american science comes of age

an institutional perspective, 1850-1930

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By the 1930's America indisputably had "come of age" in international science. America was the critical center of the world's scientific research. American scientists did perhaps the lion's share of the world's scientific work—and won consistent recognition for the quality of their work, as America's shift from fourth to first place in Nobel science laureates in the 1930's suggests.[1] In a special issue focused on long-term changes in American society and culture, the question of America's rise to international leadership in science is appropriate to pose. Yet students of American culture and science have discovered that it is far easier to agree upon the fact of America's rise to world power in science by the 1930's than to explain the phenomenon. We can cull two explanations from the scholarly literature. In 1948 Richard H. Shryock advanced the "indifference thesis." Shryock insisted that nineteenth century Americans were "indifferent" to basic scientific research; consequently America's contributions to basic science lagged behind Europe's. In the twentieth century basic science came into its own in American culture; now business leaders supported basic scientific research because industrial technology demonstrated the social and economic benefits of basic research.[2] More recently several historians of nineteenth century American science have criticized the indifference thesis.[3] And although they do not agree on many substantive issues, their work has left the impression (however unintentionally) that the origins of modern American scientific leadership lay in institutional and intellectual developments in the ante-bellum era—such as the development of scientific professionalization, of national scientific institutions and of "mature" research communities.[4]

Each explanation, moreover, raises special difficulties. The indifference thesis posits inappropriate comparisons between nineteenth century American and European culture. And it rests on unprovable assumptions; is it really demonstrable, for example, that most Americans have been less "indifferent" to basic science in the twentieth than in the nineteenth century? And since much basic research has had relatively little industrial or economic application, Shryock's argument appears highly questionable. The historians of ante-bellum American science are probably closer to the mark when they stress the importance of developments within the scientific community. Yet this view overlooks the fundamental changes in science after the mid-nineteenth century, the radical discontinuities in the culture of science, in the ideas of science, which drastically raised the standards for participation in scientific research. In the nineteenth century scientific disciplines grew in many ways: new sciences and sub-sciences emerged; higher mathematics became an integral part of the physical sciences; new skills, instruments and techniques became important to the natural sciences, and, in most fields, grand paradigms crystallized. The modern sciences were taking shape as distinct intellectual structures, a complex development that began, haltingly, in the eighteenth century, but which in the nineteenth century gathered new momentum. The fragmentation and multiplication of disciplines occasioned also an enormous information explosion which mandated specialization and professionalization—the ability to identify with a particular area as an inquirer and as a person with a full-time science-related career. And the number of investigators in the sciences mushroomed, contributing to an information explosion. It was probably not until after the ante-bellum era that the full effects of these internal developments began to alter the groundrules for participating in the culture of science; and correspondingly, these internal changes in science required a new set of institutional arrangements in post-Appomattox America.

I

Thus in the sixty years between John Dalton's atomic theory and Mendeleev's periodical table chemistry became a distinct science (and an identifiable research community) fully independent of natural philosophy with its subdivisions of organic and inorganic chemistry—and more finite areas of chemical knowledge. By the 1860's and 1870's modern physics was emerging as both a recognizable discipline and a community of physics researchers, thanks to the work of such men as Faraday, Maxwell, Kelvin, Stokes, Joule, Henry and others; and physics' subspecialties —electricity, magnetism, optics, astronomy, for example—had acquired so much new information and so many new methods that each had its own distinct research community. In the nineteenth century the earth sciences, now autonomous from other sciences, underwent an elaborate sequence of inner changes, aided by the explanatory power of the uniformitarian hypothesis and the development of such specialties as terrestrial magnetism, meteorology and geodesy. And in the nineteenth century natural history fragmented into many new disciplines, such as anatomy, botany, zoology, physiology and ethnology (and such exotic specialties as oology, ornithology, mammology and paleontology) which stood for vast new quantities of information, new skills—and distinct groups of specialists.[5]

The intellectual revolution within nineteenth century science made specialization imperative by the late nineteenth century. Specialization mandated a host of innovations in scientific institutions which would enable the researcher-specialist to receive appropriately cosmopolitan training, to communicate regularly with other specialists and to pursue an occupation related to his or her scientific work. Specialization and the information explosion made it increasingly difficult, as the nineteenth century wore on, for an individual to keep abreast unless that individual held a scientific position; this was even more true in those disciplines which became experimental, for experimentation demanded not merely time, but also the physical, the financial and the human resources of the laboratory. In turn specialization also implied, not simply the creation of science-related occupations, or the founding and funding of laboratories, libraries, and the like, but a host of new institutional arrangements that would guarantee universalistic scientific standards of training, competence and performance, and, in institutional terms, the continued development of specialized research communities whose members could directly determine the circumstances of their work. Above all, these institutional arrangements necessitated the creation of a new social role for the scientist in American society—the trained, specialized researcher who could continue to participate in, contribute to, and assume leadership in, the work of his or her international scientific colleagues.[6]

I suggest that the clues to America's rise to world power in science are located in the character of American scientific and educational institutions in particular historical epochs—those epochs which were themselves defined, for our purposes, by the intellectual revolution of nineteenth century science. In turn those scientific institutions were tangible responses to changes American scientists perceived in the structures and processes of nineteenth century science. Most critical to our understanding is the social role of the scientist which American scientific institutions created in response to the internal changes in contemporary science. Before the later nineteenth century, before specialization and professionalization were virtually mandatory, American scientific institutions helped shape a particular social role for the scientist which distinguished between those persons who were interested in participating in the culture of science, as compared with those who were not, and thus drew a line between the scientist, on the one hand, and the man of letters or the clergyman, the manufacturer and the farmer on the other. But the social role of the ante-bellum scientist could not distinguish between the specialized researcher who sought original knowledge and the generalist student of nature fascinated by nature's mysteries. Indeed, it was only in the 1840's that the terms "scientist" and "man of science" were coined and came into common usage in America. Yet in mid-century America there were so few researchers and so little demand for their skills and services that they had to include within their ranks both specialized researchers such as Joseph Henry and transcendentalists and students of nature such as Henry David Thoreau—as Thoreau's reaction to an invitation to join the fledgling American Association for the Advancement of Science, below, shows. Only with such an inclusionary definition of scientist could ante-bellum scientific institutions function.[7]

Thoreau's "poor part"

March 5 1853 . . . . The secretary of the American Association for the Advancement of Science requests me, as he probably has thousands of others, by a printed circular letter from Washington the other day, to fill the blank against certain questions, among which the most important one was what branch of science I was most especially interested in, using the term science in the most comprehensive sense possible. Now, though I could state to a select few that department of human inquiry which engages me, and should be rejoiced at any opportunity to do so, I felt that it would be to make myself the laughing-stock of the scientific community to describe or attempt to describe to them that branch of science which deals with the higher law. So I was obliged to speak to their condition and describe to them that poor part of me which alone they can understand. The fact is I am a mystic, a transcendentalist, and a natural philosopher to boot. Now I think of it, I should have told them at once that I was a transcendentalist. That would have been the shortest way of telling them that they would not understand my explanations.

Quoted in Perry Miller, ed., *The American Transcendentalists: Their Prose and Poetry* (Garden City, N.Y., 1957), 1-2. Thoreau refers to the volume *Addresses of Scientific Men* [circa 1853, Spencer F. Baird Papers, Smithsonian Institution Archives, Washington, D.C.], which Baird, acting as secretary of the new AAAS, used to try to create an address-book of all possible scientists who in turn would be a national constituency for the Association. This illustrates the necessary imprecision of the concept—and hence the role—of the scientist in ante-bellum America.

By the later nineteenth century the continuing intellectual revolution of science made unworkable the ante-bellum social role of the American scientist. A severe crisis was at hand. Correspondingly a new system of scientific and educational institutions—centered in the new graduate universities—emerged and thus created a new social role for the American scientist more appropriate for the demands of contemporary science: the trained, specialized researcher who identified intellectually and occupationally professionally with a particular discipline. The incredible internal changes of nineteenth century science, now so evident, mandated scientific professionalization in specific disciplines as the minimum institutional prerequisite of further American participation in scientific culture. That such institutional innovations could and did occur at the nineteenth century's close provided aspiring American scientists with new and unparalleled opportunities for international scientific leadership—thanks to the novel possibilities created by the institutional changes which came with the arrival of a new epoch in American cultural history.

II

The years 1825-1860 marked a definite watershed in the institutional history of American science. Before the ante-bellum epoch, there was no organized, self-sustaining scientific community identifiable in American culture; no clear distinction between general cultural institutions and generically scientific institutions; no evident demarcation between the cultured gentleman and the man of science; no conspicuously American centers of scientific inquiry; and, for that matter, no large body of American scientific discoveries.[8] By 1860 much had changed, institutionally and intellectually—and rather against strong trends in the larger society. In an era of retrogression for most colleges, a handful of Northeastern colleges imported the latest European science, installed it prominently in their curricula and appointed many professors of science. In a time of increasing popularity for *laissez-faire* public policies, governments began employing scientists regularly for scientific projects. In a period notable for mass evangelical movements in religion and stern practicality in business, private philanthropists endowed scientific research institutions and provided research funds for individual scientists. In an epoch allegedly characterized by widespread social and institutional disorganization, distinctively scientific societies and journals were founded—and often survived. In a day supposedly dominated by romanticism and religious enthusiasm, some Americans made empirical contributions to international science. And in an age of the "common man" and supposed public distrust of elites, a recognizable scientific community, distinct from other cultural groups, emerged. Indeed, the institutional revolutions in higher education, in government, in philanthropy and in scientific societies interacted upon each other in complex ways to shape a recognizable social role for the ante-bellum American scientist. Each group of institutions—the colleges, government, philanthropy and scientific organizations—defined and redefined the American scientist's social role in various yet ultimately similar ways. As might have been expected in a formative era, specialized researchers necessarily shared power, authority and control of scientific institutions with those who merely consumed scientific culture—with trustees, presidents and alumni in the colleges, with elected and appointed officials in government, with non-scientist patrons of research and with such cultivators and consumers of scientific knowledge as Thoreau.

Consider the social role that fifteen Northeastern liberal arts colleges created for American scientists between 1825 and 1860. These colleges made contemporary science one-third of their curricula, quadrupled their science faculty from one to four men each and purchased expensive instruments, specimens and books, thus exposing about half of America's college students to the latest scientific knowledge and giving that knowledge a firm institutional base in American culture. The colleges institutionalized the explosion of disciplines and information. After 1815 Samuel Latham Mitchill at Columbia, Benjamin Silliman, Sr., at Yale and the chemistry professors at the Pennsylvania, Harvard and Columbia medical schools rapidly imported the era's new chemical knowledge—for example, Dalton's atomic theory. By the 1830's the colleges taught chemistry apart from the natural philosophy course—half as a year's offering. In the 1840's the colleges had laboratories, apparatus and full-time specialized chemistry professors.[9] The colleges also carried forward the work of pioneer American geologists, notably Mitchill, Silliman, Parker Cleaveland, William Maclure and the American Geological Society's other members.[10] In the 1830's many of these colleges offered distinct geology courses, complete with mineral cabinets; American geology professors now published their own uniformitarian texts—most notably Amherst professor Edward Hitchcock's *Elementary Geology* (1840), which passed through thirty editions by 1860.[11] After 1830 these colleges installed higher mathematics through calculus and abandoned natural philosophy texts of the 1780's for contemporary texts in physics and its subdivisions. New mathematics, physics and astronomy became separate courses. The colleges fortified astronomy by purchasing expensive modern equipment from Europe.[12] And in the 1840's the fifteen colleges dropped the one-year natural history course for separate offerings in its various branches,[13] thus responding to both the information explosion about North America's flora and fauna evidenced in a growing number of natural history volumes which Americans published,[14] and to the arrival from Europe of new theories, methods and instruments—for example, the cell theory of Schleiden and Schwann, intricate systems of classification and the compound microscope.[15] Obviously these colleges both diffused and preserved European science.

If these colleges largely created and institutionalized the social role of the professor of science, they did not create our modern role of university specialist-researcher. The ante-bellum science professor's role or job, even in the best institutions, was to teach undergraduates. Original investigation he could do only outside his job—or, more precisely, outside his institutional role—on his own, for essentially personal rather than institutional reasons.[16] The ante-bellum science professors did have a science-related career, but in virtually every instance they carried crushing teaching burdens. Some overcame the obstacles and published original work. Joseph Henry wrote forty-six of his most important papers while teaching heavy loads at Princeton, and Spencer F. Baird contributed a large number of ornithological contributions while teaching over six contact hours a day at Dickinson College.[17] Such achievements were testimony to personal drive, discipline and ability, not to the institutional role which these men and most ante-bellum college professors of science necessarily played. Only the famous Swiss naturalist Louis Agassiz taught under circumstances resembling those of a modern university professor of science—and precisely because of a personal attribute, his international reputation.[18] In a different way this suggests again that it was not a part of the institutional role of the ante-bellum college professor to be an independent specialist-researcher. Those who did did so because of their personal circumstances. Professors were employees, subject to the power of presidents and trustees, without academic freedom, tenure, rank and the other attributes of professional autonomy associated with the modern university professor. In the ante-bellum college, unless personal factors intervened, much of the formal institutional power lay not with the scientists but with nonscientists.

In general outline the social role governments created for scientists was much the same as in the colleges. Laymen, not scientists, defined the scientist's role; laymen held ultimate power—and much direct authority too, for that matter. In government as in the colleges scientists were employees far more than they were independent professionals. Appointed and elected public officials called the tune. Thus while Spencer F. Baird was quietly lobbying to win appointment as Assistant Secretary of the Smithsonian Institution, James D. Dana, one of his friends and supporters in the scientific community, told Baird that ". . . a word from a Political [sic] man is perhaps quite as important as from Scientific, [sic] since much depends on favor in all Washington appointments."[19] In an age often characterized by spoils politics, moreover, the politicians' power over government science and thus the scientist's role in government went further than initial appointments. Responding to various citizen and special interest pressures, politicians also shaped the missions of governmental scientific enterprises, except in those instances in which the scientists themselves possessed the personal and political gifts that would enable them to transcend their employee-dependent status within the enterprise and influence policies by persuading the politicians who controlled the pursestrings. In other words, in government as in the colleges the scientist's personal attributes mattered as much as his scientific competence, if not more, in allowing him to rise above the clearly defined institutional role of dependent employee and function as an autonomous scientific expert. The social role of the ante-bellum scientist did not really include the modern concept of the scientist as the authoritative specialist to be taken on his own terms.

Consider the social role of the scientist in the state geological surveys. In the 1830's sixteen states sponsored geological surveys, in the 1840's another five did, and in the 1850's another fourteen, including eight for the first time. The surveys provided many geologists with invaluable opportunities to acquire skills, hold science-related jobs and develop a professional geology subculture. The surveys themselves varied widely in the quality of work done, the balance between applied and basic work, and in their institutional size and financial security. In the last respect the critical factor was always the political relationship between the geologists and the legislators.[20] The New York survey, authorized in 1836, was perhaps the largest and most successful in an institutional sense, employing eight full-time geologists, a full-time botanist, a full-time zoologist and several assistants, all of whom did respectable scientific work, much of it noncommercial in its implications. Director James Hall was a brilliant lobbyist in the New York Assembly, persuading the solons to keep the survey going a decade past its termination date. The survey used about half a million dollars—a bonanza for science.[21] Geologists could and did do basic research on the sly, especially if they presented a parsimonious front to legislators, as Edward Hitchcock did for Massachusetts.[22] But proper political stroking was always indispensable, as the example of the Pennsylvania survey shows. Professor Henry D. Rogers of the University of Pennsylvania ran the Pennsylvania survey with as many as seven paid assistants from 1836 to the early 1850's and eventually consumed $82,000 in public funds. The Pennsylvania geologists made important theoretical contributions and were on the verge of significant commercial discoveries with regard to coal when the impatient legislators cut the funds. Rogers' attempts at negotiation and compromise were futile. In every instance—Douglass Houghton in Michigan, William B. Rogers in Virginia, Charles T. Jackson in Maine and New Hampshire, Dr. J. C. Booth in Delaware, J. C. Ducatel in Maryland, Henry D. Rogers in New Jersey, and W. W. Mather in Kentucky—despite wide variations in the institutional size, the budget, the quality and quantity of information, the orientation toward basic or applied concerns, the geologists had to cultivate the politicians and their constituents to keep the surveys alive.[23]

As historian A. Hunter Dupree persuasively showed many years ago, the actual role of the scientist in the federal government was always roughly the same. Scientists executed politicians' mandates except in those rare instances in which a scientist could develop his own political ties with public decision-makers.[24] In the ante-bellum years, the United States Coast Survey was perhaps the largest and most successful federal scientific operation; its example will suffice to make my point here. The contrasting experiences of the Survey's two ante-bellum superintendents underline the real social role of the government scientist. Congress authorized the Survey in 1807; it began operations in 1815 under the

Swiss-born Ferdinand Hassler, a good scientist and administrator who nevertheless was less than effective at keeping his political fences in good repair.[25] In 1818 Congress stopped funding the Survey, largely for political reasons. In 1832 Congress re-established the Survey to aid commerce—and commercial special interest groups. Again Hassler was superintendent. Thanks to some good luck and fortunate initial discoveries, Congress did not question Hassler closely until the early 1840's, when the economic downturn and Hassler's lack of political expertise sparked a Congressional investigation.[26] In 1843 Hassler died; an American with many important connections in the worlds of ante-bellum science and politics, Alexander Dallas Bache, succeeded Hassler.[27] Bache was a good scientist and administrator too, but perhaps even more importantly, he had superior political skills; and this combination enabled him to transform the Survey into the largest single federal scientific mission, with an annual budget of half a million dollars by the 1850's.[28]

After the late 1830's American scientists' research resources demonstrably improved; especially important were such new institutional resources as astronomical observatories, natural history museums and the Smithsonian Institution. But both ultimate and direct control of such research resources resided in the hands of nonscientific laymen, not scientists—unless those scientists could exert extraordinary influence over their patrons, again suggesting that the social role of the scientist in these institutions was much the same as in the colleges and in government. Lay patrons donated funds for scientific research institutions, mainly for their own purposes, not primarily for those of the scientists. Thus between the late 1830's and the Civil War about twenty modern observatories were founded with the latest equipment, including the famous Merz and Mahler telescopes. These observatories made possible by the 1860's the emergence of a small but highly skilled American school of astronomers. Yet laymen controlled the purse strings; their interests in the heavens were not those of the astronomers. Thus Williams College's trustees established an observatory because they were persuaded students would learn natural theology by studying the stars.[29] The Cincinnati Observatory, opened in 1845, was the brainchild of enterprising astronomer Ormsby MacKnight Mitchel: he sold subscriptions to Cincinnati citizens who purchased the right to view the heavens. Eventually this conflicted with Mitchel's ambitious research plans.[30] When institutions such as West Point, Georgetown College, Amherst, Dartmouth, Union, Harvard and Dickinson founded observatories, the relations between scientists and lay patrons were not as complex as in Cincinnati;[31] but lay patrons, not astronomers, called the tune. Thus it was the largess of Boston Brahmins that built the marvellous Harvard installation, which opened in 1847 with an expensive fifteen inch telescope with 2000 magnification. The impulse to raise the funds for the new facility on the Charles was a response to the spectacle of upstart Cincinnati having a better observatory than Harvard—or Boston.[32] Scientists had to handle their potential patrons with some care; thus the Dudley Observatory, of Albany, New York, floundered essentially because its director, Benjamin A. Gould, treated those members of the local gentry who supported the Observatory in so tactless, arrogant, and jejune a manner that they finally washed their hands of the project.[33] And in the other instances of ante-bellum research institutions, much the same was true: the balance of power rested with lay patrons, not with the scientists—unless the scientists had unusual personal skills which transcended the limitations of their social role. Harvard's magnificent Museum of Comparative Zoology, which opened in 1859 after a brilliant fund-raising campaign directed by the enormously influential Agassiz, was a monument to the awe with which local citizens regarded him as a scientist and his own skills in dealing with the Boston gentry.[34] The Lawrence and Sheffield scientific schools, which opened at Harvard and Yale in 1847 and 1861 respectively, became important centers of scientific research. But wealthy philanthropists donated funds because of the promise these schools held for economic and commercial benefits.[35] And the Smithsonian, which Congress founded in 1846 with James Smithson's half million dollar bequest, certainly became in the ante-bellum years an important nerve center of American scientific institutions. Its international exchange program brought precious foreign scientific literature to America; its annual *Contributions* series carried specialized reports of original research; its data-gathering operations—as in natural history specimens and meteorological observations—were invaluable for the progress of science; and the Smithsonian became, with the American Association for the Advancement of Science, the visible institutional manifestation of an emerging national scientific community. Yet these achievements flowed neither from Smithson's will (which was highly ambiguous) nor from the certainties of American politics (several groups had different ideas about the proper disposal of the gift) but from the determined efforts of such scientists as Coast Survey superintendent Bache and the Smithsonian's first secretary, Joseph Henry, who fought hard—and well—to make the Smithsonian a distinctively *scientific* institution.[36] We must not overestimate institutional resources for scientific research in the ante-bellum era. Funds were scarce; the Smithson's total annual budget was $30,000; except for the Harvard and the Naval Observatories, American observatories did not have the necessary funds for all the latest equipment in use in Europe, let alone for sufficient staff; colleges were not research institutions. In most instances, scientists paid the costs of their research; a few famous men, such as Agassiz, were fortunate enough to stitch together their own private networks of patrons for their research.[37] In the ante-bellum era, scientists had no "broker" institutions, such as the gigantic private foundations of the twentieth century or the National Science Foundation, to raise and redistribute their research funds. Hence laymen, not scientists, determined many of the research priorities.

In the three decades following 1830 American scientific societies, academies and associations took on a new, vigorous level of existence with new possibilities for survival.[38] Yet the social role of the scientist in such societies was limited in much the same way it was in other ante-bellum scientific institutions which I have discussed, for the specialists had to share power with nonspecialists for such societies to be viable in an organizational sense. With the signal exceptions of the American Association for the Advancement of Science and the American Medical Association, all ante-bellum scientific societies were local institutions, rooted in a particular urban social ecology; they were like fragile orchids, dependent upon the right combination of circumstances. Obviously an urban milieu, a modicum of economic prosperity, the presence of an active, competent research community and enough of a followership of nonresearchers to make the society self-sustaining—these were minimum requirements. Scientific societies rose and fell according to local circumstances; but, as John C. Greene has perceptively insisted, once higher mathematics was introduced into physical science, such societies could exist only for the nonmathematical natural sciences.[39] Dozens of such natural history societies appeared after 1830 on both sides of the Alleghenies, and the relations between the specialists and the cultivators or consumers of scientific culture were absolutely critical. Thus New York City remained essentially in the prescientific "societies of the arts" phase, because the city's scientific community was small, so small that it was overshadowed by Albany's impressive scientific cadre.[40] The Albany Institute, founded in 1824, became a roaring success for about two decades because distinguished researchers and local gentry could work together; as their goals became different, the Institute floundered.[41] In Boston, the American Academy of Arts and Sciences and the Boston Society of Natural History, founded in 1780 and 1830 respectively, came alive when both specialized researchers and local gentlemen of culture worked together.[42] In the West after the mid-1830's more than a dozen scientific academies and societies emerged—in Cincinnati in 1835, St. Louis in 1836 and again in 1856, Little Rock in 1837, Cleveland in 1845, Milwaukee in 1848 and in 1857, Louisville in 1851 and again in 1857, Flint in 1853, Grand Rapids in 1854 and Chicago in 1856.[43] Especially in these western cities, such natural history societies needed both competent researchers who could keep abreast of new developments and methods, and, at the same time, loyal followers, for there were never enough specialists in the western cities to make a society institutionally viable.[44]

And on a national scale the same dilemma of too few producers and too many consumers of scientific culture bedevilled the American Association for the Advancement of Science. The AAAS was founded in

1848 by a pre-existing group of specialists in the American Association of Geologists and Naturalists. The small elite of specialists which ran it in ante-bellum years had grandiose plans to use the Association to create a national culture of American science and a national constituency of American scientists.[45] Its leaders sought to invent a national culture of American science by pre-empting many issues of scientific public policy from nonscientists. They formed lobbying committees on an American prime meridian, uniform weights and measures, promotion of fish culture, a federal system of meteorological observers, ethnological surveys, a North Polar Sea expedition—and gave Bache's Coast Survey a ringing endorsement.[46] The Association's elite corps of specialists tried to create a national constituency of scientists by collaborating with the Smithsonian, by preparing natural history handbooks for nonspecialists and by instructing Spencer F. Baird, the Association's secretary, to prepare an accurate roster of all potential and actual members, complete with names, addresses, occupations, scientific interests and scientific collections and equipment. The roster (see "Thoreau box"), which still exists, obviously suggests that the Association's leaders had in mind a systematic inventory of American scientific talent for the use of such "national" scientific institutions as the Association, the Smithsonian, and perhaps the Coast Survey.[47]

Yet on balance the Association's grand plans were limited by the context of the age—in particular by the possibilities of the social role of the scientist in ante-bellum America. The Association's specialist-researchers had some power; they could torpedo the National Institute for the Promotion of Science when they came to suspect its scientific character, and they could influence the direction the Smithsonian would take.[48] But the Association's ambitious plans to invent a national culture of American science and thus affect scientific public policy came to naught. So did the effort to create a national scientific constituency, even though the Association held its annual meetings in different cities to stimulate that constituency. The Association's membership had a high turnover; of the more than 2100 individuals who joined the Association before 1861 only 23 percent were still members by then.[49] It was only after the Civil War (which the Association barely survived) that membership stopped fluctuating and began to grow steadily.[50] While the small coterie of specialists who dominated the Association probably made the membership problem worse by often using the Association for their own private ends, the real cause of the membership problem was the wide intellectual, professional and experiential gap between specialist-researchers in science and consumers of scientific culture.[51] The Association's elite had not yet created an impersonal scientific community for the simple reason that it was probably impossible. In a larger sense the Association's difficulties and promises reflected those of ante-bellum scientific institutions generally. Ante-bellum scientific institutions helped shape and define a generalized social role for the scientist, but they did not and could not create two indispensable preconditions for scientific professionalization and professionalism—a culture of scientific professionalism, a body of impersonal, cosmopolitan values and symbols of authority permeating the functions of institutions and the roles of men; and, even more importantly, direct institutional autonomy, or scientific self-determination. In a sense scientific professionalization and professionalism are political phenomena in the history of culture and of science, for they mean the extent of self-determination which a cultural elite successfully claims for itself in the larger society. The social role of the ante-bellum scientist facilitated the expression of professionalism by some scientists, but it could not underwrite the social and institutional processes of professionalization. That had to await the dawning of a new epoch in American cultural history.

iii

By the early 1900's a new network of American scientific and educational institutions had taken shape as an interrelated system in response to the drastic inner changes in the structures and processes of science so manifest at the nineteenth century's close. At the center of the new network were the graduate universities, which began to exert an influence on national cultural trends by the 1890's. For our purposes what the new universities did was create new possibilities and a new social role for the American scientist not feasible in the ante-bellum era, save under extraordinary and perhaps singular circumstances. That social role was the academically trained researcher who professionally identified with a particular science. Such an individual could and did keep abreast of the latest work in his field. The possibilities inherent in his social role meant that, given a decent chance, he could contribute to knowledge and perhaps become distinguished. What the universities in particular did was to introduce impersonal and universalistic standards of training, competence and performance for all sciences, and, as importantly, institutional mechanism for achieving these standards for whole generations of aspiring and practicing scientists—through graduate programs, full time scientific careers, research facilities, and, above all, high social and institutional approval for original research, or at least, for the academic motto of publish and profit. Now American scientific institutions could produce entire generations of specialist-researchers across the whole spread of scientific disciplines, from the hard physical sciences to the softer social and behavioral disciplines. The emergence of generations of researchers did not depend upon the accidents of personality and biography, at least not primarily. Parenthetically this shift can be followed in the American Association's post-Appomattox history. Membership doubled from 953 in 1877 to 1,922 in 1882, and remained on that plateau until the early 1900's, when it doubled again, to about 4,000, and it increased to about 8,000 in 1910. In 1882, in response to the inner changes in science, a new generation of Association leaders abolished the old generalized physical and natural science meeting sections for nine "lettered" sections representing distinct disciplines, so that specialists in each could meet together for professional intercourse. Implicit in the 1882 reorganization was the shared recognition that it was necessary to distinguish both among the many legitimate sciences and between specialists and nonspecialists. By the early 1900's the rising academic scientists in the Association moved the date of the annual meeting from late August, a time presumably convenient for persons in many different occupations, to Christmas-week, a time specifically convenient for academics.[52]

By the early 1900's enough of the private graduate universities, such as Johns Hopkins, Cornell, Chicago, Clark and Stanford, together with older institutions, such as Harvard, Yale and Columbia, were setting a newer and higher standard in scientific and scholarly life. This encouraged a growing number of state universities, such as California, Wisconsin and Michigan, to imitate them and become centers of advanced, specialized research and instruction. Less favored public institutions, including land-grant, polytechnic and agricultural schools, followed suit to the limits of their resources and abilities, often providing undergraduate training for the new generations of scientists and then providing post-doctoral professional employment. This institutional revolution in American higher education provided many more possibilities for scientific specialization and professionalization than had the rather limited ante-bellum revolution in the fifteen Northeastern liberal arts colleges. Of course the new universities benefited from far more prosperous times than did the ante-bellum colleges. By the close of the Gilded Age, college degrees were worth something vocationally. Even more importantly, the universities could create the social role of the autonomous research-specialist, with academic freedom, tenure, facilities, intellectual stimuli and the like, because the inner revolution of science made evident to educated laymen the wisdom of scientific self-determination, because ambitious university presidents wanted the best faculty and competed with one another for them, and because in many instances the university professorate created its own external client populations and pressure groups which would concede much freedom to the professors.[53]

Consider the blossoming of chemistry in America. More than any other science, chemistry had major support from business and industry in its institutional development. Yet the social role which the new scientific institutions, especially the new universities, created mattered a great deal. It influenced both the direction and the velocity of chemistry's institutional growth. Sophisticated chemistry instruction began at Harvard in 1848, but had a heavily applied bias in the Lawrence school—as Harvard called its technical department—until 1863 when German-trained Oliver Wolcott Gibbs, newly appointed, introduced graduate courses in basic chemistry. In the 1870's and 1880's the Harvard College and Lawrence chemistry courses were combined and new chemistry faculty were appointed to do original research. In 1875 Charles Loring Brace synthesized the first organic compound at Harvard; within twenty-five years Harvard chemists had synthesized over 4,000 organic compounds and had done much basic research in hygenic, inorganic and physiological chemistry. Theodore W. Richards' brilliant work in atomic chemistry won him a Nobel prize and a growing number of German students.[54] In broad outline Yale's pattern of institutional development in chemistry was similar to Harvard's, as was Johns Hopkins', where the able chemist Ira Remsen developed a first class chemistry graduate program on the classic German model, immersing graduate students in the latest literature and the most exacting methods, and, above all, making original investigation the central experience for all Hopkins faculty and students. Most of the Hopkins chemical research was basic, not applied—although someone discovered saccharin by accident.[55] By the late 1870's at least sixty colleges offered a minimum of three undergraduate years of chemistry, usually with the laboratory, and some, like Iowa State College, launched chemistry *with* the laboratory.[56] Not surprisingly the number of professional chemists mushroomed from about 450 in 1850 to almost 10,000 in 1900. The influence of the universities upon the chemistry profession is suggested by the fact that in the early 1920's about two-thirds of all chemists held the doctoral degree and about forty percent held academic appointments.[57] Obviously chemistry benefited from industrial patronage, but the new universities provided advanced training, supplied professional credentials, gave chemical research a strong basic focus and created full time scientific careers for a large minority of professional chemists.

In many respects physics lagged behind chemistry institutionally and intellectually until the 1890's. Most American physicists taught experimental and mechanical physics—not the most exciting fields of physics. The number of physicists as late as the 1880's was perhaps 150, and there were few high-grade physics laboratories or graduate programs.[58] In the 1890's enormous changes took place in the science of physics in Europe—the discovery of X-rays, radioactivity, and relativity. American physicists responded to these exciting new intellectual challenges in many ways. The better graduate universities upgraded the importance of physics research, even though it had little apparent economic or industrial application. It was only after physics instruction and research were in the process of being improved that the industrial and economic applications of physics became obvious, especially to the electrical industry, which, in the years 1900 to 1920, became a major source of energy for urban centers for lighting and trolley-cars, and in industry, especially in the production of aluminum. Such electrical firms as Westinghouse now began to employ electrical engineers who really understood physics. This meant that engineering schools now demanded that their students take physics courses, which gave the academic physics profession a growing student clientele. In turn the growth of physics as an undergraduate "service" offering permitted the expansion of graduate and basic research programs in physics in the better graduate universities. By the early 1920's perhaps eighty percent of American physicists held academic appointments and seventy percent held the doctorate. By the late 1920's the American physics profession had grown sufficiently in certain major universities, and enough American physicists had learned the new theoretical physics in Europe, that American physicists could participate in the new quantum mechanics and atomic physics.[59] Doubtless physics developed in part because of its potential for applied work; but even more important were the interactions of the new universities, the changing American physics community and the radically transformed science of physics, which together made the United States an important center of international physics work by the 1930's.

The biological sciences also underwent a rapid institutional development, thanks in no small measure to the new scientific institutions, especially the graduate university. Biology's potential for economic application helped its institutional development in the Gilded Age. Farmers and other pressure groups, for example, encouraged the U.S. Department of Agriculture to develop certain lines of research—economic entomology, for example—which later benefited both basic research and the development of scientific institutions.[60] And they persuaded agricultural colleges to launch programs in agricultural chemistry and agricultural hybridization, programs which perhaps ironically assisted the development of basic chemistry and genetics programs later on.[61] Generally speaking, however, it was the prestigious graduate universities which imported the new experimental biology from Europe and thus provided, through the development of advanced programs of research and instruction, the institutional basis for American scientific eminence in biology after 1900. Columbia University, for example, promoted a brilliant department of zoology after the early 1890's, not from any particular dream for a higher gross national product, but because presidents Seth Low and Nicholas Murray Butler were ambitious to have the best department in America if not the world. On Morningside Heights Thomas H. Morgan began the genetics work which won him a Nobel prize; Edmund Beecher Wilson did outstanding work on the cell; and Henry Fairfield Osborn was a most prolific paleontologist.[62] Other universities—Harvard, Clark, Chicago, Johns Hopkins and Wisconsin, for example—followed a similar pattern of development, as did a host of land-grant institutions a little later, partly because of their political commitment to agricultural hybridization.[63] Thus was developed the institutional foundation of modern experimental biology in America. Modern biology, and certainly genetics, had some applied economic potential which assisted their institutional development, but far more important were the opportunities the graduate universities offered to the new academic scientist. By the early 1920's almost sixty percent of all botanists and seventy-five percent of all zoologists held academic appointments. And most of the rest were government scientists, which suggests that the relations between professional biology and the larger economy were quite indirect, not direct. As in the instance of physics, it was basically student demands for service courses (in the case of biology, for such fields as forestry, agriculture and pre-health studies) which provided the institutional endowment for the elaboration of graduate programs in basic biology.[64]

Modern experimental psychology essentially grew up with the new universities and then acquired something of an applied base. In America psychology emerged as a scientific alternative to the old-time moral philosophy; it experienced its most rapid institutional and intellectual development in the new universities (not the old-time colleges) after 1890. At Harvard, William James created a psychology program within the philosophy department. In the 1890's he hired the German psychologist Hugo Muensterberg to direct the laboratory, train the graduate students, and teach the undergraduate psychology course.[65] At Harvard and elsewhere, psychology became a popular course with students; Muensterberg's basic Harvard College course soon enrolled over 360 students. He worried, ". . . what will the country do with all of these psychologists?"[66] Most undergraduates took psychology as preparation for such growing careers as social work and teaching. On the graduate level psychology grew enormously—largely in response to the demand for undergraduate psychology teachers with the Ph.D. Between 1884 and 1918 about two score American universities granted 427 doctorates in psychology; as early as 1900 or so, there were strong graduate programs on native soil—at Harvard, Clark, Cornell, Columbia, Chicago and elsewhere. These early experimental psychologists were acutely aware they had to make upstart psychology a respectable science in the university; as one such pioneer put it, when he ". . . came into the field, the important thing for experimental psychology was to make it an academic subject, to assure its collegiate and university status. Laboratories had to be organized, and textbooks had to be written."[67] Psychologists founded over eighty laboratories and more than a dozen journals—the latter first as private nonprofit ventures, later as owned by associations and societies impersonally.[68] Even though many academic pioneers of psychology sang the promises of applied psychology, as late as World War I barely ten percent of all professional psychologists held nonacademic appointments.[69] This essentially academic institutional development of psychology was the institutional platform from which American psychologists elaborated modern learning theory in the 1920's.[70] It was only in the 1920's and later that psychologists began to enter non-academic positions or to consult much with private business clients.[71] By then a self-sustaining profession and science of psychology had long existed. Thus was the importance of the new social role created by the graduate universities.

And the new universities made possible other redefinitions of the social role of the American scientist simply not possible in ante-bellum years. The universities could create enough specialist-researchers, for example, to make genuinely specialized scientific societies a social possibility—or, perhaps, an inevitability. These new scientific societies were national in outlook; they drew sharp distinctions between the professional and the amateur, and excluded the latter by various means. Together university and scientific society helped create professional scientific subcultures and a role for the scientist-specialist. Consider the American Chemical Society, initially founded in 1876, and reconstituted in 1891 by a new generation of professional chemists.[72] The revitalized society rapidly enrolled most of the nation's working chemists. It organized thirteen local sections, which met monthly, thus permitting many chemists to participate in the discipline, the Society and the profession regularly. The Society imposed new cosmopolitan standards of professional participation, new definitions of the social role of the professional chemist not possible in ante-bellum years. Membership was by nomination and election only. The Society's Council conferred full membership on those with formal training when there was evidence that they were productive and respected chemists. Increasingly specialized training, including the doctorate, and research productivity became criteria for membership. The Society also took over the *Journal of the American Chemical Society,* upgrading its standards by publishing annual bibliographies and summaries of chemical research with global comprehensiveness, and even publishing an annually revised atomic weight table.[73]

Such societies emerged in the other sciences, too. In 1899 a well-established group of astronomers founded the Astronomical and Astrophysical Society of America when they became convinced there were enough specialist-researchers to make such an organization viable. As in other instances, a pre-existing elite determined membership criteria. AASA members could nominate candidates for membership, but only the powerful Council could elect them. The AASA's founders announced that the society's purpose was ". . . the advancement of astronomy, astrophysics, and related branches of physics." Mere interest was insufficient; only a ". . . person deemed capable of preparing an acceptable paper on some subject of astronomy, astrophysics, or related branch of physics . . ." was eligible. The American Physical Society, also launched in 1899, was organizationally quite similar to the AASA, and functioned according to the same kinds of rules, criteria and definition of the role of the scientist.[74] In the biological sciences, the American Society of Naturalists was founded in 1883 just for "professionals." "Professional" meant, in the 1880's and 1890's, a full-time science-related career; after 1900, it came to mean higher standards, usually the earned doctorate and some evidence of research activity.[75] The Society for Experimental Biology and Medicine recruited by invitation only and expelled all members who did not present an original paper at least once every two years.[76] The psychologists created the American Psychological Association in 1892. Increasingly the Association upgraded its standards to include only the academically trained researcher in much the same fashion as other scientific societies.[77] Quite obviously, a new social role for the American scientist had been created by the new possibilities of American culture.

Finally, the new social role of the scientist as researcher-specialist received institutional recognition and sanctification in both the government and in the new research institutes funded by the gigantic philanthropic foundations of the twentieth century. By the 1920's, the federal scientific bureaus were usually run by specialists who now possessed the power to determine how their appropriations would be spent, to identify new research areas as they emerged, and to determine their own inner institutional affairs. In other words, in the federal scientific establishment as in the universities and the new societies, there was not only open recognition of the professional autonomy of the specialized expert, but a buffer of scientific administrators between the lay decision-makers and the scientific researchers. For all practical purposes the scientific administrators, who functioned in a sense as brokers for the researchers, and the researchers ran things together.[78] And thus the new social role of the scientist was reinforced again. Similarly, private foundations began ceding a large measure of autonomy to scientific researchers after 1900 or so; often a new class of professional foundation managers came to the fore (many of them products of the new university culture). They made the actual decisions about which projects received funding.[79] The most spectacular example was the Carnegie Institution of Washington, created in 1902 by Andrew Carnegie with an endowment of ten million dollars—all for scientific and scholarly research. Carnegie gave the trustees enormous discretion: they could define critical areas for support, select particular projects to fund, and, in the largest sense, determine research priorities and policies. Before the World War, the Institution had established ten major departments of research, each of which carried on its own autonomous research programs—the Department of Terrestrial Magnetism corrected many navigational maps, the Solar Observatory on Mount Wilson, in California, made many contributions to astrophysics, and the Department for Experimental Evolution became a major research laboratory in the new science of genetics, providing much support to both resident and temporary investigators over the years.[80] With the appearance of the large-scale foundation and the scientific research institute, the American scientific professoriate now had benefited from a long-term institutional revolution which made possible America's rise to world eminence in science.

Iowa State University

footnotes

1. Joseph Ben-David, *The Scientist's Role in Society: A Comparative Study* (Englewood Cliffs, 1971), 13-20, 193.

2. Richard H. Shryock, "American Indifference to Basic Science during the Nineteenth Century," *Archives Internationales d'Histoire des Sciences*, 28 (1948-1949), 3-18.

3. Nathan Reingold, "American Indifference to Basic Research: A Reappraisal," in George H. Daniels, ed., *Nineteenth Century American Science: A Reappraisal* (Evanston, 1972), 38-62; George H. Daniels, *American Science in the Age of Jackson* (New York, 1968), *passim.*

4. In addition to several essays in Daniels, ed., *Nineteenth Century American Science: A Reappraisal,* see also Sally G. Kohlstedt, *The Formation of the American Scientific Community: The American Association for the Advancement of Science, 1848-1860* (Urbana, 1976); Daniels, *American Science in the Age of Jackson*; Daniels, "The Process of Professionalization in American Science: The Emergent Period, 1820-1860," *Isis* 58 (1967), 151-166.

5. See the remarkable E. S. Dana, *A Century of Science in America* (New Haven, 1918), especially thorough on 19th century American scientific work.

6. Ben-David, *The Scientist's Role in Society*, 139-168, has a different perspective on the ante-bellum era.

7. Kohlstedt, *The Formation of the American Scientific Community*, 190-223, discusses the problem of membership retention for the American Association for the Advancement of Science—and shows that a fellowship was as indispensable as a leadership.

8. Brooke Hindle, *The Pursuit of Science in Revolutionary America 1735-1789* (Chapel Hill, 1956); Raymond P. Stearns, *Science in the British Colonies of America* (Urbana, 1970).

9. Stanley M. Guralnick, *Science and the Ante-Bellum American College,* Memoirs of the American Philosophical Society 109 (Philadelphia, 1975), 94-104; see also Dana, *A Century of Science in America,* 60-192.

10. George P. Merrill, *The First One Hundred Years of American Geology* (New Haven, 1924), 1-126; Dana, *A Century of Science in America,* 60-192; Cecil J. Schneer, "Ebenezer Emmons and the Foundations of American Geology," *Isis* 40 (1969), 439-450.

11. Guralnick, *Science and the Ante-Bellum American College,* 107-109. George P. Merrill, "Contributions to the History of American Geology," *Annual Report of the Smithsonian Institution* (1904) (Washington, 1906); Merrill, *Contributions to a History of American State Geological and Natural History Surveys: Bulletin of the United States National Museum,* 109 (Washington, 1920); Merrill, *The First Hundred Years of American Geology* (New Haven, 1924), are detailed accounts of geology in America.

12. Guralnick, *Science and the Ante-Bellum College,* 47-77.

13. *Ibid.*, 109-114.

14. William M. and Mabel Smallwood, *Natural History and the American Mind* (New York, 1941), 285-351; Dana, *A Century of Science in America,* 391-401, 439-454.

15. William Coleman, *Biology in the Nineteenth Century: Problems of Forum, Function, and Transformation* (New York, 1971), 16-56.

16. Guralnick, *Science and the Ante-Bellum American College,* 109-114; Hofstadter and Metzger, *The Development of Academic Freedom in the United States,* 209-234.

17. Guralnick, *Science and the Ante-Bellum College,* 192; Charles Weiner, "Science and Higher Education," in David Van Tassel and Michael G. Hall, eds., *Science and Society in the United States* (Homewood, Illinois, 1966), 170-175; William H. Dall, *Spencer Fullerton Baird. A Biography* (Philadelphia and London, 1915), 1-220 and Dean Conrad Allard, Jr., "Spencer Fullerton Baird and the U.S. Fish Commission: A Study in the History of American Science" (Unpublished doctoral dissertation, George Washington University, 1967), 1-24.

18. Nathaniel Southgate Shaler, *The Autobiography of Nathaniel Southgate Shaler* (Boston and New York, 1909), 95-100.

19. As cited in Dall, *Spencer Fullerton Baird,* 156.

20. Merrill, *The First One Hundred Years of American Geology,* 127-390; Merrill, *Contributions to a History of American State Geological and Natural History Surveys*; Walter B. Hendrickson, "Nineteenth Century State Geological Surveys: Early Government Support of Science," *Isis* LII (1961), 357-370.

21. Merrill, *Contributions to a History of American State Geological and Natural History Surveys,* 327-362; John M. Clarke, *James Hall of Albany, Geologist and Paleontologist* (Albany, 1921), and Nathan Reingold, ed., *Science in Nineteenth Century America: A Documentary History* (New York, 1964), 162-174.

22. Merrill, *Contributions to a History of American State Geological and Natural History Surveys,* 149-158; Stanley M. Guralnick, "Theology and Religion Before Darwin: The Case of Edward Hitchcock, Theologian and Geologist (1793-1864)," *Isis* 43 (1972), 529-543.

23. Merrill, *Contributions to a History of American State Geological and Natural History Surveys,* 428-455, 158-238, 507-511, 129-136, 299-306, 51-52, 137-148, 307-326, 102-103.

24. A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, 1957), 20-119.

25. Florian Cajori, *The Career of Ferdinand Rudolph Hassler, First Superintendant of the United States Coast Survey: A Chapter in the History of Science in America* (Boston, 1929).

26. Dupree, *Science in the Federal Government,* 29-33, 51-56.

27. Merle M. Odgers, *Alexander Dallas Bache, Scientist and Educator* (Philadelphia, 1947); B. A. Gould, "Eulogy on Prof. Alexander Dallas Bache," *Proceedings of the American Association for the Advancement of Science* (1869), 1-47.

28. Dupree, *Science in the Federal Government,* 100-105.

29. Howard S. Miller, *Dollars for Research: Science and Its Patrons in Nineteenth Century America* (Seattle, 1970), 26-27.

30. *Ibid.,* 29-33.

31. Guralnick, *Science and the Ante-Bellum College,* 83-93.

32. Miller, *Dollars for Research,* 34-39.

33. *Ibid.,* 39-47; The Alexander Dallas Bache Papers, Manuscripts Division, Library of Congress, Washington, D.C., contain interesting materials on the Dudley Observatory affair.

34. Edward Lurie, *Louis Agassiz: A Life in Science* (abr. ed.: Chicago, 1960), 212-251.

35. Miller, *Dollars for Research,* 71-97. See also Russell H. Chittenden, *History of the Sheffield Scientific School of Yale University* 1846-1922 (2 vols.; New Haven, 1928) and Samuel Eliot Morison, *Three Centuries of Harvard* (Cambridge, 1937).

36. Dupree, *Science in the Federal Government,* 66-90; Miller, *Dollars for Research,* 3-23; W. J. Rhees, comp. and ed., *The Smithsonian Institution Documents Relative to Its Origin and History 1835-1899* (Smithsonian Institution, Miscellaneous Collections, 4-43, Washington, 1901), I, 5-439; George Brown Goode, ed., *The Smithsonian Institution 1845-1896, The History of Its First Half Century* (Washington, 1897), 1-58; Geoffrey T. Hellman, *The Smithsonian: Octopus on the Mall* (Philadelphia, 1966), 26-55.

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44. Henry D. Shapiro, "The Western Academy of Natural Sciences and the Structure of Science in the Ohio Valley, 1810-1850," in Oleson and Brown, eds., *The Pursuit of Knowledge in the Early American Republic,* 219-242.

45. I am deeply indebted to Professor Henry D. Shapiro of the University of Cincinnati for these and other insights.

46. Based on my research in AAAS *Proceedings,* 1848-1866.

47. ...., *Addresses of Scientific Men,* bound volume of circulars, circa 1853, Spencer F. Baird Papers, Smithsonian Institution Archives, Washington, D.C.

48. Sally G. Kohlstedt, "A Step Toward Scientific Self-Identity in the United States: The Failure of the National Institute," *Isis* 62 (1971), 339-362.

49. Kohlstedt, "Savants and Professionals: The American Association for the Advancement of Science," in Oleson and Brown, eds., *The Pursuit of Knowledge in the Early Republic,* 303.

50. *Ibid.,* 304.

51. Daniel deB. Beaver, "The American Scientific Community, 1800-1860: A Statistical-Historical Study" (Unpublished doctoral dissertation, Yale University, 1966), 156-185, 359, 361, shows the most active authors of scientific papers lived in but several Northeastern cities, followed full time scientific careers, and had a college degree—thus most unlike many "amateurs."

52. See the table in AAAS *Proceedings,* 62 (1910), 21. The L. O. Howard Files, James

McKeen Cattell Papers, Manuscripts Division, Library of Congress, Washington, D.C., illustrate academic scientists' influence on the Association.

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60. Dupree, *Science in the Federal Government,* 149-183.

61. L. E. Noland, "History of the Department of Zoology, University of Wisconsin," *Bios* 21 (1950), 83-109; Morison, ed., *The Development of Harvard University,* 508-517; Edward H. Beardsley, *Harry L. Russell and Agricultural Science in Wisconsin* (Madison, 1969); Charles Rosenberg, "Science, Technology and Economic Growth: The Case of the Agricultural Experiment Station Scientist, 1875-1914," in Daniels, ed., *Nineteenth Century American Science: A Reappraisal,* 181-209.

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64. Rossiter, "Women Scientists in America Before 1920," 313.

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66. Hugo Muensterberg to James McKeen Cattell, February 25, 1899, Cattell Papers. See also: Robert M. Yerkes, "The Scientific Way," typescript autobiography, 83-109, Robert M. Yerkes Papers, Yale University Medical Library; Hugo Muensterberg, "Report of the Psychological Laboratory 1909," "Report to the President—1904," Hugo Muensterberg Papers, Boston Public Library, Boston.

67. Edward Bradford Titchener to Robert M. Yerkes, August 14, 1914, Yerkes Papers.

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80. For annual reports of each department, see Carnegie Institution of Washington, *Year Book No. 1* (Washington, D.C., 1902), *et seq.*