Big Era 8
A Half–Century of Crisis
1900–1950 CE

Landscape Teaching Unit 8.6
Revolutions in Science and Technology, 1900–1950

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World History for Us All
A project of San Diego State University
In collaboration with the
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http://worldhistoryforusall.sdsu.edu/

Why this unit?

This unit examines wide-ranging changes in the first half of the twentieth century in the fundamentals of what we know, and how we know it, about the universe, the composition and behavior of matter, and our biological inheritance. Rapid growth of technology and its increasing interaction with science accelerated complexity in this era, as illustrated in this unit in the fields of physics, aviation, and biology. The changes in science and technology opened up unprecedented opportunities and dangers for humanity which all of us will be living with for a long time. Understanding how these changes came about, the historical conditions that influenced them, and the short- and long-range effects of these developments will help us understand how to cope with their consequences today.

Unit objectives

Upon completing this unit, students will be able to:

1. Compare the state of science and technology at the end of the nineteenth and the middle of the twentieth centuries, and describe changes.
2. Analyze the changing relationship between science and technology.
3. Describe what promoted, and what held back, developments in science and technology from 1900 to 1950.
4. Explain in what ways science and society influenced each other.
5. Marshal arguments for and against difficult decisions that science and technology raised during this period.

Time and materials

This unit is versatile. The number and variety of discussion questions and activities provided is meant to give teachers the choice to use what most suits their interests and circumstances.

Each of the three lessons can stand on its own. Depending on time available and other circumstances, teachers may choose to forgo

- one or even two of the lessons;
- some of the Student Handouts within lessons;
- some of the discussion questions and activities.

To facilitate modifications, discussion questions and activities are keyed to specific Student Handouts, and summary questions are identified.

Time taken will vary, depending on teachers' selections from the materials provided, on coverage of detail, and on whether some Student Handouts and activities may be assigned as homework.

One example of barebones coverage in only one class period that still touches on each Unit Objective would be:

- The teacher summarizes the main points of the Historical Background (desirable for the barebones approach, but not vital).
- The students read Student Handout 1.2 and respond to questions/activities 1, 3, 4, 5, and 8 based on it.

Doing all parts of Lesson 1 with choices from among its questions and activities would take two periods. Lessons 2 and 3 could be tailored to one more class period each.

No materials are needed other than pencil and paper.

Author

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The historical context

By 1900, science and technology had discovered, invented, harnessed, developed, and constructed much that is now part of our everyday lives. Among them were electricity; the internal combustion engine and automobiles; the germ theory of disease and anesthesia; the telegraph, telephone, radio, and sound recording; photography and moving pictures; submarines, torpedoes, and machine guns. If a time machine could take us back to 1900, we would find that daily lives were in many ways familiar to us. But if visitors from that time were to come and see us now, they would find our world in many ways not only unfamiliar and confusing, but incredible.

Among many other things, they would be baffled by television, computers, the Internet, airplanes, antibiotics; vitamin pills, genetically-engineered crops, nuclear weapons, space shuttles, and space stations. All of these and a great deal else came about as a result of changes in science and technology during the half century starting in 1900.

The consensus then was that the physical universe followed laws that allowed accurate and reliable prediction when enough information was available. Space was uniform and static. Elements were fixed and unalterable. Atoms were indivisible, unchangeable, indestructible, and the smallest material entities that could exist. Humans were qualitatively different from all other living things. By 1950, the research on atoms in physics, the quantum theory, the relativity theory, the uncertainty theory, and the Darwinian synthesis in biology had overturned all of these presumed truths. The changes were not about details of what was known of the universe but about fundamentals.

In several realms, science was pushing limits during the first half of the twentieth century. It penetrated ever deeper into both non-living matter on the subatomic scale, into living matter within cells, and into the composition of the extraterrestrial universe. Physicists and geneticists worked with components of experience that were:

- at the extremes of size, both at the large end (Einstein's space-time) and at the small end (subatomic particles, components of chromosomes);
- at the extremes of speed (acceleration of subatomic particles, light);
- at the boundaries between that which is, and is not, alive (viruses);
- demanding specialized and complex methods and equipment to study nature and the universe.

There were changes not only in the ideas scientists worked on and the technologies they needed to pursue them, but also in where they worked and how. The increasing complexity of both research problems and the technology needed to make experiments led to:

- The concentration of cutting-edge research, initially in prestigious universities, and then in industrial laboratories and governmental research institutes as well. By the 1930s, virtually all scientific research and technological production were carried on in large specialized buildings outfitted with specialized equipment, housing dozens or hundreds of professionals. The role of the non-professional solo experimenter and inventor shrank, though it did not disappear.
- More collaboration in tackling research problems. Until about 1920, scientific papers had one author—the one who conducted the research reported on it. By 1950, multi-author papers were getting to be the majority, produced by team research involving a group of contributors, often from different specializations, disciplines, and countries. Interdisciplinary projects multiplied. University laboratories hosted scientists from other nations. Cutting edge research results were reported on and discussed in increasing numbers of scientific societies and meetings.
- The growing need for money to fund more and more expensive research, and the possibility that funders would influence research directions and even results.

As scientific research became dependent on more and more complex technology, technology became increasingly dependent on science. In the late nineteenth century, technology began to develop as applied science in fields such as chemistry, thermodynamics, and electromagnetism. From 1900 on, industry routinely looked to science to support its aims. Industries built and equipped laboratories and recruited scientists from universities to staff them. For scientists, the higher industrial pay scale was offset by loss, to a varying extent, of the autonomy they had had in universities to determine the aims and methods of their research.

New technologies also became gradually infused with science. For instance, while it was tinkerers, inventors, and mechanics who accomplished the earliest development of airplanes, strong scientific input was required to invent jets and rockets. The reverse also happened: early experimentation with fruit flies in genetics research required very little in the way of technology, while by 1950 complex and expensive equipment was a necessity. Gradually, the distinction between science and technology tended to blur. Research that found new knowledge and work that used technology to translate discoveries into useful and marketable products was joined as Research and Development, or R&D. Pure science was no longer merely a search for truths about the material universe. It also became a significant part of the work that went on in industrial laboratories.

Governments became actively involved with science and technology as they realized that pure science had much to contribute to new weapons and that applied science advanced industries. Decisions about what research to fund became matters of public policy, and science moved closer to the power centers of society. Governments increasingly enlisted scientists for both economic and military projects. They also built laboratories and founded research institutes. Scientists were increasingly consulted as advisers and pulled into war work. World War I was labeled by some "the chemists' war," owing to scientists' work on poison gases. World War II was dubbed the "the physicists' war" because of concentration on development of the atomic bomb. By 1950, it was generally accepted that a nation's power depended not only on its military and industrial production but also on the caliber of its scientists, scientific equipment, universities, and research institutes.

Scientific discoveries became increasingly difficult to grasp and dealt with phenomena further and further away from everyday experience. Yet they came to play a significant part in industry and government. To maintain an informed electorate, scientific popularization became desirable. Scientific information gradually seeped into the minds of non-scientists as multiple bridges between professional science and the general public emerged. Some journalists specialized in writing about science for the mass media. In 1919, when one of the basic predictions of Einstein's general relativity theory was confirmed, front page headlines appeared in major American and European newspapers. Articles and editorials about them continued to stream out for months. Journals such as *Scientific American* gave information about the results of ongoing scientific work in non-specialist language. Radio and, later, TV programs reported routinely on scientific developments.

There were spin-offs from science that affected society in unanticipated and unpredictable ways. Darwin's biological evolutionary theory was transmuted, and not only by non-scientists, into Social **Darwinism**. This ideology, in the name of the idea of the "survival of the fittest," emerged in the nineteenth century but deeply influenced politics, economics, and social policies in the U.S., Britain, Germany, and elsewhere in the twentieth. It was used to justify, among other things, imperialism, racism, cutthroat capitalism, and restrictive immigration policies. In its efforts to identify the mentally-handicapped who might be classified as "unfit" and subject to sterilization, it gave birth to the intelligence test movement. Physicists' successful splitting of the atom generated the problem of nuclear waste disposal, which continues to have both environmental and political implications.

Difficult moral and practical issues arose. Could a theory that applied in the natural sciences be applied to society? Were scientists responsible for the results and use of their work? Was it justifiable to stop scientific work because the possible results were considered too dangerous or were disapproved of by some? Who should, or could, make and enforce such decisions, and under what circumstances?

The scientific and technological changes that raised such issues played themselves out against a backdrop of numerous disruptions and crises: large-scale death and displacement of civilian populations in two world wars and other conflicts; the dissolution of empires and emergence of new states; several **revolutions**, civil wars, genocides, and purges; the **Great Depression**; emergence of organized opposition to colonialism; the start of the **Cold War**; large and accelerating population growth; women's widespread gains in voting rights and access to specialized jobs. These developments coincided with revolutionary changes in:

- Astronomy (acceptance of an expanding universe, the "**Big Bang**" theory of the universe's origins).
- Medicine (discovery of vitamins, sulfa drugs, antibiotics, insulin, radiation therapy).
- Technology (assembly lines, automation, computers, transistors).
- Synthetics (Bakelite, nylon, acrylics, pesticides, and fertilizers).
- Psychology (Freud's theory of the unconscious, multi-pronged studies of the mind's various aspects, heredity and environment).
- Anthropology (cultural relativism, evolutionary theory).
- Arts (Cubism, abstraction, Dada, Surrealism, dissonance, atonality, and electronic music).

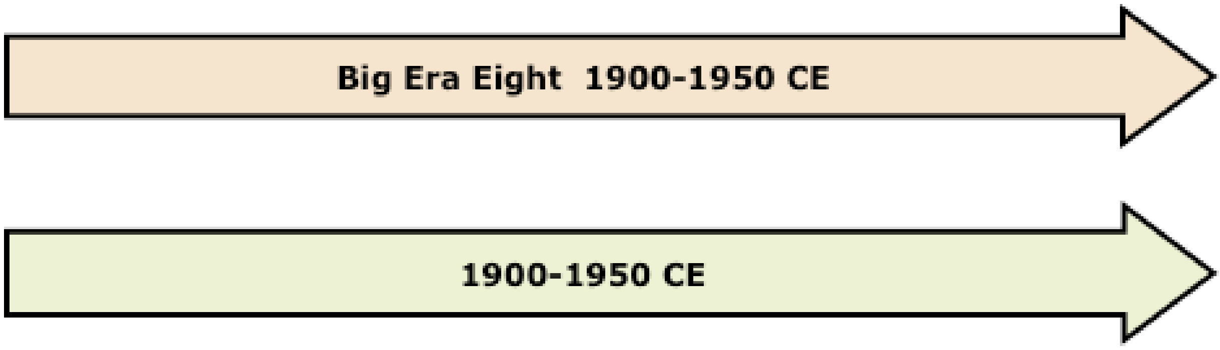
A telephone made of Bakelite, a type of plastic developed in the early twentieth century. The phone, manufactured in Germany, dates to 1938.
Source: Bakelite Museum, http://www.bakelitmuseum.de/

The crises of the first half of the century laid the foundations for the possibilities of:

- Detonation of weapons that could wreak possibly terminal havoc worldwide.
- Human presence in space.
- Cloning and genetic engineering.
- Creating a living organism from non-living chemicals.

The half-century of changes in science and technology after 1900 contributed enormously to an improved quality of life and held out the promise of continuing to do so. These changes also raised unprecedented moral, social, economic, political, and environmental problems—most of which are still with us.

This unit in the Big Era Timeline



Introduction to the Lessons

Students may work on most activities and questions as a whole class, as individuals, or in groups. Results of individual and group work usually need to be shared with the whole class.

The label "Document" refers to the original (boxed) source together with its head note.

Giving students questions they are going to be asked to answer and activities they will be asked to do before they read the documents on which the questions and the activities are based may help their concentration, comprehension, and performance. More documents, questions, and activities are provided than need be used in order to allow choices, depending on class interests and circumstances. Multi-part questions are generally of increasing difficulty. Not all parts need be asked of all students.

Encouraging students to keep notes of answers to discussion questions and results of activities will help them organize and make sense of extensive or unfamiliar information. Reviewing notes will help towards success on assessments.

Introductory Activities

Students may be asked to do the following introductory activities before reading any of the Student Handouts. These activities alert students to some of the core issues to be dealt with. If time is limited, they may be omitted without detracting from students' ability to deal with the rest of this Teaching Unit or from fulfilling its objectives.

Ask students to brainstorm the following.

A. This Teaching Unit's title refers to revolutions in science and technology. What would have to have happened to make using the term "revolutions" appropriate in the cases of science and of technology? What would make you question the appropriateness of the term? Is the yardstick you are using to measure the appropriateness of the term "revolutions" the same for science and for technology? Why or why not? Would it be the same for political "revolutions"? Explain.

B. What characteristics distinguish science from technology?

C. Does science influence society? How? Does society influence science? How? Give some examples.

Lesson 1
Physics
Runaway Changes, Surprising Discoveries

Questions and Activities

Ask students to refer to the information in Student Handout 1.1 (Science and Technology Grow).

Explain how information from Student Handout 1.1 can be used as evidence for the increasing importance of science and of technology.

1. What factors promoted the growth and importance of science? Refer to information from the documents in constructing your answer.

2. Assess the soundness of the claim that technology and science are closely related, drawing on the documents in Student Handout 1.1.

3. What does the way the scientist and his surroundings are shown in the cartoon in Document D suggest about science in India in 1948? How does this compare to the way the scientist and his surroundings are shown in the framed picture, dated 1930, on the wall behind the seated scientist? Consider their tools, workspace, activity, company, and the atmosphere, and describe changes. How might the fact that the cartoon was drawn for a physicist who was the Indian Government's Defense Research Advisor have influenced the content of the cartoon?

4. How reliable is the cartoon as historical evidence? What leads you to accept, or to question, its reliability? How might evidence from other documents in Student Handout 1.1 be used to support the accuracy of the cartoon's portrayal? Does this evidence suggest that the situation shown in the cartoon applies more widely to science than only in India? Why or why not?

Ask students to refer to the information in Student Handout 1.2 (Physics: Certainties Are Shattered).

1. Describe the differences between what was known about the material universe in the nineteenth century (Document A), and what was known about the same topics in the mid-twentieth (Documents C to H).

2. What would you say were the four or five most significant changes in knowledge about the material universe during the first half of the twentieth century? Why? How did you decide what made them "most significant"?

3. Ask students to construct a table like the one below. Have them make a judgment about the items in the left column in terms of their importance in promoting the development of science between 1900 and 1950. Have students indicate their judgment by writing a number from 0 to 5 in the right column. 0 means no importance, and 5 means extremely important.

Scientific interests	
Industrial needs	
Consumer demand	
Profit motives	
International events	
Government decisions	
Environmental concerns	
Media coverage	
Other (what?)	

4. Construct a conversation between a supporter and an opponent of the argument that scientific work should be considered from the point of view of the possible benefits (or dangers) of its results to society or individuals. As supporter, or as opponent, what action would you recommend if your opinion were to be followed? What resistance to your recommendation would you anticipate, and from whom?

5. Assess the role played by technology in the development of scientific work in physics during 1900-1950. How did technology's role change during that period? Why?

6. If you were a government official working on the budget in the 1920s and 1930s, what arguments could you use to justify to taxpayers expenditures to support science? How, if at all, would arguments used today be different? Why?

7. What arguments could support the claim that physicists who worked on the atomic bomb bore the responsibility for the consequences of using it? What arguments might be made to deny that physicists bore responsibility?

8. Do you agree with Oppenheimer's statement that "the true responsibility of a scientist ... is to the integrity and vigor of his science"? Why or why not? What dangers to society might general acceptance of the statement produce?

9. Under what circumstances, and why, would you consider it justifiable to stop a scientific inquiry? How, and by whom, could such a prohibition be enforced? What

arguments would you use to support your point of view? What arguments might be made by someone opposed to your point of view?

10. In what ways were nineteenth-century scholars' beliefs about matter and the universe shattered by 1950? (This activity could serve as assessment.)

11. How would you explain to a fellow student what it was that made changes in science during 1900-1950 "revolutionary"? (This activity could serve as assessment.)

Ask students to refer to the information in Student Handout 1.3 (Different Places, Different Developments).

1. Compare the British and the Egyptian views in Document A. What problem(s) do they identify? Where do they place blame? What might account for any differences in their views?

2. Create a conversation between a supporter and an opponent of "protective discrimination" such as is described in Document C. Would such discrimination be controversial in the U.S. today? Why or why not?

3. What similarities were there in science as practiced in the countries featured in Student Handout 1.3? What differences were there? What historical reasons might account for the differences?

4. What held back, and what promoted, the development of science according to the documents in Student Handout 1.3? (This activity could serve as assessment.)

5. Were there "Revolutions in Science and Technology" in the areas of the world dealt with in Student Handout 1.3? Explain. (This activity could serve as assessment.)

Ask students to refer to all three Student Handouts in Lesson 1.

1. At the time when several countries laid claim to their own brand of science on ideological grounds, what evidence from Lesson 1 could be presented in favor of the view that science was international?

2. Imagine that you are a journalist in the 1930s specializing in reporting on science. Write an opinion editorial based on your acquaintance with science internationally that argues either for, or against, a role for government in science. Support your argument with evidence from Lesson 1.

3. Suppose you were hired to consult with the government of a Third World country that wished to increase its scientific capacity. Drawing on information from all three Student Handouts in Lesson 1, consider:

- What problems for achieving this goal would you draw attention to?
- What remedies would you recommend?
- What part would technology play in your recommendations?

4. Evaluate the validity of the claim that, of all the features of society, war had the most influence on science in the first half of the twentieth century. What evidence would you look for that might increase your confidence in the correctness of the claim? What evidence might lead you to question it?

5. In what ways did each of the following influence science during 1900-1950? (This activity could serve as assessment.)

- Politics
- Economics
- Ideologies (Beliefs)
- Other (what?) ____

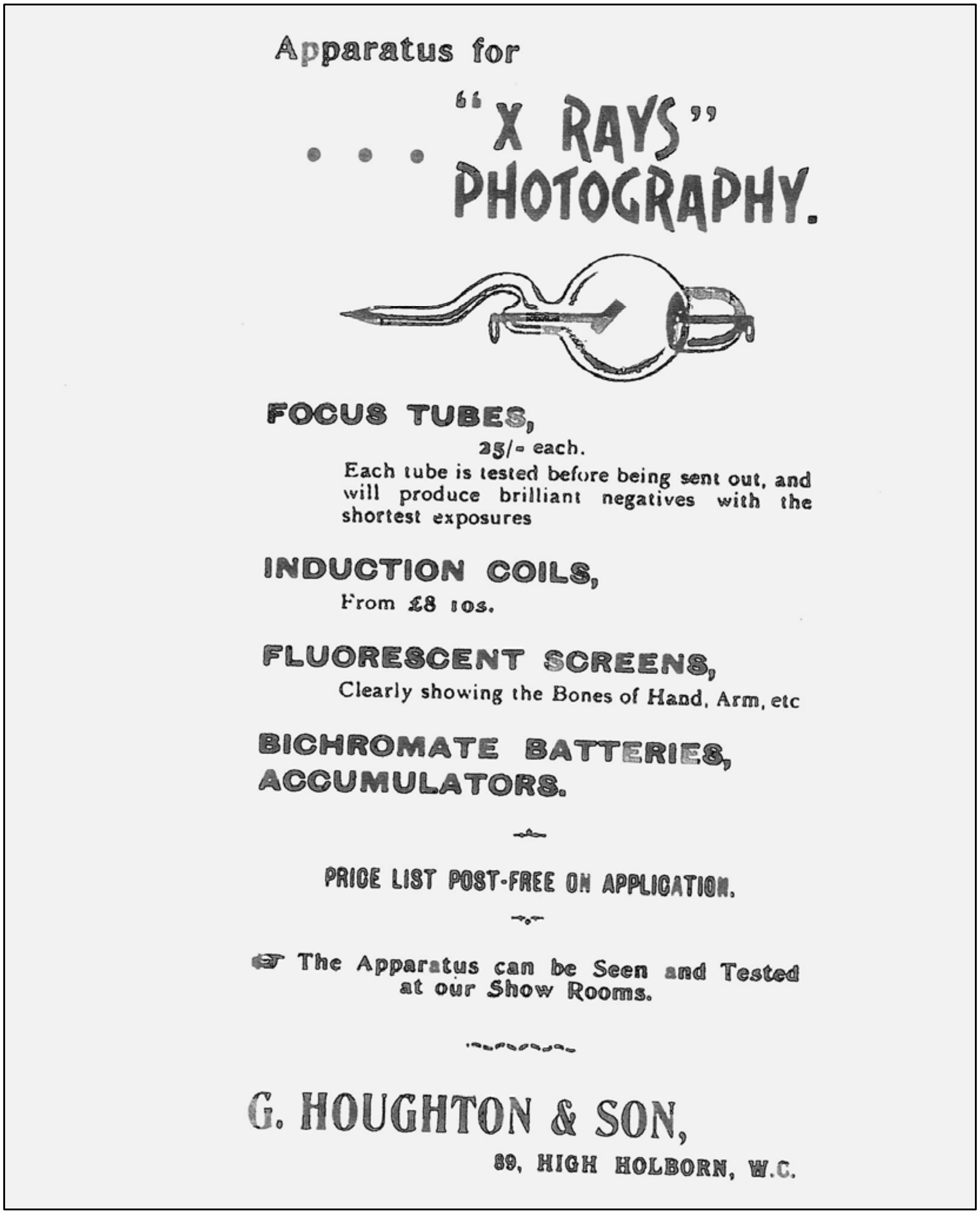
Extension activity

Compare the changes in knowledge of the physical universe achieved during the first **Scientific Revolution** (about mid-sixteenth to mid-seventeenth century) with those achieved during the 1900-1950 period. Use relevant evidence from any part of Lesson 1. Which period brought about the more "revolutionary" changes? Explain what definition of the term "revolution" you are using, and support your argument with evidence.

Lesson 1

Student Handout 1.1—Science and Technology Grow

Document A
Technology for Physicists Depicted in 1897



Source: John Ziman, *The Force of Knowledge: The Scientific Dimension of Society* (Cambridge: Cambridge UP, 1976), 215.

Document B

Technology for Physicists before World War II

Up to the 1930s, basic research in "pure science" was overwhelmingly, though not exclusively, done by researchers in universities. Laboratory space and equipment were provided with funds from the university and grants from private foundations. It was in universities where other scientists, with different specializations and from different disciplines, were conveniently available for the consultation, collaboration, and teamwork that became increasingly important. Because of the growing need for funds for complex technology, private industry and, later, government stepped in to help support science research.

[In 1895] Ernest Rutherford ... arrived at Cambridge University to begin research … The sort of equipment they used could be bought for a few pounds—not much money even in those days. Even … in 1919 … the apparatus was made in the laboratory workshop by a skilful technician, and could be held in the hands.

[In 1928, a nuclear researcher at the University of California created the cyclotron, a subatomic particle accelerator.] Inspired by a paper from a Norwegian engineer, [this] was a pie-shaped concoction of glass, sealing wax, and bronze. A kitchen chair and a wire-coiled clothes tree were also enlisted to make the device work. [It proved that] whirling particles around to boost their energies, then casting them toward a target like stones from a slingshot, is the most efficient and effective way to smash open atomic nuclei. The accelerating chamber of [this] cyclotron measured five inches in diameter and boosted hydrogen ions to an energy of 80,000 electron volts. Access to scientists and students from other disciplines, as well as to engineering staff, was critical to … success.

By 1930, … the scale had increased in size and cost. The first linear accelerator of nuclear particles to higher energies … cost the substantial sum of 1,000 pounds and occupied the best part of a room with its column of insulators to carry a voltage of several hundred thousand volts. Experiments with this device required the collaboration of several research workers, but were essentially simple and direct. …

[The next upgrade] gave particles of a million electron volts. They were lucky to find a big electromagnet weighing 85 tons that nobody wanted, so it only cost about $10,000 to build.

By 1939 it had been "stretched" into a much bigger machine, 60 inches in diameter, yielding particles of 12 million electron volts. But costs were now in the $100,000 range, and proper engineering design had taken over from the makeshift hand-made structures of the first apparatus, but could still be operated by a few physicists and technicians working informally together. …

Sources: John Ziman, *The Force of Knowledge: The Scientific Dimension of Society* (Cambridge: Cambridge UP, 1976), 215-19; second paragraph: Berkeley Lab, *Science Articles Archive*, Ernest Lawrence's Cylotron: Invention for the Ages, http://www.lbl.gov/Science-Articles/Archive/early-years.html

Document C
Technology for Wartime Physics, 1940s

By far the largest and most important scientific and technological undertaking during the 1940s was the development of nuclear energy and nuclear weapons.

The American government's support of the nuclear plan, named the **Manhattan Project**, began with a $6,000 grant in 1940. At first, the operation took place in university laboratories, funded mostly by private foundations. The following year, Hitler invaded the Soviet Union, and the President authorized an all-out effort. Special facilities were created with government funding. In 1942, the army became actively involved and supervised the project. Soon, major industrial companies were invited to play a part. A number of distinguished European physicists who came to the U.S. to escape Hitler's anti-Jewish policies were vital to the project's success. Eventually, project research took place at thirty locations across the U.S., Canada, and the United Kingdom, involving some 135,000 people. The cost ended up at $3 billion in 1940 dollars.

The following is by a Lithuanian-born journalist, the chief science reporter for the *New York Times*. He won the Pulitzer Prize for his coverage of the secret U.S nuclear weapons program. He was the only press representative given access to it.

Surprises meet the visitor to the various plants [built to work with uranium in the preparation of an atomic bomb] in 1943. He enters one of the great buildings in which U[ranium].235 is being concentrated by the electromagnetic method. He no sooner passes through the door than he finds himself confronted by a monumental structure that practically fills the entire space of the building.

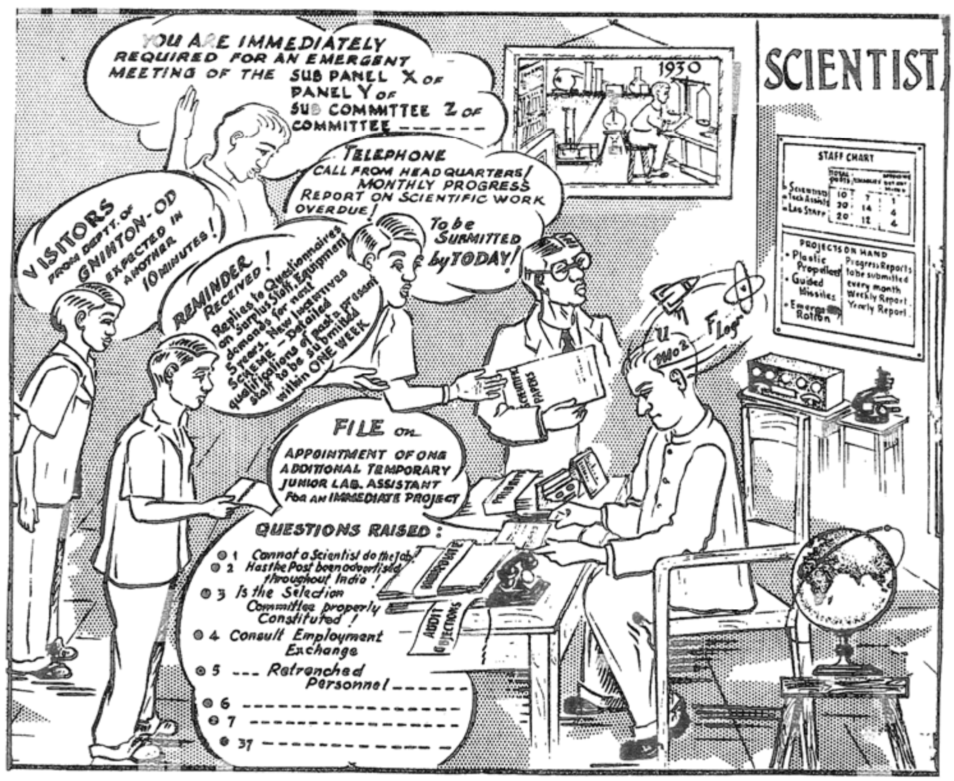
Merely the appearance of this inner structure is impressive enough, but suddenly he learns the incredible fact that practically the entire monumental mass, occupying many tens of thousands of cubic feet, constitutes one giant electromagnet. … He then finds that these magnetic mastodons form but a part of a colossal isotope separation apparatus, descendant of a device known as a mass spectrometer, which, before the war, occupied a small space in a physics laboratory.

[In] another plant … U.235 is concentrated by the gaseous diffusion method. He hears a roar from behind massive walls and is informed that it is the sound of molecules of a gaseous uranium compound racing through a barrier that separates the U.235 from the U.238. The barrier, he learns, is an entirely new product that had never existed before. It contains myriads of holes, each no larger than two-fifths of a millionth of an inch. Casually he is told that this barrier consists of nearly ten thousand miles of porous tubing, encased in more than a million feet of equipment, practically none of which existed before the war. And then he finds out that the entire system of more than a million cubic feet is operating in a vacuum. … To examine the gaseous diffusion plant's "brains," the visitor would have to take a ten-mile walk to look at every control panel on just one floor.

Source: W. L. Laurence, *Dawn Over Zero: Story of the Atomic Bomb* (New York: Alfred A. Knopf, 1946), 120-3.

Document D
The Physicist's Work in 1930 (picture on the wall)
and in 1948 as an Indian Cartoonist Depicts It

This cartoon was drawn for the distinguished Indian physicist Dr. D. S. Kothari when he became Defense Research Advisor to the Government of India in 1948.



Source: John Ziman**,** *The Force of Knowledge: The Scientific Dimension of Society* (Cambridge: Cambridge UP, 1976), 228.

Document E
Science for Technology

"Fundamental" or "basic" research, practiced in the service of "pure" science, stood opposed to "applied" or "industrial" science, at least in the minds of many scientists. These terms may be roughly summed up. The goal of pure science was to produce knowledge (for which it increasingly needed technology). The aim of applied science, as well as of technology, was to produce or improve material objects (for which it increasingly needed science). In industry, scientists with physics and chemistry specializations were generally most in demand. Lured to industry from academic careers, scientists received better pay but gave up some of the freedom that they had had in universities to determine what they worked on and how.

At the turn of the twentieth century, the figure of the American industrial scientist was a remarkably new thing. … In part, industrial science was imported … from late nineteenth century German chemical, pharmaceutical, and electrical industries … And in part American developments were responses to … commercial competition, cost cutting, and anti-monopolistic political sentiment [that] encouraged big, innovating industries [to undertake] in-house research. … It was thought [that this], including a small but very significant proportion of fundamental research ["pure" as opposed to "applied" science], could result not just in cost-cutting and improved production, but also in the development of totally new products or even new industries.

By the 1920s, industrial science in America had emerged as … something to be encouraged by government. … In 1928, the director of the engineering division of the National Research Council announced that "research is now a universal tool of industry." …

[To some, though], the very idea of industrial science might even be a contradiction. The goal of scientific inquiry was Truth; the goal of industry was Profit. … Yet the clear divide between pure and applied, [between science and technology], and between the institutions in which these supposedly different forms of inquiry were housed, was not accepted by all.

In 1920, it was estimated that American industry was spending $20 million in about 300 research laboratories. … Just before the stock market crash in 1929 it was reckoned that about $130 million was spent in more than 1,000 [industrial] laboratories. In 1940, $234 million went to support work in industrial laboratories. … With the Cold War, expansion of government support of industrial research related to military concerns. In 1950, $2 billion … was spent on industrial R&D [research and development], most of this now coming from the Federal Government and creating the "military-industrial complex." As a percentage of U.S. national income, industrial research expenditures increased spectacularly from 0.04% in 1920, to 0.87 in 1952.

Source: Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008), 94-100.

Lesson 1

Student Handout 1.2 –Physics: Certainties Are Shattered

Document A
Prelude: The Comfortable Consensus

In the nineteenth century, the Western cultural consensus was that humans had a firm fix on the nature of the physical universe based on the achievements of the scientific revolution of the sixteenth through the eighteenth centuries. The outlines of this general agreement, some of which began to be questioned by the end of the century, were as follows.

Space is uniform, unchanging, and independent of all other features of the universe.

For all observers anywhere in the universe, measurements of time and space would be identical. One hour and one mile on earth are one hour and one mile on the moon, on Mars, or anywhere else.

Filling all of space is the "light-bearing ether"—a stable, invisible, weightless substance needed as a medium for conducting light.

Light is a wave that moves as a continuous beam between its point of origin and point of arrival.

Matter and energy are separate and different.

All matter is made up of tiny particles called atoms, which cannot be created, divided, changed, or destroyed. All atoms of each element are identical.

The smallest atom (that of the element hydrogen) is the smallest entity that could exist. But not all scientists agreed that atoms really did exist.

The essential character of elements is fixed and unalterable.

The laws of nature are not subject to chance or uncertainty.

We can keep improving the accuracy of our measurements if we simply improve the instruments we use to do the measuring with.

Source: Compiled by Anne Chapman from a wide variety of sources.

Document B
We've Got It All

Lord Kelvin (William Thomson), a venerable and richly-experienced British scientist, made the pronouncement below in 1900. Many other physicists shared his belief.

There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.

Source: Qtd. in Walter Isaacson, *Einstein: His Life and Universe* (New York: Simon and Schuster, 2007), 90.

Document C

The Mystery of Newly-Discovered Rays

Experimenters were puzzled in the late 1800s when they sent a high-voltage charge between a positive and a negative electrode in a glass bottle nearly emptied of air. They unexpectedly found a pale, dim glow coming from the negative end (cathode). Studying these so-called "cathode rays" became a hot new field of scientific work.

German physics professor Wilhelm Roentgen's experiments led him to conclude, in 1896, that cathode rays must be some new radiation of an unknown type. To reflect his bewilderment about their nature, he dubbed the new radiation "X-rays." He found that they passed through flesh almost unchecked, but caused bones to cast a shadow on photographic film. By the end of the year, several hospitals were using X-rays.

Cathode rays held more surprises. Studying them between 1897 and 1900, English physicist J. J. Thomson found that his "rays" were not rays at all but a stream of particles. Investigating them, he discovered the first subatomic particle, the electron.

His discovery that atoms can "split up" opened the way for later work on the artificial production of nuclear energy—both benign and dangerous.

On the hypothesis that the cathode rays are charged particles moving with high velocities … [they] … must be small compared with the dimensions of ordinary atoms or molecules. Electrification [transmission of electric energy] essentially involves splitting up the atom, a part of the mass of the atom [the electrons] getting free and becoming detached from the original atom.

I can see no escape from the conclusion that [cathode rays] are charges of negative electricity carried by particles of matter. … What are these particles? Are they atoms, or molecules, or matter in a still finer state of subdivision? … We have in the cathode rays matter in a new state … a state in which all matter … is of one and the same kind; this matter being the substance from which all the chemical elements are built.

Sources: Thomas Crump, *A Brief History of Science: As Seen through the Development of Scientific Instruments* (New York: Carroll and Graf, 2001), 211; American Institute of Physics, Center for History of Physics, *The Discovery of the Electron*, http://www.aip.org/history/electron/jj1897.htm

Document D

The First Case of Radiation Sickness

Marie Curie, French-Polish head of the physics laboratory at the University of Paris, said in 1900: "The spontaneity of radiation [as in cathode and X-rays] is an enigma, a subject of profound astonishment." She tackled the enigma by studying the rays given off by various substances, which led her to the theory of radioactivity. In 1903, she was co-winner of the Nobel Physics Prize with her husband, who had shown that radium is continually generating energy and that, potentially, "the energy liberated in the transformation of atoms would be extraordinarily great."

In 1911, she won a second Nobel Prize, for chemistry. Ignorant of the dangers, she continued her research with radioactive materials. Not only her laboratory, but her house also became contaminated. Her lab books, even now, have to be kept in lead-lined boxes, and her cookbooks are still too dangerous to handle. But although she felt increasingly ill, she continued working. She died of radiation sickness in 1934.

> [In 1897], I was engaged in some work on uranium rays. … I wanted to know if there were other elements, giving out rays of the same kind. … It took many years of hard work to finish that task. There was not one new element, there were several of them. But the most important is radium. Now, the special interest of radium is in the intensity of its rays which are several million times greater than the uranium rays. … If we take a practical point of view, then the most important property of the rays is the production of physiological effects on the cells of the human organism. These effects may be used for the cure of several diseases [among them cancer]. …
>
> But we must not forget that when radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of the direct usefulness of it. It must be done for itself, for the beauty of science, and then there is always the chance that a scientific discovery may become like the radium a benefit for humanity.

Source: Marie Curie (1867-1934): *On the Discovery of Radium*, *Modern History Sourcebook*, Paul Halsall, ed., http://www.fordham.edu/halsall/mod/curie-radium.html

Document E

Strange Nature and Behavior of Atoms Revealed

English physicist Ernest Rutherford specialized in studying atoms, each so small that the size of one of them would be to a millimeter as the thickness of a sheet of paper is to the height of the Empire State Building. In 1901, he and a colleague discovered that, as a radioactive atom gives off radiation, it changes into the atom of a different element.

He also found that he could change nitrogen atoms into oxygen atoms when he hit them with a helium nucleus. He thereby realized the alchemists' dream of transforming elements (though not their ambition of turning lead into gold.)

As a result of such experiments, he found that there was within every tiny atom an even tinier but very heavy central nucleus, about 1/100,000 the size of the atom. The much lighter particles called electrons were scattered at the atom's edge. If the nucleus was imagined to be the size of a tennis ball, the electrons would be several miles away. The rest of the atom was empty.

Eventually, many more subatomic particles besides electrons were discovered, and information about their exact distribution and interaction underwent changes. But Rutherford's basic conclusions continued to hold. Tiny as they were, atoms contained tinier particles still, in complex arrangements. And all matter, from metals to living things, was made up mostly of empty space. Below, Rutherford tells of what he found in the first two decades of the twentieth century.

> Radioactivity ... [is] accompanied by chemical changes in which new types of matter are produced. ... [It is] clear that the changes in question are different in character from any that have been before dealt with in chemistry. … We are dealing with phenomena outside the sphere of known atomic forces.
>
> I had observed the scattering of alpha particles … [given out by radioactive substances. When these were] shot at thin gold foil, [it] was as though you had fired a 15-inch naval shell at a piece of tissue paper and the shell came right back and hit you. … It was then that I had an idea of an atom with a minute massive center, carrying an [electrical] charge.

Sources: First paragraph: qtd. in A. E. E. McKenzie, *The Major Achievements of Science*, Vol. 2: *Selections from the Literature* (Cambridge: Cambridge UP, 1960), 153.; second paragraph: Oracel ThinkQuest, *Discovery of the Nucleus*, http://library.thinkquest.org/28582/history/nucldisc.htm

Document F

Introducing the Troublesome Quantum

Light was not a mysterious new ray. But new information about its behavior did pose a mystery. German physics professor Max Planck worked with electromagnetic radiation at the University of Berlin. His mathematical calculations forced him, in 1900, to conclude that energy (as in light and radiation) did not flow continuously like water from a tap. It was released in separate, individual packets, each of which came to be called a quantum. This flatly contradicted the accepted wave theory of light (confirmed by experiments), which described light flowing as an even, continuous beam. He found his own results difficult to swallow.

The quantum theory concluded, and eventually proved, that both matter and radiation behave both wave-like and particle-like. This was hard to accept. Harder still to accept was that this theory allowed the prediction of probabilities only, in situations where classical physics would have predicted certainties. It was quantum theory, however, that worked when dealing with subatomic particles and situations that involved near-light speed motion. Decades later, it contributed to work with computer chips, lasers, and the electron microscope.

> This is the most essential point of the entire calculation—energy [is] composed of a very definite number of equal finite packages. … I was ready to sacrifice any of my previous convictions about physics. …
>
> My unavailing attempts to somehow reintegrate the … quantum into classical theory extended over several years and caused me much trouble. …
>
> If anybody says he can think about quantum problems without getting giddy, that only shows he has not understood the first thing about them.

Sources: Walter Isaacson, *Einstein: His Life and Universe* (New York: Simon and Schuster, 2007), 90; Max Planck, Wikipedia, http://en.wikipedia.org/wiki/Max_Planck#Black-body_radiation; Max Planck, Light-Science.com, http://www.light-science.com/maxplanck.html; *Quantum Physics: Max Planck*, On Truth & Reality, http://www.spaceandmotion.com/Physics-Max-Planck.htm

Document G
The Next Shock Was Relativity

German-Swiss-American physicist Alfred Einstein warned that he dealt, as he conservatively stated, in "somewhat unfamiliar conceptions for the average mind." It would probably have surprised him that part of his very abstract theory eventually played a role in the development of the very practical Global Positioning System now used in all kinds of transport. His theories have been reliably confirmed.

His special theory of relativity (1905) was produced in his spare time while working as technical assistant at the Swiss Patent Office. It showed that:

- The speed of light is constant; nothing can move any faster; and it does not need any medium to move through (Good-bye "light-bearing ether").
- Mass and energy are equivalent. This means that there is a truly huge amount of energy tied up in every material thing.
- Measurements of both length and time intervals will differ for two observers moving relative to each other at close to the speed of light. At such speeds, distances appear to shrink relative to the observer, and time slows.

Einstein also helped develop early quantum theory. But he became increasingly unhappy with its insistence that it would deliver only probabilities and not certainty. In 1916, Einstein completed his mathematical formulation of a general theory of relativity. This theory proposed that matter is distributed unevenly in space. Close to matter, the shape of space is distorted, as is the flow of time. In this document he explains his relativity theory without mathematics.

> Turning to the theory of relativity itself, I am anxious to draw attention to the fact that this theory is not speculative in origin; it owes its invention entirely to the desire to make physical theory fit observed fact as well as possible. … The abandonment of certain notions connected with space, time, and motion hitherto treated as fundamentals must not be regarded as arbitrary, but only as [demanded] by observed facts. …
>
> I stand at the window of a railway carriage which is traveling uniformly, and drop a stone on the embankment. … I see the stone descend in a straight line. A pedestrian who observes the misdeed from the footpath [on the embankment] notices that the stone falls to earth in a parabolic curve. …
>
> The stone traverses a straight line relative to a system of coordinates rigidly attached to the carriage; but relative to a system of coordinates rigidly attached to the ground (embankment), it describes a parabola. …

Sources: First paragraph: qtd. in A. E. E. McKenzie, *The Major Achievements of Science*, Vol. 2: *Selections from the Literature* (Cambridge: Cambridge UP, 1960), 157-8; second paragraph: qtd. in *The Book of the Cosmos: Imagining the Universe from Heraclitus to Hawking*, ed. Dennis R. Danielson (Cambridge, MA: Perseus Publishing, 2000), 357-8; third paragraph: Walter Isaacson, *Einstein: His Life and Universe* (New York: Simon and Schuster, 2007), 128.

Document H

Facing the Inevitable: Scientific Certainty Cannot Always Be Achieved

As a result of theoretical, mathematical, and experimental work between the two world wars, scientists came to the apparently inescapable conclusion that relativity, probability, chance, and uncertainty were inherent in the nature of the universe. No new technology, no improvement in the precision of observation, calculation, or measurement, no increase in objectivity could ever overcome them.

In the selection below, an American physicist and educator explains the uncertainty principle, worked on by several researchers during the 1920s and formulated by German physicist Werner Heisenberg in 1927.

> Perfect accuracy cannot be achieved no matter how fine the measuring instrument. There exists some uncertainty in every measurement we make, not only as a result of imperfect measuring instruments, but because of the unavoidable interaction between the observer and the observed.
>
> To observe an object requires that at least one photon [the subatomic particle that carries visible light] bounce off it. A photon bouncing off a baseball in flight alters its motion [so little it is unnoticeable], and its motion is not altered by the presence or absence of a witness. To "observe" an electron, on the other hand, is a different story.
>
> A single photon bouncing off an electron appreciably alters its motion—and in an unpredictable way. If, for example, we wish to determine the position of the electron very accurately, the wavelength of light used to detect it must be short. A short wavelength, however, corresponds to a large quantum of energy, which greatly alters the electron's state of motion. If, on the other hand, a long wavelength corresponding to a small quantum of energy is used, the change in the electron's state of motion will be smaller, but the determination of its position by the coarser wave will be less accurate.
>
> The act of observing something as tiny as an electron produces a great uncertainty in either the position or the motion being measured. Although this uncertainty is completely negligible for measurements of position and motion for everyday objects, in the atomic domain it is a predominant fact of life.

Source: Paul G. Hewitt, *Conceptual Physics* (Boston: Little, Brown, 1971), qtd. in *The Ascent of Man: Sources and Interpretations*, ed. John F. Henahan (Boston: Little, Brown, 1975), 262.

Document I

Changes in the Position of Science in Society

Science had succeeded not only in changing humanity's view of the physical universe. It was also both undergoing changes in its relationship to society and actively shaping that relationship.

Before World War I, scientific research … was modestly funded, oriented around the individual investigator, and regarded as culturally important but not universally relevant to national politics; after 1945, U.S. science moved to … million-dollar research budgets, multiple-investigator teams and intensive federal support for … research.

[During World War I, leaders of scientific organizations such as the National Research Council and the National Academy of Sciences began efforts] to persuade society of science's value to national needs. [They claimed] a new social function for science by hammering home the connection between research and industrial productivity: Pure science was "the bedrock of progress." "None recognizes this so clearly as those industrial leaders who have profited greatly from discoveries in pure science ultimately adapted to practical ends."

When hostilities eliminated most trade exchanges … American industrial chemists began to develop substitutes for [unavailable] German products. [They] also helped to design such horrible new weapons as mustard gas. … Each new product and social improvement brought praise [but some, also blame] to scientists. …

Industrial laboratories experienced almost threefold growth in the 1920s; but basic research funding … did not keep pace with applied research. … The scientific community could not attract crucial industrial donors [who preferred to invest "in their own company laboratories, where technologically promising discoveries could be patented before they were published."]

[In the 1930s, when] physics had already been moving in the direction of "controlling" the atom … [some] scientists [entered] into the political mainstream.

After World War II, [there was] a new sense of the inevitability of research. … There was also a new sense of the political usefulness of science [and the] realization that each new advance carried the potential for *both* benefit and harm. Acknowledgement of this ambiguity … grew during the 1930s and 1940s. … In 1945, a report to the President … outlined a plan [which was accepted] for organizing science after the war. It proposed ... federal funding of basic research to encourage scientific progress [resulting from] "the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown."

Source: Marcel LaFollette, *Making Science Our Own: Public Images of Science, 1910-1955* (Chicago: University of Chicago Press, 1990), 7-15.

Document J
Unleashing Atomic Power

In the 1930s, Hungarian, Russian, German, French, and Italian scientists thought about and experimented with the problem of freeing the energy within the atom. In 1939, physicist Lise Meitner and her collaborators in Germany demonstrates that a uranium nucleus, while bombarded with neutrons, would split with a great release of energy. To make large-scale use of this energy, one fission event must trigger another, so that the process spreads throughout the nuclear fuel as in a set of dominoes.

Also in 1939, the year Hitler invaded Poland, physicists in both Germany and America demonstrated the possibility of such a chain reaction. The American effort to beat the Germans in the development of an atomic bomb was launched with full government funding and collaboration between scientists, technicians, industry, and the military. It succeeded in less than thirty-three months. The first bomb was tested at Alamogordo, New Mexico on July 16, 1945.

Below are recollections of that trial run. Edward Teller, later known as the "father of the hydrogen bomb," recorded the first two paragraphs. Robert Oppenheimer, the Scientific Director of the Manhattan Project, wrote the third. A month after the test at Alamogordo, American planes dropped the uranium bomb nicknamed "Little Boy" on Hiroshima, killing between 80,000 and 140,000 people. On August 9, a second bomb, dropped on Nagasaki, resulted in some 80,000 more deaths. So far, these have been the only military uses of atomic weapons.

> We were all lying on the ground, supposedly with our backs turned to the explosion. But I had decided to disobey … and instead looked straight at the bomb. … I put on dark glasses under welder's glasses, rubbed some ointment on my face to prevent sunburn from the radiation, and pulled on thick gloves. … For the last five seconds we all lay there, quietly, waiting for what seemed an eternity, wondering whether the bomb had failed. … Then at last I saw a faint point of light. … The question "Is this all?" flashed through my mind. … A few seconds later all the scientists were standing, gazing open-mouthed at the brilliance. A loud crack some two minutes later, the sound wave rolling across the desert from twenty miles away, caught them by surprise. … The condensation cloud produced by the fireball changed shape as it was blown … by the winds. Eventually it became a many-mile long question mark. We returned to the bases with hardly a word. We knew the next nuclear explosion would not be an experiment. … In the control bunker "a few people laughed, a few people cried. Most people were silent," Oppenheimer recalled. "I remembered a line from the Hindu scripture, the *Bhagavad Ghita*: … 'Now I am become death, the shatterer of worlds.'"

Source: Peter Goodchild, *Edward Teller: The Real Dr. Strangelove* (Cambridge, MA: Harvard UP, 2004), 105-6.

Document K

What Place Has Morality in Science?

"If you scientists don't work on weapons," President Roosevelt said in 1940, "the National Socialists [Nazis] will conquer the world."

A few years later, the U.S. Secretary of War appointed a committee of scientists to recommend how to use the bomb about to be tested. The secret Franck Report they released on June 11, 1945 recommended that the weapon not be used on Japan. Availability, the report stated, does not dictate use: poison gas, in spite of its availability, generates such horror and revulsion that it is not used.

The report warned that "if the United States would be the first to release this new means of indiscriminate destruction upon mankind, she would sacrifice public support throughout the world, precipitate the race of armaments, and prejudice the possibility of reaching an international agreement on the future control of such weapons." Polling of over a hundred scientists who had been involved in its design and production showed a similar reluctance to use the bomb at all, or only after non-lethal demonstrations and as a very last resort.

The author of the text below (written in 1955) was Robert Oppenheimer, known as the "father of the atomic bomb." He had been in charge of its development.

> The physicists felt a peculiarly intimate responsibility for suggesting, for supporting, and in the end … for achieving the realization of atomic weapons. Nor can we forget that these weapons, as they were in fact used, dramatized so mercilessly the inhumanity and evil of modern war. … The physicists have known sin; and this is a knowledge which they cannot lose. But no scientist … can hope to evaluate what his studies, his researches, his experiments may in the end produce for his fellow men, except in one respect—if they are sound, they will produce knowledge. …
>
> The scientist should assume responsibility for the fruits of his work. I would not argue against this, but it must be clear to us all how very modest such assumption of responsibility can be, how very ineffective it has been in the past, how necessarily ineffective it will surely be in the future. …
>
> The true responsibility of a scientist, as we all know, is to the integrity and vigor of his science.

Source: J. Robert Oppenheimer, *The Open Mind* (New York: Simon and Schuster, 1955), 88, 90-1.

Lesson 1
Student Handout 1.3—Different Places, Different Developments

Document A
Two Points of View

About 1900, a British official expressed his opinion of Egyptian engineers as follows.

> The Mohammedan [Muslim] has not yet learned to look on engineering as a learned profession worthy of a gentleman. The result is that, with very few exceptions, the Government engineers are very ignorant and lazy … and too timid to hold their own against unscrupulous pashas. … English engineers have been obliged, however, to accept them such as they are, and more than one has responded loyally to the new calls made on their brains and energies. …

By the 1930s, an Egyptian professor of education explained.

> Technical schools are graduating a number of students annually, but the lack of factories and private enterprises makes it difficult for these graduates to earn a living. … Technical schools (as well as secondary schools) do not take into account the needs of the country. … The majority of the people employed in repairing, oiling, and all kinds of work pertaining to motor-cars … are Europeans. … Electric, water, and gas companies … employ Europeans.

Source: Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford UP, 1988), 311-12.

Document B

Attitude of Colonial Powers in Africa to Technology and Science for Their Subjects

During the first half of the twentieth century, almost all of Africa was under the control of colonial powers. Science hardly even occurred to anyone in colonial policies about African education or employment. As for Westerners in Africa, there were few or no facilities, opportunities, or motivation for them to "do science."

One celebrated complaint against European colonialists was that they educated only a pitifully small number of Africans beyond the secondary level, especially in technical fields. The first technical college in the Gold Coast opened in 1951. South of the Sahara, only one college was open to Africans before World War II, and that was in South Africa. … Even the West African colonies of France and Britain, which formed the most developed and commercialized region of sub-Saharan Africa and the one with the longest contact with Europe, were politically and economically much less developed than Egypt or India, and the question of education revolved around the training of clerks and craftsmen, rather than engineers and agronomists. …

In 1925, the Advisory Committee on Native Education in the British Tropical African Dependencies issued a memorandum on "Education Policy in British Tropical Africa. … It recommended that Africans be taught vocational subjects:

"It should be the aim of the educational system to instill into pupils the view that vocational (especially the industrial and manual) careers are no less honorable than the clerical, and of Governments to make them at least as attractive–and thus to counteract the tendency to look down on manual labor."

The goal of these policies was to discourage Africans from flocking to the cities and joining the hordes of office-seekers. … These ideas … aroused opposition from many Africans, who resented the closing of opportunities in better-paid clerical work.

Source: Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford UP, 1988), 312-15.

Document C
What Part Did Education Play in India?

By the late nineteenth century, Indians under England's colonial government complained often and loudly about the lack of opportunities for scientific and technical education. In 1904, Indians themselves founded an Association for the Advancement of Scientific and Industrial Education. It collected donations from the public to fund sending Indian students to Japan, the United States, or Europe to train in science and technology. In 1909, an Indian industrialist founded, and funded, the Indian Institute of Science that taught both pure and applied sciences. The unsympathetic colonial government dismissed these enterprises, claiming that they would only add to "the discontented hordes of unemployed graduates." Below, late-twentieth-century scholars describe the role of science and technology education in India.

> University College of Science and Technology [was founded] in 1914 [with donations from] lawyers and nationalists who endowed chairs [elite faculty positions] in physics, chemistry, mathematics, and botany, [and laid down that] "the chairs must always be filled by … persons born of Indian parents." At a time when leading Indian scientists encountered difficulties in securing fair treatment in appointments to prestigious Indian scientific and educational service, such protective discrimination seemed warranted. …
>
> Whereas Indian philanthropy provided the initiative for much of the country's scientific and industrial development from the last quarter of the nineteenth century until the 1930s, [from then on it was thought to be] the responsibility of the **state**. … More than one hundred institutions for scientific training and research were established between 1947 and 1950.
>
> [War helped, as the last official report on technical education in British India showed:] "The experience of war … has compelled a large expansion of industry and created a greatly increased demand for technicians of all grades, while at the same time the urgent need for skilled … workers had led to almost every technical institution in the country becoming a centre for Technical Training Schemes. … Many young men, who would otherwise not have embarked on a technical career, have been recruited under these schemes and the prejudice against industrial employment has been steadily breaking down."
>
> [But problems remained, as shown by a 1946 report to the Empire Scientific Conference:] "Those familiar with the facilities provided in the modern laboratories in America or Britain would find it hard to understand the handicaps that beset the scientific workers in India at every step. Lack of equipment, lack of accommodation, long hours of routine work, and finally the eternal want of funds are some of the problems that handicap science teaching and scientific research in Indian universities."

Sources: Thomas Owen Eisemon, *The Science Profession in the Third World: Studies from India and Kenya* (Buffalo, NY: Praeger Special Studies, 1982), 77, 88, 91-2; Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford UP, 1988), 343.

Document D

Science is Directed to "Prove" the Party Line in the Soviet Union

In 1929, the Communist Party in the Soviet Union began to seriously intervene in scientific matters. A late-twentieth-century historian describes the situation there.

> From Stalin's speech at the first all-Union Conference of Agrarian Marxists it was clear that henceforth … conformity with the rural policy of the Communist Party would be the criterion of truth. "Theory" would now have to prove the correctness of this policy and research would now have to confirm the existence of the "facts" which were postulated by this theory and hence the correctness of the theory. The research workers' findings would have to demonstrate that what the politicians said was true.

Source: John Marks, *Science and the Making of the Modern World* (London: Heinemann, 1983), 395.

Document E
Aryan Physics

Phillipp Lenard had won the 1905 Nobel Prize in Physics for his work on cathode rays. He publicly protested when Einstein, a Jew, was awarded the prize for work in the same subject area in 1921. In 1933, the National Socialists came to power in Germany and legalized **anti-Semitism**. Two years later, Lenard was invited to speak at the opening of a new physics institute. The following are the statements of his views.

> I hope that the institute may stand as a battle flag against the Asiatic spirit in science. Our Führer has eliminated this same spirit in politics and national economy, where it is known as **Marxism**. In natural science, however, with the over-emphasis on Einstein, it still holds sway. We must recognize that it is unworthy of a German to be the intellectual follower of a Jew. Natural science, properly so called, is of completely Aryan origin. … But it will be replied to me, "Science is and remains international." It is false. In reality, Science … is racial and conditioned by blood.

Source: John Marks, *Science and the Making of the Modern World* (London: Heinemann, 1983), 267, 268, 376.

Document F
To Be Red and Expert

After the 1949 Communist takeover in China, great emphasis was put on "thought-reform," that is, insistence on ideological correctness. It was much used against intellectuals in the early days and often involved sending them to the countryside to work with their hands as laborers. At the same time, science and technology were strongly promoted. The document below is by a Chinese mathematician, writing in the 1960s with reference to conditions in China following 1949.

> I am a "self-made" man from the old society. My efforts made me deeply attached to the science which I had studied. … Sometimes I even asked that the realities of the motherland be adapted to my favorite specialty, instead of letting the requirements of the Revolution determine the direction of research. …
>
> Fortunately … the local Party organization did some timely ideological work on us. … "Empty talk and high-sounding theories" have given way to "practical and hard work." … [I now] realize … that class struggle, production struggle, and scientific experiment are united in an integral whole … there cannot be a new-type scientific worker who can carry out scientific experiment well but whose idea of class is indifferent. … Scientists in the past … could not be compared with the scientists who have grown up with the help of Mao Tse-tung's thoughts and who combine in themselves redness and expertness.

Source: Franz and Orville Schell Schurman, eds., *Communist China* (New York: Vintage Books, 1967), 167-8.

Document G

China Was Getting There

Almost constant fighting in civil wars and against the Japanese did not favor scientific development in China. There was a temporary upsurge in the 1920s and 1930s. Universities, research institutes, scientific societies, and journals were founded. Students were encouraged to study in Japan, Europe, and the U.S., about forty percent of them graduating abroad in the sciences and engineering. Ten times as many graduated in China. They tended to prefer, however, studying the humanities and social sciences because they had greater prestige.

The following is by an American historian of science writing in the 1960s.

> Now that China is emerging scientifically, as one can tell by the fact that we now routinely translate their chief journals as we have translated those in Russian for many years, one may expect it to reach [equality with the West] perhaps within the next decade or two. The Chinese scientific population is doubling every three years. … In 1949 China had no scientific journals; in 1959, it had 400.

Source: Derek J. De Solla Price, *Little Science, Big Science* (New York: Columbia UP, 1963), 101.

Document H

Japan Gains Scientific Equality

Both the government and private industry founded research institutes in Japan from the early 1900s on, but they focused mostly on industrial science and military technology. There were individual exceptions, people who worked in “pure,” or theoretical, rather than applied, science. The following is by an Italian-American nuclear physicist, writing a history of his field.

[Hantaro Nagaoka, one of Japan’s distinguished theoretical physicists, visited Europe at the turn of the century. Later, he became a world-class scientist. He wrote the following letter, in English, to his Japanese professor in 1888]: “There is no reason why the whites shall be so supreme in everything, and as you say, I hope we shall be able to beat those *yattya hottya* [pompous] people in the course of 10 or 20 years. … Another great requisite in beating those whites is how to make our work known. This is a great difficulty. As a first step we can not write in Japanese and make the westerners understand our writings. … We must, if possible, learn to write and speak [in their language] clearly and fluently.”

Nagaoka published many papers in Western journals. … Most notable is a 1903 proposal of an atomic model similar to the solar system. [Two main predictions of his model were confirmed, but the model was flawed in other ways, and abandoned later.]

Most important because of his own discoveries was Hideki Yukawa. … He founded a journal … which acquired world importance, especially in theoretical particle physics. … Yukawa was the first Japanese to win the Nobel Prize in Physics, in 1949 [for his explanation of how the atomic nucleus holds together]. … The Japanese came to see him as living proof of having reached scientific parity with the West. Thus Nagaoka could still see his dream fulfilled before dying in 1950.

Source: Emilio Segré, *From X-Rays to Quarks: Modern Physicists and Their Discoveries (*Berkeley: University of California Press, 1980), 244-5.

Lesson 2
Aviation: Breaking Barriers

Questions and Activities

Ask students to respond to the following:

1. It has been said: “The flights [in the late 1920s] were crazy and hazardous, and as noteworthy and world-changing as the fifteenth- and sixteenth-century voyages over the ocean in search of the Spice Islands …” What did the aviators of the early twentieth century have in common with the naval explorers of the fifteen and sixteen hundreds? In what ways did they differ, other than technology? Do you agree that they were equally “world changing”? Why and how? Or why not?

2. What was there about the experiences and personalities of the men involved in the design and development of airplanes and rockets that triggered their interest and contributed to their success? What similarities, if any, were there?

3. Describe difficulties met with in the development of aviation and airplanes in the West and in India. In what way(s), if any, did they differ? Did the same difficulties apply to rockets as it did to aviation and airplanes in the West?

4. Evaluate the importance of government support in the development of aviation before World War II. In what ways was it influential? What changes were there in the part government played?

5. What else, besides government support, promoted the progress of aviation, airplanes, and rockets in either (or both) the West or India?

6. Taking into account both airplane production and airplane use, what construction and what training had to be arranged and financed to make aviation possible on increasing scales?

7. Based on the pictures on pages 42 and 45 , give a short account of changes and continuities in airplane design between 1903 and 1917. List similarities and differences between your account and that given in the documents. In your judgment, was it worthwhile to include the pictures as well as the text in the Lesson? Why or why not?

8. What factors do you think influenced airplane design?

9. How did the relative importance of science and of technology in the development of airplanes change over time? What reasons can you suggest for the changes? Support your conclusion with information from Lesson 2.

10. Create a conversation as it might have happened in 1914 between a supporter and an opponent of airplane use in combat in World War I. Would the arguments on each side have been the same in 1916? Why or why not? Would the same or similar arguments have applied, for and against, to the use of the atom bomb in World War II? Why or why not?

11. What did it take to put a human into the air and then into space? Support your argument with information from Lesson 2. (This activity could serve as assessment.)

12. Is the term “revolution” fitting as a description of what happened in aviation between 1900 and 1950? Why or why not? Explain what definition, or characteristics, of the term “revolution” you are using. (This activity could serve as assessment.)

Lesson 2
Student Handout 2.1—Aviation: Inspiration, Experimentation, Luck

Document A
The Long Road from Dream to Reality

The dream of human flight has a long history, but detailed, practical, continuing attempts to design a flying machine only began in the early nineteenth century. The basics of flight, such as the relationship between weight, lift, drag, and thrust, were then worked out. Tests numerous experimenters made with gliders led to the design and patenting of a "flying machine" in the mid-nineteenth century. Although it was never built, it had an enormous influence on various later designs, many tested and none successful, in England, France, Germany, Russia, and the U.S. The tests proved that propellers were suitable for moving a plane forward and also that steam engines were not suitable power sources for flight. This problem was not solved until the invention of the internal combustion engine near the end of the century.

Finally, it was the Wright brothers in the United States who turned dream into reality. It was not easy. They had:

- Observed birds in flight for years.
- Read and analyzed all available information about flying machines.
- Tested earlier theories with balloons and kites.
- Designed and built a wind tunnel to test the shapes of wings and tails of gliders.
- Invested a great deal of effort, time, ingenuity, and money, bearing all costs and doing all the construction work themselves.
- Done it all with no formal education, having never even finished high school.

The result was their successful launch of the world's first manned flight in a heavier heavier-than-air craft at Kitty Hawk, North Carolina, in December 1903. Their plane was made of wood and fabric. It weighed some 600 pounds, had a twelve-horsepower engine, and traveled 120 feet in twelve seconds at a height of ten feet. They continued to seek improvements, which came interspersed with a number of failures.

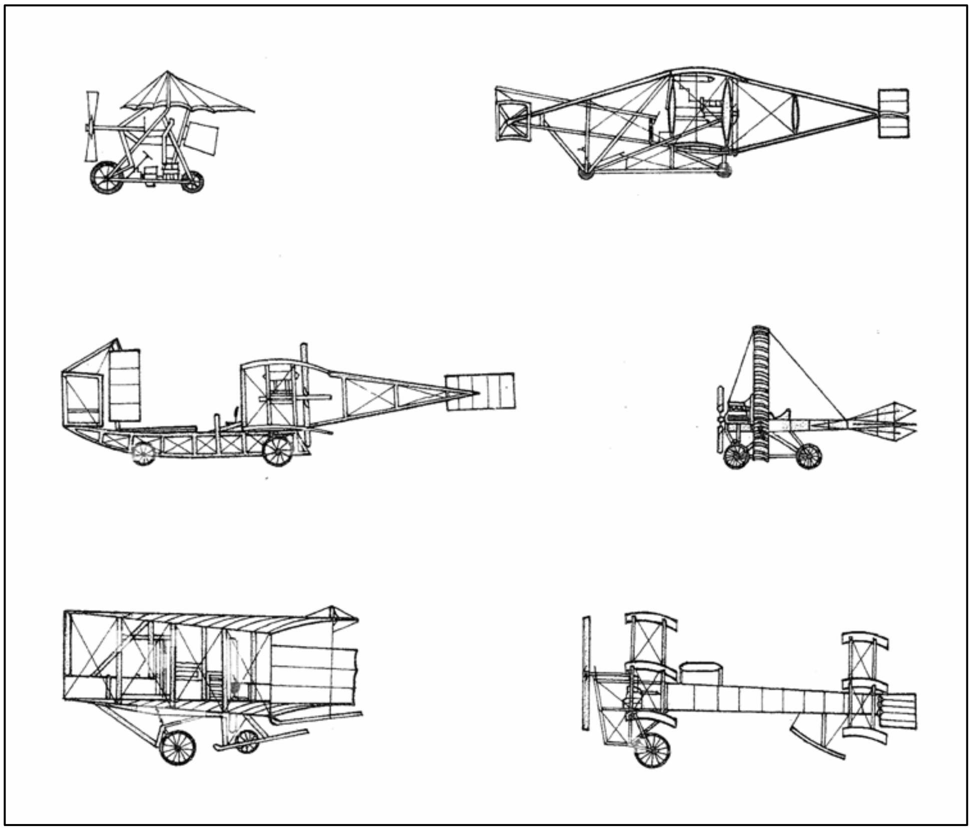
They tried to interest the U.S. government and military in at least taking a look at their airplane but were turned down.

In 1909, though, theirs was the first airplane to be bought by the U.S. government and to be equipped with a machine gun. They taught army personnel how to fight with it. The same year aircraft were first used in warfare for both reconnaissance and bombing in Italy's invasion of Libya. An early historian of aviation gave the following account.

[The Wright brothers, Wilbur and Orville] have set the year 1878 [when they were eleven and seven years old] as the time when their thoughts first turned to flying. It was then that their father presented to them … a toy helicopter fashioned along the lines which Leonardo da Vinci had laid down some centuries before. … [In his thirties], seated one day in the bicycle shop which furnished him and his brother with their livelihood, Wilbur Wright idly twisted the top of a box which had contained an inner tube. Then it was that arose in his mind the idea which … became the basis of the system which brought the Wrights' success—the idea of the warping wing [a way of controlling the rolling motion of the plane]. …

It was [Frenchman] Louis Bleriot's eighth machine, constructed in 1908, which brought him the first incontestable success which 8 years of experimentation, punctuated by 50 crashes and marked by the expenditure of $150,000, had made him so richly deserve. This machine was the first power-driven monoplane to fly successfully with a man. … [He] kept it in the air for 8 ½ minutes. … Most early planes … got into the air more as a result of good fortune than mathematical knowledge on part of the designer. … [By 1911], freakish designs of untrained inventors began to be replaced by machines resting upon sound, if elementary, aerodynamics. … Engine designers were coming to the aid of aviation by improving the internal combustion engine. … Aircraft had, by 1920, crossed oceans, penetrated Africa, and linked England and Australia.

Source: F. Alexander Margoun, *A History of Aircraft* (New York: Whittlesey House, McGraw-Hill Book Company, Inc., 1931), 274-5, 345, 357, 413.



Freakish designs of untrained inventors, 1903-1910.

Source: Paolo Matricardi, *The Concise History of Aviation* (New York: Crescent Books, 1984), 14-15.

Document B

From Private Passion to National Necessity

The Hague Peace Conference in 1899 went on record to state that no aircraft, present or future, would be allowed to take a combatant part in war. World War I changed that. Once military uses of flight were accepted, governments began pouring money into aircraft development.

Allied planning called for the design of huge military transport planes to replace the merchant shipping being battered by German U-boats. Airplane specifications called for a mostly-wood construction in order to cut down on the use of the metals which were of strategic importance. The fixed landing gear had large wheels to allow operation on soft, unsurfaced fields. There was little in the way of instrumentation, and pilots considered the open cockpit necessary for safe flying. The war gave rise to a sizeable aviation industry, which involved large investments in equipment, training, and manpower.

After the war, there were both continuities and changes. Many civilian airliners were direct descendants of wartime transport aircraft. But a shift from fabric to aluminum parts became necessary. A closed cockpit became standard.

The following account was written before World War II, when military technologies pioneered during World War I, including the airplane, submarine, and tank, became even more important.

An editorial opinion [in *The Times* newspaper in 1906 stated] "all attempts at artificial aviation … are not only dangerous to human life, but foredoomed to failure from an engineering standpoint."

[Few believed enough in flight to help pay for it. Subscriptions from naval officers and their wives financed a biplane fitted with floats to experiment with in 1911; a patriotic civilian paid for more machines and an aerodrome.] The tendency to look upon airplanes as interesting toys of doubtful utility had been so strong that there was real astonishment—followed by an equally real thrill—when the news came, after the outbreak of war, that our aviators had been able to fly to the war front instead of having their machines packed in crates for the journey [by ship] across the Channel. …

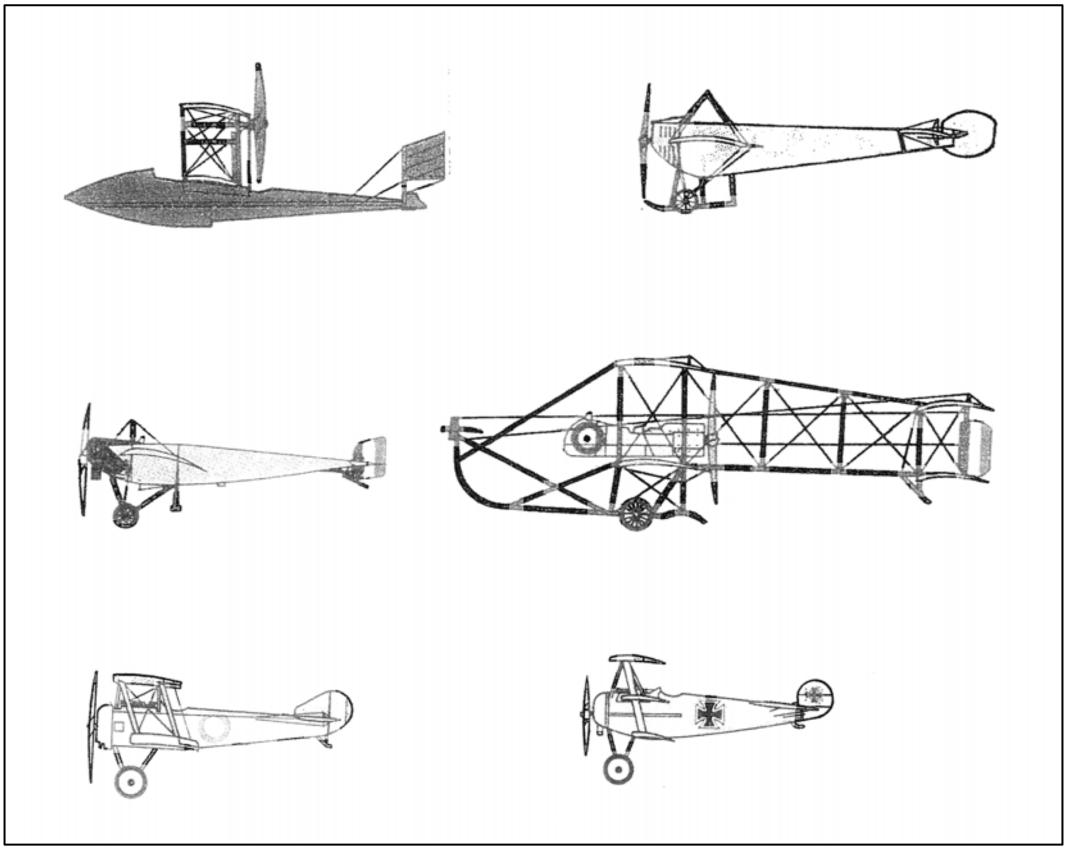
The war had not been in progress for very long before the value of the flying service was widely appreciated … and demands came for more and more machines. … Trained designers were few, and the whole staff of the Royal Aircraft Establishment drawing-office numbered only six at the outbreak of war. … As rapidly as possible, fresh helpers were brought in. A knowledge of draughtsmanship in regard to ships or of motor-car design, of engineering generally … proved a valuable asset. The necessity for skilled work was clear. A single aeroplane required the preparation of as many as four hundred dimensional drawings. …

[There was also need for manufacturers.] Firms that up to 1914 were busily engaged in making motor-cars or furniture, organs, pianos, and gramophones, were induced to take up the manufacture of aeroplanes and to install a new plant. A lengthy delay was involved in the violent change-over, and the constant alterations in design as a result of fresh experience added to the complications. … Few people thought much about air fighting in those days …

The general view, even in military circles, was that … any victory would depend on some lucky chance. … There was a transitory period in which pilots began to throw things at one another, and a Frenchman was credited with sending an enemy machine down by throwing a brick at its propeller and smashing it. … Very soon … small bombs were being carried. … There were pilots of naval machines who, several months after the outbreak of war, had to carry bombs in their laps because there was no other place to put them. …

When we sent out all the aeroplanes we had in August 1914, there were sufficient to form only four squadrons on the Western front. By the end of the war they had been increased on that front to 84 squadrons.

Source: George Fyfe, *From Box-kites to Bombers* (London: John Long Limited, 1936), 40, 50, 52-3, 55, 56-8.



Passenger airliner, reconnaissance planes, fighter planes, 1910-1917.

Source: Paolo Matricardi, *The Concise History of Aviation* (New York: Crescent Books, 1984), 20, 24, 28-9.

Document C
Chasing Distance, Speed, and Altitude

Up to the mid-nineteen thirties, individual enthusiasts contributed to technical progress by testing the airworthiness of machines and the feasibility of routes under various conditions. Flying displays and demonstration flights attracted large crowds. Race meetings offered trophies for speed and endurance. International competitors came for prizes and prestige, and they drew thousands of spectators. Some countries began to develop airworthiness standards for planes, and competence requirements for the licensing of pilots.

Aircraft industries began to grow, and universities established schools of aeronautical engineering. The military sponsored the application of new technologies developed by researchers. Civilian designers of commercial aircraft sought to attract passengers. For instance, a Russian plane built to carry seventy-six persons in the 1930s had a movie auditorium, a radio-broadcasting studio, and a complete printing plant for publishing a newspaper in flight. In 1938, planes carried 3.5 million passengers; by 1952, 45 million annually.

> [In the late 1920s] a veritable swarm of pilots leaped into their planes and began making records and headlines. … [They] went alone … in pairs, in groups, in monoplanes and biplanes; in flying boats and rigid airplanes. … Mostly they were daredevils. Some were scientists. … Others were publicity-mad, drunk with the poetry of flight, though most of them were matter-of-fact, making a business of flying. By 1930 … there had been over a hundred great distance flights by pioneers. … The flights were crazy and hazardous, and as noteworthy and world-changing as the fifteenth- and sixteenth-century voyages over the ocean in search of the Spice Islands. …
>
> For the next decade, the airplane went everywhere. It chased lions on the African veldt. It went on dramatic rescue missions. It sowed seeds, and sprayed insecticide on orchards.
>
> In the search for speed, for sustained range, for altitude, designers tried literally everything. … Every part of the airplane had been the subject of restless experimentation. … Hundreds of variations have been made and tested in the air.
>
> The old way of designing successful aircraft was by intuitive guess. The modern [1943] flying clipper is built on the basis of scientific analysis. One detail of engineering—the stress analysis—alone covers more than 1,000 pages for each design. After the rough designs have been passed on, 1,000,000 [yes, that is the figure given by the author] hours of work are necessary to draft the final blueprint.

Source: Burnet Hershey, *The Air Future: A Primer of Aeropolitics* (New York: Duell, Sloan, and Pearce, 1943), 12-14, 19, 21.

Document D

A Lot of Fun, Some Risk, and a Little Glamor

Civil aviation began in India with the extension of a British airline's London-Karachi route to Delhi in 1912, when India was still a colony. In 1929, the author of the text below got the first pilot's license issued in India and founded India's first commercial airline in 1932, which later became the national airline, Air India. Soon there were several competing airlines, all of which were nationalized by the then-independent Indian government in 1953. Home-grown Indian aircraft design began in the 1950s.

By the time I began flying in 1929, much of the romance had gone out of aviation along with its great heroes. Fortunately, however, there was still a lot of fun, some risk and a little glamour left in individual flying. … A prize of 500 pounds—a considerable sum at the time—… was offered [in 1930] to the first Indian who flew solo between India and Britain in either direction in not more than thirty days. … I decided to try my luck … but lost … by just two and a half hours. … Exactly thirty years later, I flew, as a passenger this time, from London to Bombay [Mumbai] on a jet in the same number of hours and minutes as I had taken days and hours in 1930. …

[In 1933, the colonial government] of this country has barely awakened as yet to the tremendous value of speeding up communications and to the almost unlimited future of air transport. I am personally convinced that air transport will not attain its true value … until flying is done day and night, but night flying is only possible with very extensive, and expensive, ground organization in the shape of lighting equipment, emergency landing grounds, wireless communications, radio beacons, etc. … [This] must, and can, only be undertaken by Government. Considering the attitude of Government towards commercial aviation … the position is not very promising. …

[In the 1930s, one of the three Indian airlines at the time] Tata Airlines consisted … of one Puss Moth, one Leopard Moth [single engine planes], one palm-thatched shed, one whole-time pilot, assisted by [an ex-R. A. F.—Royal Air Force—Englishman] and myself, one engineer on a part-time basis, two apprentice mechanics and unlimited optimism. … The Bombay "airport" was a dried mud flat serviceable only during eight months of the year. … As there were no lighting facilities at any of the airfields on the route no night flying was possible. … With a night stop … the average speed … was a snappy forty miles an hour. …

While the War [World War II] disrupted and curtailed some services, it also created opportunities … such as the survey of the South Arabian route on behalf of the R. A. F., the carriage of supplies to Iraq, the transport of civilian refugees from Burma, and the overhaul and maintenance of R. A. F. equipment.

Source: J. R. D. Tata, *Keynote: Excerpts from his Speeches and Chairman's Statements to Shareholders*, ed. S. A. Sabavala and R. M. Lala (Bombay: Tata Press Limited, 1986), 15, 16, 19, 26-7.

Document E

Jets: New Technology, New Capabilities

Propeller planes continued to be improved and developed until after World War II. But the piston engines they used had problems when approaching the speed of sound (660 miles per hour at 20,000 feet). For speeds beyond that, radical changes were required. The account below is based on several post-World War II sources.

> As the first 40 years of powered flight drew to a close, aircraft equipped with reciprocating engines had about reached the end of their development in what must be ranked as one of the most spectacular engineering achievements in history. Although some further technical refinement was possible, the technology of that class of aircraft had reached a plateau with little prospect of major improvement in the future.
>
> In the closing months of World War II, however, there emerged a revolutionary new type of propulsion system: the jet engine. Although operationally introduced in somewhat primitive form, the subsequent development of this entirely new type of propulsion system resulted in advancements in aircraft design that have been almost as spectacular as those which characterized the first 40 years of powered flight.
>
> In [both Britain and Germany], jet aircraft came into service after about 5 years of intensive engineering development, the testing of prototypes, redesigns, etc., … preceded by about 5 years of … research. [This] was founded upon more than 50 years of [broader] research on the thermodynamics of internal combustion engines and turbines, and this, in turn, rests on several centuries of basic research on classical physics and continuum mechanics which culminated in the concept of energy in the middle of the [nineteenth] century.
>
> Perhaps the greatest impact of the jet engine on our modern way of life has been in the area of mass transportation. Introduction of the jet-powered transport in 1952 heralded the beginning of a revolution in domestic and international air transportation that has accompanied the development and refinement of the jet-powered transport.
>
> The modern jet transport with its high speed, safety, and economical appeal, has altered people's concepts of the relative accessibility of various places in the United States and throughout the world. … Whereas air travel was once regarded as the province of the adventurer and the affluent, all classes of people are now traveling by air both for business and pleasure. Americans are traveling today by air in unprecedented numbers, on schedules undreamed of 20 or 30 years ago, and are seeing and experiencing cultures in other parts of the country and the world to an extent that would have been incomprehensible to past generations.

Sources: Laurence Loftin, Jr., *Quest for Performance: The Evolution of Modern Aircraft*, http://www.hq.nasa.gov/office/pao/History/SP-468/ch9.htm; last paragraph**:** John Ziman, *An Introduction to Science Studies: The Philosophical and Social Aspects of Science and Technology* (Cambridge: Cambridge UP, 1984), 153.

Document F

Towards the Deeps of Space: Three Pioneers of Getting There

Konstantin Tsiolkovsky

One of eighteen siblings born in a Russian village to an immigrant Polish forester, Konstantin Tsiolkovsky first dreamed about the possibility of space flight when he was seventeen. Having become deaf as a child, he could not attend school but was a great reader. The science-fiction novels of Jules Verne helped to inspire his interest in science and space. Mostly self-taught, he became a high school mathematics teacher, scientist, and visionary writer. Besides science-fiction novels, into which he introduced real technical problems, Tsiolkovsky wrote over 500 works on space travel and related subjects. His book *Exploration of Cosmic Space* was published in 1903.

Among his contributions to the project of humans in space are his designs for:

- rockets with steering thrusters and multi-stage boosters.
- airlocks for exiting a spaceship into the vacuum of space.
- space stations.
- closed-cycle systems to provide food and oxygen for space colonies.

His ideas had lasting impact. Even though he never created any rockets himself, he influenced many young Russian engineers, scientists, and designers. He lived to see a younger generation of them begin to make his visionary concepts reality. Among these individuals was the chief designer of the Soviet space program that launched humanity into space with Sputnik in 1957.

Robert Goddard

American Robert Goddard became interested in space in 1898 when, as a sixteen-year-old, he read H. G. Wells' science-fiction classic, *The War of the Worlds*. His first writing on the possibility of a rocket fueled by liquid rather than gunpowder came in 1909. Five years later, he patented a multistage rocket using liquid fuel. He then designed experiments to prove that a rocket would perform in a vacuum such as space, and built rockets himself, at his own expense.

He also discussed the use of rockets not only to reach the upper atmosphere, but to escape Earth's gravity altogether; and, as a "thought experiment," to reach the moon. (The Soviet space probe Luna 2 was the first arrival on the moon in 1959.) In a letter to one of his sponsors he discussed:

- photographing the moon and planets from rocket-powered fly-by probes.
- sending messages to alien **civilizations** in outer space on inscribed metal plates.
- the use of solar energy in space.

He was ridiculed and criticized by the media and fellow-scientists for his "too far out" ideas. In spite of such discouragement, and after five years of experimenting with various fuels and hardware designs, he launched the first-ever working liquid-fueled rocket in 1926. It rose just 41 feet during a 2.5-second flight. He continued to work on improvement.

His salary as a physics professor did not stretch to cover the costs of his research. Looking for funding, he introduced his work to the U.S. Army. The Army could see no military applications, and so was not interested. After repeated refusals from potential sponsors, he finally was given a grant by a foundation. This allowed him to produce rocket models that reached an altitude of 1.7 miles and to work out plans to control steering.

Later, these plans were put to use by the Nazi designers of the German V2 rockets used to pound England during World War II. And some of the American officers, who saw the worth of his rockets (though they were not influential enough at the time to get the Army to sponsor them), eventually became important in the U.S. intercontinental ballistic missile and space programs. So his indirect influence cast a long shadow.

Hermann Oberth

Romanian-born German national Hermann Oberth had become fascinated by Jules Verne's novel, *From Earth to the Moon,* as an eleven-year-old. This book, and other space flight literature that he eagerly read in the coming years, led Oberth to intensive study of the technical aspects of interplanetary travel. Still in his teens, self-taught in mathematics, he already conceived a multi-stage, liquid-fueled rocket. Later he constructed a model rocket. But as a schoolteacher he did not have the money to continue building, though he did continue to work on design.

In his twenties, he wrote a dissertation on space travel that was rejected for being "too speculative." The year after, in 1923, he published a book that:

- explained the mathematical theory of rocketry.
- applied it to possible designs for practical rockets.
- considered the potential of space stations and human travel to other planets.

It was enthusiastically received.

In the 1920s and 30s, amateur rocket enthusiasts flocked to rocket clubs that sprang up all over Germany, Russia, the U.S., and several other countries. Experimental rockets were designed, tested, and sometimes flown, and attempts made to translate Oberth's theories into working spacecraft.

Oberth advised many, and eventually attended the launch of the Saturn V rocket that carried the Apollo 11 crew on the first manned lunar landing mission in July 1969.

Sources: Text adapted by Anne Chapman from information in various Internet sources.

Lesson 3
Biology: Darwin's Controversial Legacy

Questions and Activities

Ask students to refer to the information in Student Handout 3.1 (Social Darwinism: Was it a Logical Extension, or a Perversion, of Darwin's Theory?).

1. Imagine a situation where, for whatever reason, unless three out of ten in a group are sacrificed (killed, or allowed to die), all ten will die. On what basis would a Social Darwinist decide who should be sacrificed? How could the Social Darwinist decision be defended? What alternatives would you suggest as a basis for making such a decision? How could your suggested alternative(s) be defended?

2. Give evidence in support of the following statement: "Social Darwinism's success was promoted by the fact that it favored keeping existing power relationships in place."

3. What was going on (politically, economically, socially, or any other way) during the first half of the twentieth century that influenced the acceptance of Social Darwinism? How?

4. Create a conversation between a person defending the claim that Social Darwinism was a logical extension of Darwin's theory and a person arguing against it. Both sides should support their argument with information from Student Handout 3.1.

5. Is it justifiable to apply ideas from biological theory to society? Why or why not?

6. In what ways did interpretations of Darwin's evolutionary theory influence society? Draw on information in Student Handout 3.1 for your answer. (This activity could serve as assessment.)

Ask students to refer to the information in Student Handout 3.2 (Opposition to Darwin's Evolution).

1. In the part of his Scopes trial speech quoted in Document B, on what grounds was Prosecutor Bryan objecting to the teaching of Darwinian evolution in science classes?

2. What compromise did Malone, speaking for the defense, suggest? Could such a compromise have been acceptable to the prosecution? Why or why not?

3. Could the defense have proved that Scopes was innocent? Why or why not?

4. Would you agree with the view that the Scopes trial was not about breaking the law, but about publicity for two opposing points of view? Why or why not?

5. Was bringing the test case justifiable? Why or why not? Support your argument with information from Student Handout 3.2.

6. In what ways were issues of morality involved in the Scopes trial? Explain.

7. Suppose you were asked to testify as an expert witness advising a government about whether to impose regulations on scientists concerning
   - the aims and methods of their research.
   - the teaching of the results of their research.

   What advice would you give? Why? What questions would you want to ask, the answers to which could change the advice you gave? Why?

8. Compare the reasons that the Soviet and the Nazi states had for supporting and for opposing scientists' work in their country. What did their governments want from science? By what yardstick(s) was science evaluated in each?

9. List what you see as the most important consequences of government influence on science, both for good and ill. Explain how you arrived at the decision of what was "most important." (This activity could serve as assessment.)

Extension activity

What would you say the current U.S. government might want from science? By what yardstick(s) would you say it might be likely to evaluate science? Compare your answers to those you gave in question 8, above. How would you account for any differences or similarities?

Ask students to refer to the information in Student Handout 3.3 (The Evolution of Darwin's Theory of Evolution).

1. Compare features of the development of Darwin's theory during 1900-1950 with Darwin's ideas about evolution. Identify any similarities and differences.

2. What changed in genetics between 1900 and 1950?

3. If you had to pick one event as decisive in the history of research in genetics before 1950, what would it be? Why?

4. What moral issues were raised by results of genetics research?

5. (This activity draws on some broad points from Lesson 1.) List similarities and differences between the research done with atoms and that done with cells from 1900 to 1950. Consider topics such as:
    - What was the relationship with technology?
    - What advanced, and what held back, the research?
    - What moral issues were met with?
    - What was the impact on society?

6. List the information about developments in biology between 1900 and 1950 that you think should be included in a world history textbook. Explain your reasons for your choices. (This activity could serve as assessment.)

Ask students to refer to information in all three Student Handouts in Lesson 3.

1. Identify what you consider Darwin's legacy to be, and explain in what ways it was controversial.

2. Which had the greater impact on the daily lives of more people during the first half of the twentieth century, Social Darwinism, or genetics? In what ways? Which had the greater potential for such impact after 1950? Explain, using information from any part of Lesson 3 to support your argument.

Lesson 3

Student Handout 3.1 —Social Darwinism: Was it a Logical Extension, or a Perversion, of Darwin's Theory?

Document A
Survival of the "Fittest"

Darwin published his book *On the Origin of Species by Means of Natural Selection or the Preservation of Favored Races in the Struggle for Life* in 1859. It had a strong and long-continued influence on biological sciences. It was also interpreted in ways that influenced society, being co-opted in support of political ideas, government policies, and economic theory.

The core of Darwin's theory of evolution was:

1. Within a species, there was competition for available resources: food and mates.

2. Traits (characteristics), both variable and inheritable, existed in every species.

3. Those variations best adapted to the environment favored survival and reproduction more than others.

4. It was the traits only of those who were fit enough to survive competition and to reproduce that were passed on to the next generation.

5. The species changed as favorable traits were inherited while others failed to be passed on and therefore gradually died out.

6. All living things were connected, and traced their ancestry to a common source.

Soon after the publication of *On the Origin of Species*, Social Darwinism was born. This **belief system** continued to flourish in England, America, Germany, and elsewhere in the twentieth century and is not dead yet. It arose from a misapplication to society of Darwin's scientific theories on which it claimed to be based.

Its basic principle was "survival of the fittest," a phrase coined by a British economist. Fitness meant victory in the struggle (primarily with other people) for survival and success. Social Darwinists claimed that, to ensure human improvement, the weak and unfit should be allowed to die or at least be prevented from reproducing. Some advocated euthanasia. Foes of Darwinism, such as William Jennings Bryan, thought a straight line ran from Darwin's theory (according to him, "a dogma of darkness and death") to such beliefs. To others, they distorted what Darwin wrote, and were perversions of his theory.

To its followers, Social Darwinism meant that:

1. Governments should not try to regulate the economy or cure social ills such as poverty.

2. Imbalances of power and the struggle for success between individuals, classes, races, and **nations** are justified, because some are fitter to succeed and survive than others.

Such thinking could be, and was by some, used to justify and promote:

1. Seizing of land and resources from the "unfit:" imperialism, **colonialism**.

2. The superiority and dominance of some "races:" whites, Aryans.

3. Cutthroat, laissez-faire capitalism with no restraints.

4. Class struggle.

5. Eugenics programs: selective breeding to improve the human race. Advocates of eugenics variously suggested:
   - Outlawing marriage and sex with members of "inferior" groups.
   - Sterilization of the mentally ill, blind, deaf, epileptic, alcoholic, criminal, or "immoral." In the U.S., a couple of dozen states since 1910 had involuntary sterilization laws. Some were not repealed until the 1970s. Such laws also existed in Japan, Canada, Sweden, and elsewhere. Nazi Germany drew on, but surpassed, U.S. examples, and sterilized half a million people.
   - Genocide, such as the mass murder of Jews, Roma (Gypsies), and the mentally or physically disabled in Nazi Germany.
   - Neglect, the notion that the poor, being unfit, should not be helped, since they were evolutionarily selected to be weak and eventually to die off in destitution.
   - Promoting reproduction of the "better stock." The American Eugenics Society, formed in 1923, launched a widespread campaign to encourage middle class native white Protestants to have more children**.** Nazi Germany pushed motherhood with money and medals; Hitler touted it as the foundation of his racially-pure community, and encouraged single (Aryan) women to get pregnant by temporary (Aryan) SS mates.

Text by Anne Chapman, based on information from a wide variety of sources.

Document B

Struggle and the Favored Races: Evolution Used to Justify Imperialism and Racism

Karl Pearson, author of the selection below, was an aggressive eugenicist who applied his Social Darwinism to entire nations. He openly advocated "war" against "inferior races," and thought this followed logically from his scientific work on human measurement. He was a close associate of Darwin's cousin, Francis Galton, who founded the eugenics movement and the science of measuring mental abilities.

Today's IQ tests have their origins in his work.

> What I have said about bad stock seems to me to hold for the lower races of man. How many … thousands of years have the … negro held large districts in Africa undisturbed by the white man? Yet their intertribal struggles have not yet produced a civilization in the least comparable with the Aryan [northern European]. Educate and nurture them as you will, I do not believe that you will succeed in modifying the stock.
>
> History shows one way, and one way only, in which a high state of civilization has been produced, namely the struggle of race with race, and the survival of the physically and mentally fitter race. … This dependence of progress on the survival of the fitter race … gives the struggle for existence its redeeming features. …
>
> You may hope for a time … when American and German and English traders shall no longer compete in the markets of the world for their raw materials and for their food supply, when the white man and the dark shall share the soil between them and each [work it] as he pleases. … [But] when that day comes mankind will no longer progress. … Is it not a fact that our strength depends on [trade routes and free markets] and upon our colonies [which] have been won by the ejection of inferior races? … [The statesman] must insure that the fertility of inferior races is checked and that of the superior stock encouraged. …

Source: Karl Pearson, *National Life from the Standpoint of Science* (London: Adam and Charles Black, 1905), *passim.*

Document C

How to Prevent the "Decline of the Race"

British statesman Winston Churchill championed forcible sterilization. As Home Secretary in 1910, he introduced a proposal (which failed) to sterilize "mental degenerates." Had it passed, it would have affected 100,000 people, with others being sent to government labor camps. He felt this would save the British race from decline.

In Germany, the initial concern was about the declining birthrate among the privileged classes. After the devastation of World War I, cost-cutting by sterilization to reduce inmates in asylums and hospitals gained in appeal. When Hitler came to power, he introduced euthanasia for "useless eaters" (mental patients.) The technology of the gas chamber was first developed in connection with this program, and then used in the genocide of Jews on racial grounds.

In the U.S., the eugenics movement was fueled by anxieties about the huge growth in immigration. In addition to sterilization, it strongly supported limits on immigration from non-European countries, a restriction on welfare benefits to poor families, and bans on interracial marriage or "miscegenation." Some went further, and advocated euthanasia.

Examples of eugenicist opinions are shown by the quotes below.

British Statesman Winston Churchill, 1904

The unnatural and increasingly rapid growth of the feeble-minded classes, coupled with a steady restriction among all the thrifty, energetic, and superior stocks constitutes a race danger. I feel that the source from which the stream of madness is fed should be cut off and sealed up before another year has passed.

U.S. Progressive Reformer John Randolph Hayes, 1920s

There are thousands of hopelessly insane in California; the condition of those minds is such that death would be a merciful release. How long will it be before society will see the criminality of using its efforts to keep alive these idiots, hopelessly insane, and murderous degenerates. … Of course the passing of these people should be painless and without warning. They should go to sleep at night without any intimation of what was coming and never awake.

Nazi Leader Adolf Hitler, 1925

He who would live must fight. He who does not wish to fight in this world, where permanent struggle is the law of life, has not the right to exist.

[The state] must declare unfit for propagation all who are in any way visibly sick or who have inherited a disease and can therefore pass it on, and put this into actual practice. … Those who are physically and mentally unhealthy and unworthy must not perpetuate their suffering in the body of their children.

U.S. Supreme Court Justice Oliver Wendell Holmes, 1927

It is better for all the world, if instead of waiting to execute degenerate offspring for crime, or to let them starve for their imbecility, society can prevent those who are manifestly unfit from continuing their kind. … Three generations of imbeciles are enough.

Sources: OpenLearn, *Social Darwinism and Eugenics*, http://openlearn.open.ac.uk/mod/resource/view.php?id=193612; http://hnn.us/articles/1796.html; Eugenics Archive, *Eugenics Laws Restricting Immigration*, http://www.eugenicsarchive.org/html/eugenics/essay9text.html; Haynes quote: History New Network, *The Frightening Agenda of the American Eugenics Movement*, http://hnn.us/articles/1551.html; Hitler quotes: Tony Howarth, *Twentieth Century History: The World since 1900* (Harlow, England: Longman, 1979), 127, and Diane Paul, *Controlling Human Heredity: 1865 to the Present* (Atlantic Highlands, NJ: Humanities Press International, 1995), *passim.*

Lesson 3
Student Handout 3.2—Opposition to Darwin's Evolution

Document A
Legal Action in the U.S.

In his book *On the Origin of Species*, Darwin stated that "when the views … in this volume … are generally admitted, we can dimly foresee that there will be a considerable revolution in natural history." He was right, though general acceptance of his views was a long time in coming.

Scientific opposition on various grounds was gradually overcome. For instance, the many new fossil finds (including different **hominids**) overcame the objection that there was not enough evidence of the intermediate forms required if species changed gradually by natural selection.

The opposition to evolution on the grounds that it contradicted the biblical account of creation could not be overcome by factual evidence, and persisted. This opposition took various forms: preaching from pulpits, revivalist meetings, rallies, speeches, and political activity. Legal action was taken by the State of Tennessee, where legislators passed the following statute in 1925. (At that time, fourteen more states had anti-evolution laws pending. Only two actually enacted such laws, which were struck down by the Supreme Court as unconstitutional in 1968.)

The controversy continued over insistence on acceptance of the biblical account of the creation of species, as opposed to the assertion that all species, including humans, evolved by means of natural selection from earlier life forms. In the first decade of the twenty-first century, denial of the latter assertion was still influencing public opinion and educational decisions in the U.S.

> Be it enacted by the General Assembly of the State of Tennessee, that it shall be unlawful for any teacher in any of the Universities, Normals, and all other public schools of the State which are supported in whole or in part by the public school funds of the State, to teach any theory that denies the story of the Divine Creation of man as taught in the Bible and to teach instead that man has descended from a lower order of animals. …
>
> Be it further enacted, that this Act take effect from and after its passage, the public welfare requiring it.

Source: Anne Janette Johnson, *Defining Moments: The Scopes "Monkey Trial"* (Detroit: Omnigraphics, 2007), 156.

Document B

Test Case Challenging the Law: The Prosecution

Several town notables in Dayton, Tennessee, had heard that the American Civil Liberties Union offered to help defend anyone challenging the new law. They agreed that "nobody could teach biology without teaching evolution." They were confident that publicity from a controversial trial would help their small town. They found someone willing to stand for a test case: John Scopes, a twenty-four-year-old general science teacher, who said he had assigned readings on evolution from the state-approved biology textbook.

Famous lawyer Clarence Darrow volunteered for the defense at no cost. Offering to act for the prosecution was William Jennings Bryan, fundamentalist crusader against evolution which he feared would undermine traditional values.

The following are excerpts from Bryan's argument against the defense's request to admit testimony from scientists and religious leaders. The defense wanted to call them in order to get the case dismissed on the grounds that the law was unconstitutional, rather than to gain an acquittal. Bryan was severely mauled by Darrow on cross examination, and the eventual guilty verdict was reversed a year later by the Tennessee Supreme Court on a technicality, not on the grounds the defense had hoped for. The meaning of the trial was debated hotly and at length.

Shall [children] be … compelled to link their ancestors with the jungle? … Why, my friend, if they believe it, they go back to scoff at the religion of their parents! …

[Scientists] come here with this bunch of stuff they call evolution, that … nobody can tell how it came, and they do not explain the great riddle of the universe—they do not deal with the problems of life—they do not teach the great science of how to live—and yet they would undermine the faith of these little children in that God who stands back of everything … They did not tell us where … between the cell at the bottom of the sea and man, where man became endowed with the hope of immortality …

If this doctrine is true … that means they eliminate the virgin birth … the resurrection of the body … the doctrine of atonement … [They] force upon … the children of taxpayers of this state a doctrine that refutes not only their belief in God, but … takes from them every moral standard that the Bible gives us …

We cannot humiliate the great state of Tennessee by admitting for a moment that people can come from anywhere and protest against the enforcement of this state's laws on the grounds that it does not conform with their ideas. …

Source: Leslie H. Allen, *Bryan and Darrow at Dayton* (New York: Russell and Russell, 1925), qtd. in Anne Janette Johnson, *Defining Moments: The Scopes "Monkey Trial"* (Detroit: Omnigraphics, 2007), 165-7.

Document C
The Defense Responds to the Prosecution

International divorce lawyer Dudley Field Malone was another volunteer member of the defense team. Below is an excerpt from what his opponent Bryan said was "the greatest speech I ever heard," which Malone gave in response to Bryan's prosecutorial speech above. Not, of course, in time for this trial, but one religious authority, Pope Pius II, did declare in 1950 that evolution did not contradict essential Catholic teachings.

These gentlemen say the Bible contains the truth—if the world of science can produce any truth or facts not in the Bible as we understand it, then destroy science, but keep the Bible.

And we say, "Keep your Bible." Keep it as your consolation, keep it as your guide, but keep it where it belongs … in the world of theology … and do not try to tell an intelligent world and the intelligence of this country that these books written by men who knew nothing of the accepted fundamental facts of science can be put into a course of science. …

This law says … that only the Bible shall be taken as an authority on the subject of evolution in a course in biology. … Are the teachers and scientists of this country in a combination to destroy the morals of the children to whom they have dedicated their lives? Is the church the only source of morality in this country? …

For God's sake let the children have their minds kept open. … Make the distinction between theology and science. Let them have both.

Source: Leslie H. Allen, *Bryan and Darrow at Dayton* (New York: Russell and Russell, 1925), qtd. in Anne Janette Johnson, *Defining Moments: The Scopes "Monkey Trial"* (Detroit: Omnigraphics, 2007), 168-70.

Document D

Government and Party-backed Opposition in the USSR

Famine was the result of Stalin's policy of collectivization in 1929-32. Fast practical results in producing sorely-needed larger harvests seemed to be promised by the Russian biologists Michurin, Lysenko (who wrote the text below), and their followers. Unfortunately, the promise was based on incorrect ideas.

They believed in the inheritance of acquired characteristics, that changes in an organism due to the influence of the environment during its lifetime would be inherited by its offspring. This theory had lost virtually all scientists' support outside the USSR by the 1940s.

Nevertheless, the need for food, combined with a willingness to accept Communist Party policy as the touchstone of truth, gained Lysenko and his work the powerful backing of Stalin and the Party. Those who opposed Lysenko were fired, exiled, or imprisoned. Teaching genetics anywhere was banned, because it did not agree with Lysenko's ideas. Books on genetics were withdrawn from libraries; stocks of the fruit-fly used in genetic experiments were destroyed.

These were very big changes in a country that, up through the 1920s, had been established as a world center for research in genetics. It was here that biologists first applied statistics and mathematical modeling to the study of genetics in populations.

> His investigations led I. V. Michurin to the [conclusion that] "It is possible, with man's intervention, to *force* any form of animal or plant *to change more quickly and in a direction desirable to man* [emphases in original] …"
>
> The Michurin teaching flatly rejects the fundamental principle of Mendelism-Morganism [Western genetics] that heredity is completely independent of the plants' or animals' conditions of life. [It] does not recognize the existence in the organism of a hereditary substance [gene] which is independent of the body.
>
> Changed [genes] … always occur only as the result of changes in the body of the parent organism, as a result of direct or indirect action of the conditions of life [the environment] upon the development of the organism.

Source: From T. D. Lysenko's address, *The Situation in Biological Science*, 1948, qtd. in A. E. E. McKenzie, *The Major Achievements of Science*, Vol. II: *Selections from the Literature* (Cambridge: Cambridge UP, 1960), 147.

Document E

Science as a Pawn in the Struggle between Socialism and Capitalism

The Soviet government mandated acceptance of only one theory of genetics, and saw that theory as the handmaid of ideology.

> Michurin's materialist direction in biology is the only acceptable form of science, because it is based on dialectical materialism, and on the revolutionary concept of changing Nature for the benefit of the people. … The struggle between [Michurin's conclusions and Western genetics] has taken the form of the ideological class-struggle between socialism and capitalism on the international scale, and between the majority of Soviet scientists and the few remaining Russian scientists who have retained traces of bourgeois ideology. … There is no place for compromise.

Source: From a statement by the Presidium of the USSR Academy of Sciences, 1948, qtd. in A. E. E. McKenzie, *The Major Achievements of Science,* Vol. II: *Selections from the Literature* (Cambridge: Cambridge UP, 1960), 146-7.

Document F

Ideology Trumps Science

In Nazi Germany, genetics was considered to be of great ideological, military, and economic importance to the government, since it could be used to promote Hitler's "pure race" policies. Basic research was generously funded, career chances were expanded, and restrictions on experimental work were minimized. Most of Germany's leading geneticists—including those who before 1933 had criticized anti-Semitism—actively helped construct the racial state, that gave geneticists the support they thought was their due. All but Jewish ones. Those were fired and hounded. Most fled abroad. Hitler himself is reported to have said the following.

> If the dismissal of Jewish scientists means the annihilation of contemporary German science, then we shall do without science for a few years.

Source: John Marks, *Science and the Making of the Modern World* (London: Heinemann, 1983), 376.

Lesson 3

Student Handout 3.3—The Evolution of Darwin's Theory of Evolution

Rival theories persisted

By 1950, Darwinism had competed with alternative theories of species change for nearly a century. Perhaps as many as a dozen theories, other than Darwin's, flourished for various lengths of time. Most of them were gradually abandoned as they lost support. The following theories survived, holding that:

- There was no such thing as evolution because there was no species change. God had created static species, complete with all their characteristics, once and for all.
- Species change was due to environmental change, which led to changes in behavior in members of a species. The new behavior changed parts of their bodies, and these changes were inherited. (This theory, which flourished in Russia in the 1940s, is also known as the inheritance of acquired characteristics).
- Changed species resulted rapidly from mutations, abrupt random changes in the stuff within the cells that carried the substance of heredity.

Darwin's critics also complained that he had not satisfactorily answered two questions central to his theory:

- Where did the continuous supply of variation within a population, needed for natural selection to work on, come from? (The leading theory in Darwin's time was that inherited traits blended in the offspring, which decreased available variation).
- Exactly how were inherited traits (characteristics) passed on to the next generation? (Darwin's own tentative idea was that body cells might shed tiny particles that collected in the reproductive organs, and were then passed on.)

Answers came slowly and variously.

The role of peas and "factors"

A retiring Central European monk who had never been in touch with Darwin produced the beginnings of answers before the questions were even asked. Gregor Mendel spent many years experimenting with cross-breeding pea plants in the 1860s. The first to apply mathematics to biology, Mendel found that:

- Each parent contributed a "factor" (what was later called a gene) that determined a particular trait in the offspring.
- Traits inherited from parents remained unchanged as they passed on from one generation to the next.
- Inherited traits showed up in offspring only if at least one of the inherited "factors" was a dominant form of the trait.

- Different “factors” from each parent, like one for green, another for yellow peas, did not blend and produce greenish-yellow offspring, but green and yellow according to predictable mathematical ratios in each succeeding generation.

Unknown by Darwin and overlooked for decades, Mendel’s work was controversial for some twenty years after its rediscovery in 1900. However, it continued as one of the basic elements in later genetics theory.

Mendel had no physical location for his “factors,” and no proof of their physical reality. But by 1900 it was suspected that inherited characteristics had something to do with chromosomes, the paired rod-like bodies visible in the nucleus of cells.

The role of fruit flies and chromosomes

Next to Professor Thomas H. Morgan’s office at Columbia University was a cramped room furnished with a few old tables and thousands of milk bottles in which fruit flies were bred by the millions. Here he and his graduate students studied fruit fly inheritance in the early twentieth century. By this time, what they were doing was called “genetics.”

One of the students noticed a connection between the fruit fly’s inheritance of certain traits, and details of its chromosomes—evidence for the latter’s role in inheritance. Going a step further, Morgan’s research group showed that treating chromosomes with X-rays changed both chromosomes and the heritable characteristics (traits) that were governed by them. They also found that genes, Mendel’s “factors,” were linearly arranged on chromosomes (see picture on page 70); and that a particular hereditary characteristic was associated with a specific chromosome location (gene). This was the physical basis for transmission of traits according to Mendel’s laws.

During sexual reproduction, with each parent contributing one to the pair of chromosomes, some chromosome segments bearing genes were shuffled and recombined. The genes ending up in the newly-formed reproductive cell were randomly sorted from various possible combinations of maternal and paternal genes. This contributed to the genetic variability of the offspring.

The role of mutations

Mutations were identified around the turn of the century. They were hereditary traits that would appear suddenly, commonly, by chance, and with unpredictable effects. Their cause was damage or change to a gene that changed the genetic message carried by it, and therefore the trait governed by it. This way, new traits would arise, such as white eyes in a species of fly that had produced only red-eyed individuals for hundreds of generations.

Morgan showed that mutations could also be deliberately produced. He created mutations both from the outside by X-raying his fruit flies, and from the inside by breaking up individual chromosomes. By introducing new traits, mutations gave yet another answer to how variability continued to be available in a population.

Mutation and natural selection in conflict

For a generation or more after 1900, Darwin's theory of natural selection acting on small variations within a population was losing acceptance. Some argued that, instead of natural selection, there must be a built-in "direction" to the variation that arose in each generation, helping to push each species towards progress. Others held it was new, large mutations that fueled rapid evolutionary change rather than natural selection working slowly on small variations. Champions of mutation and of natural selection each defended their own theory and sought to defeat the other.

Reconciliation of mutation and natural selection

A new line of research began in the 1920s, known as population genetics. It involved statistical study, outside the laboratory, of variations in many members of a species. It found that a common way a new species could come into being is by a combination of mutation, natural selection, and geographical segregation.

Part of a population can become separated from its fellow-species members by some barrier such as a flooded valley, a glacier tongue, or rising sea levels. The separated population will evolve differently from the population it has been cut off from. Its members will become adapted to their specific environment, different from the original habitat. They will do so by natural selection acting on variations that arise by mutations, some of which, being random, will differ from those in the original population.

As a result, over time, their genetic make-up will be different enough that, should the barrier be removed, interbreeding with the rest of the population will have become impossible. A new species will have arisen, by a combination of genetics (mutation) and natural history (evolution by natural selection).

The role of the tobacco plant virus, and the nature of "life"

A study of the tobacco plant virus in the 1930s posed new questions. Viruses (and there are many different kinds) are among, or perhaps the, smallest living organisms that are known to exist—if they are accepted as alive, that is.

The researchers had found that the virus they worked with was made up of much the same combination of protein and **DNA** as were chromosomes in living cells—but the virus lacked a cell's structure. It needed a host cell, within which it assembled itself similarly to non-living crystals. Viruses appeared to act like inanimate chemicals, but also presented evidence of being living and growing organisms. They adapted to their environment. For instance, they developed resistance to new antiviral drugs quickly, helped by high mutation rates.

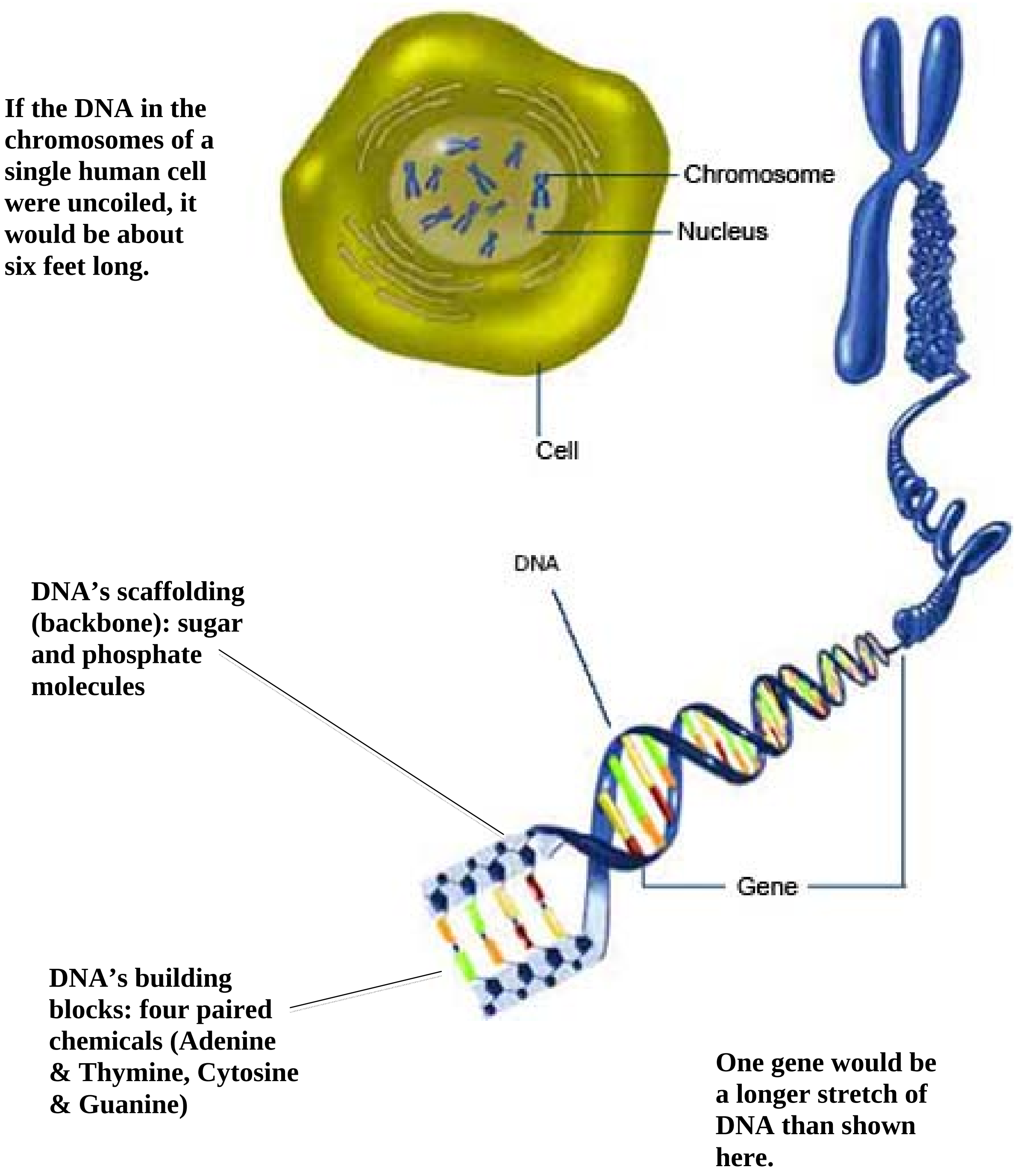
The researcher working on them stated that viruses make it "difficult, if not impossible, to place a sharp line separating living from non-living things …" Whether viruses were alive, not alive, or something in between, and just what being "alive" meant, continued to be debated.

The road to DNA

Physicists during the first half of the twentieth century analyzed the structure of the atom in increasing detail in the hope of understanding matter at its most fundamental. Similarly, biologists analyzed the structure of the cell in increasing detail with the hope of understanding life at its most fundamental level.

By the mid-nineteenth century, scientists had identified chromosomes in the cell nucleus. By the 1920s, the gene was recognized as a particular segment of a chromosome, and chemical analysis had shown that the latter was made up of DNA and protein. By the 1930s, there was increasing evidence that DNA held the genetic information for the organism, and instructions for making proteins. It was by1953 that DNA’s composition down to the chemical level, as well as its double helix structure, were known. One of the discoverers of DNA’s structure said of the discovery that “we had found the secret of life.”

The Mechanism of Inheritance as Known by 1953



Source: Adapted from the National Institute of General Medical Sciences, *The New Genetics*, http://publications.nigms.nih.gov/thenewgenetics/chapter1.html

Beyond the science: Darwin's impact on society

Darwinian theories generated outgrowths and interpretations that stretched it far beyond science. The most widely influential was Social Darwinism (see Student Handout 3.1, Document A).

But the nature-nurture debate about whether it was heredity or environment that determined human personalities and abilities, also affected many people and various aspects of life. This controversy influenced:

1. Biological theory, with Darwin himself, and Social Darwinists, favoring biology. Believers in the inheritance of acquired characteristics gave the greater weight to the environment.

2. The understanding of human mental development from childhood to adulthood, and educational policies based on it. For instance, belief that intelligence as measured by IQ was determined by one's genes would reduce the likelihood of funding for remedial education.

3. Nation-wide public policies of governments. The Nazis thought human nature was defined by one's race. The communists followed Marx's idea that human nature was influenced by social structures, especially class, and not biologically fixed. Both beliefs had political, economic, and social results.

The "evolutionary synthesis:" combination of change and continuity

By 1950, Darwin's theory had become modified in its details in ways that adapted it to changing scientific environments, and had pretty well disposed of the competition. At an international meeting in 1947, leading scientists from the various schools of evolutionary thinking met. They unanimously rejected competing theories, and agreed to what was still Darwin's theory, enriched and modified in detail by the new ideas and new evidence about genetics and about species change.

Acceptance of the evolutionary synthesis spread rapidly among biologists. Among non-scientists, widespread resistance to agreement with Darwinian evolution continued.

Consequences at the time and for the future

By the mid-twentieth century, practical applications of genetics already had wide-reaching consequences. They deeply influenced medical science, helping in the diagnosis and treatment of various human diseases and conditions. They helped determine paternity in legal cases. They promoted disease resistance in **agriculture**, and led to the greatly-increased yields of the "Green Revolution" that, starting in the mid-1940s, took off in 1961 with a large-scale reduction of starvation in the developing world.

Genetics has also opened the door to discoveries with global, and mind-wrenching, consequences.

In1952, the first animal (a frog) was cloned, and nine species of **mammals** were cloned during the rest of the twentieth century. Experiments with combining DNA from different organisms eventually, in the 1970s, resulted in the first "bug-built drug" for human use: insulin, an anti-diabetic. In the first decade of the twenty-first century, several research groups have made substantial progress towards building life from non-living components.

Source: Text by Anne Chapman, based on information from a wide variety of sources.

Assessment

1. Suppose you were asked to pick something that best summed up the revolutionary nature of the scientific and technological changes of the first half of the twentieth century. Would you pick something scientific or something technological? Why? What, specifically, would be your choice? Why?

2. Was it in science or in technology that there was more of a revolution? Defend your position with specific information from the unit.

This unit and the Three Essential Questions

HUMANS & the ENVIRONMENT	How have waste products of air travel contributed to environmental problems in the past cetury?
HUMANS & other HUMANS	What role did team-based, interdisciplinary, and international collaboration play in the achievements of science between 1900 and 1950?
HUMANS & IDEAS	In what variety of ways have scientific ideas met opposition from ideologies and belief systems? Can you think of examples today where that opposition occurs?

This unit and the Seven Key Themes

This unit emphasizes:

Key Theme 6: Science, Technology, and the Environment.

Key Theme 7: Spiritual Life and Moral Codes

This unit and the Standards in Historical Thinking

Historical Thinking Standard 1: Chronological Thinking

The student is able to (F) reconstruct patterns of historical succession and duration in which historical developments have unfolded, and apply them to explain historical continuity and change.

Historical Thinking Standard 2: Historical Comprehension

The student is able to (F) appreciate historical perspectives–(a) describing the past on its own terms, through the eyes and experiences of those who were there, as revealed through their literature, diaries, letters, debates, arts, artifacts, and the like; (b) considering the historical context in which the event unfolded—the values, outlook, options, and contingencies of that time and place; and (c) avoiding “present-mindedness,” judging the past solely in terms of present-day norms and values.

Historical Thinking Standard 3: Historical Analysis and Interpretation

The student is able to (D) draw comparisons across eras and regions in order to define enduring issues as well as large-scale or long-term developments that transcend regional and temporal boundaries.

Historical Thinking Standard 4: Historical Research Capabilities

The student is able to (F) support interpretations with historical evidence in order to construct closely-reasoned arguments rather than facile opinions.

Historical Thinking Standard 5: Historical Issues: Analysis and Decision Making

The student is able to (E) formulate a position or course of action on an issue.

Resources

Resources for teachers

American Institute of Physics, http://www.aip.org/history/exhibits.html. A very useful guide to links for a wide variety of online resources for the history of physics and allied fields: pictures, voice clips, essays, quotes, and exhibits. Reading level varies, but much would be accessible and attractive to students.

Browne, Janet. *Darwin's Origin of Species: A Biography*. New York: Atlantic Monthly Press, 2006. Brief, reader-friendly background that helps in understanding the still-current debates ignited by Darwin's work. Its reception and impact are set against the historical context of economic and political developments, and broader intellectual currents. The roots of opposition to his case for evolution as well as reasons for its firm establishment a century or so later, the continued controversy, and his widespread legacy are explained clearly and concisely. It mentions, but does not deal with, the global impact. Most relevant are chapters 4 and 5.

Chaikin, Andrew. *Air and Space: The National Air and Space Museum Story of Flight.* The National Air and Space Museum, Smithsonian Institution in association with Bullfinch Press/Little, Brown, 1997. This lavishly-illustrated, exhaustive but inviting rather than exhausting account brings to life the story of aviation. The authoritative text is based on extensive documentary research as well as interviews with historians, aviators, astronauts, and engineers, and gives information with a light touch. It could be a useful research source for competent students.

Crouch, Tom D. *Wings: A History of Aviation from Kites to the Space Age.* Washington, DC: Smithsonian National Air and Space Museum in association with W. W. Norton, 2003. All but some 90 pages of its 639 pages of text deal with the pre-1950 period. Chronological in approach, it discusses business aspects of early aircraft production, and ties technology to sales; connects aviation to the arts and popular culture; provides detail about engineering, materials, and the impact of design on speed, publicity, and sales while avoiding technical jargon; points out the role of governments and of military aviation research in the development of air transport and the aviation industry. International in scope, though its focus is on the U.S. Personal information about the characters introduced, illustrative anecdotes, information that is specific without being dense or overwhelming, and telling quotations from a variety of participants in the events covered, enliven the text.

Marks, John. *Science and the Making of the Modern World*. London: Heinemann, 1983. Probably your single best bet for thoroughness and convenience. Half of it deals with the twentieth century. Individual chapters explore the various sciences. Others outline their differing paths in Nazi Germany, Communist Russia, Japan, China, the Third World, and liberal capitalist societies. A useful five-point summary follows each chapter. It needs no scientific background to be eminently readable; originally targeted to undergraduate students.

Headrick, Daniel R. *Technology in World History*. Oxford: Oxford UP, 2009. A history of invention around the globe from Paleolithic times to the present in 148 pages. The author compares the development of technology in different parts of the world, providing a sweeping account.

Headrick, Daniel R. *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940.* Oxford: Oxford UP, 1988. Valuable for information on technology in the late nineteenth and early twentieth centuries in the colonial societies of Malaya, parts of Africa, and India in Chapters 8 and 9. Straightforwardly informative, with paragraph-length quotations and statistics from original sources.

McClellan, James E., III and Harold Dorn. *Science and Technology in World History: An Introduction*. Baltimore: The Johns Hopkins UP, 1999. The three chapters that deal with the twentieth century give a concise overview of the topic, with a focus on the West. The rest of the world is treated in the chapter devoted mostly to technology in the context of nineteenth-century industrialization and colonialism, and post-World War II emerging markets. The chapter on relativity and quantum physics gives a compressed but unusually clear account of these topics. The third relevant chapter, on applied science and technology, usefully touches on careers in those fields and discusses women in science. That the account of life science is almost entirely restricted to the nineteenth century is a minus; the bibliography's list of "cool websites" is a plus. Some students could handle reading selected passages.

National Academy of Sciences and Institute of Medicine. *Science, Evolution, and Creationism.* Washington, DC: The National Academies Press, 2008. It provides concise, clear, and easy-to-understand answers and explanations for a large variety of questions that may arise when dealing with Darwinian evolution and with the controversies it triggered. Its three chapters: Evolution and the Nature of Science; The Evidence for Biological Evolution; and Creationist Perspectives, include issues such as the nature of science, the

case for creationist opposition to evolution, differences between science and religion, and support for the claim that acceptance of evolution is compatible with religious belief. Its target audience includes able (high school) students. A useful bibliography lists books for children and young adults with grade levels indicated.

Resources for students

Aaseng, Nathan. *Yearbooks in Science: 1930-1939.* New York: Twenty-First Century Books, 1995. Some of the eight individual chapters focus more on science, others on technology. Between 6 and 19 pages long, they deal with physics, chemistry, outer space, medicine, measurement and detection, construction, communication and information, and transportation. The book discusses dead ends and failures as well as successes.

Henderson, Harry and Lisa Yount. *Twentieth-Century Science*. San Diego, CA: Lucent Books, 1997. It deals with physics, astronomy, medicine, and the information revolution, selectively incorporating technology with science. It covers a great deal of information without overdoing the detail in its 85 pages of generally-engaging text, enlivened by occasional excerpts from original sources. Useful glossary; a list of important dates helps identify less relevant because post-1950 content, about half the book.

McGowen, Tom. *Yearbooks in Science: 1900-1919.* New York: Twenty-First Century Books, 1995. Individual chapters on physics, chemistry, astronomy, biology, geology, and aeronautics/astronautics, 6-20 pages each, give easy to understand explanations of the scientific discoveries. Colloquial language, non-intrusive editorial comments, and information that gives the scientists a human dimension, enhance readability.

Rinard, Judith E. *The Book of Flight: The Smithsonian Institution's National Air and Space Museum.* Buffalo, NY: Firefly Books, 2001. About half the 120 pages deal with the pre-1950 period. It gives an informative and easy to understand chronological account not only of events, developments, and individual personalities but, briefly, of groups such as flight attendants, Tuskegee airmen, and kamikaze pilots, as well as considerable non-technical information about technological change. The museum's collections provide the lavish illustrations, which are tied to, clarify, and enhance the text. Useful glossary.

Sources of documents in the Student Handouts

Crump, Thomas. *A Brief History of Science: As Seen through the Development of Scientific Instruments.* New York: Carroll and Graf Publishers, 2001.

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Laurence, William L. *Dawn over Zero: The Story of the Atomic Bomb*. New York: Alfred A. Knopf, 1946.

Loftin, Laurence L., Jr. *Quest for Performance: The Evolution of Modern Aircraft*, at http://www.hq.nasa.gov/office/pao/History/SP-468/ch9.htm

Magoun, F. Alexander. *A History of Aircraft*. New York: Whittlesey House, McGraw-Hill Book Company, Inc., 1931.

Marks, John. *Science and the Making of the Modern World*. London: Heinemann, 1983.

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Correlations to National and State Standards

National Standards for World History

Era 8: A Half-Century of Crisis and Achievement, 1900-1945. 3C: The student understands the interplay between scientific or technological innovations and new patterns of social and cultural life between 1900 and 1940.

California History-Social Science Content Standards

Grade Ten, 10.4.1: Describe the rise of industrial economies and their link to imperialism and colonialism (e.g., … Social Darwinism …).

Michigan High School Content Expectations

World History and Geography. WHG Era 7 – Global Crisis and Achievement: 1900 – 1945. 7.1.4: Global Technology – Describe significant technological innovations and scientific breakthroughs in transportation, communication, medicine, and warfare, and analyze how they both benefited and imperiled humanity.

Conceptual links to other teaching units

A Half Century of Crisis
1900 – 1950

8.6
Revolutions in
Science and Technology

8.7
Environmental Change
The Great Acceleration

Scientists tell us that about 18,000 to 15,000 years ago the earth entered the "Holocene," an era of global climatic warming that succeeded the Pleistocene, or last great ice age. Now, some scientists argue that for the past three centuries or so, we have been living in the "Anthropocene," that is, an era when the earth's geologic, hydrologic, atmospheric, and biological systems have been changing primarily as a result of human action. "Anthropocene" derives from the Greek word "Anthropos," meaning "human." There is no doubt that humans have intervened in the natural and physical environment at an accelerating pace during the twentieth century and that advances in science and technology have made that possible, for good or ill. The study of environmental change in the first half of the twentieth century, the subject of Landscape Teaching Unit 8.7, is inseparable from developments in science and technology. For example, we may attribute partly to air travel, one of the lesson topics in this unit, the worsening of atmospheric pollution from internal combustion engine exhaust.