Introduction

When the Chicago World’s Fair opened its gates in 1933, visitors from an earlier era would have been amazed at the wealth and power Americans enjoyed. Science and technology were the unquestionable stars of the fair, and the enormous Hall of Science was the centerpiece. Originally called the Temple of Science, this building demonstrated that the modern life enjoyed by most Americans owed it all to developing basic scientific principles as the bedrock upon which rested the creation of exciting and convenient modern machines and appliances. In the Hall of Science, people encountered a massive periodic table of the elements that formed the base of an even bigger revolving globe; they could study the working model of an oil refinery and learn how the science of physics made their televisions work. To ensure that visitors did not miss the point, the motto of the Hall of Science was “Science finds, industry applies, man conforms.” (Rydell, 2000)

Even more than the remarkable inventions, exciting experiments, and provocative displays was the very structure of the event. It represented a hard-won realization on the part of industrialists, scientists, inventors, and universities: that their common interests were more important than their differences, and that together, they could make science and technology the engine of the economy and the culture. Led by some of the most prominent men in the country, the fair’s design and execution were deliberately tailored to persuade Americans to embrace a new world made by science. It was a message Americans seemed happy to hear. The changes that created this new synergistic relationship between science and society developed due to relations forged during World War I (Rydell, 1985; Katzir, 2017; Kohler, 1991; Kargon, 2015).

Science and World War I

The relationship between scientific practice and World War I was significant, not because science won the war, but because the war married science and industry, while work on national defense proved the salience of scientific research to private foundations. The war work created a new class of scientific administrators who oversaw research teams working on a common problem. As a result, cooperative research became the gold standard of scientific activity in university settings.

Before the First World War, scientific enterprise remained the work of scattered individuals working in isolated university laboratories at particular research institutions. One or more powerful patrons supported their work. Government funding was available for applied sciences through
the Department of Agriculture. There was little interest when Edward Charles Pickering suggested bringing all astronomical research into a collaborative enterprise like a corporate holding company. Nor could he induce the new foundations such as the Carnegie Institute of Washington to finance his research scheme. After the First World War, universities, foundations, and corporations forged new bonds that transformed scientific activity by funding basic research. Cooperative research and scientific collaboration came to fruition in the 1920s, primarily due to government-sponsored research during the First World War (Kohler, 1991: 9–10).

U.S. shipping was threatened by the outbreak of the war in Europe in 1914, as the German doctrine of unrestricted submarine warfare led to the sinking of U.S. merchant vessels. Secretary of the Navy Josephus Daniels turned for assistance to the most well-known man of science in the United States, Thomas Edison. Daniels was impressed by Thomas Edison's interview with the New York Times on the importance of inventions in modern warfare. The U.S. Navy had an established history of supporting scientific enterprises such as the Wilkes Expedition, 1838–1842. During the Civil War, the Navy reached out to civilians and created a consulting board. At the onset of the war in Europe, Josephus Daniels followed suit by inviting Edison to head the newly formed Naval Consulting Board (NCB); initially, the board sought new defenses against the German U-Boats. After the U.S. entered the war in 1917, the group turned to offensive weapons. Despite having modeled research and development in his enterprises, which often consisted of chemists, physicists, and mathematicians, Thomas Edison rejected basic research, calling it unnecessary for the war effort. Edison held that there was sufficient existing knowledge for engineers and inventors to deploy on behalf of the Navy. Thus, the NCB did not support basic research (Hughes 2004). The leadership in the NCB included Edison, Frank J. Sprague (1857–1934), Elmer Sperry (1860–1930), and Willis Whitney (1868–1958), who directed the consulting board to screen the thousands of inventions suggested by the public to the government. None of these ideas had a significant impact on the war, as Clarence Lasby noted in his study published in the 1960s. Of the 110,000 suggestions offered, only one made it into production (Lasby, 1966: 260). Although the Naval Consulting Board did little for the war effort itself, the organization created the Naval Research Laboratory (NRL), which did important work on radar between the wars. It also set a precedent for the role of science and defense in the future, one not lost on the undersecretary of the Navy and future president Franklin D. Roosevelt (Lasby, 1966; Dupree, 1957: 306–307; Kevles, 1995: 105–106; Roland, 1985).

Upset by the lack of scientists on the NCB, one established leader in the scientific community wanted to rectify this by creating an organization open to basic research. George Ellery Hale (1868–1938) had status in U.S. science due to his family's wealth and a reputation for research. Furthermore, he was a scientific entrepreneur who successfully spearheaded the construction of the Yerkes Observatory in Wisconsin in 1897, and persuaded the Carnegie Institute of Washington to fund the Mount Wilson Solar Observatory building in 1904. In addition, Hale helped organize the American Astronomical Society and founded the Astrophysical Journal in 1895. Hale also established international organizations to support research in astronomy.

Using his scientific and political connections, Hale suggested that the federal government create a new organization, a National Research Council as part of the National Academy of Sciences. Hale wrangled an invitation to meet with President Woodrow Wilson to argue for including scientists in national defense. Wilson approved Hale's scheme and signed an executive order creating The National Research Council (NRC) in June 1916. The NRC directed and promoted science and technology to fight the war but was subsumed by the military, which insisted that the conduct of scientific war work be under the auspices of military supervision and required that researchers accept an Army commission and serve in installation away from their home facilities.

The war work of the NRC was conducted through different branches or divisions. A key point in the literature of this era is that World War I was a “chemist’s war,” a term coined during the war and long perpetuated by historians of science. Indeed, the Chemical Services Branch, created
in 1918, was the largest and brought together over 5,500 chemists from across the United States to work on producing chemicals needed in the war effort, such as helium for airships and nitrates for explosives. The Chemical Services also conducted work on chemical weapons research and poison gas. James B. Conant (1893–1978), who went on to play a crucial role in organizing scientists during the Second World War, began his career as a scientist-entrepreneur by leading research for the Chemical Services Branch on lewisite, a poison gas (Lasby, 1966: 236; Dupree, 1957: 321; Katzir, 1995: 137).

Physicists also played a role in war work. Hale brought the physicist Robert Millikin (1868–1953) to serve as vice-chair of the NRC, and was in charge of physicists using sound ranging to develop an effective means of submarine detection. Based in New London, Connecticut, and drawing on researchers from Yale, Chicago, Rice, Cornell, and Harvard, the team created a listening device capable of detecting submarines by the noise of their engines (Cohen, 1945; Wright, 1966: 294–295; Dupree, 1957).

The National Research Council also spawned the Psychological Services Branch under the direction of Robert Yerkes (1876–1956). Yerkes was president of the American Psychological Association (APA) and offered his assistance to the War Department by devising a test for all recruits to determine qualifications for military service by measuring their mental ability. The military accepted the offer in the spring of 1917, and a committee consisting of Robert Yerkes (1876–1956), Lewis Terman (1877–1956), and Henry H. Goddard (1866–1957) revised the test Alfred Binet (1857–1911) had created in France. The team gave this Intelligence Test to an estimated two million Army recruits and later revised it as the Stanford-Binet test. Although the Army terminated the examinations in 1919, psychologists emerged from the war with enhanced status, and cognitive testing, specifically the Stanford-Binet and the concept of the IQ, entered the public lexicon. After the war, psychologists advocated widespread cognitive testing, which became a firmly established practice in general education throughout most of the twentieth century. In later years, IQ testing found its way into scientific racism and mass sterilization (Kohler, 1987; Kennedy, 1980; Cravens, 1988; Carson, 1993; Kevles, 1995).

Overall, the war dramatically impacted the way Americans practiced or viewed science. The federal government made the National Research Council permanent in 1918 and a Naval Research Laboratory in 1923. A. Hunter Dupree suggested that the infusion of research into the economy was a critical factor in the adoption of research and development by corporations in the 1920s. The large-scale cooperative research model that brought together scientists from different disciplines created a generation of scientists eager to continue this practice in the interwar years. Finally, civilian contributions to science and the rise of scientific managers such as Hale, Millikin, and Conant led scientific enterprises for the next 30 years (Dupree, 1957: 323–324).

**Science, Industry, and Foundations, 1920–1940**

Once the war ended, the government demobilized and shut down the research programs of the war era and resulted in scientific patronage shifting to private foundations in the interwar years.

Hale and his colleagues on the NRC, Millikin and Yerkes, played a crucial role in connecting scientists to industry and the wealthy foundations in the interwar years. They believed that the strength of the postwar economy was dependent on the use of scientific research. Hale's work on the National Research Council convinced some corporations to embrace scientific research and development in the 1920s. The large-scale cooperative research model that brought together scientists from different disciplines created a generation of scientists eager to continue this practice in the interwar years. Finally, civilian contributions to science and the rise of scientific managers such as Hale, Millikin, and Conant led scientific enterprises for the next 30 years (Dupree, 1957: 323–324).
Engineering of the NRC promoted industrial research, offering tours of industrial research facilities to those interested in their benefits. Carty, who worked at AT&T, was joined by Frank Jewett (1879–1949) and Willis Whitney (1868–1958). These men were vocal advocates of industrial research and supported it in popular and professional business journals and by directly pressuring their corporate peers. Robert Yerkes, who headed the NRC Research Information Service, tracked the role of scientists in industry, which rose from some 300 firms before the First World War to 2,200 by the eve of the Second World War. To train future researchers, many corporations provided fellowships and contracted with university scientists to conduct research at their universities to prepare the next generation of PhDs for industrial research (Reich, 1985: 253–254, 256).

Philanthropic organizations such as the Carnegie Institution and the Rockefeller Foundation sought to create programs to train the industrial scientists of the future, which they saw as beneficial for industry and society. They provided capital funds to create new scientific facilities at some universities and provided money to endow fellowships for students to study in these new spaces. The NRC played a pivotal role in this. In 1920, the Rockefeller Foundation provided the NRC with $100,000 for fellowships and continued that level of funding through the 1920s. The NRC and the Social Science Research Council (SSRC) became the main conduit by which foundations funded the development of the physical and social sciences (Dennis, 1987: 507). The most popular vehicle for this support came from research fellowships for PhD candidates. By the mid-1920s, a dozen or so foundations supported scientific research through scholarships or funding to the institution. Still, the most significant financing came from just seven institutions associated with the Carnegie and Rockefeller endowments. Between 1916 and 1940, the NRC alone channeled $12 million into fellowships. Wycliffe Rose, who oversaw the General Education Board and the International Education Board of the Rockefeller Foundation, relied on the NRC to advise him on which projects to fund. Due to the influence of NRC leaders, Rose favored institutions such as the California Institute of Technology, Princeton, and Stanford. Indeed, Caltech, where Hale, Noyes, and Milliken were based, became, through foundation grants, a world-class center for science. After Karl Compton became president of the Massachusetts Institute of Technology, he too secured funding on par with that directed to CIT, and by the eve of World War II, MIT had outstanding facilities and a cadre of trained researchers. The success of institutions in winning funding was keyed to the scientific administrators who ran various departments of science and presided over these universities.

Beardsley Ruml (1894–1960), the director of the Laura Spelman Memorial fund from 1922 until 1929, had served in the Psychological Services Branch of the NRC and worked on administering intelligence tests. He believed that social science should play a significant role in shaping American society and, as the director of the Laura Spelman Memorial fund, provided over $21 million to research in the social sciences.

The Great Depression and Science

With the Wall Street Crash of 1929 and the onset of the Great Depression, university endowments diminished, capital campaigns failed, government budgets were cut, and foundation endowments suffered, causing them to be more selective in their funding for scientific research. Warren Weaver (1894–1978), who directed the Natural Sciences Division of the Rockefeller Foundation from 1932 until 1955, was convinced that general science had come far enough in the United States and that most disciplines no longer needed capital investments for infrastructure or fellowships. Instead, he determined to target the funds from the Rockefeller Foundation using two principles: (1) he would invest in those sciences that would provide the most significant returns; (2) that any research must directly benefit humanity. Accordingly, he cut funding to the NRC and directed that organization to put at least half of the remaining funds toward biological sciences. In addition, he directed funds to specific research agendas in genetics, medical research, and agriculture (Kohler, 1991; Kevles, 1995: 247–249).
**Development in the Disciplines, 1920–1940**

Foundations and corporate funding underwrote the development of American science facilities, the expansion of academic programs, and the increase in the number of PhDs. By the 1930s, private financing helped American scientists match their counterparts in Europe in many research areas, including physics and genetics, and research had become the *sine qua non* of academic scientists (Dennis, 1987, 508; Kohler, 1991).

Quantum physics grew apace in the U.S. due to foundational support for American researchers working on doctorates or doing postdoctoral work in European centers for quantum physics. A generation of new theoretical physicists benefited from this, including Julius Robert Oppenheimer (1904–1967), who earned his PhD at Gottingen University with the support of the Rockefeller Foundation. With foundation support through the NRC, leading universities built up physics by hiring theoretical physicists and launching a research agenda that made the U.S. on par with the more established European research center. Savvy NRC leaders such as Hale and Millikin used foundation support to turn the Throop California Polytechnic Institute into the California Institute of Technology, or Caltech. Caltech was a model of scientific research in physics and physical chemistry in the interwar years (Kevles, 1995: 169). Developments in the physical sciences, especially quantum physics, was essential, Kevles and others have argued, to understand how European émigrés fleeing Nazi persecution were able to so quickly integrate their research activities into U.S. institutions (Kevles, 1995: 282; Moyer, 1985).

Physical chemistry also matured in the period between the wars, and as with physics, the discipline benefited from the leadership at Caltech. The development of new areas of study for physical chemistry, such as examining the structure of the atom, came about through the oversight of A. A. Noyes, who was lured to California by George Ellery Hale. Noyes was given $200,000 to set up a lab and hired Richard C. Tolman (1881–1948) and Linus Pauling (1901–1994). As a result, Caltech became a center for X-ray crystallography (Servos, 1990).

The field of genetics also burgeoned before World War II. Universities created new genetics departments, the American Genetics Society was founded, and an academic journal, *Genetics*, was launched in 1916. The work of Thomas Hunt Morgan (1866–1945) was seminal in establishing the study of genetics in America. Morgan earned his PhD at Johns Hopkins in experimental embryology and morphology and taught at Bryn Mawr before accepting a position at Columbia University in 1904. At Columbia, Morgan turned his attention to studying the chromosomes of *Drosophila melanogaster*, a fruit fly whose limited number of chromosomes and rapid breeding habits made it an ideal experimental animal to study the role that genes play in inheritable traits (Kohler, 1994). Supported by the Carnegie Institute of Washington, Morgan set up the fly room at Columbia University and, with a research team consisting of Hermann Muller (1890–1967), Calvin B. Bridges (1889–1938), and Alfred Henry Sturtevant (1891–1970), worked on mapping the chromosomes of *Drosophila*. According to Cravens, the researchers “helped establish the chromosomal theory of heredity, traced the inheritance of many traits with elegant precision” and “uncovered many complexities of inheritance such as multiple factors, sex linkages, crossing over, and the influence of environment” (Cravens, 198: 159). The culmination of this work was the 1926 publication of *The Theory of the Gene*. Morgan left Columbia in 1928 to take a position at the California Institute of Technology, where he continued his research for another ten years but made fewer contributions to the field of genetics (Allen, 1979; Cravens, 1988; Kevles, 1985; Morange, 2021).

Of major significance in this period was the Neo-Darwinian Synthesis of the 1930s. Sewall Wright (1889–1988) used the work of geneticists such as Morgan to show that mutations, crossovers, and other variations could explain natural selection on a subpopulation of a species that became isolated from the genes of the larger population. It also explained genetic drift, or a shift in a population’s evolutionary path. Sewall and other scientists who worked on populations...
were now able to tie evolutionary theory to Mendelian genetics. The evolutionary synthesis was furthered by the work of Theodosius Dobzhansky (1900–1975), who had followed Morgan to Caltech. Dobzhansky moved his research from the fly room to the field and applied genetics theory to populations living in nature. His work led to *Genetics and the Origin of Species* in 1937, which is considered a defining text for establishing evolution as the organizing principle of biology (Kohler, 1994; Cain, 2009).

While some research thrived after World War I, eugenic research waned in the interwar years as it was tied to scientific racism. Before World War I, eugenics was considered a field of biology and influential in the conservation movement (Allen, 2013). Eugenics work was supported by the Carnegie Institute of Washington, which funded the Eugenics Record Office (ERO)—founded and directed by Charles Davenport (1866–1944). Davenport directed the ERO from 1910 until his retirement in 1934, and he, along with Harry Laughlin, conducted eugenics research that supported eugenic legislation. Laughlin played a crucial role in crafting the National Origins Act of 1924, which limited emigration from Eastern and Southern Europe because the people there were considered inferior to Western Europeans. Laughlin wrote model legislation that passed legal challenges and ultimately allowed states to legally mass sterilize thousands of individuals deemed unfit by eugenic science (Kevles, 1985).

Eugenics as a scientific discipline declined for a variety of reasons. One was that the science of genetics showed a more sophisticated interaction between biology and the environment. Additionally, many social scientists rejected the simplistic eugenics theories through their work on the Social Sciences Research Council. Using their leverage with the Russel Sage Foundation, they obstructed the work of Robert Yerkes when he attempted to use the NRC to promote scientific racism by investigating black migration from the South through the lens of eugenics. Educated Americans had been slowly withdrawing their support for eugenic theories, but this accelerated when Adolf Hitler rose to power and passed laws in Germany condemning anyone who was not sufficiently Aryan. After Vannevar Bush (1890–1974) became director of the Carnegie Institute of Washington in 1939, he withdrew all funding from ERO, further diminishing research in the field (Kevles, 1985; Allen, 1986; Cravens, 1988; Lombardo, 2008). Despite its decline in official scientific circles, racial and ethnic superiority remained across American culture, and thus the ideals of eugenics persisted through the twentieth century (Paul, 2016; Rydell, 2010).

### Science and the Public, 1920–1940

Throughout the 1920s, an era of “scientism” dominated, and science was seen as the fundamental means to solve problems in American society. Corporations and scientists were happy to explain that the material benefits of automobiles, airplanes, radios, refrigeration, vacuum cleaners, and other appliances were the outcome of scientific research and corporate development. The public appetite for science was led by organizations such as the American Association for the Advancement of Science (AAAS) hired a press officer and sponsored weekly radio programs on science, as did leading museums such as the Smithsonian Institution, the American Museums of Natural History in New York, and the Field Museum in Chicago. Edward Slosson ran the Science Service for the Scripps chain of newspapers. *Harpers*, *Scribner’s*, and *Atlantic Monthly* devoted pages to natural Science. *Popular Science Monthly* and *Scientific American* were standards for Americans who wanted to learn more about scientific progress. Meanwhile, the American Chemical Society, concerned about the lingering negative feelings toward poison gas and other chemical products, launched a public relations campaign to demonstrate the importance of chemistry for life (LaFollette, 2009).

Science was not only popularized; it was sensationalized in the 1920s. The arrest of John Scopes for breaking a Tennessee law forbidding the teaching of evolution and his subsequent trial transfixed
the nation. It was the first trial to be heard in real-time via radio and newspaper, and newsreel coverage was extensive (Larson, 2006). For many, Scopes was a scientific hero, one they could equate with the image of scientific heroes portrayed in Paul de Kruif’s bestselling *The Microbe Hunters*, which appeared the same year as the trial, or in the fictional medical scientist Arrowsmith in the eponymous novel by Sinclair Lewis (Rosenberg, 1963; LaFollette, 2009). Albert Einstein achieved celebratory status in the 1920s for his work on relativity, and after he immigrated to the United States to take a position at Princeton’s Institute of Advanced Study, it seemed to many that the center of scientific activity had moved to America (Nelkin, 1995; LaFollette, 2009).

The public image of science faced a temporary decline with the onset of the Great Depression, when some pundits blamed science for creating unemployment by replacing humans with automation. Others in the media suggested that science was neither rational nor dispassionate. They cited the ugly and public feud between Robert Millikin and Arthur Holly Compton over cosmic rays as evidence of this (Kevles, 1995: 238). Still, others suggested that scientists were selfish and lived in an ivory tower pursuing esoteric knowledge while ignoring the bread-and-butter issues of the general public that greatly needed their attention. However, lay audiences were soon inspired by demonstrations of scientific progress at expositions and world’s fairs. The tie between science and the fairs came about through the cooperation between fair authorities and the National Research Council. The NRC was central to the creation of connection science to the military, industry, and government, and in the 1930s, its sights on the public. Using newspapers, radio, and the Science Service under Edward Slosson, they sought to bolster the image of science in serving society. The link with the world’s fairs began when George Ellery Hale met with Rufus Dawes (1867–1940), the president of the Chicago Fair Corporation and the Museum of Science and Industry in Chicago. Dawes was interested in hosting a world’s fair in Chicago and was looking for advice from the National Research Council. After meeting with representatives of the fair committee, the NRC saw an opportunity to burnish the image of science in public and established a Science Advisory Committee, headed by Frank B. Jewett, to assist with Chicago’s Century of Progress in 1933 and the New York World’s Fair in 1939 (Rydell 1985).

The Chicago Century of Progress Fair, which ran from 1933 to 1934, built a Temple of Science as the centerpiece of its celebration of American ingenuity, although they renamed it the Hall of Science by the time the fair opened to the public. Despite the name change, the fair depicted America as a modern Eden, a place where the fruits of the tree of knowledge were not forbidden but open to all humanity. The fruit of the tree were the applied sciences of transportation, food science, and human comfort. At the tree’s root was basic or research science (Rydell 1985: 533). Furthermore, the elements of this fair indicated that the research done by modern corporations such as General Motors, General Electric, and the Ford Motor Company would soon solve the Great Depression and make even more incredible strides for humankind. As corporations showcased their goods, they subtly showcased how scientific research came to be identified as the essence of American science (Kargon, 2015). Franklin Roosevelt, inspired by this message, created a presidential advisory board in 1934 to provide this service to the U.S. government. The Science Advisory Board was led by Karl Compton (1887–1954), president of MIT and a leader in the NRC (Rydell 1985: 535; Kargon and Hodes, 1985).

**Science in World War II**

The Second World War changed the direction of scientific activity in America by developing a permanent relationship between the federal government and scientific research, leading to what Derek De Solla Price called Big Science (De Solla Price, 1963). Big Science is characterized by large-scale, national, and heavily capitalized scientific projects that have become the norm since World War Two. During the war, research on radar and the atomic bomb tied government and national defense
agendas to scientific activities and eroded the ties between academia and scientists (De Solla Price, 1963; Greenberg, 1967).

Some have suggested that the relationship between government and science during World War II was the natural consequence of the interwar development of a generation of scientific entrepreneurs such as Karl Compton (1887–1954), president of the Massachusetts Institute for Technology, who led Roosevelt’s Scientific Advisory Board. The board also included Frank Jewett (1879–1949), president of the National Academy of Sciences; James B. Conant, president of Harvard University; and Vannevar Bush, president of the Carnegie Institute of Washington and former dean of engineering and vice president of MIT. All played a significant role in shaping science policy during and after the Second World War (Roland, 1985).

Some historians point to the letter from Albert Einstein to President Roosevelt in 1939, drawing attention to developments in physical sciences, which included the splitting of the atom through fission and the knowledge the energy released by this could be used to generate power or create weapons of mass destruction. After receiving the letter, FDR created an Advisory Committee for Uranium chaired by Lyman J. Briggs of the National Bureau of Standards (Rhodes 1986; Greenberg, 1967: 24).

In 1940, Vannevar Bush was one of the top men of science in America. He was president of the Carnegie Institution in Washington and chair of the National Advisory Committee on Aeronautics, a Smithsonian–based research agency established to advance aviation through science. Concerned about the war in Europe, and following a pattern established by his mentor at the NRC, the late George Ellery Hale, he approached President Franklin Roosevelt, requesting the establishment of a new agency to assist in national defense. As a result, Roosevelt created the National Defense Research Council (NDRC) in June of 1940. It was this turn of events that led the historian A. Hunter Dupree to declare that 1940 marked the “beginning of a new era” for the relationship between government and science (Dupree, 1957: 369). The leadership consisted of representatives of the service branches and the scientific establishment, including Karl Compton, James B. Conant, Frank Jewett, and Richard Tolman. Bush insisted that the agency be under civilian control, that the scientists employed to do government research could remain civilians, and that they stay in their facilities working under government contract. Bush then began a system of contracting with universities to conduct research in their facilities and to compensate universities for the costs of doing so.

Most of the weapons research ended up under the authority of Bush, first at the NDRC and later at the Office of Scientific Research and Development (OSRD). For example, Bush wrested control of radar work from the Naval Research Lab and placed it under the civilian oversight at the Radiation Laboratory, or Rad Lab, at MIT. Bush would also have oversight over the making of the atomic bombs. Initially, after receiving the Einstein letter, Roosevelt created the Advisory Committee on Uranium with representatives from the Army and Navy and chaired by Bureau of Standards director Lyman Briggs. Much of the committee’s effort, 1939–1940, was directed toward discerning whether they could achieve controlled fission. Finally, in June 1940, the research was placed under the National Defense Research Council (NDRC).

To further scientific research into defensive and offensive work, on 28 June 1941, Roosevelt issued an Executive Order establishing the Office of Scientific Research and Development (OSRD) under the leadership of Vannevar Bush, who reported directly to Roosevelt. The OSRD subsumed the NDRC and other agencies, and critical areas fell under the domain of the scientific administrators, with James B. Conant in charge of the atomic bomb and Karl Compton, the Radiation Laboratory at MIT, supervising developments in microwave radar to detect low-flying aircraft better and improve ground defenses’ ability to target planes. Physicists also worked on the proximity fuse, which allowed a bombshell to detonate near a target, thus creating more damage.
James Bryant Conant was a scientific administrator who oversaw the atomic bombs' research, development, and targeting as head of the National Defense Research Council, 1942–1945. Conant earned his PhD at Harvard in 1916 and then joined the war effort by working in the Chemical Services branch of the U.S. Army. After the war, he returned to Harvard as a professor of chemistry and later department chair. Named president of Harvard in 1933, Conant drew attention to the plight of Britain in a nationwide radio broadcast in the spring of 1940, which resulted in him becoming one of America’s leading interventionists in the European war. This, in addition to his academic leadership, led to his appointment in June 1940 to the NDRC. Between 1940 and 1942, Conant oversaw

The Manhattan Project

Figure 7.1 Vannevar Bush played a crucial role in World War II and created the National Science Foundation after the war.
projects related to bombs, chemical weapons, and fuels and research on atomic bombs. Conant played a crucial role in atomic bomb research and the eventual targeting of Hiroshima and Nagasaki (Dupree, 1957: 363–370).

The work of the Manhattan Project was sprawling and spread from coast to coast in the United States and involved thousands of physical scientists from both university and corporate research laboratories. The steps in creating the bomb were numerous, but a survey of a few critical experiments demonstrates the complexity of the atomic weapons program. As early as March of 1940, Enrico Fermi (1901–1954), an émigré, showed that a relatively rare isotope of uranium, U235, could be fissioned with slow neutrons. In March of 1941, Glenn Seaborg (1912–1999) succeeded in creating the element plutonium, which was more readily fissionable than U238 or uranium. British scientists working on their bomb project, called Tube Alloys, suggested that the amount of uranium necessary to make an explosive device was relatively small. However, it still took immense effort to produce the amounts of enriched uranium and plutonium needed to create just the first three bombs. Harold Urey (1893–1981), working at Columbia University, found a means of gaseous diffusion to separate U235 from U238, while electromagnetic separation was demonstrated by Ernest Lawrence (1901–1958), working at the Radiation Laboratory. Finally, in December of 1942, working in the Metallurgical Laboratory at the University of Chicago, Fermi created the first controlled chain reaction (Rhodes, 1986).

Enormous production facilities were required to produce the relatively small quantity of uranium, U235, and plutonium necessary to make an atomic bomb. In the fall of 1942, FDR turned over the production of the bomb to the United States Army Corps of Engineers. General Leslie Groves (1896–1970) was appointed director of this phase of the atomic bomb program. Groves is credited with calling the process the “Manhattan Project.” The first production facility was created at Oak Ridge, Tennessee, also known as the Clinton Engineer Works. At peak production, 40,000 people were employed in the plants. The DuPont corporation built the production facilities, which consisted of various large-scale separation plants: electromagnetic, gaseous diffusion, and later thermal diffusion units that separated U235 from U238. In addition, a small atomic pile produced plutonium. The first production facility was the electromagnetic plant operated by a subsidiary of the Eastman Kodak Company. The second plant erected was a gaseous diffusion plant run by Union Carbide. The atomic pile, built in the winter of 1943, operated under the direction of the Metallurgical Laboratory of the University of Chicago. Working at total capacity, these plants produced the material used to make the bomb dropped on 6 August 1945, on Hiroshima, Japan. Hanford, the second site, eventually employed 125,000 people in the effort to convert uranium into plutonium. Hanford produced the plutonium for the Fat Man bomb dropped on Nagasaki on 9 August 1945 (Rhodes, 1986).

With the approval of General Groves, Compton gave the job of pulling together the elements of the Manhattan Project to J. Robert Oppenheimer (1904–1967), whom Compton appointed to be the scientific director at Los Alamos 1942–1945. Julius Robert Oppenheimer (1904–1967) was a leading theoretical physicist at Caltech, and from 1939 until the revocation of his security clearance, he played a vital role in developing the application of atoms to energy and defense in the United States. Born into a wealthy New York family, Oppenheimer showed an early promise for science and graduated first in his class with a degree in physics from Harvard after three years of study. He went to Gottingen University on a fellowship and earned his PhD when he was 22. After returning to the United States, he assumed a joint appointment in physics at the University of California at Berkeley and the California Institute of Technology in Pasadena. In the 1930s, he attracted and trained the best physicists in the country, and some say he created an American school of physics (Rhodes, 1986).

Oppenheimer recognized the weapons potential of atomic fission in 1939 and was an early member of the research community, pursuing this through the auspices of the Office of Scientific
Research and Development (OSRD). By 1941 he worked full time on atomic energy under contract with Berkeley. In February 1942, Oppenheimer was asked by General Leslie Groves to lead the design, construction, and testing of the atomic bomb, and it was Oppenheimer who suggested the site that became known as Los Alamos in New Mexico. Here Oppenheimer gathered the most capable and talented physicists and chemists in the United States and proved himself a skilled administrator. After years of research and a cost of $2 billion, the teams produced three bombs. On 16 July 1945, one was successfully tested at Alamogordo, New Mexico. A second, nicknamed Little Boy, was dropped on Hiroshima on 6 August, immediately killing tens of thousands of people and ultimately as many as an estimated 200,000 from radiation sickness. A third bomb, nicknamed Fat Man, was dropped on 9 August 1945, on Nagasaki, killing tens of thousands of people and 70,000 within a year (Rhodes, 1986).

The collective work of American scientists, European émigrés, and industrial entities such as Eastman Kodak, financed by the U.S. government, altered American science and made the United States the unchallenged leader of the West. As a result of the war effort, the thousands of scientists and engineers who worked on radar and the atomic bomb projects either joined other universities and enhanced their science programs or became part of a new postwar federal bureaucracy under the National Science Foundation. The National Science Foundation was the brainchild of Vannevar Bush, who wished to create a permanent relationship between the federal government and scientific research (Bush, 1970).

**New Directions**

The historiography of this period is told in other chapters in this volume (see Lubell and Whitesides), so I shall not repeat it here. Instead, I offer new directions for research in this field. Overall, the area has remained stable, the classic texts of the 1980s and 1990s remain in print, and as you will see in other chapters, such works as Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America*; Robert E. Kohler, *Partners in Science: Foundations and Natural Scientists, 1900–1945*; Richard Rhodes, *The Making of the Atomic Bomb*, are mainstays of the history of this period. The next phase of work will be a study of those obscured by official reports and denied positions of influence. Many of the essays in this volume reframe science in the United States by raising questions about gender construction, speciesism, structural racism, accessibility and neurodiversity, immigration, and how power was used and abused in the history of American science. Applying these new frames of reference to the period 1915–1945 will allow future researchers to ask new questions about this era and revisit the sources with fresh ideas.

**Notes**

1 The introduction was co-written with Deborah Fitzgerald of MIT.

**References**


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