Scientific Discoveries and Inventions

National Survey of
Historic Sites and Buildings

The National Survey of Historic Sites and Buildings

Theme XX

The Arts and Sciences

INVENTIONS AND SCIENTIFIC DISCOVERIES

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United States Department of the Interior
Stewart L. Udall, Secretary

National Park Service
George B. Hartzog, Jr., Director

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PREFACE

The National Survey of Historic Sites and Buildings is a resumption of the Historic Sites Survey begun in 1937, under the authority of the Historic Sites Act of 1935. During World War II, and the emergency following, it was necessary to suspend these studies. The Survey has now been resumed as part of the National Park Service MISSION 66 Program.

The purpose of the Survey, as outlined in the Historic Sites Act, is to "make a survey of historic and archeologic sites, buildings, and objects for the purpose of determining which possess exceptional value as commemorating or illustrating the history of the United States." In carrying out this basic directive, each site and building considered in the Survey is evaluated in terms of the Criteria for Classification, which are listed in the appendix of this report.

When completed the Survey will make recommendations to the Director of the National Park Service and the Secretary of the Interior as to the sites of "exceptional value." This will assist the National Park Service in preparing the National Recreation Plan, including sites which may be administered by the National Park Service to fill in gaps in the historical and archeological representation within the National Park System. It will also recommend and encourage programs of historical and archeolcgical preservation being carried out by state and local agencies.

This study is a joint product. The narrative section was written under contract by Dr. Benjamin F. Gilbert, Professor of History at San Jose State College, California. Historian Charles W. Snell, Western Region, San Francisco, coordinated the theme study. Historians Ray H. Mattison, Midwest Region, Omaha; William Brown, Southwest Region, Santa Fe; Horace J. Sheely, Jr., Southeast Region, Richmond; and S. Sydney Bradford, Northeast Region, Philadelphia, contributed the material on the individual sites in their respective regions that appears in this study.

After completion, the study was presented to the Consulting Committee for the National Survey of Historic Sites and Buildings. The Committee consists of Dr. Waldo G. Leland, Director of the American Council of Learned Societies; Dr. S. K. Stevens, Executive Director of the Pennsylvania Historical and Museum Commission; Dr. Louis B. Wright, Director Folger-Shakespearean Library; Mr. Earl H. Reed, Chairman Emeritus American Institute of Architects; Dr. Richard H. Howland, Head Curator, Civil History,

Smithsonian Institution; Mr. Eric Gugler, Member Board of Directors, American Scenic and Historical Preservation Society; Dr. J. O. Brew, Peabody Museum of Archeology, Harvard University; Mr. Frederick Johnson, Curator, Robert S. Peabody Foundation for American Archeology, Phillips Academy; Mr. Robert R. Garvey, Jr., Executive Director of the National Trust for Historic Preservation; and Dr. Ralph H. Gabriel, Sterling Professor of History Emeritus, Yale University, and Professor of American Studies, American University.

The over-all Survey, as well as the theme study which follows, is under the general direction of John O. Littleton, Chief, National Survey of Historic Sites and Buildings, who works under the general supervision of Herbert E. Kahler, Chief, Division of History and Archeology Studies, of the National Park Service.

George B. Hartzog, Jr.
Director

PART I

A HISTORY OF SCIENTIFIC DISCOVERIES

I. COLONIAL PERIOD, 1600-1775

Evolution of nautical and geographic science and the discovery of America.

The revival of applied science was an important aspect of the Renaissance opening the Age of Exploration and causing the expansion of Western Civilization. The Arabs and the Crusaders had transmitted the compass to Europe from China. The compass, a device for determining directions by means of a magnetized needle swinging on a free pivot and pointing to the magnetic north, was used by the Silicians during Marco Polo's time. By the beginning of the fourteenth century the compass was generally used by sailing vessels in the Mediterranean. The discovery of America by Columbus was a result of the development of the mariner's compass. Although Columbus had not acquired knowledge of the methods of astronomical navigation, he could plot his courses by use of the compass and by relying on dead reckoning.[1]

The astrolabe, an instrument for determining latitude, was in use by Europeans as early as the thirteenth and fourteenth centuries. Tables of solar declination published by Jean de Koenigsberg in 1473 aided in the use of the astrolabe. By improving the instrument mariners were enabled to sail at night by the light of the stars. In the Iberian Peninsula the Portuguese were the first to use the astrolabe, and it was introduced into Spain by Amerigo Vespucci.

The quadrant, a simplification of the astrolabe, was another instrument that assisted navigation. Although latitude could be determined, the problem of figuring longitude remained unsolved until about the middle of the seventeenth century, when the chronometer was invented. The scientific views of Columbus and his contemporaries were those of the Middle Ages and in actuality ships out of sight of land never knew their exact east-and-west position. Hence they sailed by dead reckoning, calculating their position by the estimated speed of the ship.

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[1] Frederic C. Lane, "The Economic Meaning of the Invention of the Compass," American Historical Review, LXVIII (April, 1963), p. 605.

Besides the improvement of navigational instruments, explorers were assisted by advancements in the study of geography and astronomy. A large number of coast charts, called portolani, were made. These plotted the coast lines of Europe and North Africa with a considerable degree of accuracy. In 1409 a Latin translation of Ptolemy, the great geographer of the Roman Empire, appeared. His belief that the earth was round was accepted again by many Europeans.

In the fourteenth and fifteenth centuries the science of cartography centered in Italy and Portugal. In 1419 Prince Henry the Navigator, governor of the southernmost province of Portugal, built a residence, naval school and arsenal, library, and observatory on the Rock of Sagres. Here trained mariners, some of whom were Italians, studied geography and navigation and sent out expeditions down the African coast. The use of movable type made for more rapid printing causing scientific and geographical discoveries to be widely disseminated. More maps were printed and as a result map making became a science and a profession. At Prince Henry's naval school maps were studied and corrected. Navigational tables were improved, nautical instruments were advanced, and new types of sailing ships were devised by naval architects at the school. With larger ships mariners could venture into the uncharted Atlantic.

The discovery of America in 1492 was no isolated event, but the culmination of a series of maritime developments. The study of astronomy, geography, and cartography, the improvement of navigational instruments, and the advancement of shipbuilding were all factors in leading to the discovery of America. While Spain and Portugal were the pioneers in ocean exploration and in New World colonization, because of their earlier acquisition of scientific and technical knowledge, the latecomers as colonizers were soon to learn. Shortly after Spain and Portugal attempted to divide the new lands between themselves, John Cabot sailed on his expedition for the King of England in 1497. However, successful English colonization of North America was delayed until 1607.

America's discovery as a stimulus to science.

While the discovery of America was made possible because of scientific advances, the discovery of new lands in turn stimulated scientific interest in Europe as data concerning the strange plants and animals and the Indians came to the attention of European scholars. America was colonized when a scientific awakening was astir in Europe. Scientists came to the New World and scientific ideas were to cross and recross the Atlantic. European science had long learned lessons from the Orient and was now ready to learn from America.

In the spring of 1585, Sir Walter Raleigh sent out a fleet of seven ships commanded by Sir Richard Grenville to "discover, search, find out, and view such remote, heathen, and barbarous lands, countries, and territories not actually possessed by any Christian prince, nor inhabited by Christian people." Raleigh selected Thomas Harriot, a young and brilliant scientist, to survey the new land, to serve as historian and geographer, and to prepare an account of the natives, mineral resources, and flora and fauna of the area.

The expedition landed at Roanoke Island in the waters between Palmico and Albemarle Sounds. At this site of the first English settlement in North America Harriot began to map the area and to take notes. He collected specimens of animals and birds. Besides mammals such as the raccoon, otter, marten, and skunk, Harriot brought strange birds to England. Among the plants he carried back to England were corn and tobacco.* John White, the artist of the expedition, painted pictures of the Indians as well as of the plants and the animals.

The next year the first colony was forced to return to England because of hunger and warfare with the Indians. Harriot never returned to America, but his scientific observations were published in _A Briefe and True Report of the New Found Land of Virginia_ (1588). In England he continued his scientific research and became England's leading astronomer as well as an eminent mathematician. His great work, _Artis Analyticae Praxis ad Aequationes Algebraicas Resolvenda_, published posthumously in 1631, had inventions that gave algebra its modern form.[1]

By the time Jamestown was settled, European scholars were aware of the wonders of the lands overseas. Interest in the flora and fauna, in mineral specimens, in fossils, and in Indian artifacts of America was widespread. The origin and religion of the natives were studied. The anthropology, botany, climatology, mineralogy, and zoology of America were studies that interested the explorers and settlers. Astronomical calculations based upon observations made in America were to be of value to European scientists.

In colonial times science was not specialized nor separated into compartments. It was generalized into two broad fields, natural philosophy and natural history. The former comprised physics, chemistry, and mathematics and the latter comprised geology, botany, and zoology. Actually most colonial scientists investigated in both fields and an individual scientist might be a physician, a botanist, a mathematician, and an anthropologist.

* Sara A. Dickson, _Panacea or Precious Bane, Tobacco in 16th Century Literature_ (New York, 1954), 132, proves that tobacco was introduced in England prior to 1570, coming by way of Spain.

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[1] Bernard Jaffe, Men of Science in America (New York, 1944), 1-10

Field naturalists were the pioneers in the development of American science. They discovered, described, and classified the numerous animals and plants of the virgin land. The naturalists included physicians, clergymen, lawyers, wealthy planters, college professors, and some non-professional people. They collected botanical and zoological specimens and were intrepid explorers. They traveled primitive and dangerous roads often at their own expense when funds were limited. Although these American naturalists did not advance new hypotheses, they contributed knowledge to support the theories of fellow scientists in Europe. The early collectors were field naturalists, but once learned societies were established in America, they were joined by museum curators, who classified the material collected in the field.

Noted colonial scientists:

The John Winthrops

John Winthrop, Jr., eldest son of the famous first governor of Massachusetts Bay Colony, and himself a governor of Connecticut, was the first notable scientist to appear in America. He collected a scientific library of a thousand books and his home became a scientific center. He owned what was probably the first telescope in the English colonies. He subsequently presented it to Harvard in 1672 and it was the first scientific instrument possessed by the college.[1]

John Winthrop, Jr. was a student of astronomy, chemistry, medicine, and witchcraft. He is believed to be the first American member of the Royal Society of London. He studied celestial bodies with his three-foot refractor telescope and in a letter sent to the Royal Society predicted the discovery of Jupiter's fifth satellite. In 1635 he organized a "chymist's" plant, the first in the colonies, where he produced chemicals needed by the colonists. He also set up a glassworks as well as a saltworks to aid the fishing industry. Moreover, in 1641 he organized the first ironworks in the New England colonies at Saugus (Lynn) in Massachusetts. Although he prospected for iron, lead, tin, and copper in the New England hills, he failed to solve the shortage of metals. Winthrop has been called, "the pioneer industrial chemist in the New World."[3]

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[1] I. Bernard Cohen, Some Early Tools of American Science: An Account of the Early Scientific Instruments and Mineralogical and Biological Collections in Harvard University (Cambridge, 1950), p.9.

[2] The ultimate discovery of this satellite by the astronomer, Edward E. Barnard, was made in 1916.

[3] John W. Oliver, History of American Technology (New York, 1956), p. 66; for a sketch of Winthrop see Samuel E. Morison, Builders of the Bay Colony (Boston, 1930).

John Winthrop, III (1714-79) was a noted astronomer and physicist, who held the Hollis professorship of mathematics and natural philosophy at Harvard. He observed the nature of sun spots in 1739. The Massachusetts provincial legislature assisted in financing his astronomical expedition to Nova Scotia in 1761 to observe the transit of Venus across the sun. In 1769 the Pennsylvania Assembly financed the construction of telescopes and observatories for another study he made of the transit of Venus. In addition to two scientific papers on the transit of Venus, Winthrop also authored his Two Lectures on Comets (Boston, 1759).

John Winthrop III was the first American seismologist; he explained earthquakes in terms of natural causes rather than divine punishments. He read A Lecture on Earthquakes in the college chapel at Harvard on November 26, 1755. In this lecture he described the earthquake of November 18th that "so lately spread terror, and threatened desolation throughout New England." Actually this earthquake had been harmless, but Winthrop also studied the destructive Lisbon earthquake of November 1, 1755, in which 15,000 persons lost their lives.[1]

Thomas Brattle

Thomas Brattle (1658-1713), a prominent Boston merchant and trustee of Harvard, made significant lunar and solar observations with the telescope that John Winthrop, Jr., had donated to Harvard. He was the first colonial to observe the variations of the magnetic needle. In his leisure hours he also compiled an almanac of celestial motions. His studies assisted in determining the exact longitude of Boston. He is most noted for his observation of Halley's Comet in 1680, which he reported to the Royal Society of London. The data was cited by Sir Isaac Newton in his Principia. In 1692 Brattle condemned the Salem witchcraft proceedings and he was an organizer of the Brattle Street Church of liberal Puritan dissidents in 1699.

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[1] For a bibliographical listing of letters and papers of the two Winthrops see Whitfield J. Bell, Jr., Early American Science (Williamsburg, 1955), pp. 78-79.

JAMES LOGAN

One of the founders of American colonial science in the Middle Colonies was James Logan (1674-1751), botanist and mathematician. Born in Ireland, Logan arrived in Philadelphia in 1699 as William Penn's secretary. Logan, during the next 50 years, occupied a key position in the affairs of Pennsylvania, contributing much to the rapid development of this colony.

Logan's strenuous public career did not prevent him from pursuing his interest in science. He assembled the outstanding scientific library in the English Colonies, his near 400 scientific and mathematical works even surpassing Harvard College's library in 1735. He published numerous papers dealing with subjects such as the motion of the moon, suggested improvements of the quadrant, and improvements in lenses. His greatest accomplishment, however, was made in botany.

In 1727, in a carefully controlled experiment, Logan proved the vital role of the male element, pollen, in the fertilization of corn. He repeated the experiment in 1728, but delayed making his findings public until 1735-36.

The announcement of Logan's experiment excited scientists in Europe. In 1738 Linnaeus, the great Dutch botanist, wrote to Logan stating that Logan should be placed "among the demigods of science."[1] Logan's discovery remained influential for several decades after 1800.

Logan also assisted and stimulated the interest of young botanists such as John Bartram. On his death in 1751, Logan left his great scientific library to the City of Philadelphia.

David Rittenhouse

An excellent example of a self-taught colonial scientist is seen in the career of David Rittenhouse (1732-1796), a Pennsylvania farm boy, who made himself master of Newton's Principia. In an eulogium delivered before the American Philosophical Society on December 17, 1796, Dr. Benjamin Rush stated: "Without literary friends or society, and with but two or three books, he became, before he had reached his four and twentieth year, the rival of the two great mathematicians in Europe!"[2]

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[1] Frederick B. Tolles, "Philadelphia's First Scientist, James Logan," ISIS, 47 (1956), 28.

[2] Benjamin Rush, An Eulogium, Intended to Perpetuate the Memory of David Rittenhouse...(Philadelphia, 1796), p. 9.

As a boy Rittenhouse tinkered with tools and studied mathematics. He became a successful clock and instrument maker. In 1767 he began construction of an orrery (a model simulating planetary motion), which was purchased by the College of New Jersey (Princeton). This was described as a "master-piece of ingenuous mechanism." Rittenhouse made a second orrery, after the model of the first, for the College of Philadelphia. Rush in his eulogium remarked: "His mathematical instruments have been esteemed by good judges to be superior in accuracy and workmanship to any of the same kind that have been imported from Europe."[1]

In making his observation of the transit of Venus in 1769 for the American Philosophical Society, Rittenhouse built an observatory and a transit telescope; the telescope was said to be the first made in America. He made a fairly accurate estimate of the distance of the sun from the earth as well as a discovery of the atmosphere surrounding Venus. In 1775 Rittenhouse delivered the annual oration before the American Philosophical Society, speaking on the history of astronomy. In 1785 he invented a collimating telescope which was one of the first to have spider webs in a telescope's eyepiece. In 1793 he discovered a comet.

On several occasions Rittenhouse's engineering talents were called upon and he surveyed the boundaries among various colonies when territorial disputes arose. He served as treasurer of Pennsylvania from 1777 to 1789 and President George Washington appointed him first director of the United States Mint (1792-95). Rittenhouse's discoveries were published in the Transactions of the American Philosophical Society and he succeeded Benjamin Franklin as president of the society upon the latter's death in 1791. Rittenhouse was also recipient of many honorary degrees and he was elected to membership of the American Academy of Arts and Sciences in 1782 and of the Royal Society of London in 1795.[2]

John and William Bartram

In 1728 John Bartram (1699-1777) laid out a botanical garden of five acres on the west bank of the Schuylkill River, at Kingsessing, near Gray's Ferry, and he built a house of hewn stone with his own hands. The grounds are now a part of the Philadelphia park system. Bartram was encouraged in his systematic studies by James Logan. Hence he learned Latin in order to read the works of the Swedish

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[1] Ibid., p. 10.

[2] An early account of his life is William Barton, Memoirs of the Life of David Rittenhouse (Philadelphia, 1813). A recent biography is Edward Ford, David Rittenhouse, Astronomer-Patriot, 1732-1796 (Philadelphia, 1946).

botanist, Carl Linnaeus. On various collecting expeditions Bartram traveled from the Great Lakes to Florida. In his gardens he cultivated and studied the specimens collected on his journeys. He experimented in hybridizing and sent specimens to European scientists and horticulturalists. He corresponded with many English scientists and with Linnaeus who called him the "greatest natural botanist in the world." Another correspondent was Peter Collinson, a Quaker merchant in England, who was interested in horticulture. Bartram and Collinson corresponded for nearly fifty years and Collinson located patrons in England for Bartram's expeditions.

When the Swedish botanist and student of Linnaeus, Peter Kalm, traveled in North America on a natural history survey from 1748 to 1751, he was assisted in his studies by Bartram. In 1765 George III appointed Bartram as his American botanist. Bartram contributed to the Transactions of the Royal Society of London and he was one of the original founders of the American Philosophical Society. On April 26, 1769, the Royal Academy of Sciences at Stockholm elected him to membership. Many scientists gathered at Bartram's gardens which were a favorite resort of Benjamin Franklin and George Washington.

The elder Bartram trained his son, William (1739-1823), who participated in his work and continued it after his father's death. William Bartram become a botanist in his own right as well as an ornithologist. Like his father he published an account of his travels. Also he prepared a list of American birds, which was the first extensive study on American ornithology.[1]

Cadwallader Colden

Dr. Cadwallader Colden (1688-1776) was a versatile practicing physician who wrote medical treatises and studied mathematics, physics, astronomy, anthropology, and botany. Born in Ireland, he graduated from the University of Edinburgh, then the best medical college, in 1705. He served as lieutenant governor of New York from 1761 to 1776 and was a loyalist.

His Principles of Actions in Matter published in its definitive edition in 1751 at London was his most significant work. In this obscure and technical study he attempted to explain the force of gravitation and dared to grapple with the larger problems of Newtonianism. He explained the universe in materialistic terms and virtually ruled out supernaturalism in his belief that all existence depended on matter and motion. Besides gravitation he also studied the nature of light.

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[1] Helen G. Cruickshank, ed., John and William Bartram's America: Selections from the Writings of the Early American Naturalists (Garden City: The Natural History Library edition, Anchor Books, 1961). This volume contains a biographical sketch of John and William Bartram from William J. Youmans, ed., Pioneers of Science in America (New York, 1896).

Despite his theoretical approach, he maintained an utilitarian attitude toward science which was probably most evident in his medical treatises. He authored a *Treatise on Wounds and Fevers,* contributing to materia medica.

In the field of methematics he wrote *An Introduction to The Doctrine of Fluxions*. As an American botanist he was considered second only to Bartram. He classified plants in the vicinity of his home, Coldengham, and supplied Linnaeus with descriptions of the flora of New York for publication in the *Transactions* of the Royal Society of Upsala. In the field of anthropology he is remembered for his objective treatment of the Indians in his *History of the Five Indian Nations*, the first volume of which appeared in 1727.[1]

John Morgan

Dr. John Morgan (1735-89) served his apprenticeship under a European-trained physician, Dr. John Redman, in Philadelphia. To gain further training from British doctors he became a medical lieutenant in the Pennsylvania militia during the French-Indian War. Once he learned all he could from the army he attended the medical school at the University of Edinburgh.

Morgan objected to the apprentice system of training doctore and developed a plan to reform American medicine. He persuaded the trustees of the College of Philadelphia (later University of Pennsylvania) to establish the first medical school in Colonial America. In arguing for his plan Dr. Morgan stated:[2] 'Oh! let is never be said in this city, or in this province, so happy in its climate, and its soil, where commerce has long flourished and plenty smiled, that science, the amiable daughter of liberty and sister of opulence, droops her languid head, or follows behind with a slow unequal pace. I pronounce with confidence this shall not be the case, but, under your protection, every useful kind of learning shall here fix a favorite seat, and shine forth in meridian splendor."

The medical school was founded in 1765. Morgan lectured in materia medica and Dr. William Shippen, Jr., lectured in anatomy and surgery. Morgan was the greatest medical teacher of the colonial period and he urged his students to experiment and specialize. In 1768 he organized the Philadelphia Medical Society. From 1775 to 1777 he served as director-general of hospitals and physician-in-chief of of the American Army until removed by Congress. He was charged with neglect and wrongdoing, but later exonerated by Washington and by Congress.

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[1] For an excellent summarization of Colden's scientific interests and contributions see Max Savelle, *Seeds of Liberty: The Genesis of the American Mind* (New York, 1948), pp. 44-45, 93-100, 108-09, 117, 121-26.

[2] As quoted in *ibid*., p. 84.

[3] James T. Flexner, *Doctors on Horseback* (New York: First Collier Books Edition, 1962), pp. 21-[illegible].

Jaret Eliot

The Rev. Jaret Eliot (1685-1763), a graduate and later trustee of Yale College, was a minister, physician, botanist, and agricultural scientist. He is particularly noted for his experiments in agriculture and mineralogy. He also introduced sericulture into Connecticut. He authored the first agricultural treatise in America. The first of his six essays entitled, Essays Upon Field-Husbandry in New England, was published in 1748. The essays were completed in 1761 and appeared in one volume with an index. He described the drainage of swamps, crop diversification, sheep breeding, diseases of wheat, and agricultural implements.

When Eliot convinced himself that black particles in sea sand were magnetic iron, he had a workman at his son's iron works smelt some sand into a bar of iron. He wrote about this successful experiment in his Essay on the Invention, or Art of making very good, if not the best Iron, from black Sea-Sand. For the essay he earned a gold metal from the London Society for the Encouragement of Arts, Manufactures and Commerce. Eliot also trained about fifty medical students and has been called the "Father of regular medical practice in Connecticut." 1

Benjamin Franklin

While Benjamin Franklin (1706-90) was less of an exact and mathematical scientist than either Winthrop, Colden, or Rittenhouse, he gained a greater reputation as a practical scientist and inventor. It is true that his political and diplomatic careers were important, but science dominated his thinking. His scientific interests pervaded his long life from the time he was a young printer in Philadelphia until he was a venerable sage. Franklin was the first American to gain international fame. Contemporaries called him "the Newton of Electricity" and and his two greatest achievements were his electrical kite experiment and his invention of the lightning rod. Although he was primarily famous as an electrician, this natural philosopher was also interested in agriculture, astronomy, aeronautics, botany, chemistry, ethnology, geology, mathematics, medicine, meteorology, navigation, and paleontology. For example, Franklin was the first meteorologist in America. He wrote on this subject from the time of his return trip from London to Philadelphia in 1726 until his long-range forecasts in 1786. He studied wind currents, eclipses, and the causes of storms.[2]

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[1] Herbert Thoms, The Doctors of Yale College, 1702-1815 and the Founding of the Medical Institution (Hamden Conn., 1960), pp. 17-27.

[2] Cleveland Abbe, 'Benjamin Franklin as Meteorologist," Proceedings of the American Philosophical Society, XLV (May-Sept., 1906), pp. 117-28.

When Franklin witnessed some electrical demonstrations performed by Dr. Adam Spencer in Boston in 1743, he immediately acquired a deep interest in electricity. The next year Spencer repeated his performances in Philadelphia with the delighted Franklin acting as his agent. Then Franklin bought Dr. Spencer's apparatus and obtained other equipment. In 1747 he began a series of experiments in Philadelphia that were to engross his attention for several years.

Franklin built a laboratory in his home, making improvements in condensers and batteries. In 1748 he retired from his printing business so he could devote more time to his studies. He made an analysis of the newly invented Leyden jar. He discovered that the charge in a Leyden jar is negative on the inside and positive on the outside and he demonstrated that the two charges balance each other. Until Franklin's experiments, a theory of two different kinds of electricity had been accepted. Franklin asserted that there was only one kind of electricity and he contributed the concepts of plus and minus charge. Although his one-fluid electrical theory was not entirely correct, Franklin approached the modern conception of the electrical nature of matter. Moreover, he originated words like battery, condenser, conductor, armature, electrician, and positive and negative electricity.

Franklin reported his findings to Peter Collinson in England and these were printed in 1751, as *Experiments and Observations on Electricity, made at Philadelphia in America, by Mr. Benjamin Franklin, and Communicated in several Letters to Mr. P. Collinson, of London, F.R.S.* The book was the most significant one produced in America during the eighteenth century; it appeared in five English editions and in three French editions, one Italian, and one German. The climax of Franklin's studies with electricity was his famous kite experiment of 1752 in which he demonstrated that lightning was electricity. He was soon awarded many honorary degrees by colleges and universities at home and abroad and the Royal Society in London awarded him the Copley Medal. Franklin's experiments had great utilitarian value. His studies of heat and ventilation also had practical use; for example, he invented the Franklin stove and made useful suggestions in regard to clothing.[1]

Alexander Garden

Dr. Alexander Garden (1730-91) of Charleston, South Carolina was a physician and botanist who had settled in America shortly after earning his medical degree in 1753 from Marischal College (later

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[1] The literature on Franklin is voluminous. For a classic study see Carl Van Doren, *Benjamin Franklin* (New York, 1938). Also see Verner W. Crane, *Benjamin Franklin and a Rising People* (Boston, 1954) and Roger Burlingame, *Benjamin Franklin, The First Mr. American* (New York, 1955).

Aberdeen University) in Scotland. He corresponded and exchanged botanical notes with Colden and John Bartram. While more exact than Bartram in his scientific method, Garden was obscure in comparison. He also corresponded with Linnaeus, Collinson, and Johann Gronovius, the Dutch botanist, who authored Flora Virginica (1739-43).

Garden classified the flora and fauna of Carolina and had an interest in the medicinal properties of plants. He contributed a paper on the electric eel to the proceedings of the Royal Society of London. In 1763 he was elected a member of the Royal Society of Upsala and in 1773 a fellow of the Royal Society of London. As a Tory he moved to England, after the American Revolution broke out. John Ellis, the English naturalist, named the "gardenia" in recognition of his botanical work.[1]

Scientific Societies

Probably the first scientific society organized in English America was the Boston Philosophical Society. Formed in 1683, it lasted only briefly and was headed by Increase Mather. Members met to discuss natural philosophy. It has been said that Wolferdus Senguerdius, a Dutch scholar, utilized data gathered by this society in his Philosophia Naturalis.[2]

The earliest permanent scientific society was the American Philosophical Society proposed by Benjamin Franklin in 1743. In the form of a circular letter Franklin issued a "Proposal for promoting useful knowledge among the British plantations in America." Among the principal features of the "Proposal" were the following:[3]

> "That one Society be formed of Virtuosi or ingenious Men residing in the several Colonies, to be called 'The American Philosophical Society who are to maintain a constant Correspondence.
>
> "That Philadelphia being the City nearest the Centre of the Continent-Colonies...be the Centre of the Society.
>
> "That at Philadelphia there be always at least seven Members, viz. a Physician, a Botanist, a Mathematician, a Chemist, a Mechanician, a Geographer, and a general Natural Philosopher, besides a President, Treasurer and Secretary."

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[1] Louis B. Wright, The Cultural Life of the American Colonies (New York: Harper Torchbooks edition, 1962), pp. 230-31. For the very few references on Garden see Bell, Early American Science, pp. 58-59.

[2] Oliver, History of American Technology, p. 32.

[3] Edwin G. Conklin, "A Brief History of the American Philosophical Society," (Reprint from Year Book of the American Philosophical Society for 1959). p. 36.

The American Philosophical Society was actually preceded by a Junto established by Franklin in 1727.[1] Hence the change of the local Philadelphia Junto, consisting of Franklin and his friends interested in science, into an inter-colonial society was a broadening of its purpose.

The American Philosophical Society was inactive between 1744 and 1768. In 1768 it was united with a rival organization called the American Society whose origin was traceable to Franklin's original Junto. At the election on January 2, 1769, Franklin was made president. Upon his death in 1790, he was succeeded by David Rittenhouse. Among the earliest members were John Bartram, Cadwallader Colden, and Benjamin Rush. The Transactions of the Society is the is the oldest scientific periodical in the United States, being issued since 1771. Over half of its first volume was devoted to papers on the transit of Venus in 1769. The Society was the first organized group to consider agriculture as a science and it made date available to farmers. However, mention should be made of the New York Society for Promoting Arts which was organized in 1766 to advance agriculture.[2]

In 1780 the American Academy of Arts and Sciences was founded in Boston. John Adams was one of its sponsors and James Bowdoin served as first president. Similar in structure to the American Philosophical Society its members included scholars and notable citizens of Boston and Cambridge.

The Royal Society of London, organized in 1662, was the scientific center for both England and the colonies. Several American scientists were elected fellows and they and others published their discoveries in its publication. John Winthrop, Jr., was the first fellow elected from the colonies. Another was William Byrd II of Virginia, who had accumulated his scientific library at Westover.

As related earlier the Philadelphia Medical Society had been organized in 1768 by Dr. John Morgan. A Massachusetts Medical Society was established in 1781. Another early scientific group was the Salem Marine Society which had been organized in 1766.[3]

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[1] See Peter S. Du Ponceau, An Historical Account of the Origin and Formation of the American Philosophical Society (Philadelphia, 1914).

[2] Rodney H. True, "The Early Development of Agricultural Societies in the United States," Annual Report of the American Historical Association for the Year 1920 (Washington, D. C., 1925), p. 296.

[3] A brief summarization of scientific organizations appears in Oliver, History of American Technology, pp. 82-87.

Role of colonial colleges

The colonial colleges were all small and their primary purpose was to train ministers of various religions. Nonetheless, the colleges offered study in science. In organizing the curriculum at Harvard College during the 1640's President Henry Dunster included courses in mathematics, physics, astronomy, and botany. At first Aristotelian physics and Plotemaic astronomy were taught, but gradually the way was prepared for the teaching of Copernican and Newtonian science. In 1686 a significant change occurred at Harvard, when Charles Morton's natural science textbook, Compendium Physicae, was adopted. This text helped to spread the scientific discoveries of the Enlightenment in New England.

As mentioned previously Governor John Winthrop had donated a telescope to Harvard in 1672. In the early eighteenth century the college acquired sufficient scientific apparatus to open a special room as a "Philosophy Chamber." In 1727 Thomas Hollis endowed a chair in mathematics and natural philosophy. The first incumbent was Isaac Greenwood, who introduced new courses in mathematics and taught Newtonian physics. He was succeeded by John Winthrop IV, who held the chair for over forty years and taught the most advanced scientific ideas in the colonies. A fire in 1764 destroyed all of Harvard's scientific apparatus, but it was replaced within fifteen years by superior equipment.

Other colleges did not pursue scientific endeavors as vigorously as Harvard. Aristotelian theories prevailed at Yale until well into the eighteenth century. President Thomas Clap of Yale studied comets and meteors, but when he resigned in 1766, science at the college came to a virtual standstill. Then in 1770 Yale finally established a chair of mathematics and natural philosophy.

As early as 1711, William and Mary College had appointed a professor natural philosophy and mathematics, but he was not successful. By the 1760's William and Mary acquired an able scientist and stimulating professor in the person of William Small, who had a profound influence on his young student, Thomas Jefferson. In later years Jefferson stated that Small "probably fixed the destinies of my life." In 1765 a medical school was organized at the College of Philadelphia, laying the foundation for the University of Pennsylvania's later eminence in medicine. Within a few years King's College also founded a medical school.

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[1] The first chapter of Cohen, Some Early Tools of American Science, is entitled, "The History of Science at Harvard." Louis W. McKeehan, Yale Science: The First Hundred Years, 1701-1801 (New York, 1947). Theodore Hornberger, Scientific Thought in the American Colleges, 1638-1800 (Austin, 1945).

Popularization of science and the impact of Newtonianism.

Almanacs, magazines, and newspapers conveyed knowledge of science to the common people in colonial America. Benjamin Franklin's Poor Richard's Almanack and Nathaniel Ames's Astronomical Diary were popularizers of science; both spread ideas of Copernican and Newtonian science. The American Magazine (1757-58) devoted space to original problems in the study of mathematics. At least one book, Mark Catesby's The Natural History of Carolina (London, 1731-43) was widely read. *

On occasion colonial newspapers presented scientific ideas and controversies. During the Boston smallpox epidemic of 1721 a newspaper war raged over the value of inoculation. Paradoxically, Cotton Mather, the Congregational clergyman who had combined a strange mixture of rationalism and superstition, favored inoculation. Mather, an advocate of Newtonian science, had been elected a fellow of the Royal Society of London in 1713. He persuaded Dr. Zabdiel Boylston to inoculate patients against smallpox. James Franklin and his young brother, Benjamin, opposed Cotton and Increase Mather. Benjamin Franklin at the time was only fifteen and he later admitted his error. [1]

In the Boston Gazette of June 17-24, 1734, a Harvard College instructor advertised that during his summer vacation he would offer lectures on astronomy, using "the Orrery, and all such Machines, instruments and Schemes as are used by Astronomers,... except only that it wants only of Sir Isaac Newton's Reflecting Telescopes, which New England has not, as yet, been honoured with." As an enticement to females the instructor added:[2] "If the Curiosity and Desire of Knowledge, justly admired in the Fair Sex should excite any of Them; there will be some Expedient found out that They may be gratified twice a week in the Afternoon, with their usual Tea and a Familiar Astronomical Dialogue."

Newtonian science profoundly appealed to the American people in the eighteenth century, and it affected all aspects of intellectual life and reached all classes. It fostered rationalism, forcing religion to adapt itself to science. In colonial America the new science of observation and controlled experiments helped to free men's minds, bringing about an exchange of ideas that encouraged mutual criticism. It led to a degree of cultural unity as evidenced in the formation of the American Philosophical Society. Although American science was not as advanced as European science, the colonists endeavored to keep —

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*Flora Caroliniana by the South Carolina botanist Thomas Walter (1740-1789), was also much admired by Jefferson.

[1] The newspaper controversy between the Franklins and the Mathers over inoculation is described in Frederic Hudson, Journalism in the United States (New York, 1873), pp. 67-71 and in James M. Lee, History of American Journalism (Garden City, Rev. Ed., 1923), pp. 29-31.

[2] As quoted in Willard G. Bleyer, Main Currents in the History of American Journalism (Boston, 1927), pp. 73-74.

abreast and their scientists contributed some data to the body of knowledge. From its colonial beginnings American science has been utilitarian in approach. Hence it was not surprising that Benjamin Franklin, a significant scientist of the world was also America's greatest colonial inventor.

II. AMERICAN REVOLUTION ERA, 1776-1789

Disruption of science.

The Revolutionary War had an adverse effect on science. In fact scientific progress began to decline even earlier because of the tensions in 1774 and 1775. The demands of war pushed science into the background as many scientists entered war activities. Scientific journals suspended publication and many libraries were destroyed. Several importent scientists became Loyalists and left the colonies.

Scientific activities had been primarily urban and the larger cities, Boston, New York, Newport, Philadelphia, and Charleston were temporarily occupied by the British. The war closed the normal channels of communication between American and European scientists who found it difficult to exchange ideas. Shortly after the outbreak of the Revolution, Cadwallader Colden and John Bartram died. Alexander Garden, a Loyalist, moved to England. Hence natural history in America suffered with the loss of these botanists.

Many of the colleges were closed during the war. Provincial troops used Harvard College buildings as barracks and the library and scientific equipment were removed to the countryside for safety. At the College of Philadelphia American troops occupied the buildings as barracks; later the British used them as a hospital. King's College was occupied by American troops and then by British Troops. At the College of William and Mary it appeared at first that science might benefit when Tories were removed from the faculty. The Rev. James Madison becamse president and he was anxious to improve the sciences. In 1779 Thomas Jefferson attempted to cultivate science in reforming the university, but as war came to the area the college also became a hospital.

The work of scientific societies was also disrupted by the political turmoil preceding the war and then by the conflict itself. For example, the American Philosophical Society failed to hold meetings for nine months in 1774 because of a preoccupation of members with the Coercive Acts. Meetings were not held between January 1776 and March 1779

because of the British occupation of Philadelphia and because of disputes between Whig and Tory members. The New Jersey Medical Society was suspended during the entire period of the war. Medical schools also suffered.

Stimulating influences.

Despite the disruption in science caused by the Revolution, improvements were made in medicine as Americans learned from British, French, and Hessian doctors. Several medical handbooks were published to aid doctors serving with the Continental Army. Dr. John Jones published his *Plain, Concise, and Practical Remarks on the Treatment of Wounds and Fractures* (New York, 1775). Dr. William Brown, physician general of the Middle Department, published his *Pharmacopoeia Simpliciorum et Efficaciorum* (Philadelphia, 1778). American doctors observed British surgeons operating upon the wounded and learned about hospital administration from the French. Valuable lessons in dentistry were also learned from the French during the war.

A number of scientists came with the invaders. Johann David Schöpf, a Hessian physician, wrote about American geology, climate, and fauna as well as materia medica upon his return to Germany. The Rev. Frederick V. Melsheimer, a German scholar serving as chaplain of a regiment of Brunswick dragoons, stayed in America after the war; he later became a professor at Franklin College and the first American entomologist.[1]

Scientific organizations.

As related in the previous chapter, the American Academy of Arts and Sciences had been organized at Boston in 1780. Its purpose was[2] to "cultivate every art and science which tends to advance the honor, dignity, and happiness of a free, independent virtuous people." Harvard faculty members held many of the offices in the organization. A number of distinguished European scientists were elected as nonresident members, including the English chemist, Joseph Priestly, the Swiss mathematician and physicist, Leonard Euler, and the French astronomer, Joseph Jérôme Le Francais de Lalande. In 1785 the Academy published the first volume of its *Memoirs* with sections on astronomy, natural philosophy and natural history, and medicine.

The Massachusetts Medical Society was founded in 1781. It was granted power "to examine All Candidates for the Practice of Physic and Surgery." Besides regulating the medical profession the society also furthered medical knowledge by exchanging information with other medical

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[1] Both the disrupting and the beneficial influences of the Revolution upon American science is described in Brooke Hindle, *The Pursuit of Science in Revolutionary America, 1735-1789* (Chapel Hill, 1956),pp.219-379

[2] As quoted in Oliver, *History of American Technology*, p. 86.

societies both at home and abroad. In 1790 the society published its first volume of *Medical Papers*. An earlier medical organization was the *Medical Society of Sharon* organized in 1779 by physicians from Connecticut, Massachusetts, and New York. In 1781 the Medical Society of New Jersey was revived and encouraged a clinical approach to medicine.

Noted scientists.

Dr. Benjamin Rush (1746-1813) has been called both the father and the "vampire" of American medical practice. A pupil of Dr John Morgan and an apprentice of Dr John Redman, he studied at Edinburgh. A physician more than a scientist, Rush was sometimes an unscientific physician. In actuality he never experimented, but relied upon theoretic remedies. Although he prescribed bleeding and purging, he became the most influential American physician of his time. He was a professor of chemistry at the College of Philadelphia from 1769 to 1791. After its merger into the University of Pennsylvania, he continued his lectures before prospective doctors until 1812.

Rush served as a military doctor in 1777 and 1778. In this capacity he was quite able, publishing his pamphlet, *Directions for Preserving the Health of Soldiers* (Lancaster, 1778). He blamed the many deaths of American soldiers on the officers who neglected enforcement of hygienic regulations.

Dr. Rush was also an important political leader. He had signed the Declaration of Independence and became a member of the Continental Congress. From 1797 to 1813 he was Treasurer of the United States Mint. He was a member of the Pennsylvania ratifying convention, and in the year of the Constitution was ratified he wrote: "All the doors and windows of the temple of nature have been thrown open by the convulsions of the late Revolution. This is the time therefore to press in upon her altars."

Rush worked diligently, though unscientifically, during the Philadelphia yellow fever epidemics of 1793 and 1797. He was an ardent reformer, who opposed slavery and favored temperence. He authored an influential temperance tract entitled *Inquiry into the Effects of Spirituous Liquors upon the Human Body*.

Through his lecturing and writings Rush probably influenced more prospective doctors than any other medical educator of his day. He was the author of *Medical Inquiries and Observations* published in five volumes from 1789 to 1798. Perhaps his most significant contribution was his *Medical Inquiries and Observations upon the Diseases of the Mind* (1812). This was the first systematic study on mental diseases. He urged humane treatment of the insane and proposed that the insane be treated by occupational therapy. Some of his ideas foreshadowed the methods of modern psychoanalysis.[1]

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[1] Flexner, *Doctors on Horseback*, pp. 67-119. The standard biography is Nathan G. Goodman, *Benjamin Rush, Physician and Citizen* (Philadelphia, 1934)

Among the American scientists exiling themselves from the colonies because of Loyalist sympathies were Dr. John Jeffries (1774-1819) and Benjamin Thompson (1753-1814). Jeffries was a Boston physician who had graduated from the University of Aberdeen. He studied meteorology in New England. When the British evacuated Boston, he accompanied the Redcoats to Halifax. Then he served briefly as a surgeon major of the British troops in the colonies After the Revolutionary War, he settled in London and practiced medicine. In the 1780's Jeffries became interested in "aerostation" as ballooning was called at the time.[1]

On November 30, 1784, Dr Jeffries and Jean Pierre Blanchard, a French aeronaut, made in England the first scientific observations from a balloon.[2] In the ascent Jeffries obtained specimens of the upper air which were analyzed by Henry Cavendish, the English chemist and physicist, who determined that their chemical composition did not differ very much from that of air at ground level [3]

On January 7, 1785, Jeffries and Blanchard made the first crossing of the English Channel by air. In 1790 Jeffries returned to his native Boston practicing there until his death.

Benjamin Thompson or Count Rumford, a physicist and adventurer, was born in Woburn, Massachusetts in 1753. As a Tory he spied for the British during the Revolution. In 1776 he went to London and became Undersecretary in the Ministry for Carolina and Georgia. He returned to America as a cavalry officer with the British Army, participating in the devastation of Long Island. After the American Revolution he returned to Europe and began one of the most remarkable careers in the history of science, entering the service of the Elector of Bavaria, who made him Count Rumford of the Holy Roman Empire in 1792. Count Rumford made significant studies in ballistics and invented a device to measure the power of gunpowder.

Count Rumford also invented many heating devices such as pots, kettles, pans, and stoves. A heating engineer, he designed the modern fireplace and flue. He developed a calorimeter and a photometer, making improvements in lighting His greatest contribution, however, was in physics, and this discovery was that heat is a form of energy

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[1] Dirk J. Struik, *Yankee Science in the Making* (Boston, 1948), pp. 54-55.

[2] C. H. Gibbs-Smith, *Ballooning* (London, 1948), p. 38.

[3] A. Wolf, *A History of Science, Technology, & Philosophy in the 18th Century* (New York: Harper Torchbook Edition, 1961), Vol. II, p. 580.

Rumford was also a founder and patron of scientific societies. He founded the Royal Institution in London in 1800 and planned the organization of the Bavarian Academy of Arts and Sciences at Munich in 1801. He donated $5,000 to the Royal Society in London and a like amount to the American Academy of Arts and Sciences. The latter organization has awarded the Rumford Medal for research in heat and light. Count Rumford also established a professorship at Harvard "of the application of science to the art of living;" Jacob Bigelow became the first incumbent. Dr. Bigelow was a botanist and professor of materia medica. Rumford had learned his first lessons in science from Professor John Winthrop at Harvard. Although Count Rumford, in the opinion of many contemporaries, was considered to be something of a rogue, Americans have tended to remember only his genius as a scientist.[1]

III. EARLY REPUBLIC, 1790-1829

Scientific societies and education.

In spite of their national names the American Philosophical Society and the American Academy of Arts and Sciences were not national institutions in their early history. Although they attempted to pattern themselves after the great European scientific societies, they were more local in character. Yet Philadelphia and Boston were the scientific and cultural centers of the early Republic. The colleges offered no advanced training in science and the federal and state governments offered few inducements to scientific advance. Though facilities for scientific and technological research and training were largely undeveloped, the new government was anxious to foster scientific discoveries and inventions. President Washington in his first annual message to Congress, January 8, 1790, stated:[2]

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[1] Struik, Yankee Science in the Making, pp. 55-58; Cohen, Some Early Tools of American Science, pp. 22, 29, 37, 80, 129; Mitchell Wilson, American Science and Invention: A Pictorial History (New York, 1954), pp. 24-31.

[2] James D. Richardson, A Compilation of the Messages and Papers of the Presidents, 1789-1897 (Washington, D.C., 1899), Vol. I, p. 66

> "The advancement of agriculture, commerce, and manufactures by all proper means will not, I trust, need recommendation; but I can not forbear intimating to you the expediency of giving effectual encouragement as well to the introduction of new and useful inventions from abroad as to the exertions of skill and genius in producing them at home, and of facilitating the intercourse between the distant parts of our country by a due attention to the post-office and post-roads.
>
> 'Nor am I less persuaded that you will agree with me in opinion that there is nothing which can better deserve your patronage than the promotion of science and literature."

In 1792 Dr. James Woodhouse and other chemists organized the Chemical Society of Philadelphia. It has been asserted that it was the first chemical society in the world. Another chemical society was established at Philadelphia in 1811 with James Cutbush as president.[1]

Through the efforts of Dr. Edward Cutbush and Thomas Law, the Columbian Institute was organized at Washington, D. C. in 1816 as a national scientific group. Local business and professional men, some civil servants and army and naval officers, many Congressmen, and six Cabinet members became members. Among the scientists and statesmen enrolling were Henry Clay, Charles Wilkes, Richard Rush, Joel R. Poinsett, and former Presidents John Adams, Thomas Jefferson, and James Madison.

The objectives of the Institute were to foster practical arts and sciences, to study agriculture, to encourage mechanical and scientific discoveries, and to offer its findings to the federal government. Congress issued a charter to the Institute in 1818 and granted it five acres of land for a botanical garden near the Capitol. Although the Institute was fairly active in the 1820's, it never received financial assistance from Congress which it had sought. The technical papers on mathematics and astronomy read before the Institute by William Lambert, a pension office clerk, pointed out the need for a national observatory.

The Connecticut Academy of Arts and Sciences was established in 1799 as the first state academy of sciences. The first of many city organizations to foster technical education was the Mechanics Institute established at Boston in 1795. At Philadelphia the Franklin Institute was founded in 1824. In 1826 this organization began publishing the Journal of the Franklin Institute under the editorship of Thomas P. Jones, professor of mechanics at the University of Pennsylvania. The journal disseminated mechanical, scientific, and technical data. It became the official organ of the United States Patent Office and from 1828 until 1843 it recorded American patents.[2]

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[1] Oliver, History of American Technology, p. 152.

[2] Oliver, History of American Technology, pp. 87, 194-95.

The first substantial natural history museum in the United States was established in 1812 as the Academy of Natural Sciences of Philadelphia. This institution made Philadelphia aready known as the nation's scientific capital, "the Mecca of American biologists."[1]

Among the first agricultural societies formed in the early Republic were the South Carolina Agriculture Society (1785), the New York Society for Agriculture. Arts, and Manufactures (1792), and the Massachusetts Society for Promoting Agriculture (1796) By means of their publications these societies encouraged scientific agriculture.[2] In 1819 the New York State Agricultural Society was established through the efforts of Governor De Witt Clinton. Stephen Van Rensselaer, the Society's president, engaged Amos Eaton to make a geological survey of Albany and Rensselaer Counties. Eaton also made a survey of the Erie Canal route from Albany to Buffalo and these surveys won him fame as the "Father of American Geology.[3]

In 1819 a group at Yale College interested in geology formed the American Geology Society. Among the founders were Professor Benjamin Silliman of Yale and William Maclure, the Scottish geologist and pioneer scholar of American geology. Maclure's Observations on the Geology of the United States (1809) signalized the beginning of American geological writing of a scientific nature. The next year Archibald Bruce began to publish the American Mineralogical Journal, the first geology publication in the United States. William Maclure served as president of the American Geological Society until his death in 1840. The society then declined in influence and disappeared.[4]

At the opening of the nineteenth century colleges and universities began to give more emphasis to science and technology. In 1802 Yale College appointed a young lawyer, Benjamin Silliman (1779-1864), as its first professor of chemistry and natural history. He at once went to Philadelphia and attended the lectures of Benjamin Rush, Benjamin Barton, and Caspar Wistar. Silliman did not give his first lecture until 1804. In the fall of that year the Yale Corporation appropriated $9,000 to purchase books and apparatus for use in teaching chemistry and physics. In April 1805 Silliman sailed for Europe to spend the appropriation. Besides buying equipment he also studied in London and in Edinburgh. Upon his return to Yale in 1806 he decided to specialize in geology. In 1808 be began delivering public lectures on chemistry and geology. These popular lectures were well received for many years by audiences in the larger cities in the country. In 1818

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[1] R.T. Young, Biology in America (Boston, 1922), pp. 52-53.

[2] True, "The Early Development of Agricultural Societies in the United States," pp. 298-99.

[3] Oliver, History of American Technology, p 151.

[4] Nye, Cultural Life of the New Nation, p. 91: Carroll L. and Mildred A. Fenton, Giants of Geology (Garden City, 1952), p 134.

Silliman established the American Journal of Sciences and Arts, later renamed the American Journal of Science. Silliman trained a number of students. Among these were his son, Benjamin, Jr. and his son-in-law, James Dwight Dana.[1]

As mentioned in the previous chapter, Jacob Bigelow occupied the Rumford chair at Harvard from 1816 to 1829. His lectures, which were started in 1816, became popular both with Harvard students and with Bostonians. He discussed such subjects as architecture, chemistry, engineering, mechanics, and mineralogy.

In 1825 the Rensselaer Polytechnic Institute opened at Troy, New York. It was founded by Stephen Van Rensselaer "for the purpose of instructing persons who may choose to apply themselves in the application of science to the common purposes of life." Professor Amos Eaton, a lawyer and brilliant scientist, was the heart and soul of this first institute of practical study. Courses were offered in astronomy, botany, chemistry, civil engineering, and geology. Laboratory work was stressed in instruction. The earliest school of agriculture in the nation was established at Rensselaer.[2]

Noted scientists

In 1792, when Dr. James Woodhouse, Dr. Benjamin Rush, and others had founded the Chemical Society of Philadelphia, a revolution was stirring within the world of chemistry. Antoine L. Lavoisier, the French chemist and father of modern chemistry, in the Treatise on Elementary Chemistry (1789) explained that the real basis of combustion was oxygen. He exploded the "Phlogiston" theory and reformed the nomenclature of chemistry. Dr. Samuel L. Mitchell introduced the new theory to Columbia College in 1792 and in the pages of his journal, Medical Repository. Lavoisier's theories were debated. Dr. James Woodhouse, who had been trained in medicine by Rush, popularized the doctrine of Lavoisier in his students' laboratory manual, The Young Chemist's Pocket Companion (1797). Woodhouse taught chemistry at the University of Pennsylvania and attacked the phlogiston theory, which most chemists, including Joseph Priestley, had accepted.

Dr. Thomas Cooper (1759-1839), an English physician, came to the United States in 1792. As a teacher he helped to spread the new concepts of Lavoisier's chemistry in America. On April 5, 1811, he was appointed professor of chemistry and mineralogy at Carlisle College (later Dickinson). He favored the practical application of chemistry

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[1] Thoms, The Doctors of Yale College, pp. 123-26; Struik, Yankee Science in the Making, pp. 160-62.

[2] Oliver, History of American Technology, pp. 150-51.

and also believed that chemistry should be related closely to other cultural subjects. He taught for five years at Carlisle where he made chemical experiments and wrote A Practical Treatise on Dyeing and Calico Printing. Following teaching positions at the University of Pennsylvania and at the University of Virginia, he became professor of chemistry at the College of South Carolina in 1819. The next year he was appointed president of the college where he evolved into a leader in education as well as a leader in Southern politics.[1]

George Washington (1732-99) and Thomas Jefferson (1743-1826) had mutual interests in scientific agriculture. Both kept diaries and garden books in which they described the agricultural and horticultural practices at Mount Vernon and Monticello. Washington's five farms at Mount Vernon were comparable in some respects to agricultural experiment stations. He tested seeds, practiced soil conservation, engaged in selective breeding of sheep, raised exceptional wheat crops, and tested new machinery. He corresponded with the English agriculturalists, Arthur Young and Sir John Sinclair. Washington was associated with the Philadelphia Society for Promoting Agriculture founded in 1785. In his last annual message to Congress, December 7, 1796, President Washington proposed boards of agriculture to collect and diffuse information and to encourage "a spirit of discovery and improvement." However, the government did not create a commissioner of agriculture until 1862.[2]

Jefferson was more of a scientist than Washington. Besides agriculture, Jefferson was interested in archaeology, astronomy, botany, chemistry, ethnology, exploration, geology, medicine, paleontology, and inventions. Although his knowledge was not always complete nor entirely correct, he did a great deal to advance the status of science in the United States In a letter of appreciation to President Willard of Harvard College for his receipt of an honorary Doctorate of Laws, Jefferson wrote:[3]

> "The botany of America is far from exhausted, its mineralogy is untouched, and its zoology totally mistaken. We have spent the prime of our lives in procuring your students the precious blessing of liberty. Let them spend theirs in showing that it is the great parent of science and of virtue, and that a nation will be great in both ways in proportion as it is free."

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[1] Jaffe, Men of Science in America, pp. 78-103.

[2] Richardson, Messages and Papers of the Presidents, Vol. I, p. 202; Ulysses P. Hedrick, A History of Horticulture in America to 1860 (New York, 1950), pp. 169-75.

[3] As quoted in Jaffe, Men of Science in America, p. 89.

Jefferson's reputation as a scientist was due primarily to his Notes on the State of Virginia which he had prepared in 1781. He described in detail the topography, natural history, and natural resources of Virginia. The book was first printed privately by Jefferson in Paris in 1785. An English edition was published at London in 1788. The first American edition was published in Philadelphia in 1788 and the next year a German translation was printed in Leipzig.

Beginning in 1796 Jefferson served as president of the American Philosophical Society for eighteen years He assisted in writing the first American paper on paleontology for the Society in 1797. At his farms in Monticello Jefferson practiced scientific agriculture and invented new machines. While on his diplomatic mission to France he carried out scientific investigations in Europe. As President of the United States he used his high office to encourage scientific advance. He was forced to restrict his personal scientific pursuits to a certain degree, but he had once said that nature had intended him "for the tranquil pursuits of science" and that "science is my passion; politics is my duty."

Jefferson like Franklin gained an international reputation as a scientist and inventor. He also had an utilitarian attitude toward science. Although Jefferson made no basic contribution to science such as Franklin had in electricity, he possessed wider interests than Franklin. Jefferson had a greater appreciation than any of his countrymen of the value of science in promoting the general welfare of the young Republic.[1]

Joseph Priestley (1733-1804), the English clergyman and chemist, found asylum in the United States after his house and personal effects had been burned because of his sympathy with the French Revolution. In 1794 he and his wife settled in Northumberland, Pennsylvania where they resided in the same house with the Thomas Cooper family. Priestley taught his experimental techniques in chemistry to Cooper, Dr. James Woodhouse, and Dr. John MacLean, who became professor of chemistry at Princeton. When Priestley died in 1804, Cooper continued to use Priestley's chemical laboratory and apparatus. Priestley's greatest work had already been completed before his coming to America, yet the discoverer of oxygen was influential in American scientific circles during the last ten years of his life.[2]

Constantine Samuel Rafinesque (1783-1840) was an important botanist and naturalist in the United States who had been born in Constantinople

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[1] For details see Edwin T. Martin, Thomas Jefferson: Scientist (New York, 1952).

[2] Wilson, American Science and Invention, pp. 32-35

of French parentage. He traveled throughout the United States on collecting expeditions and described many new species of plants and fishes. Considered an eccentric, he found it difficult to make a livelihood in the United States. After being refused a number of college positions, he was finally appointed professor of botany, natural history, and modern languages at Transylvania College in Kentucky in 1819. He taught there for seven years. Among his major works were *Ichthyologia Ohioensis* (1820) and *Medical Flora of the United States* 1828-30). His greatest contribution was that he helped draw the attentio of European naturalists to the natural scientific treasures of America.[1]

Nathaniel Bowditch (1773-1838), a self-educated astronomer and mathematician, was born in Salem, Massachusetts. He made five sea voyages in the China and East Indian trade between 1795 and 1803. In 1799 he prepared the first American edition of J. H. Moore's *The Practical Navigator*, which he expanded and published in 1802 as *The New American Practical Navigator*. In compiling this work, Bowditch used the manuscript logs that had been collected by the East India Marine Society of Salem. He translated and made commentaries on four out of the five volumes of Pierre Simon Laplace's *Celestial Mechanics*. At his own expense he made this valuable work available to the English-speaking world. Bowditch also wrote on comets, meteors, and solar eclipses.

The "arithmetic sailor" assisted in making seamanship a science and his greatest work, *The New American Practical Navigator*, has gone through scores of editions. For over a century and a half mariners have relied on Bowditch. Since the 1860's the book has been published by the United States Hydrographic Office and is known as "H.O. No. 9," meaning the ninth publication of the Hydrographic Office.[2]

Famous naturalists.

Alexander Wilson (1766-1813), the ornithologist, was born in Scotland. A weaver and peddler he came to the United States in 1794. He became a teacher in rural schools in New Jersey and eastern Pennsylvania. His neighbor, William Bartram, interested him in ornithology. Assisted by Alexander Lawson, who prepared plates of the birds described, he began publishing his *American Ornithology* in 1808. In his travels he journeyed through the eastern states, down the Mississippi, and to the borders of the Southwest. Wilson has been called the father of American ornithology.

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[1] Jaffe, *Men of Science in America*, pp. 104-29.

[2] Robert E. Berry, *Yankee Stargazer: The Life of Nathaniel Bowditch* (New York, 1941). For a shorter account see Paul E. Rink, "Nathaniel Bowditch: The Practical Navigator," *American Heritage*, XI (Aug., 1960), pp. 56-60, 85-91.

Wilson's successor, John James Audubon (1785-1851), was born in Santo Domingo. As a boy he studied art in Paris. When he was 19, he became manager of his father's farm at Mill Grove, Pennsylvania. As a hobby he sketched birds. In the forests of Kentucky and Ohio he hunted rare birds. For a short period he was a taxidermist in the Western Museum at Cincinnati. In 1826 he went to England to look for a publisher and brought out the volumes of his Birds of America from 1827 to 1838. This work was hailed as a classic. His Ornithological Biography (1839) and Synopsis of the Birds of North America (1839) next added to his fame.[1]

Thomas Nuttall (1786-1859), an English botanist and ornithologist, came to the United States in 1808. His interests in plants was encouraged by Benjamin Barton, the Philadelphia botanist. Nuttall traveled in 1810-11 along the Kansas, Platte, and Missouri Rivers. From 1818 to 1820 he traveled in the interior of Arkansas. From 1822 to 1834 he was curator of the botanical gardens at Harvard. In 1832 he published A Manual of the Ornithology of the United States and Canada.

In 1834 Nuttall journeyed across the Rockies to the Columbia River. He sailed to Hawaii and then to California. At San Diego Richard Henry Dana was surprised to see Nuttall; in Two Years Before the Mast, Dana wrote: "I had left him quietly seated in the chair of Botany and Ornithology in Harvard University, and the next I saw of him, he was strolling about San Diego beach, in a sailor's pea-jacket, with a wide straw hat and barefoot, with his trousers rolled up to his knees, picking up stones and shells."

Nuttall returned to the East around the Horn with Dana aboard the Alert. He resided in Philadelphia until his return to England in 1841. Although his writings were not as significant as those of Wilson or Audubon, he did classify many new genera and species. His explorations in the wilderness and to distant lands were surely an indication of real scientific interest as well as personal courage.[2]

Scientific contributions of exploring expeditions.

While Jefferson's interest in exploration was primarily expansionist, it had a strong scientific bent. When Jefferson was Ambassador to France, he and John Paul Jones conversed with John Ledyard, "the American Marco Polo," who planned an expedition to the Northwest coast. Jefferson suggested to Ledyard that he traverse Russia and Siberia, and

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[1] Young, Biology in America, pp. 19-32.

[2] Struik, Yankee Science in the Making, pp. 266-68.

from Kamchatka cross to Alaska where he might find passage to Nootka. Then he could journey eastward into the unknown interior of North America. Ledyard failed in an attempt to gain the patronage of Empress Catherine of Russia, but he succeeded in obtaining the support of Sir Joseph Banks, president of the Royal Society of London, as a sponsor. By the fall of 1786 Ledyard wrote to Jefferson that he was preparing to cross Siberia. Ledyard reached Irkutsk and was ready to sail with Captain Billings of the Russian navy, when he was arrested on February 24 1788, by two Cossack police and brought back to Moscow. Ledyard's romantic dream ended, and the next year he died in Cairo.[1]

In 1792 Jefferson persuaded the American Philosophical Society to finance an expedition by the French scientist, André Michaux, who intended to "ascend the Missouri River, cross the Stony Mountains, and descend down the nearest river to the Pacific." Jefferson drafter Michaux's instructions to "take notice of the country you pass through, its general face, soil, rivers, mountains, its productions--animal, vegetable, and mineral." He also instructed him to make astronomical observations, to study the aborigines, and to search for fossils.

On January 18, 1803, Jefferson asked for an appropriation of $2,500 to finance the Lewis and Clark Expedition. He stated:[2] "The interests of commerce place the principal object within the constitutional powers and care of Congress, and that it should incidentally advance the geographical knowledge of our own continent can not but be an additional gratification." When Congress approved, it established a new precedent of appropriating money on basis of the commerce clause for a scientific exploration. Moreover, the Army was to sponsor the expedition and it was to explore foreign soil.

Captain Meriwether Lewis spent several weeks at the American Philosophical Society in Philadelphia for a scientific briefing. He learned how to make celestial observations, to collect flora and fauna, and to study the Indians.

The Lewis and Clark Expedition of 1804-1806 made significant discoveries in botany, ethnology, geography, geology, and zoology. A vast mine of geographical information and considerable data concerning the Indians, particularly those of the Plains, were accumulated. Dried plants, fossils, rock specimens, and Indian utensils, weapons, and items of clothing were collected. The journals kept on the expedition were gradually published, but not in a satisfactory manner.[3]

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[1] Dorothy O. Johansen and Charles M. Gates, *Empire of the Columbia. A History of the Pacific Northwest* (New York, 1956), pp. 59-63.

[2] Richardson, *Messages and Papers of the Presidents*, Vol. I, p. 354.

[3] A Hunter Dupree, *Science in the Federal Government, A History of Policies and Activities to 1940* (Cambridge, 1957). pp. 26-28.

After the Louisiana Purchase, Jefferson planned supplemental expeditions up the Red and Arkansas Rivers. On April 15, 1804, Congress appropriated $3,000 for this purpose. In the winter of 1804-05 Sir William Dunbar and R. George Hunter made a scientific expedition up the Ouachita River in Louisiana. In May 1806 the Freeman expedition of Civilians and soldiers set out to explore the source of the Red River, but it failed because of Spanish resistence.

Next Jefferson sent out an Army expedition in 1806 under Lieutenant Zebulon Montgomery Pike in an attempt to discover the source of the Mississippi. Although the expedition did not succeed in its purposes, it was deemed a success and Pike was sent on a second expedition in 1807 to the Southwest. Pike was imprisoned by the Spaniards and his maps and papers were confiscated. He was taken to and detained in Chihuahua and eventually released on the Louisiana border. From memory he made his valuable report in 1810 which added to the geographical and scientifi knowledge of the Southwest.[1]

During the War of 1812 further western expeditions were delayed. With the return of peace in 1815 interest in these was revived. John C. Calhoun in his capacity as Secretary of War organized the expeditions of Major Stephen H. Long of the topographical engineers. In 1817 Long selected sites for forts on the Arkansas River and then on the Mississipp

As part of an overall military plan the Yellowstone Expedition of 1819, commanded by Long, was sent out to discover the source of the Platte, Red, and Arkansas Rivers and the principal tributaries of the Missouri. Among the scientists in the party were Thomas Say, a zoologist, August E. Jessup, a geologist, and Dr. Edwin James, a botanist. For over a year these scientists collected mineral specimens, plants, insects, and skins of animals, and studied geology and weather conditions. Thomas Say studied the several Indian tribes and their vocabularies. Although the expedition was largely a failure, since it had not discovered the sources of either the Platte River or the Red River, the scientific results were a decided improvement over those of the Lewis and Clark Expedition. The collections were classified and studies were published. James, Say, and Long wrote an *Account of the Expedition from Pittsburgh to the Rocky Mountains* which was published in 1823. Thomas Say (1787-1834) also wrote various zoological papers and Dr. John Torrey studied the dried plants that had been collected by Dr. James.

In 1823 Calhoun sent out another expedition headed by Long. Thomas Say served as zoologist and botanist and Professor William Keating of the University of Pennsylvania served as geologist. The party ascended the Mississippi and reached the source of St. Peter's River. In 1825 at London the *Narrative of An Expedition to the Source of the St. Peter's River* was published in two volumes. One hundred pages were devoted to Say's notes on insects. Say's collection of plants and flowers were studied by Lewis David von Schweinitz, a botanist, who

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[1] Leroy R. Hafen and Carl C. Rister, *Western America* (Englewood Cliffs, 1950), pp. 183-86.

authored a Synopsis of North American Fungi in which over 1,200 new species and seven new genera were included.[1]

West Point, Coast Survey, and Office of Chief of Engineers.

In 1802 during the Jefferson administration the Corps of Engineers of ten cadets and seven officers was created and constituted the Military Academy at West Point. A tradition of French mathematics and an interest in science existed from the beginning. In 1816 Crozet, one of Napoleon's engineers, became head of the engineering department. In 1816 and 1817, Sylvanus Thayer (1785-1872), a graduate of the Academy class of 1808, studied the theory and practice of fortifications in France. From 1817 to 1833 Thayer as superintendent of West Point improved the science and engineering departments. French textbooks were used and the educational concepts of the École Polytechnic were introduced. West Point engineering graduates became the most skilled engineers in the country. Their skills were called upon to perform engineering work for civilian projects and on the railroads in the twenties and thirties.[2]

In 1807 President Jefferson agreed to allow a geodetic survey of the coast by the Swiss geodist, Ferdinand Rudolph Hassler. However, diplomatic problems arising from the Napoleonic War caused the Coast Survey to be suspended. Hassler then taught mathematics at West Point for two years and at Union College for another two years. Despite the war, Hassler was in England from 1811 to 1815 purchasing instruments for the government for its proposed survey of the Atlantic coast. Finally in 1816 and 1817 he began his field work, but in 1818 Congress passed an act stating that only army or naval officers could be employed in the Coast Survey. For the next twelve years the Navy made local surveys, but they were of no real scientific value.

After the establishment of the Office of the Chief of Engineers, the Corps of Topographical Engineers became important in various surveys. By provisions of the Survey Act of 1824 the Corps developed a plan for western and for Atlantic coast canals and for a road from Washington to New Orleans. By 1825 army engineers were improving the navigation of internal waterways and working on the national road.[3]

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[1] Jaffe, Men of Science in America, pp. 138-42; Dupree, Science in the Federal Government, pp. 28-29, 35-36.

[2] American Military History, 1607-1958 (Washington, D.C., 1959), p. 119; Struik, Yankee Science in the Making, p. 245.

[3] Dupree, Science in the Federal Government, pp. 29-33, 36.

IV. PRE-CIVIL WAR PERIOD, 1830-1860

Scientific surveys.

The United States Coast Survey was revived in 1832 and Ferdinand R. Hassler became superintendent for the second time. Hassler fought for civilian control and good pay for scientific personnel. Most of his assistants were Army and Navy officers whom he had to give additional training. Hassler worked north and south from New York, and by the time of his death in 1843 the Coast Survey had covered an area from Point Judith in Rhode Island to Point Hinlopen in Delaware.

Alexander Dallas Bache succeeded Hassler as superintendent, holding the position from 1843 to 1867. Bache continued the survey of the Atlantic coast and the Gulf of Mexico. Among the many studies he organized were one of the Gulf Stream, one of the magnetic force of the earth, and studies on the depth of the oceans and forms of animal life. In 1851 at Bache's suggestion Louis Agassiz studied the coral reefs of Florida for a ten-week period while aboard a Coast Survey schooner. Extracts from his study were printed in the annual report of the Coast Survey in 1852. Bache also introduced a greater use of scientific instruments; for example, the electric telegraph was used in determining longitudes.[1]

The North Carolina geological survey of 1824-1828 was the first of a series of important state surveys. It was made by Dennison Olmsted, who performed the entire task alone and received no compensation except for traveling expenses. The results of the survey were published.

In 1830 Massachusetts authorized a survey by Edward Hitchcock as geological surveyor and Samuel Borden as trigonometrical surveyer. Hitchcock published the final report of his survey as early as 1833. It classified minerals, described mountains, catalogued animals and plants, and the part on "Scientific Geology" has been called a textbook on geology.

The Massachusetts survey made the nation aware of its resources and the need for exploring them. In 1837 Hitchcock made a second survey and published his final report in 1841. By that year eighteen other states had undertaken geological surveys. The New York geological survey, begun in 1836, was of special importance because it included a stratographic record made by the eminent paleontologist, James Hall.[2]

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[1] Struik, Yankee Science in the Making, pp. 196, 282, 324-25.

[2] Ibid., pp. 183-88; Merle Curti, The Growth of American Thought (New York, 1943), p. 327.

Scientific contributions of exploring expeditions.

Henry Rowe Schoolcraft (1793-1864), son of the director of the famous Van Rensselaer glassworks, explored the mineral deposits of southern Missouri and Arkansas in 1817 and 1818. In 1820 he was with the Lewis Cass Exploring Expedition to the Lake Superior region. Schoolcraft served as Indian agent in the Lake Superior area from 1822 until 1836, and then served as superintendent of Indian affairs in Michigan until 1841. He made studies of Indian customs and folklore. Although he gained a reputation as an ethnologist, his information was not entirely correct. Schoolcraft's most noteworthy trip was his government sponsored expedition of 1832 to the upper Great Lakes. The party discovered Lake Itasca, the source of the Mississippi.[1]

The Topographical Engineers of the Army made important surveys and astronomical observations while mapping the West. The most famous of the military explorers was John C. Fremont, who served his apprenticeship with the French scientist and mathematician Joseph Nicolas Nicollet, who commanded an exploration of the Minnesota River in 1838. Frémont learned mapmaking and was trained in exploring by Nicollet.

Frémont's Expeditions are best remembered for popularizing the West and for gaining him the unmerited title of "the pathfinder." The reports of the first two expeditions were published by the government in large editions and in a private printing. While the expeditions were scientific in character, they were utilized by Fremont for self-aggrandizement and the third expedition became involved in the conquest of California. Nonetheless, scientific reports were prepared, flora and fauna were collected, and excellent maps were drafted by Charles Preuss. Reports of the second and third expeditions had the first accurate accounts of the crystalline rocks, granitic, metamorphic, and volcanic at the core of the Sierra Nevada. These reports were widely read and considered valuable by geologists.[2]

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[1] Robert E. Riegel, *America Moves West* (New York, Rev. Ed., 1947). p. 327; Cardinal Goodwin, *The Trans-Mississippi West (1803-1853): A History of the Acquisition and Settlement* (New York, 1922), pp. 59-60.

[2] Cardinal Goodwin, *John Charles Fremont: An Explanation of His Career* (Stanford University Press, 1930, pp. 27-29, 35-36, 91-92; Frank M. Anderson, "Pioneers in the Geology of California," in *Bibliography of the Geology and Mineral Resources of California to December 31, 1930* by Solon Shedd (Sacramento: Division of Mines Bulletin No. 104, 1933), pp. 2-3.

On August 11, 1838, Secretary of Navy James K. Paulding ordered Lieutenant Charles Wilkes to command the United States Exploring Expedition. Wilkes with talents in astronomy, navigation, and terrain description was a logical choice. A week later six naval ships comprising six hundred officers and men, including a corps of scientists, set sail from Hampton Roads. Among the civilian scientists were mineralogist James Dwight Dana, botanist William Rich, horticulturalist William D. Breckenridge, philologist Horatio Hale, naturalists Titian R. Peale and Charles Pickering, and conchologist John P. Couthony. The expedition spent almost four years in exploring the Antarctic regions, the islands of the Central Pacific, and the coast of Western America. Wilkes had special instructions to devote six months to exploring the Pacific slope, and to survey San Francisco Bay.

The expedition reaped many scientific treasures, collecting data on anthropology, ethnology, zoology, geology, meteorology, botany, hydrography, and physics. Many charts were made based upon the surveys and these were used by the Navy even as late as World War II. The natural history collections were arranged and described by the National Institute. The seeds and plants collected by the expedition formed the basis for the United States Botanic Gardens. In 1844 the Narrative of the United States Exploring Expedition During the Years 1838, 1839, 1840, 1841, 1842 was published in five volumes with an atlas of five maps. An atlas of fifty-five charts was published in 1858. By 1876 a total of nineteen volumes had been published.

In a sense the expedition served as a training ground for young American scientists who gained needed field experience. For example, James Dwight Dana, the eminent American geologist, wrote on the geology of the Hawaiian Islands and of Washington, Oregon, and California.[1]

In 1851 the Navy sent out the De Haven Expedition to the Arctic to search for Sir John Franklin of the British Navy. From 1853 to 1855 Elisha Kent Kane headed a second expedition into the Arctic. The Geographic Society of New York, the American Philosophical Society, the Smithsonian Institution, the Coast Survey, and the Naval Observatory assisted with the scientific aspects of the expedition. In 1856 Kane authored Arctic Explorations.

The North Pacific Exploring Expedition of 1853-56 surveyed and mapped the North Pacific Ocean and had the assistance of leading scientists and scientific societies. In the fifties the Naval Astronomical Expedition to Chile was made by Lieutenant James M. Gilliss. The Pacific Railroad surveys of the fifties dispatched by Secretary of War Jefferson Davis also had important scientific

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[1] Daniel Henderson, The Hidden Coasts: A Biography of Admiral Charles Wilkes (New York, 1953); Anderson, "Pioneers in the Geology of California," p. 2; Dupree, Science in the Federal Government, pp. 60-61.

aspects, contributing to the knowledge of the flora, fauna, and geology of the West.[1]

Early Anthropologists and Ethnologists

The infant sciences of Anthropology and Ethnology began to develop in the United States prior to 1860. Among the first in these fields was Caleb Atwater (1778-1867). Atwater was born at North Adams, Massachusetts, and graduated from Williams College in 1804. After residing in New York City, he settled at Circleville, Ohio in 1815. Here he practiced law and devoted his spare time to the study of the earthworks and other antiquities in the state of Ohio. His first paper on this subject was published in 1820, in the American Antiquarium Society's Archaeologia Americana, Volume I. Atwater continued his efforts in this field and also published accounts of his visits with various Indian tribes of the Middle West in 1829 and the early 1830's.[2]

The pioneering work of Henry Rowe Schoolcraft (1793-1864) as an ethnologist making studies of Indian customs and folklore has already been mentioned (see page 32), but the generally recognized "father of American Anthropology" was Lewis Henry Morgan (1818-1881). Morgan was born near Aurora, New York and graduated from Union College at Schenectady, New York in 1840. He was admitted to the bar in 1844 and settled at Rochester, N. Y. in 1851, where he resided for the remainder of his life.

When Morgan returned to Aurora from college in 1840, he joined a secret society called the "Gordian Knot," which was patterned after the Iroquois Confederacy. After making a study of the Iroquois Indians the society became known as "The Grand Order of the Iroquois," with Morgan as its directing spirit, and its chief purposes to study and preserve Indian lore, to educate the Indians, and to reconcile them to the conditions imposed by civilization. Morgan's casual interest in Indian matters was thus transformed into a serious investigation of Iroquois institutions and customs, which in turn led him to further research among other American Indian tribes and finally in the field of World Anthropology.

As a result of his service to the Indians, Morgan was adopted into the Hawk clan of the Seneca tribe in 1847. This induction admitted Morgan into the innermost councils of the tribe and gave him every facility for pursuing his studies. Morgan began publishing the results of his studies in 1846. In 1849 the University of the State of New York made an appropriation for the enlargement of its Indian collection and placed Morgan in charge of this project. His book, League of the Ho-de-no-sau-nee, or Iroquois (1851), although a pioneering work, has been called" the first scientific account of a Indian tribe." By 1862 Morgan had extended his studies to the Indian tribes

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[1] Dupree, Science in the Federal Government, pp. 94-99.

[2] Dictionary of American Biography I, 415-16.

of the middle West, ultimately recording notes on the kinship systems of some 70 tribes. His major work, Ancient Society or Researches in the Lines of Human Progress, was published in 1877-78. In it he propounded the doctrine of the common origin and psychic unity of all races of men and asserted that they passed through successive stages of savagery, barbarism, and civilization. His theory that the family had evolved from a state of promiscuity and his interpretation of kinship terms brought about much acrimonious debate. Although anthropologists today find Morgan's evolutionary scheme and methods, as applied to primitive society, extremely tenuous, his conclusions had far-reaching influence in his day.

By 1869 Morgan has also extended his interest to Indians of the Southwest. Visiting that area in 1878, he played a role in launching the first steps to preserve the ruins of the Pueblo Indians.

Finally, Morgan was instrumental in organizing the section of Anthropology of the American Association for the Advancement of Science in 1875 and was its first chairman. In 1879 he was also elected president of this association.[1]

Smithsonian Institution.

By 1838, when the original charter of the Columbian Institute for the Promotion of Arts and Sciences expired, the organization had declined in influence. Two years later it was superseded by the National Institute for the Promotion of Sciences, which had been organized by Secretary of War Joel R. Poinsett. The new organization cared for the specimens collected by scientists of the Wilkes Expedition. The National Institute tried to control Smithson's bequest, but in 1846 Congress created the Smithsonian Institution. The National Institute and the Smithsonian Institution functioned side by side until 1861. In that year the Institute ceased and its collections became part of the Smithsonian.

Although the Smithsonian Institution became known as the "American Treasure House of Science," it was much more than a repository for collections. Under the capable leadership of its first secretary, Joseph Henry (1797-1878), the Smithsonian engaged in research in pure science with utilitarian goals. In his first annual report to the Board of Regents of December 8, 1847, Henry announced that the first publication of the Smithsonian Institution would be an ethnological study. He also related that preparations had been made "for instituting various lines of physical research." As an example, he mentioned the subject of terrestrial magnetism which besides its theoretical interest had a "direct reference to navigation and the various geodetical operations of civil and military life."

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[1] B. J. Stern, Lewis Henry Morgan, Social Evolutionist (Chicago, 1931).

As another subject of research Henry mentioned "an extensive system of meteorological observations, particularly with reference to the phenomena of American storms.[1] In his second annual report, dated December 13, 1849. Henry stated:[2]

> "The first volume of the Smithsonian Contributions to Knowledge has been published and partially distributed. It consists of a single memoir on the Ancient Monuments of the Mississippi Valley, comprising the results of extensive original surveys and explorations by E. G. Squier, A.M., and E.H. Davis, M.D. It is illustrated by forty-eight lithographic plates, and by two hundred and seven wood engravings. The mechanical execution of the volume will bear comparison with that of any publication ever issued from the American press."

The Smithsonian Institution increased and diffused scientific knowledge in implementing the purposes of Smithson's bequest. It was the first organization in the United States to perform general scientific work with a regular staff. It organized scientific studies in the nation, particularly in the field of anthropology and meteorology. In fact Henry started the weather report system by organizing a corps of observers and by using the telegraph for simultaneous reports. 3

Henry inaugurated a series of publications. Annual reports were issued, Smithsonian Contributions to Knowledge were published, and in 1862 the series known as Miscellaneous Collections was begun. The publications were distributed free to the more important depositories throughout the world. A museum and an exhibit hall were maintained. Popular lectures on Science were presented in Washington, D.C. Grants were made for original scientific investigations, stimulating private research.[3]

Naval Observatory.

Complementing though conflicting with Henry's meteorological work, was that of Matthew Fontaine Maury (1806-73), the "Pathfinder of the Seas." In 1830 the Secretary of Navy organized the Depot of Charts and Instruments. Twelve years later it became the Naval

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[1] "First Report of the Secretary" in Eighth Annual Report of the Regents of the Smithsonian Institution (Washington, D.C., 1854), pp. 144-46.

[2] Ibid., pp. 156-57.

[3] The best account of the Smithsonian is Paul H. Oehser, Sons of Science (New York, 1949); for a brief account see The Smithsonian Institution (Washington, D. C., 1961).

Observatory with Maury serving as superintendent from 1842 to 1861. Maury was more interested in oceanography than astronomy. He conducted researches on ocean winds and currents, making wind and current charts of the Atlantic, Pacific, and Indian oceans. Maury studied the old logs of ships and used merchant ship and naval captains as observers. He collected his data throughout the world, and he issued a series of Wind and Current Charts and published Sailing Directions. Maury's directions were a great advantage to commercial shipping interests in that they reduced the time of passage from port to port.

Maury developed a system of universal meteorological observations. Through his influence an international congress met at Brussels in 1853,-attended by scientists of ten commercial nations. He achieved world-wide cooperation in his work. In 1855 Maury authored his Physical Geography of the Sea which was the first textbook of modern oceanography.[1]

The conquest of pain.

The demonstration of the effectiveness of either as an anesthesia was a great American scientific discovery made in 1846 by the Boston dentist, William Thomas Green Morton (1819-68). This triumph was to revolutionize surgery. At the suggestion of Dr. Charles T. Jackson (1805-1873), a physician and professor of chemistry, Morton tested ether on animals and himself. In 1846 Dr. John Collins Warren, a surgeon, made the first public demonstration of ether as a surgical anesthesia in an operation performed on October 16, at the Massachusetts General Hospital. Dr. Morton administered the ether to Gilbert Abbot, the patient. The next month Morton and Jackson received a patent for the use of "letheon." From 1842 to 1846, Dr. Crawford W. Long (1815-78), a Georgia surgeon, had also used ether as an anesthesia in performing eight private operations, but he did not publish an account of his work until December 1846. Morton's efforts to profit from his discovery brought conflicting claims from Jackson and Long, and also Dr. Horace Wells, a former partner of Morton who had privately experimented with ether in 1844. As a result Morton became involved in controversy and litigation. Ultimately Morton's claim was recognized, when he was elected to the American Hall of Fame in 1920. Shortly after Morton's successful demonstration of 1846, the English medical journal, Lancet, stated:[2]

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[1] A standard biography is C. L. Lewis, Matthew Fontaine Maury: The Pathfinder of the Seas (Annapolis, 1927).

[2] As quoted in Jaffe, Men of Science in America, p. 167, who has a chapter on Morton, pp. 154-78; also see Flexner, Doctors on Horseback, pp. 273-324, for a chapter on Long and Morton.

> "The discovery of Dr. Morton will undoubtedly be placed high among the blessings of human knowledge and discovery. That its discoverer should be an American is a high honor to our transatlantic brethren; next to the discovery of Franklin, it is the second and greatest contribution of the New World to science."

Scientific meetings, organizations, and publications.

In 1831 about five hundred chemists and manufacturers attended the first chemical convention in the nation held at New York City. In 1844 an important precedent was established when the first Scientific Congress was held at Washington, D. C. Scientists of such stature as Matthew Fontaine Maury and Alexander Dallas Bache read papers and various meetings were held on astronomy, chemistry, geology, meteorology, paleontology, physiology, and other subjects.

In 1842 the Association of American Geologists and Naturalists, the first permanent scientific organization of national scope, was organized at Philadelphia. In 1848 it became a general professional society, being renamed the American Association for the Advancement of Science. One of the purposes of the Association was "to hold periodical meetings, and to promote intercourse between those who are cultivating science in different parts of the United States." The AAAS also published its Proceedings.

After 1840 the number of scientific journals and magazines increased. Among these was the popular and permanent journal, Scientific American, first published in 1845. Science textbooks also began to appear in this period. In 1846 James and Robert Rogers authored a chemistry textbook which enabled colleges to introduce courses in that subject. James Dwight Dana, while a professor natural history at Yale, wrote his Manual of Geology (1862) and his Textbook of Geology (1864).

Scientific schools.

Although college education was based primarily upon classical studies in the decades before the Civil War, colleges and universities were beginning to offer degrees in science and engineering. The School of Applied Chemistry was established at Yale College in 1847 with John Pitkin Norton and Benjamin Silliman, Jr., as professors. Nine years later an effort was made to raise a permanent endowment for the Yale Scientific School. Joseph E. Sheffield, a railroad promoter, provided a building and gave gifts to the school. In 1861 the school was named the Sheffield Scientific School and its primary interest became the teaching of chemistry.

In 1847 a scientific school was organized at Harvard. Ten years later it was endowed by Abbott Lawrence. The primary objective of the Lawrence Scientific School was engineering, but it

did not have an engineering laboratory until 1892. In 1851 the Chandler School of Sciences and Arts was established in Dartmouth. The Massachusetts Institute of Technology was granted a charter by the Massachusetts legislature in 1861. Four years later this Boston school was opened with William B. Rogers as president.[1]

Science in the Old South.

Despite the agrarian outlook of the ante-bellum South, its colleges and universities offered a certain amount of scientific instruction. In 1827 an astronomical observatory was built at the University of North Carolina. In 1854 this institution opened a "School for the Application of Science to the Arts" and offered a bachelor of science degree. By 1852 South Carolina College had an astronomical observatory in operation. Among the science teachers at this college before the Civil War were John and Joseph Le Conte. In Lexington, Kentucky at Transylvania University Constantine Samuel Rafinesque taught natural history and R. H. Bishop taught natural philosophy. Dr. Eugene Hilgard in his *Report on the Geology and Agriculture of the State of Mississippi* (1860) acknowledged his indebtedness to Professor William D. Moore of the University of Mississippi for assistance in the systematic arrangement of the survey's collections. While the Southern colleges as a whole were probably not as advanced in their scientific curricula as those of the North, they demonstrated a great interest in the natural sciences.

Among the Southern people there existed a popular interest in science. Scientific lectures found receptive audiences in the South. The people read scientific articles in their newspapers and magazines. Many attempts were made to establish scientific museums, but these were generally unsuccessful; an exception was the Charleston Museum which became an admirable scientific organization.

Among the significant scientists of the Old South was the Virginia planter, Edmund Ruffin, who conducted experiments for restoring the fertility of Virginia soil. In his *Essay on Calcareous Manures* (1832) he reported that marl, a clay deposit mixed with calcium carbonate, corrected exhausted soils to an extent that they could assimilate fertilizers. In 1860 he authored his *Notes on the Cane-Brake Lands of Alabama* and in 1861 he wrote his *Agricultural, Geological, and Descriptive Sketches of Lower North Carolina and the Similar Adjacent Lands*. As a result of his research and writings Ruffin has been considered "the father of soil chemistry in America."

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[1] Oliver, *History of American Technology*, pp. 237-38, 242-45; Struik, *Yankee Science in the Making*, pp. 337-57.

Moses Ashley Curtis, the North Carolina botanist, published many important papers in the American Journal of Science, the Journal of the Academy of Natural Sciences of Philadelphia, and the Journal of the Linnaean Society of London. In 1860 his Woody Plants of North Carolina appeared as Part III of the Geological and Natural History Survey of North Carolina.

A brilliant geologist of the Old South was Oscar Montgomery Lieber, who had worked on geological surveys in Mississippi and Alabama. In 1856 he became State Geologist of South Carolina and published the Reports of the Geognostic Survey of South Carolina (1857-60). In the summer of 1860 he accompanied Professor Charles S. Venable on an astronomical expedition to Labrador.

Scientists of the Old South made contributions to the national scientific societies. Many Southerners were active in the work of the American Philosophical Society and of the Smithsonian Institution. William B. Rogers of the University of Virginia served as a president of the American Association for the Advancement of Science, and on the eve of the Civil War, Frederick A. P. Barnard, president of the University of Mississippi, was its president.[1]

V. CIVIL WAR ERA, 1861-1865

Morrill Act of 1862.

The Morrill Land Bill was first introduced into Congress in 1857. It first passed in 1859, but was vetoed by President Buchanan. With the opposition of Southern Congressmen and Senators removed by the Civil War, the act passed and was signed by President Lincoln on July 2, 1862. The act granted some 13,000,000 acres of the public domain for the support of industrial and agricultural education. Entitled, "An Act donating Public Lands to the Several States and Territories which may provide Colleges for the Benefit of Agriculture and the Mechanic Arts," the measure gave a great impetus to the movement for state universities.

While the cause of agricultural education benefited, scientific and engineering education also benefited. The Morrill Act had been written so that both established colleges and new ones might

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[1] Thomas C. Johnson, Jr., Scientific Interests in the Old South (New York, 1936).

use the fund. According to the act, "the leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and mechanic arts." Senator Justin S. Morrill had not intended that the schools only benefit the farmers, but he expected them to be scientific in purpose. Connecticut was one of the first states to accept the land scrip and it used the money entirely for the Sheffield Scientific School at Yale College.

As a result of the Morrill Act new colleges such as Cornell and Purdue and state universities such as those of Ohio and Illinois were established. While some states sold their lands unwisely on the market, others were more careful. The classic example is Cornell University in New York which benefited tremendously from the Morrill Act. A bill providing additional funds to the land-grant colleges was finally passed in 1890. By that time over fifty colleges had been established under provisions of the historic measure introduced by Justin S. Morrill, who "lighted candles of wisdom."[1]

The National Academy of Sciences.

The North was greatly aided in the task of winning the Civil War by the possession of superior scientific and technical skills. President Lincoln recognized the value of scientific research when he signed the act on March 3, 1863, creating the National Academy of Sciences. While the Academy did not significantly contribute to victory in the Civil War, its creation established an important precedent for twentieth century military conflicts. The article of incorporation stated:[2]

> "The academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose; but the academy shall receive no compensation whatever for any services to the Government of the United States."

The first meeting of the National Academy of Sciences was held on April 22, 1863, and Alexander Dallas Bache was elected president. The membership at first was restricted to fifty, but the limit was removed in 1870. Among the prominent members were Louis Agassiz, Wolcott Gibbs, Asa Gray, Joseph Henry, and Benjamin Silliman, Sr., and his son. Bache appointed five numbered commit-

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[1] Henry S. Commager, ed., Documents of American History (New York, 6th ed., 1958), Vol. I, pp. 412-13; Fabian Franklin, The Life of Daniel Coil Gilman (New York, 1910), pp. 70-73.

[2] As quoted in Richardson, Messages and Papers of the Presidents, X, p. 439.

tees which studied: (1) weights, measures, and coinage, (2) ways to protect the bottoms of iron ships from salt, (3) the magnetic deviation of the compass in iron vessels, (4) the hydrometer invented by Joseph Saxton, and (5) the question of continuing Maury's current charts and sailing directions.[1]

United States Coast Survey.

In addition to being president of the National Academy of Sciences during the war, Bache was also superintendent of the Coast Survey. In May 1861 he proposed a commission to devise plans for naval operations against the South. The commission as organized included Captain Samuel F. Du Pont as president, Commander Charles H. Davis as secretary, Major John G. Barnard of the Corps of Engineers, and Bache. The commission gathered data useful for a blockade and selected objectives for amphibious operations. The commission planned the successful assault on Port Royal in South Carolina. After the Port Royal victory, Du Pont was able to extend the blockade of the South.[2]

Smithsonian Institution.

The war curtailed many of the scientific activities of the Smithsonian Institution. For example, its weather reporting system was disrupted by the secession of the Southern states and by restrictions placed on the use of the telegraph. However, the museum continued to sponsor expeditions such as those of Dr. Elliott Coues, an Army surgeon and eminent ornithologist, in Arizona and New Mexico and of Robert Kennicott in the central part of Canada. Kennicott journeyed from Chicago to Fort Yukon and back during the period from May 19, 1859 to February 11, 1862. He studied fauna and geology of the region under the joint sponsorship of the Smithsonian Institution and the Audubon Club of Chicago. During the winter of 1861-62 Kennicott catalogued his Arctic collection at the Smithsonian. In the June 1863 issue of its Collections, he authored "Descriptions of Four New Species of Spermophilus." In March 1865 Kennicott accepted the position of Chief of Explorations of the Western Union Telegraph Expedition to Alaska with the stipulation that he could appoint a corps of assistance, who would collect specimens for both the Chicago Academy of Sciences and the Smithsonian Institution.[3]

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[1] Dupree, Science in the Federal Government, pp. 141-46; Oliver, History of American Technology, pp. 286-87.

[2] Dupree, pp. 132-33; H. A. Du Pont, Rear-Admiral Samuel Francis Du Pont, United States Navy, A Biography (New York, 1926), pp. 105-13

[3] Dupree, Science in the Federal Government, pp. 131-32; Benjamin F. Gilbert, "Arts and Sciences in Alaska: 1784-1910," Journal of the West I (Oct., 1962), pp. 144-45.

Application of science to the tools of war.

At the White House, on June 11, 1861, Joseph Henry, Secretary of the Smithsonian Institution, introduced a young balloonist named Professor Thaddeus S. C. Lowe to President Lincoln. Lowe informed Lincoln of his plan for a military balloon reconnaissance which included a telegraphic air-ground communication. On June 18, Professor Lowe demonstrated the practicability of his balloon for military observation. He took up a telegraph wire and sent Lincoln the "First Balloon Dispatch," reading as follows: [1]

"To President United States

> This point of observation commands an area nearly fifty miles in diameter--The city with its girdle of encampments presents a superb scene--I have pleasure in sending you this first dispatch ever telegraphed from an aerial station and in acknowledging indebtedness to your encouragement for the opportunity of demonstrating the availability of the science of aeronautics in the military service of the country.
>
> T.S.C. LOWE"

Following the demonstration, Lincoln gave Lowe a letter of introduction to General Winfield Scott, but the General of the Army displayed no interest at their meeting. On July 25, Lincoln wrote a note to Scott, stating:[2] "Will Lieut. Genl. Scott please see Professor Lowe, once more about his balloon?" When Scott refused to see Lowe, the professor returned to the White House and informed the President about his inability to obtain the appointment. Lincoln then took Lowe in person to the Winder Building where General Scott finally listened and agreed to accept the idea of a balloon corps.

Lowe was appointed Chief of the Aeronautic Section and the next year seven balloons were put into operation. Lowe also designed a barge, the Coeur de Leon, on the Potomac as the "first aircraft carrier in history" to make ascensions from water. Lowe's telegraphic reports in several military maneuvers were of value to the Union Army. However, Lowe being a civilian never gained proper support for his reconnaissance plans; he resigned and the balloon corps was soon abandoned.[3]

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[1] As quoted in Robert V. Bruce, Lincoln and the Tools of War (Indianapolis, 1956), p. 86.

[2] Roy P. Basler, ed., The Collected Works of Abraham Lincoln (New Brunswick, 1953), Vol. IV, p. 460.

[3] Bruce, Lincoln and the Tools of War, pp. 85-88; Patricia Jahns, Matthew Fontaine Maury & Joseph Henry: Scientists of the Civil War (New York, 1961), pp. 178-79.

In addition to balloons the Civil War also witnessed the use of ironclads. Scientific and technological lessons were learned from the engagements between the Virginia and the Monitor at the Battle of Hampton Roads. Among other naval innovations were the efforts of the Confederate States Navy to produce "submarines" and Torpedoes.[1]

American military medicine improved as a result of the Civil War. The Medical Department of the Army which had been in a condition of confusion and incompetence in 1861 was well-organized by 1865. An ambulance corps, base hospitals, and field services were established and mass medical examinations were given. The Medical Department was required to maintain vast records which were later used for research. The Army Medical Museum and Library grew out of the war and became a great center of medical bibliography. A few doctors engaged in research during the war. For example, S. Weir Mitchell studied neurology and wrote Gunshot Wounds and Other Injuries of Nerves (1864)

American physicians for the first time organized and operated large general hospitals. They learned the value of training and discipline in nursing. Many country doctors were forced to become surgeons. The sanitary lessons of the Civil War helped to prepare the nation for the public health movement which developed in the last third of the nineteenth century.[2]

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[1] James P. Baxter, The Introduction of the Ironclad Warship (Cambridge, 1933); E. P. Potter and J. R. Fredland, eds., The United States and World Sea Power (Englewood Cliffs, 1955), Ch. 18.

[2] Dupree, Science in the Federal Government, pp. 128-30; George W. Adams, Doctors in Blue: The Medical History of the Union Army in the Civil War (New York: Collier Books Edition, 1961).

VI. INDUSTRIAL AGE, 1866-1913

Impact of Darwinism.

Darwinism had a tremendous impact upon science, religion, and industry in the United States. The Darwinian controversy, which raged after 1859, became part of the already existing conflict between science and orthodox interpretation of the Bible.

Louis Agassiz (1807-73) was the most vocal critic and antagonist of the Darwinian theories. He opposed the theory that new species originate and survive by the process of natural selection; instead he held to the generally accepted belief that all species were immutable since Creation.

The Swiss naturalist had gained international recognition before his migration to America in 1846. He had become famous because of his glacial theory which had broken new ground in geology. He had published *The Fishes of Brazil* (1829) and the *History of the Fresh Water Fishes of Central Europe* (1839-42). From 1848 until his death he was a professor of natural history at Harvard's Lawrence Scientific School. He introduced the laboratory method in zoology, and encouraged American naturalists to examine the internal functions of animals instead of concentrating on classification. Agassiz made zoological explorations to Brazil in 1865, to Cuban waters in 1869, and just before his death he traveled around the Horn to California. His collections became part of the Harvard Museum of Comparative Zoology.[1]

Agassiz's colleague at Harvard, Asa Gray (1810-88), was the outstanding scientific proponent of Darwinism. A distinguished botanist, Gray had collaborated with John Torrey in preparing the *Flora of North America* (1838-43). As a professor of natural history at Harvard he made cambridge the center of American botanical studies. He wrote textbooks, manuals, and other books on botany.[2]

Darwin had corresponded with Gray before his *Origin of Species* had appeared and Gray was the first American scientist to defend the new theory. In a review of *On the Origin of Species by Means of Natural Selection* (1859), appearing in the March 1860 issue of

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[1] The best biography of Agassiz is Edward Lurie, *Louis Agassiz: A Life in Science* (Chicago, 1960). An earlier one is *Charles F. Holder, Louis Agassiz, His Life and Work* (New York, 1893).

[2] An outstanding biography is A. Hunter Dupree, *Asa Gray, 1810-1888* (Cambridge, 1960).

the American Journal of Science, Gray explained both the views of Darwin and Agassiz. He summarized their differences in one sentence as follows: "The theory of Agassiz regards the origin of species and their present general distribution over the world as equally primordial, equally supernatural; that of Darwin, as equally derivative, equally natural."

Gray attempted to remove the obvious materialism from Darwin's theory by asserting that natural selection did not exclude the hand of God from nature. Gray's argument in Darwinian controversy was that Darwin's theory had no special relation to religion and that one could believe in God after accepting evolution. Gray's many articles on the subject were published in 1876 under the title of Darwiniana.

Agassiz's rejection of Darwinism impeded its acceptance among New England scientists. Gray defended Darwinism only after reconciling it with religion. Jeffries Wyman (1814-74), a distinguished professor of anatomy in the Lawrence Scientific School and curator of the Peabody Museum at Harvard from its organization in 1866, maintained a neutral position. He stated:[1] We arrive at no reasonable theory which takes a position intermediate between the two extremes." Wyman made this statement in 1863. In a letter of 1871 he stated:[2]

> 'It is a curious fact that the opponents of evolution have as yet started no theory except the preposterous one of immediate creation of each species. They simply deny. After many trials I have never been able to get Agassiz to commit himself to even the most general statement of a conception. He was just the man who ought to have taken up the evolution theory and worked it into a good shape, which his knowledge of embryology and palaeontology would have enabled him to do. He has lost a golden opportunity, but there is no use in talking of that.'

Wyman's research on the anthropoid ape contributed to the discussion on evolution. In 1847 he wrote the first scientific description of the gorilla as a separate species of ape. Just prior to his death Wyman noted that man "must have gone through a period when he was passing out of the animal into the human state, when he was not yet provided with tools of any sort, and when he lived the life of a brute." In preparing his Descent of Man (1871), Darwin used the material collected by Wyman.

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[1] As quoted in Druik, Yankee Science in the Making, p. 312.

[2] Ibid.

James Dwight Dana (1813-95), the geologist, remained publicly silent on the Darwinian controversy between Agassiz and Gray, but when the fourth edition of Dana's Manual of Geology appeared in 1895, he accepted most of Darwin's concept of man's rise.

During the Civil War Yale's Sheffield Scientific School sent a promising young graduate, Othniel Charles Marsh (1831-99), to Europe to study vertebrate paleontology. Marsh improved his own scholarship, and also obtained for Yale College the Peabody Museum of Natural History by maneuvering the philanthropic instincts of his wealthy uncle, George Peabody. During four summers, beginning in 1870, Marsh led parties of Yale students and graduates into the Western prairies and Rockies in search for bone fossils. Marsh's first major monograph was Odontornithes: A Monograph on Extinct Birds of North America.

Thomas Henry Huxley, the English biologist, credited Marsh with bridging the gap between the reptiles and the birds. Huxley said: "The discovery of the toothed birds by Marsh completed the series of transitional forms between birds and reptiles and removed Mr. Darwin's proposition that 'many animal forms have been utterly lost' from the region of hypothesis to that of demonstrable fact." On August 31, 1880, Darwin wrote a letter to Marsh, stating in part as follows: 'Your work on these old birds and on the many fossil animals of N. America has afforded the best support to the theory of evolution, which has appeared within the last 20 years..." Marsh also collected horse fossils and exploded the theory that the horse had originated in the Old World by demonstrating that the horse was indigenous to America.

In 1882 Marsh was appointed Vertebrate Paleontologist of the United States Geological Survey and in 1887 Spencer F. Baird appointed him Honorary Curator of the Department of Vertebrate Paleontology in the United States National Museum. From 1883 to 1895 Marsh was also president of the National Academy of Sciences. While with the Geological Survey from 1882 to 1892, Marsh collected a mass of materials. The Survey published his Dinosaurs of North America and his Vertebrate Fossils of the Denver Basin in 1896.[1]

New World of Chemistry.

Josiah Willard Gibbs (1839-1903), a Yale professor of mathematical physics, in his studies of themodynamics revolutionized accepted concepts of the behavior of matter and energy in its application to several scientific fields when he published his paper, On the Equilibrium of Heterogeneous Substances, in the Transactions of the Connecticut Academy of Arts and Sciences in 1876. His "phase rule" was a great American contribution to pure

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[1] Charles Schuchert and Clara M. Le Vene, O.C. Marsh: Pioneer in Paleontology (New Haven, 1940). Jaffe, Man of Science in America, pp. 279-306.

chemistry, but American scientists did not realize the significance of his generalization until years later. It developed the fundamental principles underlying chemical equilibrium. His highly abstract "phase rule" had a number of important industrial applications in the field of alloys and in the manufacture of Portland cement. The German chemist, Wilhelm Ostwald, called Gibbs "the founder of chemical energetics."

Gibbs performed much of the ground work for the science of physical chemistry. He did pioneer work in vector analysis, in statistical mechanics, and in the measurement of energy. From his studies developments were made in radioactivity, the theory of relativity, electrochemistry, colloid chemistry, and modern synthetics.

Although Gibbs was elected to the National Academy of Sciences in 1877, and was awarded the Rumford Medal of the American Academy of Arts and Sciences in 1879, he was not well known in American intellectual circles. In his biographical sketch of Gibbs, Bernard Jaffe has stated:[1] "Gibbs was a great scientist who strove to bring order out of the heterogenous mixtures of metals and salts in solution. He was also a symbol of America struggling to bring system and law out of the chaos of an expanding industrialism."

Edward Williams Morley (1838-1923) was a great American chemist and physicist, who is best remembered for his series of experiments with Albert A. Michelson. The two men made the Michelson-Morley ether-drift experiment at the Case School of Applied Science in Cleveland in 1887. The nature and significance of this experiment will be subsequently explained in this chapter under physics. In 1902-04 Morley also made experiments with Dayton C. Miller on the ether-drift.

In 1868 Morley accepted an offer from Western Reserve University to a professorship in natural philosophy and chemistry. In addition to his researches in the ether-drift, Morley also studied the variations of atmospheric oxygen content, thermal expansion of gases, and the densities of oxygen and hydrogen.[2]

New Astronomy.

In the Industrial Age a new science of astronomy arose which was named astrophysics. Whereas the earlier astronomy attempted

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[1] Jaffe, *Men of Science in America*, p. 328; Jaffe's full sketch appears on pp. 307-30. Also see Floyd D. Darrow, *The Story of Chemistry* (New York, 1930), pp. 77-78.

[2] Jaffe, *Men of Science in America*, p. 356.

to find out how the heavenly bodies move, the new astronomy attempted "to determine the present constitution and the evolution-history of the stars, the comets, the sun, the planets." Spectrum analysis, celestial photometry, and celestial photography became the three major lines of research. Astrophysics, the daughter of astronomy, was directly related to chemistry, technics, and physics.[1] Improved telescopes and larger observatories were built. The observatories were supported by universities and staffed by distinguished scientists. Research in the new astronomy was costly, and philanthropists such as James Lick and Charles T. Yerkes gave the necessary financial assistance.

Among the eminent astronomers of this age was Maria Mitchell (1818-89), the first woman to be admitted to the American Academy of Arts and Sciences. As a young girl she had helped her father, William, a Nantucket astronomer, with his observations. On October 1, 1847, Maria Mitchell discovered a comet. As a result she gained international recognition and was awarded the gold medal of the King of Denmark. In 1865 she was appointed to the chair of astronomy and director of the observatory at the newly founded Vassar College where she studied the sun, Jupiter, and Saturn. Her brother, Henry Mitchell (1830-1902), became the leading American hydrographer. He served with the United States Coast Survey from 1849 until 1888 and authored such works as his Tides and Tidal Phenomena (1868). After her death an observatory was dedicated to her memory at Nantucket and her name was enrolled in the American Hall of Fame in 1922.[2]

Benjamin Peirce (1809-80) was a professor of mathematics and astronomy at Harvard from 1833 until his death. He was also consulting astronomer for the Nautical Almanac from 1849 to 1867, and Peirce succeeded Alexander D. Bache as superintendent of the Coast Survey from 1867 until 1874.

Peirce was noted for his accurate computation of the general perturbations of Uranus and Neptune and for his research on the rings of Saturn. He wrote papers in a new mathematical field, Linear Associative Algebra, first lithographed in 1870, and then printed in 1881, in the American Journal of Mathematics.[3]

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[1] Edward S. Holden, Hand-Book of the Lick Observatory (San Francisco, 1888), pp. 81-82.

[2] Helen Wright, Sweeper in the Sky: The Life of Maria Mitchell, First Woman Astronomer in America (New York, 1949).

[3] Struik, Yankee Science in the Making, pp. 330-35.

Benjamin Apthorp Gould (1824-96) was the first American astronomer to be trained in Europe. He founded the Astronomical Journal in 1849. From 1855 to 1859 he was director of the Dudley Observatory in Albany, New York. He was associated with Peirce in the longitude department of the Coast Survey from 1852 to 1867. He adapted the telegraphic method to obtain the longitude difference between Washington and Greenwich by using the first trans-atlantic cable.

Beginning in 1865, Gould studied the southern celestial hemisphere. In 1870 he organized the Cordoba Observatory in Argentina, and in 1872 he established meteorological stations south to Tierra del Fuego. He determined magnitudes of southern stars which were published in Uranometria Argentina in 1879. He also prepared zone catalogues of the southern stars which were published in Resultados del Observatorio Nacional Argentino en Cordoba (1879-96).[1]

Samuel Pierpont Langley (1834-1906) was both a famous astronomer and an aeronautical pioneer. As an assistant astronomer at Harvard Observatory he discovered two faint stars in the great neubula in Sagittarius. For a year he taught mathematics at the Naval Academy and directed its astronomical observatory.

From 1867 to 1887 Langley was professor of astronomy and physics at the University of Pittsburgh and director of its Allegheny Observatory. He invented the bolometer and used it in 1878 to make spectral measurements of solar and lunar radiation. His paper on The Bolometer and Radiant Energy (1881) became a scientific classic. In 1881 Langley organized an expedition to Mount Whitney in order to study the quantity and quality of the sun's radiation to the earth.

While at the University of Pittsburgh, Langley first developed his interest in the theory and practice of heavier-than-air flight. In 1887 he became Secretary of the Smithsonian Institution and began to concentrate his studies on aeronautics. During Langley's tenure as Secretary the Astrophysical Observatory was established at the Smithsonian. His writings were collected and published as The New Astronomy in 1888. Langley received many honors, being elected to the Royal Society of London, Royal Society of Edinburgh, and the Accademia dei Lincei of Rome.[2]

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[1] Struik, Yankee Science in the Making, p. 336; the index of this book and its revised 1962 edition both erroneously give Gould's life span as 1787-1859, instead of 1824-96.

[2] Jaffe, Men of Science in America, pp. 331-59; Paul H. Oehser, Sons of Science: The Story of the Smithsonian Institution and Its Leaders, (New York, 1949), pp 110-140.

Simon Newcomb (1835-1909), a professor of mathematics at the Naval Observatory, was a leading astronomer of the nation. In 1875 he was offered the directorship of the Harvard Observatory, but decided to remain in government service. From 1877 to 1897 he was superintendent of the *Nautical Almanac*. The Naval Observatory and *Nautical Almanac* enjoyed their golden age during Newcomb's incumbency. Assisting Newcomb, was the eminent astronomer George W. Hill, who studied the theory of the motions of Jupiter and Saturn and who devised a new method to calculate the moon's motion. From 1884 to 1894 and from 1898 to 1900, Newcomb was a professor of mathematics and astronomy at Johns Hopkins University. Throughout his career he contributed to scientific journals and authored such books as *Popular Astronomy* (1878), *The Stars* (1901), and *Astronomy For Everybody* (1902).[1]

George Davidson (1825-1911), the astronomer and geographer, had a long career with the Coast Survey on the Pacific Coast. He arrived in California in 1850 as head of an astronomical and triangulation party. In 1857 Davidson erected a small observatory on Rincon Hill in San Francisco. He later built a temporary observatory at Washington Square in San Francisco where he interchanged time signals with the Harvard Observatory using the telegraph. On March 18, 1869, Superintendent Benjamin Peirce informed Davidson that the success of his telegraph work had "attracted the attention generally of the public on the Atlantic."

Davidson worked to establish a large observatory on the Pacific Coast. His proposal eventually materialized through the beneficience of James Lick. However, Davidson favored a Sierra Nevada site. When Lick decided on a site in the Coast Range, Davidson ended his role as an adviser to Lick. In 1879 Davidson built a small observatory at Lafayette Park in San Francisco where he performed his Coast and Geodetic Survey work until the 1906 earthquake.[2]

Edward Singleton Holden (1846-1914), a West Point graduate, was an astronomer at the Naval Observatory in Washington, D. C. from 1873 until 1879. In 1881 he became director of the Washburn Observatory of the University of Wisconsin. After serving as President of the University of California, he became the first director of the Lick Observatory on Mt. Hamilton from 1888 until 1897. In 1889 Holden founded the Astronomical Society of the Pacific.[3]

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[1] Dupree, *Science in the Federal Government*, p. 185; Struik, *Yankee Science in the Making*, p. 330.

[2] George Davidson, "Letters and Reports to Benjamin Peirce, Superintendent of United States Coast Survey, 1866-1875," (Manuscripts, The National Archives, Washington, D.C.). Oscar Lewis, *George Davidson: Pioneer West Coast Scientist* (Berkeley, 1954).

[3] Dupree, *Science in the Federal Government*, p. 184; Holden, *Hand-Book of the Lick Observatory*, *passim*.

Edward Emerson Barnard (1857-1923) was on the staff at Lick Observatory for eight years and in 1895 he became an astronomer at Yerkes Observatory. He discovered five satellites of Jupiter and the nebulous ring around Nova Aurigae. While at Lick Observatory he began to photograph the Milky Way.[1]

Edward Charles Pickering (1846-1919) was director of the Harvard Observatory from 1876 to 1919. He was famous for his work in stellar spectroscopy and in stellar photography. In 1891 he established an observation station at arequipa in Peru with the assistance of his brother, William Henry Pickering (1858-1938), an astronomer who had discovered Phoebe, the 9th satellite of Saturn.[2]

Dr. George Ellery Hale (1868-1938) was the organizer and director of the Yerkes Observatory of the University of Chicago. Hale had persuaded Charles T. Yerkes, a wealthy Chicagoan, to donate the funds for a telescope. Hale was also the organizer and director of the Mount Wilson Solar Observatory from 1904 until 1923.

About 1891 Hale invented the spectroheliograph simultaneously with the French astrophysicist, Henri Alexandre Deslandres. Hale did significant research in solar and stellar spectroscopy. He also performed editorial work for *Astronomy and Astrophysics* in the early 1890's and later for the *Astrophysical Journal*.[3]

Observatories.

The Allegheny Observatory of the University of Pittsburgh was founded in 1860. Its principal instrument was a 13-inch Fitz refractor. When Langley was director, it became the leading observatory on matters relating to solar physics. The liberal gifts of William Thaw of Pittsburgh was the source of main support.

Harvard Observatory, which began operations in 1847, had a distinguished history under such directors as William Crouch Bond, George Phillips Bond, Joseph Winlock, and Edward Charles Pickering. Its principal instrument was a 15-inch Merz refractor with which George Phillips Bond discovered a new satellite of Saturn in 1848 and made his extensive studies on Saturn in 1850, on the nebula of Orion, and on the great comet of 1858. When Pickering became director in 1877, he emphasized research in astrophysics.

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[1] *The Lick Observatory* (Berkeley: 12th ed., 1951), p. 20.

[2] Holden, *Hand-Book of the Lick Observatory*, p. 114.

[3] David O. Woodbury, *The Glass Giant of Palomar* (New York, 1944), pp. 7-18.

The Lick Observatory atop Mt. Hamilton was the first research observatory in the Far West. The Lick Trustees provided a 36-inch equatorial refractor, a 12-inch equatorial refractor, and a 6 ½-inch meridan circle instrument. When the University of California acquired the observatory in 1888, it was considered its "crowning possession." For eleven years the 36-inch telescope at Lick Observatory was the largest in the world. Edward E. Barnard discovered the faint fifth satellite of Jupiter in 1892 at the new observatory. An atlas of the moon was prepared by the Lick staff based upon photographs made with its great glass. The astronomers at Lick performed pioneer work in the study of sunspots and double star systems.

The University of Southern California planned a telescope to outdo the Lick Observatory, but the regents could not obtain the money to pay lens-maker Alvan G. Clark of Cambridgeport for the two huge glass disks that he had ordered from an optical firm in Paris. As a result the University of Chicago was able to acquire the lens for a 40-inch telescope at its Yerkes Observatory which opened at Williams Bay, Wisconsin in 1897.

The decision of the Carnegie Institution of Washington, D. C. to build the Mount Wilson Solar Observatory in the San Gabriel Mountains was made upon a recommendation of Samuel P. Langley in 1902. Two years later Dr. George Ellery Hale was appointed director. Its principal instrument at first was a 60-inch reflecting telescope. The observatory staff concentrated upon the study of the sun. The comprehensive studies of sunspots at Mount Wilson resulted in the announcement of a general theory of sunspots. In 1906 John D. Hooker of Los Angeles gave Mount Wilson Observatory the money to acquire a telescope mirror of 100-inch aperture.[1]

Aeronautics.

As related before, when Samuel P. Langley became Secretary of the Smithsonian, he emphasized aeronautics. In 1891 he authored his *Experiments in Aerodynamics*. In 1893 Albert F. Zahm and Octave Chanute organized an international conference at Chicago on aerial navigation. Among the scientists attending were Langley and Robert H. Thurston, director of the Sibley School of Mechanical Engineering at Cornell University. Papers presented at the meeting included those by Dr. Zahm on "Stability of Aeroplanes and Flying Machines," Langley on "The Internal Work of the Wind," and Lawrence Hargrave on "Flying Machine Motors and Cellular Kites."

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[1] Holden, *Hand-Book of the Lick Observatory*, pp. 113-17; William W. Campbell, "A Brief History of Astronomy in California," in Zoeth S. Eldredge, ed., *History of California* (New York, 1915), Vol. V, pp. 231-71; George E. Hale, *Ten Years' Work of a Mountain Observatory: A Brief Account of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington* (Washington, D.C., 1915).

In the early nineties Langley built his *aerodromes*. On October 24, 1894, he launched an *aerodrome* for a flight of about two and a half seconds. On November 28, 1896, *Aerodrome No. 6* flew three-quarters of a mile.

During the Spanish-American War Langley was asked to build a flying machine that could be used in aerial reconnaissance. Langley accepted and engaged Charles M. Manly, an engineer, to build an engine in the shops of the Smithsonian Institution. The completed flying machine, designed to carry a pilot, failed in two trials on October 8 and December 8, 1903. Nine days after Langley's second failure, the Wright brothers succeeded in conquering the air. Although Langley was ridiculed by the press for his failure, he was on the right path and he is considered a pioneer in the theory and construction of heavier-than-air machines.[1]

Among other American pioneers in aeronautics were John Joseph Montgomery and Octave Chanute. As a student at St. Ignatius College (University of San Francisco) Montgomery first studied the problems of flight and earned his bachelor and master of science degrees. In 1883 he studied the flight of gulls in the San Diego area and built his first glider. He made controlled winged flights near Otay. Montgomery's report at the Chicago conference in 1893 impressed Octave Chanute, who also began to experiment with gliders near San Diego. In 1898 Montgomery became a physics professor at Santa Clara College. He continued his experiments with gliders until his fatal mishap on October 31, 1911, near Evergreen in the Santa Clara Valley.[2]

Octave Chanute (1832-1910) in his *Progress in Flying Machines* (1894) brought together much information acquired by both European and American flying machine experimenters. He had also authored *Aerial Navigation* (1891). Chanute designed a number of gliders. His greatest contribution was that he designed movable control surfaces and his gliders had good stability in flight. The Wright brothers later acknowledged the value of Chanute's experiments and designs.[3]

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[1] Jeremiah Milbank, Jr., *The First Century of Flight in America* (Princeton, 1943), pp. 189-92. David C. Cooke, *The Story of Aviation* (New York, 1958), pp. 37-41.

[2] Kenneth M. Johnson, *Aerial California: An Account of Early Flight in Northern & Southern California, 1849 to World War I* (Los Angeles, 1961), pp. 11-20; "John J. Montgomery, Pioneer Airman," *Union Title-Trust Topics* IV (Sept.-Oct., 1950), p. 12

[3] Cooke, *op.cit.*, pp. 30-31.

Modern Physics.

President Daniel Coit Gilman in launching the new Johns Hopkins University in 1875, selected Henry Augustus Rowland (1848-1901) as the first professor of physics upon the recommendation of General Michie of West Point and of Professor James Clark Maxwell of Cambridge University. During a conversation at West Point Gilman became acquainted with Rowland's intellectual powers and unusual aptitude for experimental science. At the time Rowland was an assistant instructor at his alma mater, Rensselaer Polytechnic institute in Troy, New York. Gilman later said that Rowland had told him his dreams for science and that he had told Rowland his dreams for higher education. After Gilman reported the interview to the Johns Hopkins Trustees, they replied: "Engage that young man and take him with you to Europe, where he may follow the leaders in his science and be ready for a professorship."

Thus Rowland began his twenty-six years' career with Johns Hopkins University. He invented concave gratings used in observing the solar spectrum. In 1879 he made an accurate determination of the mechanical equivalent of heat. In 1888 he completed a large *Photographic Map of the Solar Spectrum*. He prepared a table of solar spectrum wave-lengths which appeared in the *Astrophysical Journal* in 1895-97. Rowland also discovered the magnetic effect of electric convection, and he investigated alternating currents.[1]

Albert Abraham Michelson (1852-1931), the first American scientist to receive a Nobel Prize, was born on December 19, 1852, in the Polish town of Strelno in German territory. In 1854 the Michelsons moved from Poland to New York City. In 1856 Michelson's father opened a dry-goods store at Murphy's in Calaveras County, California. When Albert Michelson was thirteen, he was sent to San Francisco to attend Boys High School. He lived in the home of the school's scholarly principal, Theodore Bradley. The school's curriculum stressed mathematics, natural sciences, and languages. Principal Bradley encouraged Michelson's scientific interests, and put him in charge of the scientific apparatus at the school then located on Powell Street.

After his graduation in 1869 from Boys High School, Michelson returned to his home which was now located in Virginia City, Nevada. Michelson decided to apply for an appointment to the Naval Academy at Annapolis. On June 10, 1869, he passed a written examination, but failed to win an appointment. Armed with letters from his Congressman and from Theodore Bradley, young Michelson decided to appeal directly to President Grant. He journeyed to Washington by the new transcontinental railroad. Michelson's personal plea with President Grant on the White House steps assisted him in

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[1] Fabian Franklin, *The Life of Daniel Coit Gilman* (New York, 1910), pp. 197-99; Florian Cajori, *A History of Physics* (New York: Dover edition, 1962), pp. 177-78, 205, 221, 263-64, 268, 325, 328.

winning the appointment to Annapolis.

Following his graduation and two years of duty at sea, Ensign Michelson was appointed instructor of physics and chemistry at the Naval Academy. He began to experiment with the measurement of the speed of light. In 1879 he attended the St. Louis meeting of the American Association for the Advancement of Science and presented a paper entitled, "Experimental Determination of the Velocity of Light," which appeared in the April 1879 issue of the American Journal of Science. Simon Newcomb, the retiring president of the American Association for the Advancement of Science, was greatly impressed by Michelson's experiments and supported further experiments. Newcomb was able to get Michelson transferred to the Nautical Almanac Office. However, Michelson shortly left Newcomb and took leave from the Navy for further training in German and French universities. When Michelson completed his European training, he endeavored to obtain a professorship of mathematics at the Naval Academy. When he failed in this attempt, he resigned his commission in the Navy on September 30, 1881. Almost immediately Michelson was appointed professor of physics at the Case School of Applied Science in Cleveland and given a leave for the academic year 1881-82 to continue his research in Europe.

In 1889 Michelson resigned from the Case School and became a professor at Clark University in Worcester, Massachusetts. While there the Royal Society of London awarded him its Rumford Medal. Because of a conflict over money with President G. Stanley Hall of Clark University, Michelson accepted the offer of President William R. Harper to head the department of physics at the new University of Chicago. Here he carried out research projects in his effort to make Chicago a center of spectroscopic activity. Michelson's fame grew and he was awarded many honorary degrees. He received a degree from the University of Paris in 1895 and the scarlet robe of Cambridge University in 1899. Both Michelson and Mark Twain--two Calaveras County celebrities--were bestowed honorary doctors of law degrees at Yale University in 1901. From 1901 to 1903 Michelson served as president of the American Physical Society, and in 1923 he was elected president of the National Academy of Sciences.

Michelson's entire life was concerned with the problem of the speed of light. He was the first to determine the speed of light. He invented several scientifically valuable optical instruments. For example, he invented an improved interferometer for measuring distances by means of the length of light waves. As mentioned earlier, he performed the famous ether-drift experiment with Morley in 1887. This experiment demonstrated that the absolute motion of the earth through ether is not measurable. Michelson's revelations in physics became a starting point in the development of the theory of relativity.

The significance of Michelson's great scientific work was realized in his life time. In 1907 he was awarded the Nobel Price for Physics, receiving it for his experiments in measuring the speed of light. Thirteen years after his death the Michelson Laboratory of the United States Naval Ordnance Test Station at China Lake, California was named in his honor.[1]

Michael Idvorsky Pupin (1858-1935), professor of electro-mechanics at Columbia University from 1901 to 1931, was born in Yugoslavia and came to the United States in 1874. He was both a scientist and inventor. He did research in theoretical science and utilized the results on practical problems. His inventions are discussed in the history of inventions section, but his major writings are mentioned here. In 1895 he authored Electro-Magnetic Theory and in 1923 he wrote his autobiography entitled, From Immigrant to Inventor, which won the 1924 Pulitzer Prize for Biography or Autobiography.[2]

Robert Andrews Millikan was born in Morrison, Illinois in 1868. He taught at the University of Chicago from 1896 to 1921. In 1921 he became director of the Norman Bridge Laboratory of Physics at the California Institute of Technology. Millikan was credited with being the first to isolate the electron and to measure its charge. Most of his writings appeared after 1913, and are beyond the scope of this study; however, it should be mentioned that he received the Nobel Prize in Physics in 1923. Millikan was the second American to be so honored, Michelson being the first.[3]

Medicine.

American medicine made tremendous strides in the Industrial Age. In 1869 President Charles W. Eliot of Harvard University initiated reforms in the medical school. Pennsylvania, Columbia, and other older universities did likewise. Johns Hopkins University began instruction in medicine in 1886 and opened a medical school in 1893. Its medical faculty under the brilliant leadership of Dr. William Henry Welch attracted able students throughout the nation.

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[1] Bernard Jaffe, Michelson and the Speed of Light (Garden City: Doubleday Anchor Original, 1960); Cajori, A History of Physics, pp 150, 174-78, 199, 322-25; Archibald J. Cloud, Lowell High School, San Francisco, 1856-1956 (Palo Alto, 1956), pp 17-18.

[2] Michael Pupin, From Immigrant to Inventor (New York: New Edition, 1925).

[3] Cajori, A History of Physics, pp. 329-31, 335, 340, 354, 368-69, 371; Robert A. Millikan, Autobiography (New York, 1950; R. A. Millikan, "The Last Fifteen Years of Physics," Proceedings of the American Philosophical Society LXV (1926) pp. 68-78.

The American Medical Association had been founded as early as 1847, but it did not have a scientific journal until 1883. In 1890 the Association of American Medical Colleges was founded. In cooperation with this new organization and the state medical licensing boards, the American Medical Association reformed medical education. In 1885 the Association of American Physicians was organized, and in 1901 the American Association of Pathologists and Bacteriologists was organized.

One result of the many American medical discoveries of this period was the eradication of yellow fever. Dr. Walter Reed (1851-1902), an Army surgeon, in 1900 headed a commission, including James Carroll, Jesse W. Lazear, and Aristides Agramonte, which investigated the transmission of yellow fever. Dr. Carlos Finlay of Havana had recognized that the Aedes Aegypti mosquito could transmit the disease from yellow fever patients to non-immune persons. By controlled experiments the commission proved Finlay's views. Unfortunately, Lazear died from the bite of an infected mosquito, and Carroll acquired the disease in non-fatal form. The researches of these medical heroes improved sanitation in the tropics.

Dr. William Crawford Gorgas (1854-1920) as chief sanitary officer freed Havana from the scourge of yellow fever at the turn of the century. Acting as chief sanitary officer for the Panama Canal Commission, from 1904 until 1913, he eradicated yellow fever at Panama, and made the building of the canal possible.

The work of Dr. Howard Taylor Ricketts (1871-1910) serves as an example of how the discovery of a civilian pathologist aided public health. Following his studies in dermatological pathology and blastomycosis at the University of Chicago, Ricketts proved the theory that wood ticks transmitted Rocky Mountain spotted fever. He also discovered that body lice transmit typhus. Unfortunately, he died from typhus fever while investigating it in Mexico with Russell M. Wilder.

The American Public Health Association was established in 1872, with Dr. Stephen Smith being elected as its first president. Only Massachusetts, California, Virginia, and the District of Columbia had established boards of health prior to 1872. The new organization performed important work in encouraging the state governments to develop public health standards. Members of the Association carried on significant researches in bacteriology with its practical applications to public health.[1]

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[1] Francis R. Packard, The History of Medicine in the United States (2 vols., New York, 1931); Esmond R. Long, A History of American Pathology (Springfield, 1962); Mazyck P. Ravenel, ed., A Half Century of Public Health (New York, 1921).

Advances in other sciences.

Thomas Hunt Morgan, the eminent American zoologist, was born in Lexington, Kentudy in 1866. He was a professor at Columbia University from 1904 to 1928, and then became director of the Kerckhoff Laboratories of Biological Sciences at the California Institute of Technology. In 1933 he was awarded the Nobel Prize in physiology and medicine. He discovered many of the mechanisims involved in heredity. He experimented in the new field of genetics, demonstrating that physical characteristics were transmitted by "genes." His research brought about modifications in the theory of evolution. Among his early publications were Regeneration (1901), Evolution and Adaptation (1903), Experimental Zoology (1907), and Heredity and Sex (1913).[1]

Herbert McLean Evans, the anatomist and embryologist, graduated from the University of California and then did graduate work at Johns Hopkins University. In 1909 he demonstrated the origin of the vascular trunk from capillaries. He became a professor at the University of California where he performed significant research which is beyond the chronological scope of this historical survey.[2]

George Washington Carver (c. 1864-1943), the negro botanist, chemist, and agronomist, was born of slave parents in Missouri during the Civil War. He earned his bachelor and master degrees of science at Iowa State University. He had a brilliant research career at Tuskegee Institution in Alabama where he was director of the Department of agricultural research. He applied science to agricultural practices. He was particularly successful with his peanut experiments which resulted in many edible and industrial uses. He also developed new uses for the sweet potato and for the pecan. Carver's scientific work was important in giving the Southern farmers the planters crops that they could sell profitably.[3]

Role of the federal government.

While science declined in the military services after the Civil War, scientific research in the Department of Agriculture and in the Department of Interior developed. In 1879 the United States Geological Survey was formed as a permanent bureau within the Department of Interior. Clarence King was the first director and he was succeeded by John Wesley Powell in 1881. Powell made the survey national in scope and hired a large number of scientists. Although Powell expected practical results from government science, he did not neglect basic research. As related earlier, he hired Othniel C. Marsh as Chief of Paleonotology. While the main work was concerned with preparing a

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[1] Jaffe, Men of Science in America, pp. 383-427.

[2] Ibid., pp. 428-66.

[3] Oliver, History of American Technology, p. 553; Dies, Titans of the Soil, pp. 180-81.

topographic map and a geologic map, Powell also organized a chemical laboratory in Washington. In 1892 the appropriation for the geological survey was cut and work was restricted to topography.

In 1871 Spencer F. Baird was appointed first Fish Commissioner, serving without salary. He trained university students such as C. Hart Merriam and George Brown Goode, who became important zoologists. The marine biology station was established at Wood's Hole in Massachusetts. In 1903 the Fish Commission became the Bureau of Fisheries in the Department of Commerce.

In the early eighties an economic ornithology section was established within the Division of Entomology of the Department of Agriculture. In 1886 it became the Division of Economic Ornithology and Mammalogy with C. Hart Merriam (1855-1942) as its head. In 1896 it was renamed the Division of Biological Survey. It carried on a research program in natural history.

Scientific interest in forest protection was urged by Dr. Franklin B. Hough at the American Association for the Advancement of Science meeting in 1873. In the next decade forestry work became a division of the Department of Agriculture under Bernhard E. Fernow. Charles Sprague Sargent, the famous American arboriculturist, made his significant "Report on the Forests of North America" for the census of 1880. Hough, Fernow, and Sargent were pioneers in the conservation movement and performed important scientific work in laying the foundation for an expanded role by the federal government.

Significant landmarks in the federal scientific establishment were creation of the National Bureau of Standards in 1901 and the Bureau of Mines in 1910. Both of these bureaus engaged in applied research for governmental and private agencies.

In 1883 the Department of Agriculture established a Veterinary Division under Daniel Elmer Salmon (1850-1914). The next year Congress provided for a Bureau of Animal Husbandry, and Salmon served as its chief from 1884 to 1905. He started a meat inspection system and devised methods to suppress the contagious diseases of cattle. Dr. Theobald Smith while working for the Bureau discovered the organism causing Texas fever; he demonstrated that it was transmitted by a cattle tick. In 1893 the Bureau's final report on Texas fever appeared, and it indicated that government science had made an important discovery.

The passage of the Hatch Act in 1887 provided for the establishment of agricultural experimental stations in all states. This law was second only to the Morrill Act in importance in fostering scientific agriculture.[1]

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[1] Dupree, Science in the Federal Government, pp. 149-83, 195-270; Ravenel, A Half Century of Public Health, pp. 414-19.

From 1883 to 1912, Dr. Harvey Washington Wiley (1844-1930), who had been a professor of chemistry at Purdue University and State Chemist of Indiana, headed the Bureau of Chemistry of the Department of Agriculture. He led the campaign against food adulteration and assisted in winning enactment of the Pure Food and Drug Act of 1906. He also studied the beet sugar problem. As an apostle of pure food Wiley won many honors. He was elected president of the American Chemical Society, and he presided over the first world congress of chemists meeting at Chicago in 1892. From 1899 to 1914 he was also a professor of agricultural chemistry at George Washington University. His major publication was three-volume work entitled, _Principles and Practice of Agricultural Analysis_ (1894-97).[1]

Exploring expeditions.

The Navy had nothing comparable to the Wilkes Expedition in this period. In 1869 the Bureau of Navigation dispatched several expeditions to examine an isthmian canal route.[2] Naval officers operated the steamer _Albatross_ in its research in marine biology for Spencer F. Baird, the Commissioner of Fish and Fisheries. Zera L. Tanner served as captain and Seaton Schroeder served as executive officer and navigator.[3]

In 1881 Lieutenant Adolphus W. Greely commanded an Army expedition to Lady Franklin Bay to establish a station for scientific observations and for geographical discovery. In the spring of 1882 James B. Lockwood with a small detachment explored the northeastern coast of Greenland in latitude 83° 24' N. A relief vessel failed in two attempts to reach the expedition. The detachment then abandoned its ship and retreated southwards in boats. Lockwood died at Cape Sabine, and when relief arrived in June 1884, only seven men had survived out of Lockwood's party of twenty-four.[4] More successful was the Arctic expedition under Lieutenant P. Henry Ray of the Signal Service which erected a meteorological and astronomical observatory at Point Barrow in 1881. In the field of exploration Army expeditions in the interior of Alaska were made in the period 1883 to 1885.[5]

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[1] Dies, _Titans of the Soil_, pp. 152-58.

[2] Dupree, _Science in the Federal Government_, p. 186.

[3] Seaton Schroeder, _A Half Century of Naval Service_ (New York, 1922), pp. 159-70.

[4] Percy Sykes, _A History of Exploration_ (New York: Harper Torchbook edition, 1961), pp. 320-21.

[5] Benjamin F. Gilbert, "Arts and Sciences in Alaska: 1784-1910." _Journal of the West_ I (Oct., 1962), p. 146.

Science in the Far West

The first scientific society on the Pacific Coast, the California Academy of Sciences, was established at San Francisco in 1853. In 1859 several residents of San Francisco formed the Pacific Observatory Association, but their proposal to erect an observatory was not realized.[1] The great developments in California in the field of astronomy have already been described elsewhere in this chapter. In 1870 the San Francisco Microscopical Society was organized by members of the California Academy of Sciences. In 1881 the Geographical Society of the Pacific was established at San Francisco with George Davidson serving as its president for thirty years. In its *Transactions and Proceedings* articles on geographical and scientific subjects were published.

Several Southern California cities organized natural history societies beginning in the 1870's. The San Diego Society of Natural History published the *West American Scientist* from 1884 to 1919. In 1896 the Southern California Academy of Sciences was organized at Los Angeles.[2]

Geological surveys were first made in California in the early fifties. In 1860 Josiah Dwight Whitney was made State Geologist and his survey lasted until 1874. The Whitney survey accumulated much scientific data and acted as a training school for several scientists such as William H. Brewer and Clarence King who were to gain national recognition. In 1876 the California State Geological Society was organized at San Francisco. Four years later it evolved into the State Mining Bureau and exists today as the Division of Mines and Geology. Several California geologists such as Joseph Le Conte and Andrew C. Lawson became nationally prominent through their scholarly writings.[3]

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[1] Benjamin F. Gilbert and Edward J. Farrell, "Cultural Beginnings of San Francisco," *San Francisco Quarterly* XV (Spring, 1949), pp. 6-7; Robert C. Miller, "The California Academy of Sciences and the Early History of Science in the West," *California Historical Society Quarterly*, XXI (Dec., 1942), pp. 363-71.

[2] Henry W. Splitter, "The Development of Science in Los Angeles and the Southern California Area (1850-1900)," *Quarterly of the Historical Society of Southern California*, XXXVIII (1956), pp. 90-140.

[3] Frank M. Anderson, "Pioneers in the Geology of California," in Solon Shedd, *Bibliography of the Geology and Mineral Resources of California* (Sacramento, 1933), pp. 1-24.

Besides the scientific and medical societies and the geological survey, California schools and colleges encouraged scientific studies When the California State Normal School was located at San Francisco, Dr Henry Gibbons, an eminent local physician, lectured on botany. After the school moved to San Jose in 1871, Henry B. Norton, George Kleeberger, and Volney Rattan were among the early instructors in science. Rattan had authored a botany manual entitled, A Popular California Flora.[1]

In 1868 the newly chartered University of California engaged the Le Conte brothers to assist in laying a strong foundation for science instruction. John Le Conte taught physics and Joseph Le Conte taught geology. John C. Merriam, the first graduate student, was attracted to the University of California by the writings of Joseph Le Conte. Merriam later became a noted paleontologist and president of the Carnegie Institution.[2]

Stanford University during its first year of existence in 1891 established the Hopkins Marine Biological Laboratory at Pacific Grove. Eastern and European scientists made studies there and the results were published in scientific journals. Among the early science teachers hired at Stanford were John C. Branner in geology, Charles Henry Gilbert in vertebrate zoology, and John M. Stillman in chemistry.[3]

The California landscape attracted many field naturalists For example, Dr James Cooper studied the fauna and ornithology of California for over forty years Jántos Xántus, a Hungarian naturalist, collected specimens for the Smithsonian Institution during his Army service at Fort Tejon from 1857 to 1859 Later as a tide observer with the Coast Survey at Cape San Lucas in Lower California and then as United States Consul at Manzanillo, Xantus again sent specimens to the Smithsonian.[4]

John Muir explored Yosemite beginning in 1868, and was to devise a controversial hypothesis concerning the valley's origin in glacial erosion. Muir studied the wildlife, mountains, and valleys of California and the glaciers of Alaska. Muir was the author of books and magazine articles and a founder of the Sierra Club His first book, The Mountains of California (1894), had a wide distribution While Muir was not an exact scientist, he was a great lover of nature who preached conservation at an opportune time.

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[1] Benjamin F. Gilbert, Pioneers For One Hundred Years, San Jose State College, 1857-1957 (San Jose, 1957), p. 205.

[2] William W. Ferrier, Origin and Development of the University of California (Berkeley, 1930), pp. 531-35.

[3] Orrin L. Elliott, Stanford University, The First Twenty-Five Years (Stanford University Press, 1937), pp. 52-59, 107-08.

[4] Henry M. Madden, Xántus, Hungarian Naturalist in the Pioneer West (Palo Alto, 1949).

Edward Palmer (1831-1911), the plant explorer of the West, collected archaeological, ethnological, and zoological specimens. He was a scientific explorer who helped to make known the flora and fauna of the Far West.[1]

David Starr Jordan (1851-1931), an eminent biologist and educator, was one of the best known scientists in the West. A graduate of Indiana Medical College, he taught in three universities before he became president of Stanford University in 1891. Jordan made his greatest contribution to science as an ichthyologist. He studied the fishes of the rivers of the Middle West and the South and in the waters of the Pacific Coast from San Diego to Seattle. His publications on ichthyology were numerous and of scientific value. For example, he authored with Barton W. Evermann, *The Fishes of North and Middle America* (1896-1900).[2]

Luther Burbank (1849-1926) as a young truck gardener in Massachusetts was influenced by his reading of Darwin's *Variation of Animals and Plants Under Domestication*. He developed the Burbank potato. In 1875 he moved to Santa Rosa, California where he established a nursery and gardens. He experimented with plants and tested Darwinian theories. He improved old varieties, combined wild types with degenerated cultivated types, and developed new forms of plant life.[3]

Although Burbank the horticulturalist was called a scientist by David Starr Jordan and others, his methods were actually more like those of an artist. His methods were not entirely original, but he increased the economic values of plant life.

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[1] Rogers McVaugh, *Edward Palmer, Plant Explorer of the American West* (Norman, 1956).

[2] Rockwell D. Hunt, *California's Stately Hall of Fame* (Stockton, 1950), pp. 429-34.

[3] Among the biographies of Burbank are Walter L. Howard, *Luther Burbank: A Victim of Hero Worship* (Waltham, 1946) and Henry S. Williams, *Luther Burbank: His Life and Work* (New York, 1915); also see David Starr Jordan and Vernon L. Kellogg, *The Scientific Aspects of Luther Burbank's Work* (San Francisco, 1909).

PART I (Continued)

A HISTORY OF INVENTIONS

VII COLONIAL PERIOD, 1600-1775

Transmission of European tools and technology

The first settlers of Virginia quickly realized that successful colonization depended upon the transplanting of skills, tools, and technologies to the New World. In an effort to save the Jamestown settlement Captain John Smith in 1609 urged officials of the London Company to send him 30 carpenters, husbandmen, blacksmiths, and masons, rather than a thousand additional people similar to the gentlemen already in Virginia. The original folly of adventurers searching for treasure ceased, and the company began to ship skilled artisans with tools, implements, and utensils. Once the Jamestown settlers began to produce pitch, tar, clapboards, pearlash, and tobacco the survival of the colony was made possible. Among the Pilgrims settling at Plymouth were many skilled husbandmen and artisans who brought tools and techniques from England and Holland. The later colonists were also skilled artisans. For example, William Penn in advertising for emigrants sought industrious husbandmen and mechanics.[1]

The existence of abundant raw materials in colonial America encouraged crude manufactures. Forest resources enabled the colonists to engage in lumbering, shipbuilding, the manufacture of naval stores, and the making of potash. A plentiful supply of wood fuel permitted them to make iron, glass, brick, and pottery. Mineral resources, particularly iron ore, were also available.[2]

Colonial craftsmen.

Although the colonial economy was primarily agricultural, craftsmen played a significant role in American development. In the seventeenth century American craftsmen and husbandmen had to struggle in the wilderness to make a living. Under the rural and frontier conditions most immigrants became farmers Crafts actually did not flourish in colonial America until the eighteenth century when the population began to double every twenty years As a greater urban economy evolved the demand for the products of craftsmen increased After 1763 the English colonists sought more and more to foster home industry and to become self-sufficient.

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[1] Oliver, History of American Technology, pp. 1-11.

[2] Victor S Clark, History of Manufactures in the United States (New York, 1929), Vol. I, pp. 73-86

In the seventeenth century household manufacturing was more important in America than commercialized industry. A labor shortage, the lack of capital, poor transportation, and the small market were among the factors that at first hindered the growth of industrial enterprises. In general colonial industries were small and simply converted raw materials into crude products.[1]

Agricultural implements.

In colonial America where land was plentiful and labor was scarce the farmer was not concerned with soil conservation, but he was anxious to adopt labor-saving devices. The colonial farmer improved the axe, the plow, and the harrow. He usually substituted the cradle for the hand scythe to cut grain.[2]

In the late colonial period Jared Eliot of Connecticut, who was both a practical and scientific agriculturalist, experimented with a seed drill in an attempt to simplify and improve the one perfected by the English agriculturalist, Jethro Tull. With the assistance of President Thomas Clap of Yale College and of Benoni Hylliard, a master wheelwright, Eliot invented a plow and drill which was capable of opening furrows, dropping seeds and fertilizer, and covering them in one operation. After Eliot's death, Benjamin Gale improved the machine.[3]

Clothing and leather industries.

In the beginning the colonists depended upon England for clothing. After sheep were introduced into the colonies, the production of clothing began. Indians and trappers supplied colonial settlers with doe and buck skins and hides were imported from the Spanish West Indies making a leather industry possible. Also linen production developed.

In 1638 five weavers arrived at Rowley, Massachusetts. Here the first cloth was manufactured in English America. By 1700 cloth manufacturing existed in most colonies, but it was mostly manufactured by the family in the household unit.[4]

Thomas Beard, a shoemaker, was a passenger aboard the Mayflower, and he became pioneer of the American boot and shoe trade. In 1616 shoemakers and tanners were plying their trades in Virginia, as well as cultivating the ground.

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[1] Carl Bridenbaugh, The Colonial Craftsman (Chicago: University of Chicago Press, First Phoenix Edition, 1961), passim.

[2] Oliver, History of American Technology, p. 23.

[3] Bridenbaugh, Colonial Craftsman, pp. 50-51; Herbert Thoms, The Doctors of Yale College, 1707-1815 (Hamden, Conn., 1910), p. 13.

[4] Oliver, History of American Technology, pp. 37-48. Efforts were made to introduce the silk industry at Jamestown in 1607 and the linen industry in 1612.

In 1636 Philip Kertland began the manufacture of shoes at Lynn, Massachusetts. In 1750 John A. Dagyr established a shoe shop at Lynn. Hiring skilled craftsmen to specialize on specific operations, he started a factory system on a small scale.[1]

Transportation and communication.

Small craft were built in Virginia as early as 1611. Rowboats and shallops were constructed by the colonists for coastal travel The first major shipbuilding was begun in New England in 1629. On July 4, 1631, the thirty-ton sloop, *The Blessing of the Bay*, was built for Governor John Winthrop. By 1670 Massachusetts had produced 730 vessels. In the seventeenth century the main shipbuilding centers were at Boston, Charleston, Salem, and Scituate In 1690 a naval vessel, the Falkland, was constructed for the Royal Navy at Portsmouth, New Hampshire. This warship was built by colonial shipwrights under contract in a private shipyard.

Pennsylvania was another center of colonial shipbuilding. By the time of the American Revolution shipbuilding was a major industry in Philadelphia Certain technological advances were made in American shipyards For example, in 1713 Andrew Robinson devised a "schooner" that rode the water's surface; its speed and maneuverability presaged the later development of the clipper ship In the eighteenth century shipbuilders in England were alarmed by American competition

On the river highways of America the colonists traveled in canoes, flatboats, and ferries Land travel in Colonial America was primitive Roads were poor and bridges were few, but the colonists developed some vehicles. After 1700 the American sedan and the gig were devised The Conestoga wagon was manufactured in the Conestoga Valley of Lancaster County, Pennsylvania. It could transport two to four tons of freight with safety over the hills of Pennsylvania. After 1750 stagecoach lines were in operation between Boston and New York and between New York and Philadelphia.[2]

Iron and steel products.

At an early date iron ore was discovered in the peat bogs and ponds of eastern Massachusetts. John Winthrop, Jr., organized the "Company of Undertakers for the Iron-Works" in London in 1641. This group erected an iron foundry and forge at Saugua, Massachusetts in 1641.

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[1] Oliver, *History of American Technology*, pp. 37-48; George Houghton, "How the American Shoe Has Become Standard," in *The Making of America* edited by Robert M. La Follette, Vol. VII (*Science and Invention*), hereinafter cited as *Science and Invention* edited by La Follette, p 376

[2] Oliver, *History of American Technology*, pp. 49-60; Howard I Chapelle, *The History of the American Sailing Navy* (New York, 1949, pp. 3-51.

After obtaining iron ore deposits, Joseph Jenks, a metalworker and mechanic, produced some iron by using sea shells and corals for flux and by using charcoal as fuel. Jenks and other mechanics produced hinges, horseshoes, pots, and pans for Bostonians. In 1654 Boston engaged Jenks to build "an Ingine to carry water in case of fire." Even prior to the Saugus foundry, an iron foundry had been established at Falling Creek, Virginia, in 1620-1622.

By 1710 iron manufacturers in the mother country were complaining of competition from the colonies. By 1750 furnaces, forges, and mills were operating in New England, the Middle Colonies, Maryland, and Virginia. A few steel products were also produced in the colonies.[1]

Glassmaking

Glassmaking was the first industry in English America. As early as 1608 German and Polish craftsmen in Virginia made glass, pitch, tar, and soapashes. In 1639 a glassworks was established at Salem, Massachusetts. It was subsidized by the General Court. Caspar Wistar, a German emigrant, was the successful pioneer glass manufacturer in colonial America. He established his plant in Salem County, West Jersey in 1738, manufacturing bottles, table crystal, and window glass. Since glass was a luxury in colonial times, its manufacture was not extensive.[2]

Patents.

Although manufactures were not highly developed and inventions were few in Colonial America, bounties, subsidies, and monopolies were, nonetheless, granted to skilled craftsmen at various times. These beneficial measures encouraged both old skills and new inventions. Moreover, a degree of patent protection also developed in the colonies. What was probably the first patent was granted to Joseph Jenks by the Massachusetts General Court. On May 6, 1646, he obtained a fourteen-year monopoly for improved sawmills and scythes. By 1695 Jenks had developed a new type of scythe. He made the blade of the heavy English scythe longer and thinner, and he strengthened it by welding an iron bar along its back.

Generally colonial patents were for processes rather than for machines. However, Rowland Houghton of Boston was granted a seven-year patent in 1735 for a theodolite. During the last century of the colonial period only South Carolina granted patent protection for new machinery. In 1691 South Carolina enacted what was probably the first general patent law in America, "for the better encouragement of the making of engines for the propagating the staples of this colony."

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[1] Oliver, pp. 66-73; Dirk J. Struik, *Yankee Science in the Making* (Boston, 1948), pp. 10-11.

[2] Oliver, *History of American Technology*, pp. 74-75.

In 1732 and 1733 South Carolina by special acts granted patent rights to three inventors of rice-cleaning machines [1]

VIII AMERICAN REVOLUTION ERA, 1776-1789

War industries

Despite its lack of governmental power the Continental Congress initiated herculean efforts to meet the demands of war Even before the Revolution the Continental Congress had encouraged development of manufactures after passing the nonimportation agreements When actual hostilities broke out in 1775, the colonies possessed sufficient iron to meet military requirements A line of forges already existed from New Hampshire to South Carolina To insure an adequate supply of war materials Congress and colonial legislatures offered awards for producing iron woolen goods, potash, and firearms Workers employed at furnaces and forges were exempted from military service

The Connecticut Council of Safety requisitioned the Lakeville furnace owned by a Tory and prepared it to cast cannon and ammunition Guns for New York forts were produced at this furnace The Pennsylvania and New Jersey furnaces were called upon to manufacture war supplies in 1775 and 1776 because of their proximity to the major scene of military operations Hence the Durham Iron Works in Pennsylvania cast cannon and the Cornwallis furnace in Lancaster County, Pennsylvania cast shot and shells [2]

Between 1776 and 1782 ordnance plants were also established at Philadelphia at Yellow Springs Pennsylvania Springfield Massachusetts and Fredericksburg Virginia Colonial gunsmiths had made excellent rifles several decades before the outbreak of the Revolution About 1750 the so-called "Pennsylvania rifle" had been designed Its long barrel and rifled bore created a weapon of great velocity and accuracy

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[1] Oliver History of American Technology, p. 67; Cyrus N Anderson "The United States Patent Laws" in Science and Invention edited by La Follette pp 380-81; Clark History of Manufactures in the United States Vol I pp 47-53

[2] Oliver History of American Technology, pp. 91-93

and it was used effectively at long range against the British Red Coats Colonial riflemen engaged in sniping and guerrilla warfare wore down British morale.[1]

The colonial soldiers faced a serious shortage of gunpowder Following Lexington and Concord all available gunpowder was seized and measures were taken to encourage more production. Powder mills were built in the vicinity of Philadelphia and Lancaster, Pennsylvania Five years after the defeat of Cornwallis, Pennsylvania had twenty-one powder mills The explosives industry continued to flourish in America after the war

At Bunker Hill the Massachusetts troops suffered from a lack of gunpowder. With the assistance of Paul Revere, who had studied mill techniques in Philadelphia, Massachusetts authorities were able to erect a powder mill at Canton which supplied powder for the Massachusetts troops.[2]

During the war General George Washington pointed out the need for trained engineers. Four skilled French engineers served on Washington's staff and they assisted in building fortifications at Valley Forge and Yorktown. Thaddeus Kosciusko, the Polish patriot, was appointed colonel of engineers in the Continental Army, and he was put in charge of building fortifications at West Point in 1778 to 1780. David Rittenhouse was one of the few Americans with engineering experience. As a member of the Pennsylvania Committee of Public Safety he experimented on improving ammunition intended for use in rifled cannon and muskets. After the Revolutionary War ended, efforts were made to found a West Point Academy. A school was established in 1794 to train engineers, of which there was a great shortage in America, but the institution was destroyed by fire in 1796, and the academy at West Point was not reestablished until 1802.[3]

Among the inventions made during the American Revolution to counteract the superiority of British naval power was a unique iron chain constructed to stretch across the Hudson River at West Point. Peter Townsend, master of the Sterling Iron Works, forged a chain 500 yards in length. Completed in April 1778, it weighed 180 tons, had 750 links, and was held in place by twelve tons of anchors. The chain was intended to prevent the British from gaining control of the entire river by blocking the river. In this task the chain was a failure.[4]

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[1] Roger Burlingame, March of the Iron Men (New York: The Universal Library edition, c. 1960), pp. 119-34.

[2] Oliver, History of American Technology, pp. 96-97; Clark, History of Manufactures in the U.S., Vol. I, p. 222.

[3] Oliver, History of American Technology, pp. 98-99.

[4] Burlingame, March of the Iron Men, pp. 144-46.

David Bushnell (1742?-1824), an officer in the Continental Army, invented a submarine boat, the predecessor of the modern submarine. Applying the theory of the propelling screw, which had been conceived by the Swiss mathematician Daniel Bernoulli, Bushnell constructed a wooden craft capable of submerging when weighted with lead. The Turtle was a one-man submarine driven by a crank which turned a screw propeller. The vessel traveled at a speed of three miles per hour. One oar moved the boat horizontally and another moved it vertically. It had a small conning tower for the operator's head and had windows. Two automatic ventilating tubes enabled the operator to submerge for a thirty minute interval.

The weird craft also contained a device to attach a mine or torpedo to the hull of an enemy vessel. The mine containing over 100 pounds of powder was attached near the stern of the craft by a screw. The mine was a timed bomb with a gunlock and a clock. One August night in 1776 the Turtle piloted by Sergeant Ezra Lee tried to attach its lethal charge to the hull of the 64-gun H.M.S. Eagle, flagship of Admiral Howe, in New York harbor. Lee maneuvered the Turtle against the side of the Eagle, but he was unable to attach the egg-shaped bomb to the warship's wooden hull which was protected by a copper sheathing. Lee was compelled to surface; he released his mine and it exploded in the East River.

The submarine experiment failed as a weapon of warfare, but its principle had been demonstrated. Although the government refused to give additional support to Bushnell's submarine invention, the next year he succeeded with two experiments in mine warfare.[1]

Wool processing and spinning.

In October 1776 the Continental Congress offered a clothing bounty to men willing to enlist for the duration of the war. Until 1777 clothing supplies were either largely procured from imports or from prize goods of privateers. In March of that year James Mease was appointed Clothier-General and was instructed to develop a sound clothing supply system.[2]

To meet the demand for uniforms certain improvements were made in wool processing. The war had cut off the supply of hand cards and

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[1] Ibid., pp. 146-48; Oliver, History of American Technology, pp. 100-101; E.P. Potter and J.R. Fredland, eds., The United States and World Sea Power (Englewood Cliffs, 1955), pp. 256-57; Bernard and Fawn Brodie, From Crossbow to H-Bomb (New York: A Laurel Science Original, 1962), p. 116.

[2] For an account of the Continental Army uniform see John C. Fitzpatrick, The Spirit of the Revolution (Boston, 1924), pp. 117-38.

Americans had to produce their own. Carding was done by hand and usually by the hands of women and children. A young Delaware inventor, Oliver Evans (1755-1819), invented a machine which cut and bent the teeth. Later he introduced a device which inserted the bent teeth in a leather frame. Evans's card-making machine was a remarkable improvement in carding.[1]

Another wartime improvement in clothing manufacturing was made by Christopher Tulley, who made improvements on a spinning machine. His invention enabled a single operator to spin twenty-four threads of cotton or wool at one time.[2]

IX EARLY REPUBLIC, 1790-1829

Franklin, Washington, and Jefferson as inventors.

Benjamin Franklin died on April 17, 1790, shortly after the launching of the new Republic which he had helped to create. As the greatest American colonial scientist and inventor he had bequeathed the young Republic a technological tradition. His theories had assisted in opening the electrical age and his utilitarian approach towards inventions had produced such practical device as the Franklin stove and bifocals.

In 1742 Franklin invented the "Pennsylvania fireplace' which retained heat that was formerly wasted by going directly up the chimney. When offered a patent for this invention, he refused it. Franklin's attitude was that his invention should be a gift to the world. He expressed himself thusly in his autobiography: "That as we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours; and this we should do freely and generously." Just before his death Franklin expressed his pleasure concerning rapid progress of inventions.[3]

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[1] Burlingame, March of the Iron Men, pp. 139-42.

[2] Oliver, History of American Technology, p. 101.

[3] For Franklin's other inventions see Roger Burlingame, Benjamin Franklin, The First Mr. American (New York: Signet Key Book, 1955), pp. 87-97.

George Washington's chief scientific interest centered in agriculture. He frequently attempted to design farm implements. For example, he designed an automatic seeder. As president he constantly encouraged scientific pursuits and inventions.[1]

Among the founding fathers Thomas Jefferson probably possessed the greatest faith in the ultimate benefit to the general welfare of advances in science and technology. While on his diplomatic mission to France, Jefferson studied mechanical inventions in Europe. After observing the clumsy plow used by French peasants, Jefferson conceived a moldboard based on mathematical principles in 1788. Jefferson's diagrammatic explanation of his moldboard was published in the Transactions of the American Philosophical Society. In recognition of his invention the French Academy of Agriculture awarded Jefferson a gold medal in 1805. In its citation the Academy stated: "America received the plow from Europe; it is admirable that America should give it back to to Europe, its gift perfected." Models of the improved plow were exhibited in the French National Museum of Natural History, in the National Conservatory of Arts and Crafts at Paris, and in the Philadelphia Society for the Promotion of Agriculture. Jefferson corresponded with Jethro Wood and others concerning improvement of the plow. However, the principles of plow construction as developed by Jefferson were not actually used by American farmers. At a later date, when Wood's plow was introduced and used by farmers, the principles developed by Jefferson were finally incorporated in plow.

Jefferson was interested in conveyances, machinery, and implements; for example, he designed or altered carriages, gigs, and wagons. He invented a hempbeater, and devised a leather buggy top, a swivel chair, and a dumbwaiter.[2]

Patent Act of 1790.

The basis of all patent legislation in the United States is the clause in the Constitution vesting Congress with power "to promote the progress of science and useful arts by securing for limited times to authors and inventors and exclusive right to their respective writings or discoveries." The first patent act was signed by President Washington on April 10, 1790. It authorized the granting of patents without examination of the prior art. "Any useful art, manufacture, engine, machine or device or any improvement thereon not before known or used" could be patented for fourteen years. The authority to grant patents was given to the Secretary of State, Secretary of War, and Attorney General. Thomas Jefferson as Secretary of State was the first Administrator of the patent act and he has been called, "the father of the American patent office." The first patent was granted to Samuel Hopkins of Vermont for "a new method of making pot and pearl ashes." The second patent was given for a new process of candlemaking. Oliver Evans received the third patent for improved flour mill machinery.

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[1] Oliver, History of American Technology, pp. 108-12.

[2] Edwin T. Martin, Thomas Jefferson: Scientist (New York, 1952), pp. 67-106 discusses his interest in inventions.

The first board was variously named the "Patent Board," "Patent Commission," and the "Commissioners for the Promotion of Useful Arts." The Board believed that inventions should be "sufficiently useful and important." Jefferson usually handled patent applications, and decided whether or not to grant a patent. An amendment of 1793 to the patent act was intended to simplify procedure; it allowed patents to be granted upon the applicant's oath's that his invention was original. Between 1793 and 1836 unimportant amendments were added to the patent act. An act of July 4, 1836 marked the birth of the modern patent system. The law definitely established an examination system and created the Patent Office.[1]

Hamilton's Report on Manufactures, 1791.

On December 5, 1791, Alexander Hamilton, the Secretary of Treasury, issued his most significant economic paper, the Report on the Subject of Manufactures, in which he urged the introduction of new machines in manufacturing. He expressed his belief that the nation should diversify its labor force and develop a high degree of skills. Hamilton proposed a national fund to attract skilled mechanics and to import new machines. Moreover, he even favored paying a premium to inventors of new manufacturing processes. Although Hamilton's ideas concerning inventions were too advanced to be adopted, many of his other ideas were accepted.[2]

Agricultural implements and milling machinery.

In 1797 Charles Newbold of Philadelphia took out the first American patent for a cast-iron plow. Although Jefferson and other gentlemen farmers were interested in it, the farmers refused to accept it, believing that the iron would poison the soil and cause the growth of weeds. In 1800, two brothers, Robert and Joseph Smith of Bucks County, Pennsylvania, patented a cast-iron plow that was used in Pennsylvania and New Jersey until 1850.

In 1814 Jethro Wood (1774-1834), a farmer of Cayuga County, New York, obtained his first patent of a cast-iron plow. In 1819 Wood obtained a second patent for his "improved" cast-iron plow and

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[1] Cyrus N. Anderson, "The United States Patent Laws," in Science and Invention edited by La Follette, pp. 381-83; Harry Kursh, Inside the U. S. Patent Office (New York, 1959), pp. 14-24.

[2] James B. Walker, The Epic of American Industry (New York, 1949), pp. 50-51; Robert B. Morris, The Basic Ideas of Alexander Hamilton (New York: Pocket Books, Inc., 1957), pp. 275-86.

sales reached 3,600 that year.[1] Wood's second plow was the first cast-iron plow to be generally accepted in the United States. His plow was made in separate pieces and a broken share or moldboard could be readily replaced. The demand for iron plows increased and the manufacturers of Wood's plows could not supply them in sufficient quantity. Wood's patent was infringed and he devoted his last years in an effort to protect his invention.[2]

In addition to his card-making machine Oliver Evans also invented flour mill machinery. By the 1790's Evans obtained patents on his machines which elevated grain mechanically to the top of the mill. The grain was cleaned during its gravity transmission to the hoppers where it was ground and then conveyed again to the top of the mill. The grain was cooled, bolted, and barreled during a second descent. These various operations were made without any manual operation. Victor S. Clark in his classic study of American manufactures stated:[3] "This may have been the first instance of any uninterrupted process of mechanical manufacture, from raw material to finished product, in the history of industry."

Rise of the factory system.

Samuel Slater (1768-1835) was born in Derbyshire, England. As a young apprentice he learned cotton-spinning in England during the Industrial Revolution when inventions radically changed the textile industry. He became familiar with cotton-spinning machinery and the inventions of James Hargreaves and Samuel Crompton.

Slater was an apprentice in the factory of Jedediah Strutt, who was a partner of Richard Arkwright, the inventor of the spinning frame which had revolutionized manufacture of cotton yarn. In 1789 Slater was attracted to the United States by an article in a Philadelphia newspaper stating that a bounty had been paid for the design of a textile machine.

Slater had memorized the secrets of Arkwright's patents and with the financial support of Moses Brown, a retired merchant, he built an Arkwright cotton-mill at Pawtucket, Rhode Island. On December 20,

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[1] Oliver, History of American Technology, pp. 129-30; Leo Rogin, The Introduction of Farm Machinery in Its Relation to the Productivity of Labor in the Agriculture of the United States during the Nineteenth Century (Berkeley, 1931), pp. 22-23.

[2] Burlingame, March of the Iron Men, p. 224.

[3] Clark, History of Manufactures in the U. S., Vol. I, p. 179; also see Roger Burlingame, Machines That Built America (New York: Signet Key Book, 1955), pp. 25-29.

the water-powered mill produced the first cotton yarn ever manufactured automatically in the United States. The ingenius Slater helped to start the Industrial Revolution in America. In 1791 the first mill was closed and a new factory was built to handle all processes of yarn manufacturing in one building. This was opened in 1793 and the factory system quickly spread throughout New England.[1] By 1815 that region had 130,000 spindles.

Cotton gin.

In 1793 Eli Whitney (1765-1825), a recent Yale graduate, invented the cotton gin which removed seeds from the cotton boll. The invention was conceived while Whitney was a guest on the plantation of Mrs. Nathanial Greene in Georgia. Whitney entered a partnership with Phineas Miller to manufacture cotton gins, but before he could get his invention patented it was copied by others. Whitney and Miller were unable to make profits because of infringements and lengthy litigation. Whitney's invention caused the cotton industry to expand and it shackled the South with slavery by revitelizing the peculiar institution.[2]

Introduction of Interchangeable Parts and Mass Production.

At some date shortly before 1785, a Frenchman named La Blanc began the manufacture of muskets on the system of interchangeable parts for the French Government. Machinery had been developed sufficiently to finish the complete lock, but the work on the barrels and stock was still done by hand. Thomas Jefferson, fascinated by this concept, visited La Blanc and reported on August 30, 1785: "He presented me the parts of 50 locks taken to pieces, and arranged in compartments, I put several together myself, taking pieces at hazard as they came to hand, and they fitted in the most perfect manner."

Jefferson's efforts to induce La Blanc to come to the United States were unsuccessful, but Jefferson informed Eli Whitney of these French efforts. Failing to profit from the cotton gin, Whitney now looked for some other occupation, and he seized upon the concept of production of interchangeable parts. In the spring of 1798 he outlined his plan to the Secretary of the Treasury: "I should like to

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[1] Arnold Wells, "Father of Our Factory System," American Heritage, IX (April, 1958), pp. 34-39, 90-92.

[2] Arnold Whitridge, "Eli Whitney, Nemesis of the South," American Heritage, VI (April, 1955), pp. 4-10; Holland Thompson, The Age of Invention (New Haven, 1921), pp. 32-52.

undertake the manufacture of ten to fifteen thousand stand of arms. I am persuaded that machinery moved by water, adapted to this business would greatly diminish the labor and greatly facilitate the manufacture of this article. Machines for forging, rolling, floating, boring, grinding, polishing, etc., may all be made use of to advantage."

Secretary of War Oliver Wolcott, alarmed by a threat of war with France, entered into a contract with Whitney on June 14, 1798, for the production of ten thousand muskets within two years. Whitney at once set to work, but time was required to erect a factory and to design the needed machinery, and two years passed before his mill at Whitneyville, Connecticut, was able to begin operations in 1800. Further difficulty with devising machinery hindered Whitney's pioneering efforts, and eight more years passed before he was able to complete the contract by delivering the last of the ten thousand muskets in 1808.

He did better, however, with his second United States contract for fifteen thousand muskets; awarded in 1812, he completed delivery within the specified two year period.[1]

In 1801 Simeon North was also awarded a Government contract for producing pistols and he began manufacturing these weapons on a system somewhat similar to Whitney's, first at Berlin and later at Middletown, Connecticut.

While both Whitney and North devised machinery to do a portion of the work, much of the task of producing these arms still had to be done by hand and their machinery was also not precise enough so that the parts of their weapons were truly interchangeable.[2]

The next step in the evolution of interchangeable parts and mass production was effected by John Harris Hall (1778-1841) of Portland, Maine. On May 21, 1811, Hall, a boat builder, took out a patent on a breech loading flintlock rifle which he had invented. His efforts to have this weapon adopted by the United States Army failed in 1813, but in 1817 the Government purchased 100 of Hall's rifles for testing purposes. These extensive trials were not completed until March 19, 1819, when the War Department signed a contract with Hall for the manufacture of his rifles at the United States Armory at Harpers Ferry. Under this agreement, and in consideration of $1,000 plus his salary of $60 a month as an Assistant Armorer, Hall was to supervise the production of 1000 of his rifles.

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[1] It might be noted, however, that the U. S. Armory at Harpers Ferry was producing 10,000 muskets a year by 1810.

[2] Abbott P. Usher, A History of Mechanical Invention (Cambridge, Revised Edition, 1954), 378-381.

Hall arrived at Harpers Ferry in May, 1819, and was assigned United States land on the Island of Virginius, in the Shenandoah River, a short distance from the U.-S. Musket Factory. Hall proceeded to invent and develop the water-powered, precision machinery needed to produce his rifle by a completely automated process, which required no hand work other than assembling the individual parts. The first thousand rifles were completed in 1825 and the second thousand by 1827.[1]

On January 6, 1827, a special commission of weapon experts, appointed to examine Hall's rifle and machinery at Harpers Ferry, reported to Colonel George Bomford, Chief of Ordnance:

"It is well-known, we believe, that arms have never yet been made so exactly similar to each other by any other process as to require no marking of the several parts and so that those parts, on being changed would suit equally well when applied to every other arm. But the machines we have examined effect this with a certainty and precision we should not have believed till we witnessed the operations. To determine this point and test their uniformity beyond all controversy, we requested Colonel Lee. Superintendent of the United States Armory at this place to send to Hall's armory five boxes containing 100 rifles manufactured by him in 1824, and which had been in the arsenal since that period. We then directed two of his workmen to strip off the work from the stocks of the whole 100, and also to take to pieces the several parts of the receivers, so-called, and to scatter them promiscously over a large joiner's work bench. One hundred stocks were then brought from Hall's armory which had been just finished, and on which no work or mounting had ever been put. The workmen then commenced putting the work taken from off the stocks brought from the United States arsenal on to the one hundred new stocks, the work having been repeatedly mixed and changed by us and the workmen also, all this was done in our presence, and the arms, as fast as they were put together, were handed to us and minutely examined. We were unable to discover any inaccuracy in any of their parts fitting each other, and are fully persuaded that the parts fitted, after all the changes they must have undergone by the workmen, as well as those made designedly by us in the course of two or three days, with as much accuracy and correctness as they did when on the stocks to which they originally belonged. In uniformity, therefore, in the component parts of small arms is an important desideratum (which we presume will not be doubted by anyone the least conversant with the subject) it is in our opinion completely accomplished by the plan which Hall has carried into effect. By no other process known to us (and we have seen most, if not all, that are in use in the United States) could arms be made so exactly alike as to interchange and require no marks on the different parts. And we very much doubt whether the best workmen that may be selected from any armory, with the aid of the best machines in use elsewhere, could, in a whole life, make a hundred rifles or muskets that

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[1] Charlotte Judd Fairbairn and C. Mead Patterson "Captain Hall, Inventor," *The Gun Report*, V, Nos. 5 & 6, (October & November, 1959)

would, after being promiscuously mixed together, fit each other with that exact nicety that is to be found in those manufactured by Hall."[1]

While Whitney was the first in the United States to experiment with the system of interchangeable parts and mass production, John H. Hall was the first to translate these theories into reality.

In 1828 and 1829 the Government let contracts for producing the Hall rifle to Simeon North of Middleton Connecticut, Henry Deringer of Philadelphia, Robert and John D. Johnston of Middleton, Connecticut, and Reuben Ellis of New York City. All these contractors except North, however, changed or voided their contracts because they were unable to build the precision machinery to produce the Hall Rifle. Only North, with Hall's assistance, was eventually able to fulfill his contract, although North's rifles never reached the same high degree of perfection as achieved by Hall.[2]

Hall's mass production techniques were also applied at the United States Musket Factory at Harpers Ferry and the United States Armory at Springfield. In the mid 1850's the British government decided to modernize its arms production and sent a special commission to the United States. After a careful study of the public and private armories in this country, the British Government hired the Master Armorer at Harpers Ferry Armory to establish and superintend the great Enfield Armory in England where American techniques and machinery were utilized to produce weapons.

In 1830 the mass production techniques spread from the arms industry to the clock making industry. Terry and Chauncey Jerome of Connecticut were pioneers in this field. Terry began the process by making wooden clocks in large lots and Chauncey completed it by substituting brass for wood in the wheelwork. The use of brass permitted the wheels to be prepared expeditiously and accurately by stamping them with dies from sheets of brass. This technique led to the mass production of cheap brass clocks.[3]

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[1] National Archives, copy of report in the research files of Harpers Ferry National Monument.

[2] Fairbairn and Patterson, V, No.6 (November, 1959) p. 19.

[3] Abbott P. Usher, A History of Mechanical Inventions, 380-81

Introduction of steam power.

Two Englishmen, Thomas Savery and Thomas Newcomen, introduced the first successful steam engine. Their engines were used to pump water out of the coal mines of England. James Watt, the Scottish inventor, invented the modern condensing steam engine in 1765. His improvements made the steam engine more than a pump and it was converted into a machine that could move the wheels of industry. In partnership with Matthew Boulton, Watt manufactured steam engines at the Solo Engineering Works near Birmingham from 1775 to 1800. The steam engine became a machine that revolutionized industry and introduced the modern factory system.[1]

Oliver Evans, the "Watt of America," constructed the first high-pressure engine in the United States. As related earlier Evans had invented a carding machine and had improved milling machinery. In 1801 Evans demonstrated that his engine could drive machines to ground plaster and saw marble. Two years later he was building engines in his Philadelphia shop near the Schuylkill River. He constructed a steam dredge for the city of Philadelphia to clean the docks. He constructed a scow with an engine which ran on rollers by steam to the river. The vehicle, christened Oruktor Amphibolos, had its rollers replaced by a stern paddle and it steamed on the water. This scow, which was also a steamboat, has been called the first automobile.[2]

A Connecticut clockmaker, John Fitch (1743-98), was one of several inventors who successfully operated steam-driven boats in America before 1790. In 1786 he built a small vessel with six side paddles and propelling machinery. Two years later Fitch built The Thorton with three paddles at the stern; the vessel had a maximum speed of eight miles an hour. By 1790 Fitch maintained a regular passenger service on the Delaware River between Philadelphia and Trenton. However, Fitch's steamboat never made a profit. Another pioneer steamboat builder, James Rumsey (1743-92) of Maryland, began his experiments in 1774. In 1787 he demonstrated a boat on the Potomac which was driven by streams or jets of water forced through the stern by a steam pump.

John Stevens (1749-1838), a rich New Jersey landowner, became interested in the work of Fitch and Rumsey. In 1791 Stevens obtained patents on a vertical steam boiler and an improved steam engine. In the 1790's he made experiments with steamboats. In 1802 Stevens built a small twin-screw launch, the Little Juliana. In 1806 he built a

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[1] W.F. Decker and Waldemar Kaempffert, "Putting Steam To Work," A Popular History of American Invention edited by Waldemar Kaempffert (New York, 1924), Vol. I, pp. 467-84; R.J. Forbes and E.J. Dijksterhuis, A History of Science and Technology (Baltimore: Pelican Book, 1963), Vol. II, pp. 374-81.

[2] Decker and Kaempffert, "Putting Steam to Work," pp. 484-88.

larger steamboat, the Phoenix. In June 1808 the vessel made the first ocean voyage in steam navigation from New York to Philadelphia. For several years it plied the Delaware River between Philadelphia and Trenton.

Robert Fulton (1765-1815) was born in Lancaster County, Pennsylvania. For over ten years he was an artist painting portraits in Philadelphia and England. About 1793 he became interested in mechanical experiments and studies. In 1796 he wrote a treatise on canal navigation and invented a submarine in Paris. In 1802 Fulton met Robert R. Livingston, the United States Minister to France, who was interested in steam navigation. Fulton and Livingston agreed to construct a steamboat to ply on the Hudson between New York and Albany. After making experiments on the Seine in 1803, Fulton returned to the United States in 1806. The Clermont was constructed on the East River. On August 9, 1807, this steamboat commenced its famous voyage from New York to Albany. It steamed 150 miles in thirty-two hours. The return trip to New York was made in only thirty hours. Although the Clermont was not the first steamboat, it was the first one operated at a cost which could prove profitable to its owners. Fulton succeeded where others had failed because he combined the mechanical knowledge of both Europe and the United States. He possessed the ability to improve his design as he built successive steamboats. Fulton more than any one else made the steamboat a practical vehicle of transportation. In 1811 Fulton, Livingston, and Nicolas Roosevelt launched the New Orleans on the Ohio River at Pittsburgh as the first steamboat on Western waters. In 1812 it steamed from Pittsburgh to New Orleans, marking the start of inland transportation in the United States.[1]

Iron industry.

The basic processes of iron-making underwent few advances in this period. The demand for additional iron production was met by increasing the number of furnaces rather than by introducing new furnace practices. However, after the War of 1812, Isaac Meason introduced the rolling and puddling method of refining iron at Plumstock in western Pennsylvania.

In this era Pittsburgh had its beginnings as the "Iron City of America." The first foundry had been built in Pittsburgh in 1805, and the first puddling and rolling mills were erected in 1819. By 1829 eight rolling mills and nine foundries were in operation at Pittsburgh.[2]

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[1] For details see James T. Flexner, Inventors in Action: The Story of the Steamboat (New York: Collier Books Edition, 1962).

[2] Oliver, History of American Technology, pp. 166-67; Clark, History of Manufactures of the U. S., Vol. I, p. 412.

Textile and woolen technology.

The many inventions of the textile and woolen industries in the period of the Early Republic brought about an end to the homespun age. In 1828 John Thorpe of Providence, Rhode Island, invented the ring spinner which enabled finer yarn to be spun at higher speed.

Arthur and John Schofield introduced power carding and spinning-machinery in the woolen industry as early as the 1790's in Massachusetts, but it was another forty years before the various processes of woolen manufacture were merged into a single industry. MeanWhile, Elisur Smith of Walpole, Massachusetts invented an ingenious card-making machine. In 1826 John Goulding invented his condenser and then years later William Crompton of Massachusetts patented his loom in England which enabled fancy woolens to be woven on power machines. Crompton's loom, however, needed certain improvements which were made in the 1850's before it was adopted in the United States.[1]

Transportation.

As population moved from the seaboard areas into the interior a need arose for improved means of inland transportation. Canal construction was urged as early as 1772. The first important canal was constructed around the falls of the Connecticut River at South Hadley, Massachusetts. It was built with the assistance of Dutch capital and completed in 1794. The Middlesex Canal connecting Boston with the Merrimack River was started in 1794, and was opened to traffic in 1804. The construction of the Erie Canal from 1817 to 1825 which connected Lake Erie at Buffalo with the Hudson River, however, opened the great Canal Age, which extended into the 1850's.

The building of the Erie Canal gave American surveyors valuable experience. The canal has been referred to as the first American engineering school. For example, Canvass White (1790-1834), who planned the locks and gates, discovered a "natural cement" with hydraulic properties which could be made from a rock discovered near the canal line. Nathan S. Roberts (1776-1852) supervised building of the flight of five locks at Lockport which were cut out of solid rock.

In general the construction of roads and turnpikes was left to local authorities, but in 1806 Congress authorized construction of the Cumberland Road or National Turnpike, a broad paved highway built across the mountains. By 1818 it was opened as far as Wheeling, Virginia on the Ohio River, a distance of about 130 miles from Cumberland, Maryland. In 1833 it reached Columbus, Ohio.

The first important surfaced road was the Lancaster Turnpike built from 1792 to 1794; it was a sixty-six mile toll road running west from Philadelphia. Other states immediately constructed similar turnpikes.

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[1] Oliver, *History of American Technology,* pp. 162-63; Clark, *History of Manufactures in the U.S.*, Vol. I, pp. 426, 456.

Several early bridgebuilders demonstrated remarkable skill. Timothy Palmer built the 'Permanent Bridge" in 1800-05 over the Schuylkill in Philadelphia which replaced a log-pontoon crossing. Theodore Burr built the Trenton Bridge in 1805 and the 360-foot span over the Susquehanna at McCall's Ferry in 1815. The latter was soon destroyed by ice. Lewis Wernwag built the 340-foot Colossus Bridge over the Schuylkill at Fairmount in 1812, but it was destroyed by fire in 1838. These pioneer bridge projects were not constructed scientifically, and the proper analysis of stresses did not appear until mid-century.[1]

X PRE-CIVIL WAR PERIOD, 1830-1860

Colt Revolver.

Samuel Colt (1814-62) was born in Hartford, Connecticut. At the age of sixteen Colt went to sea as a sailor from Boston to Calcutta. On the voyage he whittled a wooden model of a revolving pistol. He later devised a method of revolving a cylinder containing cartridges and of locking it into alignment with a fixed barrel. He automatically rotated the cylinder and cocked the hammer by the same action. Colt took out patents in England, France, and the United States, and by 1836 had obtained financial support, establishing the Patent Arms Company at Paterson, New Jersey.

Colt failed in his attempts to have the government adopt the revolver. The original Colt was sold to frontiersmen fighting in the Seminole Indian War of 1837, and also to Texas Rangers. The first model was called the Colt-Puterson Revolver. Colt's second model was named the "Walker Colt" after Samuel H. Walker, Captain of the Texas Rangers, who had suggested a trigger guard and a loading lever. The Texas Rangers first used the Colt Revolver in the Battle of the Perdernales against mounted Comanches.

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[1] Oliver, History of American Technology, pp. 174-80; James K Finch, The Story of Engineering (New York: Anchor Books, 1960), pp. 259-65. Lewis Wernwag operated a mill on the island of Virginius at Harpers Ferry in the 1820s.

In 1842 the Patents Arms Company became bankrupt, but Colt was able to regain his patent which he had relinquished to the company. Finally during the Mexican War the Colt Revolver was accepted by the government. His first order for one thousand revolvers were manufactured in Whitney's factory. When the order was completed, Colt opened his own factory at Hartford. Elisha K. Root supervised building of the new factory and its machinery. The Colt factory became the leading arms factory in the world and it improved upon the mass production techniques of John Hall. The Colt Revolver also facilitated the settlement of the Great Plains because it enabled the whites to fight the Indian on horseback.[1]

Vulcanization of rubber.

India rubber became a craze in the United States in the early 1830's. In 1833 E. M. Chaffee of Boston and others established the Roxbury India Rubber Company. The company manufactured caps, shoes, coats, wagon covers, and cabin covers. Other companies were organized in Massachusetts and New York, but the products were soon reduced to a molten state. Charles Goodyear (1800-60), an amateur inventor, began experiments to improve rubber when the so-called "India-rubber fever" was subsiding. After several years of disappointment, in 1839 Goodyear accidentally discovered the process of vulcanization. Further experiments enabled Goodyear to produce a new stretchable material which was resilient, waterproof, and an excellent insulator. In 1844 he patented the process. His invention was applied to many uses and became an important item in industry.[2]

Sewing machine.

Walter Hunt invented several items between 1832 and 1859. Among these were a machine for making nails and rivets, ice plows, a repeating gun, velocipedes, and the safety pin. In 1832 in a New York City shop he built a sewing machine embodying the eye pointed needle and the shuttle. Hunt gave up his idea in 1838; later he attempted to obtain a patent, but it was denied on the ground of abandonment.

Beginning in 1843 Elias Howe (1819-67) worked on the design for a sewing machine. Howe was assisted financially by George Fisher, who provided a home for Howe and his family in Cambridge while he produced his machine. The sewing machine patented by Howe on September 10, 1846,

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[1] Roger Burlingame, Machines That Built America, pp. 82-94; Holland Thompson, The Age of Invention, pp. 187-91; Walter Prescott Webb, The Great Plains (Boston, 1931), pp. 170-79. Also see Webb's article, "The Story of Some Prairie Inventions," Nebraska History, XXXIV (Dec., 1953), pp. 234-35.

[2] Thompson, The Age of Invention, pp. 157-74.

was the real beginning of the sewing machine industry in the United States. However, Howe's machines were never put on the market. Unable to secure capital at home, Howe went to England and sold his English patent to a corset manufacturer.

Improvements were made on the sewing machine in 1849 by John Bachelder and in 1850 by Allen B. Wilson. On August 12, 1851, Isaac M. Singer (1811-75) was issued a patent for a sewing machine constructed from his own design. While Singer's machine was a decided improvement over Howe's, he also used an eye-pointed needle. Howe sued Singer for patent infringement. After winning his case, Howe agreed to a pooling of sewing machine patents. Seven companies formed the pool and Howe received a royalty for every machine sold. Later Singer invented several devices which further improved the sewing machine, making it useful to industry and a household necessity.[1]

Transportation.

Before the advent of the railroad the principal manufacturing centers of the United States were located near the coast or near navigable waters. As early as 1786 Oliver Evans of Philadelphia had attempted to obtain the right to operate "steam carriages" in Pennsylvania and Maryland. As related in the previous chapter he had demonstrated in 1804 that a steam carriage could run.

The greatest exponent of adopting the steam locomotive in America was the inventor, John Stevens, who had built a practical steamboat in 1808. In 1815 Stevens received the first railway charter in the United States from the State of New Jersey. While George Stephenson was still experimenting with steam on the Stockton and Darlington Railway in England, Stevens built a rack-rail engine. It was propelled by a cogwheel engaging a rack bolted to the ties. In 1826 Stevens built a circular railroad track at Hoboken. He operated an experimental locomotive with a multitubular boiler which he had invented.

The first locomotives used in the United States in a commercial way were imported from England. In 1827 Horatio Allen imported a Stephenson locomotive, the "Stourbridge Lion." A trial run was made on the tracks of the Delaware and Hudson Canal Railroad by Allen as engineer. The locomotive drove over the road successfully, but since it was too heavy it was soon withdrawn from service.

Meanwhile, in 1827 the Maryland legislature authorized the Baltimore and Ohio to build a railroad. Peter Cooper, owner of the Canton Iron Works in Baltimore, designed a small locomotive called the "Tom Thumb."

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[1] John A. Boshard, "The Sewing Machine," in Science and Invention edited by La Follette, pp. 339-50; Peter Lyon, "Isaac Singer and his Wonderful Sewing Machine," American Heritage, IX (Oct., 1958), pp. 34-38, 103-09.

It had one cylinder, weighed one ton, and had between one and one-and-a-half horsepower. In August 1830 it drew a car with passengers on a 13-mile track from Baltimore to Ellicott City. In January 1831 the "Best Friend of Charleston" began operation on the Charleston and Hamburg Railroad. The engine was designed by Horatio Allen, who had left the Delaware and Hudson. The locomotive was built by the West Point Foundry at Cold Springs, New York. It pulled forty passengers in four cars; later this engine exploded. Allen next designed the "South Carolina" mounted on two pivoted trucks which permitted the wheels to follow a sharply curved track. This idea was an important American innovation and invention.

On August 9, 1831, the "De Witt Clinton," the most famous of pioneer American locomotives, was built at the West Point Foundry for the Mohawk and Hudson Railroad. It ran from Albany to Schenectady and with three coaches of passengers it went fifteen miles an hour.

In the early thirties Matthias W. Baldwin (1795-1866) studied English locomotives and then constructed "Old Ironsides" for the Philadelphia, Germantown and Norristown Railroad. This engine was modeled after the British type, but Baldwin soon began to use his own concepts in locomotive development. By 1839 Baldwin had built 120 locomotives.

In addition to improvements in locomotive designs Americans improved train designs as rolling stock began to lose its stagecoach and rail-wagon appearance. American locomotives were made lighter and speedier. Wooden rails, protected by only thin iron straps, were replaced by more durable iron rails. In the 1840's the experimental stage of the railroad was over. Roads were combined into through routes. By 1860 railroads extended as far west as the Mississippi. From 32 miles in 1830 railroad mileage had increased to 30,626 miles in 1860.[1]

After the successful venture of the steamboat New Orleans, a number of improvements were made to American rivercraft. As early as 1812 Daniel French and Henry Miller Shreve (1875-1851) began to build steamboats in Brownsville, Pennsylvania, on the Monongahila River. In 1814 Shreve acquired an interest in one of the pioneer steamboats on the Mississippi. In 1816 he designed and launched the Washington, the protoype of the western river steamboat, with shallow draft and high-pressure engines mounted on deck. Steam navigation on the Mississippi and Ohio rivers thereafter became practical and steamboats assisted in opening the West.

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[1] Waldemar Kaempffert, A Popular History of American Invention (New York, 1924), Vol. I, pp. 3-67 relates the story of American railroading. Burlingame, March of the Iron Men, pp. 244-59; Thompson, The Age of Invention, pp. 74-83.

Technological advances were also made in ocean craft. In 1816 packet lines began plying between the United States and Europe. By the 1830's regular sailings were run between Boston and Philadelphia. The packet ships developed a new design. The drag aft was eliminated and the ship was able to sail on more even keel. In 1839 the *Roscious* of 1009 tons, the largest packet ship yet built, appeared.

In 1845 the first of the actual clippers, the *Rainbow*, was launched for the China trade. The naval architect, John W. Griffith, designed the vessel which was the earliest large ship of the extremely hollow bow type. The most famous of the clipper builders was Donald McKey (1810-80), who built 160 vessels in his East Boston yards. Among his speedy clippers were the *Flying Cloud*, *Sovereign of the Seas*, and *Great Republic*. The clippers were engaged in trade with California and the Far East. With their speed and large cargo capacity they enjoyed a brief but glorious success.

The first ocean steamship was the American built steamer *Savannah*. On May 26, 1819, she sailed from Savannah for Liverpool, making the passage in 25 days. A combination sail and steam ship, she was equipped with auxiliary steampower. The British were the first to develop subsidized steamship lines. In 1845 Congress finally passed a measure granting mail contracts. Two years later Edward K. Collins and his associates were granted a mail contract between New York and Liverpool. Collins engaged the naval architect, George Steers, and four paddle-wheel steamers modeled after packet ships were built in the yards of William H. Brown and of Brown & Bell in New York. The vessels powered with 800-horsepower steam engines averaged 316 miles in a day. With the coming of the California gold rush two lines of steamers were opened to Panama by George Law and William H. Aspinwall. In a ten-year period the Pacific Mail Steamship Company carried 175,000 persons to California.[1]

John Ericsson (1803-89), the Swedish engineer and inventor, came to the United States in 1839. Ericsson had experimented with stern propellers in England. In 1837 he built a screw steamer which was launched on the Thames. He also designed a 50-horsepower engine for the iron screw steamer, *Robert F. Stockton* which sailed across the Atlantic in 1839 and was used as a tug boat on the Delaware and Raritan Canal.

Ericsson's acquaintance with Captain Robert F. Stockton of the United States Navy was a factor in his selection to superintend the building of the U.S.S. *Princeton*. The hull of the vessel was built at the Philadelphia Navy Yard and the machinery by the engineering firm

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[1] Oliver, *History of American Technology*, pp. 191-201; Carl C. Cutler, *Greyhounds of the Sea: The Story of the American Clipper Ship* (New York, 1930), pp. 87-162; Alan Villiers, "The Drive for Speed at Sea," *American Heritage*, VI (Oct., 1955), pp. 14-21, 100-101.

of Merrick and Towne in 1842 and 1843. The 954-ton vessel was 164 feet long and had a 30½ foot beam. Its original screw propeller was known as "the Ericsson" and consisted of a cast brass hub with six arms. In 1845 the original propeller was replaced by a six-bladed screw without any supporting drum. The *Princeton* was the first screw steam warship and also the first warship in which all machinery was below the water line. A tragic accident, causing the death of both the Secretary of Navy and the Secretary of War aboard the *Princeton*, was caused by a gun explosion. Although Ericsson was blameless, the friendship between Captain Stockton and Ericsson was breached. Moreover, Stockton tended to take credit for Ericsson's inventions and Ericsson was never paid for his services which in reality marked the beginning of the steam navy of the United States.[1]

Communications.

In 1828 Robert Hoe (1784-1833) built the first cylinder press in the United States. With his son, Richard M. Hoe (1812-1886), he made several other improvements; in 1844 they devised the rotary combined cylinder press. However, with the beginning of the first penny newspaper in 1833, a speedier press was needed. In 1847 Richard Hoe invented the revolving press. Thirteen years later newspapers in large American cities relied on the Hoe Lightning press. The inventions of the Hoes made possible the modern newspaper.[2]

Joseph Henry (1797-1878) was the scientist behind the invention of the telegraph. In 1831 he published the results of his researches on the design and construction of electromagnets. Four years later he demonstrated the electromagnetic relay principle. Henry sent currents from a multiple cell battery through a mile wire to an electric magnet which rang a bell.

In 1832 Samuel F. B. Morse (1791-1872) became interested in transmitting signals and messages from a distance. Morse conceived a telegraph, and was assisted by Joseph Henry, Professor Leonard D. Gale of Columbia University, and Alfred Vail. In 1837 Morse began to give successful demonstrations. By 1843 he gained Congressional support and $30,000 was appropriated to build a telegraph line between Washington and Baltimore. On May 24, 1844, Morse transmitted his first message over the electromagnetic telegraph.[3]

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[1] Frank M. Bennett, *The Steam Navy of the United States* (Pittsburgh 1896), pp. 61-74; James P. Baxter, 3rd, *The Introduction of the Ironclad Warship* (Cambridge, 1933), pp. 12-16.

[2] James H. Collins, "The Story of the Printed Word," in *A Popular History of American Inventions* edited by Kaempffert, Vol. I, pp. 243-52.

[3] Roger Burlingame, *Scientists Behind the Inventors* (New York: Avon Book, 1960), pp. 42-54; Thomas Coulson, *Joseph Henry, His Life and Work* (Princeton, 1950), pp. 208-34; Mitchell Wilson, "Joseph Henry" in *Lives in Science* edited by Dennis Flanagan (New York, 1957), pp. 141-53.

Agricultural implements.

Among the many advances in agricultural technology in this period were the steel plow and the reaper. In 1837 at his blacksmith shop in Grand Detour, Illinois, John Deere (1804-86) invented a plow of saw steel. Since saws were scarce and expensive, he at first imported steel from Germany. At a later date he was able to place an order for steel with a firm in Pittsburgh. Deere's plow furrowed the sticky Illinois soil quickly with an economy of labor. In 1843 he added a foundry to his shop, enabling him and a partner to manufacture 400 plows. Four years later Deere moved to Moline, Illinois, and increased his annual production to 700 plows. In 1857 his firm attained an output of 10,000 plows. Other manufacturers besides Deere turned out steel plows on a factory basis and they were widely used in the prairies.[1]

The most significant agricultural implement invented in this era was the reaper. The successful reaper invented by Cyrus Hall McCormick (1809-84) was the twenty-third American reaper that was patented. McCormick devised seven important principles. One of these was to have the horse draw the machine from the side. He also had a knife, divider, fingers, reel, platform, and wheel. The moving parts were geared to the wheel to make them automatic. His first trial was made in 1831 on the family farm in the Valley of Virginia. After making improvements, McCormick obtained his first patent in 1834. He sold his first machines in 1840, and in 1844 he established a small factory at Brockport, New York on Lake Erie, and one in Cincinnati.

To capitalize on the prairie market McCormick opened a large factory in Chicago in 1847. At first he formed a partnership with William B. Ogden, but soon bought him out. By 1851 McCormick was producing one thousand reapers a year. During the fifties McCormick became rich. His reaper won the grand prize in 1851 at the London Exposition, and by 1859 he had manufactured 50,000 reapers. The significance of the reaper was that it made grain-growing on the prairies possible. During the Civil War it freed Northern manpower for the armies, and it enabled the North to feed part of Europe besides its own people.[2]

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[1] Oliver, History of American Technology, p. 224; Rogin, The Introduction of Farm Machinery, pp. 33-34.

[2] Rogin, pp. 84-93; Edward J. Dies, Titans of the Soil (Chapel Hill, 1949), pp. 77-83.

XI CIVIL WAR PERIOD, 1861-1865

Arms and weapons.

In the first part of this study mention has already been made of the experiments with balloons and ironclads during the Civil War. Upon the outbreak of the war five cannon factories existed in the north: atSouth Boston; Cold Springs, N.Y.; the Ames Foundry at Chicopee, Massachusetts; the Phoenixville Foundry outside Philadelphia; and Pittsburgh, Pa. By 1863 other factories were built at Providence, Boston, Portland, and Reading. The West Point Foundry at Cold Springs, New York manufactured the Parrott rifled gun and the large Rodman smoothbore guns were cast at the Fort Pitt Foundry in Pittsburgh. In 1849 Lieutenant Thomas Jefferson Rodman had devised a process for cooling the large cannon cast hollow at the Fort Pitt Foundry. In 1861 Captain Robert Parker Parrott invented a rifled cannon which used cylindro-conical shot. The West Point Foundry, at Cold Springs, N.Y., of which Parrott was president, supplied the government with these big guns during the war. Charles James of Rhode Island and Benjamin Hotchkiss also experimented with rifled cannon and rifled projectiles. While some military leaders at first opposed the acceptance of rifled cannon, experiments with the new cannons convinced President Lincoln and the people generally that they were superior.[1]

At the beginning of the war the North had two Federal armories at Springfield, Massachusetts and Harpers Ferry, Virginia, that could manufacture small arms. The latter was burned by the Union Army on April 18, 1861 to prevent its capture, but Virginia state troops were able to strip it of some machinery which was taken to the Richmond and Fayetteville Confederate arsenals. In Hartford, Connecticut,the Colt Arms Works and the Sharps Rifle Works increased their production of small arms. Other private armories in the north also vastly increased their capacity during the war.[2]

A number of advances in weaponry were made during the Civil War. President Lincoln, who was anxious to take advantage of the North's superior technological abilities, became particularly interested in ordnance. For example, Lincoln ordered machine guns called "the

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[1] Clark, History of Manufactures in the U.S., Vol. II, pp. 16-17; Bruce, Lincoln and the Tools of War, pp. 147-50.

[2] Clark, History of Manufactures in the U.S., Vol. II, pp. 20-21.

Union Repeating Gun." This gun is said to have been invented by either Edward Nugent or William Palmer.[1] On November 4, 1862, Richard J. Gatling (1818-1903) patented his invention of a rapid-fire gun called the "Gatling gun." This multibarreled machine gun was crank-operated. Toward the end of the war it was used by Admiral Porter and by General Butler, but it was not officially adopted by the United States Army until 1866.[2]

President Lincoln was also interested in submarine inventions. He endorsed a submarine built by a Frenchman, M. Brutus de Villeroi and he recommended consideration by the Navy of a submarine proposed by Oliver B. Pierce. The Navy also examined a submarine model devised by Pascal Plant, but it was not accepted. A rocket torpedo invented by Plant proved to be a similar failure in a demonstration.[3]

Transportation and communication.

The Civil War was the first war in which the railroad was used as a weapon to give armies mobility. General D.C. McCallum directed the Union's military railroad operations. During Sherman's march through Georgia in 1864, McCallum was able to deliver 1,600 tons of war materials each day. The electric telegraph was also adapted to military purposes. The Union Army developed an electrical communication device called the Beardslee magneto-electric telegraph set. It was portable and could signal over several miles. The instrument was developed by George W. Beardslee and adopted by Albert J. Myer, the Union chief signal officer. The "Flying Telegraph Train" consisted of two Beardslees in two wagons along with hand reels, five miles of insulated wire, and 200 lance poles. Although the Beardslee system was successful in the Battle of Fredericksburg, it was discarded in November 1863.[4]

Food and clothing.

Purchases of clothing and boots and shoes for the Union military forces stimulated manufacture of these items. The sewing machine was introduced into the production of uniforms and shoes. The shoe industry

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[1] Bruce, *Lincoln and the Tools of War*, pp. 118-23.

[2] *Ibid.*, pp. 290-91.

[3] *Ibid.*, pp. 176-78.

[4] Eugene F. Hart, "Revolution in Technology and Logistics," *Army Digest*, XVI (Aug., 1961), pp. 100-13; Mark Boatner, III, *The Civil War Dictionary* (New York, 1959), p. 54.

changed from household to factory manufacture. A mechanical device for sewing the uppers to the soles with great speed was first patented by L. R. Blake and later improved by Gordon McKay. The McKay sewing machine was put on the market in 1862. It enabled a worker to sew several hundred pairs of shoes in a day.[1]

William Underwood, an Anglishman, introduced the canning industry to the United States. Shortly after his arrival in America in 1817, he established a business in New York where he preserved fruits and pickles in glass jars. In 1825 Thomas Kensett began to preserve oysters and fruits in a tin canister, introducing the term "canning." The canning industry was not important until after 1840 when the commercial canning of oysters and fruits started in the Baltimore area. With the decline in the price of sugar about 1860 the industry was appreciably stimulated and salmon canning developed in California, and then on the Columbia River 1864-67.

In 1861 Gail Borden opened a factory in Wassaic, New York, where he condensed and canned milk. The Union Army commandeered the entire output for soldiers. As a result of improvements in canning fruits and vegetables were canned.[2]

The Civil War stimulated the inventive genius of the American people. At the height of the war effort more patents were issued in the North than ever before in the entire country. Expansion of the agricultural implement, food processing, clothing, and shoe industries gave an impetus to new inventions. To solve the problem of labor scarcity many labor-saving machines were devised. The Patent *Report* for 1863 indicated that 40,000 reapers and mowers were manufactured and sold for that year. The Baltimore *Farmer and Mechanic* estimated that 66,975 reapers and 38,025 mowers were manufactured for the 1864 harvest.[3]

Confederate torpedo and submarine warfare.

The preponderance of Union sea power caused the Confederate States to reply upon the use of torpedoes, mines, and submarines in an effort to compensate for its lack of a navy. Matthew Fontaine Maury resigned from the Naval Observatory following the secession

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[1] Clark, *History of Manufactures in the U.S.*, Vol. II, pp. 32-33; Emerson D. Fite, *Social and Industrial Conditions in the North during the Civil War* (New York, 1910), pp. 88-92.

[2] Oliver, *History of American Technology*, pp. 271, 281; Clark, *History of Manufactures in the U.S.*, Vol. II, p. 33.

[3] Fite, *Social and Industrial Conditions in the North during the Civil War*, pp. 99-100; Rogin, *The Introduction of Farm Machinery*, pp. 91-92.

of his native Virginia. He devised a plan for a system of torpedo defense and persuaded the Confederate government to appropriate $50,000 for a naval submarine battery service. 'Torpedoes' or mines were planted in Southern harbors for defensive purposes. Mine warfare took a toll of over twenty federal warships, but shortages of materials and insulated wire hampered Confederate torpedo manufacture.[1]

The Confederate States experimented with several submarines, but they proved impractical. The *Pioneer* built by private parties sunk during a dive. A second submarine sunk in shallow water. A third submarine, the *Huntley*, sunk the U.S.S. *Housatonic* off Sumter on February 14, 1864. However, the *Hunley* became caught in the hole that her torpedo had torn in the *Housatonic* and she went down with her victim. The *Hunley* was the first deep submersible. Her hull was a boiler and she had diving fins and ballast tanks. A crew of eight powered the vessel with a hand-cranked propellor.[2]

XII INDUSTRIAL AGE, 1866-1913

Steel industry.

In 1857 William Kelly (1811-88), of Kentucky, an American ironmaster and inventor, had patented a process for making steel inexpensively by blowing air through molten pig iron to oxidize the excess carbon and other impurities. Kelly named his process "pneumatic" or airblown." An Englishman, Sir Henry Bessemer, had discovered the same process in 1854. Bessemer added six openings near the bottom of his converter through which air could be blown up and into the molten metal. When Bessemer applied for a patent in the United States, Kelly protested and in a court action Bessemer failed to obtain an American patent. In 1862 the Cambria Iron Works in Johnstown, Pennsylvania, engaged Kelly to build a converter. A demonstration proved that the converter would work, but no steel was made. In 1864 the Kelly

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[1] Daniel Ammen, *The Navy in the Civil War: The Atlantic Coast* (New York, 1898), pp. 140, 147-48, 157-60.

[2] Mitchell Wilson, *American Science and Invention* (New York, 1954), pp. 210-11; this book has pictures of the submarines as does Theodore Roscoe and Fred Freeman, *Picture History of the U. S. Navy* (New York, 1956), nos. 811-16.

Pneumatic Process Company, organized by William F. Durfee, built a converter in Wyandotte, Michigan, where steel was made. About the same time Alexander M. Holley of Troy, New York made steel in an experimental way under rights acquired from Bessemer in 1865. A threatened patent war was averted, when Holley bought the Kelly patents and combined the two processes. In 1867 the first steel rails rolled in the United States were made at the Cambria Works in Johnstown. Large-scale production of steel by the new methods was quickly extended in the early seventies.

Following the introduction of the Bessemer process, improved blast furnaces were built. James Gayley (1855-1920), an American inventor and metallurgist, invented a bronze cooling plate for the walls of blast furnaces which was patented in 1891. Three years later he invented the dry-air blast.

In 1868 Abram S. Hewitt introduced the open-hearth method of making steel in the United States at the Cooper Hewitt Company in Trenton. At first there was little demand for this type of steel which was more costly and limited in use. About 1879 technical improvements were introduced which increased the capacity of open-hearth plants. In 1892 the United States production of open-hearth ingots reached 670,000 tons compared with 4,168,000 tons of Bessemer steel. By 1900 the open-hearth plants produced over half the tonnage of Bessemer steel. The superiority of the open-hearth process was due to the fact that it could employ a greater variety of ores and also because open-hearth steel was tougher than Bessemer steel. By the end of the century the United States led other nations in steel production and the American economy was based upon steel consumption, which was utilized in making rails, locomotives, ships, and skyscrapers.[1]

Petroleum.

In the late 1840's a few individuals searched for an inexpensive illuminant as a substitute for whale oil because of the high price charged by the New Bedford Whaling interests. In the United States Abram Gessner had distilled oil from coal as early as 1846, and he took out a patent for an improved illuminating oil in 1854. Gessner called his product "kerosene," but it was not popular because of its smell. In the 1850's Colonel A.C. Ferris made an attempt to devise a lamp which would burn petroleum. At this same time Samuel M. Kier was selling refined petroleum from his salt wells for medicinal purposes. In 1854 George A. Bissell and Jonathan G. Eveleth, two New York lawyers, began to prospect for oil in Pennsylvania. Two years later Bissell conceived the idea of drilling wells for oil. On March 23, 1858, Bissel and Eveleth formed the Seneca Oil Company and engaged Colonel Edwin L. Drake

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[1] Oliver, *History of American Technology*, pp. 314-29; Clark, *History of Manufactures in the U.S.*, Vol. II, pp. 231-49; Roger Burlingame, *Engines of Democracy: Inventions and Society in Mature America* (New York, 1940), pp. 54-72.

as field superintendent. At Titusville on Oil Creek Drake started for oil, but his workers were flooded by water. Drake next decided to drive an iron pipe through the water, quicksands, and clay down to bedrock. Obtaining the services of William A. Smith, who had drilled deep salt wells for Samuel M. Kier, Drake drove 49 feet of pipe to bedrock. After cleaning this out, the workmen drilled to a depth of 69½ feet. On August 28, 1859, a vein of oil was struck. "Drake's Folly" started to produce 40 barrels of oil a day and the petroleum industry was started. As the industry expanded oil pumps were introduced. In 1864 Colonel E.A.L. Roberts patented a torpedo which was used in "shooting" wells. Many tools were invented to solve the problems of oil production. For example, the rotary drill was devised in 1901 for use in the sandy soil of the Texas oil fields.[1]

Mining.

The application of machinery has been an important American contribution to mining progress. Edward E. Mattison, a native of Connecticut, is said to have invented the process of hydraulic mining in 1852 or 1853 at American Hill, located north of Nevada City, California. Mattheson did not patent his process and several California inventors made devices for use in the new process. Some writers claim that the process was invented at Yankee Jims in Placer County, California. Here it was introduced by Colonel William McClure. Hydraulic mining flourished in California until about 1883 and spread from this state to other parts of the mining world.[2]

J. J. Couch of Philadelphia, utilizing a French invention, made the first rock-drill in the United States in 1849. It was operated by steam, but apparently did not function well. With the assistance of a Boston inventor, J. W. Fowle, he improved it. Couch and Fowle built a perfected drill in the railroad shops of Fitchburg, Massachusetts. Charles Burleigh bought the patent rights in 1866, calling it the Burleigh drill. This compressed air drill was used in boring the Hoosac railroad tunnel in Western Massachusetts in 1867, also in the Colorado mines, and it was later used on the Sutro Tunnel to tap the Comstock Lode at Virginia City, Nevada in 1874.

After the discovery of silver-lead ore at Leadville, Colorado in 1877, a number of inventors including Simon Ingersoll, A.C. Rand, George Githens, and Henry C. Sergeant further improved compressed air drills. About 1897, J. George Leyner, a Colorado machinist, invented the jackhammer. The piston moved up and down and acted as a hammer.

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[1] Oliver, *History of American Technology*, pp. 331-44; Guy E. Mitchell, "Striking Oil," in *A Popular History of American Invention* edited by Kaempffert, pp. 83-106.

[2] C.A. Logan, "History of Mining and Milling Methods in California," in *Geologic Guidebook Along Highway 49--Sierran Gold Belt* (San Francisco: Division of Mines, Bulletin 141, Sept., 1948), p. 33; Robert L. Kelley, *Gold vs. Grain: The Hydraulic Mining Controversy in California's [illegible] Valley* (Glendale, 1959), p. 27.

The drill was hollow in order that water or air could be pumped through it to clear away rock dust.[1]

Before the California gold discovery the stamp mill had been introduced from Europe into the southern Appalachian gold mines. But the crude European mill was rapidly and vastly improved in California. By 1858 there were over 280 quartz mills in California and the number of stamps in these mills was 2,610. The foundries and machine shops of San Francisco ,such as the Union Iron Works, manufactured much complicated mining machinery. The experience gained in constructing machinery for the early quartz mines of California and later for the Comstock and other mines in Nevada enabled San Francisco machinists to produce the finest stamp mills and mining equipment in the world.[2]

Several notable mining inventions were also made in San Francisco. For example, Joseph Moore and George W. Dickie of the Risdon Iron Works invented the famous Chollar-Norcross Pump in the 1880's.

In 1860 Philip Deidesheimer of El Dorado County, California, was employed to timber the third gallery (175 feet underground) of the Ophir Mine on the Comstock. He invented a system of timbering known as the square set (timbers locked together in hollow cubes and each cube interlocked with the next in endless series) which was widely adopted among miners for use in large and deep ore chambers. In 1863 G.F. Deetken of Auburn, California obtained a patent for an inexpensive chlorination apparatus which was an improvement over the process of separating gold from auriferous suphurets first discovered by the German chemist, Plattner. The famous V-flume was invented by James W. Haines of Genoa, Nevada in 1868, to transport lumber from the mountains for use on the Comstock Lode.[3]

Lumbering.

During the Industrial Age the inventions of many American lumbermen contributed to the rapid rise of the lumbering industry. Several of these inventions were developed in the Far West. The flume was used to transport redwood logs in the West about 1890. The flume of the Fresno Flume and Irrigation Company had been built originally for irrigation purposes, but in 1891 it was used for carrying lumber from a sawmill at Shaver to a planing mill at Clovis, California, a distance of 65 miles.

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[1] James H. Collins, "Mining Copper and the Nobler Metals," in *A Popular History of American Invention* edited by Kaempffert, Vol II, pp. 66-70.

[2] Logan, "History of Mining and Milling Methods in California," pp. 33-34; T.A. Rickard, *The Stamp Milling of Gold Ores* (New York: 2nd ed., 1897), pp. 35-74; Rodman W. Paul, *Mining Frontiers of the Far West* (New York, 1963), 31-32.

In 1864, John Dolbeer and William Carson, two pioneers of the California redwood lumber industry, organized the Dolbeer & Carson Lumber Company. The year before Dolbeer had applied for a patent on a mechanical tallying machine. Its purpose was to count the number of board feet cut during a certain period. In 1881 he devised the Dolbeer Steam Logging Donkey which enabled steam power instead of man power and oxen power to move the logs through the forests. The invention,patented in 1882, revolutionized logging in the United States, allowing crews to get the logs to the railroad and mills in a shorter time. On December 25, 1883, Dolbeer patented his "Improved Logging Engine." Both his machines were used in the redwood region for the next thirty years.

On November 23, 1883, Horace Butlers of Ludington, Michigan obtained a patent for power log-skidding machinery. This system of transporting logs by wire ropeways was later improved by Spencer Miller and G. Haines Dickinson. The first ground skidder with power was operated in the pine regions near Pitcock, Georgia in 1896. In 1897 W.A. Fletcher of Kirbyville, Texas invented the first pine logger. Meanwhile, when railroading became a vital part of logging in the 1880's, various types of locomotives were designed to meet the problems of lumbering. In 1885 the first Shay locomotive with gears adjusted to give it more drawing power was manufactured.[1]

Electrical industry.

The Electrical Age was ushered in following the Civil War. The first electric lighting to have commercial value was arc lighting. In 1808 Sir Humphry Davy, the English chemist, gave the first public demonstration of an arc light. An electric current supplied by a battery was passed between two pieces of charcoal. After touching the carbon electrodes together, Davy drew them apart, forming an electric arc emitting a brilliant light. For the next fifty years scientists and inventors attempted to improve the arc light, but it remained a laboratory instrument.

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[3] John S. Hittell, The Commerce and Industries of the Pacific Coast (San Francisco, 1882), pp. 417-24, 429-30, 432; Eliot North, Comstock Mining and Miners (Berkeley, 1959), pp. 89-90.

[1] Joseph Illick, "The Story of American Lumbering," in A Popular History of American Invention edited by Kaempffert, Vol. II, pp. 150-98; H. Brett Melendy, "Two Men and a Mill: John Dolbeer, William Carson, and the Redwood Lumber Industry in California," California Historical Society Quarterly, XXXVIII (March, 1959), pp. 59-71.

Charles Francis Brush (1849-1929) was the American pioneer in the investigation of arc lighting. After graduating in 1869 from the University of Michigan with a bachelor's degree in chemistry, he opened an office as consulting chemist in Cleveland. In his spare time he experimented with electricity, building a dynamo. With the financial assistance of George W. Stockley of the Cleveland Telegraph Supply Company he began to produce arc-lighting apparatus. In the workshops of this company Brush built an improved dynamo and a simplified arc lamp. In 1877, Dr. Nicholas Longworth, a Cincinnati physician, was the first to purchase Brush's single-light generator and arc lamp which was used to light the porch and yard of his home. Brush continued to make technical improvements and in 1879 the city of Cleveland introduced street lighting by arc lights using the Brush equipment. However, the Cleveland experiment did not lead to the establishment of an arc-lighting company or even a contract with the city.

Meanwhile, the Cleveland Telegraph Supply Company had obtained Brush's patents and changed its name to the Brush Electric Company. This Cleveland company was represented in San Francisco by William Kerr, who was promoting the new lighting apparatus on the Pacific coast. At San Francisco George H. Roe and others incorporated the California Electric Light Company. In exchange for stock and a directorship in this new company William Kerr relinquished his rights to the Brush equipment. A plant was erected at Fourth and Market Streets where the Brush machines were housed. It began operating in September 1879, and it was the first electric central station in the world. A fire in 1880 destroyed the plant and a new building was opened on O'Farrell Street. In October 1881 a larger plant was erected on Jessie Street between Third and Fourth Streets. In 1888 a second powerhouse was erected at Townsend Street and Clarence Place. Meanwhile, in 1879 and 1880 Brush central stations were built in New York, Boston, Philadelphia, and other cities.[1]

Thomas Alva Edison (1847-1931) was born at Milan, Ohio. As a young telegrapher he took jobs at several places. In 1868 he worked as a repairman with the Gold and Stock Telegraph Company. He invented an improved stock ticker, earning $40,000. With this initial capital he started to manufacture stock tickers and telegraphic devices in New York City. In 1877 he decided to devote his full time to inventions, setting up a laboratory in Menlo Park, New Jersey, and began experimenting with incandescent lights. For several decades scientists had been working with the incandescent lamp. Edison was anxious to develop

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[1] Harold C. Passer, The Electrical Manufacturers, 1875-1900 (Cambridge, 1953), pp. 11-21; Charles M. Coleman, P.G. and E. of California: The Centennial Story of Pacific Gas and Electric Company, 1852-1952 (New York, 1952), pp. 55-62.

a light that could be used for home and office illumination since arc lighting was restricted to street and other large space lighting. With the assistance of Grosvenor P. Lowrey, the Edison Electric Light Company was organized in 1878 to finance the work of the "Wizard of Menlo Park." On October 19, 1879, an incandescent bulb with a filament of carbonized cotton thread burned for forty hours. Edison's lamp proved practical and he secured his basic patent on January 27, 1880. Edison also designed and manufactured his dynamos, current-carry conduits, bulb sockets, and current meters. In 1882 the Edison Company opened the Pearl Street Station in New York City which was the first extensive system of distributing electric power. The perfected incandescent lamp opened an entire new world of electrical marvels.[1]

When electricity was first introduced, a power could only be transmitted short distances because direct current was employed. George Westinghouse (1846-1914) and his associates introduced alternating current whereby the flow of current could be increased or decreased by a transformer. Westinghouse obtained the patent rights of a "secondary generator" invented by two Europeans. In 1886 William Stanley and other engineers at a Westinghouse laboratory in Great Barrington, Massachusetts devised an alternating-current lighting system. Shortly thereafter Pittsburgh and Buffalo installed Westinghouse stations.

George Westinghouse also developed alternating-current motors which were widely used by 1890 for industrial purposes. The introduction of the steam turbine in the 1890's lowered the cost of electricity and expanded its use in factories. Electrical energy could now be transmitted great distances from larger central stations.[2]

Agricultural technology.

James Oliver (1823-1908), an industrialist, was born in Scotland. He came to the United States in 1835, settling in Indiana. In 1868 he secured a patent for making a plow from chilled iron. This plow proved superior to the cast-iron plow. When Bessemer steel was introduced, Oliver used steel instead of iron in manufacturing plows at his works. About 1864 the sulky plows carried on wheels were devised and produced by F.S. Davenport and Robert Newton on a commercial scale. In 1865 J.C. Pfeil invented a gang or riding plow with an operator's seat.

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[1] Oliver, *History of American Technology,* pp. 343-50; also see Matthew Josephson, *Edison, A Biography* (New York, 1959).

[2] Oliver, *History of American Technology*, pp. 353-56; Passer, *The Electrical Manufacturers*, 1875-1900, pp. 310-13

After 1874 improved corn planters and grain drills assisted farmers in increasing their acreage. In the seventies many improvements were made in the reaper. Automatic binders were introduced; the wire binder was first used in 1873, but it was soon replaced by the twine binder. By 1880 3,000 twine binders had been marketed by the William Deering & Company of Illinois.

The combine, a combined harvester and thresher, became an important technological advance in grain harvesting in California during the 1880's. The first combine used in California was probably the machine belonging to George W. Leland, who harvested 600 acres of wheat in Alameda County with a combine in 1854. The production of vastly improved combines began at Stockton, California in 1876. By 1886 several types of combines were used in the Sacramento Valley and in the San Joaquin Valley of California. [1]

The last frontier of the American West, the Great Plains, was opened in the period between 1870 and 1890. Among the inventions that assisted in opening this sub-humid area was barbed wire. A commercially practical version of barbed wire was invented by Joseph F. Glidden, a farmer of De Kalb, Illinois in 1873. His patent application was disallowed at first, but finally accepted on November 24, 1874. Glidden was not the sole inventor of barbed wire, for there were several who had invented various types, both practical and impractical.

Glidden twisted together two strands of wire so that they held pointed wire barbs at short intervals. He began producing barbed wire fencing in a small factory at De Kalb in 1874. The wire manufacturing firm of Washburn and Moen of Worcester, Massachusetts bought into the Glidden enterprise and began mass production of wire fencing in 1876. While barbed wire fencing solved the problem of a lack of timber on the plains, it was also a significant factor causing the disappearance of the cattle kingdom. In addition to barbed wire and improved farm machinery, certain modifications made in the windmill in the 1870's also facilitated opening of the Great Plains.[2]

Food technology.

Nicholas Appert, a Partisian chef, invented a process in 1804 for preserving food in hermetically sealed glass containers. His process spread to England and the United States. Ezra Daggett, about 1819, was probably the first American to utilize this process in this country, and his son-in-law, Thomas Kennett, secured patents. At first food was preserved in glass jars, but after 1823 tin cans were used.

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[1] Oliver, *History of American Technology*, pp. 363-67; Rogin, *Introduction of Farm Machinery*, pp. 110-25.

[2] Walter Prescott Webb, *The Great Plains* (Boston, 1931), pp. 295-318 and "The Story of Some Prairie Inventions," *Nebraska History*.XXXIV (Dec., 1953), pp. 229-43.

In the 1850's a machine press to cut tops and bottoms for cans was invented. Usually the food was put through a hole in the top which was soldered over a cap. In 1876 the Howe floater was designed which rolled the cans. This machine used solder, but toward the end of the century the can became solderless. By 1885 the manufacture of cans became a separate industry. While canneries were established throughout the nation, they were concentrated in California and Maryland. The problem of food fermentation was solved in 1895, when Professor Henry L. Russell completed his experiments to eliminate the swelling and unpleasant odors of canned foods.

In this period refrigeration was also developed. In 1875 Dr. Carl Linde produced a practical compression machine and in 1885 E. E. Hendrick invented an exhaust-steam absorption machine. About 1877 Gustavus Swift, a Chicago meat-packer, and an engineer named Chase devised a refrigerated railroad car which stimulated the meat-packing industry.[1]

Transportation.

The technological features of American railroads were vastly improved in this era. Steel rails were substituted for iron rails. Improved roadbuilding machines were introduced and outstanding railroad bridges were built. The first steel-arch railroad bridge, the Eads Bridge at St. Louis, was completed in 1874 across the Mississippi River. James B. Eads (1820-87), an engineer and inventor, used pneumatic caissons in constructing foundations for the bridge. Steel was also used to construct railroad locomotives which became larger and heavier.

Sleeping-cars were used in the United States as early as 1836, but the so-called "bunk" cars lacked comfort. In 1858, George M. Pullman (1831-97) designed sleeping cars for the Chicago and Alton Railroad. In 1864 he designed and patented the Pullman car with its folding upper berth, and the next year he patented the seat cushions to make the lower berth.

While the hotel-like features of the railroad attracted more passengers, the new safety devices did likewise. George Westinghouse (1846-1914) invented the air brake which was first used on passenger trains in 1868. The next year he organized the Westinghouse Air Brake Company to manufacture his invention. Westinghouse also invented automatic railroad signal devices.[2]

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[1] Oliver, *History of American Technology*, pp. 377-90; Clark *History of of Manufactures in the U.S.*, Vol. II, pp. 507-08; Walter, *The Epic of American Industry*, pp. 186-87; Earl C. May, *The Clanning Clan* (New York, 1937), 107-113.

[2] Oliver, *History of American Technology*, pp. 415-27.

Technological advances in shipbuilding were not as dramatic as they had been in the age of the clippers. Masters of the new industrial capitalism lacked interest in shipbuilding because of high construction costs and because of English predominance in that endeavor. Nonetheless, shipbuilding continued to make some progress in the United States. In the 1880's the building of the "New Navy" revolutionized the design and machinery of American warships. George W. Melville (1841-1912), Chief of the Bureau of Steam Engineering in the Navy from 1887 to 1903, produced machinery that made our warships preeminent and gained for himself a reputation as one of the most distinguished marine engineers. For example, his adoption of coil boilers was a step that freed the Navy from a tangle of conventional practices. Triple expansion engines were utilized with many innovations.

Wooden naval vessels gave way to iron and eventually to steel ships. Improvements in armor plate were made by Hayward A. Harvey in 1888 and by William Corey in 1895. The velocity and range of naval guns were increased and Bradley A. Fiske (1854-1942), a naval officer and inventor, invented a range finder of excellent precision, an electric ammunition hoist, and an electric communication system for interiors of warships.[1]

Andrew Smith Hallidie (1836-1900), the pioneer wire rope manufacturer of San Francisco, established his factory in 1858. The flat woven-wire cables manufactured in his plant were used in the California and Nevada gold mines for hoisting from great depths. In 1867 he invented the "Hallidie Ropeway," a device by which an overhead wire rope could convey supplies in the mountainous mining country. For two years Hallidie experimented with an underground cable moving street cars. In 1873 he perfected his invention of a cable car with a grip capable of seizing and holding a moving cable which moved on a track up a steep hill. On August 1, 1873, the Clay Street Railroad began operation, demonstrating a new method of street car transportation. In the 1880's cable car lines were constructed in most large American cities; Chicago had the largest system with 82 miles of track and 710 grip cars. Despite high maintenance costs, the cable car was superior to the earlier horsecar.[2]

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[1] Ibid., pp. 428-31; Bennett, The Steam Navy of the United States, pp. 771-844.

[2] Edgar M. Kahn, Cable Car Days in San Francisco (Stanford University Press, 1940); Frank Parker, Anatomy of the San Francisco Cable Car (Stanford University Press, 1946).

After the advent of the cable car, several inventors developed the electric street car. Among early pioneers was Stephen Dudley Field (1846-1913), who also invented a multiple-call district telegraph box and a dynamo quadruplex telegraph. In 1875 Field applied for a patent for an electric railway which would use current from a stationary dynamo and which would be delivered through a third rail to the car-wheels and traffic rails. In the early 1880's Thomas Edison experimented with an electric locomotive at Menlo Park, New Jersey. At the Chicago Railway Exposition of 1883, an electric-elevated railway was put into operation under the Field and Edison patents.

Charles Joseph Van Depoele (1846-92), the "Father of the Trolley," was born in Belgium in 1846. As early as 1874 he demonstrated the practicability of electric traction. In 1883 he built two small electric railways and secured a patent. In 1888 he sold his patents to the Thomson-Houston Electric Company of Lynn, Massachusetts, and entered this company's employ. He built several of the early electric railways in the United States and Canada. In 1883 Leo Daft also developed a successful street car. He installed car lines in several Eastern cities and in St. Catharines, Ontario.

The interurban system developed from the work of Frank Julian Sprague (1857-1934), an electrical engineer and inventor, who organized the Sprague Electric Railway and Motor Company in 1884 to manufacture electric motors. He installed the first modern trolley system at Richmond, Virginia in 1888. Sprague is considered the "father of electric traction," for he invented the multiple-unit system of electric train control. Within a three-year period two hundred street car systems were built or planned on the Sprague system. The electric car quickly replaced the horsecar, and even the cable car except on steep grades. The success of the electric car in urban service caused its expansion to intercity and rural operation. By 1901 about 15,000 miles of electric railway existed in the United States. The interurban systems expanded until about 1908. In the end the automobile replaced the industry, but was not a real threat until about 1911. The automobile did not reduce the number of interurban passengers until after 1917.[1]

Although the bicycle was first developed about 1800, it was not widely adopted until the 1880's. The first American to manufacture bicycles was Albert A. Pope, who patented a safety bicycle in 1886 or 1887. His first bicycles, manufactured in a sewing-machine shop in Hartford, Connecticut, weighed over 100 pounds. Pope and other bicycle manufacturers began to reduce the weight. They made frames of thin tubing and also put ball bearings in the wheels. By 1896

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[1] T. Commerford Martin, "Electric Cars and Trains," *A Popular History of American Inventions* edited by Kaempffert, Vol. I, pp. 106-33; George W. Hilton and John F. Due, *The Electric Interurban Railways in America* (Stanford University Press, 1960).

By 1896 there were over 4,000,000 riders in the United States and over 250 bicycle manufacturing companies.

The pneumatic tire and the chain-and-sprocket mechanism gave the bicycle speed. Bicycle clubs were formed and "bike-racing" contests were held. In 1880 the League of American Wheelmen was organized and influenced the good-roads movement. In a real way the bicycle craze prepared for the mass production of the automobile.[1]

The evolution of the modern automobile was a gradual process. Steam-driven carriages had existed for nearly a century before the German technician, Nikolaus A. Otto, invented a four-cycle compression-type internal combustion engine in 1876. The Otto Engine Works produced gas engines for stationary work, but not for road vehicles. In 1884 Gottlieb Daimler invented a light high-speed gasoline engine. The same year another German, Carl Benz, built a gasoline automobile.

In 1877, an American lawyer and inventor, George B. Selden (1846-1922), built a gasoline engine. He also made drawings of a carriage to be driven by a three-cylinder engine mounted crosswise on the front axle. He applied for a patent which was granted on November 5, 1895, for a gasoline-driven vehicle.

In the early nineties several American inventors pioneered in building automobiles. In 1892 Charles E. Duryea (1862-1938), sometimes called the "father of the automobile," built a gasoline-propelled car. In 1895 he and his brother, J. Frank Duryea, organized the Duryea Motor Wagon Company at Springfield, Massachusetts. In 1892 Henry Ford built his first gasoline car, and he tested it successfully on the road the next year. Hiram P. Maxim developed a gasoline engine and automobile during the 1890's. In 1894 Elwood Haynes of Kokomo, Indiana built an automobile. Ransom E. Olds had produced a three-wheel steam vehicle in 1887; in 1896 he began work on a gasoline vehicle. He was the first to put an inexpensive gasoline automobile on the American market. In 1897 Alexander Winton built the first large cars.

By the turn of the century the United States had acquired the technological knowledge to launch the automobile industry. By the time Henry Ford began his real production in 1903, other automobiles such as the Olds, Haynes, Winton, Locomobile, Packard, and Cadillac had already won recognition. Ford refused to join the Association of Licensed Automobile Manufacturers, who paid royalties to the owners of the Selden patent. Ford insisted on standardization and mass production. In 1908 he introduced the Model-T, a light four-cylinder

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[1] James A. Barnes, Wealth of the American People: A History of Their Economic Life (New York, 1949), pp. 510-11; Burlingame, Machines That Built America, pp. 134-40. Pope began manufacturing the "Columbia" bicycle in 1877.

touring car of 20 horsepower that carried five passengers. Ford promised it would run 22 to 25 miles per gallon of gasoline and that its tires would run 10,000 miles. This model enabled Ford to produce a car in large quantity at low price. By 1913 Ford was able to adopt the moving assembly line, and he had produced a car for the millions. The American family quickly became geared to the automobile.[1]

Americans such as Thaddeus Lowe, John J. Montgomery, and Octave Chanute had experimented with balloons and gliders in the nineteenth century. Samuel P. Langley and Charles M. Manly built an internal combustion engine for a flying machine. In their trial flight of October 7, 1903, the *Aerodrome* dove into the Potomac River near Washington. While their machine did not fly, Langley had contributed knowledge of wind resistance and air pressure as well as certain instruments.

Two brothers, Wilbur and Orville Wright, were successful pioneers of flight. At the Wright Cycle Company in Dayton, Ohio the two brothers had a bicycle shop. In 1896 they began to study the mechanics of flight. Before they attempted powered flight they studied the problems of stability, control, and balance in gliders. Eventually they developed a wing design and designed their own motor and propellers. On December 17, 1903, they made the first successful flight in a motor-powered airplane at Kitty Hawk, North Carolina. On its second flight the plane remained in the air 59 seconds and flew 852 feet. After making improvements, the brothers succeeded in making a circular flight of 24½ miles in 38 minutes at Dayton, Ohio on October 5, 1905. In 1906 they secured a patent for their flying machine. In 1909 the American Wright Company was organized to manufacture airplanes.[2]

Communication.

An underwater cable insulated with gutta percha was first laid in 1845 between England and the European Continent. In 1842 Morse's sea cable between Governor's Island and Castle Garden had been laid in the United States. Matthew Fontaine Maury mapped the Atlantic floor; an Englishman, William Thomson, solved the problem of sending messages over a great distance without relays, and Cyrus W. Field provided the organizing genius to lay the Atlantic Cable. In 1858 a cable was laid connecting England and the United States, but this first Atlantic Cable

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[1] H.W. Perry, "The Rise of the Automobile," in *A Popular History of Am. Inventions* edited by Kaempffert, Vol. I, pp. 134-74; Roger Burlingame, *Henry Ford* (New York: Signet Key Book, 1956); Hiram P. Maxim, *Horseless Carriage Days* (New York: Dover Edition, 1962).

[2] David C. Cooke, *The Story of Aviation* (New York, 1958), pp. 42-94; Omega G. East, *Wright Brothers National Memorial* (Washington, D.C.: National Park Service, Historical Handbook Series No. 34, 1961)

failed. In 1866 a new cable with technical improvements met with great success.[1]

Elisha Gray (1835-1901), an American inventor of several telegraph and telephone appliances and adjuncts, invented in 1873 a telegraph relay, a telegraph switch, and an annunciator which could be used in hotels and offices. Gray was searching for a way to transmit the tones of the human voice.

In 1871, Alexander Graham Bell (1847-1922), who was born in Scotland, came to the United States as a teacher of speech for the deaf. From 1873 to 1876 he experimented in an effect to develop the telephone. Bell had his associate, Thomas A. Watson, design an instrument, which they called the "harmonic telegraph." While experimenting with this instrument Bell finally invented the telephone and received a patent in 1876. At first the telephone was merely a curiosity, and Bell and Watson had to give many public demonstrations before the invention was accepted. The Bell Telephone Association was organized in 1877, and in 1878 the first telephone exchange was opened at New Haven, Connecticut. Within five years the telephone had wide commercial use.[2]

An Italian, Guglielmo Marconi, invented wireless communication and made successful experiments in 1895, taking out his first patent in England in 1896. The American pioneer in wireless telegraphy and radiotelephony was Lee De Forest, who was born in Council Bluffs, Iowa in 1873. In 1907 De Forest patented his audion tube which made long distance radio possible. A three-electrode vacuum tube, it was used as a detector and amplifier. The tube detected electrical waves and released a large amount of electric power from a source at the receiver which could amplify signal-making power. In 1908 he installed radio telephony on American warships. In 1910 he broadcast Enrico Caruso's voice by radio. De Forest, who patented over 300 inventions, is sometimes referred to as "the father of radio."

Another pioneer in radio science was Michael I. Pupin (1858-1935), who had been born in Yugoslavia and came to the United States in 1874. He became a professor of electromechanics at Columbia University. Among his inventions was a system of multiplex telegraphy and the Pupin coil which extended the range of long-distance telephony.[3]

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[1] Arthur C. Clarke, '"I'll Put a Girdle Round the Earth in Forty Minutes,"' American Heritage, IX (Oct., 1958), pp. 40-44, 85-96.

[2] Oliver, History of American Technology, pp. 435-39; Alexander G. Bell, "Beginnings of the Telephone," in Science and Invention edited by La Follette, pp. 171-82.

[3] Oliver, History of American Technology, pp. 496-502; Michael Pupin, From Immigrant to Inventor (New York: New Edition, 1925).

Business machines.

In the Industrial Age as business expanded a number of recording and tabulating devices were invented. As early as 1829, William A. Burt of Detroit had invented a primitive typewriter called the "typographer." The modern typewriter was invented by Christopher Latham Sholes (1819-90), a Milwaukee printer. Together with Carlos Glidden and Samuel W. Soule he was granted a patent in 1868. The Sholes machine, which he called a "typewriter" had an up-strike type bar, a circular type basket, finger keys, and a cylindrical roller. Sholes improved his machine to make it type accurately and rapidly. After Glidden and Soule relinquished their rights, Sholes sold his rights to James Densmore. Densmore interested the Remington Arms Company in its manufacture, and in 1874 the Remington typewriter was marketed as the first practical machine.[1] The typewriter became an essential machine in the business world and it enabled women to secure positions in business and the professions.

In the 1870's Frank S. Baldwin (1838-1925) attempted to improve the Colmar calculating machine which had been developed in France. In 1874 Baldwin exhibited his "arithmometer" at Philadelphia. In 1902 he invented an improved calculating machine which was later redesigned with J.R. Monroe as the Monroe calculating machine. A second pioneer in revolutionizing bookkeeping was William S. Burroughs (1857-98), who gave up a bank clerk's position in Auburn, New York to experiment with an adding machine. By 1886 he perfected an adding machine, and the American Arithmometer Company was organized to market the machine.

In 1879 James J. Ritty of Dayton, Ohio invented a cash register. Ritty had difficulties in marketing his invention. In 1884 John H. Patterson acquired Ritty's company and organized the National Cash Register Company. The pioneer in developing an automatic system of compiling, recording, and tabulating data was Dr. Herman Hollerith, a statistician. In 1887 he used punched cards to register collected data.[2]

Phonograph, photography, and motion pictures.

The phonograph was invented by Thomas A. Edison in 1878. While working on the repeating and embossing telegraph, he conceived the idea of a phonograph. Edison's first machine was crude, but he made improvements. In 1901 the Edison gramophone was put on the market.[3]

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[1] Harry E. Barbour, "The Development of the Typewriter," in Science and Invention edited by La Follette, pp. 365-69; for details see Richard N. Current, The Typewriter and the Men Who Made It (Urbana, 1954).

[2] Walker, The Epic of American Industry, pp. 270-76.

[3] Jerome S. Meyer, Great Inventions (New York: Pocket Book Edition, 1962), pp. 262-64.

George Eastman (1854-1932), an American inventor and industial leader, perfected a process for making photographic dry plates in 1880. In 1884 he patented a transparent flexible film which was the first commercial film. Cut into narrow strips, the film made on coated paper, was wound on a roller. In 1888 he invented the "Kodak," a portable hand camera.

Among the pioneers in motion picture photography was Eadweard Muybridge (1830-1904), who photographed animals in motion as early as 1872, when he was engaged by Leland Stanford of California to prove that a running horse had all four feet off the ground at one phase of his stride.

In 1888 the Edison laboratories at Menlo Park, New Jersey started work on the kinetoscope. With the assistance of William K. L. Dickson, the Edison-Dickson kinetoscope was constructed. As a result peepshows were shown beginning in 1894. C. Francis Jenkins (1867-1934) with the assistance of Thomas Armat invented the modern motion picture projector. He patented the machine in 1895. Jenkins's inventions prepared the way for the making of movies as a new form of commercialized amusement.[1]

Technical education and journals.

The growth of scientific and technical education in the United States was tremendous in this period. The Massachusetts Institute of Technology, Yale's Sheffield School, the land-grant colleges, mining schools, and other mechanical and technical institutions fostered interest in applied science. In California the Throop University of Pasadena, presently California Institute of Technology, was established in 1891. Mechanics institutes and manual training schools in the different sections of the nation also contributed to the advance of technical education. Several technical and engineering societies were established; for example, the American Society for Engineering Education was organized in 1893.

The Engineering and Mining Journal was established in 1866. It issues portrayed the new tools and machines used by the nation's expanding industries. Among the engineering journals launched in this era were *Engineering News*, *Electrical World*, *Technologist*, and *Railroad and Engineering Journal*. A number of scientific and technical journals appeared such as the *American Chemical Journal*, *American Machinist*, and *Popular Science Monthly*. Articles on popular and applied science continued to appear in the general American publications.[2]

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[1] Ibid., pp. 81-86; Oliver, *History of American Technology*, pp. 442-44, 504-07.

[2] Oliver, *History of American Technology*, pp. 309-12; Robert H. Fernald, "Progress in Engineering," in *Science and Invention* edited by La Follette, pp. 297-315.

Awareness of American technological advances.

At the Paris Exposition of 1867 the inventive genius of the American people was well displayed. Cyrus McCormick won a grand prize as well as the Cross of the Legion of Honor for his reaper. Cyrus Field was recognized and praised for the Atlantic Cable. The Howe sewing machine was awarded gold medals.

The Centennial Exhibition of 1876 at Philadelphia had a Machinery Hall that impressed both foreign observers and Americans alike. The famous Corliss engine of 1,500 horsepower was the main attraction. A large number of European inventors, scientists, and industrialists came to Philadelphia to gain knowledge of American technology.

At the Columbian Exposition at Chicago in 1893 the electrical exhibits constituted the major technological attraction. The exhibits of American machines were also a primary attraction. The next year the Chicago fair was copied at San Francisco by its Mid-Winter Fair held in the Golden Gate Park. The displays in the Mechanical Arts Building were a main feature.

The United States exhibited models of its agricultural, textile, and mining machinery at the Paris Exposition of 1900. In the first decade of the twentieth century American technical skills were demonstrated at home in the Pan-American Exposition at Buffalo, the Louisiana Purchase Exposition at St. Louis, and the Alaska-Yukon-Pacific Exposition at Seattle.

As the nineteenth century closed the ripened maturity of American technology was evidenced by the exchange of visits between American and European scientists and technicians. Moreover, by the 1890's a considerable number of American machines were exported to Europe. For example, American shoe machinery was adopted by several German shoe manufacturers. In a report dated April 25, 1898, Frederic Emory, Chief of the Bureau of Foreign Commerce of the Department of State, indicated that the reports of consular offices proved a growing popularity of United States manufactures. This was particularly evident in iron and steel products, labor-saving machinery and tools, boats, shoes, bicycles, electrical supplies, and locomotives. Emory asserted that in certain industries production surpassed domestic consumption and that additional foreign markets were needed if American operatives and artisans were to be kept employed. In 1893 manufactures comprised less than one-fifth of United States exports. By 1903 the figure had risen to one-third, and in 1912 it rose to 47 per cent.[1]

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[1] Oliver, History of American Technology, pp. 297-309; Clark, History of Manufactures in the U.S., Vol. III, pp. 1-2.

XIII CONCLUSION

Summarization and trends in scientific and technological history of the United States.

In the beginning American scientific and technological ideas were primarily an expression of European intellectual thought. In fact the American scientific tradition was English in origin, and a similarity remained between the two traditions for a long time. However, American science was always more utilitarian.[1] As soon as America was discovered European science was stimulated by interest in the new lands. Actually scientific knowledge has always crossed and recrossed the atlantic whether there be peace or war.

During the colonial era American science was not specialized, being generalized into the two broad fields of natural philosophy and natural history. Despite their generalization the colonial naturalists were pioneers in advancing American science. A certain degree of popularization has always characterized American scientific development. This was true even in the colonial era when almanacs and newspapers disseminated scientific data. The American Revolution tended at first to disrupt our scientific advance, but soon a burst of scientific activity occurred. When the United States gained their independence, Americans remained for a time dependent upon Europe for scientific and technological guidance, but gradually facilities for research and training were improved; moreover, the national government became interested in fostering scientific discoveries and inventions.

The existence of a frontier stimulated the inventive and scientific genius of the American people. With an entire continent to settle inventions were needed to reduce distances and to develop the land. For example, locomotives in America became heavier and faster compared to those of Europe. To tame the different frontiers of America inventions such as the Colt revolver, the reaper, and barbed wire were devised. The unique problems of the various mining frontiers of the West called for solution and these were met by American mining engineers and inventors who became preeminent in designing mining equipment and machinery. Science was fostered by several exploring expeditions sponsored by the national government in the period before the Civil War. As early as the 1820's a few state governments began to undertake geological surveys.

Americans have always been a nation of joiners and her scientists and inventors held meetings and formed scientific and technological societies. Many of these organizations launched publications, and the United States today has many scientific and technical journals that date back to the last century. In the beginning college education

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[1] Stephen F. Mason, A History of the Sciences (New York: Collier Book, New Rev. ed., 1962), p. 389.

was based primarily upon classical studies, but by the 1840's colleges and universities began to offer instruction in science and engineering. After the Civil War technical and scientific education was further stimulated by the evolution of the land-grant colleges.

When the nation became involved in the Civil War, the Union was sustained in part because of the superior scientific and technical skills of the Northern people. However, scientific and technological knowledge was never confined to the more industrial and populated areas of the Northeast. Scientific interests existed even in the Old South. After the Civil War as industry spread into the South, technological advances were also made in that section. In the Far West technical and scientific developments occurred virtually from the time of the first settlements with greater advances existing in the more populated area of California.

America's greatest scientific and technological advance came after the Civil War when an increasing industrialization and urbanization occurred. In this age of finance capitalism business expanded and factory methods and standardizations were widely adopted. Scientists and inventors were called upon to devise new business machines and to improve means of factory operation and transportation. The attraction of American wealth encouraged increased immigration to the United States, and the American scientific tradition was strengthened in this era by the arrival of many actual and potential European scientists and inventors. Hence Albert A. Michelson, a Polish immigrant, became the first American to receive a Nobel Prize in science. The sciences of astronomy, chemistry, physics, and medicine, to mention only a few, made tremendous strides in the Industrial Age. Americans became the foremost pioneers in developing such modern inventions as the telephone, automobile, and airplane.

Significance of America's role and her contributions.

The major significance of American scientific discoveries and inventions through the years is that these advances made the United States the wealthiest nation in the world. They enabled Americans to be well fed and gave the average man an abundance of the comforts of life. Most of the inventions were utilitarian and practical. Besides giving the American people ample food, clothing, and housing, an emphasis on producing labor-saving devices gave them more leisure for education, travel, and entertainment.

Science and technology are basicially and naturally international in tradition with no race or people having a monopoly of wisdom. Americans have always benefited from the scientific and inventive contributions of other peoples. In turn the United States aided the rest of the world by its own scientific and technological know-how. In fact by 1900 American ingenuity was welcomed in many foreign lands. Many nations, particularly Japan and Russia, imported machinery from the United States. After the Spanish-American War, when the United States became a world power, her machines were also introduced into Cuba and the Philippines.

In the baccalaureate address delivered at the University of Wisconsin on June 20, 1909, Joaquin Nabusco, Brazilian Ambassador to the United States, spoke on "The Share of America in Civilization." He pointed out that American inventions had brought about a standardization and a unification. In part he said: "The Age of Franklin will not end as the Age of Midas. You have changed the rhythm of life, you write in quick tempo, and the world is catching from you the spirit of rapid transportation...."

American science and technology about 1913.

On the eve of World War I the United States was on the threshold of assuming a position of world leadership. An American Empire was created following our victory over Spain in 1898. In a large measure the ease with which the United States defeated Spain was due to her technological superiority. Since the eighties the United States had been emerging as a great naval power. The new steel navy and the superior weaponry of the United States were results of the advances in American science and technology. In 1898 the United States passed Great Britain in iron and steel production. By 1900 the United States passed Germany in machine tool production.

In 1900 agriculture remained the leading industry in the United States with a third of the population engaged in farming, but the manufacturing industries were on the march. Industry was moving west and south. Its density increased in the Great Lakes region and it was bringing new promise to the South. At the turn of the century as the United States became more urbanized and industrialized, the national government and the states began to increase their scientific functions. For example, the public health movement gained momentum. Also efforts were made to insure pure food and drugs, conservation, and safety in industry. Scientific research became an accepted function of government. By 1913 the American people realized more than ever that science fostered democracy. However, modern science and technology were changing the world so rapidly that the future of American democracy was soon tested by the impact of World War I.

The interplay between science and invention.

Scientific discovery (basic or "pure" science) and invention (applied science) are related and dependent upon each other. The discoveries of scientists frequently lead to inventions, and conversely sometimes inventions lead to scientific discoveries. For example, Joseph Henry discovered electromagnetism; once this phenomenon was known the telegraph could be invented. In American history, particularly in the early period, science has been more applied than basic. Although the United States has had scientists of international standing since Franklin's day, the number were few until the Industrial Age. With the advance of scientific education in the United States after the 1870's a greater emphasis was placed on basic science.

In a sense the United States received much of its basic science from Europe until more recent times, but inventions and engineering achievements made the United States an industrial giant and world power by 1900. Throughout our history scientists have aided inventors and inventors have aided scientists. Sometimes it is difficult to distinguish between a scientist and an inventor. A good example is the career of Michael Pupin, who as Roger Burlingame appropriately said: "was the scientist behind his own inventions."[1]

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[1] Roger Burlingame. Scientists Behind the Inventors (New York, 1960), p. 72. In this book the author explores the interrelationship between science and invention.

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The book is a history of the work of artisans and craftsmen in Colonial America. This is a scholarly study by a competent American historian.

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The book covers the period from 1865 and is a useful study.

_____, Machines That Built America (New York, 1953).

This book is a brief and popularly written history of the more significant machines in American history, but it is not a thorough study.

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The book is a study of the social pattern which made the United States. The viewpoint is technological invention and its place in the formation of social trends. The book is scholarly and has an extensive bibliography.

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This is an excellent and scholarly study with documentation. It mainly follows a chronological approach, but also has chapters on such topics as agriculture, conservation, medicine, and public health.

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The book contains articles by various scientists. Although it is not a complete study, it is one of the few books relating to science in this area.

Hindle, Brooke, The Pursuit of Science in Revolutionary America, 1735-1789 (Chapel Hill, 1956).

This scholarly and documented study has been highly praised by American historians specializing in cultural history. The author has an excellent chapter on the American Philosophical Society.

Jaffe, Bernard, Men of Science in America (New York, Rev. ed., 1958).

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Johnson, Thomas C., Jr., Scientific Interests in the Old South (New York, 1936).

In this study of the attitudes of the planters, politicians, and professional people of the Old South toward the natural sciences the author attempted to explode the myth that the section lacked scientific interests. The book has extensive footnotes and is based upon sound research.

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The first volume treats transportation, communication, and power and the second volume covers natural resources and labor-saving machines. The chapters are written by various specialists in non-technical language. These volumes are not entirely accurate and are not based upon sound scholarship. Nonetheless, they contain much data that is not readily available.

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This is a reliable history of the Smithsonian Institution by the chief of the Editorial and Publications Division. The book has a chronology of principal events in Smithsonian history and a selected bibliography.

Oliver, John W., History of American Technology (New York, 1956).

This book is a comprehensive history of American technology and invention. While the emphasis is on technology, the study contains much of value pertaining to scientific history. It is a text for courses in its subject and is scholarly. The book, however, does contain errors.

Struik, Dirk J., Yankee Science in the Making (New York: Collier Book, Rev. ed., 1962).

This study covers United States science and technology from colonial times to 1865. It is a classic with an extensive bibliography and documentation.

Thompson, Holland, The Age of Invention (New Haven, 1921).

The volume is in the Chronicle of America Series. The book merely outlines the personalities of a few American inventors and relates their significance. It covers the period from Benjamin Franklin to the conquest of air.

Walker, James B., The Epic of American Industry (New York, 1949).

The book is written for the general reader and is an account of the rise of industry, commerce, business, transportation, and communication in the United States. It has considerable data on specific inventions such as the telephone, automobile, and business machines.

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The book is a general history of the development of American science and invention covering the period from Franklin's experiments with electricity to the beginning of the atomic age. The narrative lacks details, but the book has over one thousand documentary pictures.

SITES OF EXCEPTIONAL VALUE

1. Lick Observatory, California

Location. Santa Clara County, on Mount Hamilton, 24 miles east of San Jose.

Ownership and Administration. University of California at Berkeley.

Significance. Lick Observatory, established in 1888 on top of Mount Hamilton, was the first great research astronomical observatory in the Far West. Among the distinguished American astronomers associated with this observatory were Edward S. Holden and Edward E. Barnard. The astronomers at Lick performed pioneer work in the study of sun spots and double star systems and many other significant astronomical discoveries were also made here.

In 1874 James Lick, who had come to California in 1847 and made millions in selling real estate in San Francisco, donated $700,000 to the University of California for the purpose of building a great observatory. In 1876 Congress granted land for site and this, with later grants, now totals about 3,100 acres. Lick died in 1876, but his trustees provided a 36-inch equatorial refractor, a 12-inch equatorial refractor, and a 6 1/2-inch meridian circle instrument. When the University of California was given the completed observatory in 1888, it was considered its "crowning possession". Until 1899, its 36-inch telescope was the largest in the world.

Edward Singleton Holden (1846-1914) served as the director of the Lick Observatory from 1888 until 1897. A West Point graduate, Holden had been an astronomer at the Naval Observatory at Washington, D. C. from 1873 to 1879; he was next director of the Washburn Observatory of the University of Wisconsin in 1881, and finally President of the University of California. In 1889 Holden founded the Astronomical Society of the Pacific. In 1892 he discovered the faint fifth satellite of Jupiter, and an atlas of the moon as also prepared by the Lick staff based upon photographs made with its great glass.

Edward Emerson Barnard (1857-1923) was another distinguished astronomer who served on the Lick Staff from 1888 to 1895. While at Lick he began to photograph the Milky Way and also discovered five satellites of Jupiter and the nebulous ring around Nova Aurigae. He left the Lick Observatory in 1895 to become an astronomer at the Yerkes Observatory of the University of Chicago, at Williams Bay, Wisconsin.

The modern study of nebulae was begun at Lick in 1898 and more than 33 comets and 4,800 double stars have since been discovered and charted.

Present Appearance. The Lick Observatory is situated on the summit of Mount Hamilton, 4,029 feet altitude. A narrow paved road, making 365 turns in the last five miles, leads to the mile-long ridge at the summit, thus affording an interesting ascent.

Although subsequent additions have been made to the observatory's equipment and plant, the original buildings and telescopes are still in use and intact. James Lick is buried under one of the supporting pillars of the 36-inch telescope.

The observatory is open to visitors from 1 to 5 pm daily, except on University holidays.

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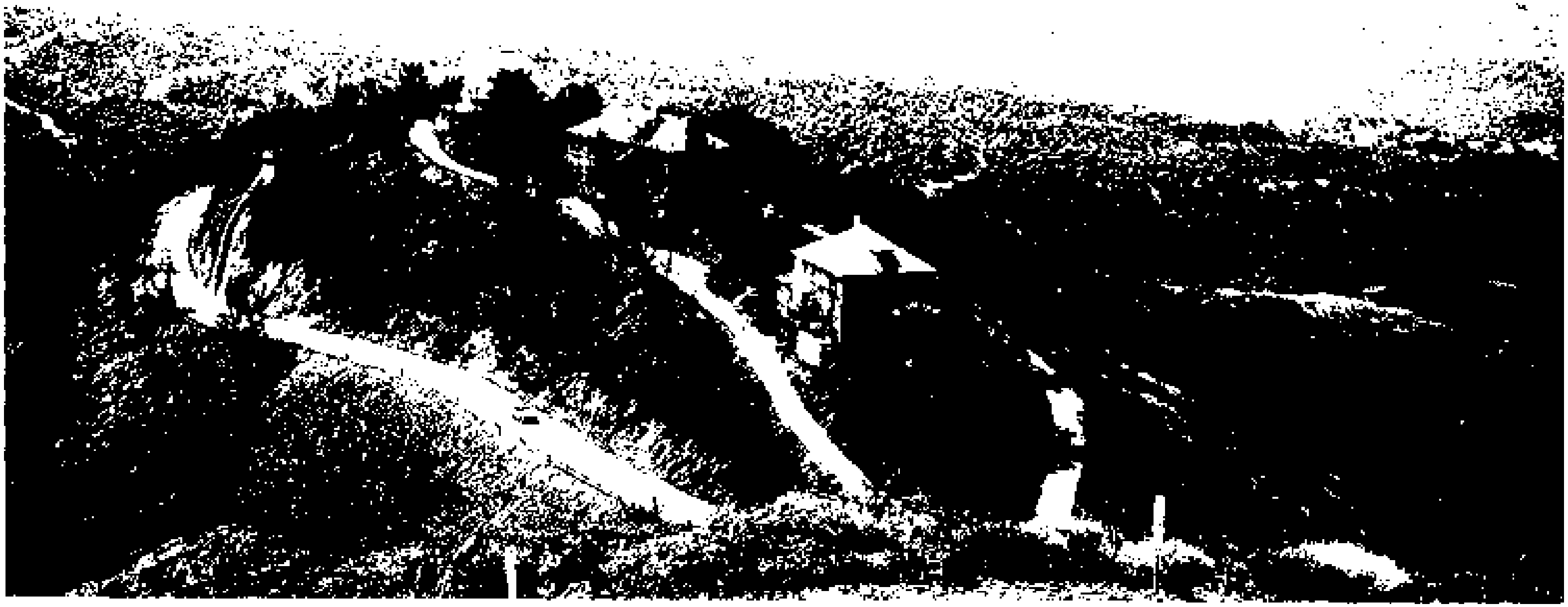

Lick Observatory, Mount Hamilton, California

NPS Photo, 1961

JAMES DWIGHT DANA HOME, CONNECTICUT

Location: New Haven County, 24 Hillhouse Avenue, New Haven

Ownership: Dr. Kingman Brewster, Jr., President, Yale University

Significance

James Dwight Dana transformed geology from an investigation of individual rocks and minerals into a study of the earth's evolution. The work of this scholar stimulated the interest of legions of Americans in geology, as well as bringing him international fame as one of the world's major geologists. It was a remarkable accomplishment for the owner of the imposing house at 24 Hillhouse Avenue, New Haven.

Born in 1813 in Utica, New York, Dana manifested an early interest in geology. While attending the local high school, he accompanied a science teacher on field trips and began to collect minerals. When he entered Yale University, Dana's interest in geology was heightened as he sat in Benjamin Silliman's classes. Silliman, the first great teacher of chemistry and geology in America, was not forgotten when Dana became a tutor in mathematics to the midshipmen on board the U.S.S. Delaware in 1833, after being graduated from Yale. When the Delaware visited the Mediterranean, Dana continued his study of geology whenever he had the opportunity to land, and when he returned to New York in 1834 he carried off the ship a collection of rocks and minerals.

Once ashore in America, Dana quickly accepted an offer to become an assistant to Silliman. Although he analyzed rocks for his mentor and created some geological charts, Dana still had a lot of time at his own disposal. He used this opportunity to investigate the construction of minerals. Crystallography, as Dana's study was called, constituted a new branch of geology, and the young scientist soon made himself one of its leading adherents. His measurement of thousands of angles in crystals fathered his devising of a mathematical relationship between a crystal's angles and axes. To help himself in his work, he made glass models of crystals, an almost pioneering step in the Country. The culmination of his study appeared in 1837, when Dana, only twenty-four, published his System of Mineralogy. This work is a classic of its kind, and geologists still use it. In Dana's day, the book pleased the layman as well as the scientist, stimulating numerous amateurs to collect rocks and minerals.

The man who had written the surprisingly popular geological work was undistinguished, except for his mind. About five feet nine inches tall, Dana was slender, had deep blue eyes and brown hair, until it turned gray. Plain in his likes and forthright in his statements, Dana shunned public life; he only lectured to classes because he had to. He had a vigorous, questioning and flexible mind, however, and he never shrank from any problem. Most remarkable was his willingness to change his point of view on scientific matters, even if he had to modify or abandon some of his own ideas. Dana married a daughter of Silliman in 1844, and then erected his house on Hillhouse Avenue.

Although firmly established as a geologist by 1837, Dana's evolutionary, world-wide concept of geology only developed during his participation in the Wilkes Expedition of 1838-42. Sponsored by the United States and led by Lieutenant Charles Wilkes, the expedition covered a large part of the globe's surface in its quest for scientific information. Dana had a splendid opportunity to study geological matters. When the trip was half over, Dana in June, 1840, wrote from the Fiji Islands that the natives were cannibals and preferred roasted white men. More important, he said that he had made almost a hundred drawings of caverns, craters, mountains and rock formations. Moreover, he had collected numerous fossils. After the expedition's return to the United States, Dana spent ten years in producing his reports. The very nature of the reports, one on zoophytes in 1846, then one on geology and a final one on crustacea in 1854, shows how Dana's point-of-view had been broadened. The reports appeared in beautiful volumes, but in such limited quantities because of Congress' parsimony that Dana did not receive copies of them.

Dana's appointment as the Silliman professor of natural history and geology at Yale in 1849, which position he held for almost fifty years, did not impede his work. Not only did he complete his reports of the Wilkes Expedition, but in 1862 he published his <u>Manual of Geology</u>. In this book Dana pictured geology as a vast, global experience, showing from the beginning of time how the interaction of air, water, heat and pressure underlay the evolution of the earth. He had thus travelled far beyond a mere commentary on individual rocks and minerals; he told how mountains, valleys, plateaus and plains had been formed. Subsequently, his <u>On the Origin of Continents</u> and <u>Corals and Coral Islands</u> explained the formation of mountains and coral reefs respectively. His interest and desire to learn never flagged, and when seventy-four he took his family to Hawaii to show them the island's volcanoes. There the natives called him "the rock-breaking medicine man."

When a man's age prevents him from learning, Dana maintained, then it was time for him to die. But even Dana found it difficult to accept the theories of Charles Darwin. Not because his mind had fossilized, but because his Puritan heritage opposed a mechanistic explanation of man's development. As the years passed, however, Dana accepted more and more of Darwin, finally agreeing with the Englishman's concept of man's rise. Dana always maintained, though, that a divine act began the origin of man.

When he died on April 14, 1895, Dana left behind 215 published works, a legacy of faithful teaching and a new concept of geology. All of this entered the mainstream of American science, enriching it in a seldom equalled fashion.

Present Condition

Henry Austin, a prominent New Haven architect, designed the house that Dana built in 1849. The two-story, stone building, covered with a cream-colored plaster, followed the Italian or Tuscan style. Its flat, overhanging roof, was topped with a low cupola.

Inside, the high-ceilinged, spacious rooms reflect the era of the house's construction. Large windows provide a maximum of daylight. Beautiful parquet floors are still extant, as is most of the other decorative detail.

The building now houses the Department of Industrial Administration of Yale University. Only minor changes, such as the boarding-up of some fireplaces, have been made since Yale acquired the house in 1962.

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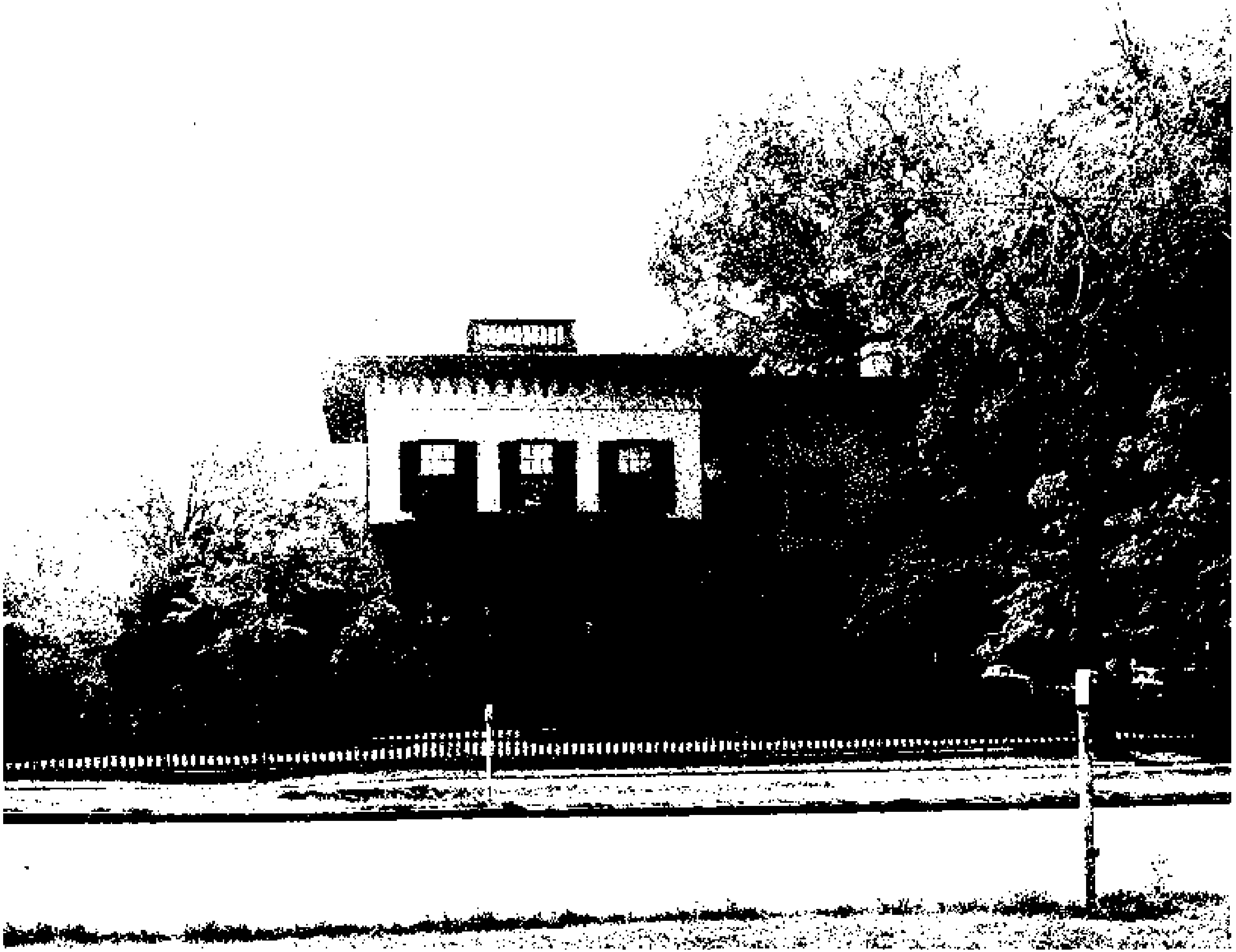

James Dwight Dana House, New Haven, Connecticut

NPS Photo, 1961

OTHNIEL C. MARSH HOME, CONNECTICUT

Location: New Haven County, 360 Prospect Street, New Haven

Ownership: Dr. Kingman Brewster, Jr., President, Yale University

Significance

The stupendous skeleton of a Brontosaurus Excelsus Marsh in the Hall of Invertebrates at the Peabody Museum of Natural History in New Haven dwarfs human beings. This gigantic sauropod dinosaur lived eons ago, and it has been only within the last century that knowledge of it and other archaic creatures has been augmented. Much of the credit for our familiarity with antediluvian animals belongs to Othniel C. Marsh, after whom the brontosaurus in the Peabody Museum was named. Moreover, Marsh not only discovered and studied an incredible number of vertebrate fossils, he pioneered in reconstructing the skeletons of ancient beasts, reptiles and birds. He, more than any other American, startled both the scientist and average citizen into a greater awareness of the significance of the primeval animal world.

Marsh, who became the New World's first professor of Paleontology, developed a passion for fossils in his youth. Born on October 29, 1831, he collected minerals and fossils as a boy. After entering Yale University, he traveled in New York, New England and Nova Scotia during his summer vacations, searching for fossils. His second trip to Nova Scotia produced the fossil of an unknown vertebrate, and this discovery confirmed his determination to follow a scientific career. Marsh won his diploma in 1860; for the next four years he pursued advanced work, both at Yale and abroad. The university then appointed Marsh Professor of Paleontology.

The young professor possessed physical and mental strength, as well as wealth. Of medium height, Marsh had a solid, robust build, which stood him in good stead on his collecting expeditions. His good humor and thoughtfulness also aided him on his field trips. But beneath his friendliness lay a steel-like will, which propelled Marsh on an individual course in his work with ancient vertebrates and caused him to disdain cooperating with others. A celebrated feud with a rival paleontologist, Edward Drinker Cope, resulted. The two resolute specialists, like embattled dinosaurs, fought each other fiercely, to their discredit and the disadvantage of science. At the same time, Marsh spent his own funds in a lavish manner on his work. Moreover he induced his wealthy uncle, George Peabody, to establish the Peabody Museum at Yale, now one of the Nation's major museums of natural history.

Soon after joining Yale's faculty, Marsh inaugurated his collecting. He led the first Yale Scientific Expedition to the American West in 1870, largely underwriting its costs. The thirteen members of the group, plus its military escort, roamed in Nebraska, northern Colorado, Wyoming and California. Because Marsh encouraged Indians to bring in bones, he became known as the "Bone-Medicine man." This trip and later expeditions in the 1870's produced quantities of bones and led to some major discoveries. Fossils of birds with teeth (heretofore unknown), of niosasaurs or sea serpents, and of winged reptiles, toothless pterodactyls, were found. Although these fossils startled America, the Country was little prepared for the massive flow of dinosaur bones to New Haven that began late in the 1870's.

Marsh, who had not originally intended to concentrate on dinosaurs, became enamored with them in 1877. When he received in that year a letter describing deposits of dinossaur bones in Wyoming, Marsh sent an assistant to investigate. And when the assistant wrote that at Como Bluff, Wyoming, dinosaur bones lay in tons over a seven mile area, Marsh became a modern victim of the long-dead reptiles. Under his direction, digging at Como Bluff lasted until 1892. He insisted upon extreme care and thoroughness in collecting, with the result that bones reached New Haven in excellent condition. Moreover, Marsh's demand that nothing be overlooked, produced remarkably complete specimens. As box after box of bones reached Yale, the rapturous Marsh was able to describe one new dinosaur after another, until at the end he had written of eighty new kinds of dinosaurs and thirty-four new genera.

Fascinating as they were in themselves, the fossil birds, reptiles and animals that Marsh dug from the ground also gave incontrovertible support to Charles Darwin's theory of evolution. A convinced believer in evolution himself, Marsh's discoveries dismayed many an opponent of Darwin's revolutionary theory. Darwin's foes, for example, had pointed to the difference between reptiles and birds in discounting evolution. But Marsh's finding of cretaceous birds in 1872-73, with their teeth and other reptilian characteristics, had illustrated the genetic similarity between the two families. In addition, the paleontologist's amazing collection of fossil horses illustrated the evolution of the horse from about the size of a fox to that of an ass.

Marsh's tremendous energy did not fail him until his death on March 18, 1899. Because of the overwhelming collection of bones at Yale and his other activities, he did not publish as much as he had hoped to do. Nevertheless, his contributions to paleontology guide his successors in the scientific world today.

Present Condition of the Site

Marsh began constructing his home in 1876 and completed it in 1878, although the interior was not fully finished until 1881. The building cost about $30,000, as did its furnishings. The structure is a massive, three-story brownstone building, with a tower. Inside there are eighteen rooms, the most interesting of them being the octagonal reception room. Marsh especially enjoyed this room, which he called his "Wigwam," and he filled it with mementoes of every kind. As he never married, Marsh lived in the house in lonely grandeur.

The Yale Forestry School occupies the building, known as Marsh Hall, today. Its rooms are used as offices and classrooms, but the building remains largely as Marsh erected it. The fireplaces, corner cupboards and dark, heavy woodwork are untouched. Marsh's "Wigwam" is now empty, but it still reflects the spirit of the builder.

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Othniel C. Marsh House, New Haven, Connecticut

NPS Photo, 1967

ELI WHITNEY ARMORY SITE, CONNECTICUT

Location: New Haven County, Mill River Dam, Whitney Avenue, Whitneyville

Ownership: Mr. Arthur L. Corbin, Jr., President, New Haven Waterworks, 100 Crown Street, New Haven

Significance

There is general agreement that few men have equalled Eli Whitney's influence upon American History. A machine of his, the cotton gin, spurred the rise of a cotton economy in the ante-bellum South at the very same time that his successful development of the idea of the standardization of parts stimulated the industrial growth of the North. Subsequently, the two sections met in battle, with the North and industrialism triumphing. Whitney is a man we cannot ignore, then, even if little more than the site of his armory in Whitneyville remains.

When Whitney was born on December 8, 1765, no one would have dared to predict that he was fated to change "the ethnological, economic, political, ethical and industrial face"[1] of America. It is true that as a youth he possessed a strong mechanical bent, doing such widely desperate jobs as repairing violins and constructing a forge to make nails. But his parents, suspicious of college and the supposed dissolute ways of students, restrained him from entering Yale until 1789, when he was twenty-three. Fortunately, his late entrance did not abash him, and Whitney obtained his degree in September, 1792. Shortly thereafter, he sailed to South Carolina, to take a tutoring position.

Once in South Carolina, he abandoned the tutoring job; instead, he invented the cotton gin. Intrigued by endless talk about the need for a machine that would really clean cotton of its seeds, Whitney decided to invent that machine. By June, 1793, he had accomplished his goal. Whitney's gin's great innovation consisted of a revolving cylinder, with hook-like spikes, that tore the cotton away from a stationary breastwork.

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[1] Roger Burlingame, March of the Iron Men (New York, 1940), 170.

The possibilities of the gin, especially when water-powered, struck both Whitney and the planters. While the inventor returned North to secure a patent and establish a gin factory, the planters began to make their own gins. Whitney soon took on a Southern partner; and the partners planned to build gins and charge for their use, not sell the machines. But early in 1795 Whitney's New Haven factory burned; and by 1796 Whitney and his partner had been forced to take legal steps in the South to protect their interests. Whitney soon discovered, however, that Southern courts were not too interested in upholding his patent. Georgia courts in particular aroused little enthusiasm in Whitney, and at one time he said:

> I have a set of the most Depraved villains to combat
> & I might as well go to Hell in search of Happiness
> as apply to a Georgia Court for Justice.[2]

The legal struggle continued for years, in other Southern States as well as Georgia, and most of the profits were consumed by legal expenses. Despite Whitney's small profit from the gin, the machine greatly stimulated cotton production. So much so, that the South grew over 2,000,000,000 pounds of cotton in 1860 versus a production of 1,500,000 pounds in 1790.

Whitney's persistence in pursuit of justice in the South highlights a vital aspect of the man's character. He had a determination that quailed before no difficulty. When working on a project, he became immersed in it, even going without food or sleep. If this dedication failed to redeem his interest in the gin, it paid off handsomely when he established his armory. Aside from machinery, Whitney was interested in little else. He paid no attention to political or social problems, and although he attended church, displayed no passionate concern with religion. Perhaps his concentration on machines helps to explain his late marriage in January, 1817, to Henrietta Edwards, who at thirty-one was Whitney's junior by twenty-one years.

Whitney's frustration from the battle over the gin did not deter him from applying his mechanical genius to a new undertaking in 1798. And, in writing to the Secretary of War on May 1 and offering to make ten or fifteen thousand stands of arms, Whitney probably realized

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[2] Quoted in Jeannette Mirsky and Allan Nevins, The World of Eli Whitney (New York, 1952), 1962.

that he would not be hampered by competition. There were no arms factories in the United States at that time.[1] It is obvious that Whitney had carefully developed his plans for an armory, because his offer to produce at least ten thousand muskets in two years was astounding. After all, each musket produced at that time was an individual, handmade item. Nevertheless, Oliver Wolcott, who headed the War Department and who was alarmed by a threat of war with France, entered into a contract with Whitney on June 14, 1798, for the production of ten thousand muskets within two years.

The amazing contract fathered Whitney's armory at Whitneyville and the first successful use of machines in mass production. It took Whitney over ten years to complete his first Federal contract, rather than two, but by the end of that decade he had created the jigs, machines and production methods that made the mass production of standardized parts possible. His second Government contract in 1812 for fifteen thousand muskets heralded the dawn of a new industrialism, for Whitney fulfilled the contract within two years.

The New Haven genius had not been the first to think of the production of interchangeable parts. But he successfully applied the principle for the first time. It is also worthwhile to note that Whitney's approach to manufacturing was all inclusive. He, for example, in determining production costs not only included the obvious expenses, but also the interest on the invested capital and the cost of insurance. Moreover, he built the first mill town in America at his plant for his employees.

Whitney, now affluent, died on January 8, 1825. One of America's most brilliant sons, his legacy will never be forgotten.

Present Condition of the Site

The site of Whitney's armory is about all that remains of his arms factory. Part of Whitney's dam across Mill River has been incorporated into the present dam, and the foundations of some armory buildings are extant. A small stone building stands on the site, and it is purportedly a survivor from Whitney's day. Further research on that structure is necessary, however, to substantiate that theory.

The New Haven Waterworks has several buildings on the site. One is used by a small manufacturing concern.

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[1] Whitney's Armory began production in 1800; the U.S.Springfield Armory in 1795, and U.S.Armory at Harpers Ferry in 1801.

References: Roger Burlingame, March of the Iron Men (New York, 1940); L. Sprague de Camp, The Heroic Age of American Invention (New York, 1961); Constance McL. Green, Eli Whitney and the Birth of American Technology (Boston, 1956;) Jeannette Mirsky and Allan Nevins, The World of Eli Whitney (New York, 1952); Dirk J. Strink, Yankee Science in the Making (New York, 1962).

The Eli Whitney Armory about the time of the Civil War.

Courtesy, Olin-Mathieson Chemical Corporation

Only extant building of Whitney Armory, Whitneyville, Connecticut

Courtesy, Olin-Mathieson Chemical Corporation

DR. EPHRAIM MC DOWELL HOUSE, KENTUCKY

Location: 125-127 S. Second Street, Danville, Kentucky

Ownership: Kentucky Medical Society

Significance

Ephraim McDowell established medical practice in early Danville, Kentucky after having studied under Dr. Alexander Humphrey of Virginia and in Scotland at the University of Edinburgh and with the brilliant private teacher, John Bell. He did not study at the University long enough to earn a degree, but he gained a broadened understanding of the medicine of that day and particularly of anatomy and surgery.

In Danville, McDowell collected an excellent library. He was always a student and, with the young men studying in his office, carried on dissections during each winter. Very soon he had established a reputation as the best surgeon west of Philadelphia. McDowell was not only a skilled operator, but possessed all the higher attributes which made up the character of a great surgeon--intense conscientiousness and a scrupulous regard for the welfare of the patient.

In December of 1809, McDowell's skill faced a serious challenge when he was called to aid Mrs. Thompson Crawford. Two local doctors told McDowell that Mrs. Crawford was pregnant; he soon realized, however, that she was suffering from an ovarian tumor. Eminent surgeons then uniformly held that such was the danger of peritoneal inflammation that opening the abdomen to extract the tumor was inevitable death. They believed that exposing the inner wall of the abdomen invariably produced fatal infection. At that time the dressing of wounds, amputations, and care of broken bones and sprains, stones, ruptures, and tracheotomies covered the whole scope of surgery. Surgeon did not dare invade the great cavities of the body. Some doctors had discussed the possibility of excising tumors, but no surgeon had ever been willing to hazard such an operation.

Dr. McDowell discussed these facts with his patient and pointed out, however, that removal of the tumor was her only hope. He agreed that if she were prepared to face the risk of death, that he would remove the tumor. Mrs. Crawford accepted and was removed to the McDowell home in Danville where there were facilities and assistance.

Although he faced stubborn opposition in Danville, Dr. McDowell and his nephew performed the operation on Christmas Day. The operation was successfully completed, but the real danger still lay ahead. Would the patient develop the deadly infection, peritonitis? Mrs. Crawford's

convalescence was brief and within twenty-five days she resumed the active life of a pioneer housewife. She remained in excellent health until her death at the age of seventy-nine.

McDowell's operation was one of the most important in the history of surgery; his cure for the usually fatal ovarian tumor was only a small part of his discovery. Even more significant was his demonstration that the abdominal cavity could be cut into safely. This operation was a forerunner of a major part of modern surgery; its success combined with the revival of Caesarian sections to destroy a false taboo and blaze the way for other surgeons.[1]

Recognition of McDowell's work was slow in coming. McDowell waited seven years, until he had operated three times successfully, before publishing anything on his discovery. He then published an inadequately written account in an obscure journal. The result was adverse criticism at home and abroad. A subsequent article in the same journal, written after two additional operations, hardly improved the situation. Finally, a report addressed to his old Edinburgh teacher, John Bell, was published by John Lizars in the Edinburgh Medical and Surgical Journal for October 1824, seven years after it was first written. In 1827, the University of Maryland conferred on him the honorary degree of doctor of medicine. McDowell is considered today to be "the father of abdominal surgery."

Present Condition of the Site

The Kentucky State Medical Association has bought and restored the McDowell home to its original state. The women's auxiliary of the Society has completely refurnished the home in authentic period pieces, and has secured many McDowell papers and personal items. Of especial interest is the small bedroom on the second floor above the dining room. This is the room in which it is believed the operation was performed.

Adjoining the house is the McDowell Apothecary Shop. In 1795, Dr. Ephraim McDowell and Dr. Adam Rankin started the practice of medicine in this small two-room brick building. Two years later, they purchased the building, and it was used by them or their successors as an apothecary shop continuously until 1856. The back room was the doctor's office and the front room was operated as a physician-owned apothecary shop. An apprentice to Doctors McDowell and Rankin prepared medicines for their patients.

The Apothecary Shop has been furnished with a collection of 18th and early 19th century apothecary equipment and products.

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[1] James T. Flexner, Doctors on Horseback, Pioneers of American Medicine (New York, 1937), 130.

The house and shop are open daily under the auspices of the McDowell House Committee of the Kentucky State Medical Association.

References: "Ephraim McDowell," Dictionary of American Biography, XII (New York, 1946); James T. Flexner, Doctors on Horseback, Pioneers of American Medicine (New York, 1937); Frank J. Jirka, American Doctors of Destiny (Chicago, 1940).

Dr. Ephrain McDowell House, Danville, Kentucky

NPS Photo, 1963

ARNOLD ARBORETUM, MASSACHUSETTS

Location: Suffolk County, Jamaica Plain, Boston

Ownership: Dr. N. M. Pusey, President, Harvard University, Cambridge

Significance

The Arnold Arboretum is America's pre-eminent institution for research in ligneous plants. Charles Sprague Sargent, one of the Nation's foremost silviculturists, guided the development of what was originally intended to be a modest tree farm for Harvard University for half a century, making the arboretum what it is today. As a result, the arboretum is a thing of beauty to see and an invaluable fount of information for the study and propagation of woody plants.

James Arnold, a successful and public-spirited merchant of New Bedford, provided the means for creating the arboretum. Upon his death in 1868, Bedford bequeathed $100,000 for study and research in either agriculture or horticulture. Two of the trustees of Bedford's estate, both of whom deeply appreciated the beauty and value of trees, thought that the bequest should be used to establish a tree farm, where the scientific study of trees could be pursued. Through their efforts, Bedford's fund was presented to Harvard University on March 29, 1872, with the understanding that the university develop a tree farm, to be called the "Arnold Arboretum."

The development of the arboretum proved to be a more difficult task than anticipated, and without Sargent perhaps much less would have been achieved. When Harvard appointed Sargent as director on November 24, 1873, the young man, he being only thirty-two, apparently possessed no particularly obvious qualifications for the job. He had been graduated from Harvard in 1862, had served in the Civil War, had traveled in Europe, had done some additional studying and had married Mary Allen Robison only two years prior to his appointment. He had not impressed others with his scholarship, nor had he published any scientific papers. But this tall, reserved and persistent young man had now found his calling, and he became a superb administrator and scholar.

Sargent said of his early years with the arboretum, that no one had at first realized the challenge facing them, especially "the man selected to carry out the provisions of this agreement

/Bedford's legacy/."[1] But Sargent soon realized that the income from the trust would not be sufficient to develop and maintain a tree farm. The imaginative director then turned his eyes toward the City of Boston. Fortunately, Frederic L. Olmsted, the creator of New York's Central Park, was then working on the Boston Park system, and he and Sargent joined forces in a campaign to gain the city's help in establishing an arboretum. Olmsted, spurred by his unfailing vision, conceived of an artistically designed arboretum as forming the esthetic highpoint of the city's park system.

The crusaders fought for nine years. Finally, an agreement signed by Boston and Harvard on December 30, 1882, signified their triumph over the opposition of "town and gown," and public apathy. According to the pact, Boston received the title to the land in Jamaica Plain intended for the tree farm and then leased it back to the university for a thousand years, for a rental of one dollar a year. Looking to the future, Harvard reserved the right to renew the lease for another thousand years when the original period expired. The city also agreed to install walkways and drives, and Harvard agreed that the arboretum would form part of the park system and would be open to the public. The original 120 acres were also added to; today, the arboretum covers about 260 acres.

With the agreement with Boston signed, Sargent could concentrate on developing the arboretum. A basic desire on the part of the university guided him in this work, i.e. to grow a specimen of every kind of tree and shrub able to thrive in eastern Massachusetts. Through purchase and exchange many specimens were gained, but it soon became evident that Sargent would have to seek out plants for the arboretum. As a result, travel in search of woody plants carried Sargent and his staff throughout the United States and the Far East. It was in the Far East in particular that they found numerous plants which could grow at the arboretum, and expeditions to Japan and China supplied numerous varieties for the tree farm. Laborers planted the specimens in groups of species, and within species by families. As the farm's varied landscape, which included hills, meadows and brooks, was planted, Sargent also made every effort to make the arboretum esthetically appealing.

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[1] Quoted in Samuel E. Morison (ed.), The Development of Harvard University Since the Inauguration of President Eliot, 1869-1929 (Cambridge, 1930), 359.

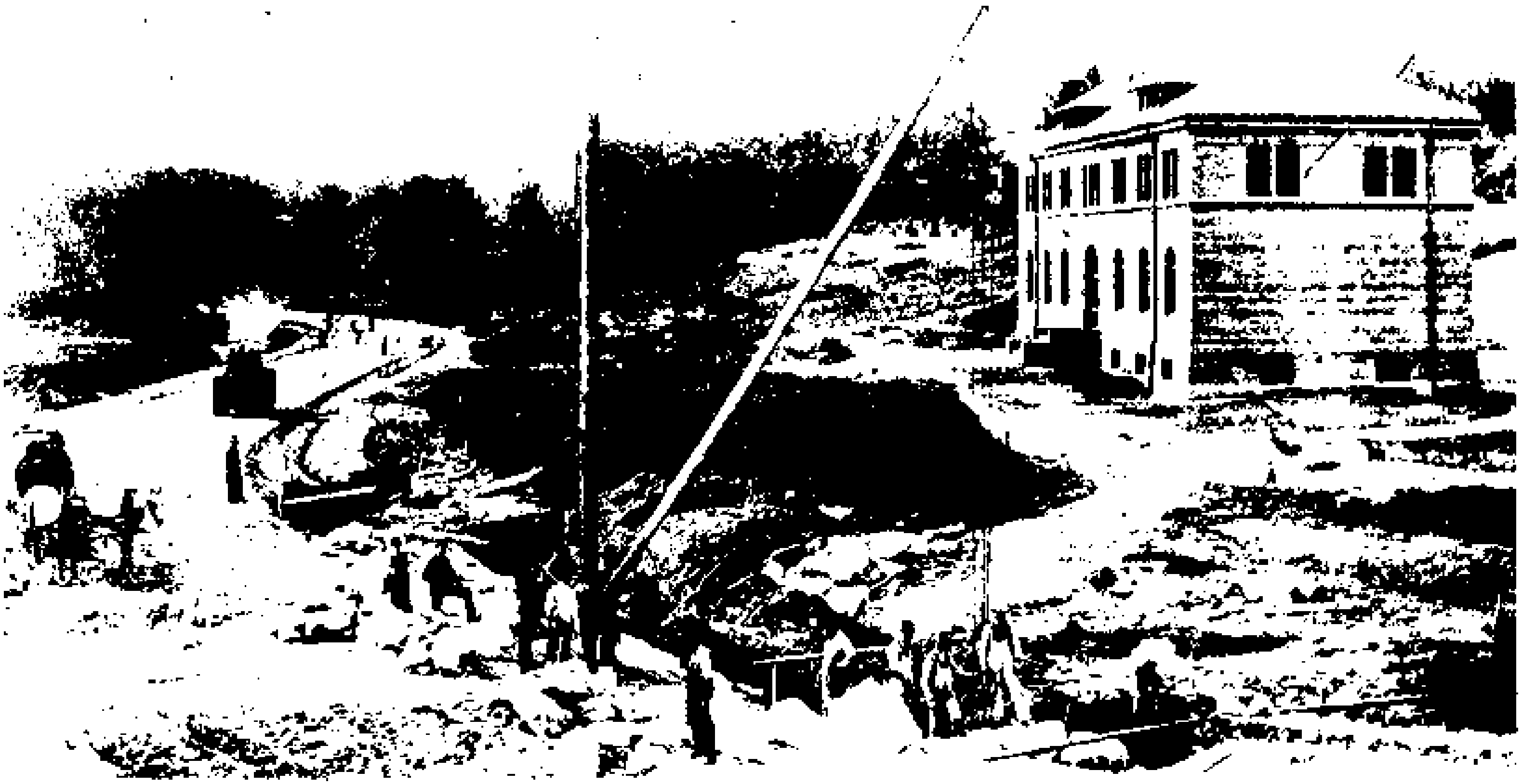
While creating the arboretum, Sargent never forgot its research aspect. He began to test woody plants immediately in order to determine which were suitable for the climate. By the time of his death in 1922, the farm had grown 1,286 plants for the first time. As the years passed, Sargent also built up a library, using his own botanical collection as a start. He also developed a herbarium, now of inestimable value in research. Moreover, in the course of his directorship, Sargent produced scores of articles and several monumental works. His Silva of North America stands as his masterpiece. This work, issued in fourteen volumes, describes and illustrates every species and variety of tree known to exist in North America north of Mexico.

Despite the value of his publications, Sargent's real monument is the Arnold Arboretum. And since his death in 1922, the arboretum has continued to grow and serve, reflecting Sargent's drive and scientific dedication.

Present Condition

The Arnold Arboretum now occupies 265 acres of hilly land in Jamaica Plain. Over six thousand different kinds of shrubs and trees cover the ground, with each plant bearing a label that gives its common and scientific name, age and origin. Paths run throughout the arboretum, and visitors are welcome to walk in the arboretum. Automobiles may be used only by obtaining a special permit at the administration building.

References: /Arnold Arboretum/, "The Arnold Arboretum," (n.p., n.d.); Hans Huth, Nature and the American (Berkeley, Calif., 1957); Harvey B. Humphrey, Makers of North American Botany (New York, 1961); Samuel E. Morison (ed.), The Development of Harvard University Since the Inauguration of President Eliot, 1869-1929 (Cambridge, Mass., 1930); Charles Sprague Sargent, The Arnold Arboretum ( ); William Trelease, "Charles Sprague Sargent," Biographical Memoirs, National Academy of Sciences (Washington, D. C., 1929).



Construction of Arnold Arboretum Administration Building, 1890, Boston, Massachusetts

Courtesy: Arnold Arboretum

Arnold Arboretum Administration Building today, Boston, Massachusetts

NPS Photo, 1963

Charles Sprague Sargent, Director of the Arnold Arboretum, 1873-1922

Courtesy: Arnold Arboretum

ASA GRAY HOUSE, MASSACHUSETTS

Location: Middlesex County, 88 Garden Street, Cambridge

Ownership: Mr. Gardner Cox, 88 Garden Street, Cambridge

Asa Gray, who was largely self-taught, survived torpedoes exploded by his pupils in his classes at Harvard, brought international luster to American botany, and stoutly defended Charles Darwin's Origin of Species in the United States, deservedly ranks as one of this Country's leading scientists.

Born of parents of English and Scotch-Irish background in Sanquoit, New York, in 1810, Gray acquired an interest in botany as a youth. Then, while attending a small medical college, he read The Edinburgh Encyclopaedia's lengthy article on botany during the winter of 1827-28. That article greatly stimulated his botanical interest; especially as it said that much needed to be done in North American botany. Gray's medical studies furthered his appreciation of botany, and before his graduation in 1831 he had already begun to collect plants. An established botanist, John Torrey, of New York, learned of the young doctor's botanical work and asked Gray if he would like to be his assistant. Gray assented, and medicine lost a promising adherent.

Gray made rapid progress in his new profession. Largely influenced by recent European developments in botany, there not even being an American work on this Country's flora, Gray boldly adopted the natural system of classification. Briefly, this system sought to establish the relationship of plants according to the similarity of their various parts. He thus spurned the long-used Linnaean system, which identified plants by the number of stamens and styles that each had. In 1836, he published his first book, Elements of Botany. Two years later, in conjunction with Torrey, Gray published the first part of the Flora of North America. This volume, plus the succeeding volumes, gave America its most notable compendium of known plants in the travelled areas of the continent. In the same year that the first volume of the Flora appeared, 1838, Gray accepted a teaching position at the University of Michigan. Fortunately for him, the university sent him abroad for a year, where he visited botanists and botanical collections. While in England he met Darwin, but discerned no greatness in the British botanist at that time.

Three years after his return to America in 1839, Gray assumed a professorship of botany at Harvard University. He held that position for forty-five years. In 1842, Gray was only thirty-two. Very slender, he weighed but 135 pounds, had a nervous energy, and always seemed to be running rather than walking. He was not an inspiring teacher. Indeed, each pupil knew his routine, even to the point of knowing when and for what Gray would call upon him. It was in Gray's early days at Harvard that some of his students enlivened affairs by setting off firecrackers in his classroom.

A prodigious worker, Gray's years at Harvard witnessed his rise to eminence in botany. As expedition after expedition sent new specimens to Cambridge, Gray and his assistants pounced on them, classified them and gave them names. Gray, at the same time, produced many books, his two volume work, The Genera of the Plants of the United States, in 1849 constituting a brilliant achievement. The work contained plates of plants by Isaac Sprague, which remain models of effective plant illustration, and descriptions of those plants by Gray. In 1858, he published How Plants Grow, a volume that sent many a child into the fields to collect plants. In addition to the preceding, Gray established an acquaintance, by correspondence if by no other means, with as many American and European colleagues as possible. Never one to hide his findings, Gray, in an unusually cooperative manner, readily shared his knowledge with others.

Perhaps Gray's most original contribution to the science of botany was his discovery of the relationship between the flora of eastern North America and east Asia. The publication of his Statistics of the Flora of the Northern United States in 1856 proved the geographical relation of plants in Asia and America. This discovery led to the rise of a new aspect of botanical study, plant geography.

Gray, in addition to his notable botanical work, ably served science in general when he led the defense in America of Darwin's bitterly attacked Origin of Species. Admirably equipped to do so because of his scientific standing, his personal leadership in his field, and his well-known religious feeling, Gray, who admired Darwin's willingness to acknowledge questions about his work, spoke forthrightly in behalf of truth in science. Reviewing Darwin's book in The American Journal of Science in March, 1860, Gray emphasized the value of science for science's sake. He wrote as if science and religion had no relation to each other. Personally committed to most of Darwin's views, Gray really pled for scientific

freedom. The Britisher valued Gray's efforts highly, and after Gray had begun a series of articles in the Atlantic Monthly in July, 1860, in support of Darwin, the evolutionist praised Gray's defense of the Origin of Species.

Because of his defense of Darwin, as well as because of his own work in botany, Gray remains one of America's notable scientists. His death on January 30, 1888, ended a chapter in our Country's scientific history that was rich in accomplishment and humanity.

Present Condition of the Site

Gray's house is a commodious, two-story, clapboard building, which was built in 1810. The structure has been moved from its original site on Garden Street to its present location. A white pilaster at either end of the front of the building, plus a white balustrade on the roof, add a striking note to the brown house.

The interior of the main section of the house has been apparently little changed since Gray's day. The main stairway, woodwork in the rooms, and fireplaces all seem original. A large room on the right as one enters the house was apparently Gray's study. This room still contains dark brown floor to ceiling cupboards.

The house is only in fair condition. Some of the exterior woodwork has decayed and the building needs to be painted. It is not known if a studio to the rear of the house is an original section of the building.

References: A. Hunter Dupree, Asa Gray, 1810-1888 (Cambridge, Mass., 1959); Harry Baker Humphrey, Makers of North American Botany (New York, 1961); Jane Loring Gray (ed.), Letters of Asa Gray (2 vols., Boston, 1894); William Irvine, Apes, Angels, and Victorians (New York, 1955); Samuel Eliot Morison (ed.), The Development of Harvard University Since the Inauguration of President Eliot, 1869-1929 (Cambridge, Mass., 1930); Dirk J. Struik, Yankee Science in the Making (New York, 1962); William Trelease, "Charles Sprague Sargent," in Biographical Memoirs, National Academy of Sciences, (Washington, D.C., 1929).

Asa Gray House, Cambridge, Massachusetts

NPS Photo, 1965

HARVARD COLLEGE OBSERVATORY, MASSACHUSETTS

Location: Middlesex County, Cambridge 38, Massachusetts

Ownership: Dr. N. M. Pusey, President, Harvard University

Significance

President John Quincy Adams lamented in his annual message to Congress in 1825 that America possessed no observatories, no "lighthouses of the skies." But before the passage of too many years, several observatories were erected. Of them all, the Naval Observatory in Washington and the Harvard College Observatory in Cambridge were the outstanding ones, with the Harvard "lighthouse" playing a primary role in the rise of American astronomy.

Many at Harvard College had always exhibited an interest in astronomy, and the desire to build a college observatory probably arose near the end of the eighteenth century. Subsequently, a makeshift observatory was established, but it proved unsatisfactory. Its inadequacy became clear in 1843, when a paucity of instruments prevented the observation of the treck of a comet. This failure was salutary, however, as it stimulated citizens in Boston, Salem, New Bedford and Nantucket to contribute $20,000 for a new observatory. This collection followed a donation of $5,000 by David Sears for the construction of a tower to house a great telescope.

William Crouch Bond, who became the new observatory's first director, supervised the building of the installation. An astronomer, and well-travelled, Bond relied upon his own experience and knowledge in supervising the observatory as it rose on a hill in Cambridge. A tower for the telescope occupied the center of the observatory. When the domed tower was completed, it had a height of thirty-three feet, but the base for the telescope, made of great granite blocks, extended twenty-six feet beneath the ground's surface. The pier's top carried a granite pedestal, weighing almost eleven tons, for the mounting of the telescope. On either side of the tower, known as the Sears Tower, sat two wings when the observatory had been fully completed in 1851.

While workmen in Cambridge erected the observatory, skilled artisans in Munich labored over a lens for the observatory's telescope. The group behind Harvard's observatory had decided upon a refracting rather than a reflecting telescope, and had placed an order for a fifteen inch lens with the same German firm that had built the refractor for Tsar Nicholas' observatory near St.Petersburg. In May, 1846, the English agents for Harvard visited Munich and chose one of the two lenses produced. As events proved, the agents had made an excellent choice, for the lens was of unsurpassed quality.

When the lens reached Cambridge in June, 1847 and was mounted, the public expressed great interest and enthusiasm, hoping for new discoveries in the heavens.

Bond, extremely proud of the new instrument, did not disappoint the new legions of amateur astronomers. In 1848, he discovered a satellite of Saturn and in 1850 an inner dark ring of the same planet, now known as "Bond's Ring." As a result of the foregoing, plus his study of stars, comets and other heavenly bodies, Bond won an international reputation for the observatory. Early recognition of his work had come in 1849, when the Royal Astronomical Society of Great Britain had elected him its first American Associate.

When Bond died in 1859, it was remarkable that he had accomplished what he had. Although zealous in his work, he had never been free of financial difficulties because of the meager budget the observatory had received from the university. A major result of the college's parsimony was that capable assistants seldom remained for long at the observatory.

Bond's successors maintained and enhanced the fame of the observatory. Edward C. Pickering assumed the directorship in 1876, and he recognized the possibilities of photography in astronomical work, some early efforts in that direction having already been made at Harvard. Thus he initiated a photographic study of the heavens. Under Pickering's direction, the observatory also began to create a library of celestial photographs, which now includes 200,000 original negatives, a unique collection.

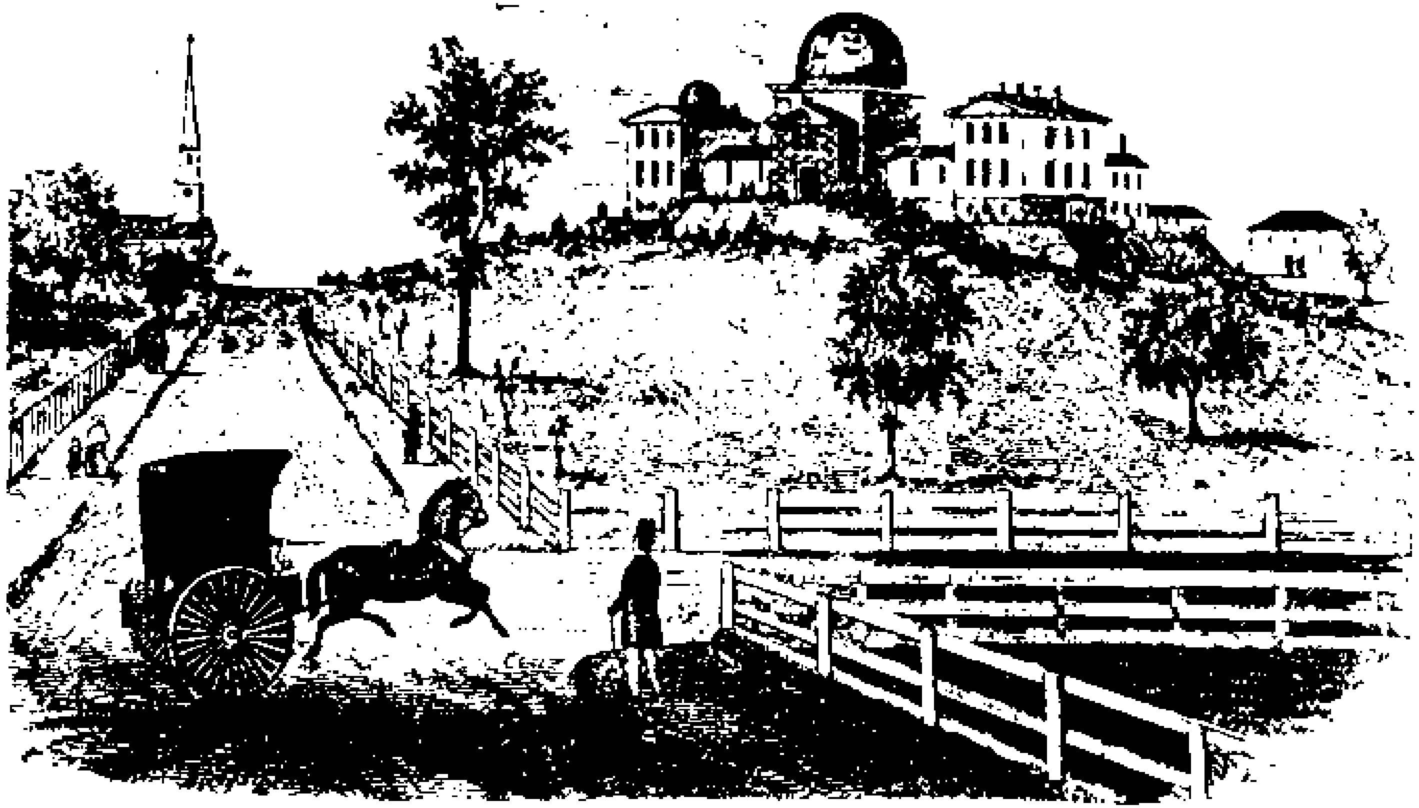
At the present time, the observatory's operations are world wide. With stations in various parts of the world outside of the United States, the observatory continues to probe the heavens in order to add to man's knowledge of the universe. Modern instruments and other developments have greatly decreased the value of the observatory's original telescope, but the refractor in the Sears Tower is a tangible link to the founding and early days of one of the world's notable observatories.

Present Condition

Sears Tower is all that remains of the original observatory. The tower is in excellent condition, however, as is the telescope in the dome. Indeed, the room in the dome is much like it was when Bond first began to peer at the heavens through the new refractor. Of subsidiary interest to the telescope is the observation chair, which Bond designed. The plush red chair, attached to the framework so that it could be moved, provides a startling note in an

otherwise somber room. An additionally interesting object is the cannonball that is on display, one of many which were used as ball bearings in the mechanism for the moveable dome.

References: Solon I. Bailey, The History and Work of Harvard Observatory, 1839 to 1927 (New York, 1931); /Harvard College Observatory/, "Toward Fuller Understanding of the Universe," (Cambridge, Mass., 1956); A. Pannekoek, A History of Astronomy (New York, 1961); James Stokley, Stars and Telescopes (New York, 1936).



Harvard Observatory about 1850. Only the center section with the dome remains today.

Courtesy, Harvard College Observatory.

Sears Tower, Harvard College Observatory, today

Courtesy, Harvard College Observatory.

"ETHER DOME," MASSACHUSETTS GENERAL HOSPITAL, MASSACHUSETTS

Location: Middlesex County General Hospital, 45 Milk
Street, Boston, Massachusetts

Ownership: Mr. Francis C. Gray, Chairman, Massachusetts
General Hospital

Significance

About 10:15 A.M., October 16, 1846, a surgeon in the operating dome of the Massachusetts General Hospital deftly began to remove a tumor from the neck of a patient. As the sure hands of the surgeon excised the growth, the male patient neither shrieked in agony, nor moaned in a pain-induced delirium. Amazed observers, doctors and students, watched. Two battered Egyptian mummies were silent witnesses. Pain, from before the time of the mummies and since, had always accompanied operations, but this operation opened a new era in medical history. As a result of having inhaled ether before the operation, the patient slept while the surgeon worked. Little wonder that the hospital's record of the operation says: "This case is remarkable in the annals of surgery."[1]

Man had long searched for a means to alleviate pain while patients were under surgery. Opium, hashish and alcohol had all been used, but without notable success. Doctors and patients continued to dread operations. Strangely enough, however, by the 1820's many people knew that both nitrous oxide and ether could cause unconsciousness; and as early as 1792 Sir Humphrey Davey had proposed using nitrous oxide in operations. Davey's suggestion went unheeded; instead, nitrous oxide (laughing gas) and ether became popular as a means of inducing jags. Ironically, it was the frivolous use of ether that caused Dr. Crawford W. Long, of Georgia, to notice that one felt no pain when "drunk" from ether. Struck by the observation, Long wondered if ether could be used during surgery, and in 1842 he successfully operated on a patient who had been put to sleep by ether. Long publicized neither this operation nor others of a similar nature, perhaps because talk of his discovery aroused fear in his neighbors. On the other hand, Dr. Horace Wells, of Hartford, Connecticut, sought to exploit his own success in 1844 in pulling a patient's tooth while he slept

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[1] Quoted in Francis R. Packard, The History of Medicine in the United States (Philadelphia, 1901), 478.

under the effect of nitrous oxide. Wells' attempt to arouse interest in his innovation failed. But a former partner of Wells' was to accomplish what neither Long nor Wells did, to prove to the world that pain could be ended in the operating room.

William Thomas Green Morton, who ended a partnership with Wells in 1843, established for all time the efficacy of ether during operations. Born in 1819 in Charlton, Massachusetts, Morton attended a dental college in Baltimore in 1840 and upon being graduated joined Wells in conducting a dental parlor. The undertaking failed to be profitable, so in 1843 Morton opened a dental office of his own in Boston and soon enjoyed a large practice. He also married Elizabeth Whitman in the same year. Despite his success as a dentist, he promised his bride's parents that he would give up dentistry for medicine and thus entered the Harvard Medical College.

While attending medical school, Morton continued his dental work. Having devised a new way of inserting false teeth, Morton sought to discover a painless means of pulling dead teeth. He experimented with various pain killing agents, but finally settled upon ether as the most effective one. On September 30, 1846, he not only put himself to sleep with ether, but also pulled a tooth from a patient put to sleep with gas. Excited by what he thought was an original discovery, Morton asked for an opportunity to use what he called his "preparation" at the Massachusetts General Hospital. Dr. John Collins Warren, the hospital's chief surgeon, acceded to Morton's request, and Morton was invited to participate in an operation at 10:00 A.M., Friday, October 16.

The domed chamber atop the central section of the hospital was filled with doctors and students by ten o'clock on Friday. Doubt about Morton's claims for his "preparation" played on the faces of most of those present, especially as at 10:10 Morton had still not arrived. Delayed by last-minute adjustments to his apparatus, Morton entered the room about 10:15, just as Warren had begun to proceed with the operation. Morton quickly moved to the patient, Gilbert Abbott, grasped one of his hands and assured Abbott that he would feel no pain. Seated in a chair, Abbott then began to inhale ether from a glass tube with a globe at its end and he fell asleep in about five minutes. Warren then operated. Visibly impressed upon the conclusion of the operation, and at the patient's statement that he had felt no pain, Warren said: "Gentlemen, this is no humbug."

Since the memorable operation in the "ether dome," man has been released from an age-old fear of operation. Or as Oliver Wendell Holmes said of Morton's use of ether,

> The fierce extremity of suffering has been steeped in the water of forgetfulness and the deepest furrow in the knotted brow of agony has been smoothed forever.[2]

Although the world rejoiced in the use of ether, Morton derived small practical benefit from his work. When forced to announce what his "preparation" was, the dentist became involved in a tragic quarrel involving himself and Wells, and to a lesser degree, Long. But Morton's real nemesis was Dr. C. T. Jackson, an erratic but brilliant scientist, who claimed he had told Morton about ether when Morton had attended his medical classes and whose virulent attacks helped cause Morton's death on July 15, 1868. Today, Long is credited with the first use of ether in an operation and Morton with proving to the world its value in surgery; but when a monument was given to Boston in 1868 commemorating the operation in the "ether dome," controversy swirling about Morton was still so violent that the donor thought it "wise to mention no names except the name of the Lord--the only safe one."[3]

Present Condition

The "ether dome" has hardly been changed since October 16, 1846. Located at the top of the central section of the hospital's original building (designed by Charles Bulfinch) and beneath a dome, the room is still used. It is hoped, however, that eventually the famous room will become a museum.

The room has a bare and utilitarian look. Two Egyptian mummies, the same that stood in the room in 1846, present the most unexpected note. A large part of the room is occupied by sharply rising tiers of seats, where students and others sit during lectures. Capping the room is the dome, through a section of which daylight can be admitted.

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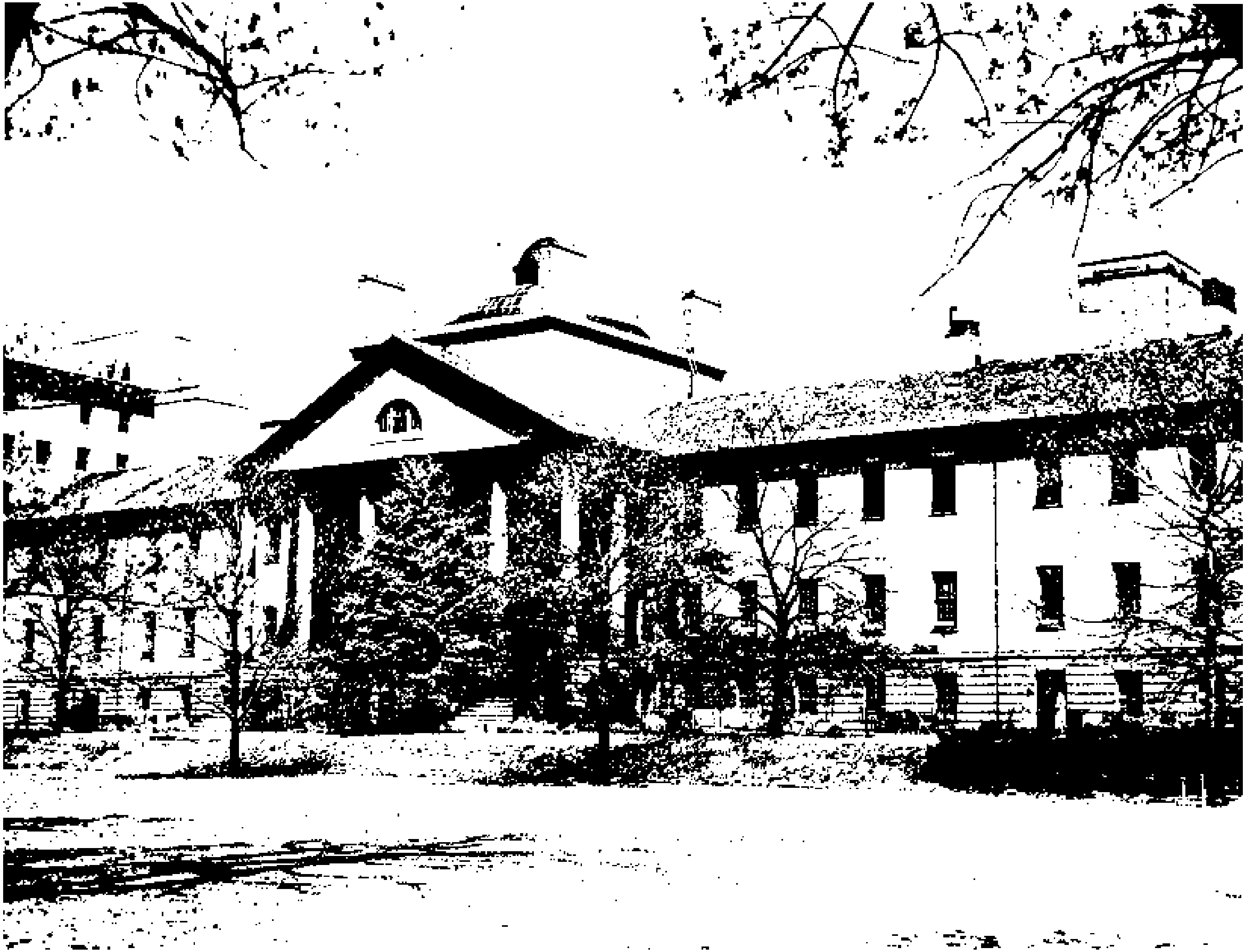
[2] Quoted in Joseph E. Garland, Every Man Our Neighbor (Boston, 1961), 14.

[3] Dirk J. Struik, Yankee Science in the Making (New York, 1962), 291.

References: James T. Flexner, "The Death of Pain," in Samuel Rapport and Helen Wright, *Great Adventures in Medicine* (New York, 1952); Joseph E. Garland, *Every Man Our Neighbor* (Boston, 1961); C. D. Haagensen and E. B. Lloyd Wyndham, *A Hundred Years of Medicine* (New York, 1943); L. J. Ludovici, *The Discovery of Anaesthesia* (New York, 1961); Francis R. Packard, *The History of Medicine in the United States* (Philadelphia, 1901); Dirk J. Struik, *Yankee Science in the Making* (New York, 1962).



Original Building of the Massachesetts General Hospital, Boston, Massachusetts

Courtesy, Massachusetts General Hospital

BENJAMIN THOMPSON BIRTHPLACE, MASSACHUSETTS

Location: Middlesex County, 80 Elm Street, Woburn

Ownership: Mr. Cecil R. Porter, President, Rumford Historical Association, 2 Poole Street, Woburn

Significance

America can claim few scientists who have rivaled Benjamin Thompson's analytical and creative ability. Even though he fled the Country during the American Revolution, this remarkable man is widely regarded as an American scientist. Moreover, Thompson's directness, determination and practicality stamp him as being much more American than European. Like a transplanted tree, he retained the inheritance of his birthplace.

The future Count Rumford of the Holy Roman Empire was born in Woburn, Massachusetts, on March 26, 1753. Upon the death of his father, about eighteen months after Thompson's birth, Thompson acquired a step-father, whom he despised. Poverty and hatred of his step-father hardened the youth, who became an apprentice to a Boston merchant in 1769. He lost that job in 1770, because of bad business conditions, and returned to Woburn. There, Thompson lived away from home, evidently did some teaching, and attended some classes at Harvard College. Several years later he moved to Concord (then Rumford), New Hampshire, to teach, where he met Sarah Rolfe, a wealthy widow, whom he married in November 1772. Two years after their marriage, the couple had a baby girl.

The American Revolution, as it did for so many others, changed Thompson's destiny. In Rumford, Thompson had won the favor of one of his wife's relatives, the pro-British governor of the colony, John Wentworth, who appointed Thompson as a major in a New Hampshire regiment. Subsequently, the young major fully committed himself to the King's cause, as by the summer of 1775 he had sent information to the British, had been tried for the same (which he had denied) and had decided to join the English. In October, 1775, he visited his wife for what proved to be a final time, and shortly thereafter sailed to England. When he returned to America in 1781, it was as a lieutenant-colonel in the British Army. In his new status, he conducted military operations in South Carolina and on Long Island, New York. After England acknowledged America's independence, the King knighted Thompson in 1784.

Until the time of his knighthood, Thompson apparently had allowed ambition to dominate him, rather than his love for science. But from his youth he had been fascinated by the natural world. When only fourteen, he had requested an older friend to explain the nature of light, what happened to clay when fired, and how winds arose.

A keen scientific curiosity in Thompson accompanied a talent to devise and carry out carefully controlled experiments. Moreover, once Thompson discovered answers to scientific problems, he was to turn the discoveries to practical uses. This characteristic manifested itself when the ambitious knight became an employee of the Elector of Bavaria.

Thompson so impressed the Elector of Bavaria when the two met in 1784, that the Elector invited the young officer to enter his service. After an initial hesitation, Thompson accepted the offer, and he spent the next fifteen years in Munich. His success in serving the elector is indicated by the fact that in 1788 he became the Minister of War, Minister of Police, a Major-General, a Chamberlin of the Court and a State Counselor. The Elector made him an imperial count in 1792, and four years later gave Thompson the virtual rule of Bavaria when the French threatened it. While the Elector and his wife enjoyed safety in Saxony, Count Rumford saved Bavaria from its ancient foe.

Thompson's success in Bavaria stemmed from his scientific and administrative abilities. He ended beggary in much of Bavaria by feeding beggars and putting them to work. He proved the food value of the potato as a staple, and after resistance against it, the potato became a basic food, in Europe as well as in Bavaria. He devised a pressure cooker, a fuelless cooker and a gas range to improve the lot of the common man. He created Munich's famous English Garden out of a swamp. Moreover, he established a military academy, a veterinary academy, and other educational institutions.

While devising scientific answers to social problems, Thompson also applied himself to pure science, investigating the nature of heat. His contemporaries held that heat was something called "caloric," a fluid that could be forced out of bodies in the nature of heat. But Thompson, in conducting experiments, involving the boring of cannon, proved that heat was a form of energy. The scientist thus established the principle of the convertibility of energy, the application of which underlies modern industry. Thompson sent a paper on his experiments with cannon to the Royal Society in London in 1798, and that report remains a major scientific landmark.

In the same year that Thompson sent his paper on heat to London, he traveled to England himself. He arrived in Great Britain as the Elector's ambassador but England refused to accept one of her own citizens as another state's minister. Nevertheless, Thompson remained in Great Britain as a private citizen for four years. His energy undiminished, the scientist founded the Royal Institution, probably the world's first research center, in 1800, invented the "Rumford" stove, and helped to organize hospitals and workhouses in England and Ireland.

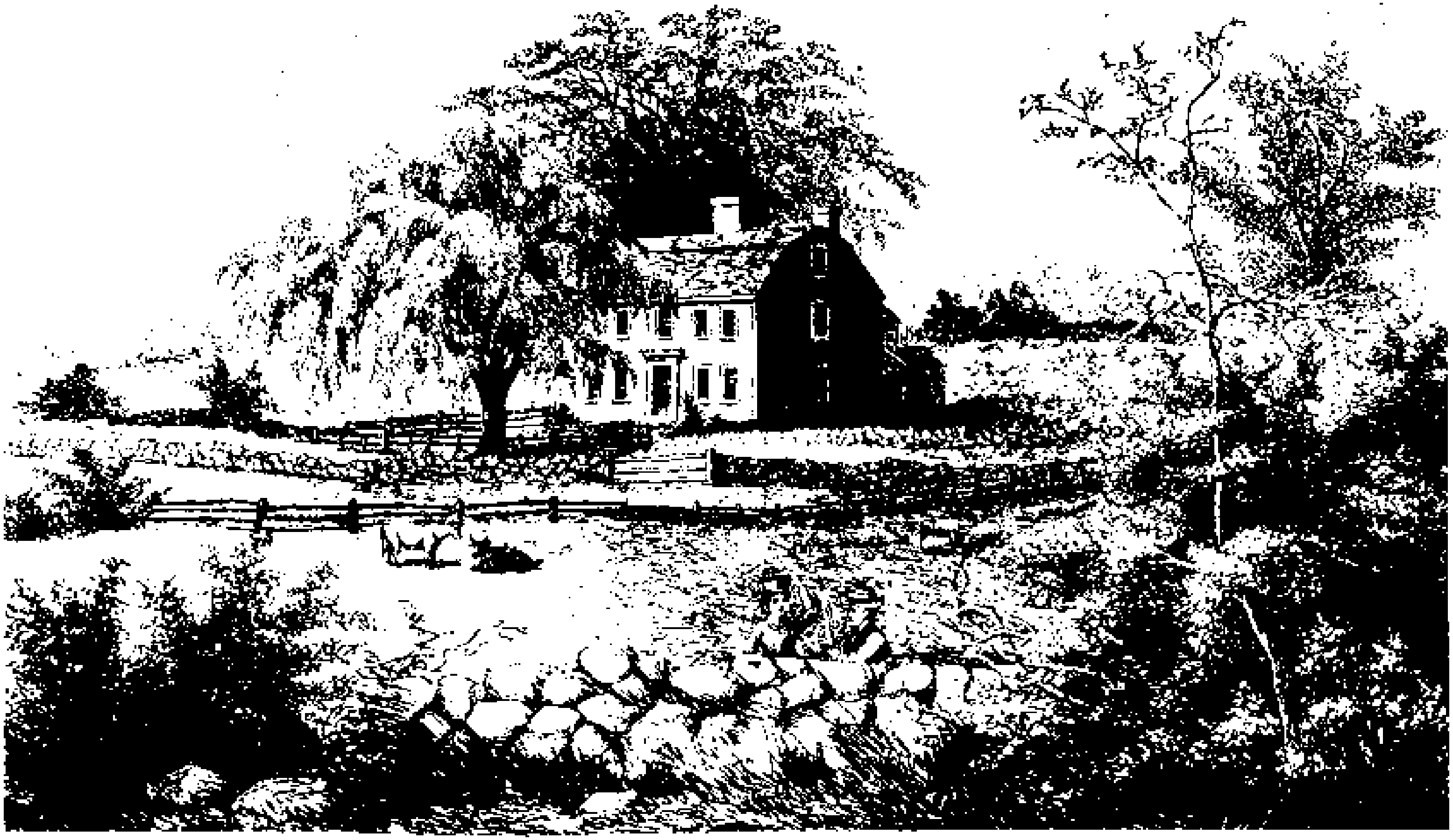
Thompson left England in 1802 and spent his last twelve years on the continent. In 1803, he moved from Munich to Paris, where in 1805 he married the widow of a famous French scientist, Anne Lavoisier. Within four years they were divorced, she having been unable to abide his constant experimenting and he having concluded that she was a harridan. On August 21, 1814, Thompson, quite alone, died.

Present Condition of the Site

Thompson's birthplace was built in the early 1700's. It is a two-story, clapboard building that has withstood the ravages of time very well and is now excellently maintained.

The interior of the house is apparently little changed from Thompson's day. The flooring, paneling and fireplaces are supposed to be original, as is the hardware. Thompson's cradle is in the small kitchen, and a room on the second floor contains additional Thompson memorabilia.

References: C. Raymond Adams, "Benjamin Thompson, Count Rumford," Scientific American, LXXI (Dec., 1950), 380-386; William Bragg, "The Contributions of Count Rumford and Michael Faraday to the Modern Museum of Science," Science, LXXII (July 11, 1930), 19-23; Bernard Jaffe, Men of Science in America, (New York, 1958); Egon Larsen, An American in Europe (New York, 1953); Dirk J. Struik, Yankee Science in the Making (New York, 1962).



Birthplace of Benjamin Thomas, North Woburn, Massachusetts

From George E. Ellis **Memoirs of Count Rumford**

Benjamin Thompson (Count Rumford) Birthplace, Woburn, Massachusetts

NPS Photo, 19[illegible]

JOSEPH HENRY HOUSE, NEW JERSEY

Location: Mercer County, Princeton University, Princeton

Ownership: Dr. R.F.Goheen, President, Princeton University

Significance

Today's electrical industry, as well as the communication industry, owes a vast debt to Joseph Henry and his inventions in the electrical field. Everytime we use an electric motor, or place a telephone call, we benefit from the genius of one of America's leading scientists and inventors.

Henry's scientific ability only manifested itself quite long after his birth in Albany, New York, on December 17, 1797. Of Scotch ancestry, the young Henry exhibited a keen interest in the stage when about sixteen. So attracted was he by the theater, that he became the leader of some local amateur thespians and wrote two plays. Fate, in the form of an accident, forced him to remain home for some time, however, and it was then that he read a book owned by a roomer, Lectures on Experimental Philosophy, Astronomy and Chemistry Intended Chiefly for the Use of Young People. And it, as Henry said, "opened to me a new world of thought and enjoyment."[1] Abandoning drama, Henry enrolled in the Albany Academy. After his graduation, he became a professor of mathematics and natural philosophy at the school in 1826. Harriet L. Alexander became his bride four years later, by whom Henry was to have six children.

When he became a teacher at the Albany Academy, Henry undertook the investigation of electro-magnetism. His independence of thought is shown by this step, for almost nothing had been done in electricity since the era of Benjamin Franklin. The mysteries of magnetism claimed his attention for some time, when one night he abruptly announced to a friend, "Tomorrow I shall make a famous experiment."[2] True to his word, Henry the next day devised the electromagnet that is so widely used today. An electromagnet contains a core of soft metal, around which are wrapped numerous coils of insulated wire. Henry's contribution to the magnet, the insulated wire and more than a single coil of wire, so improved the magnet that it could lift 600 pounds with the current of only one cell. In 1830, Henry produced an induced current by

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[1] Quoted in Bernard Jaffe, Men of Science, (New York, 1958), 186.

[2] Quoted in ibid., 188.

using his magnet, almost a year before Michael Faraday's famous experiment.

The importance of Henry's electromagnet was recognized by the inventor, but he did not pursue its application. He did build an electric motor, the world's first, which incorporated his magnet, but he looked upon that invention as only a toy. Similarly, he developed an electric telegraph, both at Albany and later at Princeton, but he also failed to exploit its commercial possibilities. Samuel F. B. Morse, with Henry's help, made the telegraph a practical thing, as Henry admitted in later years.

Henry's failure to capitalize on his inventions, both while at Albany and subsequently, conformed to his general character. He never regarded anything in science or invention as his own. A much broader view governed him; and as he said at one time:

> I have sought, . . . , no patent for inventions, and solicited no remuneration for my labors, but have freely given their results to the world; expecting only in return to enjoy the consciousness of having added by my investigations to the sum of human knowledge.[3]

Fame he also ignored. A tireless experimenter, with a simplicity of manner, a receptiveness to new ideas, and a genuine desire to cooperate with other scientists, Henry in his unique way contributed more to the world's knowledge of electricity than any other American.

This unusual American was called to Princeton University, then the College of New Jersey, in 1832. Henry taught there for the next fourteen years, he being a popular teacher. At the same time, he continued his own work, as one author says, without collaborators and without generous support from a foundation. The lack of assistants and foundation support did not impede his work, for while at Princeton he produced the electromagnetic relay (which really made the electric telegraph possible), paved the way for the development of the electrical transformer and discovered the self-induced current. Electricity only took part of his time, for he also studied problems concerning solar physics, the sun, metals and the velocity of projectiles. In the summer of 1844, for example, he spent most of his time blowing soap bubbles in an attempt to unlock the secrets of films and surface tension.

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[3] Quoted in ibid., 197.

Despite Henry's concentration on his investigations, his fame spread in both America and Europe. It was no surprise then when he was chosen as the first secretary of the new Smithsonian Institution on December 3, 1846. In accepting the job, Henry knew his own work would suffer, but he felt the call of duty and the desire to stimulate American scientific effort. For the next thirty-two years he headed the Smithsonian, making it a scientific institution of the first rank. He not only concerned himself with the institution's development in America, but sought to make it an active force in the international scene. As leader of the Smithsonian, for example, he urged scientific bodies to catalog their papers. Thus, when the Royal Society of London produced its first catalog in 1864, the Society attributed the work to Henry's urging of the publication of such catalogs.

When Henry died on May 13, 1878, he had put the Smithsonian Institution on a sound basis. Because of that accomplishment and his host of inventions, Henry rightfully occupies a leading position in the ranks of famous American scientists.

Present Condition of the Site

The dean of men, Princeton University, now occupies the Henry house. The two-story, brick and gabled roof building has been moved three times from its original site. The house is painted yellow.

References: Roger Burlingame, March of the Iron Men (New York, 1940), 270-271; Thomas Coulson, Joseph Henry: His Life and Work (Princeton, 1950), 107, 221, 233, 335-336; D. A. B.; Donald D. Egbert, (Princeton, 1947), 102-103; Bernard Jaffe, Men of Science in America (New York, 1958), 184, 186-192, 197-201; Edith W.Stone, "Joseph Henry," The Scientific Monthly, XXXIII (September, 1931), 213-226 (pp. 213-218, 221-225).

Joseph Henry House, Princeton University, New Jersey

Courtesy, Princeton University

CHARLES MARTIN HALL HOUSE, OHIO

Location: Lorain County, 64 East College Street, Oberlin

Ownership: Mr. J. A. McGrann

Significance

"Yes," Charles Martin Hall wrote his beloved sister, Julia, on July 27, 1882, "I really think I shall be a rich inventor some day."[1] When Hall died in 1914, he left an estate of some $30,000,000, the fruit of his discovery of an inexpensive, efficient method of producing aluminum. Hall had succeeded better than he had dreamed; it is doubtful if any other single invention has produced a comparable financial reward.

Hard work helped Hall to win his fabulous fortune. Born on December 6, 1863, in Thompson, Ohio, Hall developed an interest in chemistry as a stripling. His parents had to endure numerous experiments that he performed at home. And his youthful zest for chemistry brought him his first knowledge of aluminum, which he read about in an old chemistry textbook of his father's. When Hall entered Oberlin College in 1880, then, he possessed more than a hazy knowledge of chemistry and aluminum. His graduation in 1885 found him still devoted to chemistry, and determined to discover a cheap, effective means of manufacturing aluminum.

Perhaps the most amazing aspect of Hall's life is that by 1885 he had determined to become rich and that aluminum would be his means to wealth. About five feet eight inches tall, slender, and with blue eyes and brown hair, his passion for wealth had led him to read about innumerable inventors. This reading had not only made George Westinghouse Hall's hero, but had also alarmed him at how many inventors had lost the profits earned by inventions because of their failure to safeguard their rights. Hall had thus spent hours studying the patent system and, like a hermit who hides the location of his cave, he became extremely secretive. Moreover, he had begun to keep any notes or other papers related to any of his ideas for inventions, and as early as 1882 he had instructed Julia to preserve some letters in which he had discussed possible inventions, for

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[1] Quoted in Junius Edwards, *The Immortal Woodshed* (New York, 1955), 30-31.

"They may be useful in a future lawsuit or something."[2] Indeed, Hall already had become so wedded to his goal that apparently he could only spare time for music and reading. He played the piano, and read the Encyclopedia Britannica endlessly, simply pulling down a volume and starting wherever he opened the book. As a friend later said, the Britannica "was his /Hall's/ Mark Twain, detective stories, and everything all put together."[3] Hall never married.

When Hall had begun to experiment with aluminum in 1881, not many Americans knew of the metal. European scientists had worked with the metal for a long time, however, but had not been able to perfect a cheap means of producing it. Hall's able and stimulating chemistry professor at Oberlin College had commented on the need for a satisfactory commercial process concerning aluminum, remarking that the inventor would "lay up for himself a great fortune."[4] Perhaps further inspired by his teacher's remarks, Hall persisted in his work; and after graduation from college, he established a laboratory in the woodshed behind his parents' home and conducted endless experiments. Success eluded him for months, but on February 23, 1886 he finally produced a few small drops of aluminum. His process involved the electrolysis of cryolite, which served as a catalyst for molten alumna, the raw material of aluminum. Once certain of his discovery, Hall applied for patents, five of which he gained on April 2, 1889.

After the young inventor had initiated patent action, he sought to develop his process for commercial production. Several attempts to gain backers between 1886 and 1888 gave Hall little satisfaction. But in the latter year, Hall found some men in Pittsburgh who were willing to support a major effort to produce aluminum, which led to the formation of the Pittsburgh Aluminum Company. A plant was built, and although

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[2] Quoted in ibid., 21.

[3] Quoted in ibid., 165.

[4] Quoted in ibid., 34-35.

some difficulty was had in perfecting the operation, by June, 1889, the plant was producing an ever growing amount of aluminum. There was no more dedicated worker in the factory than Hall, who concerned himself with every aspect of the plant's operation. The impact of the new method is shown by the fact that the company's price for a pound of aluminum had fallen to $1.50 by the fall of 1889, whereas its original price had been $5 a pound. By March, 1891, this plant had produced a total of 87,739 pounds of aluminum.

The quick success of the concern soon led to its expansion. In 1891, Hall and his partners moved to a new plant in New Kensington, which factory by 1893 could produce a thousand pounds of aluminum a day. So great was the demand for the light metal, however, that in 1895 the concern opened a huge new factory at Niagara Falls, where cheap electric power was available. By 1907, when the company became the Aluminum Company of America, the concern was making 15,000,000 pounds of aluminum a year.

When the concern had moved to Niagara Falls, so had Hall. He erected a large house there, but ill health after 1908 curtailed his enjoyment of it and his now vast wealth. Death overtook him on December 27, 1914.

Present Condition of the Site

The house in which Hall lived with his parents until he moved to Pittsburgh in 1888 is over a century old, but its exact date of construction is not known. It is a two-story, painted brick structure, with a large porch in front and a cupola on the roof. At the moment, the building contains apartments, with rooms divided by plasterboard partitions. But there has been no fundamental change in the interior arrangement. Moreover, the floors, woodwork and fireplaces are apparently the same as when Hall lived there. The woodshed behind the house has been destroyed. A cinderblock addition stands in the woodshed's place.

References: Alfred Cowles, The True Story of Aluminum (Chicago, 1958); Junius Edwards, The Immortal Woodshed (New York, 1955); Kaiser Aluminum Company, "The 23rd of February," Kaiser Aluminum News (Jan.-Feb., 1961), 14-15.

Charles Martin Hall House, Oberlin, Ohio

NPS Photo, 1985

JAMES LOGAN HOME, "STENTON," PENNSYLVANIA

Location: Philadelphia County, 18th and Courland Streets, Germantown

Owner: James H. J. Tate, Mayor of Philadelphia

Significance

James Logan, one of the founders of the American scientific school, is relatively unknown today. Perhaps because he wrote little, perhaps because Benjamin Franklin's image is so dominant, the Nation has shown little interest in a man whose erudition and work almost equalled the sagacity and achievements of Franklin. Logan "was a kind of universal man in the Renaissance tradition--statesman, writer, scientist, philosopher,"[1] says a recent biographer; and as a scientist he demands consideration in any study of American science.

Born in the north of Ireland in 1674, Logan arrived in Philadelphia in 1699 as William Penn's secretary. Logan, during the next fifty years, occupied a key position in the affairs of Pennsylvania, contributing much to the rapid and successful development of the colony. His seat in the colony's council underscored his political influence, and between 1731-39 he acted as the chief justice of Pennsylvania's court system. Moreover, throughout Logan's career he was the colony's best and most respected negotiator with the Indians. His public life did not prevent him from amassing a fortune from the fur trade, however, which enabled him to retire to his country estate, "Stenton," in 1730. Even so, when Pennsylvania faced a crisis in 1736, Logan did not hesitate to re-enter public service, and became acting governor.

Logan's strenuous public career did not prevent him from pursuing his interest in science. Even as a youth, his fascination with mathematics and botany had been great, and as an adult he studied both intensively. He assembled the outstanding scientific library in the English colonies, his near 400 scientific and mathematical works even surpassing Harvard College's library in 1735. Logan is reputed to have imported Pennsylvania's first copy of Sir Isaac Newton's Principia Mathematica. More importantly, he read and understood that monumental work, though only self-taught in mathematics.

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[1] Frederick B. Tolles, "Philadelphia's First Scientist, James Logan," Isis, 47 (1956), 20.

With such a library at his command, Logan applied himself to various scientific problems. Numerous published papers resulted, one of which dealt with the motion of the moon, another of which suggested improvements in the quadrant, and a third of which outlined improvements in lenses. Ironically, although Logan's great scientific love was mathematics, he realized his greatest accomplishment in botany.

Through a carefully thought out and controlled experiment, Logan proved the vital role of the male element, pollen, in the fertilization of corn. The theory of "preformation," that the wind carried the male element to the female element in plants, first stimulated Logan when in 1726 he read William Wollaston's Religion of Nature Delineated. Additional reading convinced him that a male seed was just as vital to plants as the female seed, and in the summer of 1727 he tested his hypothesis on corn. Logan removed the tassels from some stalks and the filaments from others, and then he watched the development of the kernels. The results clearly showed "that the pollen was the male element and that it was necessary for the production of viable seed."[2] He repeated the experiment in 1728, but delayed making his findings public until 1735-36.

The announcement of Logan's experiment excited many in Europe. Not the members of the Royal Society of London at first, it is true, for when Logan's report was read most of those present paid small attention as they concentrated on dissecting a German cabbage and an Indian turnip. Elsewhere, scientists hailed Logan, the great Dutch botanist, Linnaeus, writing Logan in 1738 that he should be placed "among the demigods of science."[3] Subsequently, the Dutchman used the results of Logan's investigation in a paper on the sexuality of plants that received a prize from the Imperial Academy of Sciences at St. Petersburg in 1760. And Logan's botanical discovery remained influential for several decades after 1800.

Even if Logan had not succeeded in his experiment with corn, he would still be remembered in the history of American science. It was Logan who did so much to stimulate the botanical career of John Bartram. The first books on botany that Bartram read, for example, came from Logan's library. In addition, when Logan died on October 31, 1751, he left his library to the City of Philadelphia, a scientific treasure of immense value for such a young city.

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[2] Tolles, "Philadelphia's First Scientist," 28.

[3] Ibid., 29.

Present Condition of the Site

When fifty-three, Logan decided to build a country seat. He chose a site in the rolling hills just west of Philadelphia, and work on his new house began in 1727. Completed in 1730, the mansion was called "Stenton," after Logan's father's birthplace in Scotland.

The house cost more than Logan had expected, but it well repaid Logan's investment. The building was a three-story, brick structure, with a not too-steeply pitched roof that was hipped and flat-topped. Two great, tall chimney stacks rose above the roof. Inside, on the first floor, a parlor and a formal dining-room and bedroom behind them. Additional bedrooms for members of the family and for servants were on the second floor and in the garret. A specious room, running across the full front of the house, served as Logan's library.

Today, the house is in excellent condition. Beautifully maintained, it welcomes visitors as graciously in our era as it did in the builder's.

References: Ernest Earnest, John and William Bartram (Philadelphia, 1940); Brooke Hindle, The Pursuit of Science in Revolutionary America, 1735-1789 (Chapel Hill, North Carolina, 1956); Frederick B. Tolles, "Philadelphia's First Scientist, James Logan," Isis, 47 (1956);
____________, James Logan and the Culture of Provincial America (Boston, 1957).

James Logan House, "Stenton," Germantown, Pennsylvania

Courtesy, Philadelphia Historical Commission

AMERICAN PHILOSOPHICAL SOCIETY HALL, PENNSYLVANIA

Location: Philadelphia County, Independence Square, Philadelphia

Ownership: Dr. Henry Moe, President.

Significance

There is no more ancient and honorable learned and scientific society in the United States than the American Philosophical Society held at Philadelphia for Promoting Useful Knowledge. With its headquarters located in the handsome building in Independence Square that was completed in 1789, the Society, like so much else in Philadelphia, traces its birth back to the initiative of that uncommon Philadelphian, Benjamin Franklin.

Franklin, in his long and varied career, founded a number of societies and organizations, two of which loom large in the history of the American Philosophical Society. In 1743, Philadelphia's sage urged the creation of a society to stimulate interest in learning. Certain citizens then formed the Philosophical Society, and it is from this society that today's organization claims direct descent. But the new society did not flourish because its members neglected it, and it is not clear if the members even met between 1744-1767. But in 1768 the activity of a group claiming descent from Franklin's Junto, founded in 1727, stirred the dormant Philosophical Society into life, especially as the rival group, now grandly called "The American Society, held at Philadelphia for Promoting Useful Knowledge," consisted largely of people opposed to the proprietary clique in Pennsylvania. To meet the challenge, the Philosophical Society suddenly chose eighteen new members in 1768, mostly from supporters of the proprietors, the Penn family. Apparently, the two societies faced a future of learned and political competition. But wiser counsel prevailed. Instead of opposing each other in bitter rivalry, the two groups merged on December 20, 1768, forming the organization that flourishes today. And, fittingly enough, the founder of the now defunct groups, Franklin, became president of the new society.

The newly formed American Philosophical Society had high ambition. Significantly, the society desired to become a truly American society, to become more than just a Philadelphia or Pennsylvania organization. New members, consequently, came largely from outside of Philadelphia during the remainder of the colonial era. Moreover, the society elected corresponding members in Europe. These members contributed little to the society's work, but they heightened its reputation and sent books and other gifts to the society. Successful in bettering its membership, the society failed however to collect dues, even when it hired a collector at one time.

In its early days, the society devoted its efforts to both pure and applied science. Even though strapped for funds, the society, led by an interested minority, made preparations to observe the transit of Venus in 1769. Fortunately, the Pennsylvania assembly appropriated £50 to help in the work, which enabled the society to erect an observatory in Independence Square. The society also helped to stimulate general interest in the passage of Venus, with the result that a notable series of accounts about the planet's path were collected. On the practical side, the society undertook surveys of canal routes, experimented with the raising of silk worms and supported agricultural and medical study. Despite the fact that there was no coordination of the society's endeavors, its early projects remain most impressive.

Even though busy with various undertakings, the society lost little time in beginning what is now the oldest scholarly journal in America, its *Transactions*. A committee was appointed in June, 1769, to prepare a volume of scientific papers, but the first volume was not published until 1771. The society deliberately distributed the book as widely as possible in order to bolster its reputation, and in this plan the society was more than successful. Volume number 1 contained, among other papers, the material gathered under the aegis of the society from the transit of Venus, which astonished Europeans. That a new and colonial society could produce such a work was amazing, especially as many older European organizations had never published a similar volume. And from 1771 to this day, the *Transactions* have continued to merit the reputation gained from the first volume.

The American Revolution interrupted the work of the society, but since then the organization has continued to play a leading role in promoting knowledge. Now with a membership of near 600, including both American and foreign members, the American Philosophical Society's vigor benefits the entire world.

Present Condition

The society's headquarters in Independence Square were completed in 1789. Twenty years prior to 1789, when the organization had no home of its own, the society had petitioned the colonial assembly for a lot near the Pennsylvania State House, now Independence Hall. But the assembly withheld permission to erect a building there until 1785. Once the lot had been granted, the society opened a drive to raise a building fund and authorized a start on the project. Samuel Vaughan designed the two-story brick edifice, but progress on it nearly foundered when funds ran low. Only the generosity of Franklin made it possible to complete the building in 1789.

Because of the need for more room near the end of the nineteenth century, the society added a third story in 1890. This addition completely ruined the building's beauty. In 1949, the third-story was removed, and the building was restored to its eighteenth-century appearance. At the same time, it was fireproofed.

References: Gilbert Chinard, "The American Philosophical Society and the World of Science (1768-1800)," *Proceedings*, American Philosophical Society, 87 (1944); Edwin G. Conklin, "A Brief History of the American Philosophical Society," *The American Philosophical Society Held at Philadelphia for Promoting Useful Knowledge: Year Book, 1962* (Philadelphia, 1963); Brooke Hindle, *The Pursuit of Science in Revolutionary America, 1735-1789* (Chapel Hill, N. C., 1956); ________________, *The Rise of the American Philosophical Society, 1766 to 1787* (Unpublished dissertation, University of Pennsylvania, 1949); William E. Lingleback, "Philosophical Hall: The Home of the American Philosophical Society," *Transactions*, American Philosophical Society, N. S., 43, pt. 1 (1953).

Headquarters of the American Philosophical Society in 1790: Building No. 4 in center of print.

From Columbian Magazine, 1790

Philosophical Hall, with third story that was added in 1890. Philadelphia, Pennsylvania.

Courtesy American Philosophical Society

JOSEPH PRIESTLEY HOUSE, PENNSYLVANIA

Location: Northumberland County, Priestley Avenue,
Northumberland

Ownership: Governor William W. Scranton, Harrisburg

Significance

America's historic policy of welcoming persecuted foreigners has benefited the United States immeasurably. The American development of the atom bomb testifies to that. In an earlier period, the Country's reception of Joseph Priestley, the brilliant English chemist, after he was driven from Great Britain not only testified to the democratic spirit of the young Nation, but also stimulated her scientific development.

Priestley was born in Leeds, England, on March 13, 1733 (old style). Reared in a Calvinist environment, he decided to be a minister, and finished his theological training when 22. He possessed very liberal views and became a dissenting minister. In 1761, Priestley became a teacher at the Warrington Academy, where he stayed until 1767. It was during this period that he first became interested in chemistry. Perhaps his friendship with Benjamin Franklin spurred his scientific interests, for that association stimulated Priestley to write a History and Present State of Electricity. The Royal Society of London awarded him a membership in 1766 because of that book. In the following year, the neophyte scientist moved to Mill's Hill Chapel, Leeds, where his position allowed more time for scientific study.

Untrained in science as he was, Priestley chose a field that offered great opportunity for new work, pneumatic chemistry. The study of gases had attracted attention prior to Priestley's time, but it was he who became the "Columbus" of the gaseous world. And it was the brewing of beer that caused this keen observer to investigate gases.

The smoke that hovered over beer as it was brewed in a brewery near Priestley's residence in Leeds intrigued the minister. He set out to study the gas, and in 1772 he published his initial paper on pneumatic chemistry. In it he described his experiments with carbon dioxide; the paper won him the Copley medal in 1773. Hampered by a lack of implements, Priestley devised his own equipment, most of which has been little modified and is still used. Fascinated with his investigations, Priestley pursued his study and in 1776 discovered one of the key elements, oxygen. It was an astounding discovery for an individual who had been untrained in science and who had only initiated his work a few years earlier.

Priestley continued his scientific investigations after 1774, although oxygen remained his great discovery, and by 1786 he had published six volumes of scientific writings.

Priestley's work in science had not completely dominated him. He continued to be active in religious affairs, as well as assuming a positive role in political matters. The liberal religious and political views he espoused maddened many. In 1780, the fearless crusader became the leader of a dissenting group in Birmingham, which city expressed small love for a new book of Priestley's, Corruptions of Christianity. Moreover, he gained additional enemies, some of them in powerful positions, when on January 1, 1791, he published a strong defense of the French Revolution. The pamphlet fearlessly denounced Edmund Burke's castigation of the revolution across the English Channel.

Priestley's courage soon brought personal disaster. A mob howled through Birmingham for three days in July, 1791, and it destroyed the scientist's meeting-house and home. Priestley, personally uninjured, then moved to London, where he lived for three years. Already unpopular, Priestley's stock did not rise when France honored him with French citizenship. In these circumstances, it is not strange that he turned to America.

Priestley's sons had already migrated to the United States, and on April 8, 1794, the scientist boarded the Sansom for the trip to America. The emigre, who was sea-sick during the voyage, landed in New York on June 4. On the following day, the American Daily Advertiser welcomed Priestley and his wife, saying that America "has become the asylum of the greatest characters of the present age."[1] The new immigrant went to Philadelphia on June 18, where he was welcomed by the American Philosophical Society. Perhaps the Society's members would have been a little piqued if they had learned that Priestley wrote a friend, saying "I never saw a town I liked less than Philadelphia."[2] By the end of August, Priestley had bought land in Northumberland, where he built a house.

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[1] Quoted in Edgar F. Smith, Priestley in America, 1794-1804 (Philadelphia, 1920), 20.

[2] Quoted in ibid., 55.

The scientist continued his investigations in his new home. His most important discovery between 1794 and 1804, when he died, was carbon monoxide. He also became a member of the American Philosophical Society and contributed several papers to it.

At his death, on February 6, 1804, America lost a new son and the world an eminent scientist.

Present Condition of the Site

Priestley's spacious and attractive house stands on a rise above the North Branch of the Susquehanna River. The central section is two stories high and has a gabled roof. On its west side is a kitchen wing, and on the east side is a wing which housed Priestley's laboratory. The clapboard for the entire structure was kiln-dried on the grounds when the house was built.

The house has been restored after having fallen into disrepair many years after the scientist's death. It has also been partially refurnished; the library contains objects owned by Priestley.

References: William Henry, "Joseph Priestley," in Edward Farber (ed.) Great Chemists (New York, 1961); Edgar F. Smith, Priestley in America (Philadelphia, 1920); John Maxson Stillman, The Story of Early Chemistry (New York, 1924).

Early view of north side of Joseph Priestly House, Northumberland, Pennsylvania.

Courtesy, Pennsylvania Historical and Museum Commission

Modern view of north side of Joseph Priesley House, Northumberland, Pennsylvania. Note absence of balustrade on roof and added front porch.

Courtesy, Pennsylvania Historical and Museum Commission

Checklist of 13 Sites already Classified as Eligible for Registered National Historic Landmark Status and also related to this theme:

1. Luther Burbank Home and Garden, California. Classified under Theme XVIIa, Agriculture. 1883-1906 home and garden of the plant breeder.

2. John Muir Home, California. Classified under Theme XIX, Conservation of Natural Resources and Theme XX, Subtheme, Literature. 1890-1914 home of the naturalist.

3. San Francisco Cable Cars, California. Classified under Theme XVIII, Travel and Communication. Related to Andrew S. Hallidie's invention of the cable car in 1873.

4. John Deere House, Illinois. Classified under Theme XVIIa, Agriculture. Home of the inventor of the steel plow, 1837.

5. Franklin B. Hough House, New York. Classified under Theme XIX, Conservation of Natural Resources. Home of the father of American forestry.

6. Jethro Wood Home, New York. Classified under Theme XVIIa, Agriculture. Perfector of the first iron plow, 1819.

7. Samuel F. B. Morse Home, New York. Classified under Theme XVIII, Travel and Communication. Perfector of the first commercial telegraph.

8. John Bartram House, Pennsylvania. Classified under Theme IX, Development of the English Colonies, 1700-1775. Home of the great naturalist.

9. Robert Fulton Birthplace, Pennsylvania. Classified under Theme XVIII, Travel and Communication. Perfector of the steamboat.

10. Monticello, Virginia. Classified under Theme XII, Political and Military Affairs, 1783-1830. Home of Thomas Jefferson.

11. Mount Vernon, Virginia. Classified under Theme XII, Political and Military Affairs, 1783-1830. Home of George Washington.

12. Cyrus McCormick Farm and Workshop, Virginia. Classified under Theme XVIIa, Agriculture. Perfector of the mechanical reaper, 1831.

13. Edmund Ruffin Plantation, Virginia. Classified under Theme XVIIa, Agriculture. Father of soil conservation.

Sites in the National Park System Related to this Theme

1. Independence National Historical Park, Philadelphia, Pennsylvania. Franklin Court, on Orianna Street, between Chestnut and Market Streets, contains the former site of Benjamin Franklin's home, 1765-1790. His house was razed in 1810.

2. George Washington Carver National Monument, Diamond, Missouri. Home of the famous Negro teacher, botanist, and agronomist.

3. Edison National Historic Site, West Orange, New Jersey. 1887-1931 laboratory and home of the great inventor, Thomas Alva Edison.

4. Harpers Ferry National Historical Park, West Virginia. Although established primarily to commemorate events associated with the John Brown Raid and the Civil War, Harpers Ferry National Historical Park also contains the island in the Shenandoah River on which John H. Hall's Rifle Factory was located. It was here that the inventor perfected the system of mass production by the use of interchangeable parts, 1819-1841. In the 1840s and -50s, however, the United States government demolished Hall's Rifle Factory and replaced it on the same site with a huge modern plant known as the U. S. Rifle Factory. Archeological exploration has revealed that the foundations of the U. S. Rifle Factory have survived largely intact. But in view of the fact that both plants occupied the same site, it is very doubtful if any remains are left of the Hall Factory.

5. Wright Brothers National Memorial, North Carolina. Here Wilbur and Orville Wright, on December 17, 1903, made the first power driven airplane flight in history.

OTHER SITES CONSIDERED

CALIFORNIA

California Academy of Sciences

Location. San Francisco County, in Golden Gate Park, City of San Francisco.

The California Academy of Science, established at San Francisco in 1853, was the first scientific society on the Pacific Coast.

Its original buildings were destroyed by the great earthquake and fire of 1906. The academy was then reconstructed at its present site in Golden Gate Park. These large, modern buildings include the Natural History Museum, Simson African Hall, and the Steinhart Aquarium. All of these structures, with their many exhibits, are open to the public.

California Institute of Technology

Location. Los Angeles County, City of Pasadena.

Opened on November 2, 1891 under the name of Throop University of the Pacific, the California Institute of Technology was a pioneer scientific and technical school in the Far West. By the 1930s this school had grown to become one of the leading technical schools of the nation, but during the period here under consideration (prior to 1914), it had reached only high school level in its teaching.

Amos G. Throop established Throop University of the Pacific in 1891 and made the manual training department its main feature. In 1893 it was renamed Throop Polytechnic Institute. The early institute included a college, a normal school, an academy, and for a time, an elementary school and a commercial school. In 1908 the trustees decided to separate the elementary department, the normal school, and the academy, leaving only the college of technology which conferred Bachelor of Science degrees in electrical, mechanical, and civil engineering. In 1910 the name was changed to Throop College of Technology, and the school moved from its crowded quarters in the center of Pasadena to a new campus of 22 acres on the southern edge of town. The institute then had a faculty of 13 and a student body of 34. In 1921 the institute changed its name to California Institute of Technology and began to emerge as an important scientific school.

Dr. George Ellery Hale (1868-1938), the distinguished astronomer and first director of Mount Wilson Observatory, was one of the 1908 board of trustees. Hale began to build up the Institute's scientific staff.

In 1913, Robert Andrews Millikan began to spend a few months a year at Throop as Director of Physical Research. In 1921, when Dr. Norman Bridge agreed to provide a research laboratory in physics, Dr. Millikan resigned from the University of Chicago and became administrative head of the Institute as well as director of the Norman Bridge Laboratory. Millikan was credited with being the first to isolate the electron and measure its charge, and in 1923 he received the Nobel Prize in Physics, the second American to be so honored since Albert A. Michelson in 1907. Another of many other able scientists attracted was Thomas Hunt Morgan, the eminent American zoologist, who left Columbia University in 1928 to become the director of the William G. Kerckhoff Laboratories of Biological Sciences at the California Institute of Technology. Morgan discovered many of the mechanisms involved in heredity. He experimented in the new field of genetics, demonstrating that physical characteristics were transmitted by "genes." His research brought about modifications in the theory of evolution, and he was awarded the Nobel Prize in physiology and medicine in 1933.

The first Ph. D. degrees, nine in number, were awarded in 1924. By 1930 there were 138 graduate students, 510 undergraduates, and a faculty of 180. Today there are about 700 undergraduates, 590 graduate students, and a faculty of about 450.

Of the 47 buildings located on the 30-acre campus, only one, Throop Hall, erected in 1910, falls within the limits of this survey. This structure now serves as the administration building of the Institute.

Montgomery Memorial State Park

Location. San Diego County, 11 miles south of San Diego via U. S. Highway 101.

Here at Otay Mesa, in 1883, John Joseph Montgomery made the first heavier-than-aircraft flight.

One of the American pioneers in aeronautics was John Joseph Montgomery. As a student at St. Ignatius College (now the University of San Francisco), Montgomery first studied the problems of flight and earned his bachelor and master of science degrees. In 1883 he studied the flight of gulls in the San Diego area and built his first glider. In August, 1883, he made the first controlled winged flight at Otay Mesa. Montgomery's report at the Chicago conference

of 1893 impressed Octave Chanute, another American pioneer in aeronautics who was then also beginning to experiment with gliders near San Diego. In 1898 Montgomery became a physics professor at Santa Clara College and continued his experiments with gliders until his fatal crash on October 31, 1911, near Evergreen in the Santa Clara Valley.

Montgomery Memorial State Park includes 29 acres of the hilltop of Otay Mesa, from where Montgomery launched his first glider. A modernistic monument in the form of a huge glider wing commemorates Montgomery's achievement. The area around this park is being heavily built up with residences.

Mount Wilson Observatory

Location. Los Angeles County, Mount Wilson, 20 miles east of Los Angeles via State Highway 2.

Mount Wilson Solar Observatory, placed in operation in 1904, was the second of the great research astronomical observatories to be established in the Far West.

The decision of the Carnegie Institution of Washington, D. C., to build the Mount Wilson Solar Observatory in the San Gabriel Mountains near Los Angeles was made upon a recommendation of Samuel P. Langley in 1902. Dr. George Ellery Hale (1868-1938), the organizer and director of the University of Chicago's Yerkes Observatory at Williams Bay, Wisconsin, was appointed director of the Mount Wilson Solar Observatory in 1904. The principal instrument of the Mount Wilson Observatory at first was a 60-inch reflecting telescope. The observatory staff concentrated upon the study of the sun. Their comprehensive studies of sunspots resulted in the announcement of a general theory of sunspots.

In 1906 John D. Hooker of Los Angeles gave the Mount Wilson Observatory the money to acquire a telescope mirror of 100-inch aperture. By 1917 Dr. Hale had this huge reflecting telescope in operation, and until 1937 this was the world's largest telescope.

Hale resigned as director of the Mount Wilson Observatory in 1923. In 1928 he induced the Rockefeller Foundation to donate $6,000,000 for a 200-inch refractor telescope. The site chosen for this new glass was on Mount Palomar in San Diego County. The partly completed mirror was received in 1936, but it was not until 1948 that the giant telescope was completed and installed at Mount Palomar.

Mount Wilson Observatory, 5,710 feet altitude, is located in Angeles National Forest on a 1,050-acre plateau at the summit of the mountain. The original buildings, and 60-inch and 100-inch telescopes are still in use, together with the six more recent instruments. The observatory is open to the public.

Palo Alto Farm (Eadweard Muybridge)

Location. Santa Clara County, golf course of Stanford University at Palo Alto.

Among the pioneers in motion picture photography was Eadweard Muybridge (1830-1904) who photographed animals in motion as early as 1872 for Leland Stanford, working largely on Stanford's Palo Alto Farm.

Eadweard Muybridge was born in 1830 in Kingston-Upon-Thames, Surrey, England. In 1850 he came to the United States and between 1856 and 1860 established an antiquarian bookstore in San Francisco. By 1867 he had become known as a master photographer of Western scenes. In 1872 he was commissioned by Leland Stanford, one of the Central Pacific Railroad's "Big Four," to photograph the millionaire's trotter, the racehorse Occident, in rapid motion. Stanford had a theory that a running horse has all four feet off the ground at one phase of his stride. Muybridge conducted this work at Sacramento between late April and the beginning of May 1872. Despite the technical limitations of "instantaneous photography" at that time, he succeeded well enough to prove Stanford's point with the camera. On the strength of Muybridge's first efforts Stanford invested during the next decade many thousands of dollars in the photographic investigation of animal locomotion.

In the early spring of 1873 Muybridge made a second attempt to photograph the racehorse Occident. This time he devised a fast shutter, used new chemicals for faster emulsions, and for great contrast had the racetrack at Sacramento spread with white bed sheets. This second experiment was a perfect likeness of the celebrated horse. Muybridge calculated his exposure time at 1/500th of a second, the most nearly instantaneous photograph taken to that time.

In July 1877, with Stanford's encouragement and patronage, Muybridge gave up landscape photography for good and devoted himself for the rest of his life to the gigantic project of recording every aspect of motion in humans and animals, until at last the whole world knew about the "pictures that moved."

He conducted his scientific work with motion at Leland Stanford's Palo Alto Farm from 1877 to 1881, then at the University of Pennsylvania from 1883 to 1892, and finally as a lecturer and writer until his death at Kingston-Upon-Thames in 1904.

Leland Stanford began acquiring his Palo Alto Farm in 1876, and by 1891 it contained more than 8,800 acres. The portion of the farm devoted to the breeding and training of racehorses was called the Palo Alto Stock Farm and was located about one mile west of the present University quadrangle.

Here, facing the track of the Stock Farm, a laboratory or studio was erected for Muybridge in July 1877. Starting with five cameras, Muybridge then increased the number to 12 and finally 24, each placed at intervals of 12 inches, with their shutters controlled by means of an electrical device. These preparations were completed in 1878, and during that year and the next, Muybridge made a vast collection of photographs of animals in motion.

In July 1878, the photographer published and copyrighted in his own name the first of the views of these analytic photographs. Utilising an existing instrument known as the zoetrope, Muybridge devised a projecting machine which he called a zoöpraxiscope, for throwing the pictures on the screen, thus successfully synthetically reproducing the animal's movement. He demonstrated his new projector in the fall of 1879.

Muybridge completed his camera work in 1879 and then applied himself to the task of collating and printing the multitude of negatives. It was not until May 1881 that he delivered to Stanford a complete set of all the pictures he had taken.

Stanford published these studies as The Horse in Motion in January 1882.

The Palo Alto Stock Farm and Racetrack, where Muybridge made his experiments from 1878 to 1881, is now occupied by the Stanford University golf course. There are no original buildings left.

Lester A. Pelton Monument

Location. Yuba County, in the village of Camptonville, State Route 49.

The Pelton water wheel, perfected in 1878-1880, was a basic invention that permitted the rapid development of the hydroelectric industry in the United States.

Lester Allen Pelton came to California in 1850, at the age of 20, and worked as a millwright in the gold mining Mother Lode Country of Northern California. At Camptonville, high in the mountains of Yuba County he built homes, mills, and water wheels. These water wheels, much in demand in the mines, attracted his particular interest, and he began to study the force that made them revolve, in an effort to find a way to increase the speed and power of the hurdy-gurdy wheel.

These efforts led the inventor to the discovery of the "splitter" principle of the Pelton wheel design in 1878. By splitting the stream of water from the nozzle into two parts and changing the angle of the impact against the buckets attached to the wheel, Pelton found he could multiply its speed, power, and efficiency. He also introduced the use of twin buckets on the wheel instead of the single line of cups formerly used.

Pelton continued with his experiments, He obtained instruments to measure the efficiency of the wheel. After trying 40 or more different shapes of buckets, he patented his invention on October 26, 1880. He began making wheels of the new design at Nevada City, California, for quartz stamp mills and for other power uses in the mills. The Pelton wheel was quickly adopted by the gold miners.

Pelton then moved to San Francisco and in partnership with A. P. Brayton organized the Pelton Water Wheel Company in 1888. The Pelton Wheel, in its perfected form, was manufactured for a wide diversity of uses. Wheels were made up to 20 feet in diameter to produce many thousands of horsepower. They were also made as small as four inches in diameter, weighing only 20 pounds, for the operation of sewing machines and dental and other small appliances.

Production of a water wheel designed to produce maximum driving power under the high static heads characteristic of Northern California water sources was timely. It came just as the hydroelectric engineers werelaying plans for the first waterpowered generating plants. The Pelton wheel at once became a vital part of the developing hydroelectric industry. Pelton wheels today drive the generators in many a hydro-powerhouse in the West and elsewhere in the world.

The site of Lester A. Pelton's workshop in Camptonville is marked by a granite shaft, erected in 1929. On top of the monument is mounted a model of one of Pelton's earliest splitter wheels. There are no remains of the inventor's shop.

Other Sites Considered

ALABAMA

The Hill Building, Infirmary of Dr. J. Marion Sims

Location: 21 S. Perry Street, Montgomery

Dr. James Marion Sims was the founder of operative gynecology, a branch of surgery that began in the South and was developed almost entirely by Southern surgeons. Vesicovaginal fistula had resulted in enormous suffering in child-bearing women and had baffled surgeons for centuries. In 1845 Dr. Sims received several cases of this kind, which were considered hopeless, at his small hospital for Negroes in Montgomery. An accident occurred during the examination of his first fistula patient which revealed a new approach and prompted him to begin a long-term series of operations. These became a heavy burden on Sims and his family, but he was determined to carry them through. Success finally came in the thirteenth operation; two weeks later the other two patients were also cured.

Shortly after success came in this long series of operations, Dr. Sims' health failed as a result of an old ailment. During a long illness of several years duration, he wrote the history of the vesicovaginal fistula operation, which appeared in the American Journal of Medical Sciences for January 1852 and was reprinted separately in 1853.

Sims moved to New York in 1853 and soon prompted the establishment of the Women's Hospital of the State of New York. He next spent a decade in Europe (1862-1872) which was an uninterrupted series of triumphs. He returned to New York and the Women's hospital in 1872; in 1876, he was president of the American Medical Association; in 1880, he headed the American Gynecological Society. On November 13, 1883, Dr. Sims died.

A remarkable school of Southern gynecologists followed Dr. Sims' lead. This branch of surgery throughout the world was especially active during the 19th century. Today operative gynecology is often merged into general surgical practice.

The two-story, red-brick Hill Building at 21 S. Perry Street in Montgomery was the early infirmary of Dr. J. Marion Sims. In the mid-twentieth century the building became the offices of another surgical pioneer, Dr. L. L. Hill, who was the first surgeon to operate successfully on the human heart. The Hill Building is still much as it was originally. The Montgomery County Medical Association has placed a marker commemorating Dr. Sims' work to the left of the entrance.

CONNECTICUT

James Gates Percival House

Location: 381 Percival Avenue, Kensington, Hartford County

James Gates Percival, who conducted one of the earliest and most thorough geological surveys in New England, was born on September 15, 1795. As a young man he attended Yale University, where he studied medicine, although he also dabbled in botany and geology. He also wrote poetry. Yale conferred an M. D. degree in 1821, but Percival soon abandoned medicine.

This slender, dark-eyed, stooped, and brilliant individual, who unfailingly wore the same suit the year round, never persisted in any undertaking for very long. Percival had a peevish, sour temper, and he so frequently thought he detected animus in others that he found it difficult to work with people. Aside from his devotion to poetry, he wandered from one project to another; at one time he served as a proofreader for Noah Webster. In 1835, the State of Connecticut appointed him as a state surveyor, which led to Percival's outstanding geological survey of the Nutmeg State.

The story is told that while making the survey, Percival was accosted one day by a farmer. The farmer, stating that he was a taxpayer, asked Percival what he was doing. Percival surprised, and probably irritated, gazed at his questioner for a moment, then took a few pennies from his pocket and gave them to the farmer, saying:

> Here is the amount of your contribution. I would rather remit than attempt to explain.[1]

The report Percival produced after his survey astounded everyone. When it appeared in 1842, after the author had been hounded about it by the legislature, the work contained 500 pages of undigested facts and details. Whereas those responsible for the survey had expected a brief report, they received a tome that no one wished to read. Subsequently, however, James Dwight Dana, an outstanding American geologist, studied Percival's work and found much of value in it. In particular, Percival had suggested a hypothesis of mountain formation that later became accepted. Crushed at the depreciation of his work, and unpaid for his labors, Percival soon retired to the New Haven State Hospital.

At the very end of his life, he resumed his geological work. He became the state geologist of Wisconsin, but his death on May 2, 1856, limited his accomplishments in that position.

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[1] Quoted in George D. Merrill The First One Hundred Years of American Geology, (New Haven, 1924), 169.

Percival's home in Kensington was built around 1765. It is a two-story building, whose original clapboards have been covered with red painted shingles. Outside of that, plus the addition of a sunroom, a porch and a dormer window in back, the house has not been changed. The original interior paneling is extant, and the house's corner cupboards and fireplaces are original. The most interesting room in the house is Percival's study on the second floor, which contains an attractive fireplace and handsome paneling.

Benjamin Silliman House, New Haven County

Location: 87 Trumbull Street, New Haven

The American Journal of Science is one of the Nation's outstanding scientific periodicals, having served American science since Benjamin Silliman founded it in 1818. It is probably Silliman's most lasting contribution to science in the United States, but this notable teacher and popularizer of science still ranks as one of the leading scientists of the ante-bellum era.

Silliman's development as a scientist probably surprised him as much as his friends. Born on August 8, 1779, in Trumbull, Connecticut, he entered Yale when but thirteen. Known there as "Sober Ben," he exhibited some interest in science, but after being graduated in 1796 he subsequently began to study law. He passed his law exams in 1802, but he never practiced. Totally unexpectedly, Yale's president, Timothy Dwight, appointed Silliman as the college's first professor of chemistry on September 7, 1802. Unwilling to shirk this challenge, Silliman accepted the appointment and spent the next two winters studying chemistry in Philadelphia and Princeton. The new and young professor faced his first class at Yale on April 4, 1804. In a short while, Yale provided a laboratory for Silliman in the basement of a new building, and Silliman wryly commented at a later time on his subterranean quarters, saying

> How did it happen. I suppose that . . . the able civil architect . . . had received only some vague impressions of chemistry--perhaps a confused and terrific dream of alchemy, with its black arts, its explosions, and its weird-like mysteries. He appears, therefore, to have imagined that the deeper down in mother earth the dangerous chemists could be buried, so much the better . . ."[1]

Silliman spent fifteen damp, dank years in this cell.

Silliman's basement laboratory did not discourage him, and he taught at Yale until his retirement in July, 1852. Pragmatic, persistent and receptive to new ideas, Silliman made Yale a leader in chemistry and geology.

A trip to Europe in 1805 both broadened his chemical background and stimulated a general interest in geology, just as he did when he organized the Nation's first geological society, the American Geological Society, in 1819. The dynamic professor also helped to create the Yale Medical School in 1813; and in 1846-47 he led the movement to establish a precedent-breaking graduate faculty at Yale. Of course, throughout his years at Yale Silliman taught, and numerous men moved from his classes to positions of leadership in the American scientific community. One student, James Dwight Dana, became one of the world's leading geologists.

Silliman's teaching outside of Yale was also of major significance. In 1834, he began to give public lectures on geology, which he continued until 1857, and through his platform appearances he did more "to spread a knowledge of science and to stimulate people to study science than any other teacher of his generation."[2] It must have been a missionary's zeal that took him to the people, for in that day, when travel was so difficult, he spoke in such widely separated cities as Pittsburgh, New Orleans, Mobile, and St. Louis, as well as in numerous lesser towns.

A man of remarkable energy, Silliman had found time to establish the *American Journal of Science* in 1818. It took almost four years of endless toil to make the journal a success, but ever since it has enjoyed an enviable position among scientific periodicals. The magazine, also known as "Silliman's Journal" in its early period, exercised a profoundly beneficial influence upon science in the United States, especially as a forum for the announcement of the latest scientific discoveries. It continues to stimulate the Country's scientists, just as it remains a unique memorial to a great man long after his death on November 24, 1864.

The Silliman house bears little resemblance to the building occupied by the scientist. Built between 1807-09 by James Hillhouse, the house stood on Hillhouse Avenue when Silliman purchased it in 1814 for $4,500. Silliman soon made some changes, and in 1836 added a wing. After his death, the house was moved around to face on Trumbull Street in 1871; also, a room over the front porch was added at this time. Moreover, the stone walls were removed in favor of clapboard. Some years later, brick wings were added to the house.

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[1] Quoted in Edward Farber (ed.), *Great Chemists* (New York, 1961), 408.

[2] Farber, *Great Chemists*, 414.

The Benjamin Silliman House in 1836, New Haven, Connecticut.

Courtesy, New Haven Colony Historical Society

The Benjamin Silliman House today. New Haven, Connecticut

NPS Photo, 1963

GEORGIA

The Crawford W. Long Memorial

Location: Jefferson, Georgia

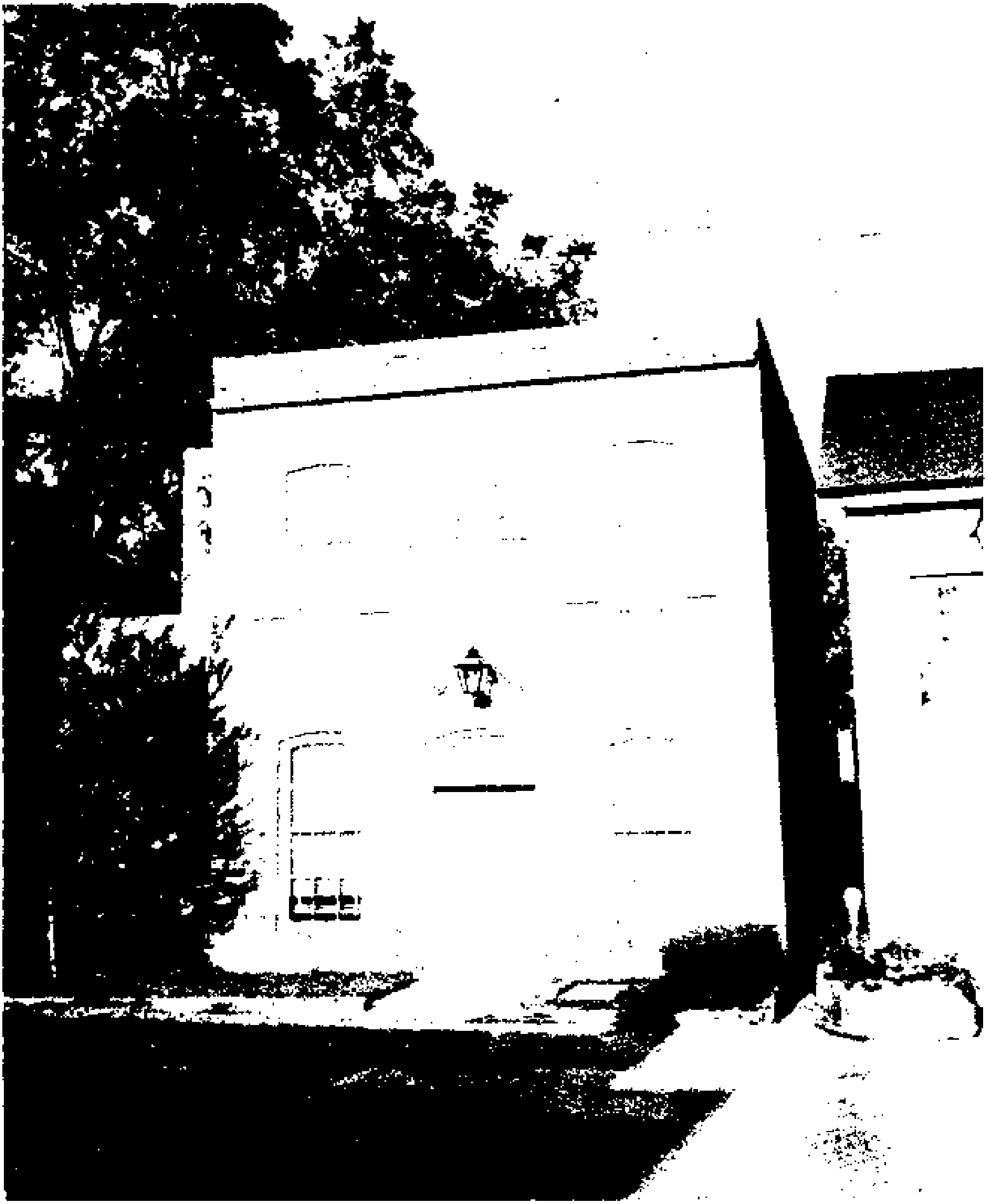
Sir Humphry Davy took a long step toward modern anaesthesia in his experiments with laughing gas. In 1799, he wrote that nitrous oxide seemed capable of destroying physical pain and suggested that it might be used with advantage in surgical operations. Surprisingly, no one acted on this suggestion for another 43 years.

In the early 1840's the effects of laughing gas were widely discussed. Wandering charlatans gave demonstrations, and "nitrous oxide frolics" were sometimes held. It was in this way that Dr. Crawford W. Long of Jefferson, Georgia, began his experiments with anaesthesia. When no laughing gas was available for a planned frolic, Long substituted sulphuric ether. Ether proved to produce the same sort of intoxication. Dr. Long shrewdly observed that his guests seemed oblivious to bruises that would ordinarily have been quite painful. From this, he began to ponder seriously the use of ether to prevent pain, and finally decided to make the test. On the 30th of March, 1842, Dr. Long removed a small tumor from the neck of one of his friends while he inhaled ether. The patient gave no evidence of suffering during the operation and indicated, after it was over, that he had experienced no pain.

If Long had immediately reported this experiment in a medical journal, there could have been no doubt that he was the discoverer. The great ether war would never have been waged. However, Long was cautious and determined to test the results through other operations. The first published account of Dr. Long's operations did not appear until 1849, in the Southern Medical and Surgical Journal. Publication seemed to have been prompted by an account of the experiments of the Boston dentist, William Thomas Green Morton. Because Long had not published his results, others rediscovered his techniques independently.

Crawford W. Long, Horace Wells, Charles T. Jackson, and William Morton all share in the discovery of surgical anaesthesia. Yet it was Morton's work that was first announced on November 18, 1846 in the Boston Medical and Surgical Journal. Morton had acted independently and conducted experiments with ether on his own initiative. He had assumed the entire responsibility for the outcome of his first public demonstrations on humans, and he thus, before anyone else, convinced the surgical world of the value of the discovery.

Although Crawford W. Long was the first to experiment with and use ether successfully in surgery, most medical authorities would agree that he loses the larger honor of acquainting the medical world with its benefits because



Crawford Long Memorial. Jefferson, Georgia

NPS Photo, 1965

he delayed publication of experiments with ether until several years after the universal acceptance of surgical anaesthesia.

The Crawford W. Long memorial in Jefferson, Georgia, was reconstructed on the foundation of Dr. Long's office before 1860 by the physician who bought his practice. This building has recently been restored and houses a museum which was dedicated and opened to the public in 1957. The memorial is administered by the Georgia Historical Commission.

INDIANA

David Dale Owen Laboratory

Location: Posey County, Church Street, New Harmony

David Dale Owen occupied an important position in the ranks of American geologists between 1820-1860. His thorough and efficiently conducted geological surveys in western America not only retain significance in the history of American geology, but also are remembered as having helped to develop that area.

Owen was born in Scotland on June 24, 1807, the third son of Robert Owen, the founder of New Harmony, Indiana. He received his early education in Europe, and he returned to London for study in geology in 1831 after having been in New Harmony since 1828. Upon his return to America, Owen attended the Ohio Medical College in Cincinnati and received an M. D. degree in 1836. In the following year he married Caroline C. Neef, whom he had met in New Harmony.

Owen began his geological career in the same year he married, 1837. For some reason he had turned from medicine, accepted a position as the state geologist of Indiana. He completed a report for the State within a year, and then he resigned. Within a short time, however, he began to work for the United States.

Owen accomplished his greatest geological work while working for the Federal Government. Although reticent and forgetful, Owen had a pleasant personality and singular administrative ability. When the Government commissioned him on August 17, 1839, to survey an eleven thousand square mile area in Wisconsin and Iowa, Owen formed a brigade of 139 assistants, trained them and set them to work. On November 14, 1839, Owen delivered a completed report on the survey. Aside from describing for the first time the mineral riches of the area, the report stands as a monument to "a feat of generalship which has never been equaled in American geological history."[1]

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[1] George D. Merrill, The First One Hundred Years of American Geology, (New Haven, 1924), 199.

The David Dale Owen Laboratory. New Harmony, Indiana

NPS Photo, [illegible]

Subsequently, Owen carried out a geological study of the Chippewa Land District for the United States. He covered all of Wisconsin, Iowa and Minnesota, and his report of over 600 pages appeared in 1852. Owen was a talented artist, and his geological drawings in his Chippewa report have hardly been equaled.

An incredible worker, Owen served as the state geologist of Kentucky and Arkansas in his last years. He had also become the state geologist of Indiana for the second time when death struck him on November 13, 1860. When he died, Owen was at work on a report. Shortly before his demise, a doctor had warned Owen that his illness, plus his constant writing, might cause his death within a week, but the geologist had ignored the prediction, saying "I only want thirteen days to finish . . . [the report],"[2] and had continued working.

Owen built his laboratory in New Harmony for $10,000. Still little changed from the time it was erected, the building's towers, pitched roofs and attractive exterior decoration give it an exceedingly interesting appearance. There is only one floor to the building, and aside from the living room, the rooms are not too large. Owen designed the building himself.

INDIANA

Thomas Say Residence

Location: Posey County, Southeast corner West and Church Streets,
New Harmony

Thomas Say, the father of descriptive entomology in America, was born in Philadelphia in 1787. Of Huguenot descent, the young Say developed an interest in science, which subsequently led to membership in the Philadelphi Academy of Natural Sciences shortly after its establishment in 1812. Say also became the curator of the Academy, but at no salary. With almost no income, the young man for months spent about twelve cents a day for food, eating little else than bread and milk. He lived in the Academy's headquarters, finding resting at night beneath the skeleton of a horse.

Say's participation in several expeditions after some years in the Academy greatly stimulated his work. A trip to Florida, which area he considered a superb place for bugs (as some still do), led to Say's initial paper on entomology, which appeared in the Academy's Journal. In 1819 and again in 1823, Say accompanied the western expeditions led by Major Stephen H. Long. Slender and tall, Say's white beaver hat amused and intrigued the Indians

[1] Quoted in ibid., fn. 41, 199-200.

The Fauntleroy House, where Thomas Say lived. New Harmony, Indiana

NPS Photo, 1962

as much as his bug collecting. And during the long, exhausting treks, Say managed to build notable collections of specimens while traversing a little known area of America.

When the second Long expedition had ended, Say returned to Philadelphia and the Academy of Natural Sciences. He not only attended to his curatorial duties, but continued his entomological studies. In 1824, he published the initial volume of his American Entomology, or Description of the Insects of North America. A second volume followed in 1825, and later a third volume, but poor public reception of the work forbade the printing of additional volumes. This work constitutes Say's major scientifi achievement, as well as representing the first great American contribution in entomology. Say, in his American Entomology, described the genera and species of American insects, plus illustrating the insects by colored engravings. There was no more artistic work of its kind in America when Say produced these volumes.

Not too long after the appearance of the second volume of the Entomology, William Maclure, an old benefactor of Say's, persuaded Say to move to New Harmony, Indiana. There he could teach and pursue his work. Say arrived at Robert Owen's socialistic community in January, 1826. A year later he married Lucy Listaire, who proved to be an ideal companion for him. Travel, teaching, and study kept Say very busy. In 1828, he published the third volume of his American Entomology, for example. Two years later, Say published his American Conchology, the plates for which his wife had largely prepared. Four years later, when only forty-seven, death cut short his career, denying to America further fruits of this perceptive, energetic scientist.

At some time, and for an undetermined period during his years in New Harmony, Say lived in the Fauntleroy House. Built in the early 1820's, the sturdy, clapboard building has housed many families, of which the Say family was the most exceptional. The house is now a museum, commemorating various aspects of the history of New Harmony.

MASSACHUSETTS

Nathaniel Bowditch House

Location: Essex County, North Street, Salem

Nathaniel Bowditch probably set a record for discovering errors in a published work when he uncovered eight thousand in a manual of navigation. Among the most grievous mistakes John Hamilton Moore had made in compiling his book, The Practical Navigator, was the citation of the year 1800 as a leap year--several sea disasters resulted. It is obvious then why one of the most remarkable scientific books ever published in America,

Bowditch's The New American Practical Navigator, rapidly supplanted the earlier British work on ships the world over.

Bowditch developed his inherently keen, analytical mind largely through his own efforts. Born on March 26, 1773, of a family who had followed the sea for generations, the young Bowditch received some schooling in Salem, Massachusetts. But when twelve he became an apprentice to a ship chandler. Although he could study only after work, the youth did not forsake his interest in mathematics. Within a year, for example, he had compiled a notebook on navigation. With borrowed books and amazing dedication, Bowditch continued to study as energetically as most boys of his age played. So impressed were two of his older friends with his zeal and ability, that in 1791 they secured permission for him to use the volumes in Salem's Philosophical Library Company. Bowditch devoured the treasures he found there. Indicative of his intellectual discipline is the fact that when only eighteen he copied all of the mathematical papers he found in the Transactions of the Royal Society of London. By the age of twenty-one, he had read, after teaching himself Latin, Sir Isaac Newton's Principia, even discovering an error in it. Moreover, with a French dictionary in one hand and a Bible in another, he had learned French.

In 1795, the slight, cheerful, bright-eyed and already gray-haired youth turned to the sea. For the next nine years, with some time off ashore, Bowditch sailed over the globe. Throughout his travels he kept a journal, filled it largely with notes on the weather, or on matters of navigation. But when he visited the Isle of Bourbon in the Indian Ocean in May, 1795, his surprise at the easy ways of the fairer sex produced this entry:

> Oh, my country, how much dearer to me is the demeanor of thy daughters than that of the women of this country.[1]

During these voyages, Bowditch continued his studies, especially those concerned with navigation. Even when he made his last voyage, as the captain of the Putnam, which he and three others owned, between November, 1802 and December, 1803, he pursued his studies. He indeed almost let the Putnam sail itself.

It was in the period between 1795 and 1802 that Bowditch produced his Practical Navigator. By July, 1799, he had already published two revisions of Moore's error laden Navigator, but then decided to produce a new book. Three years later, in June, 1802, Bowditch's erudition and genius appeared before the world in his book for seamen. Some 274 pages, the manual contained navigational aids, tide tables, astronomical tables, the duties of officers and a textbook on navigation. The material for teaching navigation constituted a remarkable innovation, and it probably stemmed from Bowditch's attempts to teach geometry to sailors while on his various

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[1] Quoted in Robert Elton Berry, Yankee Stargazer, The Life of Nathaniel Bowditch (New York, 1941), 55.

voyages. In a short time, the book achieved outstanding popularity. And as a sea captain later wrote, one after 1802 went to sea with a "Testament, a Bowditch, a quadrant, a chest of sea clothes, and a mother's blessing."[1] Subsequent editions appeared during Bowditch's life, with the author kept busy by revisions, and the Practical Navigator, although somewhat changed, remains the seaman's dearest book.

Despite the fact that the Practical Navigator was Bowditch's great work, he accomplished additional noteworthy achievements in science. His study of the Weston, Connecticut, meteor of 1867 received applause here and in Europe. Aside from that investigation and numerous other scientific papers Bowditch's translation of LaPlace's Mecanique Celeste is of especial interest. From at least the time of his last voyage, between 1802-1803 until his death, the scientist labored over translating the Frenchman's great work on mathematics and theoretical astronomy. In working on LaPlace, Bowditch said that whenever he came upon one of LaPlace's "'Thus it plainly appears,'" that he then had

> hours of hard study before . . . [him] to fill up the chasm and find out and show how it plainly appears.

The job was a stupendous one, and when the first four volumes of the translation appeared, each contained over a thousand pages. Death cut shor Bowditch's work on LaPlace's last volume (it is still untranslated). Our admiration for this scientific contribution, which brought continental mathematics to America, is increased by a realization that Bowditch spent a third of his savings, $12,000, to publish his translation.

Bowditch enjoyed more than just success in science. Although his first wife, Elizabeth Boardman, died in the same year they were married, 1798, he and his second wife, Mary Ingersoll, whom he married in October, 1800, had a happy marriage. She bore him eight children. After retiring from the sea in 1803, Bowditch had joined a life insurance company in Salem. In 1823, after accepting a position with a Boston insurance firm, he moved to Boston. Bowditch's sharp eye for figures annoyed the firm's clerks, but under his direction the company prospered. Death came to him on the afternoon of March 16, 1838.

The house that Bowditch lived in at Salem between 1811-1823, he living here longer than in any other of his numerous Salem residences, was moved from its original location at 312 Essex Street to its present site on North Street around eight years ago. It is an early nineteenth-century building and has been recently improved by the City of Salem for use by the Salem Park Department. In working on the house, the Salem Park Department removed post-Bowditch partitions, repairing the walls and floors, and the small lights in the windows. On the exterior, the old balustrade atop the house has disappeared, as have the shutters.

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[1] Quoted in Dirk J. Struik, Yankee Science in the Making (New York, 1962) 109.

The Nathaniel Bowditch House. Salem, Massachusetts

NPS Photo, 1983

Oliver Wendell Holmes House, "Holmesdale,"

Location: Berkshire County, Holmes Road, Pittsfield

Most of us remember Oliver Wendell Holmes because of two of his poems, "Old Ironsides" and 'The Deacon's Masterpiece, or the Wonderful 'One-Hoss Shay.'" Holmes was more than just an author, however, for he was a noted doctor of his day and a great medical teacher. Moreover, his paper on puerperal fever is a minor landmark in the history of American medicine.

Holmes was born on August 29, 1809, and his father, a minister, hoped that his son would also assume the cloth. But the young Holmes rejected that path, and after being graduated from Harvard University in 1829, sailed to Europe in 1833 to study medicine. In Parks, he benefited from the latest medical advances; and upon his return home received his M. D. degree from Harvard in 1836.

Holmes subsequently became a member of the staff of the Harvard Medical School, which he helped to make one of the best in the country. He shone as a teacher, especially of anatomy, enlivening his classes with wit and humor. Never of narrow interests, Holmes also wrote on medicine, as well as other subjects. When Dr. W. T. G. Morton proved the value of ether in surgery, it was Holmes who suggested that the term "anaesthesia' be used. Even more importantly, it was Holmes who first explained the cause of puerperal fever.

Once surgical methods had been developed to aid in childbirth, puerperal fever, which caused many mothers to die, immediately broke out. Doctors, who had been unable to determine the fever's cause, were astounded when in 1843 Holmes' paper, "The Contagiousness of Puerperal Fever' asserted that the doctors themselves were responsible. By means of statistical evidence, Holmes showed that it was just not an "unlucky" case when a mother died, but that those in attendance must have transmitted the germ to the victim. The author proved that chance was not responsible when his statistical analysis made it plain that one doctor who had lost sixteen mothers in one month was more than only unfortunate. Holmes also pled for antiseptic practices, and urged doctors to avoid handling a delivery if they had had a recent case of the fever.

Although we know Holmes was right, his colleagues ridiculed his conclusions. As a result, mothers continued to die from puerperal fever. It was not until the 1880's that Holmes paper was fully accepted, after other studies of the fever had given the same answer. When Holmes died on October 7, 1894, he died in the knowledge that tragedy in childbirth was far less frequent that it had been in his youth.

The Oliver Wendell Holmes House, "Homesdale", Pittsfield, Massachusetts.

NPS Photo, [illegible]

Holmes built a summer residence on part of the Wendell family lands near Pittsfield in 1849. Now known as "Holmesdale," the spacious, two-story building afforded Holmes seven of his most enjoyable summers, he spending his vacations there until 1856. It was here that he wrote "The Deacon's Masterpiece." Miss Hall's School for Girls now owns the house and uses it as a residence for teachers.

Charles T. Jackson House, "Mayflower Society House,"

Location: Plymouth County, Winslow Street at North Street, Plymouth

Charles T. Jackson possessed a brilliant and original mind, which carried him to a commanding position in American science before 1861. But he also possessed a suspicious, self-centered personality, which helped to cloud his reputation and lead him to the insane asylum late in life.

Born in Plymouth, Massachusetts on June 21, 1805, Jackson was orphaned when twelve. A guardian aided him, however, and Jackson was able to complete his medical studies at the Harvard Medical School in 1829. He journeyed to Europe in the same year and stayed until 1832. There, he continued his medical work in Paris as well as studying geology. Jackson also traveled throughout the continent, availing himself of every opportunity for further medical and geological study. He also became very interested in electricity, and collected some electrical equipment to take back to America. When he boarded the *Sully* in the fall of 1832, Jackson probably had a deeper knowledge of contemporary science than any other American.

On board the *Sully*, Jackson met Samuel F. B. Morse, a meeting that eventually led to one of Jackson's epic quarrels. The scientist and the artist discussed electricity one evening, including the possibility of sending messages electrically. Morse, stimulated by the conversation, drew a sketch of an electric telegraph upon returning to his cabin. And when the *Sully* reached America, Morse, after long and difficult years, finally perfected his instrument. Morse's success caused Jackson to claim that he really was the inventor of the electric telegraph, and he became involved in a violent fight with Morse. The quarrel did nothing for Jackson, except to divert him from his scientific work and to sap his energies.

Jackson's egocentricity also impelled him into an even more violent dispute with W. T. G. Morton. Morton, a one-time pupil of Jackson's in Boston, proved to the world the anaesthetic value of ether during an operation at the Massachusetts General Hospital on October 16, 1846. Subsequently, Jackson claimed that he had told Morton about ether, and that he, not Morton, should be regarded as the benefactor of mankind. The frenzied quarrel so seared both participants that it helped to kill Morton and pushed Jackson into an insane asylum in 1873.

The Charles T. Jackson Home, Plymouth, Massachusetts.

NPS Photo, [illegible]

Despite his unpleasantness and his tragic end, Jackson's beneficial impact on American science cannot be denied. He not only contributed innumerable ideas, but also stimulated many individuals along the path of scientific endeavor.

Edward Winslow built the Jackson house in 1754. The building has been greatly altered since its construction, especially because of a large and fairly recent rear addition. The original section of the building, however, contains paneling dating from 1754.

Salem Athenaeum

Location: Essex County, 337 Essex Street, Salem

The Salem Athenaeum owns an extremely interesting eighteenth century collection of scientific works. Added significance attaches itself to those volumes because in all likelihood the Athenaeum would never have acquired them if it had not been for the American Revolution.

In February, 1781, an American vessel out of Salem attacked and captured the *Mars*, a British ship. The captor must have been surprised to find aboard their prize a notable collection of scientific works, the scientifi library of Sir Richard Kirwin, of Dublin. Kirwin had intended the books for an institution in Quebec, but fate decreed otherwise. When the *Pilgrim*, the American ship, returned to Salem, the vessel's owners placed the books on sale.

A new cultural organization in Salem, the Philosophical Library, immediatel exhibited great interest in the books. And on April 12, 1781, the Philosophical Library paid L858:10:00 for the collection, thus acquiring an invaluable library. Included in the collection were most of the transactions of the French Academy, of the Royal Society of London, and of the Society of Berlin. The Kirwin collection also counted the works of Sir Robert Boyle and Sir Isaac Newton. Through the Philosophical Library's foresight, Salem came to possess a magnificent intellectual tool, and the volumes, for example, helped to school Salem's famous scientist, Nathaniel Bowditch. Some years after 1781, the Philosophical Library merged with the Social Library in Salem to form the Salem Athenaeum. The Social Library had been organized in March, 1760, and over the years had acquired a respectable number of books. By 1810, most of the members of the Social Library also belonged to the Philosophical Library, which situated led to the merger of the two groups on March 12, 1810.

Since 1810, the Athenaeum has occupied several buildings. Its present home was built in 1907, and is modelled after "Homewood," the Baltimore residence of Charles Carroll. The attractive structure now houses over 45,000 volumes.

The Salem Athenaeum, Salem, Massachusetts.

NPS Photo, 1963

NEW HAMPSHIRE

Samuel Morey House,

Location: Grafton County, Oxford

The antecedents of the internal combustion engine are much older than is commonly assumed. One of the first such engines was patented in 1826 by Samuel Morey, an early American inventor.

Morey was born in Hebron, Connecticut, on October 23, 1762. In 1766, Morey's father moved his family to Oxford, New Hampshire, where Morey lived until he moved to Fairlee, Vermont, a short time before his death. During his youth, Morey manifested an aptitude for machinery, which aided his subsequent lumber business. Even when well launched on his business career, Morey also studied the properties of heat and light, and over the years added to his knowledge of those forces.

Because of his investigations, Morey became particularly interested in the application of steam power to machines. By 1793, he had made a steam operated spit, for which he received his first patent. Morey developed additional steam driven machines, receiving after 1793 patents for a rotary steam-engine and a steam pump. Moreover, he visualized the possibilities of a steam driven boat, and had constructed several of them by 1797, when he built and demonstrated a steamboat in New Jersey. When Morey learned of Robert Fulton's plan for steamboats, he visited Fulton and sought to have Fulton's plan for steamboats, he visited Fulton and sought to have Fulton adopt his developments. Fulton rejected Morey's offer, but subsequently claimed Fulton had used his ideas.

It was in conjunction with his efforts to produce water gas, that Morey conceived his gas or vapor engine. After long experimentation, Morey produced a "preparing box," or carburator, in which a mixture of air and a gas could be made and carried to the engine. The solution of the fuel problem paved the way for Morey's internal combustion engine, for which he received a patent on April 1, 1826. He carried his engine to New York and exhibited it, but failed to arose interest in his invention. Morey, in spite of public apathy, realized the significance of his engine, and correctly predicted that it would one day revolutionize transportation. The accuracy of his prophecy was underlined when he constructed a boat in 1829 and installed a gas engine, which enabled the vessel to move along at seven or eight miles an hour. However, Morey again failed to secure financial backing.

Morey died on April 17, 1843. Unsung in his own day, the inventor still deserves greater attention for his contributions than he has yet received.

The Morey house is a handsome, two-story clapboard structure. Built in 1773 by Obediah Noble, the house was purchased by Morey in 1799, who made several improvements in it. Among them were the handsome doorway and Palladian window that still grace the house's front.

NEW YORK

Samuel Guthrie House, New York

Location: Jefferson County, Sackets Harbor

The discoverer of chloroform, Samuel Guthrie, was born in Brimfield, Massachusetts, in 1782. His education included little formal schooling. Indeed, his father apparently taught him medicine. Guthrie did attend two courses of lectures on medicine, one of which was presented at the Universi of Pennsylvania in 1815. But even before 1815, he had begun to practice. By the time he moved from Sherburne, New York, to Sackets Harbor, moreover, he had a wife, the former Sybil Sexton, and three children.

When Guthrie moved in 1817 to Sackets Harbor, which was to be his home for the next thirty years, he found that isolated section of New York virtually a wilderness. Undaunted, however, he acquired a farm, built a house and started his work in chemistry. The taciturn, independent and inventive Guthrie built a laboratory behind his house for his experiments. His neighbors highly approved of his investigations, especially when Guthrie produced an excellent vinegar and fine alcohol. He won even wider applause when he invented the percussion cap and a "punch lock" for exploding the cap. The flintlock musket became a thing of the past as a result of this invention.

Guthrie displayed an amazing versatility in his work. In 1830, he notified Benjamin Silliman, the great Yale chemist, that he had perfected a method of creating molasses out of potato starch. Subsequently, Guthrie sent Silliman some chloroform, which he had produced by distilling chloride of lime with alcohol in a still made of copper. And in 1832, news of the discovery of chloroform appeared in the American Journal of Science, which was edited by Silliman. Not until some fifteen years later, however, was the value of chloroform as an anodyne generally recognized. And at just about that time, Guthrie died on October 19, 1848.

The Guthrie house is a two-story, brick structure. It has an attractive front door, a gabled roof and a rear extension. The main section of the house has undergone little change, which contrasts with the much altered wing behind the house. Guthrie's laboratory stood far back of the house, and today only the laboratory's foundations are extant.

Sylvanus Thayer, Superintendent's Quarters, New York

Location: Orange County, United States Military Academy, West Point

Sylvanus Thayer, the "Father of the Military Academy," was born on June 9, 1785. In 1803, he entered Dartmouth College, where he pursued the classical course, but in 1807 transferred to West Point. He received his degree from the Academy in 1808, plus a commission as a second lieutenant

The Superintendent's Quarters, United States Military Academy, West Point, New York.

Courtesy, U. S. Military Academy

in the engineers. Until the War of 1812, Thayer worked on coastal fortifications. During the second war with England, Thayer served with the army on the Canadian border and in Norfolk, Virginia. Following the Treaty of Ghent, he sailed to Europe in order to study military engineering. He had the good fortune to study at the Ecole Polytechnique, which he enjoyed immensely. Moreover, his work at the Ecole Polytechnique impressed upon him the need for similar training in America.

After returning to the United States, Thayer became the Superintendent of West Point in 1817. He retained this position until 1833, and during his tenure made West Point an outstanding military school. Aside from ending the laxity everywhere evident at the Academy, the French-trained Superintendent laid heavy stress on improving the academic program. He borrowed freely from his experience in France; moreover, he placed a French engineer in charge of the engineering department. Text books of French origin, either in French or in translation, also became standard at West Point. Thayer's concern for thoroughness and proficiency stimulated the development of an excellent engineering department at West Point, and from it appeared many capable engineers. Indeed, West Point graduates planned and built most of the early railroads in America.

Thayer left the Academy in 1833, at his own request. In the following years, he supervised the construction of coastal fortifications on the New England Coast. Of especial importance were the fortifications he built in Boston Harbor. He retired from the army in June, 1863, having attained the rank of brigadier general. Before his death on September 7, 1872, he had endowed the Thayer School of Engineering at Dartmouth and had established a free library in Braintree, Massachusetts.

The superintendent's quarters, the oldest building at West Point, was largely completed in 1820. Numerous additions and changes were made in the following years, one of the most notable additions being the ironwork that was added to the porch during the Civil War. Thayer's office as superintendent was in the basement of the house. It is now planned to restore the office as a memorial to Thayer.

OHIO

Thomas A. Edison Birthplace

Location: Erie County, Milan

When Thomas A. Edison was born on February 11, 1847, in Milan, Ohio, Milan was a bustling, prosperous grain center. Changing conditions shortly spelled the town's economic downfall, however, and today the village is most remembered because of the attractive brick cottage in which Edison, one of America's great inventors, was born. Edison lived in the house until he was six, when his father sold it and moved to Port Huron, Michigan.

Edison's amazing career is well known to most Americans. A poor student, he largely educated himself, and by sixteen had already made several inventions in telegraphy. By 1869, after much travel, a variety of jobs, and constant experimenting, Edison had secured a lubrative position in New York. In the following year, though, Edison established a manufacturing concern of his own, having received a goodly sum for several of his inventions. Edison gathered around himself many excellent men, and his concern has been labelled the first "invention factory." And he and his cohorts did produce numerous new products, especially for the telegraph and telephone.

The scope of Edison's activities created the need for more space, so in 1877 he moved from New York. He first built a laboratory at Menlo Park, New Jersey, where he remained for a decade, but in 1887 he built an even larger factory in West Orange. In the meantime, a flood of discoveries or developments came from Edison and his colleagues--the incandescent lamp in 1879, the Pearl Street power plant in New York in 1882, and the "Edison effect" in 1883. After he had moved to West Orange, Edison continued to startle America with new things. His pioneer work with motion pictures during the 1890's alone is of the utmost significance.

In addition to his inventive ability, Edison possessed an unusual organizational talent. Numerous companies were organized by him to produce his inventions, as he felt there was little profit in devising new products if they were not put to use. Today's gigantic General Electric Company, for example, is in large part derived from concerns begun by Edison.

Edison remained an insatiable worker, even in his last years. The tremendous benefit stemming from his unremitting toil was unrecognized by the Nation in 1928, when Congress awarded him a gold medal for his contributions to mankind. About three years later, on October 18, 1931, Milan's most famous son died.

The house Edison lived in until he was six was built around 1841. The gabled brick building has a basement, ground floor, and attic. A living room occupies most of the first floor, but off of it is the room in which Edison was born. There are additional bedrooms on the second floor.

After the Edisons moved from Milan in 1853, the house was owned by others until 1894, when it was purchased by a sister of Edison's. In 1906, Edison became the house's owner, and after his death the Edison Birthplace Association, Inc., assumed control of the house. The Association restored the house in 1947. Unfortunately, only a few items of the original furnishings of the house are now in the building.

The house does not possess exceptional value because Edison lived there for only about six years and because the building contains few of its original furnishings.

The Thomas A. Edison Birthplace in the early 1880s, Milan, Ohio

Courtesy, Edison Birthplace Association, Inc.

The Thomas A. Edison Birthplace today. Milan, Ohio

NPS Photo, 196[illegible]

PENNSYLVANIA

John James Audubon Home, "Mill Grove,"

Location: Montgomery County, Norristown

John James Audubon's brief residence at Mill Grove reminds us of a highly significant period of his life. While living in the comfortable, two-story, gabled roof stone house that overlooks Perkiomen Creek, Audubon began his study of American birds and met his future wife. His subsequent career, therefore, largely stemmed from his days at Mill Grove.

Born a natural son to Jean Audubon in Santa Domingo on April 26, 1785, Audubon arrived at Mill Grove in the winter of 1804. His father owned the house and some important nearby mineral deposits, and he had sent his son to supervise his property. The young Audubon was only nineteen when he first saw Mill Grove and was poorly prepared, both in training and temperament, to manage his father's interests. Indeed, shortly after settling down, he began hunting for both food and sport, roaming the surrounding countryside.

Before coming to America, Audubon had interested himself in birds. Shortly after reaching Mill Grove, his enthusiasm for studying birds reappeared, and in April, 1804, some young pewees in a cave on the Perkiomen attracted his attention. Intrigued by the fledglings, Audubon placed a bit of silver colored thread around some of the birds' legs. About a year later, Audubon observed two of the banded pewees some distance up the creek from the cave. This, as far as is known, was the first bird banding experiment in America.

Audubon's fascination with birds was soon equalled by his interest in Lucy Bakewell, the daughter of a nearby neighbor. The young naturalist did not forget her when he moved from Mill Grove in the spring of 1805, and about three years later, on April 8, 1808, they were married.

Audubon's remarkable subsequent career has been presented elsewhere in this study. But as short as his stay at Mill Grove was, it is understandable why a leading biographer of Audubon says "it was doubtless the happiest year of his life."

Mill Grove has been restored and is now open as a museum.

David Rittenhouse Birthplace

Location: 207 Lincoln Drive, Philadelphia, Philadelphia County

David Rittenhouse, one of eighteenth-century America's galaxy of singularly talented individuals, was born on April 8, 1732 (old style), in the house built in 1707 by his great grandfather, the first colonial paper

"Mill Grove," John James Audubon Home. Norristown, Pennsylvania.

Courtesy, Montgomery County Park System

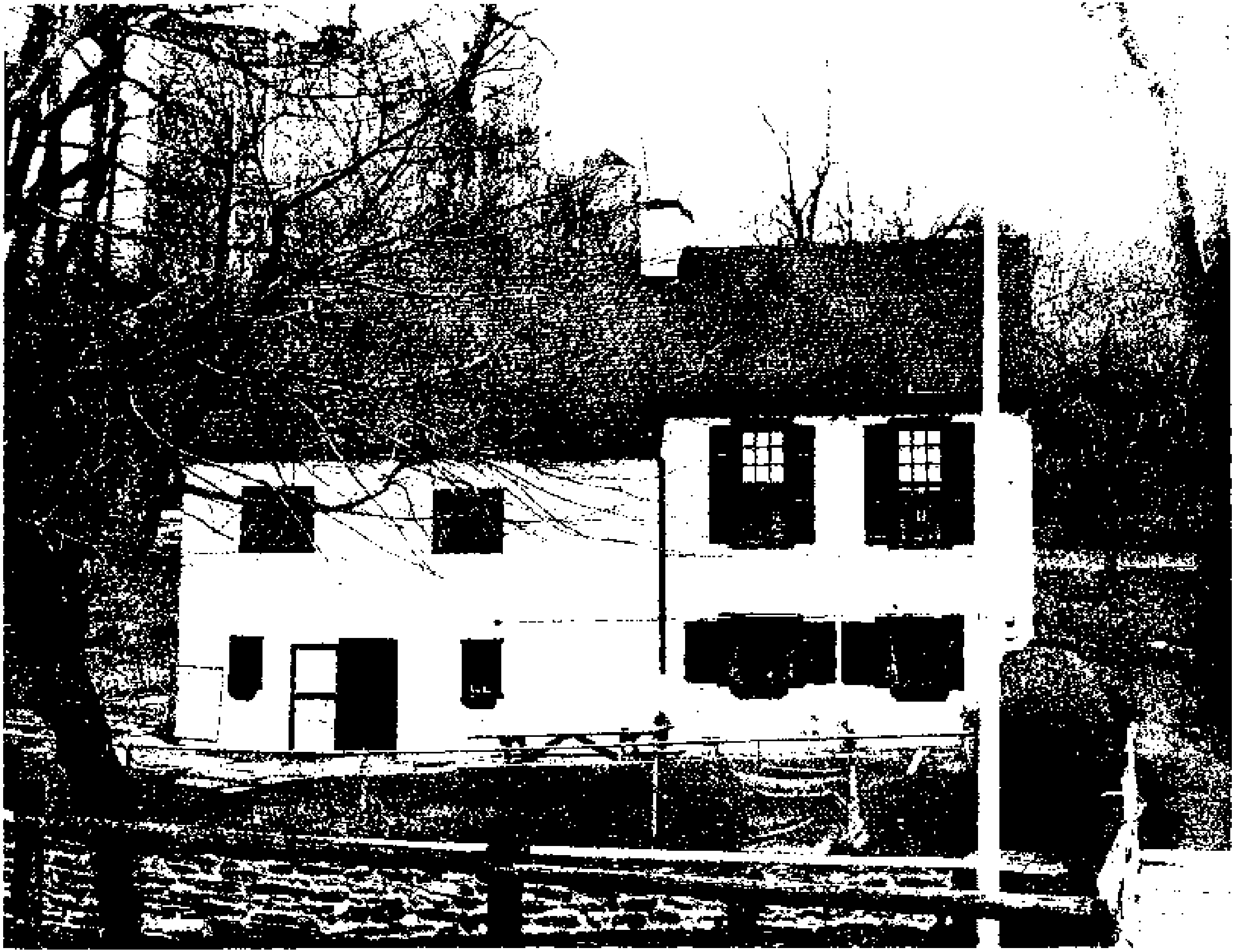
paper manufacturer. The paper mill, just upstream on Paper Mill Run from the young Rittenhouse's home, still stood in 1732, but David exhibited a greater interest in mathematics as a boy than in paper making. When he was twelve, an uncle left the bright youth a chest of tools and some books. One of the books in the bequest especially fascinated Rittenhouse, Isaac Newton's Principia Mathematica, and his study of it further whetted his interest in the physical world. Entranced by Newton, Rittenhouse absorbed all the scientific works he could, thus largely educating himself in the glories of eighteenth-century science. Skilled with his hands, the future astronomer also learned clock making, and when only nineteen opened a shop in Norriton. About nineteen years later, in 1770, Rittenhouse moved to Philadelphia.

Although Rittenhouse excelled in making clocks and although his clocks are prized today, it is as a scientist that he is best remembered. Through his own brilliance and unending study, Rittenhouse early made his mark in pre-Revolutionary science, and he remained active in the field until his death on June 26, 1796. He accepted without reservation the Newtonian heritage, strongly believing that science was man's best means for achieving happiness, and thus Rittenhouse rejected Christianity.

The scope and diversity of this notable American's works is amazing. During his life he made numerous boundary surveys, the reliability of his surveying causing him to be employed by Pennsylvania, Delaware, Maryland, Virginia, New York, New Jersey, and Massachusetts. As his reputation grew, he received commissions to investigate any number of scientific matters; and he entered into scientific exchanges with Thomas Jefferson, Benjamin Franklin, and George Washington. He himself probably enjoyed his astronomical work more than anything else, and he made and perfected telescopes as he eagerly studied the night sky year after year.

Two of Rittenhouse's most important achievements were astronomical in character. In order to observe the transit of Venus in 1769, Rittenhouse constructed the first telescope to be made in America. Through it he tracked Venus from his observatory in Norriton, compiling accurate observations of the planet's course. Two years before 1769, Rittenhouse had begun work on his famous orrery, or "mechanical planetarium." By 1771 he had produced two orreries, but only one survives, and it belongs to the University of Pennsylvania. This marvelous instrument simulates the motion of the planets that were known in Rittenhouse's era, and by using knobs an individual can determine the location of a planet on any day within 2,500 years before or 2,500 years after 1767.

Far from being just a theoretical scientist, Rittenhouse never hesitated in applying his abilities in a practical manner. During the American Revolution, he supervised the casting of cannon and in numerous other ways attempted to further America's fight for freedom. After independence, he helped to organize a national bank and in 1792 became the first director of the United States mint. For many years he played a vital role in America's preeminent scientific society, the American Philosophical Society, and he became its president upon Franklin's death in 1791.



David Rittenhouse Birthplace, back of house, Philadelphia, Pennsylvania.

NPS Photo, 1963

Shortly before his death in 1796, the Royal Society of London made Rittenhouse a foreign member in honor of his work. Both that society and his native land continue to hold Rittenhouse in high esteem.

Paper Mill Stream still flows past the Rittenhouse birthplace. Today, the two-story, gabled roof and stone building is whitewashed, with its doors, shutters, and trim painted green. The roof is steeply pitched, and a single chimney protrudes from it near the center of the house. The front of the house faces Lincoln Drive, the back the stream. From the back, one enters the ground floor, which contains the kitchen and two other small rooms. There are three rooms on the first floor and two on the floor above it. There are no Rittenhouse furnishings in the building.

This house does not possess exceptional value because Rittenhouse lived there only as a youth and because it is bare of original furnishings.

Benjamin Rush Birthplace, Pennsylvania

Location: Philadelphia County, A mile east of the junction of Academy and Red Lion Roads, Frankford

Benjamin Rush was born on December 24, 1745 (old style), in Bayberry, Pennsylvania. He received his A. B. degree from the College of New Jersey, now Princeton University, in 1760, and began his study of medicine in 1761. He studied under Dr. John Redman until 1766, when he went to Edinburgh, Scotland, to finish his medical training. By the time he had won his M. D. degree in 1768, he had become a friend and follower of Dr. William Cullen, a noted British doctor. Rush ended his foreign medical education by working at St. Thomas' Hospital in London for a while before returning to America.

Upon his arrival in Philadelphia in 1769, Rush rapidly rose to an eminent position in the Philadelphia medical world. Within five years he had built a thriving practice, as well as having served as America's first professor of chemistry at the College of Philadelphia. After the outbreak of the American Revolution, Rush became the surgeon-general of the Middle Department of the Continental Army in April, 1777. He had assumed his new duties for only a short time, when he complained strongly about the appalling state of the army's hospitals. When his complaints remained unanswered, he resigned from the army, having become disillusioned with George Washington. Indeed, by 1778, personal relations between Rush and Washington had been ended, they formerly having been good friends.

Once out of the army, Rush resumed his medical career in Philadelphia. He began to lecture on medicine at the new University of the State of Pennsylvania in 1780 and became a staff member of the Pennsylvania Hospital in 1783. During these years, as well as subsequently, he also developed a controversial theory of medicine. Heavily influenced by his old mentor, Cullen, Rush attacked the use of natural healing methods, offering instead remedies for each illness. Moreover, Rush sought to trace every sickness to one cause, the unhealthy state of the blood. To correct that situation, Rush bled patients. He was willing, for example, to remove at least four-fifths of an individual's blood in treating him. When the yellow fever epidemic in 1793 overwhelmed Philadelphia, Rush held that bleeding saved many. But William Cobbett, a pamphleteer, wrote that Rush's treatment acted as the cause of death in many instances. Furious, Rush vehemently defended his treatment, but with greater passion than reason.

Aside from practicing, Rush engaged in many other medical activities. When the University of Pennsylvania was created out of the College of Philadelphi and the University of the State of Pennsylvania, Rush became a leading member of the new institution's medical staff. He became a great teacher, and by the end of his life he had taught over three thousand students. Rush also did revolutionary work with the insane at the Pennsylvania Hospital, publishing in 1812 his Medical Inquiries and Observations upon the Diseases of the Mind, a pioneer study in the field of psychiatry.

Rush, who had married Julia Stockton in January, 1776, engaged in numerous other activities during his life. He had thirteen children, nine of whom survived youth. Politics had attracted him in his younger days, and as a member of the Second Continental Congress, he had signed the Declaration of Independence on July 4, 1776. Subsequently, he supported the movement to abolish slavery, a campaign for temperance, and a drive to improve education in Pennsylvania. When he died on April 19, 1813, Rush had many detractors, but the brilliance and diversity of his life remained immune to their attacks.

Rush's birthplace, which he apparently lived in until he was about five, in a two and a half story stone building. The original section of the house, erected in the seventeenth century, probably was a one story, square building; the second story had been added by the time of Rush's birth. The stone walls are eighteen inches thick, and there is a chimney at either end of the stone section of the present residence. A three story frame addition stands on the right end of the house as you face the building, which addition was constructed in the nineteenth century.

The house appears to be in very poor condition today. When the writer visited the house, he was refused admittance, but it was obvious that the birthplace has deteriorated greatly in the past few years. Moreover, a residential development company owns the structure and the house may be demolished in the near future.

SOUTH CAROLINA

Doctor John Lining House

Location: 106 Broad Street, Charleston

The recently restored house at 106 Broad Street in Charleston was the home of Dr. John Lining, physician, pioneer physiologist, and experimenter in electricity for a number of years. Lining was the first (1730) of a group of Scottish doctors in Charleston to do important scientific work.

Lining first turned his attention to the epidemic diseases which struck Charleston so regularly. In 1748, especially, he made a thorough study of yellow fever, and sent to Europe the earliest account from America, of its symptoms and pathology. This account was subsequently published in an Edinburgh medical journal in 1753.

Dr. Lining turned to meteorology in an attempt to relate weather to disease. Over a period of a year he conducted a celebrated statistical experiment in which he measured the intake and outgo of his body. Each day he noted the temperature, recorded the humidity, the extent of cloudiness, the amount of rainfall, and the force of the wind. He thus noted the effects of climatic conditions upon his own metabolism. These observations were, incidentally, the first published records of the weather in America.

Lining continued his weather statistics for several years, and his accounts of Charleston weather were published in communications to the Secretary of the Royal Society in 1754. Lining also corresponded with Benjamin Franklin on scientific questions, particularly electricity.

Though not a major American scientist, Lining holds a secure position in the history of science as a distinguished member of that group of intellectual Americans who played a leading part in the early development of science and medicine in this country.

Charleston Museum

Location: Charleston, South Carolina

The Charleston Museum is the oldest in the United States. In 1773, the Charles Town Library Society began its collections by appointing a special committee for collecting materials and for promoting a natural history of the province. In 1852, trustees of the College of Charleston revived the museum and located it in the college building. After several transfer and reorganizations, the museum was established in its present home of Rutledge Avenue, between Calhoun and Bennett Streets, in 1907.

Dr. John Lining House, Charleston, South Carolina.

NPS Photo, 1960

The museum has endeavored to build up a collection representative of local culture, and its galleries are devoted almost entirely to South Carolina materials.

There is continuity in the museum's collections; it still has some of the specimens from its earliest period. The present museum building is, however, relatively modern and not related to the original site.

VIRGINIA

Dr. William Brown House

Location: 212 South Fairfax Street, Alexandria

Soon after he had received his medical degree (1770) from the University of Edinburgh, William Brown returned to America and established his practic in Alexandria, Virginia. At the outbreak of the Revolution, Brown began service as a regimental surgeon. Within about a year, Congress appointed him surgeon general to the middle department of the Revolutionary Army. He was next promoted to the office of physician-general to superintend the practice in Alexandria.

While serving in the army, in 1778, Brown brought out a thirty-two page pharmacopeia designed to serve the military hospitals. It was admittedly a compilation based largely upon the Edinburgh Pharmacopeia, but it was highly selective and the first to be published in the United States. Its publication served the author's purpose of introducing a degree of uniformit throughout the several hospitals.

The William Brown House at 212 South Fairfax Street is a beautiful two-story, white clapboard house in the old section of Alexandria. This frame over brick house was erected in 1775.

Belroi, Walter Reed Birthplace

Location: Five miles west of White Marsh, Va., on State 614 at its
junction with Route 616.

Walter Reed received medical degrees from the University of Virginia and Bellevue Hospital Medical College (1870) and began the practice of medicine in Brooklyn. In 1874, Reed decided to seek an appointment in the Army Medical Corps and began this new career as an assistant surgeon, with the rank of lieutenant. Eleven years of frontier garrison life followed.

In 1890, Dr. Reed gave a new direction to this army career when he returned to graduate studies at the Johns Hopkins University Hospital while he was stationed in Baltimore. After completing a brief course in clinical

medicine, he was attached to the pathological laboratory, where he specialized in the comparatively new science of bacteriology. Three years later, he was promoted to major and detailed as Curator of the Army Medical Museum in Washington, and as Professor of Bacteriology and Clinical Microscopy at the newly organized United States Army Medical School. Here, several years later, he began his practical interest in yellow fever.

When, in 1900, yellow fever became especially severe among American troops in Cuba, Reed was made chairman of a committee to investigate its cause and method of transmission. Observation led him to discount the then prevalent idea that the disease was transmitted by fomites in the bedding and clothing of yellow fever patients. He decided to turn from the search for the specific cause and pursue the method of transmission. Thus he revived the discarded notion of Dr. Carlos Finlay that the yellow fever parasite was carried only by mosquitoes. By a thorough set of experiments, in which some of Reed's co-workers sacrificed their lives, he proved to a skeptical world that the mosquito transmission theory was correct. With this knowledge, American sanitary engineers eradicated yellow fever from Cuba. The success of the sanitary measures in Havana in controlling mosquitoes subsequently made the completion of the Panama Canal possible. Yellow fever has since been largely eliminated from the civilized portions of the world.

The birth of the father of modern public health at Belroi plantation was entirely fortuitous. In the fall of 1851, the Rev. Lemuel Sutton Reed moved with his family from North Carolina to serve Gloucester County, Virginia's Methodist congregation. Just before they were to arrive, the parsonage burned. Mrs. Reed was expecting imminently. The owner of Belroi plantation had his overseer move to a temporary shelter and turned his small frame house over to the minister and his family. In that way it happened that Walter Reed was born in a borrowed cabin consisting of two rooms and a garret. The house, about five miles west of White Marsh, Virginia, on State 614 at its junction with 616, has been restored and is well kept. The Virginia Medical Society owns the birthplace and maintains it as a memorial to Walter Reed.

Matthew Fontaine Maury House

Location: Virginia Military Institute, Lexington, Va.

Matthew Fontaine Maury, the most distinguished scientist of the South, well before the Civil War had earned the title, "Pathfinder of the Seas." His charting of the winds and currents of the oceans had single-handedly revolutionized ocean navigation.

In 1842, Maury was made Superintendent of the Depot of Charts and Instruments in Washington, which he developed into the United States Naval

Observatory and Hydrographical Office. It was here that Maury began his study of winds and currents, producing in 1847 his "Wind and Current Charts of the North Atlantic." Even more significant was his book, The Physical Geography of the Sea, which was published in 1855. This career, that led all the world to acknowledge his leadership in the maritime sciences, was tragically interrupted by the Civil War.

In the fall of 1868, after three years of exile abroad, Maury accepted a professorship at the Virginia Military Institute in Lexington. With his greatest contributions already behind him, Maury worked, taught, and wrote at the V. M. I. until 1871. In addition to his teaching duties, he undertook a physical survey of the natural resources of Virginia. He also published six or seven volumes, dealing mostly with geography. He lectured all over the country, more frequently after his resignation in 1871, urging the establishment of the Federal weather bureau which he had recommended before the war. He died at his home in Lexington in 1873.

The home in which Maury lived while teaching at the V. M. I. still serves as a faculty residence. However, Maury occupied this house for only a few of his final years. It was not associated with the great studies through which he pioneered the science of oceanography.

The National Survey of Historic Sites and Buildings

Theme XX

The Arts and Sciences

Supplement to

Scientific Discoveries and Inventions

for

The National Capital Region,
District of Columbia

August 14, 1964

United States Department of the Interior
Stewart L. Udall, Secretary

National Park Service
George B. Hartzog, Jr., Director

194-a

DISTRICT OF COLUMBIA

1. ARMY MEDICAL MUSEUM AND LIBRARY

Location: Northwest Corner, 7th Street and Independence Ave.,
S. W., Washington, D. C.

Ownership: U. S. Government, Armed Forces Institute of Pathology,
6825 - 16th Street, N. W., Washington, D. C.

Significance

Surgeon General William A. Hammond established the Army Medical Museum in 1862. The intention was to minimize the loss of lives and limbs from wounds through the centralized study of surgical and medical specimens. Thus, this became one of the first organized medicomilitary research programs in America. Probably the first photomicrographs produced in America came from the work of Surgeon Joseph Janvier Woodward, who set up the photographic department in 1863. The collections of the museum grew so quickly that quarters for the many facilities were hard to find. Finally, the present museum building was built in 1886. The Museum and Library shared this building for almost 70 years. Now, after several years in other quarters while the existence of this structure was jeopardized, the Army Medical Museum is occupying its own building once again.

Present Condition

The Army Medical Museum and Library is a brick structure of 3 stories on a raised basement. The brickwork is well executed, and there is an abundance of terra cotta ornamentation. The excellent workmanship and functional design of this structure make it a good example of late 19th century governmental architecture.

2. CARNEGIE INSTITUTION ADMINISTRATION BUILDING

Location: Southeast Corner, 16th and P Streets, N. W.
Washington, D. C.

Ownership: Carnegie Institution of Washington, 1530 P Street, N. W.,
Washington, D. C.

Significance

Since its establishment in 1902, the Carnegie Institution of Washington has directed its energies to several fields of fundamental scientific research. The Institution early decided to operate its own research organizations, and 11 departments were set up. Three of these departments were based in Washington, namely the Department of Terrestrial Magnetism, the

Geophysical Laboratory, and the Department of Historical Research. The present six research centers include the Mount Wilson and Palomar Observatories. In addition to the work of these branches, the Institution also has subsidized the work of its research associates at other institutions. During World War I, the interest of the Institution in furthering scientific research led it to help to endow the National Academy of Sciences and its offshoot, the National Research Council.

Present Condition

In 1910, the Institution completed this Indiana limestone structure, designed by the architectural firm of Carrere and Hastings. The classical design is derived from the architecture of the French Renaissance. A broad flight of stairs leads from 16th Street through a large bronze door under the Ionic portico. Within is a 2-story rotunda, a small assembly room for conferences and lectures, and executive offices on the second floor.

3. HUBBARD MEMORIAL HALL

Location: Southwest Corner, 16th and M. Streets, N. W.,
Washington, D. C.

Ownership: National Geographic Society, 17th and M Streets.

Significance

Hubbard Memorial Hall stands to the memory of Gardiner Greene Hubbard, first president of the National Geographic Society. The executive office of the Society occupied this structure from 1903 until 1913. Based on a large public membership, the National Geographic Society grew from a small scientific society to the popular institution and major sponsor of scientific expeditions it is today. Scientific research sponsored by the Society has ranged from the geography of the polar regions to the archeology of Middle America, from the conditions of the stratosphere to the ethnology of primitive peoples. During the time that Hubbard Memorial Hall was under construction, Alexander Graham Bell succeeded his father-in-law as president of the Society. It was he who launched the Society on its emphasis of the popularization of geography in order to gain a wide popular support for further scientific research. The public response caused the Society to outgrow this structure within a decade of its completion. The completion of Hubbard Hall was greeted by a Society of 2600 members; membership has grown now to over 3 million people.

Present Condition

Hubbard Memorial Hall is a 2-story, 3-bay structure which faces 16th Street. Joseph C. Hornblower and J. Rush Marshall, architects of Washington, D. C., designed the building, to be built of buff brick with limestone trim and a tile roof. The library of the Society occupies the second floor of

the building, the first floor and basement being used for office space as originally intended. The library room, which also served for Board meetings and lectures, has at the south end a copy of the large stone fireplace in the City Hall of Bruges, Belgium. In the stair hall are 5 large oil paintings on exploration, by the famous illustrator, N. C. Wyeth, painted in 1927.

4. OLD NAVAL OBSERVATORY

Location: 23rd and E Streets, N. W., Washington, D. C.

Ownership: U. S. Government, Navy Department.

Significance

With the establishment of the Naval Observatory, the federal government entered into scientific research in an important way. Here, during the first years of its life, Matthew Fontaine Maury undertook his work which made him famous. Under Maury, the Naval Observatory achieved wide acclaim for advance in astronomy, navigation, and oceanography. The charts of the Navy's Oceanographic Office still mention their debt to this man. In the post-Civil War period, distinguished and talented naval officers including Rear Admirals Charles Henry Davis and John Rodgers ably followed Maury as Superintendent of the Naval Observatory. Leading mathematicians and astronomers at the place, such as Simon Newcomb, George William Hill, and Asaph Hall, won world esteem. Early in the 1880's, the facilities no longer suitable, the Observatory began the plans which moved it to its present site far out Massachusetts Avenue.

Present Condition

The domed, brick structure which housed the Naval Observatory between 1843 and 1893 is still in use by the U. S. Navy. The center section of the north side contains the entrance to the building and is part of the original structure. The dome, now empty, once housed a 9.6-inch refractor telescope. The wings to the east, west, and south were added on at various times as needed by successive occupants of the building. In 1873, the cylindrical building at the end of the south wing was built to house another refractor telescope. With the exception of the center section near the entrance, the second floors to all the wings date since the time of the Observatory's move. The building and its more recent appendages now is occupied by the Potomac Annex of the Bureau of Medicine and Surgery.

5. OLD PATENT OFFICE

Location: F Street, between 7th and 9th Streets,
N. W., Washington, D. C.

Ownership: Smithsonian Institution, Washington, D. C.

Significance

This structure contained the United States Patent Office from 1840 until 1932. Article I, Section 8 of the Constitution gives Congress the power". . . to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive rights to their respective writings and discoveries." President Washington recommended patent legislation, and the first patent act was approved on April 10, 1790. The current patent system originated in 1836, giving individuals 17 years to make, use, and sell inventions of their own. The growth in the number of patents issued by the Office over the years attests to the encouragement this system has given to inventors. When the Patent Office moved to its new building in 1840, it had begun the collection of seeds and scientific information on agriculture which would lead to the formation of the Department of Agriculture during the Civil War. In the structure, rooms of models of patented devices stimulated American inventiveness. Moreover, the library of the Patent Office had the complete reports of both the French and the British patent offices.

Present Condition

The restrained Greek Doric design of the Old Patent Office is the work of William P. Elliot. Robert Mills supervised the execution of Elliot's design, completing the south wing in 1840. Mills also began the east wing, authorized in 1849, but he was replaced in 1851 by Edward Clark. The erection of the west and north wings completed the present structure by 1867. Although Mills had tried to make the original building fireproof, a fire gutted the interior on September 24, 1877. Elaborate plans were made to enlarge the building, but they were never carried out. In 1936, the long flight of stairs on the south side was removed to accommodate the widening of F Street.

Inside the south wing, visitors entered one of several ornate halls displaying patent models. The south hall measured 266 feet long, 63 feet wide, and its high, arched ceiling rested on several rows of columns. Much of this is being restored.

6. SMITHSONIAN BUILDING

Location: Jefferson Drive, S. W., Washington, D. C.

Ownership: Smithsonian Institution, Washington, D. C.

Significance

The Smithsonian Building has housed the administration of the Smithsonian Institution practically since its inception. The Institution, which has made many important contributions to science, originated in the mind of a little-known English scientist, James Smithson. Should his heirs die childless, he left his entire fortune, his library, and his scientific collections ". . . to the United States of America, to found at Washington under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In August 1846, ten years after the bequest became available, the Congress finally decided on the form of the Institution, appointed the regents, and authorized the construction of a building.

The first Secretary of the Institution was Joseph Henry, who shares with Faraday the credit for the basic research in electro-magnetic induction which made the invention of the telegraph possible. Later secretaries have also been chosen from the ranks of eminent scientists. The Bureau of American Ethnology is a center for ethnological research on the American Indian. The American Association for the Advancement of Science, founded in 1848, long made the Institution its national headquarters. In 1871, largely through the efforts of Spencer Baird, then Secretary of the Institution, the government established the Fish Commission to study and conserve this valuable natural resource. Since its inception, the Smithsonian Institution has contributed greatly to scientific knowledge, as well as to popular education.

Present Condition

James Renwick's Norman Revival style entry won the design competition for this building. Erected on a site on the Mall selected early in 1847, its cornerstone was laid May 1, 1847. The highly romantic building of red Seneca sandstone grew slowly as funds were available, being finally completed in 1855. Among its unique features are its finely carved ornamentation and careful overall adaptation of style to function. The building remains largely unchanged since its construction, and serves its original function.

OTHER SITES NOTED

California

1. Site of International Latitude Observatory (1898), Mendocino County, at Ukiah.

2. Murphys (site of Boyhood Home, 1856-1865, of Albert Abraham Michelson (1852-1931), Calaveras County.

Connecticut

3. The Peabody Museum of Natural History, New Haven.

Massachusetts

4. Massachusetts Institute of Technology, Boston.

5. Gray Herbarium, Cambridge.

6. Maria Mitchell Observatory, Nantucket.

7. James B. Francis Floodgate, Lowell.

8. George Whistler House, Lowell.

New York

9. Rensselaer Polytechnic Institute, Troy.

Pennsylvania

10. Edward Drinker Cope House, Philadelphia

11. Franklin Institute, Philadelphia.

12. The Academy of Natural Sciences, Philadelphia

Vermont

13. W. A. Bentley House, Jericho

West Virginia

14. James Rumsey Memorial, Shepherdstown.

CRITERIA FOR THE EVALUATION OF HISTORIC SITES AND BUILDINGS

1. Structures or sites at which events occurred that have made an outstanding contribution to, and are identified prominently with, or which best represent, the broad cultural, political, economic, military, or social history of the Nation, and from which the visitor may grasp the larger patterns of our American heritage.

2. Structures or sites associated importantly with the lives of outstanding historic personages.

3. Structures or sites associated significantly with an important event that best represents some great idea or ideal of the American people.

4. Structures that embody the distinguishing characteristics of an architectural type specimen, exceptionally valuable for a study of a period style or method of construction; or a notable structure representing the work of a master builder, designer, or architect.

5. Archeological sites that have produced information of major scientific importance by revealing new cultures, or by shedding light upon periods of occupation over large areas of the United States. Such sites are those which have produced, or which may reasonably be expected to produce, data affecting theories, concepts, and ideas to a major degree.

6. Every historic and archeological site and structure should have integrity--that is, there should not be doubt as to whether it is the original site or structure, and in the case of a structure, that it represents original materials and workmanship. Intangible elements of feeling and association, although difficult to describe, may be factors in weighing the integrity of a site or structure.

7. Structures or sites which are primarily of significance in the field of religion or to religious bodies but are not of national importance in other fields of the history of the United States, such as, political, military, or architectural history, will not be eligible for consideration.

8. Structures or sites of recent historical importance, relating to events or persons within 50 years, will not, as a rule, be eligible for consideration.

GPO 969-387