its war efforts would come to an end. Understanding that a shortage of rubber not only would impact the nation's military operations but also would devastate domestic businesses and normal civilian life, research into alternative rubber sources began in earnest.

How did the United States solve the rubber shortages? Early attempts to ease the rubber shortage focused on collecting scrap rubber to be recycled into rubber products. However, due to the complex chemistry of rubber, recycling it proved to be time-consuming and expensive. In addition, the physical properties of the resulting recycled rubber materials were significantly more problematic, and less useful, than those of virgin rubber. Although the scrap rubber drives appeared to boost morale for civilians taking part in the programs, the solution to rubber shortages was not found in these campaigns.

To provide the rubber necessary to support American involvement in the war, the country next looked to natural ways to supply its own rubber. The Emergency Rubber Project was enacted by Congress to establish guayule plantations in the western states, with the objective to produce enough natural rubber to sustain the war effort. Unfortunately, by the time the guayule shrubs had been planted and were able to produce latex for rubber manufacturing, advances in synthetic rubber production had made the Emergency Rubber Project obsolete.

Prior to the war, methods to produce rubber synthetically were already known. However, still in early stages of research, synthetic rubber could be fabricated only in small-scale laboratory batches and was very expensive. In addition, its strength and quality compared to natural rubber had yet to be determined. The U.S. government supported research and financially backed the construction of large-scale synthetic rubber factories, which caused an 830,000-ton jump in synthetic rubber manufacturing by 1945. The necessities of war accelerated synthetic rubber research to the point that significant discoveries were announced almost daily.

Whereas ordinary rubber is created from naturally occurring processes, synthetic rubber can be produced as a by-product of petroleum and other minerals. In 1944, U.S. chemists had discovered that synthetic rubber could be produced from raw materials derived from petroleum, coal, oil, natural gas, and acetylene. All rubber substances are compounds with a high molecular weight known as polymers. Polymers are made up of long hydrogen and carbon chains supporting other types of molecules called monomers.

By changing the location of the monomers on the chain through physical and chemical processes applied during production, it is possible to impart specific desired properties to the resulting polymer. Rubber's natural physical characteristics, such as elasticity, resilience, impermeability, adhesiveness, and electrical resistance, made it a useful material. However, synthetic advances in rubber's chemical properties have made it an even more useful substance. Synthetic rubber is better able to resist degradation from oil, solvents, and other chemicals, as well as hold up to time, weather, ultraviolet light, and temperature fluctuations. There are still advantages to natural rubber, however, in that it accumulates less heat from flexing and has greater resistance to tearing when hot. Advances and developments within the rubber industry since the 1940s have ensured that the possibility of future rubber shortages has been virtually eliminated.

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FOOD & AGRICULTURE

The Green Revolution

In 1798, the English economist Thomas Malthus published a provocative manuscript titled *An Essay on the Principle of Population*. In it, Malthus remarked that humans, like other species in the animal kingdom, have the ability to reproduce at a greater rate than necessary to maintain a viable population. If growth were left unchecked, Malthus concluded, world population would eventually exceed the earth's food-producing capacity, which would result in widespread famine.

Those familiar with Malthus's theory were frightened by events such as the 1930s Dust Bowl in the midwestern United States and the widespread Mexican famine which occurred in the 1940s. These were seen as first substantiating signs of Malthus's premonition. It was becoming evident that producing the amount of food necessary to feed an ever-increasing population would not be possible using existing agricultural methods.

In the early 1940s, a team of four scientists funded by the Rockefeller Foundation were sent to Mexico to assess the food shortage and to work with the Mexican government to help develop effective agricultural practices. The most significant innovation of the program came from the scientist Dr. Norman Borlaug, a plant pathologist from Iowa, who convinced the foundation to focus on the development of agricultural advances as well as the implementation of modern farming techniques.

How was food production increased? The key to coaxing higher food production from fewer acres of farm fields was discovered in the genetics of dwarf varieties of wheat. In nature, wheat varieties with tall stalks tend to outcompete wheat with short stalks for access to sunlight. Thus, tall-stalked wheat was much more prevalent as a food supply. However, Borlaug focused his studies on the smaller crops. He found that by putting less energy into the inedible vegetative parts of the plants, such as the leaves and stems, these shorter plants are able to distribute more energy to the valuable grain. Whereas tall varieties of wheat were able to provide only about 20 percent of their photosynthate—the carbon fixed via the process of photosynthesis—for producing grain, dwarf varieties could allocate as much as 50 to 55 percent of their fixed carbon to grain production. Other benefits of the shorter stalks of the dwarf varieties included the ability to support the weight of their grain and to hold their leaves more vertically. This meant that shorter crops could be planted more compactly in a smaller area, resulting in increased yields per area planted.

The "miracle wheat" cultivated by Dr. Borlaug doubled and tripled crop yields in a short period of time. In 1944, before the discovery and utilization of the high-yielding wheat plant, Mexico imported half the wheat the county consumed. Other advances, such as the use of herbicides and fertilizers, greatly increased yields so that

Figure 5.3.
Dr. Norman Borlaug with his "miracle wheat," 1970. Bettmann/CORBIS.

in 1956, upon integration of the new wheat varieties throughout Mexican farms, Mexico was self-sufficient in wheat production. For his contributions to science that helped to save millions of people from starvation, Norman Borlaug was awarded the Nobel Peace Prize in 1970.

More food, but more problems. Food production breakthroughs in Mexico soon led to the development of similar programs in other countries. In the 1960s, food shortages in Pakistan and India necessitated research on crops that could be successfully grown in those climates. Developments based on Norman Borlaug's research and principles helped India become self-sufficient in the production of cereal crops by 1974. Similarly, China and the Philippines have developed high-yielding dwarf varieties of rice.

The combination of developments in new varieties of food plants combined with advancements in agricultural techniques led to a worldwide agricultural movement known as "the Green Revolution." Not only did this movement seem to alleviate the threat of famine, it also provided an alternative to the environmentally damaging practice of slash-and-burn subsistence farming that was common in many developing nations. In the past, a rush to convert large tracts of natively vegetated areas to farmland in order to provide more food for larger populations caused the deforestation of stable, native ecosystems. These ecosystems were replaced with farms that used land in unsustainable ways. Highly weathered native soils with low nutrient values could not maintain the productivity required of fertile farmland, and these new Green Revolution advances took some of the pressure off the development of indigenous ecosystems.

Despite the obvious successes of the Green Revolution, however, this movement has drawn severe criticism on many fronts. The foremost criticisms of the movement pertain to ecological concerns about the intensive use of fertilizers, the practice of monoculture, and reliance on chemical pesticides for pest control. The negative effects of heavy use of fertilizers have surfaced in the form of eutrophication (water pollution caused by excessive nutrients). Eutrophication is characterized by a damaging growth of algae and other plants that can affect the uses of freshwater rivers and lakes. The widespread overuse of pesticides also created health hazards for inhabitants of farming towns and areas downwind and downstream of their application. Similarly, the practice of monoculture (planting only one type of crop in a large area), generated additional problems by sustaining little biodiversity. Genetic uniformity is an ideal medium for the fast spread of highly specialized pests and rapid exhaustion of the soil nutrients, resulting in a deeper dependence on more fertilizers and pesticides.

Socioeconomic critiques of the Green Revolution have centered on the argument that its innovations focused solely on higher food production and ignored the issue of population control. Critics charge that crop yields will eventually reach a point where science cannot bring about any more productivity from a given acre of farmland. Thus, challengers argue that Malthus's prediction has not been addressed, but merely delayed. Arguing the moral injustice of increasing food supplies in areas such as developing countries which cannot sustain current populations or predicted future increases, some critics eschew technological innovation in farming altogether, saying that society should "let nature follow its own course" to restrain the human population. Such commentators worry that humans have come to rely too much on controlling nature for our own purposes rather than finding ways to live sustainably within its limits.

Proponents of the Green Revolution believe, however, that investments made in the lives of the beneficiaries of the new farming practices will eventually promote a sustainable population. They claim that once a population begins to realize the benefits of better nutrition and longer life expectancies, less emphasis will be placed on reproduction to ensure a continuing workforce, and resources will be devoted to education to ensure the continuation of the improved standard of living. Time will reveal whether human society will eventually be able to use technological innovations such as the Green Revolution to strike a sustainable balance between having control over, and living in harmony with, the environment.

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MEDICINE & HEALTH

The Kinsey Report

The impact of the Kinsey Report on the study of human sexual behavior has been compared to the effects of Christopher Columbus's news of a New World. Simply put, the scientific reports *Sexual Behavior in the Human Male* (1948) and *Sexual Behavior in the Human Female* (1953), written by Alfred Kinsey, Wardell Pomeroy, and Clyde Martin, opened science to considering a realm of human experience that had been previously subject only to "speculation and suspicion." These publications, commonly referred to as the Kinsey Report, were the culmination of the first large-scale statistical study on the sexual behavior of men and women.

Why was this study so revolutionary? During the 1940s, over $30 million was spent annually in the United States in the pursuit of plant and animal breeding research. Frequent and in-depth studies of livestock breeding, the propagation of medicinal plants, and the reproduction of mice and other pests were undertaken to further knowledge in fields such as medicine, agriculture, education, and economics. However, studies of a similar nature on humans were perceived as indecent and taboo.

Growth, adaptation, and reproduction are the three basic functions of all living creatures. In human biology, reproduction was the function least explored. In part, this was so because of the societal values attached to sexual behavior; what was seen as a natural and even perfunctory act for other animals was seen quite differently for humans. To study human sexuality from a scientific perspective, one would need to suspend moral judgments and focus on obtaining accurate, factual information. This was a difficult proposition in American society, where strict moral codes as well as abundant mysteries and myths surrounded notions of sexual behavior.

In 1937, a sex education and marriage course was offered for the first time by Indiana University. Dr. Alfred Kinsey, a professor of zoology who was known for the thoroughness and conviction with which he executed his studies, was chosen to teach the class. Knowing little about the topic of human sexuality, Kinsey looked to the university library for information on the subject but found scant factual data. Therefore, Kinsey decided to collect his own data, beginning in 1938 by administering a preliminary questionnaire to sixty-two males and females and then expanding his research to include a total of 5,300 males and 5,940 females.

How was the Kinsey Report research gathered? Kinsey knew that a study exploring the nature of human sexuality would come under severe criticism and have to overcome major hurdles in order to obtain accurate information. Therefore, he and his collaborators paid particular attention to the design of the study. Kinsey sought to emulate scientific methods that emphasized objectivity and impartiality, in order to try to avoid social or moral interpretations of fact. Thus, the Kinsey Reports attempted to study and describe sexual *behavior* within a population, and to circumvent data that addressed sexual *attitudes* or moral *beliefs*.

Since about the 1920s, survey research has been considered one of the premier methods for studying human social behavior. During the 1940s, many academics focused on making survey research more scientific. Although he lacked a background in sociology, Kinsey brought his experience in researching insects to bear on the scientific approach he incorporated into his famous studies. For instance, he employed the classification techniques of taxonomy for his research on human sexuality. He also sought to ensure the accuracy of his data by retesting respondents to verify the consistency of their answers, by interviewing husbands and wives separately and then cross-referencing their answers, and by having two different interviewers rate a respondent's answers. Reasoning that the accuracy and honesty of the sexual histories he collected would depend on skilled interviewers, Kinsey paid particular attention to developing precise methods of questioning. The final survey instrument contained more than 350 questions asked during a one-on-one interview. Kinsey was practiced and skillful at collecting data; in fact, he performed over half of the 12,214 interviews.

What were the findings of the reports? The findings of the Kinsey Report seemed to corroborate the hypotheses of earlier scientists such as Freud, which held that sexual expression and behavior begin in early childhood. Furthermore, Kinsey found that the sexual patterns which men follow throughout their lives develop during and just after adolescence. The study also asserts that educational and socioeconomic factors are closely related to sexual attitudes and behaviors. For instance, males with a higher level of education were less likely to engage in premarital intercourse than males with fewer years of formal education. Conversely, the Kinsey Report revealed that women with higher levels of education were more likely to engage in premarital intercourse than females who were less educated. The reports included much more information regarding the extent and prevalence of variations in male and female sexual behaviors, including data on masculinity and femininity, homosexuality, and masturbation.

What were the impacts of the reports? While Kinsey's reports were generally well accepted, many critics still questioned both the moral and the scientific bases of the research. During the interviewing process, attempts were made by organized opposition groups to persuade Indiana University to stop the study or prevent the publication of the findings. In several cities, police interfered with the dissemination of the reports. In one case, a medical group objecting to the study attempted to sue the researchers on the grounds of practicing medicine without a license. Other objections resulting from the study came from scientists who endorsed studies of sexual behaviors of lower animals as beneficial, but felt that a study of human sexuality could not be accomplished objectively. Some scientists claimed that Kinsey's study was based on emotions and therefore could not be classified as scientific.

In light of the objections, Kinsey's study was examined by the American Statistical Association (ASA), which pored over the data and findings in a lengthy review. The ASA found that Kinsey's work was consistently above the scientific standards in place at the time it was conducted. Nevertheless, misunderstanding, suspicion, and controversy have surrounded the reports for nearly half a century, leading some commentators to conclude that society was simply not ready to be made aware of the findings of Kinsey's study. Dr. Kinsey himself stated, "It has been interesting to observe how far the ancient traditions and social customs influence even persons who are trained as scientists."

The Kinsey Reports remain among the most comprehensive research ever done on human sexual behavior, and scholars today still use the data he collected to analyze information and test hypotheses about human sexual behavior. Ironically, although Kinsey was careful to separate human sexual behavior from attitudes and beliefs in the data he collected, there is no doubt that publicly reporting on such behaviors helped change American attitudes and beliefs about sexuality. For this reason, the study remains a target of groups who fault it for contributing to a decline in moral standards. The story of the Kinsey Report illustrates how scientific research performed on topics that are closely related to societal taboos can still be marginalized and discredited, even when the scientific methods employed are state of the art. Ultimately, scientific research can never be separated from the society in which it is undertaken and interpreted.

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Dr. Spock's Baby Book

As soldiers returned home from the world war, many quickly settled in to start a family, and the Baby Boom generation commenced with the children born in 1946. Coincidentally, that year also marked the publication of a book which revolutionized the way Americans raised their children. Although his modest intention was to write a commonsense self-help guide for parents, Dr. Benjamin McLane Spock's book, *The Common Sense Book of Baby and Child Care*, became a worldwide best-selling book that has been translated into thirty-nine languages. Its sales are second only to the Bible, including more than 50 million copies in seven editions. Challenging the rigid, disciplinarian approach to child rearing prevalent at the time, Dr. Spock's book provided parents with helpful, intuitive advice delivered in a friendly, reassuring, straightforward manner much different from the cold, "scientific" tone of most of the parenting books of that time.

A natural calling. Benjamin Spock was born in New Haven, Connecticut in 1903 to affluent parents. His father was a prominent lawyer and his authoritarian mother, a woman typical of the times, was determined to raise moral, upstanding children. Spock was the eldest of six children and was introduced early in his life to the practices of child care, since he was often required to participate in the raising of his siblings. This experience shaped the course of Spock's life. He admitted to choosing the field of pediatrics for his career because he was influenced by the way his mother held baby doctors in high regard and was impressed by her "sudden humility in the presence of white-robed medical men."

Having studied both medicine and psychoanalysis, Spock was in the unique position of being the only practicing pediatrician of his time with this combination of training. In the early years of his private practice in New York City, Spock welcomed the opportunity to make house calls so that he could observe his patient with the whole family. Combining these experiences with his observations of the patients he attended to in area hospitals, Spock recognized that many parents shared the similar problem of lack of access to basic information related to child care.

Why did the book have such an impact? Once published, Dr. Spock's self-help manual made its way off the bookstore shelves and into the homes of America. In a style completely opposite to that of his contemporaries, Spock wrote in a simple, friendly manner, encouraging parents to be flexible and loving, and to treat their children as individuals. He advised parents that to ensure that their children would be happy and secure as they grew, parents should cuddle their babies and provide them with ample affection—in a time when "spare the rod, spoil the child" was the prevailing axiom.

Prior to the worldwide acceptance of Dr. Spock's book, the foremost authority on child care was John B. Watson. In his book *Psychological Care of Infant and Child* he

Figure 5.4.
Dr. Benjamin Spock with a three-year-old child, 1964. Courtesy of Library of Congress.

wrote, “Never hug or kiss [your children] never let them sit in your lap, lest they drown in ‘Mother Love.’ If you must, kiss them once on the forehead when they say good night. Shake hands with them in the morning.” It has been suggested that twentieth-century parents embraced Spock’s book because its teachings implied that it was acceptable to enjoy raising children and that a sympathetic, humanistic, child-centered approach would ultimately bring about well-adjusted young adults.

Spock’s book was also saturated with medical advice written in a simple, intuitive manner, and was available to anyone who could spare the 25 cents that the book cost. In postwar America, many young families were moving out of the cities and into the suburbs, away from parents and grandparents who had been the source of knowledge about child rearing in previous generations. Spock’s most famous piece of advice—“Trust Yourself. You know more than you think you do”—has been credited with inspiring new mothers and fathers to gain the confidence needed to become effective parents.

What were the repercussions of the book? Dr. Spock’s philosophy had immense influence over the way the Baby Boomer generation was raised. Thus, his book has been given a large portion of blame for the “amorality” that led to the antiwar and antigovernment activism which has been prevalent since the 1960s. Critics assert that Spock’s revolutionary ideas about relaxed parenting did not produce secure, well-adjusted children, but a generation of self-centered individuals lacking moral direction. He has been accused of promoting permissiveness in raising America's children. Spock's supporters, however, state that his book "embodied the optimism of Americans in being able to conquer adversity and wanting to be better than the generation before them," and maintain that his book "was a tool to achieve that goal."

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TRANSPORTATION

Scuba Gear Opens the Oceans to Amateurs

For centuries, humans have explored the skies and beyond, detailing the motion of heavenly bodies. However, as late as the 1940s the mysteries of the oceans had been largely ignored. Because people could not spend a great deal of time underwater, the earth's aquaculture remained undiscovered. Although various inventions sought to allow for undersea exploration through the years, the introduction of scuba self-contained underwater breathing apparatus gear in the 1940s made it possible for humans to become acquainted with the ocean depths in new and exciting ways.

Underwater technology. The earliest divers perfected breath-holding techniques that allowed them to submerge for a minute or so while diving for such treasures as pearls, but each dive was limited by the diver's physical condition. Then, in the mid-1500s Guglielmo de Loreno developed a large, bell-shaped dome open to the bottom of the sea that trapped compressed air below the water's surface. A diver would breathe fresh air from the dome, leave for a few minutes to explore the surrounding water, and then return to the bell for more air. However, exhaled carbon dioxide would eventually build up in the bell, making it harder to breathe with each return.

Another sixteenth century device allowed divers to breathe through a long tube reaching from the water's surface to a mouthpiece held by the diver. A regulator was needed to keep the air at the same pressure as the surrounding water so that breathing could occur. Although this breathing device worked, a mysterious problem arose as divers approached the surface: they would often suffer from nausea, dizziness, or sharp pain, and could even die. It would take centuries to understand that the cause of these symptoms was decompression sickness.

Toward the end of the nineteenth century, several inventions and discoveries helped advance the possibility of longer-term underwater exploration. In 1878, Paul Bert of France published his studies of decompression sickness. He showed that the sickness experienced by many divers was due to nitrogen gas bubbles forming in the bloodstream of the diver. It was also discovered that carbon dioxide scrubbers could eliminate excess carbon dioxide gas that collected in closed-circuit underwater breathing equipment each time a diver exhaled. By the latter half of the 1800s the first functional compressed-air scuba device was operational. Though it supplied a continuous flow of compressed air, it also kept divers gasping; thus this device was workable but far from ideal.

The aqualung. In 1943 Jacques Yves Cousteau and Emile Gagnan modified a car regulator and added a significant innovation to the existing diving technology. Instead of admitting a constant stream of air, the on-demand regulator adjusted the airflow automatically, so that air would flow only when a diver inhaled. Valves guaranteed that the pressure of the air inhaled was the same as that of the water, which increased as the diver plunged deeper.

The advances made over several centuries improved the accessibility of underwater exploration for professionals such as geologists, tunnel workers, and other adventurers. However, until the invention of the aqualung, diving was not really a leisure option for ordinary people. The specialized equipment and skill needed, ensured that only the most dedicated individuals would ever see the world significantly below the surface of the oceans. The new on-demand regulator devised by Cousteau and Gagnan helped make underwater breathing seem almost natural, and opened the oceans to amateurs.

The problem with pressure. One key obstacle to successful diving has to do with the effects of water pressure. *Pressure* is defined as the force (or push) on an object per unit area. Both air and water apply pressure to human bodies. As we go about our daily lives, we are constantly under the influence of air pressure as the molecules in the atmosphere surrounding us push against us. Under the water, pressure produces some demanding physiological realities that must be addressed through various diving technologies.

Because water is about 800 times denser than air, it exerts much greater pressure on our bodies than would an equal volume of air. The pressure of a cubic foot of air at sea level is 0.083 pound, compared to 64 pounds per cubic foot of seawater at sea level. In addition, the deeper one dives, the more pressure is exerted by the added weight of the water above the diver. The lungs are the only internal organ directly impacted by the increased pressure of diving. To breathe underwater, the air pressure

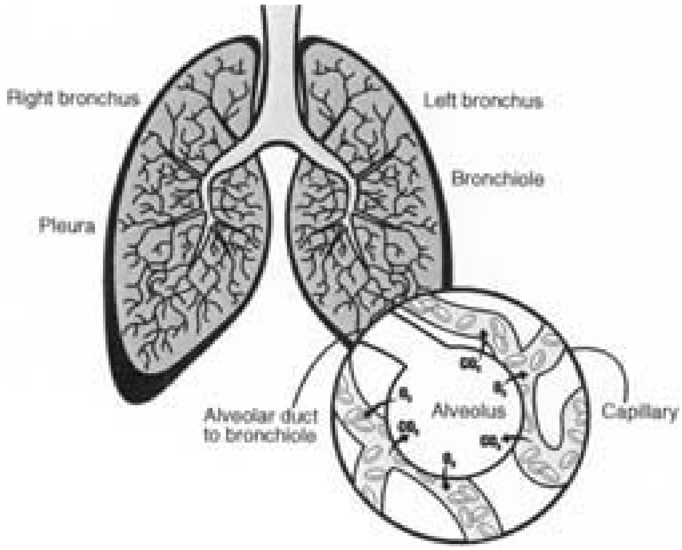

Figure 5.5.
Gas exchange in the lungs.

and water pressure must be balanced, or else a diver's lungs could not inflate due to increased water pressure outside the body.

The function of the respiratory system. The air in our atmosphere is made up of a mixture of gases, primarily nitrogen (N_2, 78% by volume) and oxygen (O_2, 21%), with a negligible amount of carbon dioxide (CO_2, 0.03%). The purpose of our human respiratory system is gas exchange. The respiratory system brings in air from the atmosphere and absorbs oxygen from it (the other components, such as nitrogen, are just inhaled and exhaled). Respiration also serves as a way to eliminate carbon dioxide—a by-product of metabolism—from the blood.

This gas exchange takes place in the inner structure of the lungs. The air we breathe through our nose and mouth moves through smaller and smaller branches of the lungs until it reaches small sacs called alveoli. Tiny capillaries surrounding the alveoli absorb the oxygen at the same time that carbon dioxide diffuses out of the capillaries and into the alveoli. The surface area of the membranes in the lungs that carry out this gas exchange would cover a large classroom floor if laid end to end.

How does diving affect the respiratory system? Many people are aware that a lack of oxygen in the body can be fatal to humans. However, too much oxygen or nitrogen accumulating in the blood can also cause serious problems. This accumulation can occur underwater, where increased pressure on the body causes changes in respiratory system functioning. Just as carbon dioxide gas dissolves into a liquid at high pressures to make carbonated beverages, so gases breathed in by a diver under pressure also readily dissolve in the bloodstream. When too much oxygen is dissolved into the blood, oxygen toxicity develops, which can result in dizziness, seizures, and drowning. For this reason recreational diving is restricted to about 130 feet because much of the extra oxygen dissolved in the blood at this level can still be metabolized, and the danger of buildup is lessened.

Nitrogen gas is inert and does not take part in the breathing process except when air pressure is dramatically increased above normal atmospheric levels, such as it is when diving. The amount of nitrogen dissolved in the blood is then drastically increased. Unlike oxygen, nitrogen is not metabolized because it is inert. Therefore extra nitrogen has nowhere to go but into the diver's blood and tissues. Two problems arise from this process. The first is nitrogen narcosis, a condition in which a diver becomes confused, dizzy, and weak with increased nitrogen in the blood. When the diver ascends, nitrogen is released from the blood, and the condition can be alleviated.

The second problem caused by dissolved nitrogen, decompression sickness (DCS), is more serious. As a diver ascends to the surface, nitrogen bubbles form as dissolved nitrogen comes out of the tissues and organs. This occurs in the same way that bubbles rush to the surface of a carbonated beverage when its container is opened: the sudden decrease in pressure causes the dissolved gas to bubble out of the solution. In the body, the larger the nitrogen bubbles that are formed, the more damage can occur, leading to painful and permanent disability such as paralysis. To avoid decompression sickness, divers should not dive too deep, should limit the amount of time submerged, and should ascend slowly to help stabilize pressure and lessen the likelihood of large nitrogen bubbles forming in the blood.

Popularizing undersea exploration. Cousteau and Gagner's scuba device was lightweight and affordable, and the physical fitness and training once required for diving were no longer a vital necessity. With the introduction of the aqualung, humans were able to increase their knowledge and appreciation of marine ecosystems. Many records were surpassed as adventurers sought to plunge to new depths and increase the amount of time spent underwater.

With the ability to spend more time under the sea, people became more aware of a previously mysterious aspect of the delicate balance of life on Earth. After his invention, Jacques Cousteau spent the rest of his life as an advocate of aquaculture. An outspoken environmentalist, he produced numerous books and documentaries until his death in 1997. Television shows such as *Sea Hunt*, diving magazines, and scuba diving programs such as those taught at YMCAs helped further the popularity of scuba as a pastime. The vibrant colors and exotic-looking creatures that characterized underwater life succeeded in capturing the imagination of people across the planet.

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HUMAN KNOWLEDGE

In the 1940s, much of the scientific enterprise was dedicated to the war effort. Significant advances in our understanding of nuclear reactions and electronic technology would come to characterize the decade. The quest for power and speed was also recognizable: explosives mushroomed into the atmosphere, computers performed lightning-fast calculations, and airplanes roared as U.S. Air Force Captain Charles Yeager broke the sound barrier in 1947, flying 700 miles per hour.

Chemical discoveries flourished in the 1940s as well. Kodak introduced color negative film, DDT was used as a pesticide, and fluoride was increasingly added to the nation's water supply. Martin Kamen discovered the radioactive carbon-14 isotope in 1940, and seven years later, Willard Libby invented carbon-14 dating, using his knowledge of radioactive decay to determine the age of wooden and other plant-based artifacts. Working for the New York State Health Department, chemists Rachel Brown and Elizabeth Hazen isolated the chemical nystatin, which proved to be a safe fungicide used to treat athlete's foot. Serendipitously, nystatin was also found to curtail mold that damaged oil paintings, and museum curators found nystatin to be very valuable. Finally, Oswald Avery introduced biologists to the chemical basis of heredity, deoxyribonucleic acid.

DNA as Life's Blueprint

As happens with many scientific advances, when humans attempt to unravel the intricacies of the natural world, it is often the culmination of several small discoveries that leads to one great breakthrough. Our attempt to understand the processes and organization of our own genetic makeup is no exception. The science of genetics began in 1865, when Gregor Mendel, using garden peas for his subject, proved the existence of basic units of heredity, now called genes. Subsequent scientists both expanded upon and refined the study of genetics and biology, discovering new bits of information. A chemical understanding of how genetic information is passed from parent to offspring was not realized until finally, in the 1940s, many scientists working toward the same goal were able to fit all the pieces together to begin to understand the complex chemistry behind life's blueprints.

Pieces of the heredity puzzle. Over several decades of studying heredity, scientists learned that somehow genetic information was passed along through cells. As the smallest structural unit of an organism that is capable of independent functioning, cells "grow" by dividing into two new cells. In the cell nucleus, chromosomes are threadlike bodies that split during this cell division, through mitosis or meiosis, in such a way that each daughter cell is given its own chromosome set. Knowing that genes were the carrier of hereditary information, in 1915 the American scientist Thomas H. Morgan established that genes are actually located on chromosomes and, in fact, are arranged in a specific linear order. In addition, it was observed that a particular hereditary characteristic determined by a gene could undergo a sudden and permanent change, or mutation. Based upon this knowledge, genes were thought to carry information by way of an arrangement of symbols that represent a specific genetic message, much the way that the dots and dashes of Morse code can be put together to express particular words. Furthermore, it was known that a change in the arrangement of the symbols within the message could transform the meaning of the message entirely.

But what were genes made of? By the 1920s, scientists had at least two possible answers to the question. Studies of cells had shown that both proteins and nucleic acids were present in chromosomes. Knowing that proteins were the more complex of the two, most scientists believed that genetic information would necessarily be housed there. Evidence would eventually suggest otherwise.

Proving the link between DNA and genetic information. In 1928, Fred Griffith, an English microbiologist, was studying the ways in which the bacterium *Diplococcus pneumoniae* causes the disease pneumonia. Although not intentionally researching genetic transformations, he made some noteworthy observations that would have significant implications in the field of molecular genetics. Through the mixing of some of the disease-causing (pathogenic) bacteria that had been killed by heat with living, non-disease-causing, nonpathogenic bacteria, a small percentage of the nonpathogenic cells became pathogens. Griffith determined that some part of the pathogenic cell remained undamaged even after the cell was killed by heat. This portion of the cell was then capable of moving into the nonpathogenic, living cells and directed them to develop disease-causing characteristics.

In 1944, the American scientist Oswald Avery, comprehending the value of Griffith's findings, expanded upon the pathogen experiments and through intense examination of the composition of the heat-killed cells, identified the "transforming factor" within Griffith's pathogenic bacterial cells as deoxyribonucleic acid (DNA). Avery's experiment combined purified DNA from "normal" donor bacteria with "abnormal" recipient bacteria that differed from the donor bacteria by just one mutated gene. The results of this experiment showed that some of the recipient bacteria were genetically altered, transformed into the donor type bacteria. Further investigations using DNase, a then newly discovered enzyme capable of breaking down DNA, defeated the transforming ability of the heat-killed cells. This test definitively suggested that it was the DNA, and not a protein, that was responsible for carrying a trait forward.

Shortly after Avery's observations were published, the scientists Alfred Hershey and Martha Chase, using bacterial viruses known as phages, were able to demonstrate clearly that when the phage infects the bacteria, only the DNA of the phage enters the host bacterial cell, leaving the protein coat outside the cell. Hershey and Chase thereby concluded that the genes of the parent phage which direct the creation, and therefore the structure of the offspring, must reside in the DNA.

What implications does the understanding of DNA have for modern times? Other scientists, building on the discoveries of Avery and of Hershey and Chase, made significant advances in understanding the form and function of DNA within a cell. These findings have had a profound effect on many aspects of our lives today. One of the largest modern projects involving DNA is the Human Genome Project. With a mission to identify the full set of genetic instructions contained in human cells, this international project employs biologists, chemists, engineers, computer scientists, mathematicians, and other scientists to work together to map and decode the physical traits of human beings. DNA is also used in legal and judicial applications to ascertain human identity. Police labs around the United States use DNA to link suspects to biological evidence such as blood or semen stains, hair, or items of clothing found at crime scenes. Another modern use of DNA is establishing paternity in custody and child support litigation, where technology has allowed for an unprecedented, nearly perfect accuracy of the determination. In addition, DNA can be used for the diagnosis of inherited disorders in adults, children, and unborn babies, including cystic fibrosis, hemophilia, Huntington's disease, familial Alzheimer's, sickle cell anemia, and thalassemia. An ability to unlock the secrets of genetic codes transformed biological sciences in the second half of the twentieth century.

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Chapter 6

THE FIFTIES

SOCIETAL CONTEXT: THE FAMILY AND PROGRESS

In the United States, life in the 1950s has been characterized by its emphasis on conformity to well-defined family roles. The Baby Boomers grew up in a time when home and family became the cornerstone of American culture. The explosion of household television sets in the post–World War II era (from 7,000 sets in 1945 to 50 million sets in 1960) helped create a common experience for people across the country, and contributed to this sense of conformity. Gathered around the television and feasting on TV dinners, dad and mom, brother and sister were seen as having a picture-perfect lifestyle. The "family-friendly" suburbs emerged as the location of choice for all-American living.

The conception of teenagers as a unique cultural group arose in the United States, and American teenagers of the 1950s had clout. By the end of the decade, estimates are that youth were spending approximately $10 billion a year on products for teens. This American fascination with youth and leisure could be epitomized by events such as the 1955 opening of the Disneyland theme park in Anaheim, California, and the television premiere of the *American Bandstand* rock-and-roll dance program in 1957.

Belief in progress and prosperity, especially through technology, seemed as vital as ever in the 1950s. Many Americans were optimistic about their place in the world. The reality of consumer culture introduced in the first half of the twentieth century grew to new heights. Wealthy companies became wealthier and expanded their size, their locations, or their product lines. During this decade, many seeds were sown for the growth of huge multinational corporations and worldwide conglomerates that would come to dominate the U.S. economy by the end of the century. The pace of the transition to a service economy also increased in the 1950s.

The trend toward social conformity perhaps resulted in a notorious and widespread suspicion of "the other" during this decade. Communists were particular targets of this paranoia, and the postwar espionage-related trials of former State Department employee Alger Hiss and radical activists Julius and Ethel Rosenberg caused real public fear. Senator Joseph McCarthy's search for communists and the hearings of the House Un-American Activities Committee disrupted the lives of numerous prominent Americans with unproven accusations and rumors of their desire to undermine the United States. The invasion of South Korea by Soviet-backed North Korean forces became symbolic of the U.S. perception of Communist expansionist tendencies, and the Korean War demonstrated the U.S. commitment to stopping this expansion in its tracks. Throughout the Cold War, fear and mistrust of ideologies on each side of the Iron Curtain led to frequent and sometimes extreme expressions of nationalism.

Within the American nation, however, those who had for too long been marginalized as societal "others" began to form organized efforts for enacting change during this period. African-Americans defied the "Jim Crow" laws that had separated them from lighter-skinned fellow citizens for decades, at the same time that Africans half a world away rebelled and lobbied for independence from colonial powers. The "separate but equal" system of educating children in the United States was declared to be unconstitutional in the landmark *Brown v. Board of Education* case in 1954. Rosa Parks refused to honor the segregation that had pervaded daily life by her choice of seat in the white section on a public bus. The groundswell of awareness of civil rights issues that would come to define the next decade was just beginning to take hold.

ARCHITECTURE & ENGINEERING

St. Lawrence Seaway Constructed

The St. Lawrence Seaway was ceremoniously opened in June 1959, in a dedication presided over by President Dwight Eisenhower and Queen Elizabeth II. The seaway connected the Atlantic Ocean to the Great Lakes, allowing ocean ships to sail into the middle of the North American continent. Five years of construction resulted in the transformation of a 14-foot-deep waterway with thirty locks into a 27-foot-deep channel with fifteen locks; the construction of hydroelectric power plants; and the complete relocation of riverside towns.

Constructing a fourth seacoast. It may seem strange to think of the Great Lakes shores as being a fourth seacoast in North America, but in 1959 the St. Lawrence Seaway created just such a geographic reality for the United States and Canada. Lake port cities such as Buffalo, Chicago, Cleveland, Detroit, Duluth, Milwaukee, and

Toronto could now host seafaring vessels that made their way from the Atlantic Ocean through the seaway to the heart of North America. Each year, grain, iron ore, coal, and steel are shipped along the St. Lawrence Seaway.

Construction of the "fourth seacoast" cost U.S. $470 million. Canada bore the burden of the costs, shouldering approximately 70 percent of the total. Locks, canals, and dams were built along the St. Lawrence River, and channels were opened to connect the Great Lakes into one continuous waterway.

There are four main sections of the St. Lawrence Seaway: the Lachine Section, which is the immediate connection to the Atlantic Ocean; the Beauharnois Section, which contains a set of dams that regulate water flow to a power plant; the International Section, which contains dams, powerhouses, locks, channels, and dikes, and is administered by both the United States and Canada; and the Great Lakes Channels, which consist of the links between lakes Huron, Erie, Ontario, Michigan, and Superior. In order to open the route to seafaring ships, the depth at all parts of the journey had to be at least 27 feet, and engineers had to dredge sections of the route to almost twice their original depth. Numerous rapids had to be bypassed as well, and elevation changes along the river necessitated well-designed systems of locks. At the completion of construction, over 6.8 billion cubic feet of dirt had been moved, and more than 200 million cubic feet of concrete had been poured.

A unique phase of the St. Lawrence Seaway construction project included the relocation of towns on the banks of the river. Primarily, this applied to the Canadian side of the waterway, which was more populated than the U.S. side in the 1950s. The riverside towns of Iroquois, Morrisburg, Ingleside, and Long Sault were rebuilt in entirely new locations, so that the old sites could be flooded to make sure the waterway would meet the necessary depth requirements. In all, 6,500 people were moved to new communities in conjunction with the St. Lawrence Seaway project.

The invasion of ecosystems. One of the problems that results from increased travel is the introduction of life-forms into new ecological niches. Over time, the plants and animals that inhabit a particular place on the Earth have developed relationships which help ensure that each species has a good chance for long-term survival. The animals and plants are able to share the Earth's resources in a delicate balance. However, if a new type of plant or animal is introduced into the ecosystem, the results could be catastrophic for some of the natives. If the alien species has some sort of physiological advantage that allows it to alter the balance of resources in the ecosystem, then native species could decrease or even die out.

Several decades after the opening of the St. Lawrence Seaway, an ocean liner accidentally transported an alien species of mussel into the Great Lakes ecosystem. Zebra mussels are native to eastern Europe, and found throughout the waters of western Europe as well. It is believed that a ship accidentally emptied ballast water containing these mussels into the St. Lawrence Seaway system in the mid-1980s. The zebra mussels are aggressive feeders and reproducers, and they quickly spread throughout the Great Lakes ecosystem, causing harm to the indigenous populations.

Zebra mussels devour the phytoplankton in the freshwater they inhabit. This makes it difficult for other species that depend on the same phytoplankton to obtain food. By the end of the twentieth century, zebra mussels had significantly altered the ecosystem of the Great Lakes region, contributing to declining populations of some native fish species. Because the mussels attach themselves to hard surfaces, they often cover the surfaces of boats and then may be transported to even further reaches of the ecosystem. Zebra mussels have also caused damage to facilities by clogging water intake pipes and screens, and blocking water flow. The environmental and economic impact of the zebra mussels has been extensive.

Balancing out costs. The St. Lawrence Seaway project increased traffic on the St. Lawrence River by 67 percent, and increased the traffic of some ports by more than 150 percent. Seaway officials estimate that since 1959, over $300 billion worth of cargo has been carried through the waterway. Although it takes longer to transport cargo by ship than by rail, very heavy goods are too costly and dangerous to ship on railroads, and so the seaway's legacy has been to provide a safe and effective means of transporting such commodities as steel and coal. Nearly half of the traffic on the St. Lawrence Seaway is headed to or from Europe, the Middle East, and Africa.

However, the increased opportunities for transportation that were engineered through the St. Lawrence Seaway have come at a cost. Transoceanic ships often inadvertently bring elements of separate ecosystems into contact with one another, with the unfortunate result that native species suffer loss of habitat and population. In the case of zebra mussels, estimates are that the species will cost the Great Lakes region at least $5 billion in damages to facilities and in cleanup costs during the first decade of the twenty-first century. While it is an amazing engineering achievement, the St. Lawrence Seaway also provides us with lessons in balancing society's needs with those of nature, and in balancing human impact on the environment.

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ARTS & ENTERTAINMENT

Rock-and-Roll Music Moves America's Teenagers

Many people remember the 1950s as the formative years of rock-and-roll music. As a cultural phenomenon, rock-and-roll became a defining aspect of teenage life during this period. Its emergence also illustrates the strange mix of segregation and commonality that often seems to characterize race relations in America.

Rockin' history. In the 1950s, artists such as Bo Diddley, Chuck Berry, Elvis Presley, Jerry Lee Lewis, Bill Haley and the Comets, Little Richard, and Buddy Holly helped define a new musical phenomenon. Rock-and-roll music borrowed its emotion and intensity from the blues, but was also influenced by rhythm and blues, gospel, country and western, bluegrass, rockabilly, and jazz. The straight chord progressions of the blues guitar became rhythmically mesmerizing, and the attitude of rock-and-roll was born.

The societal context underpinning the emergence of rock-and-roll was multifaceted. A significant development was teenage culture. The 1950s included a postwar America of economic prosperity and optimism; however, the attitudes of the decade were strongly tied to age. Some historians speculate that the experience of World War II provided a line of demarcation between adults and teenagers, resulting in a generation gap. This gap between those who experienced the drama of World War II and those too young to remember it helped bring about the rise of the teenager as a unique social group in this decade and beyond.

Another reason why teenagers could develop an identifiable culture was that they had economic clout. Teens had money and free time, and corporate America—including the entertainment industry—began to appreciate this particular market. While the large and well-established recording labels and radio personalities often catered to mainstream adult tastes, independent labels and upstart disc jockeys had nothing to lose from trying to reach the new teen audience. Cleveland radio personality Alan Freed created his popular *Moondog's Rock 'n' Roll Party* show on the advice of a local record store owner who noticed that teenagers were buying up the rhythm and blues recordings from his establishment. Dick Clark catered to teenage tastes as host of the *American Bandstand* television show. Clearly, teenagers were being noticed.

But the development of rock-and-roll is also a telling piece of the story of race relations in the 1950s. It was the music of black Americans, marketed to whites. In a country of "separate but equal," this was a new orientation. The attitude of rock-and-roll music—one of pushing boundaries, rebelling against authority, connecting with raw emotions—could be said to have been handed down from generations of slaves, reflected in musical art forms from field songs through blues, boogie, jazz, gospel, and various combinations of these. This was arguably unfamiliar territory to white Americans, who in the mainstream were accustomed to hearing crooners blend syrupy melodies with fairy-tale lyrics. The time was ripe for a merger of two societal groups looking for a way to express their identification with something—anything—other than white, middle-class, American adult life.

Play it loud. The rebellious spirit encompassed by rock-and-roll music has often corresponded to a tendency to turn up the volume. In fact, many charts that provide examples of the decibel scale of sound intensity (as it relates to perceived loudness) cite rock concerts as one of the louder and even more dangerous experiences a listener can have.

The perception of a sound's volume is related to the amplitude of the sound wave and its intensity. The amplitude of a sound wave is the amount by which vibrating particles are displaced. For example, consider a rubber band that is pulled taut and then plucked. Stretching the rubber band out a great deal to pluck it is equivalent to having a sound wave with a large amplitude; plucking it by stretching it just slightly produces a small amplitude. The amplitude of a sound wave is related to its intensity, which is a measure of the energy of the sound wave. When our ears receive sounds, intensity is translated into the volume, or loudness, we hear.

The more energetic a sound wave is, the louder we perceive its volume to be. However, the relationship is not a linear one. It takes a tenfold increase in the intensity of a sound for us to hear it twice as loud. As a result, the scale used to measure sound intensity (and for us, loudness) is logarithmic. The zero point on the scale was set to be the threshold of human hearing, and the original unit of measurement was named a "bel" in honor of Alexander Graham Bell. The bel proved to be too large a unit to allow for useful discrimination between measured quantities, so it was divided by ten and renamed "decibel" (db), and the scale was reconfigured.

In the decibel scale, each time 10 db are added to the measurement, the perceived loudness is multiplied by ten. Thus a 30-db sound appears 10 times louder to us than a 20-db sound; a 40-db sound is perceived to be 100 times louder than a 10-db sound; a sound at 50 decibels seems 1,000 times louder than the sound at 10 db; and so on. A whisper is generally in the range of 15 db, normal conversation is 60 db, and a lawnmower or busy city street falls around 90 db. Estimates on the intensity of amplified rock music range from 110 to 140 db.

The volume of music can be a problem, since loud sounds can cause permanent damage to one's hearing. Above 140 db, sounds can cause immediate injury to the ears. Repeated exposure to sounds between 85 and 140 db will likely result in hearing loss. When we hear sounds, tiny hairs in the cochlea (found in the inner ear) move back and forth, stretching and bending, and sending signals to the brain. Loud sounds can be so forceful that they cause these hair cells to bend too far and actually break off. The problem is that the cells cannot grow back, and when enough are destroyed in this way, hearing loss will result.

Volume-induced hearing loss can be said to be a socially created disease. Although listening to loud music is certainly not the sole cause of this phenomenon, it is one common reason for hearing problems in today's society. But often people who work in places where they are at risk for hearing loss—for example, around loud equipment at construction sites, or around jet engines at airports—take necessary precautions by wearing ear protection and limiting exposure where possible. Perhaps because of the rebellious attitude inherent in rock-and-roll, musicians sometimes flaunt the fact that they don't protect their ears. By the end of the twentieth century, several famous lovers of loud music (such as President Bill Clinton and rock musician Pete Townsend) publicly shared their experiences with hearing loss. Although awareness of the problem is growing, the association between rock-and-roll music and "turning up the volume" seems unlikely to be broken.

Is rock-and-roll here to stay? Although the music has gone through several rounds of transformations, the basic spirit of rock-and-roll music continues today. The vision of a few disc jockeys and record promoters who were willing to respond to the teenage market as well as to cross racial lines in the 1950s changed the arts and entertainment industry forever. Generations of young people ever since have responded musically to the call to move beyond what their parents had seen as desirable in order to push creative and societal boundaries. As one of the few truly and uniquely American cultural phenomena of the twentieth century, rock-and-roll has played an interesting role in changing the status quo.

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COMMUNICATION

Sputnik Changes the Game

Although primarily a war of political rhetoric and posturing, the Cold War between the United States and the Soviet Union certainly had memorable battles. In the 1950s, the competition over who would be first to launch an artificial satellite was one such contest. The Soviets succeeded in a virtual surprise attack when they sent *Sputnik I* into orbit on October 4, 1957.

The tiny, 22-inch sphere emitted a regular beeping sound that interrupted radio broadcasts between October 1957 and January 1958 as the man-made satellite circled the planet. For many Americans, the beeping was an ominous taunt. Those who had never questioned the technological superiority of the United States were mortified to find themselves in the position of having to catch up to the expertise of Soviet scientists. But Cold War tensions made the beeping seem even more sinister: Was this an invasion and occupation of our own skies?

A project for the International Geophysical Year. After World War II, interest in studying space escalated steadily, as it seemed a natural extension of a quest for technological dominance over the planet. In 1952, the International Council of Scientific Unions voted to name July 1, 1957, through December 31, 1958, the International Geophysical Year to coincide with a time period when the sun's activity would be particularly intense. Two years later, the council recommended that scientists resolve to launch an artificial satellite during the International Geophysical Year. In the United States, the official attempt got under way in 1955, as the Vanguard project aimed to send a satellite into orbit.

The Soviets had announced their own intention of launching a satellite during the International Geophysical Year, and publicly their schedule called for a launch in 1958. However, they surprised the scientific world and the public at large when news of the successful launch of *Sputnik I* in early October 1957 reached the press. The U.S. reaction was immediate and overwhelmingly negative. Americans at once seemed to lose confidence in the country's technological prowess and became fearful of having an enemy nation's invention pass through the sky overhead. The launching of *Sputnik* became an important turning point in the history of many scientific and technological institutions in the United States.

How do satellites work? In simplest terms, a satellite is a body that orbits another body. We can begin to understand satellite motion by considering one way in which planets acquire natural satellites, such as moons. These moons once were objects traveling through space in a straight line; however, they eventually passed by a more massive body, such as a planet, and became "captured" into an orbit by that body's gravitational pull.

While the moon was traveling through space away from interference from other objects, its inertia kept it moving in a straight line. *Inertia* is an object's tendency to continue in motion, unless it is acted upon by a force—a push or a pull—from somewhere in its environment. When a moon passes by a planet, the force of gravity pulls the two objects toward one another. Although the two bodies exert equal and opposite forces on one another, the more massive planet remains essentially where it is, and the smaller satellite moves toward the planet. If the planet is really huge in com-

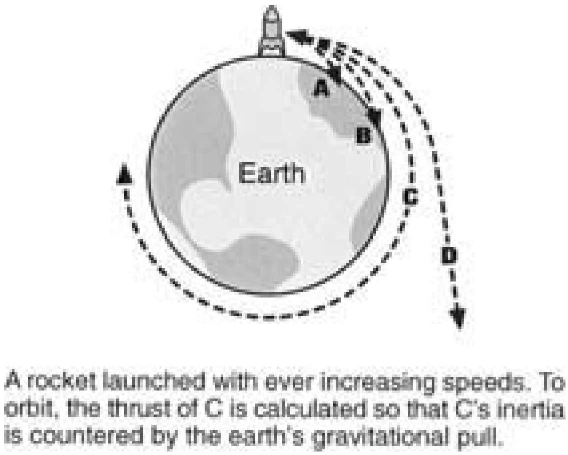

Figure 6.1.
Launching a satellite.

parison to the object moving through space, or if this object is traveling relatively slowly through space, the gravitational pull from the planet may be sufficiently large to cause the object to crash onto the planet's surface. Moons, however, are pulled into satellite motion, moving around the planet into a continual orbit. What has happened is that the moon's inertia (tendency to travel through space in a straight line) and the gravitational pull from the planet constantly act at right angles to one another, and the result is that the moon neither flies off into space along its straight-line path nor falls onto the planet, but orbits the planet in a perpetual state of "falling around" its perimeter.

In order to launch an artificial satellite into orbit, it must be given a sufficient velocity to fall around the earth. The distance at which the satellite orbits the earth is important. The closer a satellite is to the earth's surface, the faster its speed must be to keep it from being pulled down out of orbit. Also, if a satellite has a low orbit, it can be slowed by friction from the earth's atmosphere, and it will not be able to remain in orbit very long. Thus, low-orbit satellites fly around the earth beginning around 200 miles up, and they orbit the earth relatively quickly (circling once around the earth every few hours). As the distance away from the earth increases, the satellite can travel with a slower period (time to make one orbit). At 22,300 miles above the earth, a satellite takes one day to circle the planet. This means that its orbit is in sync with the earth's rotation, and essentially the satellite remains fixed over one part of the surface, rotating along with it every day. The limit for satellite altitude is about 620,000 miles above the earth, where the planet is too far away to maintain a gravitational pull on a satellite, and its inertia will carry it off into space.

***After* Sputnik.** The negative effect of *Sputnik's* launching on the collective American psyche was quite lasting. The political pressure on President Eisenhower to reassert U.S. technological competence was immense. It took several months and an embarrassing national failure (the explosion of the Vanguard rocket booster during a test in December 1957) before the United States successfully launched its own satellite, *Explorer I*, in January 1958. By July of the same year, Congress had passed the Space Act, which transformed the National Advisory Committee on Aeronautics into the National Aeronautics and Space Administration (NASA) by broadening the body's interests to include the study of and planning for space exploration and travel. By identifying NASA as a civilian organization, the Space Act allowed the U.S. government to demonstrate a serious commitment to technological superiority without aggravating military tensions with the Soviets.

Since *Sputnik*, thousands of artificial satellites have been launched around the earth. Lifestyles in the United States depend on satellite technology in many ways. Satellites can be used to photograph and study the surface of the earth and to collect weather-related data. Satellites in geosynchronous orbits are often used in communication and navigation applications, receiving and transmitting radio waves or microwaves to and from Earth and other positions in space. Manned satellites, such as the space shuttle or space stations, are used for conducting scientific research. Military applications of satellites incorporate their extensive reconnaissance capabilities. Indeed, it would seem today that the invasion of our skies—perpetrated by nations across the planet—is both well established and widespread.

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DEFENSE & DIPLOMACY

Nuclear-powered Submarine Cruises the Depths

Military strategists understood the potential significance of underwater navigation long before the 1950s. In fact, during World War II, U.S. submarines sank 30 percent of Japan's navy, even though subs made up only 2 percent of the U.S. naval fleet. However, the technology was far from perfect, and it wasn't until 1954 that a truly significant advance was made to this military technology, when a nuclear reactor was first used to power the underwater vessel. Since the Cold War, nuclear-powered submarines have substantially shaped strategic military options for the United States.

USS* Nautilus *launched. After the success of German U-boats in World War II, the advantages of submarines in military conflict became apparent. Such vessels provided a unique capability for surprise attacks and reconnaissance missions. In 1951, the U.S. Congress sanctioned the construction of a nuclear-powered submarine. Nuclear propulsion would potentially give submarines the capacity to stay underwater for very long periods of time, opening up a military advantage that far outweighed even the best-engineered contemporary subs.

Scientists from the Atomic Energy Commission developed the nuclear power source under the leadership of Admiral Hyman G. Rickover. The USS *Nautilus* was launched and commissioned in the U.S. Navy in 1954. In January 1955, the nuclear powered submarine began her seafaring journeys. The *Nautilus* moved faster and traveled farther than any submarine before her. In 1958, the *Nautilus* became the first ship to sail over the North Pole (under the polar ice cap), a feat that had previously seemed impossible.

Submarine science. The problems associated with sustaining vessels underwater for any length of time have always been related to air. For one thing, before the invention of the nuclear-powered submarine, propulsion systems relied on engines that needed air in order to function. This meant that subs needed to surface frequently. In fact, these submarines were really surface ships with the capability of "hiding" underwater for certain lengths of time. The German U-boats used during World War II incorporated a snorkel, a device that could rise above the water to collect air while the submarine was still submerged, which increased the amount of time the vessel could spend underwater. Although this represented an advance in design, submarines were still not truly underwater crafts.

This changed with the invention of the nuclear-powered submarine, which uses the heat generated from a nuclear fission reaction to propel and power the ship. In a nuclear reactor, atoms of uranium-235 are bombarded with neutrons (subatomic particles with no electric charge), which causes individual atoms to split into two atoms of smaller mass and release a great deal of energy. In the splitting process, more neutrons are released, which can collide with other U-235 atoms and continue generating energy—thus the characterization as a "chain reaction." In a nuclear reactor, the heat given off by the fission reaction is used to convert water to steam, which spins turbines connected to the ship's propellers and an electric generator. The nuclear reactor used to power a submarine is basically a scaled-down version of that found in nuclear power plants.

Nuclear power solved one of the air-related problems which limited submarine effectiveness; now that power generation did not rely on air, the vessel could theoretically stay underwater for great lengths of time. However, air was still a problem for crew members, who would need a fresh supply of oxygen in order to survive. As crew members breathe in oxygen and exhale carbon dioxide, the submarine quickly turns into an inhospitable environment. A solution was found by turning to the surrounding water for producing oxygen. In nuclear submarines today, oxygen generators use electrolysis to separate water into hydrogen and oxygen. An electric current is sent through water in order to cause a decomposition reaction to occur; water is separated into its component parts. In addition, improvements to the instruments that detect carbon dioxide levels and the amounts of other contaminants have made life on board submarines easier and safer for crew members.

Submarine strategy. The vital role played by submarines during World War II convinced military officers of the strategic importance of these craft. During the Cold War, two types of submarines were developed in the United States. "Fast attacks" were designed to quickly find and track Soviet subs. "Boomers," or ballistic missile submarines, carried nuclear weapons that could be launched underwater and travel great distances. Ballistic missile submarines became part of the U.S. weapons policy of mutual assured destruction (MAD) that emerged during the Cold War. According to MAD, the United States would have three distinct capabilities for attacking enemies with nuclear weapons (intercontinental ballistic missiles, or ICBMs; submarine-launched ballistic missiles (SLBMs); and nuclear bombs dropped from aircraft). The theory was that an enemy would not be able to destroy all three capabilities before it would be possible to use one of them against said enemy. In other words, in the event of a nuclear attack, the destruction of the attacker as well as of the attacked was assured.

Mutual assured destruction was adopted because it was believed that the fear of being destroyed would prevent an enemy from initiating a strike. But is MAD a deterrent to war? By the end of the twentieth century, the Cold War had faded away with the dismantling of the Soviet Union into independent states. Some policy makers point to the lack of nuclear war since the end of World War II as evidence that MAD works as a preventive strategy. Others, however, have argued that the assumptions behind MAD's effectiveness depend not only upon physical weapons capabilities but also upon psychological components that are difficult, if not impossible, to measure. An increased awareness of the psychological strategies related to terrorism at the end of the century also led to questioning the merits of MAD, since self-destruction (suicide) is often an acknowledged component of terrorist attacks.

Despite questions, the philosophy of deterrence still drives policy, and correspondingly, submarines have a major role to play. New submarines that are swifter, more agile, and more functionally diverse continue to be developed.

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ENVIRONMENT

Bikini Atoll Falls Prey to Nuclear Testing

Throughout the Cold War, the race between the United States and the Soviet Union to build newer and more fearsome weapons was a full-time endeavor. The dropping of the first atomic bombs on Hiroshima and Nagasaki during World War II had ushered in a new sense of military might. During the war it was the United States alone that possessed the capability to build atomic bombs, but others quickly followed suit. The Soviets tested an atomic bomb in 1950, and three years later detonated their first thermonuclear device.

Although the atomic and thermonuclear bombs developed after World War II have never been used in an act of war against another nation, they have nonetheless caused damage and destruction on a vast scale. The story of the Bikini atoll in the Marshall Islands illustrates the lasting devastation to the living environment perpetuated by a human quest for the ultimate weapon.

What happened at Bikini? On March 1, 1954, the United States commenced Operation BRAVO, and detonated its largest thermonuclear weapon ever tested. The test site was Bikini, one of twenty-nine atolls and five islands that make up the Republic of the Marshall Islands in the Pacific Ocean. The cloud that mushroomed from the 15-megaton blast rose at least 20 miles into the air. Military officials were awestruck at what they had witnessed. Most would say that they did not expect such a powerful blast, and had instead thought they would witness an explosion on the order of 3 megatons.

The celebratory tone of U.S. operations existed in sharp contrast to the curiosity and subsequent panic felt by the local witnesses to the explosion that day. As the islanders watched, winds of flames swept across the area, and strange gritty powder rained down for miles away from ground zero. A group of men in a Japanese fishing boat near the area marveled at the strange ash from the sky. Children on nearby islands played in it. By nightfall, those exposed to the radioactive fallout began to suffer from nausea, vomiting, diarrhea, and hair loss. One of the men in the fishing boat died.

But Operation BRAVO was only one event near the beginning of a long and trying saga for the native people of Bikini. Having been displaced from their homeland eight years earlier so that the United States could commence nuclear testing, they now had good reason to ask whether it would ever be possible for them to return. Questions about the safety of the environment around Bikini atoll still plague the area in the twenty-first century.

Figure 6.2.
A U.S. nuclear weapons test at Bikini atoll, ca. 1946. Courtesy of Library of Congress.

What was the weapon, and how did it affect the environment? The BRAVO test weapon was a fission-fusion bomb, a thermonuclear device. Unlike the bombs dropped on Hiroshima and Nagasaki, which used fission reactions as the source of their energy blast, thermonuclear bombs use the energy of a nuclear fusion reaction to get their power. Whereas fission is the reaction of heavier atoms splitting apart into smaller ones, fusion is a reaction in which light atomic nuclei combine, or fuse, to form heavier ones, with a resulting massive release of energy. There are technical problems with using a fusion reaction in a bomb, however. The fuel needed is unstable, and a great deal of energy is needed to start the reaction. These problems were solved by using a two-step process for the weapon; first, a fission reaction created part of the fuel and delivered the energy needed to initiate the fusion reaction, which took off in the second step.

Although events at Hiroshima and Nagasaki foretold of the absolutely devastating effects of atomic and nuclear bombs on living things, the aftereffects of these weapons were still being studied and understood during the Cold War. When radiation gets into the environment, it has long-term effects. Direct exposure can cause sickness and death in living things. However, indirect and long-term exposure to the radioactive fallout from these bombs can have severe consequences for survivors, including cancer, and the possibility of genetic mutations that can be passed along to future generations. When radioactive material is present in soil, it can get taken up by plants. Animals that eat these plants take in the radioactive isotopes, which then are concentrated in their body tissues. The problems are compounded as radioactive material makes its way up the food chain.

In the late 1960s, President Lyndon Johnson ordered the military to make provisions for returning the native Bikinians to their home island. The atoll was to be cleaned of radioactive debris and replanted with native coconut trees. When it was declared safe in the early 1970s, families began to move back to Bikini. However, within a few years, scientists discovered that the people living on the atoll had dangerously high radiation levels in their bodies, and by 1978, the islanders were forced to evacuate their home once again.

A main problem on Bikini is the presence of cesium-137 throughout the soil. This cesium is taken up by plants that are looking to absorb potassium instead. Two proposed ways of dealing with the problem are removing the soil completely (scraping the island) and treating the island with a potassium fertilizer that will block the uptake of cesium. Scraping the soil would have the advantage of removing the dangerous cesium completely, but scientists warn that it would reduce the island land cover to sand, making plant growth difficult or impossible. The potassium fertilizer would allow inhabitants to grow food, but it would not remove the dangerous cesium from the environment. At the beginning of the twenty-first century, the natives of Bikini are still unable to return to their home. Negotiations between the Bikinians and the U.S. government about the safest and most effective way of restoring the inhabitability of their island continue today.

The legacy of Bikini. Bikini atoll is a distressing example of the environmental destruction that can be caused by nuclear weapons testing. Throughout the last half of the twentieth century, the effects of such testing on the environment were cause for concern across the world. Over the years, treaties were signed that limited where nuclear testing can be done or the size of the weapons tested. (In addition, nonproliferation treaties—separately from test ban treaties—have addressed the issues of who can possess nuclear weapons, along with specifying the acceptable numbers and kinds.) By the end of the twentieth century, the nations of the world were very close to agreeing to an end for all versions of nuclear weapons testing. The Comprehensive Test Ban Treaty, drawn up by the United Nations in 1996, would have eliminated all kinds of nuclear tests and established a worldwide network with scientific capabilities for monitoring compliance. However, of the forty-four nations with some capacity to build and test nuclear weapons, only twenty-six ratified the treaty. The United States is among fifteen nations that signed the treaty but failed to ratify it, and three countries have refused to sign the test ban.

As the world looks to the future, however, the people who once inhabited Bikini atoll must still come to terms with the past. Since the late 1970s, the U.S. government has agreed to establish three separate trust funds to compensate the people of Bikini for their losses. Through an agreement between the United States and the Republic of the Marshall Islands, the Nuclear Claims Tribunal was established in 1988 to adjudicate final reparations for losses suffered by the Marshall Islanders. The tribunal awarded the people of Bikini more than $563 million in compensation. However, the full award has not been forthcoming, and experts acknowledge that a comprehensive environmental cleanup will not be possible without it. The legacy of the twenty-three nuclear devices that were exploded on Bikini between 1946 and 1958 remains: a dangerously unsafe environment and a people displaced indefinitely.

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FOOD & AGRICULTURE

The Birth of Fast Food

Although the restaurants weren't new, the idea of fast food rapidly caught on during the 1950s. "Fast food" items could be prepared quickly and efficiently. But more than food preparation, the dining experience itself was fast-paced. In some cases, restaurants didn't have tables for eating; in many cases, patrons stayed in their cars to order, and possibly eat, the meals they received. This new cultural model of "going out to dinner" caught on, and by the end of the twentieth century had spread across the globe. The fast food experience became a defining habit for Americans in the twentieth century; but at what costs?

Changing the face of restaurants. In the twentieth century, the model of restaurant efficiency was developed by White Castle. In 1916, Walter Anderson changed the sandwich known as a hamburger—a ball of ground meat cooked slowly—into a flattened ground beef patty that could be cooked quickly at a high temperature. In 1921, he partnered with Billy Ingram to expand his growing restaurant business, and three years later the partnership became a corporation known as the White Castle System of Eating Houses. White Castle streamlined operations in order to reproduce its outlets in many different locations and create the first restaurant chain in the United States.

However, it would take Ray Kroc's tireless initiative, beginning in the 1950s, to generate the restaurant that helped change American eating habits for good. Kroc was a traveling salesman who tried to sell restaurants on the benefits of his "Multimixer" machines that could mix five milkshakes at once. In San Bernardino, California, Kroc met the McDonald brothers, whose small hamburger stand was so busy it was able to keep eight Multimixers running simultaneously. Kroc persuaded the McDonalds to turn their restaurant into a chain, and opened the first franchise himself in Des Plaines, Illinois, in 1955. Four years later, the hundredth McDonald's restaurant opened in Chicago; today, there are more than 30,000 McDonald's restaurants operating in 119 countries. Other fast food chain restaurants, such as Burger King, Kentucky Fried Chicken, Wendy's, and Taco Bell, replicated aspects of Kroc's philosophy and success.

Why fast food? Historians give several reasons for the surge in popularity of fast food establishments in the second half of the twentieth century. As ownership of cars increased, Americans found more ways to spend time in them. Drive-in restaurants became part of the automobile craze, particularly among teens in the late 1950s and early 1960s. The emergence of the national highway system created opportunities for fast food chain restaurants as well: situated near exits, these venues provided travelers a chance to stop for a bite to eat without sacrificing too much time. In addition, as America became a more mobile society, the standardization of chain restaurants was comforting to some who found themselves far from home; customers were able to count on particular menu items to taste the same, no matter where they were ordered. Fast food chains were able to market themselves as family-friendly establishments by emphasizing their low prices, informal atmosphere, and special meals (and even toys) for children. As more women entered the workforce in the latter half of the century, there was a need to modify the work that stay-at-home mothers and wives traditionally performed, including cooking. By the century's end, more fami-

Figure 6.3.
An early design of McDonald's restaurant.
William A. Bake/CORBIS.

lies depended on restaurants for their meals, and fast food establishments seemed well suited for the hectic, fast-paced lifestyles of many Americans who had been taught to value speed and efficiency.

Fast food nutrition. The human body requires various kinds of nutrients to sustain its health. *Carbohydrates* (sugars and starches) are broken down to release energy in the body. Plant-based carbohydrates provide fiber, which is used by the body to regulate blood cholesterol and bowel function. *Fats* store extra energy, cushion the muscular-skeletal system, and contribute to hair and skin health. *Proteins* are complex chemicals made of smaller units called amino acids. Human bodies are able to chemically manufacture thirteen amino acids for synthesizing proteins, but there are nine amino acids that cannot be made by the body and must be obtained through food. Protein is essential for maintaining body tissues and is important to the proper functioning of the blood and the immune system. In addition to carbohydrates, fats, and proteins, the body needs a variety of vitamins and minerals to maintain good health.

Besides understanding the various components of nutrition, however, it is important to recognize that the relative amounts of these components in a dietary regimen must be balanced. For example, nutritionists suggest that 60 percent of total food calories consumed should consist of carbohydrates. Starches and plant-based carbohydrates should make up most of these calories, rather than the relatively "empty" energy provided by sugars. Fats should comprise no more than 30 percent of dietary nutrients consumed. Among the calories coming from fat, nutrition experts suggest limiting saturated fats (those which are solids at room temperature).

The most recognizable fast food products typically are high in fat and salt content, and low in vitamins, minerals, and fiber. This can be a problem if an individual's overall diet is not balanced to account for such a mismatch. Studies show that over the course of the twentieth century, American diets have changed. The proportion of fats and sugars consumed has increased since the 1950s, and the intake of complex carbohydrates has declined. Obesity has become a major problem for American society—so much so that at the beginning of the twenty-first century, concerns over weight loss and healthy diet have entered the agendas of politicians across the country.

What are the real costs of fast food? Fast food can not be blamed for all of the nutritional woes of American society. Certainly though, in combination with a more sedentary lifestyle and a lack of access to a broad range of nutritional options, a dietary reliance on fast food products can be unhealthy. However, by the end of the twentieth century, fast food menus were changing. Armed with more complete information about nutrition and health, consumers have persuaded restaurants to offer more salads and fresh foods, low-fat alternatives to traditional menu items, and smaller portions. Advertising campaigns by companies such as Subway have found success by touting the healthy, nutritious options available to customers.

However, at the start of the twenty-first century some critics have argued that the social costs of the fast food culture in America outweigh any concerns over nutritional inadequacy. In his book *Fast Food Nation*, Eric Schlosser laments that Americans currently spend more money on fast food than on higher education, personal computers, software, new cars, or media entertainment (movies, books, magazines, newspapers, videos, and recorded music). Social commentators such as Jim Hightower have warned of the detrimental effects of the standardization of corporate culture epitomized by the efficiency and uniformity of fast food chains. In addition, the fast food companies' boundless expansion has given them an enormous amount of power and control over decisions about food supply in the country, and even the world.

The fast food culture, despite its negative aspects, seems destined to remain part of the American landscape in the near future. As a society, we still tend to appreciate, and even depend upon, the speed and relative ease and efficiency with which we can obtain meals from fast food restaurants. At present, we value the uniformity of chain restaurants over the diversity of small business establishments. It remains to be seen, however, whether these values are a product of habits or of informed choices. As information about both the positive and the negative effects of the fast food lifestyle on our physical and social health becomes more readily available, Americans will be able to make their own assessments.

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MEDICINE & HEALTH

Polio Vaccine Brings Relief

For children in 1950s America, summer fun could disappear at the mention of a single word: polio. The disease, known formally as poliomyelitis, was greatly feared for its tendency to appear at random and to cause unpredictably disastrous complications for its victims. Although adults did develop the disease, polio primarily affected children. Some who contracted the disease had such a mild case that they didn't even know they were sick, others suffered permanent paralysis of one or more limbs, and occasional cases resulted in death. One consistent fact, however, was that polio hit hardest during the summer, and as a result, worried parents kept their children home from swimming pools and beaches in fear of this mysterious virus.

The emergence of polio. Although evidence seems to indicate that polio has been around for thousands of years, its major outbreaks in more developed countries during the first half of the twentieth century caused alarm and panic. In 1916, New York City reported 9,000 cases of the disease, and Los Angeles officials battled an outbreak in 1934—a single hospital treated 2,500 cases in just a few months. From 1945 to 1949, the United States averaged 20,000 polio cases per year.

During these first decades of the twentieth century, progress toward combating the disease was seemingly as unpredictable as the ailment itself. Austrian physicians Karl Landsteiner and Erwin Popper identified the virus responsible for causing polio in 1908, and scientists quickly devised a way to infect monkeys, hoping to study possible cures. A few years later, however, progress was at a standstill. During the 1920s, researchers attempted to prevent paralysis in polio patients by injecting them with variously designed serums made from the blood of previously infected humans, monkeys, and even horses. These proved ineffective, and it wasn't until 1935 that Maurice Brodie and John Kollmer tried, independently, to develop vaccines for polio. Trials with thousands of children across the country had tragic results, as many children contracted the disease from the vaccine.

After World War II, polio became more notorious. Soldiers who had served in Africa and the Middle East returned home with stories of polio outbreaks. They may have brought the disease back with them, contributing to the large number of cases each year in the last half of the 1940s. In Pittsburgh, the Sarah Mellon Scientific Foundation sponsored several research projects charged with typing the poliomyelitis virus in 1948. Jonas Salk, who had worked with the influenza virus as a medical researcher in the war effort, answered the Mellon Foundation's call and set about developing a polio vaccine. By the early 1950s, Salk's vaccine—which consisted of killed virus treated with formaldehyde and held in the body with mineral water—had successfully prevented polio among a small group of test subjects. These 1952 trials coincided with growing public desperation, as a record high of 58,000 cases of polio were diagnosed in that year. Salk's vaccine was quickly approved for testing on a national scale, and a few years and nearly 2 million tested children later, success was formally announced. On April 12, 1955, a public, somewhat sensationalized announcement declared the effectiveness of the new Salk vaccine, and a full-scale battle to eradicate the crippling polio virus was about to begin.

Disease resistance. The human body's defense mechanism against viral disease involves the production of substances known as antibodies, which attack the virus and prevent it from replicating. Viruses are not full living cells as we recognize them, and they lack the ability to reproduce on their own. When viruses invade a living organism, they take over particular cells and cause those cells to manufacture more viruses, and so turn the host organism into their own reproduction machine.

When humans are infected with a virus, chemicals on the virus signal to the body's defense mechanisms that something is wrong. Antibodies are created, which then travel through the bloodstream, seeking out the viruses and rendering them unable to invade more cells. Once these antibodies have been created, they remain in the bloodstream and give a previously infected person immunity against a future attack.

Vaccines work by stimulating human defense mechanisms to produce antibodies by tricking the body into thinking it is under a viral attack. In reality, the person is injected with either dead viruses or extremely weak, attenuated ones. These killed or weakened viruses trigger an immune response—antibodies are created, and a person is protected from future invasions by the same type of virus.

Polio's attack on the body. The polio virus attacks the human body's nervous system, particularly the spinal cord. Most people who were infected suffered a minor form of the disease, known as "nonparalytic polio." Fever, headache, respiratory or gastrointestinal problems, and muscle stiffness were symptomatic of most polio cases. Viral attacks at the bottom of the brain or base of the spinal cord seem to be related to cases where infection resulted in paralysis.

Treatment for polio sufferers was often a long, uncomfortable, and even painful process. In 1928, Philip Drinker developed the "iron lung," a coffinlike chamber that pushed on the chests of patients whose muscles had become too weak to breathe, acting as an artificial respirator. In the 1940s, an Australian nurse, Elizabeth Kenny, dramatically changed treatment methods for polio patients, with great success. Rather than splint and immobilize patients, Kenny advocated physical therapy involving hot baths and exercises to prevent devastating paralysis from taking hold. Although controversial at first, her techniques soon became the norm throughout the world.

An epidemiological anomaly? For epidemiologists, who study the origins and causes of disease outbreaks, the emergence of polio epidemics in early twentieth-century North America would seem to be a puzzling occurrence. Typically, diseases emerge, or reach epidemic proportions, under conditions that are predictable and generally identifiable. For example, when populations of people come in contact with each other for the first time, diseases tend to propagate. Many Native American communities were ravaged by smallpox when Europeans (who had immunity to the disease and could carry it without harmful effects) came in contact with them. Another familiar condition for disease outbreak is when people live close to one another and sanitation is poor; for example, the bubonic plague that decimated European cities in the fourteenth through sixteenth centuries was facilitated by flea-infested rats moving through urban centers. The polio epidemic, however, didn't seem to fit these scenarios, in part because of the unpredictable nature and seemingly unrelated conditions of the outbreaks.

Most scientists today concur that polio actually emerged in the United States in the first half of the twentieth century *because* of improved sanitation, not in spite of it. As people installed indoor plumbing in their homes and understood the importance of good hygiene, they paradoxically made themselves more susceptible to polio. To understand why, it is important to recognize that the disease is believed to be spread through contact with human fecal matter infected with the virus. Before sanitation was systematically improved, most people were exposed to the polio virus during infancy, but were protected by antibodies given to them by their mothers. Infants exposed to polio were protected from being seriously harmed by the disease because of the antibodies they possessed from their mothers; in addition, an invading virus would trigger the child's own defense mechanisms and set up lifelong protection from the disease. In other words, the maternal antibodies acted as a safety net, stopping an infant from developing a full-blown case of the disease while allowing the body's natural defenses to take effect. However, when sanitation improved, people did not come into contact with polio during infancy but still encountered the disease in later childhood or even adulthood, this time without the protection of maternal antibodies. The virus had time to inflict some damage before antibodies could develop.

The legacy of polio. After the development of the Salk vaccine in 1955, parents throughout the country were urged to have their children immunized against the disease. A majority complied, and the vaccination program was an overall success. Using an attenuated virus, Albert Sabin developed a more powerful vaccine that was approved for use in 1962. By the mid-1960s, instances of polio in North America were down dramatically thanks to the two vaccines and to efforts by health officials to make them widely available. In fact, by the end of the twentieth century, the disease was all but eliminated from the United States, although it still exists in areas of Africa and Asia. The World Health Organization (WHO) has organized vaccination programs in an effort to eradicate the disease worldwide by the early

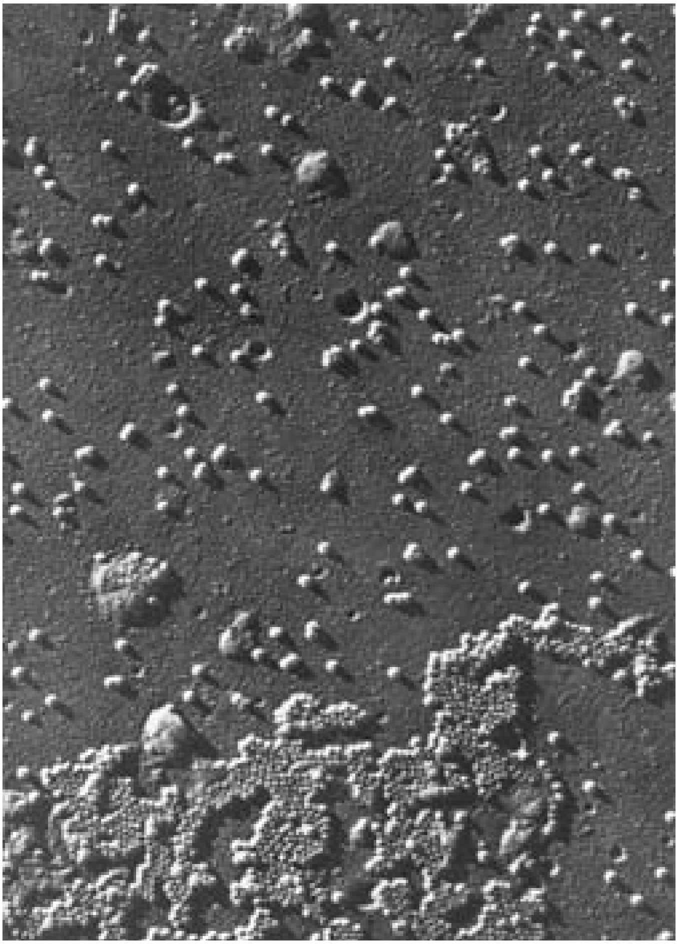

Figure 6.4.
The poliomyelitis virus. Courtesy of Library of Congress.

twenty-first century. Although the disease is no longer feared as it once was, many people still live with its effects. The WHO estimates that around 20 million polio survivors are alive today, and many of them have lived for decades with life-altering disabilities.

One important consequence of the polio epidemic was its connection to President Franklin Delano Roosevelt. FDR contracted the disease as an adult in 1921, and it left him severely paralyzed. At the time, disabled individuals were considered incapable of leading normal lives, and were routinely treated with pity or contempt. Roosevelt refused to give up his political aspirations, and used his position and wealth to help combat the disease and its effects. As part of his own attempt at rehabilitation, Roosevelt visited a spa at Warm Springs, Georgia, which he later purchased and turned into a nonprofit organization. In 1938, FDR established the National Foundation for the Prevention of Infantile Paralysis, which became known as the March of Dimes in the late 1970s. The foundation helped work toward lessening the effects of polio, including supporting some of Salk's vaccine research and immunization efforts. Activists for the rights of disabled persons have used Roosevelt's accomplishments to demonstrate that paralysis of one's limbs does not change one's ability to think or lead, and to expose the harmful societal attitudes that have challenged disabled individuals' integration into mainstream society.

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TRANSPORTATION

Highways to Cross the Country

The U.S. government's interest in highway transportation began around 1916, when it was clear that the automobile was here to stay. However, President Dwight D. Eisenhower felt strongly that a well-designed, safe, and far-reaching system of interstate highways would be critical to the future growth and the national security of the country, and during his presidency in the 1950s, he lobbied successfully for its implementation.

Two distinct experiences are said to have propelled Eisenhower's advocacy. One was his participation in the first cross-country motor caravan conducted by the U.S. Army, which took place in 1919. The convoy traveled from Washington, D.C., to San Francisco, and encountered many difficulties along the way. Besides vehicle breakdowns, the group found road conditions to be extremely inconsistent, and often treacherous. The vehicles encountered ice, mud, sand, and dust as they moved across the nation. Eisenhower contrasted this experience with what he observed in Germany during World War II. He saw that the German highway system was an incredible asset to military movement—and, he believed, to civilians as well. During his presidency, Eisenhower used stories of these experiences to convince state governors and Congress of the need for a national network of superhighways in the United States.

Federal Aid Highway Act of 1956 provides funding. As Henry Ford's Model T made automobile ownership possible for more and more Americans, the demand for better roads increased. Although a concern for public roads predated it by at least a couple of decades, the Federal Aid Highway Act of 1938 firmly established the U.S. government's interest in developing a national network of highways to connect the states. Subsequent Federal Aid Highway Acts reiterated the commitment to a national highway system and produced more specific designs for it, but the money authorized by these acts was not nearly enough to realize the goals of the project. President Eisenhower made realistic financing for the federal highway project a priority, and encouraged governors and Congressional committees to work together in order to develop a funding plan. After several rounds of compromises, the Federal Aid Highway Act of 1956 was passed by Congress and signed by Eisenhower. It authorized the federal government to pay 90 percent of the $25 billion required for the highway building project, over 40,000 miles (65,000 km) of pavement to stretch across the nation.

Some roadway science. Our highways are paved with either asphalt or concrete (or a combination of the two). The asphalt used commercially is typically a byproduct of the petroleum refining process. However, asphalt does occur naturally in asphalt lakes and in asphalt rock, a mixture of sandstone, limestone, and an asphalt binder that can be crushed and used to create paving material for roads. Concrete consists of bits of gravel and crushed stone, held together with a portland cement binder. The differences in binder materials used in cement and concrete and in asphalt give these substances their different properties. The petroleum-based asphalt binder softens in heat, making asphalt roadways more flexible than their concrete counterparts. However, the softness can result in decreased durability. Asphalt roads are generally much faster and cheaper to construct and maintain, but concrete roads are more durable. Concrete roadways also reflect more light and thus can reduce the costs of illuminating roadways for night travel.

In the northern United States, winter weather poses a particular challenge for maintaining the surface, and thus the safety, of roadways. Ice and snow on roadways can cause accidents, as well as problems in the structural integrity of the road. But why is ice such a problem?

First, freezing water causes problems on roadways because of its unique chemical properties. On a molecular level, most types of matter get denser when they change from a liquid to a solid state. The molecules that freely slide past one another in the liquid form of a substance arrange themselves in tight and regular patterns to form the crystalline structure of a solid; in this way, the same amount of matter is compacted into a smaller space, increasing the substance's density. For water, however, the particular crystalline structure that characterizes its solid phase is a hexagonal, honeycomb type of arrangement, with wide spaces between molecules. The solid phase is actually less dense than the liquid phase (which is why, for example, an ice cube floats of top of a glass of water rather than sinking to the bottom of it).

When liquid water gets into the surface of a roadway and then freezes, it expands. The roadway must either expand with it or yield to the pressure of the ice, causing strain, and possibly cracks and fissures. Air-entrained concrete is one of the roadway materials that have been manufactured to resist the strain of ice. In this type of concrete, air bubbles are part of the material, so that freezing water may expand into the air pockets and cause little or no serious damage to the concrete.

The effects of our highway system. Eisenhower's vision of a national system of roadways was realized, and has had a lasting effect on American lifestyles. In contrast to other countries in the world, where using public transportation is the norm, Americans rely on personal vehicles and allow individual agendas to dictate their transportation habits. The highway system allowed for the development of suburban America, and contributed to the movement of people away from urban areas during the second half of the century. Commuting has become a way of life for many Americans. The relative ease with which we can travel to even the remotest places in the contiguous forty-eight states has shaped the habits and mind-set of several generations of Americans. Another effect of the development of the federal highway system has been a change in commercial transportation, as trucking has replaced rail transit as the primary means of shipping goods across the nation.

Over the years, social commentators have wondered whether this emphasis on private rather than public means of transportation will ultimately do more harm than good. Oil availability and cost crises in the 1970s and 1990s led many to worry about the serious oil dependency that results from our transportation habits. Environmentalists cite the disruptive effects that building and maintaining extensive roadway systems can have on natural ecosystems. Traffic jams and gridlock often plague our cities, due to the sheer numbers of cars on the road. Exhaust fumes pollute our atmosphere and have contributed to health problems for living things at various levels.

Few characteristics have defined twentieth-century American society as thoroughly as our love affair with cars and highways. The benefits of staying connected have certainly come with costs. In the future, choices about transportation habits will no doubt be influenced by lessons from the past.

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HUMAN KNOWLEDGE

In the 1950s, significant advances were being made on the medical front. Early in the decade, Gertrude Elion, a chemist with Burroughs Wellcome Laboratories, successfully synthesized a purine compound that slowed the progress of leukemia cells. Her work led to the development of numerous other chemotherapy drugs. In a Boston hospital in 1954, Richard and Ronald Herrick underwent the first successful kidney transplant operation. Although the procedure was hailed as a success, it was possible only because the Herrick brothers were identical twins, so Richard's immune system did not reject his brother's kidney as a foreign object. It would be more than another decade until immunosuppressant drugs—based on some of Elion's work—would make organ transplants between nonrelatives a reality.

Humans continued to explore our home planet in the 1950s, from the ocean depths to the highest mountain. In the mid-1920s, the German Navy had discovered that a huge mountain range ran underwater through the middle of the Atlantic Ocean. In 1953, William Maurice Ewing and Bruce Heezen discovered a huge canyon running through this mountain range, a find that would eventually help prompt an understanding of a mechanism for the largely ignored theory of continental drift. That same year, above sea level—in fact, 8,848 meters (29,028 feet) above sea level—Edmund Hillary and Tenzing Norgay became the first humans in recorded history to reach the summit of Mount Everest.

Ironically, one of the most significant developments in science during the decade had to do with a notorious incident of nonscience. In the 1910s, an amateur geologist named Charles Dawson had announced a fossil find from Piltdown, England, that had been dubbed "the missing link" between humans and our evolutionary ancestors. Possessing characteristics of both humans and apes, the skull, jawbone, and teeth of "Piltdown Man" were the source of much scientific speculation about the evolution of humans over the decades that followed. However, with the improvement of fossil dating techniques at midcentury came a startling discovery: in November 1953, Joseph Weiner and Kenneth Oakley revealed that the Piltdown fossils were a cleverly crafted forgery. The news made headlines, and as a result of the incident many scientists professed a renewed commitment to the healthy skepticism that is meant to characterize peer review of scientific research.

In 1959 in Tanzania, however, the legitimate, 1.75 million-year-old fossil finds of Louis and Mary Leakey helped shed new and eventually productive light on the origins of modern humans. Earlier in the decade, University of Chicago doctoral student Stanley Miller had simulated going back even further in time. In his laboratory, Miller showed how the chemicals believed to have been present during the earliest environments on Earth (the "primordial soup") could have combined to form amino acids, some basic chemical components of living beings. And in Cambridge, England, one critical mystery of life's propagation through the genetic material of deoxyribonucleic acid was solved when James Watson and Francis Crick announced their double helix model of its structure.

Double Helix Unraveled

In 1943, Oswald Avery determined that deoxyribonucleic acid (DNA) was the chemical substance which carried the genetic code for living things. The news surprised scientists, who had assumed that the molecules containing life's blueprints should be extraordinarily complex, like proteins. Nucleic acids seemed to consist merely of strings of a few basic compounds, and scientists puzzled over how a relatively uninspiring polymer could give rise to all of the variety of life on the planet. In 1953, with the benefit of data collected by Rosalind Franklin and Maurice Wilkins, James Watson and Francis Crick announced a model for the molecular structure of DNA that suddenly helped scientists make sense of the mystery. It wasn't the identity of the pieces of DNA, as much as their unique arrangement, that served to create genetic variation among living things.

Prior to Avery's discovery, a few details were already known about DNA. In 1869, Frederick Miescher discovered that the major constituent of cell nuclei is nucleic acid. In the 1920s, Phoebus Levine identified two different types of nucleic acids within the cell nucleus: ribonucleic acid (RNA), and deoxyribonucleic acid (DNA). The chemical composition of nucleic acids had also been determined. The building blocks of nucleic acid are nucleotides, which are composed of the combination of one of five different kinds of nitrogen-containing bases (adenine, guanine, cytosine, thymine, or uracil), one five-carbon sugar, and a phosphoric acid molecule. The two kinds of nucleic acids are almost identical in chemical composition except that the sugar molecule in DNA is slightly different from the sugar molecule in RNA, and one of the nitrogenous bases found in DNA, thymine, is slightly different from the corresponding base found in RNA, uracil.

Although the basic components of DNA were known at the time of Avery's announcement, the structure was not. During the late 1940s and early 1950s, scientists focused on this challenge. In particular, two research groups in England began to make progress toward solving the puzzle of DNA's structure. At King's College in London, Maurice Wilkins and his research assistant, Rosalind Franklin, were using experimental techniques to try to determine how the sugar, phosphate, and nitrogenous bases were arranged in the DNA molecule. Franklin found that DNA changed form in humid conditions, and by comparing the two forms, she determined that the phosphate was on the outside of the DNA molecule. Further, Franklin's studies of one form of DNA suggested that it was helical in shape. However, she did not announce these findings publicly, feeling that she should complete more studies on the second form of DNA in order to reach a firm conclusion.

While Wilkins and Franklin focused on experimental details, another team of scientists was making a conceptual exploration of the molecule's architecture. Working together at Cambridge University, Francis Crick and James Watson were supposed to be researching other topics, but both were drawn to the mystery of DNA's structure. Rather than run experiments, they used others' findings to piece together models of the elusive molecule. Working in the early 1950s, they were familiar with research by Linus Pauling which found that many proteins have a helical, coiled shape. They also knew that Edwin Chargaff had determined that the proportions of nitrogenous bases in DNA samples followed a particular pattern: the amounts of cytosine and guanine were always equal, and the amounts of adenine and thymine also were always equal. Finally, they knew that Franklin had found that the phosphate was on the outside of a DNA molecule, and through talking with Wilkins, they became aware of Franklin's evidence supporting a double helical molecular structure.

Revelation. Albert Einstein is often quoted as having said, "Imagination is more important than knowledge." In science, this might be used to illustrate the difference between what historian Thomas Kuhn has called "normal science" and "revolutionary science." Experimental scientists are most often engaged in the business of doing "normal science"—working in the laboratory, they uncover basic pieces of knowledge about the world, bit by bit. Like Franklin's work, this process can be a painstaking effort to test and confirm tiny fragments of experimental evidence, one piece at a time. On the other hand, some scientists are drawn to a theoretical tendency to step back and sketch an outline of the big picture. They try to find logical connections between the facts. Although it is difficult and perhaps unproductive to say which type of work is more "important," it is often this second, theoretical way of working that leads to revolutionary new insights in our understanding of the world.

Because of their unique set of circumstances, Watson and Crick were poised to gain such an insight. In April 1953, the duo announced their "double helix" model of DNA. They proposed that the DNA molecule consisted of two coiled helixes, one spiraling upward and the other spiraling downward. As Franklin had found, the phosphates comprised the outsides of the DNA molecule. Between them, the nitrogenous bases connected the two coils like rungs of a ladder. Further, Watson and Crick theorized that "rungs" were composed of two bases, one attached to each coil, which paired according to the pattern suggested by Chargaff: cytosine paired with guanine, and adenine paired with thymine. Watson and Crick had succeeded in fitting the experimental together quite neatly, and the scientific community immediately recognized their achievement.

Scientific and social significance. In the decades following Watson and Crick's announcement, the mythic story of how the double helix was uncovered fascinated

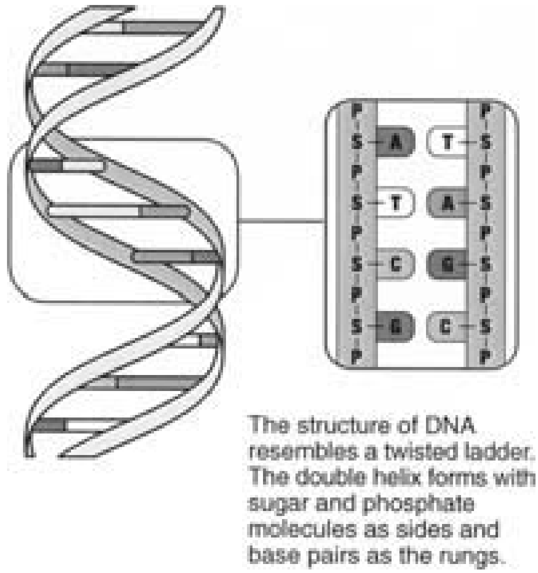

Figure 6.5.
The basic structure of DNA.

scientists and nonscientists alike. The model transformed research in the biological sciences. Once the structure of DNA was understood, many other mysteries of genetics could be studied more productively. The explanations for how DNA replicates itself, and how it codes for protein synthesis in the nucleus of cells, would eventually become evident in light of the structure of the DNA molecule. Throughout the second half of the twentieth century, bioengineers would use this knowledge to manipulate the makeup of living things, sometimes with dramatic results.

The story has also become known as a case in point for those who sought improved status for professional women in the latter half of the century. Traditionally, Watson and Crick, and to some extent Wilkins, have gotten the majority of credit for elucidating the structure of DNA. In fact, because of the achievement, the three shared the Nobel Prize for medicine in 1962. This has led many to question whether the significance of Rosalind Franklin's work has been overlooked.

Particularly because her experimental findings served as the linchpin that helped Watson and Crick pull their model together, and because Wilkins shared her data with Watson and Crick without her knowledge or consent, some have felt that Franklin was unfairly disregarded, and that perhaps she could have been first to publish news of the double helix. Accounts of the way in which Wilkins, Crick, and particularly Watson regarded Rosalind Franklin have compounded the speculation about her unfair treatment; their attitudes have variously been characterized as dismissive, patronizing, and sexist. Franklin died in 1958, which precluded her from sharing the Nobel Prize (recipients must be living, and no more than three persons can share the award). Although Franklin's side of the story can never be fully known, it serves as a reminder of many of the human dimensions of scientific research. Despite its orientation to logic, objectivity, and neutrality, the enterprise of science can never remain wholly unaffected by societal values.

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Chapter 7

THE SIXTIES

SOCIETAL CONTEXT: PUSHING THE BOUNDARIES OF SOCIETY

Unlike any other decade of the twentieth century in America, the 1960s gave rise to the transformation and reconfiguration of societal norms. Seventy million Baby Boomers disregarded and challenged the traditions of their conservative parents and "the Establishment." As young people questioned their lives, their perceptions, and their parents' expectations for them, the familiar cultural fabric of the American family seemed to be shredding.

Much of the societal change during this time was caused by a reexamination of human rights and responsibilities. In the previous decade, court-ordered racial desegregation of schools had prompted many Americans to come to terms with the inequities facing minority groups in everyday life. Civil disobedience became a popular means of expressing dissatisfaction with such systemic inequality. During the 1960s, the civil rights movement expanded, as black Americans across the country continued to speak out against the oppression that infiltrated their lives, and white Americans struggled to raise their own consciousness of these issues. Protests started with peaceful sit-ins and inspirational speeches given by the Reverend Martin Luther King Jr. Although the Civil Rights Act passed in 1964 outlawed discrimination, the pace of real change seemed sluggish. Eventually, groups frustrated by a lack of tangible results turned to more violent and radical means of civil disobedience; the Black Panthers, for instance, advocated black separatism as a means of finally escaping the tyranny they felt present in American society.

In 1960s America, women reflected on their place in society. Many women felt dissatisfied with the common expectation that they would spend a lifetime serving as a wife and mother at the expense of the political and economic freedom of choice taken for granted by their white male counterparts. Taking a cue from the successes of the civil rights movement, women's groups began organizing to fight for political and economic equality. In 1966, a group of activists including Betty Freidan, Gloria Steinem, and Pauli Murray founded the National Organization for Women (NOW) to help realize these goals.

College campuses in the 1960s were the sites of some of the most vocal calls for societal change. In addition to supporting efforts for minority and women's rights, college students turned their collective attention to human rights, broadly conceived. Interest extended beyond national borders, as American involvement in Vietnam became a hotly contested issue. College students also rallied for individual rights over one's own body: the sexual revolution and the drug culture flourished, as young people argued for a right to experiment with bodily experiences.

Likewise, art in the 1960s reflected reexamination. Books such as *To Kill a Mockingbird*, *The Feminine Mystique*, and *Catch-22* captured the moral dilemma of the time. Architects such as I. M. Pei incorporated ample space into futuristic designs to change the look of familiar surroundings. Pop artists such as Andy Warhol dared society to see itself differently. Fashion designers embraced the spirit of civil disobedience by challenging familiar standards of modesty in clothing design. While women donned miniskirts, hot pants, and go-go boots, men grew long hair and beards, much to the chagrin of anxious parents. Films such as *The Graduate* and *Midnight Cowboy* dealt with sexuality in explicit ways that movies of previous decades had not.

Music, too, would change dramatically during the 1960s. Mainstream America began to embrace black singers such as Smoky Robinson, the Supremes, James Brown, and Aretha Franklin. Rock music branched in new directions, from Elvis to the Beatles to the blaring, improvisational acid rock groups who embraced a counterculture of sex and drugs. The folk music of Joan Baez, Bob Dylan, and Peter, Paul, and Mary dared listeners to make conscious decisions about life. The spirit of freedom, experimentation, and collective consciousness was exemplified by the Woodstock Music and Art Fair, where 450,000 young people congregated in 1969 for free music, drugs, and sex.

Global relationships were strained during the 1960s. As Cold War sentiments intensified, Cuba's Communist leader Fidel Castro became a prime target of the CIA. An invasion of Cuba failed and became an embarrassment to President John F. Kennedy and the country; a year and a half later, a tense, worldwide audience saw the United States successfully prevent the Soviet Union from delivering nuclear weapons to Castro's military during the Cuban missile crisis. Across the globe, much of America's attention and resources were focused on the conflict over Communist rule in Vietnam. Although initially the United States served only in an advisory capacity, by the end of the decade its involvement in the Vietnam War had greatly escalated.

In line with the violent passions characterizing it, the decade was marred by the assassination of key political figures. In Dallas, Texas, President Kennedy was shot

Figure 7.1.
I. M. Pei's architecture exemplified a distinctive 1960s feel, Dallas City Hall, 1977. Courtesy of Library of Congress.

and killed on November 22, 1963—an event that brought the nation to a virtual standstill. Americans continued grieving as the country witnessed the assassinations of three more leaders: Malcolm X in 1965, Martin Luther King Jr. in 1968, and Senator Robert Kennedy in 1968.

In all, dramatic transformations characterized the times. Throughout the 1960s, rifts grew between those who supported opposite ideologies. Traditional versus new, old versus young, war versus peace, a suspicion of differences versus an acceptance of the human diversity of expression: such battles divided generations, neighbors, and families. Depending upon one's point of view, the 1960s was a decade of change for better, or for worse. Borrowing a phrase from Charles Dickens that has been echoed by many historians in reference to the 1960s: "It was the best of times; it was the worst of times."

ARCHITECTURE & ENGINEERING

Versatile Laser Technology

When the first working optical laser was built in 1960, its many applications were yet to be determined. Before long, however, laser technology would make it possible for humans to control light in order to cut, weld, heat, communicate, record, or measure. Today, various kinds of lasers can be found in everything from state-of-the-art research laboratories to children's toys. As a tool, the laser has become indispensable to modern life in the United States.

What is light? The word "laser" is the acronym *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation. Another way to describe the laser is that it is a device for allowing us to control electromagnetic radiation in the visible light range. In order to understand the significance of that feat, it is necessary to understand some basic scientific concepts related to light.

The nature of light has intrigued scientists for centuries. Several hundred years ago, when modern science was in its infancy, scientists who experimented with light (such as Isaac Newton and Christiaan Huygens) were not sure whether it consisted of particles or waves. With the advent of quantum mechanics at the turn of the twentieth century, scientists determined that light can act as both a particle and a wave. Some of the properties of laser light are best described by referring to the particle nature of light, while other properties of lasers are best explained by its wavelike qualities.

In the early 1900s work by Max Planck and Albert Einstein helped show that light consists of discrete bundles of energy called photons. As particles, photons can collide with other particles (even other photons), exert a force, or feel the attraction of gravity. For instance, the pressure of the sun's light on the earth is about one-sixth of a kilogram per square kilometer (1 pound per square mile). As a wave, light can act in the same way as other wave phenomena: it can be reflected or refracted, and it can interfere with other waves either to build up (amplify) its intensity or to cancel out its motion.

Light is a form of energy that consists of oscillating electrical and magnetic fields that travel at high speeds; thus, it is also called "electromagnetic radiation." These oscillations can occur at any frequency. Radio, TV, and microwaves are all very low-frequency light. Visible light occurs at medium-range frequencies. Gamma rays and X-rays are high-frequency light. The range of all kinds of electromagnetic radiation is known as the electromagnetic spectrum. Einstein discovered that the frequency of light is related to its energy; the higher the frequency, the higher the energy. Each specific energy (or wavelength) of visible light corresponds to a different color of light that we see.

Electromagnetic radiation can be emitted or absorbed by matter. On a submicroscopic level, such radiation has to do with energy changes that occur within an atom. Atoms consist of a tiny, dense nucleus that contains positively charged and neutral particles (protons and neutrons, respectively). Negatively charged particles (electrons) exist outside of the nucleus in cloudlike regions. When an extra energy source (for example, a photon of electromagnetic radiation) passes by an atom, it may absorb the energy, and the atom is said to be in an excited state. However, eventually the atom will return to its normal state, and when it does, it will release extra energy as one or more photon(s) of a specific frequency and wavelength.

What is laser light? In order to appreciate what makes laser light unique, it can be compared to the more familiar white light that emanates from a lightbulb. For a lightbulb to glow, the atoms that make up its filament absorb extra energy from an electrical current which passes through the bulb. The excited atoms eventually return to a normal state, giving off photons of visible light in the process. The photons that are emitted each have a different energy (or frequency), and thus correspond to a different color of light. However, when viewed together, the colors blend and appear to the human eye as white light. Light from a typical bulb spreads out in all directions around the bulb, the way ripples spread out when a pebble is dropped into a pond (except that the light waves travel in three-dimensional space). Thus, the light from a lightbulb also has a particular intensity, or brightness, which lessens as the light travels further away from the bulb.

The light produced by a laser is different from ordinary, visible white light in three ways: it is *monochromatic* and *coherent*, and it travels in a *plane wave front*. Laser light is *monochromatic* because it consists of only one kind of wavelength; thus, laser light appears as a particular color. The energy, or wavelength, of the photons emitted by a laser depends upon the distance that electrons drop from the excited to the normal atomic state. In the atoms that make up a laser, only one type of energy change is produced, resulting in light of only one frequency.

Second, the photons which make up ordinary white light travel in random phases, that is, the crests and troughs of one wave are not lined up with the crests and troughs of another wave. However, in a laser, the crests and troughs are in step with each other, like a marching drill team. This property of laser light is known as *coherence*. Because the beam of a laser is coherent, it can be made very powerful. Waves which are in step with one another can add their energies, so that they become amplified. Last, whereas white light from an ordinary bulb tends to spread out in all directions, the beam of light produced by a laser does not. Laser light travels in almost parallel lines with very little spreading, even at great distances. This is because the light from a laser travels in one *plane*, rather than being emitted in all directions of three-dimensional space.

How do lasers produce this special kind of light? In 1917, Einstein theorized that under the right conditions, atoms could be stimulated to emit photons of the same frequency and direction. This stimulated emission was later called *lasing*. A laser works by stimulating atoms or molecules to emit energy as visible light. Pumping energy into the atoms that make up the lasing medium eventually causes a large number of atoms to exist in an excited state. When one of the atoms returns to its ground state, it will emit a photon. This photon stimulates several other atoms to emit photons, all at the same energy.

The released photons are reflected back and forth by mirrors mounted at each end of the laser. As the photons travel, they strike billions of other excited atoms, triggering the emission of even more photons. This chain reaction produces photons with wavelengths that are all in step, or coherent. The triggering mechanism is referred to as amplification. On one end of the laser a semisilvered mirror enables the radiated high-energy laser beam to pass through the mirror, and produce the beam we see coming from the laser.

Competition and controversy. In 1953, Charles Townes invented the maser, or *m*icrowave *a*mplification by *s*timulated *e*mission of *r*adiation, the parent of the laser. The microwave frequencies produced by the maser sent powerful, coherent waves into parallel beams that did not spread out much even when they traveled long distances. However, scientists saw great promise in expanding this technology for radiation stimulation and amplification to other regions of the electromagnetic spectrum. Thus began a competitive race to build a working laser, using energies in the visible, infrared, or ultraviolet ranges.

The first optical laser was demonstrated on May 15, 1960, by Theodore Harold Maiman. Maiman used the idea behind the maser, as well as research papers published by Townes and Arthur Schawlow, to conceive of the working prototype. Meanwhile, however, Gordon Gould, a graduate student at Columbia University, had developed a workable theoretical design for laser development. He submitted a patent application for his detailed notes, which had been notarized prior to Townes and Schawlow's published articles and Maiman's device. A legal battle ensued, and was finally settled in 1977. Maiman received credit for creating the first working laser, and Gould received several patents for the laser technologies he developed.

Inventors of the laser look for a use. In the early 1960s, when the laser was in its infancy, dazzling public displays were common. The piercing, razorlike light beams popped balloons, heated steel wool to incandescence, and were used to present brilliant light shows, providing a circuslike attraction for audiences. Many skeptics felt that the laser was a high-priced toy rather than a serious scientific invention. However, by the mid-1960s, laser technology had evolved enough to be engineered into myriad devices for communications, tracking, medical, and industrial applications.

Hundreds of kinds of lasers exist today, and they can have solid, liquid, or gas components. Various lasers have different beam intensities, which make them useful for specific purposes. In medicine, lasers can reattach a retina, correct nearsightedness, painlessly vaporize tooth decay, break up kidney stones without surgery, make bloodless incisions, and remove birthmarks, warts, and tattoos. The use of a laser in atomic microscopes allows researchers to look at individual atoms. Laser technology provides a means to handle the ever-increasing data of the Information Age through its use in devices such as compact discs, laser printers and copiers, supermarket scanners, and telecommunications networks. Laser beams measure the distance from the earth to the moon, as well as minute distances, with great accuracy. They guide engineers through the building of ocean freighters, bridges, and tunnels. Lasers can drill holes through thick steel or precisely place 200 holes on the head of a pin. Military technology incorporates lasers to home in on targets as well as confuse enemy sensors seeking to detect equipment. Geologists can study earthquakes and measure the amount of pollution in the air using lasers. Future applications of laser technology seem limited only by human imagination.

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ARTS & ENTERTAINMENT

"Beam Me Up, Scotty"

In September 1966, a science fiction television program titled *Star Trek* premiered on NBC with little excitement from most viewers. The series was staged in the twenty-third century on the Starship USS *Enterprise*. According to the show's premise, the five-year mission of the *Enterprise* crew was to patrol various sectors of the galaxy, conduct scientific space exploration, regulate trade, assist those in distress, perform diplomatic missions, and push back the vast frontiers of space, where, as was announced in the prologue of the show, "no man has gone before."

Star Trek aired for three seasons. In the 1960s, the show's following was small, but creator Gene Roddenberry's vision of life in the future inspired a group of very loyal and vocal fans. The innovative writers of the series led fans to anxiously anticipate the next episode to see what new "scientific" gadget or creative thinking by Spock or Captain Kirk would safeguard the crew. Warp speed travel, dilithium crystal fuel, phaser guns, and a transporter that instantly beamed an object or person from one place to another captured the imaginations of the show's followers, who hoped one day to say, "Beam me up, Scotty." Devoted enthusiasts of *Star Trek* wrote of a longing to visit new worlds and promoted the idea that space travel would indeed be plausible in the foreseeable future.

Is interstellar travel possible? Researchers have identified many barriers to interstellar travel. For one, the method of propulsion employed must add no additional mass to the system and be cost- and time-efficient. Another issue concerns the speed at which an interstellar craft must travel. A velocity near or even greater than the speed of light is necessary, or the time required to travel to other star systems would be prohibitive.

Space travel requires a workable system that provides enough energy for a spaceship to overcome the earth's gravitational force, energy to propel a ship forward in a vacuum or change directions, and enough energy to slow the ship for a soft landing. For example, the trip to the moon required a multistage Saturn rocket to return the three astronauts in a tiny capsule. In comparison, interstellar travel would present greater challenges, primarily because of the much larger distances involved. The distance from Earth to the star Alpha Centauri is 4 light-*years*, whereas the distance to the moon is 0.7 light-*seconds*. Imagine the size of a spaceship needed to transport a crew and supplies for a 40-year trip to reach a distant star, realizing that there are no "energy stations" in space for a fill-up. Increased amounts of fuel carried on board would add to the mass that is lifted during launch and carried through space. Therefore, the propulsion needs to be of little or no mass, similar to the small "dilithium crystals" used to fuel the USS *Enterprise* that sailed on *Star Trek*.

In 1996, NASA established the Breakthrough Propulsion Physics Project (BPPP) to pursue affordable, credible research on conceivable propulsion designs. Researchers talked of two options. The first would be an onboard engine that could be fueled by chemical, fission, fusion, or antimatter reactions. A second option would be an offboard propellant design analogous to the way wind propels a sailboat. In space, however, lasers and particle beams would be used to direct a "sail."

Onboard propulsion options. A chemical engine would produce hot gases that would act to push a space vehicle forward. However, the amount of chemicals needed for a trip to the nearest star would be more than the mass of the earth itself, and the maximum possible speed for travel would be much too slow. Using nuclear fuel for a fission or fusion reaction engine could result in a velocity closer to the speed of light; unfortunately though, the speed is still ten times too slow to reach a nearby star system within a 40-year period. The fuel needed would be considerably less than that for a chemical reaction, but still impractical (e.g., 1,000 supertankers' worth for a fusion reaction design). In addition, the radiation hazard associated with nuclear fuel would compromise the safety of the design.

A matter–antimatter, or ion, engine theoretically would provide 100 percent efficiency, and move the space vehicle at the speed of light. However, this engine would still need about 10 tons of matter, even soaring in a small space shuttle for the 80-year round trip. This amount of antimatter, approximately equivalent to 10 million Hiroshima bombs, is 100 million billion times more than is presently produced, would present a critical handling problem, and would cost the equivalent of the entire U.S. federal budget every year for the next 7 billion years. Obviously, antimatter propulsion is not an option at the present time.

Offboard propulsion. The limitations of onboard propulsion systems have prompted scientists to consider using a "light sail" to power a spaceship. In the early 1900s, Max Plank and Albert Einstein helped show that light exists as discrete bundles of energy, called photons, that are emitted and absorbed as particles but travel as waves. As a particle, light is a real substance and is attracted by gravity just like any other substance. Photons also exert a force when they strike an object. It is estimated that the pressure of the sun's light is equal to one-sixth of a kilogram per square kilometer (or one pound per square mile), not enough to feel but enough to push a large tinfoil satellite out of its orbit by hundreds of kilometers per year.

It is reasoned that a powerful laser could strike surfaces of a spaceship and propel it through space, and if the surface perfectly reflected the laser light, it could double its efficiency. To propel the vehicle even 4 light-years would take a 100-square-kilometer sail combined with a 100-kilometer-diameter laser lens. There are problems, however: for example, without onboard propulsion, the spacecraft would not be able to stop or change directions. Also, a small misalignment of the laser beam could take several years to detect, since communication could take place only at the speed of light. Despite the present technological barriers to this design, researchers consider it a feasible way to explore space in the future.

What if we could travel faster than the speed of light? Einstein's special theory of relativity holds that nothing travels faster than light in a vacuum. This constant, first measured to an accurate magnitude in 1676 by the Danish astronomer Olaus Roemer, is now thought to be approximately 300 million meters per second. Recently, scientists have speculated that warp speed—faster than the speed of light—could be possible if the properties of space itself are altered in just the right way.

Scientists propose that we exist in a four-dimensional space-time continuum. We use the combinations of the up–down direction; the right–left direction; the forward–backward direction; and time to locate ourselves in space-time, and to measure properties like velocity. Consider a distortion of space-time where the area in front of a spacecraft is contracted and the area behind the spacecraft is expanded. This distortion, or warp, would propel the spaceship forward, much like a surfer riding the crest of a wave. This propulsion would allow for travel at speeds greater than light.

The theory of relativity is not compromised by the example given above. To illustrate, imagine a bug in a spaceship traveling near the speed of light while the space-time continuum in which the spaceship is traveling experiences a disturbance. The spaceship would be propelled forward and the bug would be moved forward; the combined speed would be greater than the speed of light. The bug would travel faster than the speed of light relative to an observer watching from outside that space. However, the bug would still be traveling less than the speed of light relative to the ship, which is where the theory of relativity would apply. This theory of space-time hypersurfing was proposed in 1994 by Miguel Alcubierre, a Mexican physicist studying at the University of Wales. Although the technical details seem to be light-years away, many researchers now study these ripples, compressing and stretching the fabric of the space-time continuum, which the *Star Trek* crew experienced on the USS *Enterprise* in the 1960s.

***The cultural impact of* Star Trek.** Although *Star Trek* could certainly be credited with sparking the imaginations of science enthusiasts, the series was also a pioneer in addressing social and cultural issues. For instance, the starship carried an ethnically mixed crew with a woman in a top command position, which had never before been seen on U.S. television. Television's first interracial and interspecies kisses were shown on *Star Trek*. Its optimistic view of the future and moral lessons about kindness contrasted sharply with the starkly violent coverage of the war in Vietnam that dominated newscasts of the period. *Star Trek* seemed to offer many viewers hope for a better tomorrow.

Although the original series was canceled in 1969, fans continued to keep the characters, stories, and vision alive. A nonprofit fan publication titled *Star Trek Concordance of People, Places and Things* soon appeared, and a subculture of "Trekkies" created newsletters and held national conventions. In fact, it could be said that Gene Roddenberry's creation has never really gone away—eventually, a *Star Trek* cartoon appeared, as did several spin-off series and motion pictures. The characters and stories are still very much present at the beginning of the twenty-first century.

In addition to their success in keeping various versions of *Star Trek* in circulation, fans were able to honor the show ten years after its premiere. In 1976, fans started a write-in campaign urging the White House to select the name *Enterprise* for the first reusable space shuttle orbiter. The shuttle was to be named *Constitution*, in honor of the bicentennial. However, President Gerald Ford heeded the advice of the "Trekkies," and members of the *Star Trek* cast watched the unveiling of the *Enterprise* as the Air Force band played the theme from *Star Trek*. Although *Enterprise* was only a prototype shuttle that was used for glide tests, to fans it represented one more step toward realizing the dream of one day fully exploring the universe.

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COMMUNICATION

Integrated Circuits

The impact of integrated circuits (IC) upon communications technologies in the twentieth century has been said to be comparable to Gutenberg's introduction of printing with movable type: it allowed for unprecedented mass accessibility of information. Although the integrated circuit dramatically increased the scope and effectiveness of communications technologies, other devices also reaped the benefits of the new technology. In general, the integrated circuit made electronics convenient and widely available as its invention paved the way for diverse and unanticipated methods for machines to control machines.

Transistor makes ICs possible. Prior to the introduction of the integrated circuit, the invention of the transistor played a pivotal role in the development of electronics. Because it served the same function as the vacuum tube but was many times smaller, the transistor allowed new kinds of electronic devices to be built, and existing electronic devices to be built much smaller. However, forward-thinking engineers speculated about ways to reduce the size of transistors even further.

In the late 1950s, a group of electronics experts formed the Fairchild Semiconductor Corporation, with the intent of enhancing transistor technology. One of the group's important discoveries was that silicon could replace the germanium originally used as the base for the transistor, to give improved performance at higher temperatures. However, the innovators at Fairchild Semiconductor suspected that finding a way to put all of the components of an electric circuit—transistors, capacitors, resistors, wires, and the rest—on one tiny crystal would be the significant advancement they sought. For this work, Robert Noyce was awarded a patent in 1961 for the first integrated circuit.

Jack Kilby, a researcher for Texas Instruments, had introduced the first germanium-based integrated circuit in 1958 by incorporating several electronic components on a single piece of semiconductor called the TI404. Although his device predated Noyce's, the two are recognized to have independently conceived of working models, and to have invented the technology that revolutionized electronics. Kilby was awarded the Nobel Prize for physics in 2000 for his invention (Noyce had died in 1990, and the Nobel Prize cannot be awarded posthumously).

What is an integrated circuit? An integrated circuit (IC), also known as a microchip or chip, was a new and revolutionary electronic component. With the advent of the IC manufacturing process, resistors, diodes, and transistors were no longer recognized as distinct electric circuit elements but were seen as one integrated device in which discrete components were no longer discernible. The entire circuit is formed in a single-crystal (monolithic) chip of silicon semiconductor.

The old, separate electric circuit components were much larger, less reliable, less efficient, and more expensive, and gave off too much heat in comparison to a new chip that could perform the same functions. In contrast to devices using conventional transistors, the IC lasted five times longer on average and was considerably smaller and lighter. A transistor-based pulse decoder circuit weighed 50 pounds, whereas a new model using integrated circuits weighed only 12 ounces.

A microchip looks like a centipede (a rectangular "body" with "legs" branching off from it), but the size of an actual IC is a square centimeter (or an M&M candy) with wire pins to carry the electric code signals. The core of the chip is the semiconductor material; usually that is the chemical element silicon, which can contain thousands or even millions of circuit components networked together to work as one unit. In the early 1960s, the integrated circuit consisted of ten individual components on a silicon chip just one-quarter of an inch (6 millimeters) square. By the 1970s, ICs could incorporate thousands of components in a single chip of the same size, and by the end of the twentieth century, ICs were designed with as many as 5.5 million transistors on a single chip. The precise measurements associated with IC design are on the magnitude of microns or less. That translates to one millionth of a meter, or one hundredth of the diameter of a human hair.

How is a microchip made? To make the microchip, a silicon cylinder similar to a roll of frozen cookie dough is sliced into thin layers about one-hundredth of an inch thick. Silicon dioxide, an electrical nonconductor, is applied to each side of the silicon wafer. Next a special chemical coating called *photoresist* is applied. The photoresist hardens in the presence of ultraviolet light. Patterns are made by using a mask that prevents some areas of the photoresist from hardening, similar to the way that a stencil is used for etching glass. The remaining soft areas of the wafer are chemically dissolved, leaving behind part of the silicon dioxide. More layers are made by masking and etching until holes are formed through the sections of wafer where the unexposed photoresist once was. This process is called *photolithography*, and it forms the pattern for an actual circuit.

Impurities are purposely added to the silicon layers to form a semiconductor, a substance that varies its electrical conductivity depending upon variables such as temperature and current size. To eliminate all unwanted impurities, such as airborne particles or those brought in by humans, the manufacturing environment is a thousand times cleaner than today's cleanest operating rooms. Workers wear special coveralls and a state-of-the-art filtration system removes substances of microscopic size from the air.

After all of the layers are complete, the last masking places strips of aluminum on the wafers in order to allow for electrical connections through the holes. These layers can be as thin as a few molecules thick. Each wafer will be cut to make several hundred chips, each chip less than a centimeter square.

The ubiquitous IC. Few tools have impacted our society as profoundly as the integrated circuit. The miniaturization of electronics made possible by the IC contributed to its use in virtually all modern electronic devices, and drastically reduced the cost of many electronic products. The IC made it possible for engineers to create the first microprocessor, which contributed to the proliferation of home computer use in the last decades of the twentieth century.

Even the inventors of the integrated circuit may have been surprised by the dramatic ways it changed society. Jack Kilby has noted that at the time of its invention, no one realized that the IC would reduce the cost of electronic goods by a factor of a million. The miniature integrated circuit changed the world so completely in less than 50 years that it is hard to imagine what the next 50 years of chip development may bring.

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DEFENSE & DIPLOMACY

Helicopters in Vietnam

Prior to the creation of weapons of mass destruction such as the atomic bomb developed by the United States to end World War II, military strategies implemented by the United States were based on the principles of "massive retaliation." Up to this point, wars had been fought and won by the use of overwhelming force, available to only a handful of countries able to provide the ample quantities of money, fuel, weapons, and manpower necessary to support such an effort. However, as other powerful nations, such as the Soviet Union, began to develop the technologies needed to design and construct similar weapons of mass destruction, the leaders of the world's superpowers came to understand that a massive nuclear strike would only lead to retaliation and, ultimately, mutual annihilation.

Spurred by the fear of total destruction inevitable with nuclear war, armies after World War II employed methods of combat that regressed to the techniques used in earlier periods. Characterized by small battles fought with conventional weapons and guerrilla forces carried out in Third World regions, these low-to-mid-intensity conflicts, known as "brushfire wars," necessitated the development of new military strategies, technologically diverse weapons, and innovative ideas to maintain mobility in the terrains typical of these volatile regions.

How did helicopters aid the U.S. military in Vietnam? The most distinctive symbol of combat of the 1960s was the helicopter. Limited by their power, size, and capabilities, helicopters were used only marginally in World War II and the Korean War, primarily in support roles such as search-and-rescue operations. However, as the face of war changed from large armies fighting across vast fronts to small battles fought in hostile territories, the needs and requirements for military operations also changed.

During the early 1960s, while providing support to allies in the warring region of Vietnam, U.S. military advisers stationed in South Vietnam worried about how the densely vegetated terrain could affect the services provided by the United States. Recognizing the limitations of fixed-wing aircraft in a jungle setting, the U.S. Army began to examine the usefulness of and requirements for helicopters to enhance the combat effectiveness and tactical mobility of ground forces, termed "air mobility." During the Vietnam War, helicopters were used for transporting troops and providing armament capable of rapid and precise firepower. A crucial advantage was the ability to add the element of surprise to military operations because of the versatile mobility of helicopters. Their ubiquitous use during the Vietnam War established that helicopters were as indispensable to the army as the jeep.

How do helicopters fly? Helicopters are also called rotary aircraft, which underscores the way in which they operate. Using the thrust created by the spinning blades of the main rotor above the aircraft, helicopters are able to take off and land vertically, dispensing with the need for cleared runways. Helicopters can also move sideways and backward, rotate in a circle, and hover in the air. As the blades of the main rotor turn, lift is created by the airflow around them, causing the aircraft to rise. By changing the angle, or pitch, of all the blades of the rotor, the helicopter can be made to move up and down. Changing the angle of each blade at the same selected point in its circular pathway causes the helicopter to move forward and back.

A rotor on the tail of the helicopter stabilizes it. This second rotor can be orientated perpendicular to the direction of the main rotor, or it can have a parallel orientation but rotate in the opposite direction from the main rotor. The counteractive thrust produced by this second rotor prevents the helicopter body, or fuselage, from rotating in the opposite direction of the main rotor. The second rotor is also used to direct the helicopter to the right or left.

The lift necessary to raise and lower an aircraft is created by the air traveling over the blades of the propeller. The concept of lift is best explained by examining a prin-

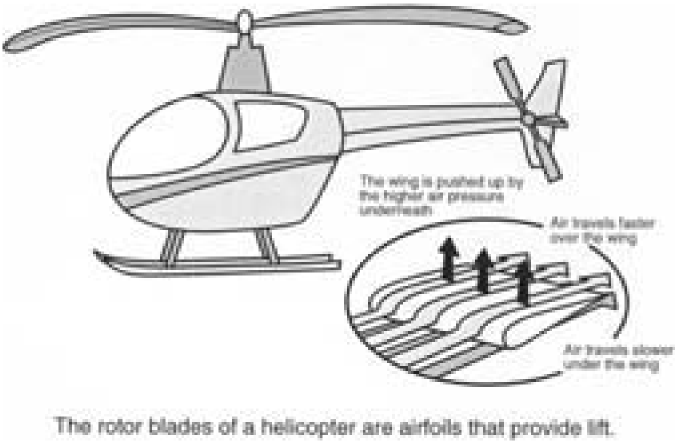

Figure 7.2.
The lift of a helicopter.

ciple discovered by the Swiss scientist Daniel Bernoulli: that as the velocity of a fluid increases, its pressure decreases. The blades of the rotor, like a wing on an airplane, are airfoils. An airfoil is curved over the top of the blade and straighter underneath. As air hits the blade, it splits, moving both over and under the blade. Since the top of the blade has more curve than the bottom, the air moving over the top has farther to travel and must move faster than the air moving underneath. In accordance with Bernoulli's Principle, the air moving over the top of the blade now has decreased air pressure compared to the slower-moving air under the blade. Thus, lift is created. The faster the blade moves through the air and the greater the forces become, the greater the lift.

How did the use of helicopters impact the Vietnam War? When helicopters were first used in Vietnam in 1962, Communist troops ran off at the sight of the helicopters carrying their opponents into battle. Shortly thereafter, however, it was discovered that helicopters were relatively easy targets to bring down. Communist training manuals contained details of effective ways to shoot down helicopters, including where to aim to cause the most damage. Even with its perceptible weaknesses, the helicopter's proven usefulness far outweighed its limitations.

Helicopters were regularly used to quickly shuttle and deploy troops into combat zones. In addition, helicopters could be equipped with guns, grenade launchers, and guided missiles capable of accurately taking out targets or aiding ground troops in combat. Perhaps the most significant use of helicopters in Vietnam was for use in combat search-and-rescue missions, where they were employed to recover pilots who had been shot down behind enemy lines.

Since the end of the Vietnam War, helicopters have evolved in both form and function to better serve the varying needs of the military and commercial uses. Now they are an integral part of military combat, and many warfare strategies have been designed around the versatile helicopters.

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ENVIRONMENT

Alaskan Oil Discovered and Tapped

Although oil exploration in Alaska actually began late in the nineteenth century, and the first oil field was drilled near the Gulf of Alaska in 1902, it wasn't until March 1968 that the most substantial oil field in the United States was discovered. The area near Alaska's Prudhoe Bay came to be known as the "North Slope" because it lies on Alaska's northern shore between the Brooks Range and the Arctic Ocean. The discovery of the 16.4-billion-barrel field proved to be the largest oil field in North America, surpassing the 5-billion-barrel field discovered in East Texas in 1930.

How was oil discovered in Alaska? By all accounts, the existence of oil in Alaska's wilderness was known by many of its inhabitants. Early indigenous tribes had observed it seeping out of the ground and flowing into nearby waterways for generations, and the Eskimos had used it as a fuel source in their moss-wicked lamps to provide light. Alaska's explorers had seen similar seepages and had even discovered lakes of oil in the territory. Based on these findings, the speculation was that larger reserves would be found underground. Prompted by the fuel shortages caused by World War I, in 1923 President Warren G. Harding set aside large portions of the Arctic coast of Alaska to supply oil for the U.S. Navy. By 1944, however, the navy had completed its exploration of the reserve and had determined that while large oil fields did in fact lie beneath the ground, the costs of extracting the oil and transporting it to the contiguous forty-eight states would far exceed its market value.

Although the United States purchased the 586,412 square miles of northern territory known as Alaska from Russia in 1867, it was not until 1959 that Alaska became the forty-ninth state. At that time, the state government began leasing the land to commercial petroleum companies interested in northern oil exploration, since the navy was no longer concerned with its rights to the Alaskan oil fields. Government surveys indicated that 125 million acres in Alaska had oil and gas possibilities.

In the late 1950s and early 1960s, several moderately sized oil fields were discovered in the Cook Inlet area of southern Alaska. These oil finds, while providing encouraging results for prospecting oil companies, were not the large finds necessary to sustain the costly exploration for oil in such a harsh and barren environment. Exploration began to move north to the Arctic coast. Between 1964 and 1967, over 900,000 acres of land had been leased in the North Slope. With Alaskan drilling costs double the cost of drilling similar wells in the lower forty-eight states, the three top oil companies combined had spent over $4.5 million drilling a test well that resulted in no oil discoveries. Finally, in 1968, the Atlantic Richfield Oil Company (Arco) struck oil in Prudhoe Bay, marking the largest oil discovery in the history of the United States to date.

Why the interest in oil? In the time before petroleum products were readily available as a fuel source, whale oil was used to fuel the combustion necessary to provide light. By 1850, whales had been hunted to such an extent that the cost of whale oil skyrocketed and an alternative energy source was in high demand. Coal and kerosene were available, but mining costs made these alternatives prohibitive as well. In 1859, Colonel Edwin Drake drilled the first oil well in Pennsylvania and discovered a cheap, plentiful energy source that literally flowed from the ground.

Oil is called a hydrocarbon because it is a chemical mixture of hydrogen molecules and carbon molecules. Reservoirs of hydrocarbons do not accumulate in the earth by chance. Instead, oil deposits are found only in areas where four essential elements come together: the *source bed* from which the oil was formed, the *porous reservoir rock* where the oil is stored, the *trap* that captures the oil in the reservoir, and the *impermeable seal* that keeps the oil from leaking out of the trap. If one of these four elements is missing, no oil field will be present.

While seeps are good indicators of the presence of oil beneath the ground, many oil reservoirs are located under several layers of rock and thus do not display such surface indicators. To look beneath the surface topography, scientists use various methods to detect the presence of the four elements. Aerial photography, surface geology, electric well logs, and analog and digital reflection seismographs offer insight into what lies beneath the surface of the earth. Reflection seismographs are the most important and widely used geophysical exploration tool today. Sending vibrations though the earth, and then using a device known as a geophone to listen for the reflected waves sent back from rock layers, geologists can interpret the stratigraphy, or sequence of rock layers, beneath the earth's surface. After months of study and great expense, once it has been determined that there is a high probability of oil in an area, a well may be drilled.

What are the implications of oil discovery in Alaska? Even after the oil field was discovered in Prudhoe Bay in 1968, oil from the North Slope did not come on-

Figure 7.3.
The 800-mile Trans-Alaska oil pipeline. © Getty Images/PhotoDisc.

line for commercial use until 1977. Due to the harsh weather, transportation difficulties, and grueling work schedules, it took several years to develop the well fields and construct an adequate pipeline to efficiently transport the oil to processing plants. Construction of the Trans-Alaska pipeline, an 800-mile pipeline transporting oil from the North Slope to the ice-free southern port of Valdez, began in 1974 and was brought on-line in 1977. The output of oil in the pipeline peaked at 2 million barrels of oil per day in 1988.

Since the Prudhoe Bay oil discovery, there have been no additional significant oil field discoveries in Alaska. Spurred by oil shortages in 1973, a government-sponsored exploration in the North Slope resulted in the discovery of no substantial wells. At the beginning of the twenty-first century, oil consumption far exceeds domestic reserves, and current oil exploration debates have focused on the 19-million-acre Arctic National Wildlife Refuge (ANWR) to reduce the dependence on foreign oil supplies.

Exploration for, drilling for, and transporting oil always entail a risk of damage to the environment. For instance, the 1989 *Exxon Valdez* oil spill released 11 million gallons of oil into Prince William Sound, resulting in the environmental destruction of 1,500 miles of beaches and the deaths of thousands of birds, otters, seals, fishes, and whales. Opponents of oil exploration in ANWR are concerned that the environmental costs associated with drilling in the refuge outweigh the energy benefits to be gained, especially since the actual amount of oil in the refuge is unknown. It remains a challenge of the twenty-first century particularly salient to Alaska: to balance the benefits society derives from oil with the damage its extraction and transport can wreak on our natural surroundings.

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FOOD & AGRICULTURE

Pesticide Use and *Silent Spring*

In 1962, marine biologist Rachel Carson published *Silent Spring*, a controversial book outlining the detrimental effects of toxic chemicals in agriculture and other commercial industries. Based largely on a compilation of scientific studies outlining the environmental impacts of pesticides and other agrichemicals, *Silent Spring* foretold the doom of the human race if the unregulated use of artificial chemicals to alter the environment were allowed to continue. Though it was based on substantially researched technical information, Carson wrote her book in the terminology and style appropriate for the scientific literacy level of the average person and conveyed her genuine concern for the environment without complex formulas and numbers, thus connecting with a large population of readers.

What led to the concern? While working for what is now the U.S. Fish and Wildlife Service, Rachel Carson was compelled to act after hearing a friend relate a story about the harmful consequences of the chemical DDT, dichloro-diphenyl-trichloroethane, used for mosquito control in a wild bird sanctuary near her home in Massachusetts. Learning of the death of many birds and insects from the routine chemical application, Carson began an inquiry to find a governmental agency that would help to stop the use of harmful chemicals in such environmentally sensitive areas. Finding no organization willing to take a stand against the powerful chemical industry, Carson wrote an article intended to expose the hazards of DDT. However, her research into DDT led to the discovery of many more chemicals with similar dangers. Announcing that "There would be no peace for me if I kept silent," Carson began work on *Silent Spring*. During an interview with CBS, Carson stated, "The public must decide whether it wishes to continue on the present road, and can do so only when in full possession of the facts."

Silent Spring was released during a time when the public was awakening to the negative affects of the unregulated use of some synthetic chemicals. Thalidomide, which had been given to pregnant women to combat sleeplessness and nausea, was removed from the market in 1962 after having caused thousands of birth defects and infant deaths. A growing awareness of the threat of nuclear fallout from the use of radioactive chemicals in the atomic energy industry also resulted in public interest in unearthing information on the liberal use of toxic chemicals. Given these societal attitudes, the simple, straightforward manner in which *Silent Spring* was written rapidly awakened the public's interest in pesticide use in the environment. A quote from Albert Schweitzer set the tone for *Silent Spring*, and characterized the attitudes of many who took the book to heart: "Man has lost the capacity to foresee and to forestall. He will end by destroying the earth."

What is DDT? Dichloro-diphenyl-trichloroethane was first synthesized near the end of the nineteenth century. In 1942, Paul Müller showed that DDT was an effective insecticide, and just six years later, he received the Nobel Prize for his discovery. During World War II, DDT was used extensively to eliminate pests such as mosquitoes and lice in areas where soldiers were susceptible to insect-borne diseases such as malaria and typhus.

Because it is soluble in fats, DDT accumulates in the fatty tissue of animals that ingest it. Animals that are higher on the food chain receive concentrated amounts of DDT, since they eat many smaller animals that have stores of the chemical built up in their tissues. In some animals, DDT can mimic the function of the hormone estrogen, and cause malfunction of the reproductive system. In birds, DDT accumulation affects the chemical composition of eggshells. Birds with high levels of DDT in their bodies will lay eggs with thin shells, many of which cannot last long enough for a baby to develop. As a result, reproduction is hindered, and in some cases the survival of a species may be threatened.

What was the impact of the book? While the harmful effects of pesticides and other chemicals are highly documented and well known today, *Silent Spring* was the first research-based book to clearly state that some chemicals commonly used for human agricultural needs were harmful to many of the life-forms subjected to the chemicals. The book was not without its critics, however. The chemical industry and researchers challenged the book's conclusions and Carson's scientific credentials. At the urging of the public, President John F. Kennedy initiated a federal investigation of environmental pollution in 1963. A special Presidential Science Advisory Committee formed to study the effects of pesticides on the environment announced that Carson's claims in *Silent Spring* were correct, and instigated stricter and further research controls on pesticide usage.

Carson's book has been credited with laying the groundwork for the environmental movement of the 1960s and 1970s. By the end of 1962, the year *Silent Spring* was published, more than forty bills had been introduced in Congress to regulate the use of pesticides. In 1965, the United Nations held a world conference focusing on issues of pesticide usage, and nations around the world began passing restrictions on the use of DDT and other potentially harmful pesticides. In 1972, DDT was banned from sale in the United States. It is still used in some countries to eliminate malaria-causing mosquitoes.

Silent Spring spent 31 weeks on the *New York Times* best-seller list. In 1964, Rachel Carson died of breast cancer at the age of fifty-six. In 1980, she was posthumously awarded the Presidential Medal of Freedom by President Jimmy Carter for "creating a tide of environmental consciousness that has not ebbed."

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MEDICINE & HEALTH

Birth Control Pill Approved for Use

In 1960, the U.S. Food and Drug Administration (FDA) granted approval for the first drug to be used as an oral contraceptive in the United States. Women's rights advocates saw the new medical technology as an unprecedented chance for control and independence, but conservative political and religious groups saw it as a catalyst for a troubling decline in societal morality. While controversy surrounded the advent and availability of the Pill, as oral contraceptives came to be known, its acceptance and use eventually had a significant impact on women's lives in this country and around the world.

Why was the Pill needed? Throughout history, many cultures developed different methods for preventing pregnancy. However, due to a limited knowledge of human physiology, most techniques were not consistently reliable. As late as the end of the nineteenth century, numerous misconceptions still surrounded the understanding of the menstrual cycle's relationship to pregnancy. Once the cycle of ovulation and fertility was better understood, birth control advocates saw tremendous advantage in finding a reliable method of contraception that would work physiologically—as a process of a living organism—rather than just as a physical barrier, such as condoms and intrauterine devices.

The widespread industrialization of society during the first half of the twentieth century also had a significant impact on the need for birth control. In an agricultural society, having many children was a benefit, since they could work on the family farm. However, in an industrial society, where labor laws prevented children from earning an income and women were expected to stay at home, having a large family could easily launch a couple into poverty. By midcentury, when women were afforded more choices and opportunities for work and lifestyle, more began to decide to postpone childbirth or to not have children at all.

One sector who popularized the birth control movement in the United States were the champions of women's rights, most notably Margaret Sanger. Working as a nurse in New York City in the early 1920s, Sanger began her crusade to make affordable, reliable contraception available to all women, especially the poor who needed it most. Sanger and her colleagues ran a birth control clinic in Brooklyn, and despite being arrested on several occasions for distributing what was considered pornography at the time, she continued to fight for women's rights to accurate information on contraception and appropriate medical care. In 1950, funded by Katharine McCormick, heiress to the International Harvester fortune, Sanger began a search to find a scientist who would work to develop a contraceptive pill.

How was the Pill created? Supported by Sanger and McCormick, reproductive biologist Dr. Gregory Pincus and his colleague Min-chueh Chang began researching the effects of the human hormone progesterone on ovary functions. At the time it was known that injection of progesterone, a hormone produced by pregnant women, would cause a nonpregnant female rabbit's ovaries to appear pregnant. This fact was used in the Ascheim-Z test, the only reliable scientific test available in the early twentieth century to determine if a woman was pregnant. This test involved injecting a female rabbit with blood or urine from the possibly pregnant woman. After a few days, the rabbit would be killed and the ovaries examined. If the woman was pregnant, the hormones in her urine or blood would cause the rabbit's ovaries to appear pregnant. Pincus and Chang were curious to see if the results of the Ascheim-Z test would produce a similar effect of false pregnancy if injected into nonpregnant humans.

The effect of false pregnancy is the key to the physiological method of contraception. During a woman's normal menstrual cycle, an egg cell, or ovum, is released from the ovary into the fallopian tube. If the ovum is not fertilized by a sperm cell, then it is shed from the body during a woman's menstrual period, and a new ovum is released about two weeks later. If the ovum is fertilized, pregnancy results, and the hormones (such as progesterone) that subsequently flow through the woman's body prevent the ovaries from releasing additional eggs to be fertilized during the fetus's gestation. In other words, the Pill "tricks" a woman's ovaries into not releasing an ovum to be fertilized by mimicking the conditions of pregnancy.

After further animal experiments established the anti-ovulatory effectiveness of progesterone, Pincus contacted the Harvard gynecologist John Rock, who was conducting his own research on the effects of progesterone therapy on sterile women, to work on human trials of the new contraceptive. To avoid political, legal, and religious controversy over testing a contraceptive drug in the United States, large clinical trials were conducted in Puerto Rico, Haiti, and Mexico in 1956 and 1957. Results from the tests showed a failure rate of only 1.7 per 100 woman-years over a total of 25,421 menstrual cycles. Adding the hormone estrogen to the progesterone further aided in the effectiveness of the contraceptive. In 1960, less than 10 years from the start of the search for a new type of effective contraception, the Pill was approved for use as contraception in the United States.

Use and effects. Even though the Pill received relatively quick FDA approval, questions concerning society's reception of the oral contraceptive remained. Despite the enthusiasm of woman's rights advocates like Sanger, public attitudes regarding contraception were generally not amenable to the Pill's use at the time of its introduction. Into the 1950s, some states had laws forbidding the dissemination of information regarding contraceptives. Other states had laws limiting the sale, distribution, or advertising of contraceptives, and one state had made it a crime even to use contraceptives. However, once the Pill became available in 1960, questions regarding its acceptance by American society were soon put to rest. In 1961, an estimated 408,000 women in the United States were using the Pill. In 1962, the number more than doubled to 1,187,000 and in 1963, climbed to 2.3 million. By 1967, worldwide usage of the Pill was estimated to be over 12.4 million.

In the course of such widespread use, some problems began to arise within several years of FDA approval. Mild but common side effects of the Pill included nausea, water retention, weight gain, and breast tenderness. More serious side effects included blood clots, heart disease, elevated blood pressure, strokes, and depression. Questions about the safety of the long-term use of the Pill also surfaced. Some medical professionals began to wonder if the drugs had been tested thoroughly enough prior to FDA approval, and therapeutic revisions ensued. Formulation changes and dose reductions lessened the intensity of many of the side effects, and screening for preexisting health problems such as hypertension enabled health-care providers to avoid prescribing the drug to patients at a high risk for these diseases.

The Pill emerged as the most effective reversible form of birth control used in the twentieth century. Beyond the highly effective contraceptive benefits that the Pill provides, an awareness of additional noncontraceptive benefits has emerged. The Pill has been shown to regulate the menstrual cycle, which is of particular benefit for women with irregular periods; it decreases menstrual cramps and heavy flows; it reduces the symptoms of premenstrual syndrome (PMS); and it can be used to treat benign ovarian cysts. Secondary benefits of taking the Pill include decreased risk of ovarian, endometrial, and colorectal cancers, decreased risk of osteoporosis, and a decreased risk of ectopic (tubal) pregnancy.

Controversy remains. Despite its unquestionable popularity, the Pill remains controversial among segments of society. The Catholic Church, for example, officially forbids the use of birth control. Other societal leaders believe that abstinence from sexual relations is the only acceptable way of preventing pregnancy. The Pill has been cited as playing a major role in contributing to the sexual revolution of the 1960s, which critics blame for contributing to a decline in moral values, especially among young people. Even some who support a woman's choice to use oral contraceptives worry that it promotes a sense of false security among women, who consequently put themselves at risk for contracting sexually transmitted diseases.

Still, the statistics indicate that oral contraceptive use is commonplace in modern society. In the United States today, more than 80 percent of all women have used the Pill for an average of five years by the end of their reproductive lives. Without question, and beyond any moral characterization, after its introduction the Pill changed many of the expectations that society had for women, and women had for themselves.

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TRANSPORTATION

Moon Landing

Since early times, the moon has fascinated numerous human beings who have dreamed of what it would be like "up there." Myths and legends filled the heads of stargazers long before technology made it possible to actually land on the moon. On May 25, 1961, President John Kennedy proposed to a joint session of Congress the historic goal that by the end of the decade the United States should land astronauts on the moon and return them safely to the earth. On July 20, 1969, millions of people watched on television as American astronaut Neil Armstrong stepped out of his space vehicle and placed the American flag on lunar soil. Armstrong's words, "That's one small step for . . . man, and one giant leap for mankind," would rank among the best-known statements of the twentieth century.

Humans travel in space. Our early ancestors imagined ventures to the moon on the backs of birds and by the lift of balloons, but it wasn't until the late 1800s that space explorers fully understood and considered the effects of the pull of Earth's gravity. Around the turn of the century, Konstantin Tsiolkovsky, a Russian schoolteacher who is considered the father of astronautics, established the relationships between a rocket's mass and speed, and the mass and exhaust speed of the fuel used to propel it. In 1926, the American Robert Goddard launched the first working rocket that incorporated liquid fuel. By 1957, when the Russians successfully launched *Sputnik,* the first artificial satellite to orbit the earth, the dream of propelling humans to other celestial bodies seemed truly within reach.

Russian cosmonaut Yuri Gagarin became the first human to fly in space with a jaunt that lasted 108 minutes on April 12, 1961. Although the flight was neither televised nor promoted, it ratcheted up the Cold War competition between the United States and the Soviet Union to claim the most impressive space-related technological accomplishment. The National Aeronautics and Space Administration (NASA), which was created by President Eisenhower after the launch of *Sputnik,* soon made manned space travel an urgent priority.

The newly accelerated commitment to space travel in the United States commenced with Project Mercury. The Mercury program investigated the escape, orbit, and reentry factors of space flight and achieved six manned flights between 1961 and 1963. Project Gemini followed, and it included twelve flights that were used to study the effects that extended periods of space travel (up to two weeks) had on the astronauts. It also established docking procedures for spacecraft in flight.

It would ultimately be Project Apollo that established the prominence of the U.S. space program by landing on the moon. Four previous manned flights prepared the way for Neil A. Armstrong and Edwin E. “Buzz” Aldrin to touch down on the moon’s Sea of Tranquillity in their Eagle lunar module on July 20, 1969. Four days earlier, 1 million spectators watched from the launch site at Kennedy Space Center as *Apollo 11* lifted off on its journey to the moon. *Columbia,* the mission’s command module, was manned by Michael Collins, who floated in space while Armstrong and Aldrin explored the surface of the moon for two hours and thirty-two minutes.

Advance preparation. The moon landing was an extremely complex endeavor that required the work and dedication of many people. Besides the problem of engineering working vehicles, the landing environment had to be understood and the physiological needs of the astronauts had to be ascertained. The careful design of food, space suits, and a spacecraft living environment for the manned missions was a crucial element of their success.

Prior to the *Apollo 11* landing, seven unmanned *Surveyor* craft traveled to the moon to perfect the landing process and to test whether or not a spacecraft would sink in the lunar soil. Space probes called *Rangers* photographed over 17,000 close-up views of the moon’s mountains and plains in order to select an appropriate landing site.

Devising food for the astronauts was another major project. The food needed to be nutritious, free of the need to prepare it, and easy to ingest in conditions of weightlessness. In order to minimize volume and mass of the food, much of it was dehydrated or freeze-dried. Each astronaut selected his meals from over 100 food items designed specifically for space travel. The meals and drinks were sealed in pouches so that the astronauts could suck the provisions out through a nozzle. The food needed no refrigeration because bacteria could not multiply in the absence of moisture.

Space suits made walking on the moon possible. NASA scientists knew that the moon’s environment does not support human life. The moon is dry, with no atmosphere to allow for human respiration. In order for the astronauts to walk on the moon, a space suit was designed to include an oxygen life-support system contained in a backpack, and a collection system for bodily wastes. The material for the suit was made of strong fibers, metal, and plastic in order to provide maximum mobility, dexterity, and protection from micrometeoroids, tears, or extreme temperature differences (the moon’s temperature can range from −155° to +105° Celsius). The suit was white to reflect the radiant heat of the sun.

The suits weighed approximately 81 kilograms (180 pounds) on Earth and about 14 kilograms (30 pounds) in the reduced gravity of the moon. In all, the space suit consisted of about 25 layers of protective materials that provided a life-sustaining environment for the astronauts. Closest to the skin were a nylon comfort layer, a neoprene-coated nylon pressure bladder, and a nylon restraint layer. The outer layers consisted of a nonflammable material called beta cloth, a Teflon-coated fiberglass.

Figure 7.4.
Alan B. Shepard in a space suit, 1961. Courtesy of Library of Congress.

When astronauts moved outside of the space craft, a liquid-cooling garment was worn closest to the skin in combination with the space suit. It was designed to be worn no more than four to five days but could be worn up to two weeks in a nonpressurized mode.

Physiological concerns. The space suit's pressure bladder was designed to replicate the air pressure on Earth, and protect the blood from boiling. Just as opening a soda bottle creates a pressure drop that allows carbon dioxide gas to bubble out of solution, so scientists expected the dissolved gases in human blood to rush out of solution under the low pressure of the moon's environment. Normally, the earth's air pressure keeps gases such as oxygen, nitrogen, and carbon dioxide dissolved in the blood under high pressure inside the body. Because there is virtually no air pressure in space, the gases should escape from the blood, rapidly expanding the blood vessels until they burst; the lower pressure would cause the blood to "boil." The pressurized space suit was made to prevent this from happening.

Eventually, scientists learned that blood does not boil for at least a minute or so of exposure to near vacuum. It appears that the functions of the skin and circulatory system help regulate blood pressure as a function of the outside pressure on the body. However, saliva on the tongue does boil instantly in a vacuum.

Because the temperature in space is extremely cold, some researchers predicted that a person would quickly freeze to death during a space walk. However, on Earth the human body loses heat through conduction: the transfer of heat from molecule to molecule. Heat is continually transferred from the body to the surrounding air molecules. In space, there are virtually no air molecules, so the rate of heat loss by conduction would be extremely slow.

The most dangerous physiological concerns for astronauts on a space walk include lack of oxygen and sunburn. Both are related to the lack of a life-sustaining atmosphere in space. Without an atmosphere to provide oxygen, humans quickly become unconscious and die. Likewise, without a protective atmospheric layer to absorb it, ultraviolet radiation from the sun would quickly cause severe, life-threatening sunburn to unprotected areas of the skin. A final type of space protection designed for the moon landing was the biological isolation garment (BIG), designed to prevent the spread of any alien organisms picked up in space or on the moon. The astronauts put on the BIGs after splashdown and continued to wear them until they reached the quarantine facility. The astronauts were in isolation for 21 days as a precaution against the possible danger of infectious organisms; however, the procedure was abandoned after the *Apollo 14* mission, when it was established that the moon was desolate.

Space: The final frontier. It took just over a decade from the launch of *Sputnik* to land a human on the moon. The success of *Apollo 11* gave the United States the technological prominence in the space race that it desired. Although the emphasis on the U.S. space program has slowed since the 1960s, research and exploration continue. In contrast to the years of Cold War competition, at the dawn of the twenty-first century many nations have agreed to work together to explore opportunities for human existence in space. The development of a space station and deep-space probes continues to fascinate those who look for life, resources, and new living places beyond the confines of Earth.

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HUMAN KNOWLEDGE

During the 1960s, scientists continued to look both inward and outward for inspiration. Developments in the relatively new science of genetics led to a better understanding of RNA (ribonucleic acid) and its role in protein synthesis in the nuclei of cells. Charles Yanofsky and Sydney Brenner established a critical link between the order of nucleotides in DNA and the order of amino acids in proteins. In 1967, Marshall Nirenberg, Charles Caskey, and Richard Marshall compared RNA from different species of animals and suggested that the chemical basis for life is the same for all beings. On an even smaller scale, Murray Gell-Mann and George Zweig proposed in 1964 that even the smallest known particles—protons, neutrons, and electrons—were comprised of even more fundamental particles known as quarks.

Other significant work that took place in the 1960s addressed phenomena of a much greater magnitude. Working at Bell Labs in the 1960s, Arno Penzias and Robert Wilson were troubled by the consistent static they picked up on a huge antenna they were using as a radio telescope. When they couldn't account for the source of the "noise," they met with theorist Robert Dicke, who had an answer. The "cosmic noise" was the radiation created by a massive explosion that took place at the creation of the universe: Penzias and Wilson had found empirical evidence to support the Big Bang theory of the beginning of the universe. Although the Big Bang theory of a dynamic, expanding universe had developed from arguments made by Georges LeMaître and observations made by Edwin Hubble over three decades earlier, by the 1960s scientists were still split over supporting it or a steady-state model of an unchanging universe. Penzias, Wilson, and Dicke effectively dismissed any remaining controversy.

Many innovations of the 1960s continue to evolve today. In this decade, space travel became a reality, AT&T launched the first worldwide communications satellite (Telstar), and Dr. Denton Cooley implanted the first artificial heart. On the other hand, some worried about the consequences of innovations and lifestyles already established: the surgeon general warned about the lethal hazards of cigarettes, Rachel Carson prompted environmental responsibility in her book *Silent Spring*, and Ralph Nader encouraged consumers to hold manufacturers responsible for harmful products in his book *Unsafe at Any Speed*. The 1968 Treaty on the Non-Proliferation of Nuclear Weapons, a landmark international agreement, aspired to prevent the increase of nuclear weapons, strove toward disarmament, and promoted the peaceful use of nuclear energy.

A Mechanism for Continental Drift

In 1912, Alfred Wegener, a German meteorologist, theorized that millions of years ago there was only one giant land mass he called *Pangaea*. When he proposed it, the idea was ridiculed by scientists who believed that the earth's features had always been stationary. Because he was unable to propose a mechanism for how the continents drifted apart, Wegener was never able to convince the scientific establishment of his theory's worth.

Several decades later, newly collected scientific data seemed to indicate that the earth's surface characteristics may indeed be subject to dynamic change. Most strikingly, Robert Dietz, an American geologist, suggested that the seafloor was spreading. British scientists Drummond Matthews and Frederick Vine proposed a way to test the idea of continental drift, thereby rekindling interest in Wegener's theory. Matthews and Vine saw that a new theory known as plate tectonics could be the missing mechanism for the drifting of the continents. They used plate tectonics to reason that if the seafloor is indeed spreading, then different segments of the earth's crust should have different magnetic polarities which would coincide with the period when they were formed. Empirical research bore this out.

What is plate tectonics? The theory of plate tectonics, or "plate structure," was developed in the 1960s. According to plate tectonics, the earth's outer shell, the crust, is composed of fourteen large, shifting plates. These plates "float" on a layer of molten rock, which enables them to move slowly and results in the dynamic formation of some of the earth's most striking features, such as mountains, volcanoes, faults, and trenches.

Where plate boundaries converge, plates crush together and mountain ranges are born. Where plates separate, ocean trenches are formed. Volcanoes occur when the molten layer of earth under the plates erupts and covers the surface. When two plates try to move past one another and meet resistance, tension builds between them until it is suddenly released in the form of an earthquake.

The seafloor spreads as two oceanic plates move away from one another at the rate of about 1 to 10 centimeters per year. This results in the formation of new areas of crust from the magma that erupts from within the earth's mantle. When seafloor spreading was discovered, the geologist Harry Hess realized the problem it created: if new crust is continually being added to the earth, why isn't its circumference expanding? Hess realized that whenever two plates move apart, on the other side of the earth plates will be coming together. He showed that when two plates converge, some crust is destroyed in the collision and the plates become smaller. Thus, the earth's crust is constantly moving, being created and destroyed.

Studying plate motions. In the latter part of the twentieth century, modern technologies were highly successful in collecting data to support the theory of plate tectonics. Satellite laser ranging systems, synthetic aperture radars, and global positioning systems (GPS) help scientists determine where and how the earth's crust is moving. For example, SLR satellites show that the island of Maui, Hawaii, is moving northwest toward Japan at approximately 3 inches (7 cm) per year, which corresponds to theoretical predictions. The Southern California Integrated GPS Network is a group of connected GPS receivers that are used to monitor the buildup of strain along the two tectonic plates which are touching in southern California. This is done by measuring very small movements at faults that aren't usually noticeable.

Although Wegener's idea of continental drift was originally scoffed at, by mid-century its linking to the theory of plate tectonics revolutionized the field of earth science. Until the advent of plate tectonics, much of geology was a collection of cataloged observations about the features of the earth; afterward, scientists had a powerful new mechanism to explain the origin of the formations they observed.

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Chapter 8

THE SEVENTIES

SOCIETAL CONTEXT: CRISIS MANAGEMENT

Mending the societal rifts that had developed during the previous decade seemed a pressing goal for Americans in the 1970s. However, finding a balance between the conformity that characterized the 1950s and the rebellion of the 1960s would prove to be difficult. Images of violence in Vietnam had left many citizens shocked and relatively humbled about America's place in the world; yet, clashes between war protesters and supporters continued. The disagreement between the two ideologies came to a symbolic and tragic crescendo at the start of the decade: on May 4, 1970, four students at Kent State University were shot and killed by National Guard troops during an antiwar demonstration. For many Americans, the Kent State shootings signaled that it was time to put an end to the bitter divisions which had been caused by the war in Southeast Asia.

At home, the Watergate scandal created a different kind of crisis for Americans. Several members of Richard Nixon's White House staff were caught engaging in illegal activities meant to give the president the upper hand in his reelection campaign of 1972. For the first time in history, a president was forced to resign. Gerald Ford issued a pardon to Nixon upon taking over the presidency, hoping to ease the country into a faster recovery to life as usual. But other crises looming in the distance consumed the nation's attention in the years to follow.

Women continued to push for changes in their societal privileges and status during the 1970s. A few of these changes, whether real or proposed, served to polarize rather than unite the nation. The Equal Rights Amendment (ERA), which guaranteed the same rights to all persons regardless of sex, was passed by Congress in 1972. But the public saw differently; the ERA was never ratified, having failed to get the required number of states to approve it within the ten-year time limit specified by the Constitution. However, the most contested legacy of the women's liberation movement would prove to be the Supreme Court decision (*Roe v. Wade*) that forbade the government from interfering in a woman's legal right to terminate a pregnancy during its first three months. Although many other countries around the world had legalized abortion, in the United States anti-abortion advocates would rally around this issue with great tenacity. During the next two decades, the abortion debate would grow more hotly contested, and ironically, some "right to life" extremists would eventually turn to murder to express their outrage at the *Roe v. Wade* decision.

Emerging from seeds that were sown in the previous decade, the 1970s were a time of newly found environmental awareness for many Americans. Rachel Carson's *Silent Spring* had alerted the public to the interconnectedness of life on the planet, and photos of Earth taken from space by astronauts helped underscore the limited scope of our environment. On April 22, 1970, the country celebrated the first Earth Day, to promote public understanding of many issues surrounding environmental sustainability. The Environmental Protection Agency (EPA) was created to oversee the management of issues affecting the environment. The need for an agency such as the EPA was becoming readily apparent: In 1976, a group of homeowners living in the Love Canal section of Niagara Falls, New York, appealed to government officials for help in assessing the effects of pollution in their neighborhood. Love Canal had been built on top of what had once been an industrial waste site, and by the mid-1970s, residents were suffering from many medical problems, and chemical pools were bubbling up in backyards. President Jimmy Carter declared a federal emergency, residents were relocated, and millions of dollars were spent to clean up the pollution. But pollution wasn't the only environmental concern of the decade: the energy crisis led most Americans to come to terms with the finiteness of Earth's resources in unprecedented ways.

In 1973, the Organization of Petroleum Exporting Countries (OPEC), decided to stop selling oil to countries that supported Israel in the Yom Kippur War (between Israel, and Egypt and Syria). Immediately the oil embargo launched the United States into an energy crisis: gasoline prices skyrocketed, and the situation helped spark long-term economic repercussions such as double-digit inflation and a high rate of unemployment. The attention of U.S. foreign policy during the 1970s shifted in large part from Asia to the Middle East. Despite Washington's having paid much diplomatic attention to the region, however, fifty-two Americans would become victims of militants who took control of the American Embassy in Tehran in late 1979. The hostage situation unfolded over more than a year, and changed the way many Americans would think of Middle Eastern countries for years to come. Tensions between the United States and the countries of the Middle East would continue to erupt in new crises throughout the remainder of the twentieth century.

ARCHITECTURE & ENGINEERING

An Idea for Sustainable Development in California

Americans came face-to-face with their habits and patterns of energy consumption in the 1970s. The OPEC oil embargo of 1973 forced the nation to reflect on its lifestyle, in particular the dependence on oil, which is the foundation for many aspects of our daily routines. In Davis, California, Michael and Judy Corbett infused community design principles with ecological ones to conceive of and build Village Homes, an environmentally friendly neighborhood that still serves as a model of "green" development.

What was the energy crisis of the 1970s? After World War II, the United States rapidly increased its consumption of oil; in fact, between 1950 and 1974, the rate of consumption more than doubled. The easy availability and relative inexpensiveness of this fossil fuel was taken for granted. However, politics and economics converged in 1973, when the Organization of Petroleum Exporting Countries (OPEC) decided to stop selling oil to nations which had supported Israel in the Yom Kippur War earlier that year. The United States felt the blow to its economy as energy prices skyrocketed. Some filling stations ran out of gasoline, and there were long lines of cars as drivers waited to fill their tanks.

During the energy crisis, many Americans were moved to reconsider their dependence on oil and, more broadly, their consumption of energy. In the 1970s, the United States was home to about 6 percent of the world's population, but it accounted for one third of the world's energy consumption. Some Americans were motivated to change by pride or fear, not wanting to be vulnerable to other nations such as the OPEC countries, which had such enormous control over the supply, and thus the price, of oil. Others were concerned by the negative effect our energy consumption was likely to have on the environment, as resources were routinely taken from the earth without being replenished. From either perspective, the time was right for considering alternative energy sources and energy-efficient lifestyles.

Green architecture and community design. During the energy crisis, Michael and Judy Corbett had an idea for dealing with issues raised in a positive and sustained way. They acquired 60 acres of land that was once a tomato farm in Davis, California, and set out to design and construct a community that would incorporate principles of energy efficiency in building and development design. Planning for Village Homes began in 1973, construction was completed in 1981, and the community thrives today. One of the successful innovations of Village Homes was its reliance on solar energy to cut down on energy costs for heating needs.

How can energy from the sun be used in homes? It is relatively simple and quite cost-effective to use energy from sunlight to help heat a home. Passive solar design principles make use of natural processes to warm a building. In this type of design, houses use windows on the south side of the building to collect and trap warmth from sunlight. This works because of the greenhouse effect. Energy from the sun passes through the window and is absorbed by surfaces and objects inside the home (walls, floor, furniture, etc.). These objects radiate the energy they have absorbed, but rather than emitting visible light, they give off energy of shorter wavelengths—electromagnetic waves that can't be seen by humans but can be felt as heat. These waves do not pass back through the window, and instead are absorbed by the surrounding air molecules, which increases the temperature of the indoor environment. The effect is the same in a car left with closed windows for a period of time in bright sunlight; the temperature inside the car can increase dramatically.

Constructed properly, passive solar homes can do much to reduce the need for gas- or electric-powered fans and furnaces to heat a home. In the northern hemisphere, south-facing windows are used to maximize the time during which the surface will be exposed to the sun. When covered by a roof with a low overhang, the window will also help keep the home cool in the summer, since the roof will shade the window from the summer sun when it is high in the sky. Proper materials are also important in passive solar construction; if the building or furniture is unlikely to radiate the energy absorbed from the sun, it will not be useful. In addition, the home should be designed to allow for convection currents to transfer heat from the rooms directly receiving the sunlight to the rest of the building. Convection is the natural transfer of heat from warmer to colder spaces; it occurs when warm air rises and is replaced by cool air sinking underneath. The cool air is subsequently warmed, and rises; the warm air transfers its energy, cools, and sinks; and a continual cyclical pattern is established. Landscaping can also help play a role in passive solar design.

There are other, active ways to use energy from the sun to help limit a dependence on fossil fuels. Energy from the sun is still used for heat, but in this case the sun's rays are actively collected and concentrated to heat air or water, which is then transferred through the home by pumps or fans. One common active solar application is the incorporation of a solar water heater in the home. Another possibility for harnessing solar energy is to use photovoltaic cells to change light from the sun directly into electricity. In scientific terms, this process is quite efficient, since light energy is converted directly into electrical energy. In more familiar electricity-generating procedures, several extra steps are required; coal may be burned to heat water, which is converted to steam and used to move turbines that spin generators to produce electricity. Although photovoltaic cells are a desirable means of producing electricity, they are not yet cost-efficient. Thus, homes that are powered exclusively by photovoltaic cells are rare.

Success story. Even in the midst of the energy crisis of the 1970s, it was not easy to convince financial backers or inspectors that some of the design elements of Vil-

Figure 8.1.
Solar electric panels. Courtesy of Painet.

lage Homes would be acceptable to homeowners. Several decades after its inception, however, the neighborhood has proven its worth. It is estimated that the residents of Village Homes, whose dwellings incorporate at least passive solar design and rooftop solar water heaters, use an average of 40–60 percent less electricity and gas than do other homes in the area. In summer, the neighborhood of Village Homes is actually significantly cooler than surrounding ones, due to narrower, tree-lined streets that don't absorb the sun's heat as readily as traditionally constructed roadways. Most of the residents of Village Homes have chosen to remain in their community throughout the years, but homes that do go on sale in the neighborhood sell for an average of $11 per square foot more than comparable homes in Davis.

While the energy crisis of the 1970s did prompt some self-reflection by Americans, change is often easier thought of than enacted. For example, an initial push for fuel-efficient cars eventually gave way to a proliferation of inefficient transportation such as sport utility vehicles. In the United States, habits of energy consumption are still largely wasteful. At the beginning of the twenty-first century, America's dependence on oil seemed as real as ever. However, some of the projects of the 1970s have proven that alternatives are available, and even desirable. The Village Homes experiment is an example of one way in which architects and community designers have the potential to change the way we live.

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ARTS & ENTERTAINMENT

Star Wars and Cinematic Special Effects

Throughout the twentieth century, the cinema was always ready and willing to serve as an escape from reality for the moviegoing public. Over the years, Hollywood became known for its ability to whisk viewers into other times and places. In 1977, writer and director George Lucas unveiled his story from "a long time ago in a galaxy far, far away"—and Americans were instantly drawn into it. The original *Star Wars* (also titled *A New Hope*) remains one of the highest-grossing films of all time. One of the reasons for its phenomenal popularity was the film's innovative use of special effects.

Camera tricks. In 1975, Lucas created a special effects company, Industrial Light and Magic, to help him accomplish the visuals he wanted to bring to life in *Star Wars*. By changing the way that scenes were photographed, Lucas and his production team merged modern technology with moviemaking in new ways. Some camera and production techniques were commonplace, or resuscitated from previous generations, but incorporated new twists. Using methods such as the "blue screen" and motion-control camera, Lucas and Industrial Light and Magic made audiences believe they were witnessing strange ways of life on distant planets and epic battles set in deep space.

The matte, or blue screen, technique is often used in movies to make it appear that an actor or prop is somewhere he or it isn't—for example, in outer space. It is a way of filming different parts of a complicated scene separately, and then putting them together to make it appear that everyone is in the same place and everything happens at the same time. In the early days of motion pictures, this effect could be created by filming part of a scene while blocking out unwanted elements by covering the camera lens with a mask, or matte. Then the film could be rewound, a different part of the lens could be blocked, and another separate element of the scene could be filmed. When the film was developed, it would seem that the two elements had been filmed together. After the invention of the optical printer in the 1920s, masking was not needed, and composite scenes of many elements were easier to create. The optical printer is a camera and projector working together; multiple images are placed in the projector and photographed together by the camera. In this way, numerous elements can be composited into a single image.

In *Star Wars*, many of the complex and imaginative scenes were created using dozens of elements that were merged into one setting. These scenes were often created using scale models of spaceships or buildings, rather than their full-sized counterparts. Filming scale models is tricky, particularly when motion is involved. If it is not done properly, the models will seem unbelievable to audiences. When compositing moving models as elements of a particular scene, it is important that they all be filmed using exactly the same camera motion. To create the effects used in *Star Wars*, Industrial Light and Magic modernized the technique of motion-control photography. Whenever camera action had to be repeated exactly for filming various layers of a scene, the special effects crew used computers to program coordinates for the camera's location, making the repeated motion extremely precise. Combining computers and cameras in this way led to special effects much more sophisticated than anything that had been done previously, and set a new standard for visual effects in cinematography.

Lasting impressions. While *Star Wars* was acknowledged for its groundbreaking technological advances and achieved enormous commercial success, critical acclaim for its artistic content has not always been forthcoming. Some critics have held the film responsible for contributing to a desire for cinematic adventure and explicit action that sacrifices an attraction to subtle story lines and plot development. However, the cultural impact of *Star Wars* and its successor films remains. Sayings such as "May the force be with you" are still used and understood a quarter-century after the film's release, and the movie's characters have become icons of twentieth-century popular culture.

Without doubt, *Star Wars* changed the nature of the movie industry. The artistic merits of special effects may be debated, but their widespread presence in current movies is a fact of modern cinema. The advent of digital technologies for filmmaking and the ever-increasing power of computer technology have led to the continual innovation of visual effects over the last several decades.

Advances in technology have made the tedious work undertaken by Industrial Light and Magic in the 1970s virtually obsolete. Yet, Lucas's attention to detail and the central role he gave to computers in movie production remain a much-imitated model. One result of this change in moviemaking is that employees of today's special effects companies are as likely to have backgrounds in science and engineering as in art or design. In the same way that laboratory scientists and industrial engineers work to understand and modify the natural world to suit human interests, it can be said that movie special effects technicians modify the on-screen world to suit the needs of cinematic artists. In this way, the method of filmmaking introduced by *Star Wars* provides an interesting parallel between art and life.

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COMMUNICATION

Microprocessors Invented

In the 1960s, the integrated circuit changed electronics. Electrical components could now be etched onto tiny, semiconducting chips of silicon or a similar substance. In this way, circuits that would otherwise take huge amounts of materials and space to construct were literally miniaturized. By the dawn of the 1970s, the potential applications of integrated circuits seemed many, and entrepreneurial-minded engineers were poised to make history.

Two engineers who had been on the front lines of integrated circuit development, Robert Noyce and Gordon Moore, started their own company in 1968. Dubbed Intel, for Integrated Electronics, the company was quickly hired to develop some integrated circuits for Busicom, a Japanese calculator company. The request was to develop twelve separate chips that would perform separate tasks needed for an electronic calculator: memory storage, addition programs, subtraction programs, and keyboard recognition, among others. Instead, Intel engineers Ted Hoff, Stan Mazor, and Federico Faggin put all of the electronics for all of the functions on a single chip, and the world's first microprocessor, the Intel 4004, was created.

Microprocessors are also known as CPUs, or central processing units. They are basically minute versions of the large, mainframe computers that were their predecessors. In fact, the Intel 4004 measured only one eighth of an inch by one sixth of an inch, but its computing power was comparable to that of the ENIAC computer built twenty-five years earlier, which had filled an entire room. In its circuitry, the Intel 4004 included 2,300 transistors to help manage electronic information. It was able to communicate fast enough to perform 60,000 calculations each second. But how do computers understand the tasks given to them?

The language of computers. Humans communicate through the use of language systems, in which elemental components are combined into larger components to make recognizable patterns. For example, our alphabet consists of twenty-six characters, or letters, that are combined to form the words of our language; words are combined to make sentences. Our numeric system uses combinations of ten digits, 0–9, to make other numbers. Computers, on the other hand, interpret and execute instructions that are spelled out in a binary coded decimal system. In this language, all expressions are combinations of only two different pieces, which correspond to 0 and 1.

The binary system is a base-2 system of numbers. It is used in a way that is analogous to our base-10 number system; we coordinate an understanding of different digits and place values to recognize the numbers that we know. To create a sequence of numbers in our base-10 system, we allow the smallest place value (the "ones" column) to "hold" a series of ten digits before a new place value (the "tens" column) has to be added to create a higher number (i.e., we count from 0 to 9 before we make 10). Then, the tens column can be held constant while the ones column varies, again through ten different digits (10 through 19); after this the tens column can be increased by one and held constant again while the ones column moves through another iteration of ten digits (20 through 29). This process is repeated until all of the combinations of digits 0–9 in the tens and ones columns are exhausted, and then a new place value—the 100s column—must be added in order to create new numbers.

In a base-2 number system, each place value can hold only two different digits, 0 or 1. Once the combination of two digits is exhausted, a new place value must be added to create a new number. When the combination of digits in the two place values runs out, another new place value is added. We are familiar with the columns of place value in the base-10 system: ones, tens, hundreds, thousands, and so on. These place values also correspond to powers of ten: 10^0 is the ones place; 10^1 is the tens place; 10^2 is the hundreds place; 10^3 is the thousands place; and so on. Similarly, in the base-2 system, the place values are powers of 2: 2^0 is the ones place; 2^1 is the twos place; 2^2 is the fours place; 2^3 is the eights place; 2^4 is the sixteens place; and so on. In the base-2 system, all numbers are combinations of the digit values of 0 and 1 and the various place values. Figures 8.2 and 8.3 compare the patterns that emerge in each of these number systems.

Why does the computer use a base-2 system? Computers employ a base-2 number system for the sake of convenience. The 0 and 1 values correspond to states of current flow in the computer's electronic system; 1 means current is flowing, and 0 means it is not. The computer uses transistors as electronic switches; when they allow current to flow through them, the computer interprets it as a 1, and when no current is flowing, a 0 is read. In the computer's binary language, each switch point is known as a "bit" (for *bi*nary digi*t*) of information.

Figure 8.2.
The creation of numbers in base-10 and base-2 systems.

	Base-10				Base-2					
	1000s	100s	10s	1s	16s	8s	4s	2s	1s	
0=				0					0	(0)
1=				1					1	(1)
2=				2				1	0	(10)
3=				3				1	1	(11)
4=				4			1	0	0	(100)
5=				5			1	0	1	(101)
6=				6			1	1	0	(110)
7=				7			1	1	1	(111)
8=				8		1	0	0	0	(1000)
9=				9		1	0	0	1	(1001)
10=			1	0		1	0	1	0	(1010)
11=			1	1		1	0	1	1	(1011)
12=			1	2		1	1	0	0	(1100)
13=			1	3		1	1	0	1	(1101)
14=			1	4		1	1	1	0	(1110)
15=			1	5		1	1	1	1	(1111)
16=			1	6	1	0	0	0	0	(10000)
17=			1	7	1	0	0	0	1	(10001)
18=			1	8	1	0	0	1	0	(10010)
19=			1	9	1	0	0	1	1	(10011)
20=			2	0	1	0	1	0	0	(10100)
⋮			⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Figure 8.3.
Numbers represented as combinations of available digits and place values in the base-10 and base-2 systems.

Base-10 System

$125 = 100 + 20 + 5 = (1 * 10^2) + (2 * 10^1) + (5 * 10^0)$

[digit]*[place value] [digit]*[place value] [digit]*[place value]

$73 = 70 + 3 = (7 * 10^1) + (3 * 10^0)$

[digit]*[place value] [digit]*[place value]

possible digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 *possible place values:* 1 (10^0), 10 (10^1), 100 (10^2), 1000 (10^3), ...

Base-2 System

$13 = 8 + 4 + 0 + 1 = (1 * 2^3) + (1 * 2^2) + (0 * 2^1) + (1 * 2^0)$

[digit]*[place value] [digit]*[place value] [digit]*[place value] [digit]*[place value]

$6 = 4 + 2 + 0 = (1 * 2^2) + (1 * 2^1) + (0 * 2^0)$

[digit]*[place value] [digit]*[place value] [digit]*[place value]

possible digits: 0, 1 *possible place values:* 1 (2^0), 2 (2^1), 4 (2^2), 8 (2^3), 16 (2^4), 32 (2^5), ...

When many bits are joined together, the computer can read the patterns they produce and interpret them as the numeric values we recognize. Bits are most often arranged in groups of eight, corresponding to a system that is known as a byte. The on/off signals that make up a byte can occur in 256 different combinations, using the base-2 patterned numbering system described above (e.g., 0=00000000; 1=00000001; 6=00000110; 254=11111110; 255=11111111; see figure 8.2). In a computer, these 256 different signals are programmed to stand for something that is useful to humans. For example, computers can use the ASCII code to store text information by assigning 127 of the 256 values in a byte to represent punctuation marks; numerals 0–9; capital letters; lowercase letters; and basic typewriter commands ("return," "space," etc.).

Logic commands tie it together. In order to have electronic patterns correspond to human symbols, a connection must be made. In other words, the computer has to be able to follow instructions that say, for example: "when a byte reads '00100000,' that corresponds to '32,' which corresponds to a 'space' in a text document." These connections between symbols and signals are made electronically, using circuits that operate according to the principles of Boolean logic. Transistors act as gates that control the current flow according to a logical command. For example, a NOT gate accepts either a 0 or a 1 signal as input, and sends the opposite signal—a 1 or a 0, respectively—out from the gate. Gates can operate according to other logical commands, such as AND and OR. The logic of each gate determines how the electrical signals flowing into the gate are transformed and sent out of the gate. All of the complex functions of a computer are carried out through programs that use logic commands to specify how the computer should handle combinations of binary coded information.

Microprocessors are all around us. After it announced the invention of the 4004 in November 1971, Intel bought back the rights to the technology from Busicom for $60,000. Intel offered its microprocessor technology to many markets, and changed many modern inventions, from everyday appliances to specialized military equipment. Microprocessors control the operation of microwave ovens and videocassette recorders, digital watches and video games, antilock brakes and "smart" weapons.

Intel continued to develop the microprocessor technology it had created. In 1974, Intel introduced the 8080, which was useful enough to be incorporated into a design for a home computer. Today's microprocessors are many times more powerful than their earlier ancestors, incorporating tens of millions of transistors and carrying out billions of instructions per second. Still, the basic idea crafted in 1971—to put many functions together on one chip—remains the innovation behind it all.

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DEFENSE & DIPLOMACY

Agent Orange Banned in Vietnam

The Vietnam conflict was drawing to a close when the 1970s began. The fear and suspicion of communism that had characterized the 1950s and early 1960s largely had given way to a more vocal concern for human rights and a condemnation of the immorality of war. Across the nation, increasing numbers of people protested the American presence in Vietnam. In particular, the press and the public decried news of innocent villagers half a world away, caught in the violent crossfire of a war fought in unconventional ways in an unfamiliar land. One example of such a dilemma was the story of the role of Agent Orange in this devastating conflict.

Operation Ranch Hand. In the early 1960s, President Kennedy concerned himself with the tense political situation in Vietnam, and pledged his support to South Vietnam in its fight against northern Communists and rebel insurgents. One difficulty facing the South Vietnamese was the thick jungle that covered the country's landscape. It was easy for opposition forces to hide under the dense vegetation and mount frequent surprise attacks. In addition, fires set in the thick bush would spread rapidly and could cause far-reaching damage. Kennedy agreed to allow the U.S. military to support the South Vietnamese government by supplying it with powerful herbicides, chemicals that destroy vegetation or selected parts of vegetation. American advisers helped oversee defoliation missions in which large areas of jungle were sprayed with chemicals to remove leaves and expose any rebel groups who might be hiding. In addition, the chemicals were used to create fire breaks—gaps in the vegetation that would help contain fires to a localized area.

The herbicide missions in Vietnam were known as Operation Ranch Hand. The operation was kept low-key because the use of defoliants for military purposes could be construed as engaging in chemical or biological warfare. The original approval from the U.S. government to commence the mission recognized that British troops had established a precedent by using a herbicide in a conflict in Malaysia, but it also was important that the operation was more of a defensive move than an offensive one. This changed when South Vietnamese leaders began asking for help in using herbicides against North Vietnamese crops, thus removing a food source and literally starving the enemy. The United States initially resisted this application, but the tenor of the conflict in Vietnam changed dramatically after U.S. vessels were reportedly attacked by North Vietnamese in the Gulf of Tonkin. Congress moved quickly to expand U.S. military efforts in Vietnam, and Operation Ranch Hand began in earnest. From 1962 to 1971, tens of millions of gallons of herbicide were sprayed in Vietnam, to destroy ground cover as well as food crops.

Although several kinds of chemicals were sprayed during Operation Ranch Hand, the most familiar was Agent Orange, which was the major herbicide used in the conflict. The chemical was named for the orange color of the barrels in which it was shipped. Agent Orange is an equal mixture of two chemicals: 2,4-dichlorophenoxy acetic acid (2,4-D) and 2,4,5- trichlorophenoxy acetic acid (2,4,5-T). These two compounds were combined with gasoline or kerosene and sprayed from aircraft or trucks, or by hand. This herbicide was also used in the United States for farming and other commercial applications. However, in 1969, 2,4,5-T was shown to cause stillbirths and birth defects in mice, and in 1970 its use was banned in the United States. Although leaders had mixed feelings, the military decided to temporarily suspend the use of Agent Orange a few weeks later, and eventually stopped using all herbicides in Vietnam in 1971.

What makes 2,4,5-T so dangerous? When 2,4,5-T is created, a by-product of the chemical reaction is a dangerous chemical known as 2, 3, 7, 8-tetrachlorodibenzo-para-dioxin, or TCDD. After manufacture, the TCDD dioxin contaminates the sample of 2,4,5-T and, consequently, Agent Orange. In 1997, TCDD was recognized as a human carcinogen (class I) by the World Health Organization. It has been linked to several kinds of cancers, immune system disorders, and endocrine disruption in living things.

The TCDD molecule consists of two benzene rings linked by two oxygen atoms. Two chlorine atoms are linked to each benzene ring. Dioxins can form when organic matter burns in the presence of chlorine. When 2,4,5-T was produced for use as half of Agent Orange, it created conditions favorable to the production of TCDD. Because of the constant, huge U.S. military demand for Agent Orange, the samples of 2,4,5-T were left largely contaminated with the dioxin.

The hazards associated with TCDD result from its chemical properties: one major problem is that it acts as an endocrine disrupter in humans. The endocrine system is responsible for secreting, transporting, receiving, and acting on messages that direct various bodily processes. The brain sends a signal to a particular gland in the endocrine system, which then releases chemical messengers known as hormones. Glands in the human endocrine system include the pancreas, adrenal glands, thymus, thyroid, pituitary gland, hypothalamus, ovaries (in females), and testes (in males). For example, the adrenal glands secrete epinephrine (or adrenaline), a hormone that increases heart rate and blood pressure. In order for a hormone to work, it must bind to a specific kind of cell called a receptor; the two substances fit together in a specific way, like a lock and key. Once the hormone binds to a cell, it gives chemical instructions for how the cell is to respond. These chemical messages help the body to grow and develop, respond to danger, and reproduce, among other functions.

Endocrine-disrupting chemicals interfere with normal endocrine system functioning. They may block a gland from secreting a needed hormone, or they may block a hormone from binding to its target receptor cell. Or an endocrine disrupter may mimic a particular hormone, bind with a receptor cell, and prevent the actual hormone from performing a required function. In this way, chemicals such as dioxins cause damage to adults by interfering with needed biological processes; they can also cause problems with the development of fetuses, thus continuing the danger for generations.

Environmental monitoring research has found large concentrations of dioxins in our modern environment. The source of these chemicals is often debated. Because dioxins can be produced when organic compounds burn in the presence of chlorine, many human activities lead to its formation, including the incineration of wastes; burning wood; motor vehicle use; and chemical manufacturing. Research sponsored by the chemical industry has claimed that natural processes such as volcanic eruptions and forest fires contribute more dioxins than these human activities, but environmental groups disagree. Regardless of their source, endocrine-disrupting dioxins abound in today's environment and threaten the health of those who are exposed to them on a regular basis.

The story continues. Decades after the last Operation Ranch Hand missions sprayed herbicides in Vietnam, their long-term effects are still being determined. In the late 1970s, a group of Vietnam veterans who were suffering from various medical difficulties filed a class action lawsuit, claiming that exposure to Agent Orange was to blame for their illnesses. Although at first the U.S. government downplayed the possibility of this link, it eventually commissioned research to determine the credibility of the veterans' claims. Since 1991, the National Academy of Sciences has undertaken several studies of the effects of Agent Orange's use in Vietnam on people and the environment. The research has shown that exposure to the herbicide is associated with a greater rate of medical conditions including soft-tissue sarcoma, non-Hodgkin's lymphoma, Hodgkin's disease, and chloracne (a skin rash). In Vietnam, high rates of birth defects, stillbirths, and medical problems among the adult population have been blamed on exposure to Agent Orange.

Despite these studies, official sources have been unwilling to concede a direct link between Agent Orange exposure and the medical problems of U.S. veterans and Vietnamese citizens. In part, the reservation has been due to the fact that it is difficult to determine whether elevated TCDD levels in the bodies of some affected individuals are a result of exposure to Agent Orange or to some other source of dioxin. In 2003, Jeanne Stellman of Columbia University published a study of historical records from the Operation Ranch Hand missions that gives an unprecedented (because of its thoroughness) picture of the amount of herbicide use and the areas of Vietnam affected during the war. It is expected that the results of this study will allow much more definitive research on the effects of Agent Orange to be conducted, and many unresolved questions to be answered.

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ENVIRONMENT

Recycling Movement Gains Momentum

In the post–World War II years, industry grew and the nation's economy prospered. But consumer culture in the United States had created a problem: trash. During the 1950s and 1960s, the amount of solid waste being dumped in America's landfills was rising dramatically. In 1965, Congress passed the Solid Waste Disposal Act to address the problem of America's rapidly expanding garbage dumps, but this measure wasn't enough to tackle the problem.

By the late 1960s, protecting the environment was on the minds of mainstream Americans. Rachel Carson's book, *Silent Spring*, had prompted many people to think about the negative ways that human actions could be impacting other life-forms. Many people were moved by pictures of the earth taken by NASA astronauts during manned space flights: the image of "Spaceship Earth," as Buckminster Fuller called it, reminded society of the planet's fragility and finiteness. In 1970, the first Earth Day and the creation of the Environmental Protection Agency were tangible evidence of the concern. It was in this spirit that the recycling movement gained momentum in the United States during the 1970s.

Figure 8.4.
Recycling centers opened across the United States in the 1970s. © Getty Images/PhotoDisc.

What is recycling? The principles of solid-waste reduction are often summed up by a three-word phrase: *reduce, reuse, recycle.* Citizens are reminded to reduce the amount of waste produced in the first place, by placing limits on consumption, buying only what is needed in the proper amounts. In addition, waste generation can be slowed when people reuse materials and products rather than discard them. Buying items that can be used many times, rather than disposable versions (e.g., batteries, or razors) and reusing containers helps eliminate potential trash.

Recycling is the process of making new products out of waste. In 1971, Oregon passed the country's first bottle bill, which encouraged consumers to recycle glass bottles by providing refunds for returned bottles. "Buy-back" recycling centers opened a year later in the state of Washington, allowing consumers to turn in newspapers, cans, and bottles for cash. By the end of the decade, recycling centers had sprouted up across the nation, although it took until the 1990s for recycling to become a mainstream practice. It is relatively common today for several types of materials to be recycled, including paper, glass, steel, and many kinds of plastic. The most commonly recycled material today is aluminum; roughly two-thirds of the aluminum cans purchased in the United States are recycled.

Aluminum recycling. After aluminum cans are collected, they are taken to a recycling center and checked for quality. The cans are shredded, and placed in an oven where excess moisture burns off and paint is removed. The material is then filtered through a screen that removes more contaminants before the aluminum is sent to a high-temperature furnace for melting. Liquid aluminum is poured into molds and cast into ingots. The cooled, hardened ingots are flattened and rolled into thin sheets that are used to make new cans.

In contrast, aluminum that is mined from the ground must go through a much more energy-intensive process to be turned into beverage cans. First, bauxite ore must be extracted from the earth. The ore is crushed, combined with lime and caustic soda, and heated under high pressure. The aluminum oxide is dissolved, then precipitated, washed, and dried. The resulting white powder, aluminum oxide, is smelted to become molten, cast into ingots, and manufactured into sheets. This process requires a tremendous amount of energy, and only 500 pounds of aluminum metal can be recovered from every ton of bauxite that is mined. Besides lessening the stress on the earth, recycling can help conserve precious energy. Recycling aluminum to make beverage cans requires only 5 percent of the energy that it takes to create cans from bauxite. According to the Aluminum Association, Inc., recycling one aluminum can saves enough energy to run a 100-watt lightbulb for nearly 4 hours, or to run a television set for 3 hours.

The movement progresses. The Resource Conservation and Recovery Act passed by Congress in 1976 expanded the authority of the Environmental Protection Agency to deal with hazardous and nonhazardous solid waste. As a result, the federal government could play a significant role in coordinating waste management, a domain that had once been under the exclusive control of local communities. In 1989, the EPA set a goal for the country to recycle one-fourth of the solid waste produced, which was met in 1996.

Recycling was not an invention of the 1970s, or even of the modern era. The Japanese are thought to have recycled paper, as did some of the early American colonists. During both world wars, Americans were urged to support the war effort by turning in metal, rubber, and other products for military purposes. However, by the 1970s, the new awareness of solid waste as a serious pollution problem, combined with an emerging environmental sensibility, helped change attitudes about the practice of recycling. What was once an unusual task undertaken for special purposes had become, by the end of the century, a generally accepted and occasionally mandated practice.

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FOOD & AGRICULTURE

The Controversy over Saccharin

On March 9, 1977, the Food and Drug Administration announced that it no longer considered the popular artificial sweetener saccharin safe for human consumption. The results of laboratory tests conducted in Canada had determined that saccharin caused bladder cancer in rats. The public reacted with outrage. Saccharin had been used as an artificial sweetener since the turn of the century, and was the only such sweetener available since the ban of cyclamates in 1969. In the face of public pressure, Congress intervened, placing a moratorium on the saccharin ban. Still, products that incorporated saccharin were required to carry an ominous label which warned: "Use of this product may be hazardous to your health. This product contains saccharin, which has been determined to cause cancer in laboratory animals."

History of saccharin. Saccharin was accidentally discovered in 1879 at Johns Hopkins University by Ira Remsen and Constantine Fahlberg. The white, crystalline compound was several hundred times sweeter than sugar. It was initially controversial for a different reason: several years after the two researchers jointly published news of the scientific discovery, Fahlberg went on to patent and market the compound by himself, which left Remsen angry. Although saccharin was initially not well known, it became very popular during World War I and World War II, because it provided a means for coping with the sugar rationing that was part of the war effort. By the 1970s, when the FDA announced its ban, saccharin was used extensively by diabetics, who could consume the sweetener because it was not digested and therefore did not require insulin in order to be metabolized. In addition, the sweetener was popular with Americans who had grown accustomed to its taste in the many "diet" foods that had emerged since the mid-1960s.

Studies undertaken in the 1960s indicated the possibility that saccharin was linked to cancer in laboratory animals. The Canadian study which prompted the proposed ban in 1977 was more specific, confirming that male rats on a saccharin diet had developed bladder cancer. Since 1958, the Food and Drug Administration had been required to ascertain the safety of a food additive before approving it for use. In fact, the FDA was specifically forbidden to approve any substance that was a known carcinogen. However, the public reaction to the proposed ban was so strongly negative that Congress quickly passed a special act—the Saccharin Study and Labeling Act (1977)—to prohibit the ban until further study could be completed. As a compromise, products containing saccharin were required to carry a warning label noting the compound's potentially carcinogenic properties.

The "lab rat" model of research. The controversy over a ban on saccharin raised questions about the nature of scientific research and, in particular, medical research. To what degree do the results of studies performed on laboratory animals transfer to humans? Is it ever appropriate to use animals such as rats, mice, and rabbits as research subjects when the goal of research is to learn about human physiology or behavior?

Since the beginnings of formal scientific study, researchers have used rodents, rabbits, dogs, cats, and primates in experiments for learning about humans. Because mammals have similar body systems, it was reasoned that their physiological responses to experimental conditions would approximate those of humans. Today, around 90 percent of nonhuman animal studies done to learn about humans are conducted on mice and rats. In fact, strains of rodents have been genetically engineered to be susceptible to human disease or to produce chemicals, tissues, or organs that are found in humans.

Some groups today argue that using nonhuman animals for studying humans has outlived its usefulness. The National Anti-Vivisection Society gives several logical reasons for supporting this claim, including (1) the physiological (and psychological/behavioral) differences between human and nonhuman animals are extensive; (2) it is impossible to know in advance of a study which nonhuman animals will react in a way similar to humans, and which will not; (3) animal tests cannot predict the variety of side effects that new medicines or treatments will have on a diverse human population, so they must eventually be tested on humans anyway; (4) animal studies give "false negatives"—in other words, a treatment that may work on humans could be abandoned because it didn't work on a particular nonhuman animal; and (5) other methods of study that are readily available to modern researchers (such as analysis of epidemiological data, computer modeling of cellular processes, autopsies, and in vitro research) give more reliable results. Another type of argument that is made against the use of nonhuman animals for human medical research is not a scientific but an ethical one which questions whether animals such as rats and mice should be valued for their ability to serve as resources for study, or whether they should be valued intrinsically as living creatures.

Those who promote animal research contend that it is critical to scientific and medical progress. One of the main advantages, according to supporters, is time. Because rodents have a relatively short life span, the effects of disease progression that could take decades to study in humans can be studied much more quickly in rats or mice. Animal researchers often assert that studying medical-related phenomena holistically in a living organism is scientifically preferable to studying cellular-level processes. Finally, advocates of animal research argue that new strains of genetically engineered laboratory animals have decreased the physiological gap between humans and the animals that represent them in laboratory studies.

Saccharin revisited. The 1977 study linking saccharin to bladder cancer was swiftly criticized on the grounds that laboratory rats were fed enormous amounts of saccharin, equivalent in a human diet to hundreds of cans of soda a day for a lifetime. Although additional studies over the past several decades seem to confirm that saccharin is indeed a carcinogen in rats, many scientists believe that the mechanism by which this occurs has limited applicability to humans. In 1991, the FDA withdrew its request for a ban on saccharin, and by the end of the twentieth century, the warning labels had been removed from saccharin-containing products.

While some groups welcomed news of the apparent safety of saccharin, others cautioned that many more studies of human saccharin consumption should be undertaken before its carcinogenic potential in humans was dismissed. Though the accepted scientific conclusions about saccharin have changed over the last several decades, the effectiveness of nonhuman animal research remains the key issue in the debate over the artificial sweetener. For now, some questions specific to the properties of saccharin may have been put to rest; however, the general controversy over the feasibility of nonhuman animal-based research is likely to continue well into the future.

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MEDICINE & HEALTH

"Test Tube Baby" Is Born

On Monday, July 25, 1978, the world's first baby to be conceived outside of the womb was born in England. Louise Brown was dubbed the "Test Tube Baby," and her birth caused a popular sensation. Overseen by Dr. Patrick Steptoe (a gynecologist) and Dr. Robert Edwards (a university researcher), the birth marked the first successful use of a technique known as *in vitro fertilization*. For couples who wanted children but had been diagnosed as infertile, the news of Louise's birth offered hope that they, like the Browns, could someday become parents. However, others saw cause for concern, arguing that humankind's interference in the natural world had reached ethically dangerous new ground.

What is infertility? In simplest terms, infertility refers to the inability to reproduce. It may result from an inability to conceive or an inability to carry a fetus to term. Infertility is caused by a biological dysfunction of the reproductive system. In men, infertility can be caused by low sperm production or a lack of sperm production. In women, infertility can be caused by problems with the functioning of the ovaries, fallopian tubes, or uterus. Sometimes the problem is with the egg or sperm cells themselves, or with the hormones that would normally serve as the chemical regulators of reproductive functioning.

What is in vitro fertilization? In vitro fertilization (IVF) is a medical technique used to artificially induce conception outside of the womb. The words "in vitro" mean "in glass," and refer to the fact that in IVF, the sperm and egg are joined together in the laboratory. Since its introduction in the late 1970s, IVF has become a relatively commonplace medical procedure; hundreds of infertility clinics that offer IVF exist in North America alone. The success rate of IVF is variable, and the technique results in a healthy live birth approximately 15 to 30 percent of the time it is attempted. Doctors have determined that the age and health of the mother and father who contribute the egg and sperm are crucial factors which help determine the success of a particular IVF attempt.

The process of IVF begins when a man's sperm are collected and tested for their general health and ability to penetrate an egg cell. Next, a woman receives hormone injections in order to keep her body prepared for ovulation, fertilization, and implantation of an embryo, even though ovulation will be prevented and fertilization will take place outside the womb. Next, a woman's egg cells, or oocytes, must be collected. Egg cells once were recovered only by surgery; now, a needle can be inserted through the vaginal wall to remove them while progress is monitored by ultrasound. The harvesting of oocytes must be performed before ovulation occurs (before the eggs pass from the ovary into the fallopian tube).

During the next phase of IVF, eggs are placed with sperm in a laboratory dish (*not* a test tube), in a temperature-controlled and chemically regulated environment that simulates the conditions in a woman's body. Under these conditions, sperm cells try to penetrate the egg just as they would in a woman's body. If the sperm are unable to do this, a technique known as intracytoplasmic sperm injection can be used: sperm are injected into an egg to induce fertilization. After an oocyte is fertilized, the egg begins to divide, just as it would inside a woman's body. The pre-embryo, as it is called, is then inserted into the woman's body so that it can attach to the uterus and continue developing, just as a fetus would in a natural pregnancy.

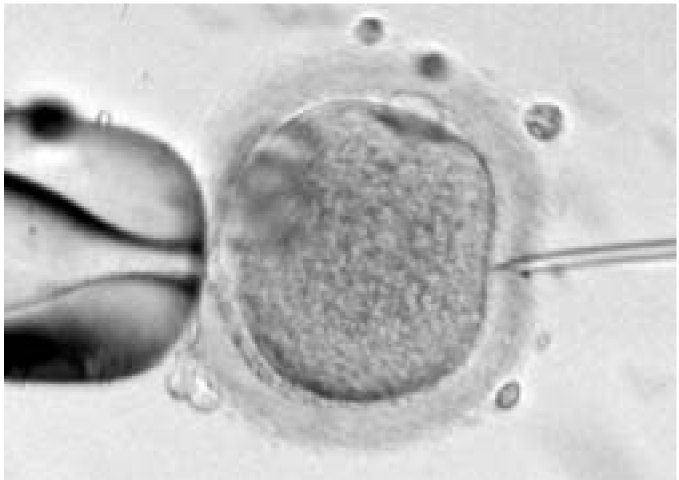

Figure 8.5.
Intracytoplasmic sperm injection can be used to fertilize an egg during IVF. R. Rawlins/Custom Medical Stock.

It is likely that during IVF, more than one egg is fertilized and develops into a pre-embryo. Sometimes multiple pre-embryos are implanted into a woman's uterus, because this increases the chances for successful implantation and pregnancy. Occasionally this procedure results in the birth of twins or triplets, and as a result, some countries have placed legal restrictions on the number of pre-embryos that can be transferred.

More often than not, IVF does not result in success. If the procedure does not work, patients must generally wait several months to try again. In vitro fertilization is a costly procedure that is usually not covered by insurance policies. Despite the potential drawbacks, IVF was used extensively throughout the last quarter of the twentieth century, and several hundred thousand babies were born through its use in the United States alone.

Changing conception, changing society. The development of IVF techniques led to definitive and potential changes in society. For instance, because it has created new options for same-sex couples or single women who want to have a child, IVF has indirectly led to a reexamination of traditional familial roles and responsibilities. Ethicists who initially questioned whether IVF was akin to "playing God" when Louise Brown was born, now address an ever-growing list of questions that have arisen because of the technique. For instance, what should be done with frozen pre-embryos when a couple dies or no longer wants them? Can they ethically be donated, used for research, or discarded? Is it justifiable that the high cost of the procedure virtually ensures that only couples who are relatively well off can afford the procedure? It is possible, but is it ethical to determine the genetic makeup of a pre-embryo and then use the information to decide whether to implant it? Science cannot establish the answers to ethical or moral questions; these must be decided on the basis of other criteria, such as cultural or religious beliefs. As the use of IVF in society continues, so will the questions surrounding it.

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TRANSPORTATION

Lessening the Environmental Impact of Automobiles

In the 1970s, automobiles underwent a significant transformation in an effort to make them safer for the environment. Beginning in this decade, newly manufactured passenger cars incorporated a catalytic converter, a device that helped to control dangerous and toxic emissions given off in exhaust fumes. Cars with these converters required a switch from leaded to unleaded gasoline, a development that also had positive environmental ramifications.

The need for catalytic converters. As traffic on America's highways increased, so did air pollution. By the time the Environmental Protection Agency was formed in 1970, air quality was a hot topic. The Clean Air Act of 1970 called for restrictions on the smog-producing chemicals found in auto exhaust; in fact, it called for a 90 percent reduction in dangerous exhaust by-products in five to six years, depending on the pollutant. The act was considered ambitious, was challenged by industry, and was amended several times in order to extend the deadlines for emissions reductions.

Automobiles contribute to a kind of air pollution known as photochemical smog, a dingy, brown haze that often appears to blanket modern cities. This type of smog is produced when chemicals in the atmosphere react with sunlight to produce dangerous substances such as ozone and peroxyacyl nitrate (PAN). Automobile engines work by making use of a combustion reaction, which occurs when gasoline fuel burns in air. Two kinds of dangerous chemicals can result from combustion in automobiles:

hydrocarbons (volatile organic compounds) and oxides of nitrogen (compounds containing nitrogen and oxygen). Although it isn't involved in creating smog, carbon monoxide is also a poisonous and polluting product of automobile combustion.

As they sit in the atmosphere, the nitrogen oxides from automobile exhaust break down and lead to the formation of ozone. Ozone actually protects the earth by absorbing harmful radiation when it exists high in the atmosphere; however, in lower atmospheric regions, it can cause the deterioration of materials such as rubber, and it can react with nitrogen oxide and hydrocarbons to produce PAN. When present in air, PAN irritates the eyes and mucous membranes.

How do catalytic converters reduce dangerous emissions? In the catalytic converter, the products of the engine's combustion reaction pass over two kinds of chemicals that act as reaction *catalysts*. Catalysts are substances that lower the energy required to initiate a chemical reaction, and so allow a reaction to occur more quickly than it would otherwise. In cars, the idea is to allow the pollutants from exhaust fumes to react, and thus break down and become nonpolluting chemicals before they reach the outside environment. Nitrogen oxides are broken into nitrogen and oxygen in order to prevent them from being expelled into the atmosphere as substances that can undergo the chain reaction which leads to photochemical smog.

In modern catalytic converters, the chemical by-products of combustion pass from the engine through a grid of platinum and rhodium. These metal catalysts hold on to the nitrogen atoms in nitrogen oxides, allowing them to separate from oxygen and recombine as diatomic molecules of nitrogen gas (N_2). Hydrocarbons and carbon monoxide are changed into carbon dioxide when they pass through another section of the catalytic converter, commonly made of platinum and palladium.

When catalytic converters work, they change the nature of automobile exhaust—rather than emitting nitrogen oxides, hydrocarbons, and carbon monoxide, cars expel carbon dioxide, nitrogen gas, and oxygen gas. However, upon their introduction in the 1970s, catalytic converters inadvertently contributed to the reduction of another type of pollution that was given off in automobile exhaust: lead. Tetraethyl lead, $Pb(C_2H_5)_4$, had been used as a fuel additive since the 1920s, when it was found to increase engine performance by reducing knocking. Since it wasn't involved in the combustion reaction, poisonous lead was then passed back into the atmosphere through exhaust. However, tetraethyl lead reacts with the metals used in the catalytic converter, making it unable to catalyze the reactions of nitrogen oxides, hydrocarbons, and carbon monoxide. For catalytic converters to work properly, tetraethyl lead cannot be present in automobile fuel. Therefore, the introduction of catalytic converters in the 1970s coincided with the introduction of unleaded gasoline.

Why was lead put into gasoline? In the early days of automobiles, much of the industry's research efforts went into securing ways to make engines more efficient. In an automobile engine, air and gasoline mix in a cylinder where a piston compresses the mixture into a small volume and a spark plug ignites it to produce a combustion reaction. The reaction causes rapid expansion of the gases and pushes the piston down to continue the cycle. One way to make an engine more powerful is to increase the compression ratio: in other words, to be able to greatly compress the air and gas mixture before igniting it. However, when cheaper fuels are highly compressed, they can ignite before the spark plug fires, causing "engine knock." In 1921, it was discovered that small quantities of tetraethyl lead added to relatively inexpensive gasoline would permit a high compression ratio and avoid knocking. Although the potential health hazards of lead were known, the industry quickly adapted to the use of leaded fuel in automobiles.

In the human body, lead causes damage to the nervous system, the brain, the kidneys, and red blood cells. When it is breathed or ingested, lead travels to the soft tissues of the body, such as the brain and kidneys, and to the blood. Some of the lead will be eliminated by the body, but whatever is not eliminated will be stored in the skeleton. This lead may be released into the soft tissues later in life. Even at low concentrations, lead can affect brain function, making cognitive processing and reaction times much slower than normal.

When tetraethyl lead was introduced as a fuel additive in the 1920s, gasoline industry workers paid the price in costs to their safety and health. In that decade, seventeen workers died from exposure to lead, and dozens more were poisoned. Despite the calls from some scientists to halt the use of leaded fuel, the market and industry expanded. As automobile use grew exponentially during the century, so did the impact of leaded fuel on the health of everyday citizens. When lead is released into the atmosphere (for example, from automobile exhaust), it eventually settles and readily accumulates in soil. It can then be taken in by plants and animals and ingested by humans, or ingested when people eat anything that has been in contact with contaminated soil. Although automobiles were not the only source of an environmental accumulation of lead during the twentieth century, they were certainly a major factor when leaded fuel was in widespread use. In the mid-1960s, researchers were shocked to find that levels of lead in human bodies were about 100 times the normal level, and environmental levels were 1,000 times normal. The introduction of catalytic converters and subsequent phasing out of leaded gasoline use in passenger cars in the United States has helped to lower these levels dramatically in the last several decades.

What has happened since the 1970s? By the end of the twentieth century, Americans were coming to terms with the fact that it seemed much easier to pollute the environment than to clean it. For many, this environmental consciousness began in earnest in the 1970s. The organization of the first Earth Day and the formation of the Environmental Protection Agency are examples of efforts toward this end. Although it was amended in 1977 and 1990, the Clean Air Act of 1970 is generally regarded to have set important goals and standards for protecting the quality of the air we breathe. In the 1970s, the environmental problems that used to concern only a particular segment of the population became concerns for the larger society.

Problems still exist, however. Catalytic converters are not infallible; in fact, they don't work well when cold, and so pollutants escape into the atmosphere each time an automobile is started up, until the converter warms to a particular temperature. Another potential problem concerns the chemical that has been widely used as a replacement for tetraethyl lead to boost the compression ratio of gasoline: methyl tertiary butyl ether (MTBE). Although MTBE is effective at helping reduce the hydrocarbons and carbon dioxide pollutants emitted in car exhaust, it is likely a carcinogen, and environmental groups worry about the chances of spills leading to contaminated groundwater supplies.

The regulations placed on automobile emissions in the 1970s have certainly lessened many of the polluting effects of cars. However, some important caveats should be noted. On a global scale, polluting exhaust and leaded gasoline use continue to be a problem, since developing nations often can't afford the higher prices associated with cleaner cars and fuels. Further, no amount of cleanup can change the effects of the volume of automobile traffic on the environment, and the large amount of carbon dioxide emissions from automobiles contributes annually to the greenhouse effect (global warming) across our planet. Since at least the 1970s, major and minor energy crises have led to critical examination of the dependence on oil caused by extensive use of automobiles, but so far without any large-scale effect on our transportation habits. Although the 1970s in America may have marked the beginning of a popular understanding of our need to protect and conserve our natural world, it appears that achieving a sustainable balance with nature in our lifestyles will be an ongoing process for many years into the future.

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HUMAN KNOWLEDGE

Technologies introduced in the 1970s would change life at home and in the laboratory throughout the remainder of the century. The first home computer, the Altair 8800, was introduced as a kit designed by engineer Ed Roberts in 1975. A few years later, Steve Wozniak and Steve Jobs introduced the Apple II computer, which enjoyed instant popularity. In medicine, Godfrey Hounsfield devised the breakthrough computerized axial tomography (CAT) scan technology that allowed doctors to see inside the body with three-dimensional detail. And in the research laboratory, the age of genetic engineering was about to commence, as scientists discovered enzymes that would allow them to cut and reattach sequences of DNA in cell nuclei.

In the 1970s, work by Sherwood Rowland and Mario Molina suggested that the chemicals known as chlorofluorocarbons (CFCs), which were commonly used in cooling systems, were dangerous to the ozone layer when released into the atmosphere. In fact, CFCs break down ozone (a molecule that consists of three oxygen atoms bonded together), causing “holes” in this protective layer of atmosphere that normally functions to absorb ultraviolet radiation from the sun. Later, the commercial use of CFCs was banned in order to slow and eventually reverse the detrimental effects on the ozone layer.

Looking beyond the atmosphere, in 1976, Thomas Kibble proposed the existence of cosmic strings—defects in the space-time continuum that are extremely dense and have an extremely large gravitational pull. The existence of cosmic strings would help explain why matter in the universe is not uniformly distributed, but occurs in clumps. Also during the 1970s, theoreticians Stephen Hawking and Roger Penrose showed that the universe had a beginning in time (the Big Bang). Hawking also worked on the implications of uniting quantum theory with general relativity, and showed that black holes should emit radiation.

Also during this decade, Stephen Jay Gould and Niles Eldredge explained the evolutionary patterns of the fossil record by introducing their theory of punctuated equilibrium. Gould and Eldredge reasoned that changes in particular species can occur quickly, and be separated by long periods of time where no changes occur. And in 1974, the newly discovered “Lucy” fossil would shed new light on the origins of humans.

“Lucy” Fossil Found in Ethiopia

In 1974, Donald Johanson and Tom Gray were mapping and surveying fossils in Hadar, Ethiopia, when they spotted some interesting-looking bone fragments. Two weeks later, the team had uncovered about 40 percent of a skeleton from a female hominid who lived millions of years ago. The fossil was named Lucy, and it led scientists to theorize a new kind of human ancestor known as *Australopithecus*.

Study of Lucy’s fossil indicated that she was about 25 years old at the time of her death. She was only about 3.5 feet tall and probably weighed around 60 pounds. Fossil dating showed that Lucy was 3.2 million years old. Lucy clearly represented an evolutionary link between apes and humans, and significantly, the position of her leg, knee, foot, and spine demonstrated that she walked upright.

Figure 8.6.
The "Lucy" fossil skeleton. 211139 © Science VU/Visuals Unlimited.

Human evolution. The hominids branched off from African apes sometime between 2.5 million and 7 million years ago. The Australopithecines were apelike creatures that began to act as humans do: covered in hair, and partially tree-dwelling, these beings traveled in groups, hunted with clubs, and were more intelligent than other primates it lived among. Later, the genus *Homo* would emerge from *Australopithecus. Homo habilis* lived 2 million to 2.5 million years ago, and was different from its ancestors in that it had a bigger brain, used stone tools, and constructed shelters.

Homo habilis eventually evolved into *Homo erectus*. This new species of human ancestor was more advanced; it used tools more extensively and stood taller than *H. habilis. H. erectus* emerged around 1.5 million years ago. The modern human species, *Homo sapiens*, appeared approximately 400,000 years ago. Scientists suspect that the *Homo* genus began in Africa (east and south), and then spread to Asia and Europe.

Lucy's significance. Before the discovery of Lucy, anthropologists had theorized that humans developed big brains, began to use tools, and then walked upright in order to be able to use their hands for work. However, Lucy, an *Australopithecus*, had a small brain, and her skeleton indicated that she indeed walked upright. This changed scientists' thinking about human development, and raised the question of what evolutionary factors led to bipedalism. Today, facilities such as the Institute of Human Origins in California continue to study the fossil record and theorize about our evolutionary past.

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Chapter 9

THE EIGHTIES

SOCIETAL CONTEXT: THE "ME" DECADE

The 1980s have been characterized as the "Me Decade" or the "Decade of Greed," typified by a generation focused on material wealth, consumption, and status, and an obsession with success. The emphasis on consumerism was epitomized by the phrase "shop 'til you drop," a common pastime for middle-class and wealthy Americans during the decade. While laborers across the country were losing jobs, corporate executives were routinely valorized, and reports of their exorbitant salaries fueled a popular desire to be a career winner. In an economically unstable time of hostile business takeovers, increased unemployment, and double-digit inflation, young people wanted secure, high-paying careers that would support a lifestyle of expensive cars and designer clothes; thus, college students in the 1980s often declared majors based on prospective salaries rather than talents and interests. Young urban professionals, or "yuppies," espoused a new American Dream: wealth, status, and image.

Social trends also owed much to an emphasis on individual excess. Adults in the 1980s became obsessed with fitness, joining health clubs, dining on the many new "lite" foods, and quitting smoking. However, an interest in image often superseded a concern with health: despite warnings about skin cancer, tanning salons became fashionable; and drug use (especially cocaine) proliferated in the face of a prominent media campaign urging Americans to "just say no." The sexual revolution was becoming a cultural norm until the mid-to-late 1980s, when the transmission of the AIDS virus was better understood and brought an abrupt halt to casual, unprotected sex.

Advances in technology changed the entertainment industry during the eighties, as personal computers and video games were increasingly found at the fingertips of youngsters. The invention of compact discs (CDs), the increased use of videocassette recorders (VCRs), the introduction of cable television, and the launching of Music Television (MTV) occurred during this decade. These changes allowed for a shift toward "home entertainment"—rather than go out to a concert or movie, for example, people opted to watch at home. This trend would eventually be blamed for contributing to a rise in obesity among Americans, as young people increasingly stayed indoors to play video games and watch television.

Technology also added to a change in the way Americans sought and received news. Faster communications capabilities, and the launching of 24-hour news outlets such as the Cable News Network (CNN), made it possible to link to life across the globe virtually immediately, at any time during the day. Thus, Americans could watch with new awareness as South Africa's white government continued to enforce its separatist policies of apartheid against the black majority; as the Iran–Iraq war and Israel's invasion of Lebanon escalated tension in the Middle East; as popular support grew for ousting dictatorships in countries throughout the world; as hundreds of thousands of Ethiopians died in the wake of relentless famine; and as students and intellectuals engaged in pro-democracy demonstrations in China's Tiananmen Square were massacred by government-sent tanks. In an unprecedented way, local tragedies had the potential to become global ones. Natural disasters—such as the eruption of the Mt. Saint Helens volcano in the United States or the Nevado del Ruiz volcano in Colombia; or devastating earthquakes in Mexico City and Los Angeles—prompted sympathy around the world. Human-induced tragedy played out before an international audience during this decade as well: news coverage of the Union Carbide toxic gas leak in Bhopal, India; the Chernobyl nuclear reactor meltdown in the Soviet Union; the explosion of the U.S. space shuttle *Columbia*; and the *Exxon Valdez* oil spill underscored the world's vulnerability to technological mishaps.

The political climate in the United States shifted toward conservative ideals during the 1980s. President Ronald Reagan championed patriotism and family values. Reagan's presidency could also be characterized by a suspicion of communism rivaling that which marked the early years of the Cold War. In various countries during the 1980s, the United States intervened to topple Marxist governments or quell Communist-backed rebel groups. The 1983 invasion of the tiny island nation of Grenada resulted in a condemnation of the United States by the United Nations. The anticommunist doctrine also led to the notorious "Iran–Contra Scandal," in which U.S. government officials sanctioned the secret sale of weapons to Iran, and diverted the proceeds to finance Nicaraguan Contra rebels trying to overthrow the Marxist Sandinista government in that country.

Ironically, while Reagan enforced a classic Cold War mind-set, by mid-decade Soviet leader Mikhail Gorbachev was enacting practices that would ultimately dismantle the Soviet Union. Because of the policies of his predecessors, Gorbachev inherited a country suffering from economic hardship, a citizenry whose quality of life had been on the decline for years, and a legacy of increasing mistrust from the international community. Gorbachev vowed to reform the Soviet Union, and his policies of perestroika (restructuring) and glasnost (openness) led to the dissolution of the Soviet bloc. By the end of the decade, Poland, Hungary, Czechoslovakia, Bulgaria, and Romania had turned their backs on communism. Americans who had been raised on Cold War fear and suspicion watched in disbelief as Germans peacefully dismantled the Berlin Wall, which had imposed a physical and ideological barrier across their country for nearly three decades. The implications of the fall of communism in Europe would continue throughout the remainder of the century.

Economically, President Reagan hoped to revive the sagging economy in the United States by cutting taxes and supporting legislation that aligned with increasing the profit margins for American businesses. However, the United States found itself growing deeper in debt during the 1980s, as the government took responsibility for bailing out corporations that had fallen prey to a rising trade deficit (particularly with Japan) or the (often illegal) tactics of Wall Street "raiders," who orchestrated hostile takeovers and perpetuated "junk bonds" in an effort to "get rich quick." By the end of the decade, the nation had over a trillion-dollar deficit and the gap between rich and poor Americans had widened considerably. In the end, the "Me Decade" dream of unbridled material wealth proved to be attainable for only a select few.

ARCHITECTURE & ENGINEERING

Restoration of the Statue of Liberty

On July 4, 1986, the United States celebrated the 100th anniversary of the dedication of the Statue of Liberty. Because a century of exposure to the elements had worn away at the familiar landmark, a three-year, multimillion-dollar restoration project was undertaken in order to preserve and protect the statue. Although complicated by the composition and scale of the monument, the restoration of "Lady Liberty" was designed to help protect the statue well into the next century.

History of the Statue of Liberty. France and the United States had been allies since colonial times, largely due to a mutual distrust of Great Britain. To recognize the centennial anniversary of America's independence, French leaders decided to commission a statue that would be presented as a gift to the United States, symbolizing the countries' friendship and common commitment to freedom. French sculptor Frédéric Bartholdi was chosen to fashion a statue, and architect Gustave Eiffel was charged with designing its interior support structure. The gift actually became a collaborative venture; the United States agreed to build the base upon which the enormous statue would eventually rest. Both countries undertook novel fund-raising activities in order to finance construction of the statue.

Bedloe's Island in New York Harbor (now called Liberty Island) was chosen to be the permanent location of the gift. The Statue of Liberty was transported across the

Figure 9.1.
The Statue of Liberty restoration was a massive undertaking. Courtesy of Painet.

Atlantic in 214 crates, then reconstructed and mounted on its base in 1886. At 305 feet, the statue was the tallest structure of its time. The pedestal was 89 feet high, and rested on a concrete foundation with walls over 50 feet thick. On the day of its dedication, October 28, 1886, office workers in New York City unreeled spools of ticker tape used on Wall Street from hundreds of windows, creating the first of the city's ticker tape parades.

Restoration of the Statue of Liberty. In 1981, a team of French and American scientists was commissioned to research repairs necessary to restore the statue to better-than-new condition without compromising the original design, and to recommend changes that would retard further corrosion. The team determined that the harsh Atlantic coastal weather, including acid rain, was the lead culprit in the deterioration of Lady Liberty. With the initial research completed, President Ronald Reagan formed a Centennial Commission under the leadership of prominent businessman Lee Iacocca to raise the estimated $85 million needed for the restoration. The project was completed under the private–public partnership of the National Park Service and the Statue of Liberty–Ellis Island Foundation.

Although the entire outer surface of the Statue of Liberty is made of copper, the commission determined that the torch was the only part of the statue that needed copper repair (at the same time, its electrical circuitry was rewired). However, the more chemically active iron skeleton of the statue was in dire need of repair; it had rusted to half of its original thickness. It was also determined that Lady Liberty's raised right arm and shoulder should be strengthened, a new elevator installed, and new bronze doors constructed to create a natural cooling system in the interior of the monument.

The iron interior frame of the statue was originally protected by a coat of tar that had disintegrated over time, and allowed saltwater to rust the frame and cause the statue to leak. During the restoration, the tar would be replaced by a protective layer of modern synthetic chemicals. To remove the tar without damage, a soft but abrasive substance had to be used. After much research, sodium bicarbonate ($NaHCO_3$), commonly known as baking soda, was selected to gently scour the tar from the copper and iron surfaces of the statue. Afterward, several different types of sealants were applied to the cleaned surfaces: a sealant to retard corrosion; an additional layer of potassium silicate and zinc dust to seal the statue's finish and prevent graffiti from sticking; and a silicone sealant to fill the spaces between the copper sheets. For reconstructing the framework, scientists selected more durable, corrosion-resistant metals such as ferallium, an iron-aluminum alloy; and stainless steel, a relatively flexible metal made of chromium, iron, and nickel.

How did the Statue of Liberty corrode? In the context of an outdoor monument or building, corrosion can be defined as gradual electrochemical (or oxidation) damage to metal by environmental elements such as acid rain. On an atomic level, this damage involves a chemical reaction in which electrons are transferred from one kind of atom to another. Atoms have three basic kinds of particles: positively charged protons and electrically neutral neutrons, which exist in the tiny, dense core (or nucleus) of an atom, and negatively charged electrons, which exist in cloudlike regions of space around the nucleus. It is the electrons that participate in normal chemical reactions. Certain numbers of electrons around an atom are more stable than others; so during a chemical reaction, atoms will gain, lose, or share electrons in order to achieve one of these stable configurations. An electrochemical reaction, also called a *redox* reaction, occurs when electrons are transferred between atoms. The substance that receives electrons is said to be an *oxidizing agent.* Oxygen is the most widely known oxidizing agent. The substance that gives up electrons is called a *reducing agent.* Metals generally act as reducing agents in redox reactions.

During its lifetime, the iron skeleton of the Statue of Liberty underwent significant corrosion. When iron is found naturally on the earth, it is combined with oxygen atoms in compounds known as iron oxides. In order to obtain iron metal, iron ore is harvested from the earth, then subjected to various chemical processes (for example, heating it with limestone and coke) in order to separate iron and oxygen atoms and extract pure metal. Rusting is the reverse of this process: iron atoms combine with oxygen in the atmosphere to form the more stable iron oxide. Each of these "opposite" chemical reactions—the decomposition of iron oxide into iron and oxygen, and the combination of iron and oxygen into iron oxide—is a redox reaction, in which electrons are transferred between atoms.

Rusting is a two-step process in which the iron is dissolved by a weak acid formed when water and carbon dioxide combine. This weak acid dissolves the iron, which in turn reacts with oxygen to form iron oxide, an orange-brown coating we call rust. The formation of rust can be accelerated in the presence of saltwater, road salt, or acid rain. One of the easiest ways to prevent rusting is to cut off the supply of oxygen and water by coating the iron or steel, a hardened form of iron, with a substance such as oil, plastic, or paint. Another process used to protect iron is called *galvanizing*—in this case, zinc is used to coat the object. Zinc metal reacts readily with oxygen, and in the presence of water and carbon dioxide (in the air), it forms a coating of zinc carbonate that protects the underlying iron. However, if the surface is not completely covered by the zinc or another substance, or if the object gets scratched, the exposed iron will quickly rust.

Another reason for the accelerated formation of rust on the Statue of Liberty was the contact between the statue's iron framework and its copper exterior. The reaction of the copper electrons with acid in the atmosphere is actually more rapid than the reaction of electrons from the iron, but as the reaction progresses, the copper draws electrons away from the iron, speeding up the rate at which free iron changes into iron oxide and accelerating the rusting process. To remedy the direct contact between the iron and copper, a layer of Teflon (or polytetrafluoroethylene) was used as an insulator and lubricant between the copper exterior and the new stainless steel frame. Teflon is virtually inactive with all chemicals, doesn't absorb moisture, and does not pose a biohazard in this application.

Why was copper used on the exterior of the Statue of Liberty? Metallic elements such as copper, silver, and gold have similar chemical properties. These substances are used by artists to make jewelry and sculptures because they are malleable (easily hammered into shapes) and ductile (easily drawn into wire), and have a sheen or luster. Silver and gold are too expensive to use for massive sculptures such as the Statue of Liberty; copper, although not as malleable as gold or silver, is much less costly.

Like iron, copper oxidizes when in contact with water, oxygen, and air. Copper and oxygen form a copper oxide, CuO, that reacts further with carbon dioxide to form copper (II) carbonate ($CuCO_3$), a substance that gives copper its greenish coating called a *patina.* Over time, another chemical reaction forms a compound in the green patina that does not dissolve well in water and therefore protects the remaining copper from further deterioration. Throughout its first century of existence, the copper skin of Lady Liberty surprisingly lost only about five-thousandths of an inch of its thickness to oxidation, making the copper exterior one of the few areas that did not need major attention.

Cultural impact of the statue. Over the years, the Statue of Liberty has come to symbolize America to people throughout the world. Some have seen the statue as an inspiration; at the beginning of the twentieth century, it greeted waves of immigrants who came to the United States, often seeking liberties that were denied in their home countries. In the 1980s, students in Communist China erected a model of the Statue of Liberty as part of their pro-democracy rallies in Tiananmen Square. Others have used ironic images of the statue to critique U.S. policy or actions. Regardless of intent, however, the association runs deep. The restorations undertaken in the 1980s were meant to help ensure that the statue remains a symbol of America for future generations.

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ARTS & ENTERTAINMENT

Video Games

By the 1980s, it had become apparent that the proliferation of new electronic technologies would restyle cultural life in the United States. One of the most profound changes occurred in patterns of entertainment. The commercial introduction of video games in 1972 had slowly reshaped the way that many Americans, especially young people, spent their leisure time. Instead of organizing a group of neighborhood friends to play baseball or tag, young people were shooting virtual asteroids or chasing video gorillas up a series of ladders.

Video games prosper. In general, a modern video game uses microprocessor technology to connect action-controlling input devices with a visual output display. The first video game was developed in 1958, before the miniaturization of electronics. Working at the Brookhaven National Laboratory, William Higinbotham created Tennis for Two as a novelty display for visitors' day. Higinbotham had to connect an analog computer to an oscilloscope screen and hardware control devices in order to electronically simulate a virtual tennis match between blips on the screen. Fourteen years later, Pong became the first commercially available video game; it borrowed the premise of its game from Higinbotham's prototype, but by 1972 computing power had changed significantly.

Three ways to play video games emerged over the last three decades of the twentieth century: people could play on arcade-based machines, home console systems, or personal computers. Arcade games were housed in large, coin-operated machines and could be played for a limited amount of time by patrons at commercial venues. Just as previous generations had gathered at penny arcades to play mechanical games of skill or chance, young people in the 1980s gathered at video arcades to sample

Space Invaders, Pac Man, or Donkey Kong. Today, video arcades, as well as many restaurants, bars, and movie theaters, offer a vast collection of arcade-style video games to customers.

At the same time that arcade-based video games emerged, a home console was introduced. People could connect the console to their television set to turn it into a video game display. In the early 1970s, home video game systems were based on analog technology and were not particularly successful; however, by the end of the decade, Atari's cartridge-based home video system would dominate the market into the 1980s. By 1983, though, software advances could not keep up with rapidly developing hardware formats, and several video game companies folded. The Japanese company Nintendo introduced its home-based Nintendo Entertainment System in 1985, and revitalized the popularity of home games. Four years later, Nintendo's Game Boy became the first portable, handheld video game system, eliminating the need for connecting a console to a television set and making video games accessible, particularly to younger players.

As personal computers became more common and general users learned more programming skills, some video game enthusiasts began to create programs that would mimic popular video games. At first, such programs were shared among circles of enthusiasts, but later, home computer games would be a popular commercial enterprise and a common way to spend time on a personal computer. The power and versatility of home computers compared to video game consoles meant that different styles of video games were developed. Often, even in early years, computer-based games could involve problem-solving and puzzle-oriented plots that required the user to make decisions about the course of the play.

The effects of video games on individuals. Video games can offer young people fun, exploration, problem solving, and learning. They have been credited with improving eye–hand coordination, reaction time, and spatial sense. However, when games *replace* rather than supplement children's traditional play patterns, some experts suggest that these electronic games may interfere with a child's natural development. Some researchers are concerned with the physiological and psychological consequences of electronic recreation on children who spend excessive hours gaming.

Since the 1980s, studies have focused on to what extent, if any, playing video games causes problems to children's physical health such as eyestrain, tendinitis, carpal tunnel syndrome, or seizures. It is estimated that about 50 percent of long-term computer users experience at least some of the following vision problems: blurred vision, dry or irritated eyes, refocusing problems when distance changes, double vision, and a need for prescription changes. Experts believe that computer-related eyestrain results from the fact that humans evolved to be hunters, where far vision was more important to everyday existence than near vision. Only relatively recently have extensive reading and close-up precision work been important to human lifestyles. With the invention of the computer, and more recently the Internet, extensive close-up work now occupies a large portion of time previously spent on activities that utilize distance vision. However, with proper diet that includes antioxidants, frequent breaks from looking at the computer screen, proper lighting, and no-glare screens, many eyestrain-related problems can be alleviated.

About one person in 4,000 is sensitive to quickly shifting patterns, light flashes, and the flicker rate of video game display screens. When exposed to these displays, such people can experience altered vision, disorientation, or even seizures. Often these symptoms can be curbed by avoiding prolonged time at the computer. Tendinitis can result from frequent and repetitive hand motion, as well as poor posture and improper typing technique.

Researchers who study psychological development have questioned whether video games foster aggression, violence, social isolation, negative sexual imagery, game addiction, and short attention spans. Over the years, as technology has become more complex, video game displays have become increasingly realistic, which worries psychologists. The concern is that extremely realistic games which are premised on committing violent acts could be training players to internalize antisocial or even criminal tendencies. The two high school students who shot and killed one teacher, twelve classmates, and themselves at Columbine High School in 1999 were reported to have compared their plans for a massacre to a popular, realistically violent video game, thus helping to fuel speculation about a causal link.

It is difficult to predict which children will be most affected by violent content in video games, or how much is too much violent content, or what frequency and duration of exposure to violent content causes a negative effect on a child. A major problem with much of the research in this area is poor research design; often the sample size is too small or mitigating variables are not properly controlled. An absence of long-term studies of the impact of video game violence is due to their relatively recent appearance; therefore, until longitudinal studies can be completed studies of the effects of television violence on youth are often used to suggest possible effects of video game use. Most psychologists agree that video games involving constant killing or maiming of others potentially harm children, since extremely violent games typically do not realistically show the consequences of violence; that is, children do not witness the pain, crying, or suffering caused by the violence on the screen. Other psychologists hypothesize that when children play games with violent objectives, they learn to associate killing with pleasurable feelings, since the excitement of winning triggers the release of endorphins in the body. Although no definitive conclusions have been reached, a meta-analysis of studies with solid methodology suggests that real-life violent video game play is positively related to aggressive behavior. The relationship is stronger for individuals who are characteristically aggressive and for males.

Another area of concern expressed by psychologists about the pervasive use of video games is the possible negative effect it may have on social development, in light of the isolation attached to gaming. Do children learn how to interact appropriately with others in a comfortable manner if they are continually preoccupied with solo gaming? Some video game critics argue that the increasing influence of electronic games will supplant customary standards of interaction and deteriorate basic social skills necessary to function effectively in society. Will children who spend excessive amounts of time playing solitary video games learn to read body language, to talk about feelings and ideas, to deal with emotions in acceptable ways in confrontational situations, and to interact with others to develop a sense of identity?

The future of video games. In spite of questions about their negative effects, video games seem destined to remain a popular pastime in the twenty-first century. By the end of the 1990s, Nintendo had sold more than a billion games worldwide, and statistics indicated that 40 percent of American households contained a Nintendo game console of some sort. Studies showed that American children were as familiar with the video game character Mario as with cartoon characters such as Bugs Bunny and Mickey Mouse. Although questions about the impact of violent video games continue, other kinds of games are likely to enhance some coordination skills and even creative thinking. As with any technology, the way it is used will determine the impact it will ultimately have on its users.

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COMMUNICATION

Fax Machines

Once, the only way to send documents from one place to another was to transport them physically—either personally or by an intermediary such as the postal service. Later, the telegraph made it possible to transform written messages into code, and transmit that code electronically across large distances. Yet some details, such as pictures, could not be sent by Morse code. The facsimile machine, or fax, was used to transmit photos to newspapers and military installations throughout the twentieth century. Although the concept had been invented over a century earlier, the technology would finally become readily available and have widespread impact on communication practices during the 1980s. Changes in the telephone networks and the standardization of transmission formats that occurred during this decade helped propel fax machines from being a novelty item to an essential business tool. Huge corporations could communicate with international partners in an instant, and small-scale retailers could transmit and receive information quickly and conveniently.

The history of facsimile transmission. As surprising as it may seem, the first fax was patented in 1843 by Alexander Bain, a Scottish amateur clockmaker, who based his fax apparatus on telegraph technology. Several years after Samuel Morse's invention of the telegraph, Bain designed a pendulum-like stylus that would skim back and forth over a raised image made of metal. Each time the stylus touched a raised section of metal, it conducted an electrical signal through a wire connected at the other end to a pen. The pen moved in a corresponding fashion, and drew a copy, or facsimile, of the image. Although Bain's theory was operational, he never accomplished a fax transmission.

In 1851 an English physicist, Frederick Blakewell, transmitted the first fax at the Crystal Palace Exhibition, and the first commercial fax service was opened between Paris and Lyon in 1865. When scientists further refined the photoelectric cell, the capability of the fax machine changed dramatically, since the photocell could distinguish colors on a *gray scale*, a continuum from black to white. Arthur Korn invented the principle of photoelectric reading, the basis of the modern fax machine, and demonstrated the first successful photographic transmission in 1902. By 1906, fax machines had found their first major use—the transmission of photos for newspapers. Korn sent the first city-to-city fax from Munich to Berlin in 1907, and within four years wire photo lines connected Berlin, London, and Paris.

In 1922 Korn transmitted images across the Atlantic by radio, and in 1924 the telephotography machine was used to send political convention photos, over very long distances, to newspapers. During wartime, troops transmitted photographs and weather and map information, and the technology continued to be valuable through the many conflicts at the end of the twentieth century.

Between World War I and World War II, governments enthusiastically encouraged the development of radio and electronic technology, and by the early 1940s radio stations attempted to broadcast fax newspapers into homes. However, a focus on the war effort led to a suspension of the venture, and the emergence of TV in the early 1950s finally crushed the growth of fax newspapers. Other, limited-use fax service companies formed, specializing in weather, law enforcement, and news coverage. The technology never became commonplace—the most compelling problem was that fax devices often used incompatible equipment or signals to transport the data. There was no standard format.

How does a fax machine work? A facsimile machine has three key functions: to scan; to transmit via a telephone line; and to receive (and print) a replica of the transmitted message. The sending and receiving devices contain a modem that translates the message into coded form and then decodes the message for the printer to duplicate at the receiving end.

The way that a fax machine works is very similar to Bain's invention. The page to be sent is divided into strips by a scanner. Each line is then broken up into black and white segments, which can be sent like the dots and dashes of Morse code and put together at the other end. This on–off conductivity principle is related to the bits used in binary code in computer design.

Digital fax machines have changed this principle only slightly. Pages are now divided into tiny squares called pixels, each of which can be either black or white. Fax machines digitize an image by dividing it into a grid of dots. Each dot is given a value of 1 or 0, corresponding to black (the presence of a dot) or white (the absence of a dot). This is transmitted as electronic computer data and then reconstructed into dots that reproduce the picture. This sequence or pattern of 1s and 0s is known as a *bit-map*.

The fax process begins when an original document passes over an optical scanner containing a row of light detectors. The scanner reads the page by dividing it into a grid of hundreds of rows and columns. A light source shines on the document and measures the amount of light reflected from each grid square, and this is recorded as varying amounts of voltage. The voltage information is then digitized and translated into a gray scale (dark black through gray to bright white). These data are transmitted over phone lines at near the speed of light. A second machine receives the signal that will be decoded and sent to the printer to copy the black, white, and gray squares in the same sequence or pattern as the original. A machine is said to have *higher resolution* when it has more squares on a page; current scanners have an area of 2 million squares or more for high resolution.

What caused the fax machine to proliferate in the 1980s? The convenient, reliable fax of the eighties was made possible when several technologies and events came together in a timely manner—some historians have described it as "demand catching up with technology." As the network of telephone lines increased, so did the potential for fax use. A 1968 court decision to allow fax machines access to public phone networks by removing restrictions on the use of non-Bell equipment furthered the possibility of widespread fax use. The decision permitted acoustic and induction equipment to interface with non-AT&T equipment on public networks; by 1969, better electrical connections also eliminated much of the noise from acoustic coupling. Direct connections between fax machines and the phone lines finally occurred in 1978, making the home and business use of fax machines much more attractive to customers.

Second, an important decision was made to develop a new standard for compatibility among fax communication formats. The first attempt to standardize occurred in 1966, but it was not until 1980 that a standard protocol for transmitting faxes at rates of 9,600 bps (bits per second) was set. These recommendations were accepted universally.

Another major contribution to the boom in fax technology was the massive support given by the Japanese government to research fax capabilities. In the early days of the telegraph, the Chinese realized that the instrument could not transport their language, which was made up of thousands of characters. However, fax technology could be used, since photo images were easily copied. Similarly, the Japanese language—with its 46 katakana phonetic and 20,000 kanji characters—didn't fit the traditional Western telegraph system. Japan's support of the world's largest facsimile research lab led to the development of fax machines that were faster, more reliable, smaller, and very affordable. By using integrated circuit technology, the Japanese made the fax machine very practical. Mass marketing helped Japan quickly capture the world's business. Fax transmissions grew to about 1.5 billion in 1985 and were estimated to exceed 18 billion per year by the turn of the century. Today, over half of the phone line usage between Japan and the United States is fax-related.

Noteworthy, too, was Federal Express's energetic 1984 advertising campaign of ZapMail, which promoted the use of fax technology (however, Federal Express dropped the idea within two years). Deregulation of the telephone industry, with its resulting rate decreases, significantly lowered the cost of faxing at a time when the postal service increased rates, slowed delivery, and therefore helped the fax market.

What we now take for granted. Although paperless communication—such as E-mail and E-mail attachments—has changed the nature of communication once more, fax machines continue to play a role in daily life. A faxed communication has the instantaneous speed and low cost of the telephone, the picture and graphic benefit of a camera, and the hard copy edge of a mailed document, and is relatively easy to operate. Receiving a faxed page of information took about six minutes in 1985, but now takes less than a minute per page. Fax machines succeeded in virtually shrinking the world; people now think in terms of time rather than distance to conduct personal and work-related business.

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DEFENSE & DIPLOMACY

Star Wars Missile Defense System

During the Cold War, the United States and the Soviet Union competitively stockpiled long-range intercontinental ballistic missiles carrying nuclear weapons. For most of the last half of the twentieth century, the world lived in constant fear of a nuclear war between the two superpowers, each of which reasoned that it could deter the other from attacking first by acquiring more and more nuclear weapons. It was thought that if offensive weapons had the capability to cause complete destruction, then defensive weapons were unnecessary. The advent of the atomic and hydrogen bombs led to an understanding known as "mutual assured destruction"—once a nation knew it was under attack, it could launch an equally destructive counterattack, and total annihilation could occur in minutes.

The fear brought on by air raids during World War II paled decades later in comparison to the fear induced by ballistic missiles—self-propelled weapons that could reach a target thousands of miles away in less than 30 minutes. It became obvious during the 1960s and 1970s that the capabilities of ballistic missiles gravely threatened the security of many nations. In spite of some progress in nuclear arms control agreements, fear of nuclear war was widespread. During the 1980s, President Reagan resurrected an earlier Cold War competitive mind-set, referring to the Soviet Union as an "evil empire" that must be stopped. It was against this backdrop that Reagan introduced his Strategic Defense Initiative (SDI) in 1983.

Ideas behind SDI. Reagan concluded that the time was right to consider a technology-based defensive strategy against nuclear attack. He envisioned a system of space-based mirrors and lasers that would detect an incoming missile and render it harmless before it could fall on the United States. Reagan spoke of a "shield" that would protect the American people. Critics dubbed the initiative "Star Wars," charging that it relied on nonexistent technology and was, like its namesake movie, merely a "science fiction" story.

Specifically, the SDI plan consisted of mirrors that would be housed on land, but launched into space when needed. Permanently space-based lasers were targeted for use in a defensive system because laser light travels at 300 million meters per second, compared to a supersonic airplane or missile, which can travel only about 700 meters per second. One laser gun tested in the 1980s was the gas dynamic laser (GDL), which burned carbon dioxide with nitrous oxide to produce high-energy bundles of light focused on a target.

The defense plan also included a laser tracking device, the anti-satellite missile (ASAT). This device would attempt to destroy incoming nuclear warheads by placing smaller interceptor missiles in their path, rendering them useless by the sheer force of the collision. Although the ASAT was demonstrated somewhat successfully in 1984, questions arose about its reliability and accuracy. Most of the devices conceived as part of the Star Wars–SDI plan required technologies that were not available in the 1980s, thus forcing an end to the project by 1992.

Ballistic missile defense technology applications. Although they were not used to build a nuclear shield, some of the technologies developed as part of SDI have been transferred to applications in medicine, manufacturing, and space technology. Two examples of medical applications have come from the development of a laser eye tracking device and the improvement of capacitor functioning. The laser radar system developed for missile tracking and space docking now provides an accurate eye-tracking device that can be used during surgery. A surgeon attempts to correct a patient's vision problem by using a laser to modify the shape of the cornea. The SDI-inspired device tracks involuntary eye movements and adjusts the placement of the laser beam for more accurate treatment.

During the SDI program, thin film capacitors were developed to provide forceful bursts of power to space-based electromagnetic weapons. The new capacitor technology is now used in lifesaving portable defibrillators. Defibrillators need capacitors that recharge quickly and deliver a specified jolt of electricity to shock a heart back to its normal rhythm after a heart attack. The sooner a heart beats normally, the better the patient's chance of survival with minimal damage to the heart and other organs.

Capacitors store large amounts of electric charge and release it as needed. A basic capacitor consists of two metal plates (A and B) separated by an insulating material. Suppose a negative charge is put on plate A, and a positively charged plate B is held near it. The positive charge from B would cause the negative charge on A to feel an attraction, but the charges would be prevented from coming together by the insulating material between them. However, the negative charges are pulled to one side of plate A, leaving room for more negative charge to accumulate behind it. This process is called *induction*. The buildup of charge is what characterizes a capacitor, a device that increases the capacity to hold a charge. The closer A is to B, or the larger the plates, the more charge plate A can hold. Capacitors are widely used in electronic devices, most often in radios, where variable capacitors match a radio station's frequency with the tuner on an individual radio.

Criticism of SDI. Many opponents of Reagan's Star Wars plan felt that the extra defense spending was unjustified, given that it would force cuts of social programs. Others were angered by what they saw as a blatant disregard for the 1972 Antiballistic Missile Treaty, which was signed by the United States. Opposition was also voiced by critics who felt that the technology was too expensive and not feasible.

Proponents of SDI saw unparalleled power in its possibility. Mutual assured destruction would no longer be the name of the game—if the United States could attack and defend, and the Soviet Union could just attack, then the balance of power was shifted, and the United States held the upper hand. During the 1980s, President Reagan and Soviet leader Mikhail Gorbachev held several meetings to discuss arms control. At a summit in Reykjavik, Iceland, in 1986, the two leaders discussed eliminating nuclear weapons. Reagan stood firm on his proposal to build a missile defense system, and talks broke down.

The dismantling of the Soviet Union and the failure of SDI technology caused President Clinton to end the program in 1993. However, at the beginning of the twenty-first century, America has returned to the idea of a nuclear missile defense system, now called Nations Missile Defense and championed by President George W. Bush. The United States withdrew from the 1972 ABM treaty, the first time that America had withdrawn from a negotiated treaty approved by the Senate. Although Reagan's SDI "Star Wars" plan eventually became science fiction, the future of missile defense for the United States is still very much in question.

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ENVIRONMENT

Chernobyl Nuclear Reactor Accident

In the early morning hours of April 28, 1986, technicians at a Swedish nuclear power plant began recording abnormally high levels of radiation in the air around the plant, though a thorough inspection identified no problems. Air monitors in Denmark, Norway, and Finland also began recording high levels of radiation. Tracing the prevailing winds to the east, scientists could only speculate on the cause and origin of the radiation spike. Later that evening, Soviet television reported, "An accident has occurred at Chernobyl Nuclear Power Plant."

Two days earlier, the world's largest nuclear accident had occurred at Unit 4 of the Chernobyl Nuclear Power Plant. Located 65 miles north of Kiev, the capital of the Ukraine, Chernobyl was home to four nuclear reactors, each capable of producing 1 billion watts of electric power. Although construction began in 1975, Reactor

Unit 4 did not become operational until 1984. The accident that occurred in 1986, initiated by a controlled experiment—ironically, designed to improve the safety of the plant—resulted in Reactor Unit 4 exploding, catching on fire, and subsequently releasing 100 million curies of radiation, which, carried by wind, spread over much of Europe.

What happened at Chernobyl? Most electric power plants function on the same principle: a high-energy source heats water to create steam, which spins a turbine in a generator to produce electric power. In a nuclear power plant, instead of burning coal or gas to create heat, highly excitable radioactive materials, such as uranium, are used to heat water for electricity production. The radioactive materials are configured in such a way that, if left uncontrolled, they will undergo a chain reaction releasing large amounts of heat and ultimately melting down the source material. In a nuclear power plant, bundles of uranium are combined with control rods, made of a material able to slow the nuclear chain reaction of the bundles (in this case, graphite). The rods and bundles are typically submerged in water, which acts as a coolant, and housed in a pressure vessel known as the reactor core. The control rods can be lifted from the bundles to produce more heat, lowered into the bundles to decrease the amount of heat given off, or lowered completely into the uranium to stop the reactions altogether in case of an accident or to change fuel supplies.

Early in the morning on April 26, prior to a routine shutdown of Reactor Unit 4 at the Chernobyl Nuclear Power Plant, technicians began preparations for an experiment intended to test the operational capacity of the turbines following a loss of main electrical power supply to the plant. Prior to the experiment, reactor operations had disabled the automatic shutdown mechanism so that it would not interfere with the test. The low power settings induced for the experiment slowed the coolant pumps, which in turn caused the water in the reactor core to boil and turn to steam. The resulting steam had significantly less capacity to dissipate and control the reactions of the uranium, and the temperature of the core began to rise to the critical point. Upon observing the temperature rise, operators induced the manual emergency shutdown of the reactor. Unfortunately, a consequence of another inherent design flaw of the reactor was a power surge triggered by the shutdown operations. This extra amount of energy caused the core to exceed the critical temperature, resulting in core meltdown.

As the uranium core began to melt and disintegrate, fragments of the fuel were ejected into the remaining coolant water, causing a steam explosion in the pressure vessel large enough to blow the 1,000-pound steel-and-concrete lid off the reactor building. Radionuclides from the reactor were propelled into the atmosphere, where prevailing winds carried them over eastern Europe. Upon destruction of the reactor's structure, the control rod casings were exposed to air, permitting a rapid oxidation and exothermic (heat releasing) reaction, which quickly raised the temperature and ignited the graphite rods. Despite attempts to smother the fire with more than 5,000

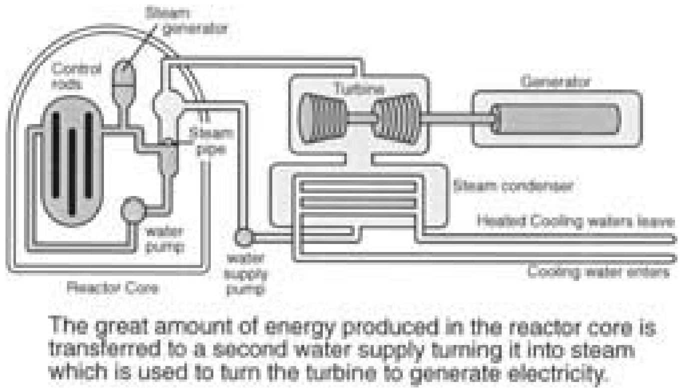

Figure 9.2. The basic operation of a nuclear reactor.

tons of boron, dolomite (limestone) sand, clay, and lead, the fire burned for nine days, releasing more radiation into the atmosphere.

Why did the Chernobyl nuclear reactor explode? After much analysis of the accident, several factors have been identified as triggering the event. The physical design of the reactor was inherently unsafe. In contrast to the light water reactors used in Europe and the United States, Chernobyl's RBMK, or pressure tube reactor, was inherently unstable under conditions of loss of coolant and/or increased temperature. In addition, the lack of sufficient containment around Chernobyl's reactors exacerbated the already dangerous situation. Postaccident analysis of the Chernobyl incident has indicated that if a containment structure had been built, no radiation would have escaped and no deaths or injuries would have resulted.

In addition, an insufficient amount of fail-safe safety mechanisms were installed. There were no physical controls to prevent operators from running the reactor under unstable conditions. The design of the operator/machine interface was not considered. While the plant engineers were aware of the serious design deficiencies, instead of taking steps to avoid such situations, they relied upon instructing the operators to avoid unstable conditions. Another factor was the inadequate training of the operators of the reactor. Education and experience are important qualifications for working with highly specialized equipment. Chernobyl plant operators admitted their training program was inadequate. While the direct cause of the Chernobyl accident has been attributed to operator error, the poor design of the reactors must bear some of the responsibility.

What are the consequences of the accident? The Chernobyl accident was consequential for both the Russians and the rest of the world. The meltdown of Chernobyl Reactor Unit 4 killed thirty-one people, mostly from acute radiation exposure.

In addition, an estimated 15,000 to 30,000 people have suffered from radiation sickness, cancer, birth defects, and other problems related to radiation exposure. Because 600,000 people were involved in the containment and cleanup of the Chernobyl accident, the full impact of the disaster likely will not be apparent for a generation. Millions of acres of agricultural lands were contaminated by radioactive fallout, and livestock continue to assimilate levels of radiation. The United Nations has estimated that nearly 6 million people currently live in contaminated areas.

After the accident at Reactor Unit 4, a concrete sarcophagus consisting of 2 feet of steel and 6 feet of concrete was constructed around the ruins encasing hundreds of tons of nuclear fuel remaining from the disaster. The three other reactor units at Chernobyl continued to operate until the plant was closed in 2000. Ultimately the Chernobyl accident focused international attention on raising the safety standards of the nuclear industry.

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FOOD & AGRICULTURE

The African Famine

In October 1984, a British broadcasting crew released horrific pictures of human starvation from an Ethiopian refugee camp and awakened the world to the famine that was affecting many African nations. Prior to this exposure, requests to the international donor community for food assistance had fallen on deaf ears. In 1981 a drought depleted the food supply in a country that rarely had surplus crops, and continued to dry up even the most fertile regions of Ethiopia. By 1984, lack of rain and increased crop disease put 5 million people at the brink of starvation and, by the end of 1985, over 1 million people had died.

What is drought? Drought, sometimes alternating with floods and civil war, can contribute to famine throughout a region. Experts say that they now know the early warning signs of long-term drought and can alleviate much of the hardship and deaths if information can reach the governments, researchers, and farmers of at-risk populations early enough to plan a strategy of relief. However, civil wars and other governmental decisions are more complicated and less easy to control.

Drought can be defined using three different criteria: precipitation, water supply, and soil moisture. The meteorological definition of drought is that an area experiences extended periods of inadequate rainfall as compared to the norm. Hydrological drought is determined by measuring stream flow or the water level in lakes and reservoirs. Agricultural drought develops when insufficient precipitation affects the growing cycle, and therefore the yield, of native vegetation and crops.

Most droughts are caused by changes in massive atmospheric circulation patterns and high-pressure systems. As a result of the sun's uneven heating of the earth's surface, the atmosphere moves in several immense loops where more heat is lost at the North and South poles than is gained from the sun, with the opposite occurring at the equator. This variation in heating and cooling causes convection currents in the atmosphere. *Convection* is the transfer of heat through the movement of a gas or liquid. When a gas or liquid is heated, it expands, becomes lighter, and rises, being replaced by cooler, denser air. The convection currents created by this process transfer excess heat from the equator to the poles, keeping the earth's temperatures from becoming too unbalanced. Another major factor in forming the convection loops is the rotation or spin of the earth, which causes these north-to-south loops to separate into six loops of convection currents.

Using computer modeling based on climate data collected for more than a century, climatologists believe that the atmosphere's circulation patterns contribute to sea surface temperature anomalies, such as the El Niño phenomenon, that can increase the probability of drought in many parts of the world. Some scientists postulate that air pollution, specifically sulfur dioxide from burning fossil fuels, contributed to abnormal cloud formation, reflecting more of the sun's energy back into space and leading to the climatic changes and drought.

What happened in Ethiopia in the 1980s? Despite early signs of crop failure and hunger in Ethiopia in the 1980s, Western relief agencies and governments were unwilling to get involved. One problem was a prevailing distrust of the Ethiopian government, which was friendly with the Soviet Union. However, increased worldwide media coverage explicitly warned of the 8 million people in danger of starvation, and eventually convinced many Western governments to donate food and money. Unfortunately, continuing storms destroyed newly planted crops and the escalated civil war diverted much of the donated food to soldiers. By the end of the 1980s, conditions gradually improved as a result of humanitarian aid, but recurring drought, civil war, and governmental policies perpetuated food scarcity in Ethiopia and many other regions of Africa at the beginning of the twenty-first century.

Some political and economic analysts suggested that the debt crisis of the early 1980s affected the meager income Ethiopian peasants received from export crops as

Figure 9.3.
Media images of the famine in Ethiopia moved people to respond with aid. Courtesy of Painet.

commodity prices dropped. Throughout Africa, the governments of developing nations enacted policies to boost export revenues, and redistributed the most fertile land to larger cooperatives, giving indigenous people the marginal lands on which to farm for domestic use. When surpluses from a given year were exported, no reserve was saved for drought years. Policies were aimed at commercialization of food production, remaking the peasant economy into an urban-based agribusiness, with little thought of food production for household consumption or domestic sale. During drought periods, peasants could not afford market prices to feed their families, and most food aid was sold, not given away. The World Bank and the International Monetary Fund were criticized for many of their practices and policies that promoted cash-crop production for export and the reduction of acreage for home consumption that led to the increase in potential famine conditions.

Musicians organize relief. As worldwide news broadcasts told of starving children, failed crops, and animal carcasses, British musician Bob Geldof had a fund-raising idea. In 1984, he organized fellow musicians (the group called themselves Band Aid) and recorded the song "Do They Know It's Christmas?" The song generated interest across the globe, and proceeds of the record sales went to famine relief. The following year, American pop stars Lionel Ritchie and Michael Jackson formed their own group of musicians and entertainers, USA for Africa, who recorded "We Are the World." American and British performers staged a 16-hour televised concert fund-raiser that stretched across the Atlantic (it was staged in Philadelphia and London).

Celebrity efforts were able to garner tens of millions of dollars in aid for famine victims. However, critics were concerned that people might mistakenly think that such donations would "fix" the famine problems of Africa. As the scholars Frances Moore Lappé, Joseph Collins, and Peter Rosset have insisted, famines are not natural disasters, but social ones. Natural events such as drought can contribute to the intensity of a famine, but ultimately human systems, policies, and arrangements often determine who will fall victim to hunger. It remains for the world to reexamine such systems in the twenty-first century.

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MEDICINE & HEALTH

The AIDS Crisis

At the beginning of the 1980s, most developed countries paid comparatively little attention to infectious diseases. The discovery of antibiotics and development of vaccines contributed to a feeling that infectious disease was under control. Instead, cancer, Alzheimer's disease, heart disease, and other noninfectious diseases blanketed newspaper pages and consumed public interest. However, panic quickly set in as a new infectious disease— acquired immune deficiency syndrome, or AIDS— baffled health organizations and spread rapidly from one population to the next.

HIV infection linked to AIDS. Although it took only a few years from its outbreak in the early 1980s to identify the human immunodeficiency virus (HIV) as the cause of AIDS, the spread of AIDS continues to devastate many parts of the world. HIV is known as a *retrovirus*, and was first isolated in May 1983 by Luc Montagnier at the Pasteur Institute in Paris. No largely effective cure or vaccine has been developed. Infection with HIV is a lifelong process, since neither the immune system nor current medical knowledge can eliminate it.

From the onset of the epidemic, AIDS researchers recognized that in the course of infection, the immune system becomes faulty and that a specific type of blood and lymphatic cell (T-lymphocytes CD4+), which stimulate the immune system, is involved. The T-lymphocytes CD4+ cells are the body's defense against fungi and viruses, and the count of such cells can predict the stage or seriousness of the disease. The lowering of the body's defenses from a healthy 1,000 T-lymphocyte count to below a 200 T-lymphocyte count allows opportunistic life-threatening infections (both viral and fungal) to infect AIDS patients, often causing death. AIDS is the final stage of the progression of the HIV virus. Between 25 and 55 percent of HIV-infected people develop AIDS within 4 to 10 years of exposure to the virus. AIDS victims commonly experience symptoms including persistent cough, fever, purplish bumps and blotches on the skin, pneumonia, parasitic infections, and occasionally dementia. Many other symptoms plague AIDS patients, which is why it was called a "syndrome"— a term that connotes a variety of signs and symptoms which are all part of the same medical affliction.

Science of a retrovirus. Viruses consist of nucleic acid (either RNA or DNA, but not both) and a few proteins, making them extremely small molecules. Viruses cannot reproduce by themselves, and rely on infecting and using the reproductive mechanism of a living cell. In a typical virus, replication of the genetic information flows from DNA to RNA to proteins, but in a retrovirus the genetic information flows from RNA to the DNA. In other words, the viral RNA, which is carried by an enzyme called *reverse transcriptase*, is used as a template for making viral DNA that can then integrate itself into the genetic information of the host. This type of viral replication remains latent in the host (often for years) until it is activated and initiates the formation of tumors or disease such as AIDS. Reverse transcriptase is not present in human cells, so the virus itself carries the enzyme, hiding it from the immune system of the host and waiting for a chance to replicate.

The first pathogenic human retrovirus, human T-cell leukemia, was discovered in 1981, just two years before HIV was isolated. The retrovirus discovery came almost two decades after Howard Temin suggested the possibility of reverse transcription, the unique method by which a retrovirus copies its genetic structure onto a host DNA. Temin and David Baltimore were awarded the Nobel Prize in 1975 for discovering the enzyme reverse transcriptase and explaining this replication. (The word "retrovirus" is from *retro,* meaning "reverse" in Latin.)

The retrovirus replication cycle begins when a virus attaches itself to and penetrates a susceptible host cell's plasma membrane. The viral RNA is then released into the cell and the reverse transcriptase directs the synthesis of a DNA copy of the viral genome, called a provirus. The resulting double-stranded proviral DNA is transported to the cell nucleus, where it may become integrated into the genome of the host cell. The provirus in the host DNA may remain latent and be transmitted to unborn babies or may be expressed by mechanisms identical to normal transcription, which leads to the synthesis of viral encoded proteins and new copies of viral RNA. The proteins, enzymes, and RNA can now be assembled to form new viral particles. In HIV these retroviruses attach to T-lymphocytes CD4+ cells of the immune system as a provirus, eventually making the immune system ineffective.

History of the spread of HIV/AIDS. Scientists now believe that HIV was present at least 25 years before its outbreak in the early 1980s. When preserved tissue (genetic material) from autopsies performed on patients who died of mysterious deaths in the late 1950s and early 1960s was reexamined, it was determined that some of these victims had HIV.

Scientists report that the HIV virus is closely related genetically to a virus that naturally infects chimpanzees and is a close cousin to a strain of African monkey viruses from which the HIV virus most likely evolved over the centuries. The virus was probably passed accidentally from chimpanzees to humans. HIV/AIDS was certainly present long before the AIDS epidemic became well-publicized in the early 1980s.

Many historians acknowledge that conditions in the 1980s were ripe for the worldwide spread of such a disease as HIV/AIDS. With the advent of the birth control pill, the sexual revolution of the 1960s encouraged multiple sexual partners, and the availability of drugs and disposable syringes in the early 1970s heightened intravenous drug use. The civil rights movement promoted an openness to gay rights, making public bathhouses more accessible to many people who unknowingly would contract and pass on HIV to others. Even advances in technology that improved transportation systems added to the factors that contributed to the worldwide spread of AIDS.

Because the first outbreak was in homosexual communities, AIDS was thought to be exclusively a sexually transmitted disease. With the same procedures used in determining the spread of hepatitis B and other sexually transmitted diseases, researchers were able to determine that not only was HIV sexually transmitted, but also that it had a long incubation period, allowing an infected person to remain symptom-free for years—and thus unaware of being able to transmit HIV to others via body fluids such as blood and semen. Shortly after announcement of the danger AIDS posed to the homosexual community, intravenous drug users were also identified as a high-risk group for HIV infection.

However, when hemophiliacs and heterosexual blood transfusion patients became infected with AIDS, health organizations realized that blood products of any sort were suspect, prompting the medical community to devise a blood screening procedure to slow the spread of this devastating epidemic. In 1984 a direct causal relationship between HIV and AIDS became apparent, and after years of research, scientists seem to understand at least part of the mechanism of the spread of the disease. It is now known that HIV is present in all blood, semen, and vaginal fluids—and to a much lesser degree, saliva—of infected people, and that it can be transmitted to another person only if these fluids enter that person's body. Skin contact will not spread the disease; neither will kissing, since the level of the virus in saliva is far too low to be infectious. The HIV virus can be spread from an infected person to others during unprotected sexual contact, intravenous drug use, blood transfusions, or blood contact with open wounds, or from mother to child before and during delivery, or while breast-feeding.

Presently the principal mode of HIV transmission is through unprotected heterosexual intercourse. According to the World Health Organization, the total number of AIDS deaths in the first quarter-century of the epidemic is approximately 25 million people worldwide, with approximately 40 million more people living with the HIV virus. It is reported that there are 5 million new HIV infections each year, and the number is increasing. The highest rate of infection is in sub-Saharan Africa, with one person in nine infected with the HIV virus; India has the second largest population of HIV/AIDS cases. Latin America, Haiti, and the Bahamas also report high rates of infection, and eastern Europe (Russia, Ukraine, and Estonia), Central Asia, and China are experiencing increases, too. Countries with effective AIDS prevention campaigns—including Poland, Slovenia, Hungary, and the Czech Republic—are finally witnessing a decrease in reported cases.

The devastation of AIDS. The personal and familial impact of AIDS is devastating. Severe emotional, physical, and financial consequences often result. The loss of family income, combined with the extra effort needed to care for the sick relative, may lead to an intolerable situation. The social exclusion faced by those infected with HIV/AIDS can often cause additional stress that accelerates the illness, and the discrimination against infected persons often serves to further the silent spread of the disease. When people are too embarrassed and unwilling to seek testing for the disease or to openly discuss prevention with a doctor, teacher, or friend, the disease can spread more readily.

At a broader level, a community or country may feel the effects of HIV/AIDS economically, such as in the loss of productive workers through absenteeism and/or death, and an increase in employer expenses due to more costly medical insurance, expanded training and recruitment, and growth in time and money spent to educate the community about AIDS prevention. Some developing countries have over 10 percent of their population affected by AIDS and another 35 percent HIV-positive, which raises complex societal issues. How does a country that is already largely poverty-stricken prioritize the many demands of caring for the sick and dying, and providing condoms and educating those not yet infected? Who will care for the orphans of HIV/AIDS victims, many of whom are already infected? In a disease-weakened society, who takes on the work previously done by those afflicted by AIDS? How do health educators sensitively address the cultural and religious beliefs about sexual practices and lack of scientific understanding that interfere with HIV/AIDS prevention?

How do we stop the spread of AIDS? Until scientists can develop a cure or vaccine, other methods are needed to slow the spread of HIV/AIDS. International standards and protocols for blood safety need to be strictly followed, and appropriate and affordable drug therapy to help care for persons living with HIV/AIDS must be available worldwide. Educational campaigns stressing changes in sexual behavior and an understanding of HIV/AIDS are crucial if communities are to openly acknowledge the grievous implications of HIV/AIDS and remove the discrimination and stigma attached to HIV/AIDS. By sustaining educational efforts, the message of prevention and the dangers of AIDS are kept in the forefront, promoting a message that goes beyond mere awareness, to a level that creates appropriate behavioral changes to curb the spread of HIV/AIDS.

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TRANSPORTATION

Space Transportation System: The Space Shuttle

During an era of recession when the United States was rebounding from the high costs of the Vietnam War and myriad social programs, the concept of a reusable space shuttle seemed ideal. Thus, the United States built the first reusable winged space shuttle, *Columbia*, and tested it on April 12, 1981. Unlike previous maiden space voyages, this flight was manned, with John Young and Bob Crippen at the helm for liftoff at the Kennedy Space Center in Florida. It took nine years, $10 billion, and numerous technical delays before the era of reusable spacecraft became a reality. For many Americans, the timing seemed ideal: in a country recovering from the humiliation of Watergate and the trauma of the Vietnam War, the successful flight of the space shuttle *Columbia* seemed to revitalize the nation's spirit.

Figure 9.4.
The space shuttle *Columbia*, 1994.

Shuttle basics. The space shuttle consists of three main parts: the orbiter, the huge fuel tank, and two large booster rockets. The shuttle's liftoff from the launch pad models that of a rocket, but the reentry into the earth's atmosphere mirrors a conventional plane as it glides to a landing. The airplane-like section of the shuttle, the orbiter, houses the astronauts. The orbiter is dwarfed by the external fuel tank and two rocket boosters, and is complete with wings, rudder, elevons, steering jets, and landing wheels. The living area consists of two levels: the flight deck above and the sleeping quarters—including a toilet and galley—below. An air lock is used to separate and navigate between the unpressurized payload area and the living and command quarters.

Astronauts control three main engines from the flight deck, and two solid rocket boosters to give the extra needed power to escape the earth's gravitational pull. Large engines and rockets power the space shuttle. The largest external fuel tank empties its fuel into the main engine, blasting the shuttle into space (approximately a 9-minute process) before separating from the orbiter and disintegrating in the atmosphere, then falling into the Indian Ocean. In addition to liquid fuel, two solid boosters detach from the shuttle within two minutes of liftoff, land by parachute in the Atlantic Ocean, are recovered, and are refilled for future flights. Two smaller orbital engines and forty-four jet thrusters help the orbiter maneuver in space and help change its speed as the gravitational pull decreases with altitude. During reentry the orbiter is initially flying at 15,000 mph, then slows down to glide at 200 mph as it approaches the 1.5-mile-long landing strip. The crew must navigate it correctly the first time, since there is no power to sustain staying in the air to reposition the shuttle.

Unlike earlier space vessels that were covered with a heat shield that incinerated during reentry, the shuttle was covered with ceramic tiles on the underside and the nose to protect it from the extreme heat of reentry. Friction caused by moving through the earth's atmosphere at high speed produced surface temperatures on the shuttle of approximately 2,500 °F (1,400 °C). On the first shuttle flight in 1981, a few of the new ceramic heat shield tiles fell off, and safety issues surrounding the heat shield continued to be a concern over the last two decades of the century. The intense heat created during reentry also causes radio communications to cease as highly heated air around the shuttle becomes electrically charged, generating a barrier that keeps radio signals from penetrating through the orbiter and creating a 15-minute audio blackout.

The shuttle has a cargo bay the size of a tractor trailer and takes payloads such as television/telephone research laboratories and satellites into space. The shuttle is used to send crews to deliver, repair, and retrieve satellites and, when necessary, deliver astronauts to, or retrieve them from, space stations.

The shuttle is refurbished and refueled after each flight. Each has a theoretical lifetime of about 100 missions. Four orbiters completed the original shuttle fleet: *Columbia* (1981), *Challenger* (1982), *Discovery* (1983), and *Atlantis* (1985). The *Endeavour* replaced the destroyed *Challenger* in 1991. Since *Columbia*'s first flight in 1981 there have been approximately 100 successful shuttle flights among the fleet. However, over the next twenty years, the idea that the shuttle would be cost-effective proved to be false. The cost in taxpayer dollars as well as human life was higher than anticipated, and refurbishing takes longer than expected, resulting in fewer flights and a higher cost per flight.

Challenger *accident.* *Challenger*'s first flight was in 1983, and the shuttle flew nine successful flights before exploding on January 28, 1986. The explosion killed all seven crew members, including the first civilian to travel into space, teacher Christa McAuliffe. Millions of people, including many schoolchildren, watched the National Aeronautics and Space Administration (NASA) launch the first teacher into space, only to witness in disbelief the horrible scene just 73 seconds after liftoff.

The Teacher in Space project was initiated by President Ronald Reagan to rejuvenate public interest in the space program. Of the 11,000 teachers who applied for the honor, NASA selected the enthusiastic, thirty-six-year-old high school social studies teacher, Christa McAuliffe, to train for the flight into space and to develop lessons she would teach from space. McAuliffe earned the respect of the other astronauts and charmed the media with her broad smile and vivacious personality. She was credited with bringing life back into the declining public approval of the space program.

Another civilian astronaut, Gregory Jarvis, an engineer employed by Hughes Aircraft Company, was instrumental in designing the Leasat satellite that was to be launched from the *Challenger*. His presence on the shuttle served as a reward to Hughes Aircraft for employing the NASA shuttles to launch all of Hughes's satellites. Both civilian astronauts paid the ultimate price for their political contributions to the NASA Space Program. The other five crew members were commander Francis (Dick) Scobee, Navy pilot Michael Smith, physicist Ronald McNair (the first African

American to fly in space), Ellison Onizuka (the first Japanese American to fly in space) and electrical engineer Judith Resnik (the second American woman in space).

After the disaster, an investigation blamed NASA for launching the flight in weather that was too cold, despite previous concerns that the rubber gaskets or O-rings might be weakened in the low temperatures. The coldest temperature reached during previous launches was well above 50° F, but on this day the temperatures had barely reached freezing (32° F) by morning. Booster rockets reassembled from former flights showed signs of partial burning of the O-rings used to seal the joints between sections of the boosters. In fact, engineer Roger Bioscopy, employed by the manufacturers of the solid rocket boosters, Morton Thiokol Company, warned in a communiqué that there was an O-ring problem months before the accident. Even the night before the launch, engineers at both NASA and Morton Thiokol separately debated about a possible O-ring failure, but no one was willing to be responsible for yet another delay. NASA relied on funds generated from delivering satellites and performing experiments in space, and carefully weighed the possible loss of future commissions if another delay made them appear unreliable. Unfortunately, revenues took priority over safety and the O-rings did fail to seal the booster, releasing flames that ignited the main fuel tank, causing the nightmare that gripped everyone watching: the loss of the *Challenger* and the ultimate sacrifice of seven astronauts.

In the months that followed, several key NASA employees were released; astronauts withdrew from the program, angered that their safety was so easily compromised; and the shuttle program was suspended for almost two years in order to redesign the shuttle and reorganize a more effective quality control system.

By the end of the twentieth century, the shuttle program had an active launch schedule; for instance, placing the 10-ton Hubble Space Telescope in orbit led to production of images of space ten times more detailed than those taken from observatories on Earth. The shuttles also supported the construction and servicing of the International Space Station. Over the years personnel on several flights have conducted experiments on how space travel affects the human body and the affects of micro gravity on a variety of organisms and objects.

Unfortunately, on February 1, 2003, the space shuttle *Columbia* disintegrated over Texas upon reentry into the earth's atmosphere. As was the case with the *Challenger*, all seven crew members lost their lives in the tragedy. The shuttle's breakup was attributed to a problem with the left wing that was caused when foam insulation fell off the craft. Once again, Americans face difficult questions about the future of the space program.

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HUMAN KNOWLEDGE

In 1980, the World Health Organization announced that smallpox—once a feared killer disease—had been eradicated. Advances in organ transplant techniques, the development of a genetically engineered vaccine for hepatitis B, and the beginning of the Human Genome Project were all biology-related successes that were overshadowed by the era's defining puzzle: the search for a way to combat the elusive HIV virus and the growing AIDS epidemic.

Scientists continued to turn their attention to environmental matters in the 1980s. When Canadian officials announced that thousands of fish in their lakes had been poisoned by pollution from U.S. industrial processes, the world took notice of the destructive effects of acid rain. In 1985, British scientists confirmed that a hole in the ozone layer existed over Antarctica, an effect caused by years of chlorofluorocarbon chemical use in many modern products. During the decade, the last wild California condor was taken into captivity, in order to save the species from extinction.

At Fermilab in Chicago in 1985, physicists tested a powerful new particle accelerator, colliding antimatter with matter. The sum of the masses of the particles generated after the collision was greater than the sum of the masses of the particles undergoing the collision, because in the process, kinetic energy was converted into mass according to Einstein's famous $E=mc^2$ equation. The world's largest "atom smasher," as the particle accelerator was called, allowed scientists to study many new kinds of matter that result from high-energy particle collisions. In 1986 and 1987, physicists discovered materials that exhibited superconductivity at relatively high temperatures, which led to excited speculation about future commercial applications. The close of the decade brought controversy and scandal, as the achievement of "cold fusion" was triumphantly announced and subsequently discredited.

Cold Fusion and the Nature of Science

On March 23, 1989, B. Stanley Pons, chairman of the University of Utah's Chemistry Department, and Martin Fleishmann of the University of Southampton, England, held a press conference to make an astonishing announcement: they had produced a successful fusion reaction at room temperature; or what was called cold fusion. The announcement stopped both the scientific community and the public at large in their tracks, because the results violated known physical laws and simultaneously encouraged speculation about an imminent end to the energy crisis. Internationally, scientists scurried to replicate the experiment.

What are fusion and cold fusion? The identity of any given element is determined by the number of protons in its nucleus. For example, atoms of hydrogen always have one proton in their nuclei; atoms of helium always have two protons; atoms of carbon always have six protons; and so on. Atoms also generally have neutrons in their nuclei, but the number of neutrons can vary, even among atoms of the same element. Such atoms, which have the same number of protons but different numbers of neutrons, are called *isotopes*. Hydrogen, the simplest element, has three different isotopes: protium has one proton and no neutrons, and is known as "ordinary" hydrogen; deuterium holds one proton and one neutron; and tritium contains one proton and two neutrons. The extra neutrons add mass, but do not change the basic chemical characteristics or behavior of the element. When atoms of the hydrogen isotope deuterium fuse together and form an atom of helium, an enormous amount of energy is released in a thermonuclear (very high temperature) reaction called *fusion*.

Fusion occurs naturally on the sun under ideal conditions of immense pressure and high temperature (millions of degrees), which are needed to initiate and sustain this thermonuclear reaction and fuse the deuterium together. The process occurs on Earth when an atomic bomb explodes: initially, a different fusion reaction occurs in order to create sufficient conditions for a subsequent fusion reaction to take place. "Cold fusion" is described as a room-temperature process that releases nuclear energy as heat in a metal such as palladium or titanium by packing it with hydrogen. According to scientific principles, high temperatures are needed to start the fusion reaction, making it extremely unlikely that cold fusion can occur in the laboratory.

Although Pons and Fleischmann gave very few details of their experimental process and data when they announced that they had achieved cold fusion in the laboratory, they did indicate that they had used electrolysis (a process that passes electrical current through a liquid to promote a chemical reaction). The two scientists immersed palladium and platinum electrodes into heavy water (water in which deuterium replaces ordinary hydrogen) and claimed that the palladium rapidly absorbed the deuterium atoms until the protons were so closely packed that they fused into helium, simultaneously releasing unpredictably large amounts of heat energy and melting the palladium electrode. The scientific community and the media received this news with responses that varied from honor to ridicule. If cold fusion could be achieved, it could serve as a remarkable new cheap, clean energy source.

The nature of science and the scientific process. For centuries, scientific research has sought to emulate a process outlined in a book written in 1668 by the Italian scientist Francesco Redi. In his study of maggots, Redi repeated the same experiment in many different ways, modifying only one variable at a time. To this day, many scientists commit to follow well-established methods that rest on the logic of experimentation introduced by Redi. The results of scientific experiments ideally evolve over centuries to provide a reliable framework for new theories, hypotheses, and discoveries. Scientists design experiments to individually account for variables that may affect a hypothesis, and replicate the process several times to account for possible instrumentation or measurement errors. After analyzing the data, they draw a conclusion and try to answer any relevant questions.

The process does not end with an announcement and uncritical acceptance of individual results. Instead, scientists are obliged to share information with professional peers through a review process that carefully critiques the clearly described experiments. Other scientists may attempt to replicate the experiment, and validate or challenge the scientific processes used by the original researcher. It is the nature of scientific research to invite others to replicate and evaluate one's work.

What went wrong? Ultimately, the cold fusion experiments were found to be based on unsound research. When Pons and Fleischmann finally did submit their paper to the British research journal *Nature*, it was rejected on grounds of insufficient details and lack of validity. Consequently, a $25 million federal funding request to continue their research was denied.

Several specific criticisms were launched at Pons and Fleischmann, the first questioning their experimental techniques. Stirring the solution during electrolysis is standard practice in order to balance the temperature throughout the reaction environment; however, Pons and Fleischmann did not stir the solution. Critics charged that this contributed to the reported elevated temperature and the melting of the palladium electrode. More important, no one could clearly explain the mechanism producing the heat. Additionally, Pons and Fleischmann did not test for or measure the production of helium as a product of the cold fusion.

In an age when communications are rapidly exchanged through fax, Internet, and telephone, many scientists feel pressured to document and patent their discoveries before someone else registers the idea. Huge financial incentives also put pressure on institutions and laboratories to promote discoveries in haste, perhaps leaving the scientific study partially undeveloped and faulty. These reasons may partly explain why Pons and Fleischmann prematurely released their findings to the press, before peers could appropriately review their process and results. Nevertheless, many scientists found the declaration of successful cold fusion to be a poor judgment, especially when Pons and Fleischmann refused to disclose detailed procedures, thereby inhibiting peer review and replication experiments. Despite the cold fusion disappointment, many scientists continue to search for a method of supplying low-cost, environmentally friendly fuel.

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Chapter 10

THE NINETIES

SOCIETAL CONTEXT: LEARNING AND LIVING DEMOCRACY

Few scholars at the beginning of the 1900s could have predicted the state of the world by century's end. The political climate of the globe had undergone an amazing transformation: from monarchies, totalitarian regimes, and colonial occupation to struggling new democracies. In the course of change, the world twice erupted into devastating global battles, and a Cold War of ideological rhetoric heightened tensions and triggered speculation about the demise of humanity.

At the beginning of the 1990s, many nations throughout the world were poised to begin their unique experiment in democracy. Brought on largely by the collapse of communism and the overthrow of dictators by rebel groups throughout the 1980s, changes in the political landscape were profound. As many countries came to terms with new ways of operating—frequently in the face of harsh economic realities—civil strife was too often an unfortunate result. Long-standing ethnic tensions; leftover struggles against dictators; remnants of colonial injustices; and institutionalized corruption all contributed to violent flare-ups as nations embarked upon a journey to redefine themselves, particularly in eastern Europe and Africa. By the final decade of the twentieth century, the United States had become the last remaining superpower and, in some ways, an "elder statesperson" of democratic ideals.

Events that marked the 1990s in the United States would command a self-examination befitting its leading role in the "new world order," as President George H.W. Bush named it. American involvement in the Persian Gulf under Operation Desert Storm prompted some to question—once again—our dependence on energy resources that are in increasingly short supply. From another angle, U.S. actions would hint at a policy struggle that continues today: that between globalization and unilateralism.

Some societal events prompted a reexamination of the nation's collective ethical commitments. Dr. Jack Kevorkian's insistence that terminally ill patients had a right to end their lives exposed new tensions on legal and moral fronts. The polarization of everyday perspectives along racial lines crystallized most evidently during two sensationalized trials of the 1990s: that of former football star O. J. Simpson, accused of murdering his wife and another person, and that of white police officers caught brutally beating a black suspect, Rodney King, during an arrest.

The impetus for reflection also came from the actions of America's young people. During the 1990s, a string of school shootings perpetrated by adolescents—the most deadly of which came in April 1999 when two students wounded twenty-three, killed one teacher and twelve classmates, and then committed suicide at Columbine High School in Colorado—prompted horror and disbelief. Many were compelled to consider the impact on children of the tolerance for violence and the lack of compassion that had seemingly come to characterize American life in the latter part of the twentieth century.

Democracies require the expression of conflicting ideologies through politics, but during the 1990s, some in the United States saw reasons to wonder where the line of expression should be drawn. The investigation, impeachment, trial, and acquittal of President Bill Clinton, because of a personal relationship with a White House intern deemed inappropriate, invited the nation to consider "the character question" in politics. Are the private lives of public officials subject to political debate? Can top-ranking officeholders even have "private" lives? Ironically, revelations about the personal lives of many of Clinton's most vocal critics led to their own departure from public office. The partisan divisions that infected the government during the course of these incidents left many questions about the effectiveness of the political process unanswered.

If the saga of President Clinton was evidence that political zeal could harm lives, other events during the 1990s showed definitively that unchecked ideological zeal could destroy them. The assassination of doctors at abortion clinics by right-to-life, anti-abortion groups shocked the nation. But more sinister tragedy lay ahead: on April 19, 1995, the country suffered one of its worst losses of the century, when a homemade bomb blew apart the Alfred P. Murrah Federal Building in Oklahoma City. Two citizens, angry and resentful of U.S. government policies, killed 168 people in an act of civil terrorism. The challenge for the United States at century's close—to come to terms with its own tensions while serving as a democratic exemplar for allies around the world—would serve as a lesson in balancing humbling internal strife with superpower might.

ARCHITECTURE & ENGINEERING

International Space Station

In November 1998, the first assemblages of the International Space Station (ISS) were placed into orbit. The event marked a tangible beginning to a massive, multi-year, multinational, multibillion-dollar undertaking to build an inhabitable research lab in outer space that continues today. According to the National Aeronautics and Space Administration (NASA), which oversees the ISS project, the station will eventually consist of more than 100 components that must be assembled over eight years. About forty spaceflights will be necessary to deliver ISS parts and supplies, and 160 space walks will be needed to build and maintain the structure. Although other space stations had been launched and used since the 1970s, in many ways the ISS represents a new level of architectural and engineering intricacy.

Space station history. During the Cold War, the Soviet Union and the United States independently developed operational space stations. Russia sent up the first space station, known as *Salyut 1*, in 1971. A crew of cosmonauts lived on the station for a little more than three weeks; however, they died in an accident upon returning to Earth. As a result, the Russians focused on doing more research, and eventually developed a second station. Space station *Mir* was launched in 1986, incorporating the fruits of technological development that had resulted from the *Salyut* program. For years *Mir* remained constantly occupied; crew members stayed for long stretches (even over a year), and vehicles traveled back and forth to replenish supplies. Although *Mir* was meant to be a long-term project, it was eventually abandoned as the ISS became a more pressing and profitable endeavor for the Russian nation.

Meanwhile, in the United States, the first space station became operational in 1973, when *Skylab 1* was launched into orbit. Unfortunately, *Skylab* was plagued with problems; it was damaged at liftoff, and had to be fixed by astronauts during a space walk about 10 days after it was sent into space. The repairs were sufficient to allow astronauts on three missions to spend a total of 171 days in *Skylab*, doing scientific research. However, in 1974 the U.S. abandoned the *Skylab* project; plans were to eventually place it into a different orbit. Four years later, a solar flare helped destabilize *Skylab*'s position in space, and by 1979 it had reentered the earth's atmosphere, disintegrating and crashing into the ocean near Australia.

Despite the public embarrassment of *Skylab*, in 1984 President Reagan announced his desire to build and operate an international "Space Station Freedom." Fourteen countries joined the United States to try to realize Reagan's vision (Canada, Japan, Brazil, Great Britain, France, Germany, Belgium, Italy, the Netherlands, Denmark,

Figure 10.1.
Russia's *Mir* space station provided valuable background information for the development of the ISS, 1995.

Norway, Spain, Switzerland, and Sweden). But perhaps the most momentum was gained when, in 1993, after the collapse of communism, Russia joined the ISS project, contributing its years of experience and expertise with space station technology. Beginning in 1994, the United States and Russia prepared for the construction of the ISS by docking the U.S. space shuttle with *Mir* on nine separate occasions. These missions helped the nations gather information that would guide the development of the ISS.

ISS architecture. Building a lasting space structure requires extensive planning and lots of time. In some ways, it is like a cosmic version of a prefabricated home; separate modules are transported to the building site, where they are put together. Of course, because of the specialized nature of the component parts and because of the unique environment of the ISS's "building site," the task is quite complex. In combination, human space walks and robotic arms assemble the ISS.

The various structures of the ISS are designed to support life on the station, as well as allow for scientific research. In addition, the station must include provisions for propulsion, communications, and navigation. It is critical that the station be able to link up with space vehicles that can deliver supplies and remove waste from the ISS. And last, a means of quick escape must be available to ISS crew members at all times, in the event of an emergency.

The "backbone" of the ISS structure is a long truss system. The many components of the space station connect to this truss system. The first component of the

ISS launched into orbit was the control module (named *Zarya*), set in place in 1998. *Zarya* houses the engines and command center of the ISS. A module called a *node* was next linked to the ISS to provide connecting points for other elements of the station. A service module was connected to the ISS in 2000. This component, known as *Zvezda*, contained living quarters and life support systems. By November 2000, the first permanent crew members, astronaut William Shepherd and cosmonauts Yuri Gidzinko and Sergei Krikalev, had arrived at the ISS. Later visits to the station led to installation of a solar array used for the electrical power system, a robotic arm, a docking station, and additional truss sections.

The future of the ISS. Although it has had many successes, the ISS has come under question by critics. Some aspects of the project have been more costly than anticipated. The time frame for completing various phases of the project has been subject to delays. There are critics who feel that the large effort being put into developing the space station would be better spent on finding ways to address social and environmental problems on Earth. When the space shuttle *Columbia* disintegrated upon reentry into the earth's atmosphere, killing all seven crew members in February 2003, some people questioned whether the potential cost in human life was too great to justify continuing a heavily funded space program.

Still, proponents argue for the benefits of having a space-based research laboratory. In space, scientists can conduct experiments in an environment of microgravity. Many physical phenomena that behave one way on Earth behave totally differently under microgravity, and researchers contend that learning about these differences can lead to expanded understandings of scientific phenomena, as well as to technological advancements. For example, crystals grow more perfectly in microgravity, and some scientists speculate that harvesting crystals grown in space could lead to better materials for everything from superconductors to medicines. Some of the research being performed on the ISS could be used to develop means for colonizing space, should future societies deem such a task appropriate. Estimates comparing the money put into the space program with the monetary benefits of technology developed as a result of space-based research range from a threefold to a sevenfold return on the government's investment.

The tragic loss of the space shuttle at the beginning of the twenty-first century led to a suspension and reevaluation of some aspects of the U.S. space program. The benefits of the ISS must be weighed against its costs, for all countries involved in the project. As the world becomes more tightly linked through improved communications and transportation throughout the twenty-first century, the scope of cooperative ventures such as the International Space Station will undoubtedly involve complex new dynamics.

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ARTS & ENTERTAINMENT

O. J. Simpson Trial

In June 1994, former football star and Hollywood actor Orenthal James (O. J.) Simpson was accused of killing his ex-wife and a friend of hers in a wealthy California community. Simpson's popularity as a member of the Professional Football Hall of Fame and a star of several well-known movies prompted great public interest in the story. When the case finally went to trial, it was televised across the nation, and for eight months, media and public attention was fixed on the courtroom drama. The science of genetics figured prominently in the story line, as many Americans heard of "DNA fingerprinting" for the first time. In the end, the trial and events surrounding it would come to take on very different meanings for different segments of American society.

The case. On June 12, 1994, Nicole Brown Simpson and her friend Ronald Goldman were found stabbed to death in front of Brown's home near Los Angeles, California. After several days of investigation, the Los Angeles Police Department decided to charge Brown's ex-husband, O. J. Simpson, with the murders. On the morning of June 17, Simpson was supposed to turn himself in to police, and a throng of photographers was waiting to capture the moment on film. Several hours later, police issued a warrant for Simpson, who hadn't shown up. Eventually, police found Simpson's car traveling along a California highway; when they attempted to have the vehicle pull over, a distraught Simpson threatened to kill himself (he was holding a gun to his head while a friend drove the car). The reporters who had missed Simpson's arrest now had another, even more sensational, story. Media helicopters converged on the scene, and tens of millions of television viewers watched the low-speed chase develop over several hours.

Eventually, Simpson was taken into custody, and in time the case went to trial. For more than 130 days, television crews covered the trial. Hundreds of witnesses were called to testify. For his defense, Simpson hired a team of expert, high-priced lawyers who came to be known as the "Dream Team." The courtroom regulars—prosecutors, judge, defense attorneys, and some of the witnesses—became household names across America. The evidence presented during the case was debated on television and radio talk shows, in workplaces, and in homes. One of the crucial pieces of evidence involved the scientific process of DNA fingerprinting.

What is DNA fingerprinting? DNA, or deoxyribonucleic acid, is the molecule that contains the genetic blueprint in each living organism. Except for identical twins, everyone's DNA is unique. Because of this, DNA can be used to establish the identity of a person in situations where such identification is necessary. One example is to establish paternity; the DNA of a child can be compared with the DNA from the mother and a possible father. Since the child will have some of the genetic makeup of each parent, the three sets of DNA can be compared to determine whether a specific man could have contributed to the child's DNA pattern. Another use for DNA fingerprinting is to link a person to evidence left at a crime scene: blood or semen, for example. If the DNA from blood left at a crime scene matches the DNA of a suspect, it can be used to definitively place the suspect at the location in question.

DNA consists of long strands of four kinds of chemical bases arranged in a specific pattern. Actually, much of the human DNA sequence is the same across all individuals, so DNA fingerprinting techniques home in on a section of DNA that is unique. Genes are sections of DNA that give coded instructions for synthesizing a particular protein. In between these genes are sections of DNA called *microsatellites* (or minisatellites). These are more or less random sequences of bases that are unlikely to be precisely the same in any two given people. During DNA fingerprinting, these sections are removed and then separated by a process known as gel electrophoresis. An electric field pushes the DNA fragments through a gel, and they line up according to size. In this way, two different samples of DNA can be compared to determine whether they come from the same individual; if so, they will produce the same pattern of fragments lined up along the gel.

The Simpson trial verdict. Even though DNA fingerprinting is a highly reliable means of identification, other social factors play an important role in whether or not DNA evidence will be used by a jury to convict a defendant. During the trial of O. J. Simpson, prosecutors presented evidence that DNA in blood found at the scene of the murders genetically matched Simpson's DNA. However, the defense attorneys argued that dishonest police officers had planted evidence at the crime scene. In the end, because the jury felt that the actions of the Los Angeles police investigators were suspect, they voted to acquit O. J. Simpson.

The sustained public fascination with the Simpson case intrigued social commentators. Some felt it was the combination of celebrity and scandal that caused viewers to faithfully tune in to media coverage of the case. In some ways, the lengthy trial was a forerunner to the popular genre of "reality television" that swept the entertainment industry by the end of the decade. But the case was most noteworthy for the tendency of viewers to see Simpson's situation in, literally, black and white; black Americans overwhelmingly believed that Simpson was innocent of the murder, and whites tended to believe he was guilty. The incident underscored how very different the same situation can look from dissimilar perspectives, and how very differently whites and blacks experienced life in America.

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COMMUNICATION

The Internet Connects the Globe

In 1990s America, the Internet became a household word. Once, only computer users with specialized interests (such as government, military, or academic groups) had a need to connect and to share information. However, due in part to the tremendous growth of the personal computer industry, developing a large-scale system of communicating between all machines became first a novel idea, and then an imperative. By the end of the twentieth century, logging on to the Internet became an almost essential element of daily life in the United States, for businesses as well as the general public.

History of the Internet. During the Cold War emphasis on technological supremacy, President Eisenhower created the Advanced Research Projects Agency (ARPA), which operated under the Department of Defense. As the importance of computing in scientific and technological research grew, so did the need to share data. By the end of the 1960s, the scientists and engineers working for ARPA wanted to be able to communicate with each other—through their computers—in a convenient and reliable way. ARPANET, a project to develop and construct such a network, was initiated in 1969.

During the 1970s and 1980s, other special-interest groups established networks to link computer users. Universities and large corporations, for example, shared a need for information exchange within their organizations. Soon the advantages of connecting these smaller, localized networks into a larger one was easily recognized. Thus, the National Science Foundation built a connection between university systems in 1986 known as NSFNet—which became an initial major backbone (or highway) of the modern Internet.

By the 1990s, it was clear that a desire to connect to other computer users was no longer the sole interest of a few special-purpose groups. The rise in popularity of home computing meant that the general public could potentially be connected in a vast network used for information-sharing, commercial, or entertainment purposes. Commercial Internet service providers—companies that constructed their own backbones to connect the public—sprang up, and began offering their services to smaller businesses and home computer users. The global reach of the Internet was quickly established, and continues to grow.

As a worldwide communications outlet, the Internet has no "owner": it is just a communications network. However, as in any kind of communication system, it is critical for shared understanding (about language, symbols, signs, practices, etc.) to exist. In 1992, the Internet Society was established to help standardize the technical language and procedures used to keep everybody connected. The Internet Society is a nonprofit group that decides upon and maintains the common means by which all of the different components of the Internet interact with each other.

Structure of the Internet. In broadest terms, the Internet is a communications network of more than 3 million individual computers. Practically, the Internet is a collection of networks of these computers that employs a standardized means for communicating between them. Each machine has an IP (or *Internet protocol*) number that serves to identify it, just as buildings have addresses or people have Social Security numbers. Physically, the computers are connected by telephone or cable lines to an Internet service provider. Service providers connect individual computers into networks, and then connect large geographic areas of computer networks with fiber optic cables. These fiber optic "backbones" are connected across the globe through more fiber optic lines, satellites, or undersea cables through which digital information is quickly transferred.

One way of describing the way that computers talk to each other on the Internet is to characterize them as *clients* and *servers*. Clients are computers that send out requests for services; servers are computers that decode the requests and act on them. When computers receive instructions or information from other computers, they use programs to translate the information into *protocols* that are understood and executed. Clients can request different kinds of services through the Internet; for example, they can ask to send or receive E-mail; send or receive programs; or browse databases of information. Individual computers can act as clients or as servers, or as both. More specifically, servers are the actual *programs* that carry out a set of instructions (not the physical machine). Typically, large computers can actually host many different kinds of servers on the same machine.

Home-based computers generally connect to the Internet directly through an Internet service provider, which is often a commercial company. Businesses or schools may first connect all of the machines in a particular office or campus to a local area network (LAN), and then connect to an Internet service provider to access the Internet. The points at which different kinds of networks connect to one another are called network access points. Traffic flow through these access points is controlled by devices called *routers*. Routers are special computers designed to make sure that requests for information given by a client are directed to the correct server.

Every machine that is connected to the Internet has an IP address to identify it. These IP addresses are numeric; they consist of four different numbers, each one a number from 0 to 255 (there are 4.3 billion different possible combinations of numbers in this system; therefore, there is room for 4.3 billion machines on the Internet). Servers that need to remain available and easily identifiable generally keep the same IP address, called a static IP address. However, machines such as home computers that intermittently log on and off of the Internet are given temporary IP addresses by their Internet service provider at the time they connect, so that they can be identified throughout a particular communication session. In the early stages of the computer networks, clients needed to know the numeric IP address for the server machine they wanted to connect with. Now, a more user-friendly text-based system of "domain names" is used. The domain name associated with a particular IP address helps classify it; for example, ".com" in a domain name refers to the fact that it is hosted by a commercial server, and ".edu" in a domain name indicates that it is associated with an educational institution.

Societal impact of the Internet. The widespread use of the Internet has changed American society in both obvious and subtle ways. Some changes are lifestyle-based; for example, many people now shop for merchandise or search for reference information on their computers, rather than travel to retail establishments or libraries. Individuals who once relied on the telephone or letters to communicate across long distances can now be connected through E-mail networks. More people rely on their home computer to provide entertainment by accessing games, music, or videos from other computers on the Internet. Other changes involve the style of communicating: in a culture where people are accustomed to communicating through face-to-face interaction, computer-mediated communication creates unique dilemmas. What is the equivalent of reading body language in computer-based dialogue? Social rules for communicating via the Internet have been developed (loosely known as "netiquette"), and actual exchanges between Internet users provide interesting topics of study for social scientists to examine.

The proliferation of the Internet has also raised questions about societal practices, priorities, and values. For example, the relative ease with which information can be accessed on the Internet, and the relative anonymity of clients and servers, help increase the possibility for perpetrating fraud. Copyrighted material can easily be "stolen" over the Internet. As more business is conducted over the Internet, the risk of having personal financial information intercepted and used illegally increases. Some policy makers have championed the promise of the Internet as a model vehicle for free speech, because it allows many different kinds of ideas from people across the world to be expressed and accessed. However, others worry about the implications of having some kinds of information easily accessible—for example, information sponsored by hate groups, information on how to build weapons, or pornography.

Without doubt, the Internet has opened unprecedented channels of communication and has the potential to play a major role in shaping the course of history. In the Information Age, access to information is a powerful tool. This fact also troubles many social commentators who are concerned about the potential for the Internet to create a new kind of class system. Rather than functioning as a great equalizer, where ideas from all corners of the globe can be presented and accessed, the Internet often serves as a virtual barrier between global "haves" and "have nots." In other words, those with greater economic means generally have greater access to information; this situation is sometimes called the *digital divide*. It remains to be seen whether the Internet will eventually lessen the impact of existing societal divisions, or solidify and perpetuate them.

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DEFENSE & DIPLOMACY

Stealth Fighters in Desert Storm

In January 1991, President George H. W. Bush ordered the U.S. military to commence Operation Desert Storm. Under the leadership of Saddam Hussein, Iraq had invaded its neighbor, Kuwait, and attempted to gain control of the country's oil supply. The U.S. armed forces became engaged in a battle to compel Iraq to withdraw from Kuwait. Fighting in the Middle East necessitated the use of new kinds of strategies and equipment. One of the signature technologies used during the Persian Gulf War was the stealth aircraft.

The F-117A. During the 1980s, a new type of aircraft was developed for the U.S. Air Force by the Lockheed Martin company. Details of the unique craft were kept secret for several years, but eventually it was confirmed that the F-117A was the world's first operational stealth aircraft. The idea behind "stealth" technology is to remain undetectable by conventional means, such as radar.

Radar (*ra*dio *d*etecting *a*nd *r*anging) technology was used throughout the twentieth century for tracking, locating, and mapping various objects. In simplest terms, radar systems work by sending out beams of electromagnetic radiation, and then collecting these beams after they have been reflected back to a detector. By measuring the energy and angle of the received beam, it is possible to calculate the position and/or velocity of the object that reflected the radiation.

Stealth aircraft are designed to corrupt the process of radar detection by two distinct methods. First, such a plane has many small, angular sections rather than the smooth, continuous lines of familiar aircraft designs. Thus, radar beams are scattered away from the detector, or reflected at unexpected angles. In this way, beams that are reflected tend to give false information to receivers which collect them; for example, large aircraft instead can appear to be small birds. Second, a stealth aircraft can be covered with a special surface that absorbs radar energy, thus contributing to inaccurate detector readings.

Stealth technology in the Gulf War. During Operation Desert Storm, F-117A aircraft equipped with laser-guided bombs flew nighttime missions. The craft used infrared beams to create a map of the space in front of and below the plane, which could be viewed by the pilot on state-of-the-art cockpit display screens. The pilot could fix a laser beam on an intended target and release a "smart" weapon that would use sensors to continually detect and home in on light from the reflected laser, making the bombs highly accurate. According to a summary report on Air Force performance in Desert Storm, the F-117A flew only 2 percent of the total air sorties in the campaign, but struck about 40 percent of the strategic targets identified by the U.S. military.

The F-117A aircraft used in the Gulf War also contributed to a psychological advantage the United States had over Iraq: the planes were expensive and complex, and uniquely "superpower" weaponry. Although some modern militaries claim to have developed ways to make stealth aircraft easier to detect, they are still considered to be one of the most effective technologies available in modern times.

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Stealth aircraft were used during Operation Desert Storm.

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ENVIRONMENT

Earth Summit Held in Rio de Janeiro

For two weeks in June 1992, representatives of 172 governments attended the United Nations Conference on Environment and Development. Over 2,000 representatives of special-interest nongovernmental organizations also attended the conference. Dubbed "The Earth Summit," the conference brought countries of the world together in order to address the issues that arise when economic practices destroy the world's environment. One outcome of the meeting was the U.N. Framework Convention on Climate Change, which addressed the responsibilities of nations to help alleviate the threat of global warming.

What is global warming? Over the last century, scientists have noted a sharp rise in average surface temperatures measured across the planet. This trend has been significant in comparison to the average temperatures for the last 1,000 years. Other noticeable transformations related to warmer climates include a decrease in the amount of snow and ice covering the earth, from mountains to arctic glaciers; a lengthening of the growing season in the world's middle latitudes; and some warm-weather animal and plant species expanding their habitats. This trend in climate change has been called *global warming*. Scientists theorize that human activities, most notably those related to the industrialization of the planet, are responsible for contributing to this temperature change.

When scientists notice a trend such as global warming, they hypothesize about the causes of the trend and devise methods of testing their hypotheses, mostly, in this case, through observations and computer simulations. Climate scientists know that the earth's average surface temperature range is kept fairly constant by a balance of natural processes. Initially, energy comes to the earth from the sun; the earth absorbs the energy, and then reradiates it as heat. The atmosphere then helps insulate the earth by trapping some of the heat it radiates and allowing some of it to escape into space. If changes occur in the activity of the sun, or in the composition of the atmosphere, this temperature-moderating process could be affected. Furthermore, if the effects are due to changes in the atmosphere, then these changes might be due to natural events of some kind, or they might be due to human activities—which have released pollutants into the atmosphere for several hundred years. Scientists who have carefully studied the phenomenon of global warming, most notably the United Nations Intergovernmental Panel on Climate Change (made up of more than 2,500 climate scientists from about 100 different countries), believe that human contributions to changes in the composition of the atmosphere are the factor most significantly related to global warming. In the United States, the National Academy of Sciences, the American Meteorological Society, and the American Geophysical Union also have taken the position that human activity is largely responsible for climate change during the twentieth century.

How do human activities change the atmosphere's function? The atmosphere helps regulate the earth's temperature through a process called the *greenhouse effect*. The greenhouse effect refers to the way in which the atmosphere traps some of the heat radiated by the earth's surface in order to keep it warm; this is analogous to the way a greenhouse allows light from the sun in through the glass, and then traps the heat inside the greenhouse when it is reradiated (the way the closed windows in an automobile can allow it to quickly warm up on a hot day). The atmosphere is a mixture of gases, and some gases are primarily responsible for absorbing heat in this way; these gases are known as *greenhouse gases*. The most significant of these gases is carbon dioxide.

When fuel such as coal, oil, or natural gas is burned, the fuel (a hydrocarbon, or compound containing carbon, hydrogen, and sometimes oxygen) combines with oxygen; water and carbon dioxide are the products of the reaction. So, for example, each car that is powered by an internal combustion engine or each power plant that uses combustion to create electricity releases carbon dioxide into the atmosphere. Natural processes on the earth work to keep the amount of carbon dioxide in the atmosphere in check. Plants take in carbon dioxide during the process of photosynthesis. For this reason, large forests are often referred to as "carbon sinks"—because they help absorb carbon dioxide from the atmosphere. However, as humans cut down trees to clear land for development, the earth loses some of its ability to regulate carbon dioxide in the atmosphere. Comparisons of the relative amount of carbon dioxide in the atmosphere from several hundred years ago (before modern societies were highly industrialized) with today indicate that CO_2 levels are 31 percent greater today.

What are the probable effects of global warming? The Intergovernmental Panel on Climate Change has predicted that the earth's average surface temperature could increase between 2.5° and 10.4° F between 1990 and 2100. The low-end figure may not seem significant, because as humans, we are used to thinking of temperature in terms of daily weather. To us, whether the temperature is 73° F or 75° F doesn't seem to matter. It is important to realize that estimates for global warming refer to the *average temperature increase* across the planet. This means that a significant number of daily temperatures will be higher enough than what was "normal" in 1990 to cause the average to rise several degrees. Scientists cannot know absolutely what effects such warming will bring, but models show that it is significant enough to cause more ice to melt, leading to rises in ocean levels. It also can cause changes in agricultural processes and ecological relationships across the planet. To put the predicted climate change in perspective, it is noteworthy to recognize that throughout the last 10,000 years, the average temperature on Earth has not varied by more than 1.8° F, and that during the last ice age, average temperatures were only 5–9° F colder than they are today.

What happened to the Framework Convention on Climate Change? The Framework Convention on Climate Change, drawn up at the Earth Summit in 1992, was a document acknowledging that human activities contribute to global warming, and called for its signatories to develop protocols for reducing the amount of greenhouse gases released into the atmosphere by their citizens. It was signed by 188 nations, including the United States. In December 1997, the first of the protocols called for in the treaty was negotiated at a meeting held in Kyoto, Japan—it is known as the Kyoto Protocol. The Kyoto Protocol specifies that by 2010, industrialized nations must collectively reduce their emissions of greenhouse gases by 5.2 percent, compared to the levels emitted in 1990. There are also incentives to reduce emissions even more than required; nations that do so would be able to sell "emissions credits" to nations that are having trouble meeting their target levels. For the agreement to go into effect, it was mandated that a certain percentage of the nations that were signatories of the original Framework Convention ratify the protocol.

At the beginning of the twenty-first century, more than 100 countries have ratified the Kyoto Protocol; the United States has not. President George W. Bush has argued that cutting emissions would be too costly to American businesses, and thus to the economy as a whole. There are organizations in the United States that resist the scientific findings of human impact on global warming, and continue to argue that natural causes are more responsible for climate change; that climate change is too insignificant to affect life on Earth; or that the best strategy is to "wait and see" what happens as a result of global warming before enacting measures to control it. Many professional scientific organizations dismiss arguments such as these, for two reasons. The first reason is scientific: although some of these positions are based on legitimate scientific proposals (for example, natural causes as well as human causes contribute to global warming), meta-analysis of the vast number of studies done on climate change shows that human impact is most significant. Second, the research conducted by global warming skeptics tends to be sponsored by industries that would be hurt financially by requirements to control greenhouse gas emissions; thus, it can be said that these studies are not sufficiently objective or bias-free. The phenomenon of global warming illustrates how societal activities can have an impact on the natural environment, and the arguments surrounding it serve to illuminate the fact that science itself is a human endeavor, subject to societal influences and pressures.

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FOOD & AGRICULTURE

Dolly the Sheep Is Introduced to the World

On February 22, 1997, researchers at the Roslin Institute in Scotland announced the startling news that they had succeeded in cloning a sheep. The team of scientists led by Ian Wilmut had been trying to find a way to develop an ideal breed of sheep for agricultural production. Dolly, as the sheep was named, had been born over half a year earlier, but she was kept secret until the February announcement. By and large, the world was caught off-guard, and the question on many people's minds was this: Did the achievement of producing a living, apparently healthy mammalian clone mean that human clones were a not-too-distant possibility?

What is cloning? In the context of Dolly's birth, *cloning* refers to a process of making an exact genetic copy of a complete living organism (*cloning* can also refer to the process of copying a gene from a strand of DNA). Dolly's DNA was an exact copy of another sheep's, so she was a genetic clone. Cloning occurs naturally in a few different ways. Asexual reproduction is one way of producing a clone; some kinds of plants have long runners that shoot out from them, then produce roots and grow into another plant which is an exact copy of the original (potatoes, grass, and strawberries, for example). Another form of natural cloning takes place when identical twins are born. At the time of fertilization, the zygote splits into two identical cells, each of which develops into an individual organism. These organisms are genetic copies of one another, or clones.

How was Dolly created? Dolly was created through a laboratory technique known as *somatic cell nuclear transfer*. Normal mammalian reproduction occurs when an egg cell from a female is united with a sperm cell from a male. The egg and the sperm each contain half of the genetic information that will determine the individual characteristics of the resulting offspring. In somatic cell nuclear transfer, *all* of the genetic material is provided to an offspring by one parent. The regular nucleus of an egg cell (which contains half of a strand of DNA) is replaced with the nucleus of a cell from the animal to be cloned (which contains all of that animal's genetic material). Next, the egg is stimulated so that it begins to divide the way a normal egg would after it is fertilized. The egg is then implanted in a surrogate mother animal, where it grows and develops, and eventually the cloned mammal is born.

Before Dolly, the technique of somatic cell nuclear transfer was first used in the 1970s to clone frogs. Researcher John Gurdon had succeeded in creating tadpole clones, but none of them survived to become adult frogs. In fact, Ian Wilmut's team tried 276 times before Dolly was successfully cloned. Although other animals have been cloned since Dolly (e.g., mice, a pig, a monkey, cattle, a deer, and a horse), the technique has a high rate of failure. Many of the eggs do not develop properly, or animals that do live, have relatively short lives. Although Dolly lived a relatively healthy life for six years and produced her own offspring by natural means, there are still many unknown factors about the effects cloning might have on the life cycles of animals.

To clone or not to clone. Researchers list several reasons for trying to clone living organisms. One is similar to the reason why Dolly was created: to effect a different kind of "selective breeding" for animals that are used for human purposes. For example, if a certain kind of cow produced more milk, agricultural researchers might want to try to clone that cow to make milk production more efficient. Historically, selective breeding is accomplished by carefully selecting male and female mates with desirable characteristics, in order to produce offspring that also have the desirable characteristics. However, when sexual reproduction is used, there is always the possibility that desired characteristics will disappear from the genetic information of offspring (i.e., "breeding out" the sought-after qualities). Another reason researchers have given for cloning animals is to help save endangered species; if only one animal of a species remains, for example, it could not reproduce sexually, but it could pos-

Figure 10.3.
Since Dolly, scientists have cloned other animals, like this first transgenic cow clone engineered to resist disease. Photo by Scott Bauer, permission granted by the USDA, Agriculture Research Service.

sibly be cloned rather than be fated for extinction. In the early twenty-first century, researchers cloned an endangered ox from India and Asia known as a gaur (which subsequently died of an infection).

Other researchers and ethicists have given reasons for not engaging in cloning. Some object to the costs and time involved in the procedure, arguing that money for agricultural research, for example, could be spent more efficiently. Some fundamentally object to experimentation with creating life through cloning, because it can be seen as an example of humans "playing God"—determining what course nature should take rather than allowing it to develop free of human manipulation. Many observers of the cloning debates draw a distinction between animal and human cloning, feeling that the latter would be unethical in a way the former is not. A main reason that many protest human cloning is because of the high failure rate of the procedure; many clones would almost certainly die and others might suffer from complications throughout their lives.

Despite objections, and even bans placed on cloning research by governments across the world, some scientists have announced an intention to study human reproductive cloning. And despite the feelings of horror expressed by some at such announcements, others welcome the opportunity for human clones. Literature and films have toyed with the idea of making human "copies" for years, but scientists point out that human clones would be *genetic* copies only; the environmental factors that work to shape a person's identity would be entirely different for a clone than for the adult DNA donor. As in many other historical instances of technology development, human cloning has the potential to move from science fiction to everyday reality. Perhaps the one certainty about cloning is that the saga will continue to unfold throughout the twenty-first century.

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MEDICINE & HEALTH

Cigarette Smoking Dangers Admitted

During the last decade of the twentieth century, public attention was intently focused on the dangers of cigarette smoking. In 1997, attorneys general from forty states filed lawsuits against the major cigarette companies, claiming that for years these companies willfully misrepresented the extent of the dangers of smoking. Citing the high costs of health care for smoking-related illnesses and the growing phenomenon of teen smoking, states sought to make the tobacco industry culpable for these problems. By 1998, the industry had reached agreements with all fifty states to pay restitution and to change its practices.

History of tobacco use and lung cancer. Tobacco was introduced into Europe in the sixteenth century and rapidly became popular, especially when smoked in pipes and later as cigars. Cigarette smoking did not become prevalent until the 1880s, when machines were designed to mass-produce cigarettes, making them affordable to the general population. However, it was during World War I, when cigarette companies gave free cigarettes to millions of soldiers, that smoking became common among men. Women seldom smoked until after the 1920s, when the women's suffrage movement sparked many lifestyle changes for women; even so, compared to men, few women smoked.

Prior to the introduction of cigarettes, lung cancer was virtually unheard-of in medical journals. In 1914 there were about 0.7 case of lung cancer per 100,000 men. In 1930, the figure increased to 3.6 per 100,000 men; and in 1950 the number swelled to 19.5 cases per 100,000 men. By 1960, the number of lung cancer cases almost doubled to 35.2 per 100,000 men. Since it takes twenty to forty years for cancer to develop, it is not surprising that the American Cancer Society found in a study done in the early 1950s that there was an irrefutable link between smoking and the development of lung cancer in men. This would later hold true for women;

females greatly increased their consumption of cigarettes in the decades that followed, when advertisements for smoking heavily targeted women in the 1930s and again in the 1970s.

As an increasing number of reliable scientific studies of the 1950s and 1960s pointed to the health risks of smoking, governments in industrial countries were urged by health officials to intervene. Cigarette smoking was a "pleasure" of affluent countries that had not yet reached the underdeveloped countries of the world. In fact, by the 1970s, lung cancer was the most prevalent fatal cancer in the Western world.

Surgeon General's cigarette warning. In 1962, the Advisory Committee on Smoking and Health to the Surgeon General was appointed to review and evaluate scientific research studies on the health consequences of cigarette smoking. The committee's 1964 report stated: "Cigarette smoking is a health hazard of sufficient importance in the United States to warrant appropriate remedial action." By correlating a variety of statistical population studies, clinical and autopsy studies, and animal experiments, the committee showed that "cigarette smokers have substantially higher rates of death and disability than their nonsmoking counterparts." The committee also concluded that cessation of smoking or considerable reduction in the number of cigarettes smoked could delay or avert a substantial portion of deaths and disabilities from lung cancer and cardiovascular disease. There was a direct relationship between death rates and exposure to cigarettes (where "exposure" takes into account the number of cigarettes smoked, strength of inhalation, and age at which smoking began).

The 1964 committee report found a causal relationship between smoking and lung cancer, as well as smoking and chronic bronchitis. A follow-up report, *The Health Consequences of Smoking, a Public Health Service Review: 1967*, added evidence which "strongly suggests that cigarette smoking can cause death from coronary heart disease." The results of a study conducted by Drs. E. Cuyler Hammond and Daniel Horn of the American Cancer Society in the early 1950s showed that the death rate for heavy smokers was 75 percent higher than for nonsmokers, and that the cancer rate was 2.5 times as great among heavy smokers. The death rate from heart disease was almost twice as high among heavy smokers as among nonsmokers. Other diseases that were suspected to be linked to smoking included cancers of the esophagus, larynx, mouth, tongue, throat, kidney, bladder, and pancreas; stomach and duodenal ulcers; liver cirrhosis; and respiratory disease such as asthma. As women joined the ever-growing number of smokers, an increased risk of miscarriage, premature births, and babies with low birth weight was attributed to smoking during pregnancy.

As a result of the many studies conducted during the mid-1900s, Congress approved the Federal Cigarette Labeling and Advertising Act of 1965, which required a warning on all cigarette packages that read: "Warning: The Surgeon General Has

Determined That Cigarette Smoking May Be Dangerous to Your Health." Five years later, in 1970, Congress enacted a stronger message to be printed on all cigarette packages: "Warning: The Surgeon General Has Determined That Cigarette Smoking Is Dangerous to Your Health." Laws were also passed to ban cigarette advertising in broadcasting media.

What is cancer? The body is made up of bones, muscles, nerves, blood vessels, and organs that are themselves made up of cells. The growth processes of living things take place at the level of the cell, the smallest unit of life. Individual cells differentiate according to their type and function; for example, some cells form brain tissue and others form lung tissue. Most individual cells are too small to be seen by the naked eye, but they grow by dividing into two cells, which continue to divide to form the visible tissues and organs of the body. When cells grow out of control, lack the ability to differentiate their form and function, and invade other tissues and organs, they are considered *cancer*. Cancer develops when damage to normal cell DNA occurs and cannot be repaired by normal body mechanisms. This abnormal growth of cancerous cells usually forms as a tumor. The cancer cells *metastasize*; that is, grow and take over normal cells that have appropriately stopped growing. Not all tumors are cancerous, however; benign or noncancerous tumors rarely take over other organs. The name of a cancer is determined by where the cancer started; lung cancer starts in the lungs. Each type of cancer has different symptoms, rates of growth, and treatments.

Environmental conditions such as pollution, high-fat diets, alcohol intake, smoking, and sun exposure provide the need for additional body repair beyond the normal process related to growth and development. With each repair, cells divide, providing a chance for abnormal cells to form. Cancers are associated with a series of changes that occur over a number of years, not just one cell change.

Why do cigarettes cause cancer? Tobacco products have been used for centuries. Why, then, has lung cancer increased alarmingly over the last several decades? The answer lies in the difference between cigarette and pipe or cigar smoke. Smoke from cigars and pipes, if inhaled deeply, causes people to become nauseated and cough. The alkaline nature of the pipe and cigar smoke makes it unpleasant to inhale. Therefore, little smoke reaches the bronchial tubes deep in the lungs.

Cigarette smoke, on the other hand, is neither alkaline nor acidic. Many smokers find it gives a lightly pleasant feeling when inhaled deeply. But deep inhalation means that cigarette smokers retain 90 percent of the substances found in the smoke in their lungs. This is equivalent to a cup of tar a year for each pack smoked per day. Tar is the greasy hydrocarbon residue resulting from burning of the tobacco. Tar, along with several cancer-causing substances, collects in the mucous membranes of the bronchial tubes and lungs. The nature of cigarette smoking also causes the smoke to bypass the effective filtration system of the nose, trapping most of the tar and nicotine in the lungs.

Nicotine, the other major dangerous component of cigarette smoke, is a powerful poison and is lethal if taken in a 70 milligram (1/400 of an ounce) dose. Seventy milligrams is equivalent to the amount found in two packs of cigarettes. However, if nicotine is metabolized slowly, its danger is not as apparent. Nicotine is addictive and reacts with neurons in the nervous system; it causes the release of a chemical called dopamine from these neurons, which induces feelings of pleasure. It has been determined that the more a person smokes, the more addicted he or she becomes, and that the pleasure is enhanced over time, making it more difficult to stop smoking. The tar and nicotine content of cigarettes was regulated to decline from 35 and 3 milligrams, respectively, in the 1960s to 15 and 1 milligrams, respectively, at the end of the century.

Litigation against the tobacco industry. It is now known that the majority of smokers start to smoke in early adolescence. According to the American Lung Association, at the beginning of the twenty-first century, each day, 4,800 adolescents (ages eleven to seventeen) smoke their first cigarette, and 2,000 of these (a total of 730,000 annually) will become regular smokers.

Several educational campaigns since the 1950s have attempted to curtail teen smoking, but they seem to have been counteracted by clever cigarette advertisements that appeal to teenagers and young adults. Although ads tended to focus on the youthful spirit, sex appeal, and independent nature of smokers, cigarette manufacturers routinely claimed that they were not marketing to teenagers. Opponents strongly disagreed, and gained governmental and public support during the 1990s. In 1996, the Food and Drug Administration issued regulations that limited billboard advertisements; restricted the type of printed materials that could advertise cigarettes; curtailed product giveaways, including samples and items with brand name logos; barred cigarette vending machines in places that children frequent, such as restaurants; and required photo identification for buyers who appeared to be under the age of twenty-seven years.

Toward the end of the twentieth century it was proven that secondhand smoke can cause lung cancer and other smoke-related diseases in nonsmoking adults and children. The research seemed incontrovertible; however, in the years between 1950 and 1993, 800 personal injury claims were filed against the tobacco industry, and none were successful. After increasing pressure and lawsuits from the federal and state governments, in 1998 the tobacco companies agreed to pay $10 billion a year to compensate states for the health care the states provided to smokers contracting lung cancer and other smoking-related diseases. Some states also passed stricter regulations on smoking; after the link between secondhand smoke and cancer was brought to light, many states employed the Clean Air Act to eliminate smoking in public places such as stores, theaters, restaurants, and workplaces. It is estimated that one-quarter of the adults in America choose to smoke today. It remains to be seen how the tobacco settlement and government restrictions put in place during the 1990s will affect the public health of the nation.

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TRANSPORTATION

Air Bags Required in Automobiles

Although there have been automobile crashes for as long as there have been automobiles, it wasn't until the second half of the twentieth century that the U.S. government got involved in regulating automobile safety. The publication of Ralph Nader's *Unsafe at Any Speed* in 1965 helped call attention to some of the safety problems associated with automobile design, and enough public interest was aroused that in 1966, President Johnson signed the National Traffic and Motor Vehicle Safety Act, which required the government to set safety standards for new model vehicles. By 1970, the National Highway Traffic Safety Administration (NHTSA) called for the phase-in of mandatory passive restraints (seat belts) in cars. During the 1980s, some car manufacturers had installed workable air bags, devices that deployed in the event of a head-on collision to provide a shock-absorbing cushion between the driver and the dashboard. In 1991, President George H. W. Bush endorsed a mandate for new safety standards when he signed legislation requiring that beginning in the 1998 model year, all cars come equipped with dual passenger air bags.

The idea of air bags. The motion of an automobile is governed by the physical laws of mechanics. When a car is in motion, it tends to stay in motion because of a property known as *inertia*. This is Newton's First Law of Motion. If a car suddenly comes to a stop (for example, because it has crashed into a barrier), the driver and passengers will keep traveling forward, because of their inertia. This creates a dangerous situation, since they can hit the dashboard, steering wheel, or windshield. An air bag is a pouch housed in the steering wheel of a car (for the driver) or the dashboard (for the front-seat passenger), which inflates nearly instantaneously after sensing that the car is involved in a collision. The air bag is designed to provide a sort of cushion in the event of a crash.

When a car crashes, it undergoes rapid *deceleration*. Deceleration is the change in velocity that occurs when something slows down. Like acceleration, it is measured by calculating how much the velocity is changing for each specified unit of time—for example, how many feet per second (a measure of velocity) each second. If a car was moving at 30 feet per second, and it came to a stop in 2 seconds, we could say that its deceleration was 15 feet per second, per second (15 ft/s^2). If the same car traveling at 30 feet per second came to a stop in 0.5 second, we would say that its deceleration was 60 feet per second, per second (60 ft/s^2).

When an object accelerates (or decelerates), there is a force acting on it. When talking of the forces in a car crash, it is common to give information in terms of the acceleration due to gravity. When an object falls from a height above the earth's surface, the force of gravity causes it to accelerate at 32 feet per second, per second. This value, 32 ft/s^2, is known as *g*. The forces a person would feel in a car crash due to deceleration are often stated as a comparison to this *g* value. For instance, in the examples given above, the person who slowed from 30 feet per second to a complete stop (0 feet per second) in 2 seconds had a deceleration of 15 ft/s^2, which is just less than half the value of *g*. We could say that the person feels about half a *g* of deceleration during this crash. In contrast, the person who stopped four times as quickly (who went from 30 ft/s to 0 ft/s in 0.5 second) had a deceleration of 60 ft/s^2, which is almost twice the acceleration due to gravity. We could say that in this case, a person crashing would feel about 2 *g*s.

Both the velocity of the car and the time it takes to come to a stop affect the force a person experiences during a crash. If the velocity before the crash is great, the effects of the crash will be greater. Also, the shorter the time taken to come to a complete stop, the greater the force felt. A velocity of 30 feet per second, as in the example above, is roughly equivalent to about 20 miles per hour.

An air bag is obviously designed to try to keep passengers from injuring themselves by hitting the front of a car during a collision. But it also helps increase a person's stopping time; by providing a cushiony resistance to the passenger's inertia, it helps their body take a little longer to come to a stop. This means that both the deceleration and the amount of force the person experiences, decrease. Although the time scale of a crash, air bag deployment, and deceleration are beyond human perception, research shows that air bags do help prevent injuries and fatalities. Estimates are that a person's chances of dying in a head-on crash are reduced by 30–35 percent when air bags are properly used.

Societal impact. Americans have had mixed reactions to the federal government's role in regulating automobile safety over the years. Some feel the NHTSA's mandates don't go far enough, and others believe that some of the requirements are an affront to civil liberties. Although air bags have certainly saved lives, they have also been implicated in the deaths of some crash victims—when someone sits too close to an air bag, or when the air bag hits a person's head and neck, rather than chest, serious injury can result from the impact. It is also important that rear-facing infant car seats never be placed in the front passenger seat when it is protected by an air bag; the baby's head rests too close to the air bag, and the impact of deployment can cause serious injury or death.

Despite some questions and objections about their use, car manufacturers continue to develop air bag technology. At the beginning of the twenty-first century, some new automobiles include side-impact and even overhead air bags designed to protect passengers from nonfrontal collisions and rollovers. Also, engineers are working to make air bag deployment controls more sensitive to unique circumstances, to maximize their safety and efficiency. As long as cars remain the primary mode of transportation in American society, the government will likely take an interest in regulating their safety.

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HUMAN KNOWLEDGE

One of the most-followed news events of the 1990s was the announcement by NASA scientists that life may have once existed on Mars. David S. McKay and colleagues had been studying a meteorite found in Antarctica in 1984. After determining that the meteorite came from Mars, the scientists found that it contained complex carbon molecules known to be a key building block of Earth-based life-forms. After ruling out the possibility that the meteorite somehow had been contaminated with living things after its arrival on Earth, the researchers concluded that Mars could once have been home to simple bacteria-like life.

The 1990s also saw the development and improvement of several kinds of technologies for studying the natural world. At the start of the decade, the Hubble Space Telescope was sent into orbit 370 miles above the earth in order to photograph the cosmos for scientists to study. Although problems with the mirror, gyroscope, and solar panels on Hubble limited its effectiveness, it was repaired by space shuttle astronauts in 1993. Hubble allows astronauts to gather information from space that would not be possible to collect from the ground, due to interference from the atmosphere. In 1993, an upgrade of the Internet system of connecting computers vastly improved its performance. The T3 carrier line allowed information to be transferred much more quickly through cyberspace. Project VORTEX (*v*erification of the *o*rigin of *r*otation in *t*ornadoes *ex*periment) helped researchers learn more about the insides of these violent storms.

The field of biotechnology also continued to expand during the 1990s. Early in the decade, gene therapy was successfully used to treat a four-year-old patient suffering from ADA deficiency, a genetic disease that allows deadly toxins to accumulate in a patient's body. The announcement of the birth of Dolly, the world's first successfully cloned mammal, galvanized the scientific community and the public at large. In addition, the Human Genome Project would set out to revolutionize the field.

Human Genome Project

During the 1990s, scientists were engaged in an ambitious project to create a map of human DNA. Humans contain approximately 31,000 genes that are collectively made up of 3 billion chemical base pairs. The Human Genome Project (HGP) was an organized, systematic, international effort to determine each gene's base pair sequence. In addition, the HGP set out to provide researchers worldwide with access to information about human genes by developing a free database in concert with advanced computer and mathematical analysis tools. An unprecedented 5 percent of the costs of conducting the study was set aside to address the ethical, legal, and social issues arising from the project.

What is the science behind the project? All living organisms are composed of cells, the basic structural unit of life. Cell regulation and reproduction are controlled by a molecule called deoxyribonucleic acid (DNA), which determines which proteins are produced and when they are needed. DNA is a double-stranded molecule shaped like a twisted ladder and is contained in the chromosomes that are housed in the nucleus of each cell. It is made of nucleotides that are composed of a sugar, a phosphate, and one of four nitrogen bases: adenine, cytosine, guanine, and thymine (A, C, G, and T). These bases fit together in a very specific base-pairing rule that determines the base rungs and complementary base rungs on the double helix ladder. A single DNA molecule incorporates millions of base pairs that control the functioning of each cell.

Genes are short sections of the DNA molecule that regulate the growth of a single-cell egg into a fully functioning adult. Genes determine physical features, blood type, sex, and, among many other physical characteristics, the likelihood of acquiring an inherited disease. They provide hereditary instructions through the definite arrangement of base pairs to form a given protein. The large, complex protein molecules, which are made up of amino acids, perform most of the functions of the cell and comprise most of the cell structure. Just one mistake in the approximately 3 billion base pair arrangements can cause the wrong protein to be formed, possibly resulting in a disease or imperfection. For example, it has been determined that the genetic error common to those who suffer from cystic fibrosis is the deletion of three base pairs out of a total of 250,000; sickle cell anemia results from a single misplaced base in a DNA sequence. The HGP was meant to facilitate the coordination of scientists to more explicitly understand how genes and proteins become activated and affect the body's chemistry and processes. The study of these proteins is a new area of science called proteomics.

A complete set of genes for an organism is called a genome. This genetic catalog functions to determine protein synthesis as described above; however, most of the genome consists of noncoding regions whose functions are yet to be discovered. It has been determined that 99.9 percent of the nucleotide bases are identical for all people, which means that human diversity is contained in a 0.10 percent difference of the genetic code. The size of a genome varies depending on the organism; a human genome has 5,000 times more base pairs than a bacterium but contains about the same number as a mouse. However, the human genome contains about two to three times as many types of proteins as a mouse genome.

Human DNA is arranged in twenty-four separate molecules called chromosomes, each ranging from 50 to 250 million base pairs. These chromosomes are fragmented into much smaller pieces, making them more accessible for purposes of replication when a cell divides. New technologies supported by the HGP, such as fluorescent in situ hybridization, help scientists locate a specific piece of DNA on the pairs of chromosomes (called gene mapping). This mapping enables scientists to locate anomalies in DNA that could contribute to the cause of any of thousands of genetic diseases.

There are two types of gene mapping, genetic (linkage) and physical mapping. Genetic or linkage mapping was conceptualized by Thomas Hunt Morgan in the early 1900s when he observed the frequency of physical characteristics in several generations of fruit flies. For pairs of characteristics that were continually inherited simultaneously for several generations, Morgan concluded that the genes which coded these characteristics must be located near one another on the chromosomes. Morgan was awarded a Nobel Prize in 1933 for developing this linkage mapping concept. Physical mapping determines the specific distance between one gene marker and another, and uses lasers, robotics, and computers for this precise technique. This gene mapping, a major goal of HGP, provides the gene sequence and relative distances between genes on the chromosomes in order to better understand the fundamental organization and mechanisms of genes and chromosomes. By mapping genomes from other organisms such as bacteria, fruit flies, and mice, research scientists hope to make comparisons that will increase the understanding of the biological functions of genes.

Societal impact of the HGP. While understanding the human genome promises to advance medical understanding of disease, there are concerns about the ethical, legal, and social implications of how the data are stored, shared, and analyzed. Several organizations, as well as the HGP administrators, have recognized the need for adequate safeguards for the ways in which HGP conclusions will be used.

On one hand, it is hoped that doctors will be able to help patients in ways never thought possible, using novel techniques to cure and prevent genetic diseases. Rather than treating a complex array of symptoms not necessarily arising from one disorder, physicians could prescribe treatments based on a person's genetic data, possibly allowing for starting appropriate procedures earlier and giving less medication. For some diseases, gene therapy can be used to insert normal genes into a patient's cells to replace nonfunctioning or missing genes.

One of the problems with knowing about a person's genetic propensity for a particular disease stems from the fact that cures are not available for all kinds of such disease. Health insurance companies may deny coverage to a person based on his or her genetic makeup, even though symptoms have not yet presented themselves. Employers may choose to not retain a worker with a specific genetic makeup if the individual is likely to contract a disease that would result in high costs to the company from absenteeism and increased insurance premiums. In light of these concerns, in 1998 President Clinton recommended that future legislation ensure that discoveries made from the HGP will be used to improve the human condition and not to discriminate against workers and their families.

Worldwide concerns are voiced about the ethics and legality of commercially patenting human gene sequences and the possible screening of embryos for preferred traits such as intelligence, height, and physical beauty to create "designer babies." Ethnic and racial groups fear that the DNA of thousands of people will be analyzed for a variety of aptitudes and then be used to unjustifiably bias people against a given race or ethnicity. One common myth is the idea that one single gene programs a person for a certain characteristic, but in fact this view is oversimplified. Scientists have yet to find a "criminal" gene or "bad seed" gene. The interplay between genetics and environment is still not very well known in the case of human social development.

The HGP ushered in a new scientific era with a commitment to a systematic genetic understanding of disease and development, and illustrates the significant role played by computers and mathematical models in biological research. In addition, the degree of international collaboration and the development of Web-based access to a plethora of scientific information through the HGP is unprecedented. The Human Genome Project has revolutionized the biomedical field, promoted the study of new areas of science, and provided insights into the biochemical and biophysical processes of life to scientists worldwide. Still, the potential to exploit this vast new database of human knowledge is very real. Experts call for the general public to be informed and scientifically literate enough to make decisions about the use of HGP data well into the future.

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