The Historical Society *of* PENNSYLVANIA

LEGACIES

SPRING 2015

VOLUME 15, NUMBER 1

Science and Technology in the Keystone State

Recognizing Our Supporters

Access and interpretation are two core elements of the Historical Society of Pennsylvania's mission. Two new initiatives are helping further these important goals, and we would like to recognize and thank the supporters who are making them possible.

First, HSP has formed an exciting partnership with FamilySearch. With the growing popularity of genealogical research, this partnership is critical in many ways. Through the FamilySearch partnership, we have welcomed Margaret and Jerrol Syme to our team. They are operating onsite scanning stations to make HSP's valuable genealogies, family trees, and other family history–related materials available online. FamilySearch also recently sponsored a booth for HSP at the RootsTech Conference in Salt Lake City. HSP staff promoted remote and online services that are offered to our members, such as online databases, archived workshops, and research by mail. Staff shared materials with more than 400 conference attendees. HSP thanks FamilySearch for these opportunities and hopes this is the beginning of a long and mutually beneficial partnership.

Another project we would like to introduce focuses on nontraditional modes of interpreting the society's collections. HSP recently received two years of support from the Pew Center for Arts & Heritage (PCAH) for a new project titled "An Artist Embedded." This project puts playwright Ain Gordon in residence at HSP as a participating member of the society's Programs & Services department. Gordon will develop formative, audience-driven programming throughout the grant period that will culminate in a full-scale production inspired by Gordon's research in HSP's collections. Feedback from a focus group and an intensive evaluation plan will help HSP with audience and program analysis as the society explores innovative ways to interpret and deliver content from its archives to new and diverse audiences. Many thanks to PCAH, whose support allows HSP to develop this "outside-the-box" programming.

For more information on HSP's partnership with FamilySearch or on "An Artist Embedded," please visit our website at hsp.org.

(LEFT) **Ain Gordon, HSP's embedded artist.**
(RIGHT) **FamilySearch volunteers Margaret and Jerrol Syme.**

The Historical Society of Pennsylvania inspires people to create a better future through historical understanding. We envision a world where everyone understands the past, engages in the present, and works together to create a better tomorrow.

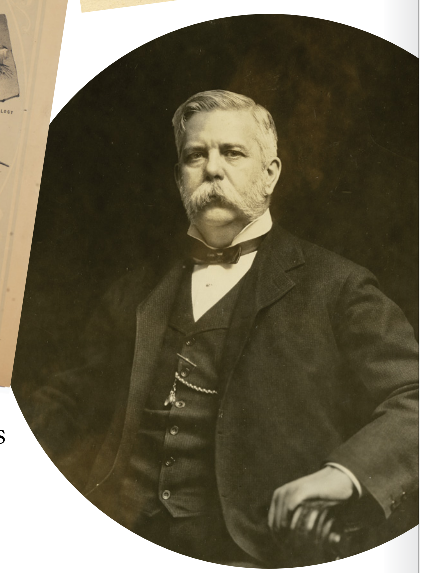
To learn more about the Historical Society of Pennsylvania and how you can support its extraordinary collections, its programs, and its publications, please visit our website at www.hsp.org or contact Jon-Chris Hatalski, Director of Institutional Development and Grants Management, at jchatalski@hsp.org or 215-732-6200 ext. 220.

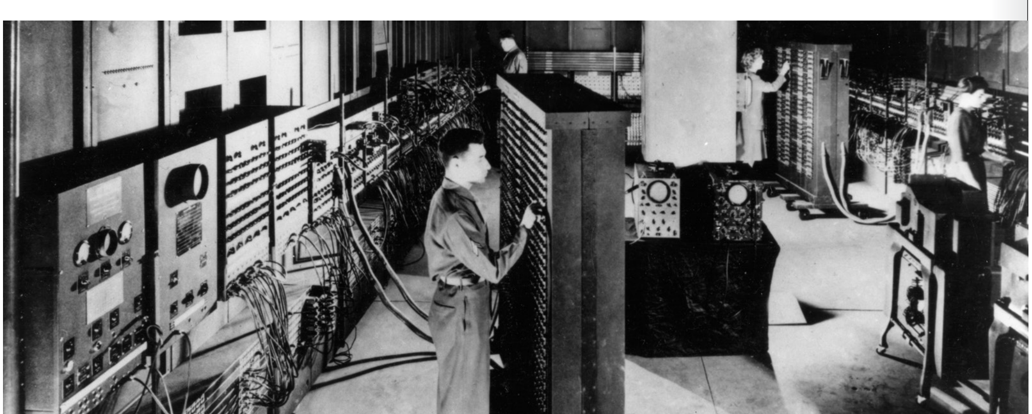
THE HISTORICAL SOCIETY OF PENNSYLVANIA 1300 LOCUST STREET, PHILADELPHIA, PA 19107-5699
TEL 215-732-6200 **FAX** 215-732-2680 **WEBSITE** www.hsp.org

The Historical Society *of* PENNSYLVANIA
LEGACIES

SPRING 2015

VOLUME 15, NUMBER 1



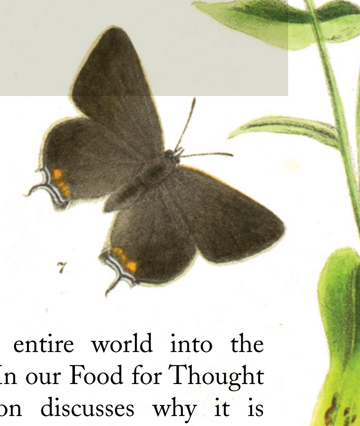


ON THE COVER

Colored drawing by Mary Peart, from William H. Edwards, *Butterflies of North America with Colored Drawings and Descriptions*, vol. 1 (New York, 1874). Courtesy of the Library Company of Philadelphia. For a discussion of Mary Peart's work, see the article "The Pride of Science" by Jessica Linker.

Unless otherwise noted, all images in *Pennsylvania Legacies* are from the collections of the Historical Society of Pennsylvania.

ISSN 1544-6360 (print); ISSN 2169-687X (online)



Historical Explorations

Science is all around us. And so it has always been. From the moment humans took an interest in the physical world around them and began trying to understand it through observation and experimentation, scientific inquiry has been an integral part of what it means to be human. Somewhere along the way, though, science became—or so it seemed—the realm of experts and specialists, something separate from our everyday lives. Yet, in the 21st century, it has perhaps never been more important for all of us to become, if not citizen scientists, then at least scientifically aware—aware of our relationship to and impact on the world around us as well as of how natural forces influence human events.

At the same time, it is important that we understand that science is not somehow fundamentally different from other fields of human endeavor. Like politics, economics, art, literature, and all else that makes us human, science is a product of its time and place. It has a history. It has changed over time, and it will continue to change. We need to recognize this reality if we are to think critically about the scientific findings presented to us, to evaluate what we think we know.

In this issue of *Pennsylvania Legacies* we share just a few of the many stories about how Pennsylvanians have engaged in the study of the physical world and used their knowledge of science and technology to revolutionize the ways in which we interact with it and with each other. In the process, we also see how the practice, sponsorship, and even funding of scientific research has changed over time in ways that can make science seem remote, inscrutable, and even suspect despite its ubiquity and centrality to our lives.

The issue begins with a look at early American science—particularly at its gendered dimensions. Jessica Linker argues that in the early 19th century women were actively involved in scientific study and practice, though in ways deemed appropriate to their sex, and that it was not until later in the century, with increased professionalization of various scientific disciplines, that scientific study was deemed inappropriate for women. Matthew White also looks at the widespread interest in science in 19th-century Philadelphia, describing the founding and early history of the Wagner Free Institute of Science, established to make scientific study available to people from all walks of life at a time when other scientific societies were more elitist in their membership. Steven Usselman takes us from the late 19th century into the 20th century, when large corporations and industrial research labs began to dominate technological progress. Usselman recounts the story of George Westinghouse's development of the air brake, which revolutionized rail travel and launched Westinghouse on his remarkable, inventive career. Finally, Paul Ceruzzi brings us into the digital age, as well as the age of research universities and government funding of scientific research, with his description of the building of the ENIAC computer for the US Army at the University of Pennsylvania during World War II and the later development of the commercial computers that brought not only the US military but the entire world into the information age. In our Food for Thought essay, Amy Slaton discusses why it is important to teach the history of science to future scientists and humanists alike. Our lesson plan gives students a chance to learn a little botany along with their history as they create their own herbaria. And for those curious to investigate further, we provide some reviews of interesting books and websites to explore.

Pennsylvania was and is a center of science and innovation. From the venerable scientific societies of Philadelphia, to the industrial workshops of Pittsburgh, and everywhere in between, Pennsylvania has been at the forefront of scientific discovery and technological development. I hope the articles in these pages will prompt readers to engage in their own explorations of this important history.

Tamara Gaskell
Historian and Director of Publications and Scholarly Programs

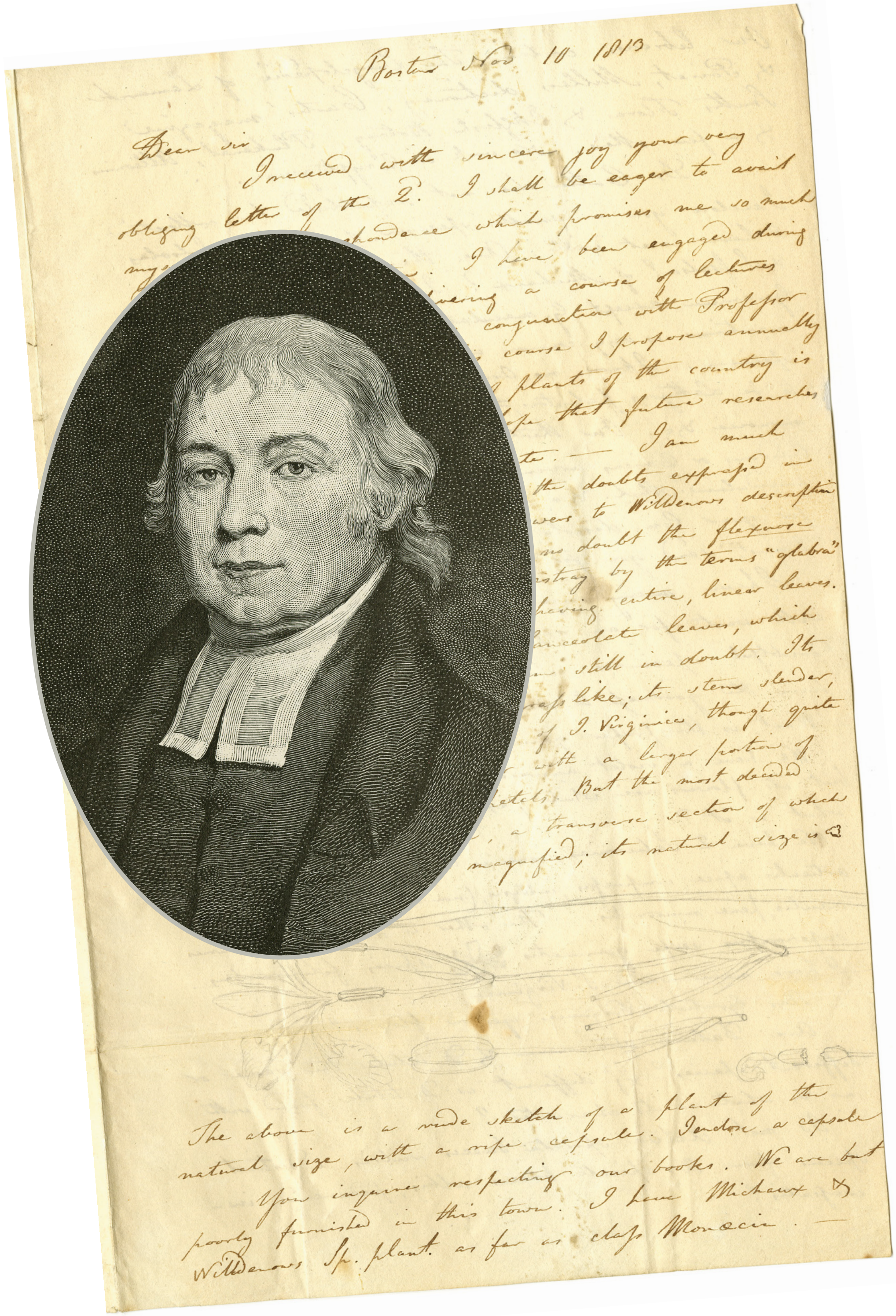
Colored drawing by Mary Peart, from William H. Edwards, *Butterflies of North America with Colored Drawings and Descriptions*, vol. 1 (New York, 1874). Courtesy of the Library Company of Philadelphia.

Classifying the Continent in the Henry Muhlenberg Papers

BY RACHEL MOLOSHOK

The Historical Society of Pennsylvania holds many collections that shed a light on various types of science history, from a letter from Sir Isaac Newton to documents on scientific and technological developments in the 20th century. HSP is particularly rich in collections that hold the papers of prominent early American scientists living in and around Philadelphia during the colonial and early national periods—then the intellectual and political center of North America. The Henry Ernest Muhlenberg papers, consisting of letters that passed among some of the most influential natural scientists in the late 18th and early 19th centuries, provide insight into the rich intellectual exchange that existed among American and European scientists and into the burgeoning fields of botany, zoology, and taxonomy.

Gotthilf Heinrich Ernst Muhlenberg, also called Henry Ernest Muhlenberg, was a Lutheran pastor and biologist from a prominent and accomplished German American Pennsylvania family. He was born in New Providence (Trappe) in 1753 and died in Lancaster, where he had lived and worked for more than 25 years, in 1815. Muhlenberg was interested in botany from at least the 1770s and was highly influenced by the work of Carl von Linné, the Swedish botanist and zoologist credited with invention of the Linnaean biologic taxonomic classification system. In *Systema Naturae* (1753), Linné identified three kingdoms (animal, vegetable, mineral), divided into classes, then further subdivided into orders, families, genera, and species. Binomial nomenclature—that is, referring to a plant or animal by its genus and species (for example, *Homo sapiens*)—is a direct product of Linnaean taxonomy. Using Linné's system, Muhlenberg contributed to the scientific community a number of new descriptions and assignations of



Undated portrait of Gotthilf H. E. Muhlenberg. Historical Society of Pennsylvania Portrait Collection. **Nov. 10, 1813, letter from Jacob Bigelow containing drawings of iris specimens.** Henry Ernest Muhlenberg Papers.

Plant specimens (identified by number) were attached to this page and removed for investigation by the recipient. Detail from a May 15, 1805, letter from G. H. Dalman.
Henry Ernest Muhlenberg Papers.

North American plants and some animals to the global scientific community; he is considered the first American-born botanist to study North American flora and fauna in a systematic fashion. Through his own hands-on research in Lancaster and collaborative work with correspondents and informants in other regions of the eastern United States and what was then the western frontier, Muhlenberg is credited with discovering and identifying several species of North American plants and animals, including a subspecies of the Chloridoideae grass, common in Mexico and the southwest United States, named "the Muhlenbergia," and the bog turtle (*Glyptemys muhlenbergii*). Several other North American plants and animals are named in his honor. In 1787, Muhlenberg founded a school that would be called "the Franklin College in Lancaster" (now Franklin and Marshall College) and became its first president. In 1791, he became a member of the *Deutsche Akademie der Naturforscher Leopoldina*, the national academy of Germany. He published several books on science, including *Catalogus Plantarum America Septentrionalis [. . .] or a Catalog of the Hitherto Known Native and Naturalized Plants of North America* (1813) and *Descriptio Uberior Graminum et Plantarum Calamariarum Americae Septentrionalis Indiginarum et Cicurum* (published posthumously in 1817). He also wrote and published works on theology and the German language.

The Muhlenberg papers consist of one box of letters to Muhlenberg, dated 1781–1816, from writers throughout the United States and Europe. Muhlenberg corresponded with scientists from countries such as Germany, Sweden, England, and France; accordingly, the letters he received are written in various languages—mostly German and English. The letters contain a rich scholarly exchange and, in particular, a view into the work of botanists in the wake of Carl von Linné's achievements in the foundations of biological taxonomy and the modern scheme of binomial nomenclature. In these letters, natural scientists from throughout the United States and Europe attempt to describe and identify various species of plants and animals, suggest names for new subspecies, answer each others' questions on botanical and zoological subjects, and develop the Linnaean taxonomic scheme. The letters often contain lists of plants and often are meant to identify the contents of separate shipments of plant and animal specimens that these natural scientists sent to each other. Sometimes, however, plant specimens would be sent attached to the letters themselves and later removed. Muhlenberg sent many specimens to his colleagues, to the point that at least one of them became overwhelmed by the sheer volume. Sir John Edward Smith, writing from England on June 14, 1796, complained "if you were to send me in general fewer species & more ample & varied specimens I should work with more alacrity, for your unexamined & accumulating hundreds (some of them mere botanical enigmas) appal [*sic*] me."

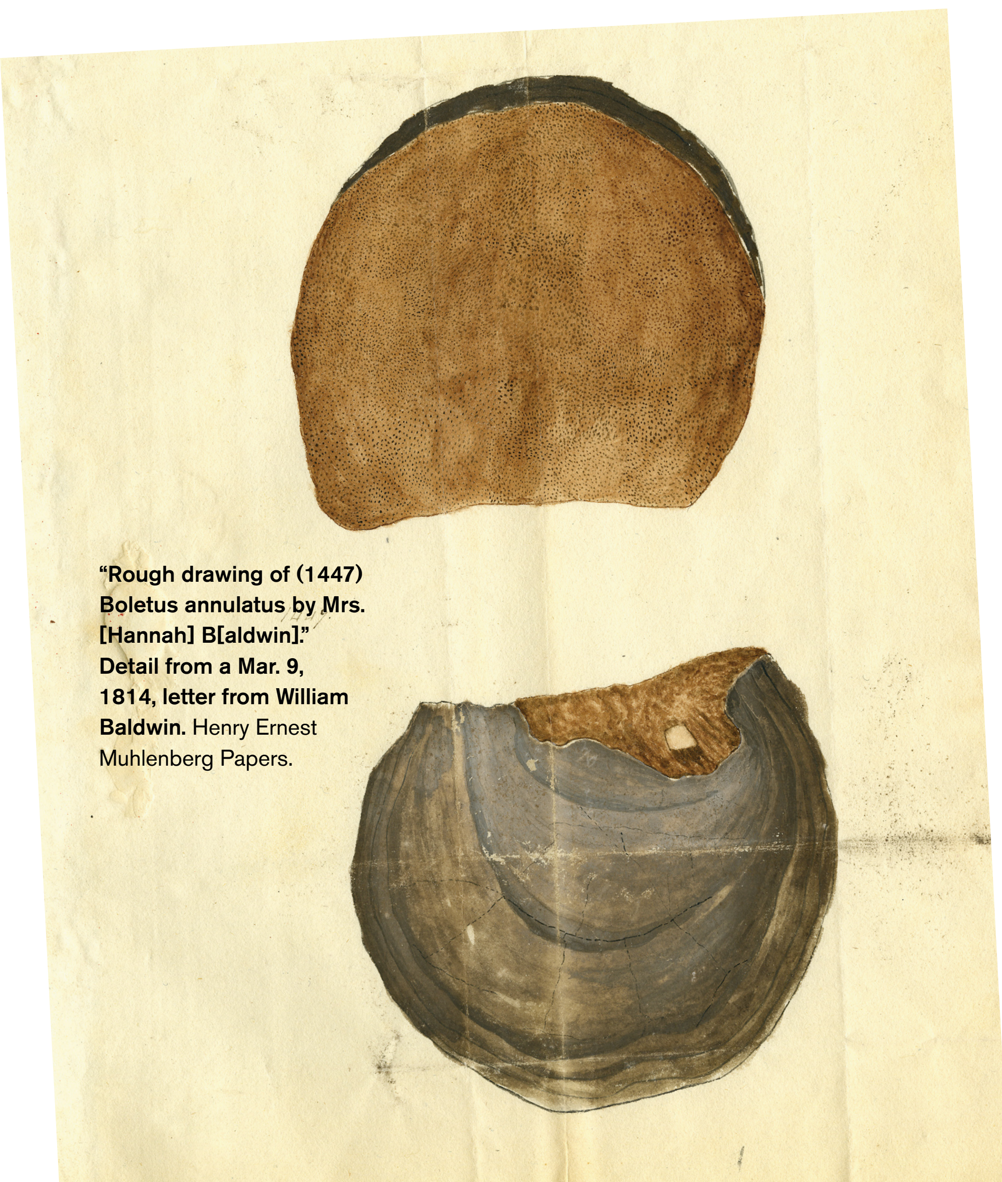
There was much work to be done in identifying and classifying the plants of

North America. As William Bartram wrote on September 8, 1792, "Notwithstanding the excellent system invented & established by Linnaus [*sic*] and the industry & labours of that celebrated naturalist in correcting & reforming botany, there still remains much confusion & error, particularly in regard to the vegetables of America." Constantine Samuel (C. S.) Rafinesque, a French scientist, linguist, and world traveler, then exploring southeastern Pennsylvania, wrote on August 8, 1805, "This country affords me a vast field for Botanical enquiries, & I will not be unoccupied in it. . . . I have made up the index of all the plants I have observed or seen in the U.S. and it contains abt. 3250 species (and I have not yet put down all the mushrooms)[,] nearly the double of the Michaux number." André Michaux, author of the then recently published *Flora Boreali-America* (*Plants of North America*) (1803), was the father and partner of François André Michaux, another of Muhlenberg's correspondents.

Muhlenberg's specialty was in studying plants, particularly grasses. But he was also interested in animals and fielded questions about the fauna of North America. Johann Christian von Schreber, for example, once asked Muhlenberg to send him a living opossum—apparently the last opossum Muhlenberg had sent did not survive the overseas journey to Germany.

In addition to sending samples and trying to answer each other's questions about specimen classifications, Muhlenberg and his correspondents gave each other professional advice (Caspar Wistar Eddy asked in a January 14, 1812, letter for Muhlenberg's ideas on the best way to organize an "introduction to botany" lecture course for a general audience); reviewed and exchanged books; shared what little news they heard from Lewis and Clark's expedition; and advised each other of potentially productive new informants and colleagues. Stephen Eliot reported in February 1812 that William Baldwin "has gone on to Indian Territory and will pass the spring in a Country which has been as yet but little explored," and thus "will add much to our present knowledge of the American plant." Baldwin in turn recommended to Muhlenberg the scientific knowledge and artistic talents of "Miss Greene, youngest daughter of the late celebrated General Greene, whose knowledge of botany perhaps exceeds that of any other lady in America" in a September 19, 1812, letter. The naturalists' letters also hint at the extent to which they relied on the labor and support of gardeners, students, and family members who made possible the pursuit of their passion for natural history. William Baldwin admitted in a September 15, 1813, letter to Muhlenberg that his five-year-old daughter Maria "has collected flowers to send to Dr. Muhlenberg, and as often requested me to inform him that she had found them."

William Bartram wrote to Muhlenberg on September 8, 1792, "We derive happiness & permanent advantages from the Study and contemplation of Nature . . . and by communicating to each other in conversation, or by letter, our discoveries & observations, our ideas & the impressions they stamp on the mind, we learn & teach the wisdom, piety, & homage to the Sovereign Lord of the Universe." He promised to "cheerfully" answer any of Muhlenberg's questions "without reserve, for it is a duty we owe to each other as a free intercourse of sentiment is the first step in our progress to Wisdom & Science." The Muhlenberg letters make clear the importance of exchange and interconnectedness in the global scientific community, even as weather, war, and sickness disrupted scientists' ability to communicate with one another. The Muhlenberg collection further sheds light on the exciting—if huge—task early American naturalists saw before them as they attempted to identify and classify the contents of the continent in the decades before the publication of Charles Darwin's work, which would shortly revolutionize not just biologic thought but taxonomic classification systems. ■



"Rough drawing of (1447) Boletus annulatus by Mrs. [Hannah] B[aldwin]." Detail from a Mar. 9, 1814, letter from William Baldwin. Henry Ernest Muhlenberg Papers.

ALMIRA LINCOLN PHELPS.

[Engraved Expressly for the January Number of Woman's Words.]

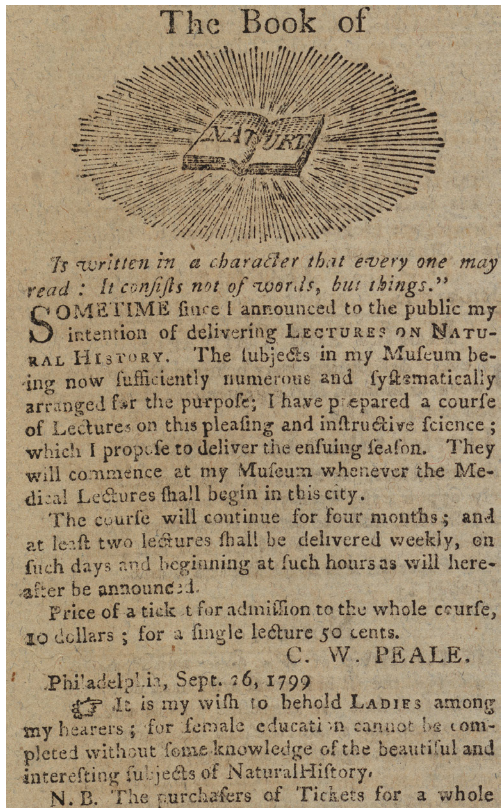
THE PRIDE OF SCIENCE:

Women and the Politics of Inclusion in 19th-Century Pennsylvania

by Jessica C. Linker

(LEFT) Almira Lincoln Phelps. Simon Gratz Autograph Collection. **(RIGHT) Plate by Lucy Say, in Thomas Say, *American Conchology, or Description of the Shells of North America. Illustrated by Coloured Figures from Original Drawings Executed from Nature* (New Harmony, IN, 1830).**

Today most people assume, not without reason, that women in 19th-century America were excluded from practicing science—but that was not quite the case. Nineteenth-century Americans believed that scientific practice was a pervasive, necessary component of daily life, and by defining it in this way they enabled women to pursue scientific work within various disciplines and venues. Over the course of the century, women attained advanced education in the sciences, were integrated into male spaces, and collaborated on scientific work with men. At the same time, due to both necessity and self-determination, women engaged with science in ways that were perceived to be relevant to their sex, essentially gendering their scientific labor. By the end of the 19th century, a number of social and cultural shifts recategorized women's scientific practice as the work of amateurs.


The Book of

NATURE

Is written in a character that every one may read: It conſiſts not of words, but things."

SOMETIME ſince I announced to the public my intention of delivering LECTURES ON NATURAL HISTORY. The ſubjects in my Muſeum being now ſufficiently numerous and ſyſtematically arranged for the purpoſe; I have prepared a courſe of Lectures on this pleaſing and inſtructive ſcience; which I propoſe to deliver the enſuing ſeaſon. They will commence at my Muſeum whenever the Medical Lectures ſhall begin in this city.

The courſe will continue for four months; and at leaſt two lectures ſhall be delivered weekly, on ſuch days and beginning at ſuch hours as will hereafter be announced.

Price of a ticket for admiſſion to the whole courſe, 10 dollars; for a ſingle lecture 50 cents.

C. W. PEALE.

Philadelphia, Sept. 26, 1799

☞ It is my wiſh to behold LADIES among my hearers; for female education cannot be completed without ſome knowledge of the beautiful and intereſting ſubjects of Natural Hiſtory.

N. B. The purchaſers of Tickets for a whole

(ABOVE) Ad for Charles Willson Peale's natural history lectures, *Claypoole's American Daily Advertiser*, Oct. 26, 1799. (FAR RIGHT) Lucy Say's certificate of membership in the Entomological Society of Philadelphia, 1863. Frederick W. Kobbé and Helen Jay De Bois Genealogical Research Papers, 1817–1944, Manuscript and Archives Division, The New York Public Library, Aston, Lenox and Tilden Foundation.

Editorial commentary included in the 1810 Philadelphia reprint of Elizabeth Fulhame's *An Essay on Combustion* elucidates early Pennsylvanian attitudes toward women practicing science. Fulhame, a native of Scotland, originally published her work in London in 1794, where it enjoyed relatively little success despite the nature of her discoveries. The anonymous Philadelphia editor responded to this in his prefatory comments, suspicious that Fulhame's treatise had not received significant critical attention because she was a woman. An impressive piece of original research, *An Essay on Combustion* summarizes a series of experiments Fulhame conducted while attempting to chemically synthesize metallic cloth in the 1780s. During these experiments, she observed phenomena that challenged the then-prevailing theories of combustion, including the work of the "Father of Modern Chemistry" himself, Antoine Lavoisier. Notably, Fulhame's objections arose because she had observed and described what would later be identified as catalysis, the acceleration of a chemical reaction by an additional substance called a catalyst. In addition to her remarkably modern understanding of chemistry, Fulhame proposed a number of practical applications for her work. In particular, she suggested the possibility of light-activated printing with metal compounds, a process integral to early photography.

Given all this, the Philadelphia editor was flummoxed: "Whether it be that the pride of science, revolted at the idea of being taught by a female, I know not." His hesitation to ascribe sexism as the reason for the work's limited reception had to do with a real belief that Americans, and specifically Philadelphians, were not swayed by the author's sex. Several years prior to the republication of her treatise, the Philadelphia Chemical Society had made Elizabeth Fulhame an honorary member. Its decision to elect her, the editor insisted, was based solely upon the merits of the first edition of *An Essay on Combustion*. Fulhame's inclusion indicates that real opportunities for women to participate in early Pennsylvania's scientific community did, in fact, exist. At the same time, however, women's inclusion was complicated by gender hierarchies that defined certain forms of scientific activity as more appropriate to their sex. The "pride of science" could tolerate women as long as they sought a balance between participation and their gender identities.

Including women in male space could play out in interesting ways. Men who believed that women should learn science accommodated what they perceived to be women's needs, sometimes to their own detriment. This proved to be the case for Charles Willson Peale, the famous early Pennsylvania painter and naturalist. In 1799, Peale began advertising natural history lectures in the Philadelphia newspapers, imploring women to attend. He encouraged male subscribers to bring a woman along for no additional cost. After investing so much effort to ensure women's presence at his lectures, Peale reassured his audience that he would omit material that was inappropriate for the "fair sex." This meant, however, that Peale could not speak freely about science and also that the men in his audience would be subject to the same restrictions imposed on the women seated beside them, unable to hear the so-called inappropriate material either. Rather than being outright excluded, women were instead welcomed to participate in ways that reinforced the belief that there were limits to their knowledge. Peale would go on to argue that women's and men's scientific practice approximated what we now call gendered divisions of labor. For men, Peale explained how science could improve various occupations, including farming, mechanics, business, and trade. In a lecture from 1800 Peale extended this argument to women, asking his audience, "if we reflect how the various parts of natural science branch out into all the household and economical concerns, can we find any part of female education of greater import?" Peale did not enumerate occupations for women as he did for men; they were simply wives and mothers. The gist of Peale's lecture was that women's scientific knowledge had specific, practical uses that were consistent with their expectations as women.

For the most part, women embraced this definition of scientific practice, often justifying advanced curricula in the natural sciences as a means to improve domestic management, child-rearing, and religious sensibilities. For example, it became commonplace for educators at female academies to equate cooking with chemistry, or to portray the kitchen as a laboratory. These sentiments were echoed in a number of

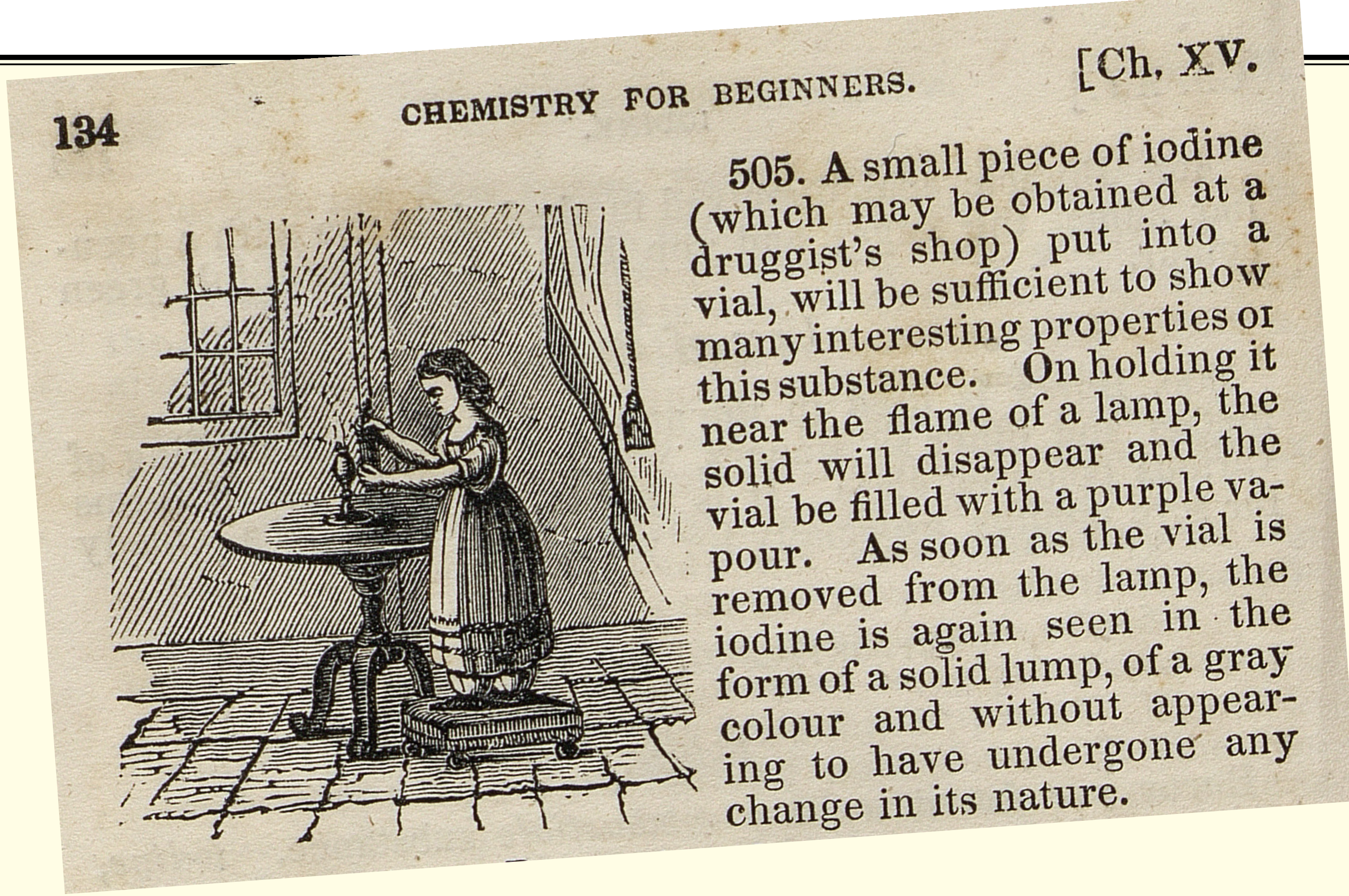
Rather than being outright excluded, women were instead welcomed to participate in ways that reinforced the belief that there were limits to their knowledge.

popular textbooks, including *Chemistry for Beginners* (1834), written by the educator and scientist Almira Hart Lincoln Phelps. Phelps, who began her career at Troy Female Seminary in the 1820s, encouraged female students to take note of common culinary happenings that could be better understood and enhanced through chemistry. In general, educators of Phelps's generation were concerned that young women were memorizing scientific information without gaining any real understanding of the material. Besides applying knowledge to everyday life, another way of demonstrating proficiency involved putting science in conversation with art and literature. Drawing intellectual connections, particularly those that evoked beauty, indicated that women's knowledge was not superficial. It also delineated a mode of expressing scientific knowledge that could manifest as poetry or artwork.

In 1838, Phelps and her family moved to Chester County, Pennsylvania, so she could assume a job as the principal of the West-Chester Young Ladies' Seminary. At the time of the move, Phelps was already the author of numerous scientific texts for young women, the most famous being *Familiar Lectures on Botany* (1829). She had been lured out of retirement from active teaching because of the possibilities she perceived to be specific to Pennsylvania. Citing recent efforts to improve the "intellectual condition of women," Phelps hoped that local citizens would support a "legislative endowment for a permanent seminary, corresponding in character and privileges with colleges for males." Furthermore, Pennsylvania's geographical position and climate would help to create a neutral space where the "daughters of our republic might assemble and forget sectional jealousies." Phelps also made no secret of the fact that she intended students to take rigorous coursework in botany, chemistry, natural philosophy, astronomy, mineralogy, and geology. Math and science classes dominated the plan of study. Phelps assigned many of her own publications as required reading; feedback from her students allowed her to revise and issue new editions fairly regularly. Phelps's pupils essentially vetted the work as they learned. Despite the call for a seminary on par with men's institutions, Phelps qualified that use of the curriculum would still be distinctly "feminine"—by which she meant useful or relevant to women's status in life and free from what she characterized as the "affectation of learning." Widespread emphasis on feminine uses of science served to further entrench the idea that women's scientific practice was somehow different from men's.

While female education expanded, Pennsylvania women increasingly gained membership in scientific societies. The Academy of Natural Sciences, founded by a group of Philadelphia-area naturalists in 1812, extended membership to women in 1842, when Lucy Way Sistare Say was unanimously elected as a member. Lucy Say's election to the Academy of Natural Sciences had much to do with her involvement with *American Conchology* (1830–38), the seminal work on American mollusks. Her husband, Thomas Say, wrote the scientific descriptions, while she was responsible for nearly all the illustrations and oversaw the hand coloring. After relocating to Newburgh, New York, later in life, Say remained active in Philadelphia's scientific community. In 1863, for example, she became a corresponding member of the Entomological Society of Philadelphia, founded in 1859 and now known as the American Entomological Society. The Delaware County Institute of Science, located in Media, Pennsylvania, allowed women to become associate members in 1846. Even before then, lack of formal membership did not prevent women from participating. The society's institutional records show that women had been donating objects to the museum as early as 1834. The second recorded donation, given on November 22, 1834, was from Chester County naturalist Abigail Kimber, who donated "Brown hematite and plumbago." Kimber collected plants as well as minerals; these she forwarded to William Darlington, who incorporated the information into his botanical index of Chester County, *Flora Cestrica*. In the 1853 edition of the book, Darlington argued that educating women in botany was the best method for diffusing the science. Kimber did exactly this, teaching chemistry as well as botany at the Kimberton Boarding School for Girls.

The multitalented Graceanna Lewis, who, like other Quaker women living in Chester County, was influenced by Kimber, joined both the Academy of Natural Sciences and the Delaware County Institute of Science. Before obtaining formal membership in the Academy of Natural Sciences, Lewis flourished under the tutelage of ornithologist John Cassin at the academy in the 1860s. Cassin, pleased with Lewis's collaboration, named the bird *Icterus graceannae* in her honor. After Cassin's death in 1867, Lewis took to lecturing, producing elaborate phylogenic charts tracing the evolution of birds from dinosaurs to accompany her talks. She researched until her death in 1912, tackling topics ranging from crystalline structures to jellyfish biology. Lewis also exhibited her work at the Centennial Exhibition of 1876 and won awards for her illustrated botanical charts at the Columbian Exposition of 1893 and the St. Louis World's Fair in 1904.



134 CHEMISTRY FOR BEGINNERS. [Ch, XV.

505. A small piece of iodine (which may be obtained at a druggist's shop) put into a vial, will be sufficient to show many interesting properties oı this substance. On holding it near the flame of a lamp, the solid will disappear and the vial be filled with a purple vapour. As soon as the vial is removed from the lamp, the iodine is again seen in the form of a solid lump, of a gray colour and without appearing to have undergone any change in its nature.

Illustration from Almira Lincoln Phelps, *Chemistry for Beginners: Designed for Common Schools, and the Younger Pupils of Higher Schools and Academies* (New York, 1839).

Chemistry for Girls

In most of the mechanical arts, and in some of the professions, those who understand Chemistry, have a great advantage over those who do not. In the cultivation of the earth, this science has also its important uses, since it teaches the farmer how to analyze different kinds of soil, and what is best fitted for particular crops.

This science bears an important relation to housekeeping in a variety of ways, as in the making of gravies, soups, jellies, and preserves, bread, butter, and cheese, in the washing of clothes, making soap, and the economy of heat in cooking, and in warming rooms;—To females then, some knowledge of Chemistry must be very desirable. They may indeed learn to perform these operations without understanding any thing of their philosophy; but it is natural to the human mind to search into the *causes of things,* and it is thus that improvements are made.

We are not to suppose that the domestic arts have yet arrived to that perfection of which they are capable; for as chemists, there has been little opportunity for the study of domestic economy in its relation to Chemistry. Young ladies who attend to this study should therefore pay strict attention to all those facts in housekeeping which may be explained upon chemical principles, such as the action of yeast upon flour, and of pearlash upon sour dough, the change of cider into vinegar, the advantage of keeping a vessel covered in order to hasten the boiling of water, &c.; they should, in short, endeavour to gain that insight into the philosophy of common things which will aid them to perform, in the best possible manner, the duties and business of ordinary life. . . .

It should be considered by every young person, that the object in studying Chemistry is not merely to *appear* learned, and make a display by talking about *caloric*, *oxygen*, &c., but in reality to become wiser, and better fitted for usefulness in the world.

There is one view in which the science of Chemistry produces in the mind thoughts of a deep and solemn kind, and calculated to humble the pride of man. When we learn that our own bodies are composed of a few elements of the same nature as those which form the very worm that crawls, and that at death the union which subsisted between these elements being dissolved, they will be separated and pass into the substance of the weeds that may spring up from their remains; we must feel with him, who, in his humiliation, exclaimed, "I have said to corruption, thou art my father, and to the worm thou art my mother and my sister." But there is a portion of ourselves which is beyond the scope of chemical science, which cannot be analyzed, because it is incapable of being separated into parts. It is that within us which thinks and feels, which knows good from evil, which is destined to an immortal existence, and which at death passes from its prison of clay to the world of spirits.

All then that is done for the improvement of the mind either in knowledge or virtue, will be permanent, while the labour bestowed upon the care and decoration of the body will perish with that frail and decaying substance. ■

Almira Lincoln Phelps, Chemistry for Beginners: Designed for Common Schools, and the Younger Pupils of Higher Schools and Academies *(New York, 1839), 10–11.*

Her participation in these scientific societies conferred credibility that broadened Lewis's access to scientific networks.

Some kinds of scientific labor seemed particularly suited to women, and this perceived expertise could translate into institutional access. In general, scientific illustration was considered to be an appropriate mode of scientific expression for women because it was consistent with feminine sensibilities. Namely, it required them to express science in artistic ways. Illustrating and coloring was not simply a paint-by-numbers game. Women needed to be able to discern and accurately depict identifying details, as plates were intended to facilitate identification of specimens. Skilled female illustrators and colorists such as Lucy Say therefore determined the academic and economic success of a number of important scientific texts. Men, such as William Henry Edwards, author of *The Butterflies of North America,* acknowledged the importance of this kind of labor, insisting that his illustrator, Mary Peart, had contributed more to his work than he had. *The Butterflies of North America* was first issued in parts from 1868–72, with further series appearing in the 1870s and '80s. Peart became the primary illustrator as of part 2, drawing more than 1,000 figures before she finished. She made her detailed illustrations by studying specimens under a microscope and kept larvae in her Philadelphia home, which she raised herself, to better understand and draw the early stages of butterfly development. In sum, Peart's efforts required scientific equipment, an impressive amount of labor and time, and familiarity with a range of species throughout their life cycle. Unfortunately, one might admire Peart's beautiful butterflies without fully understanding the process behind their creation. Without more transparency about how these books were made, it becomes all too easy to characterize Peart and other women illustrators as artists alone, rather than artists *and* scientists.

Regrettably, by the end of the 19th century the work of women who were once welcomed into Pennsylvania's scientific community began to seem less like science. Colorado naturalist and taxidermist Martha Maxwell exhibited specimens from her Rocky Mountain Museum at the Centennial Exhibition in Philadelphia only to endure skepticism as to whether a woman was indeed capable of such work. Because women had repeatedly insisted that scientific practice did not deviate from what was feminine, Maxwell's activities, which included shooting and stuffing buffalo, seemed inconsistent with appropriate scientific practice. Maxwell had been born in central Pennsylvania, and visitors tried to rationalize Maxwell's activities as a consequence of her moving westward: perhaps the frontier had made her wild. Maxwell's biographer, Mary Dartt, rebutted these allegations in 1879, drawing attention to the artistic skill and gentle hand necessary for creating scientific taxidermy exhibits. In doing so, Dartt invoked the traditional defense of women's scientific practice but also explicitly labeled Maxwell an amateur.

While both men and women had latitude to practice science as an extension of everyday life in the early 19th century, by the end of the century science had become more professionalized, and scientific practice demanded appropriate certification of training. Degrees increasingly became a requirement for serious work. Perhaps Almira Lincoln Phelps anticipated the importance of higher degrees in defining scientific practice when she called for legislative funding for a permanent female academy with privileges equal to men's universities. Diplomas from women's academies, regardless of the granting institution's pedagogical rigor, lacked a certain professional status. Women's colleges, such as Vassar and Wellesley, emerged to address this problem, but they too could be unsympathetic to problems of access. Without a degree, Graceanna Lewis failed to obtain a permanent teaching position at Vassar. Though Lewis published, publicly lectured, exhibited her research, and maintained membership in Pennsylvania scientific societies, these credentials were no longer sufficient. In her youth, Martha Maxwell had an opportunity to obtain a bachelor's degree at Oberlin College, but owing to financial difficulties she never completed her course of study there. As in Lewis's case, her lack of degree became an important factor in devaluing her work as that of an "amateur." Furthermore, the work of women who practiced science by mingling it with everyday life, art, and literature became less visible as academia trended toward expressing purer representations of science.

Forgetting historical definitions of scientific practice and the longer history of women's involvement has fostered a pernicious belief that women's scientific proficiency was and still is inferior to men's. When assessing the scientific work and knowledge of Pennsylvania women, we would do well to recall a statement issued by Elizabeth Fulhame's editor: "Although it may be grating to many, to suppose a female capable of successfully opposing the opinions of some of our fathers in science . . . she has certainly thrown a stumbling block of no small magnitude, in the way of sentiments we have been taught to consider as sacred." ■

Jessica Linker is a doctoral candidate at the University of Connecticut, Storrs, working on women and scientific practice in early America. She has been the recipient of a number of fellowships and awards, most recently at the Library Company of Philadelphia and the McNeil Center for Early American Studies.

(LEFT) Graceanna Lewis. Chester County Historical Society, West Chester, PA. **(RIGHT) Leaf chart for oak tree for public schools, by Graceanna Lewis.** Delaware County Institute of Science, Media, PA.


ANATOMY.
MAMMALIA
ENTOMOLOGY.
ORNITHOLOGY.
MINERALOGY.
THE WAGNER FREE
INSTITUTE OF SCIENCE
of Philadelphia.
Has this day elected of
a life Member in testimony whereof this Diploma is sealed with the
seal of the Society, and signed by the President, Vice President and Secretaries
this day of 185.
Presᵗ.
Secretaries
Vice Presᵗ.
FOSSIL BOTANY.
ICHTHEOLOGY.
BOTANY.
Incorporated March 9th 1855.
COMPARATIVE ANATOMY.
PALÆONTOLOGY.
CONCHOLOGY.
Lith. of P. S. Duval & Co. Philad.a

SCIENCE FOR ALL:

THE WAGNER FREE INSTITUTE OF SCIENCE OF PHILADELPHIA

By Matthew A. White

The Wagner Free Institute of Science of Philadelphia was founded in 1855 by businessman and amateur scientist William Wagner and his second wife, Louisa Binney Wagner, as a place of formal and informal educational, scientific programs for the people of Philadelphia—all "completely gratis." William Wagner was convinced that scientific education, made broadly accessible to the public, could help mitigate the worst effects of 19th-century urban America. In order to fill the gap left by Philadelphia's better-known scientific and educational institutions, which he believed had become too exclusive and elitist, he founded, built, and endowed the Wagner Free Institute of Science of Philadelphia to provide for what he referred to as the "rapidly growing want of the people" for a solid, college-level science education for free.

William Wagner, born in 1796 in Philadelphia, was the son of a successful cotton merchant and, from a young age, keenly interested in natural history. He graduated from the University of Pennsylvania in 1808 with the intention of pursuing a scientific career. Instead, his father pressured him into taking an apprenticeship with Stephen Girard, a French-born merchant and banker who was, arguably, the wealthiest American of the period—and certainly its most generous philanthropist. Over the course of his seven years working for Girard, Wagner visited ports throughout the world, transporting cotton, tea, coffee, and other cargoes for Girard and amassing a collection of natural history specimens for himself. In a few years, he was wealthy enough to leave his employer and go into business for himself. Though Wagner spent the years between 1808 and 1840 primarily in business, he maintained an interest in science and actively participated in Philadelphia's scientific community. He became a member of numerous scientific societies,

Wagner Free Institute of Science membership certificate, ca. 1855. Historical Society of Pennsylvania Collection of Certificates.
(INSET) Daguerreotype of William Wagner, ca. 1850. Archives of the Wagner Free Institute of Science.

William and Louisa Wagner's home, Elm Grove, on 17th and Turners Lane, 1876. David Kennedy Watercolors.

including the Academy of Natural Sciences and the Franklin Institute. He continued his boyhood hobby of collecting fossils, shells, and other geological specimens. And he maintained an active correspondence and personal relationships with naturalists both locally and around the world.

The early 19th century was a formative time in the history of science in America and Philadelphia, its leading intellectual city. Referred to at the time as the "Athens of America," during the 18th and first half of the 19th centuries, Philadelphia was home to a vibrant scientific community that included such names as Benjamin Franklin, Benjamin Rush, and John and William Bartram and a host of prominent scientific and medical institutions such as the patrician American Philosophical Society, the more middle-class Academy of Natural Sciences, and even Charles Willson Peale's sensational and wildly popular Philadelphia Museum. William Wagner was an active participant of this world, but found himself increasingly isolated from the scientific community, which was growing more professional and showing less interest in educating the general public.

It was his former employer's dramatic example of civic-minded generosity that inspired William Wagner to endow a scientific institution to benefit the people of Philadelphia. Upon his death in 1831, Girard left nearly his entire fortune to charitable institutions in New Orleans and Philadelphia. In the largest act of munificence in the nation's history to that time, his will included an endowment for Girard College, a home and school for poor, white orphan boys in Philadelphia. As Wagner put it, "It was mostly due to the inspiration given me by my old master . . . in erecting Girard College that I established the 'Wagner Free Institute' and allowed it to bear my name."

By 1840 Wagner was newly retired and married to Louisa Binney, a woman of solid social connections and robust financial resources. The couple embarked on a two-year honeymoon in Europe. Armed with letters of reference from American scientists and trunks of William's own specimens for trading, the Wagners visited museums of natural history across the continent, gaining inspiration. In their travel journal, they commented on the admission policies and prices for each institution. William saved his warmest praises for those that offered free admission. Upon visiting the Berlin Museum, he recorded, "The Museum is open for free to every one bravo! every day from 10–4." But he was most impressed with the Jardin des Plantes in Paris and brought back to Philadelphia lessons in museum design and governance.

Upon their return from Europe, the Wagners moved into Elm Grove, a large suburban estate north of Philadelphia in which William housed his large and growing natural history collection. He began offering free scientific lectures in his home in 1847, using specimens from his collection to demonstrate his points. Despite the distance from town, his lectures became so popular that he was given use of Municipal Hall on Spring Garden Street in Philadelphia. On May 21, 1855, the Wagner Free Institute of Science was incorporated for the education of the "practical, busy, laboring people" of Philadelphia. That year, formal courses were conducted by local scientists and educators and degrees were granted in many subjects, including geology, anatomy, biology, botany, chemistry, and civil engineering. The institute would also eventually include instruction in elocution, rhetoric, and anthropology. The faculty was drawn from local institutions such as the University of Pennsylvania and Princeton University.

In 1859 Philadelphia recalled the Spring Garden Hall for use by the city, so William Wagner began planning a new building for the institute just south of his home. To design his new building, Wagner chose John McArthur, one of the most prominent architects in Philadelphia at the time. McArthur was primarily an institutional architect; he designed banks, prisons, insane asylums, hotels, and, eventually, Philadelphia's city hall. The Wagner Free Institute building exhibits the sturdy, well-ordered lines typical of McArthur's early work on hospitals and prisons. Far from a

Louisa Binney Wagner, ca. 1841. Archives of the Wagner Free Institute of Science.

A Plan for a Free Institute of Science

The plans for the various courses of lectures, are in a similarly extended manner as those for the cabinets and the philosophical apparatus. Every branch of the natural sciences will receive attention, and be duly taught. . . .

While these sciences have each their separate spheres, they nevertheless are all inseparably connected, and form in fact but one great science. All are engaged in making known the great fabric of creation, which is one vast indivisible system, its several parts depending on each other, and interweaving and moving together in the most wonderful harmony. The field of operations for this Institution will therefore be as wide as the great creation, and as beautiful and grand as the glories that everywhere garnish the earth and the skies.

The practical application of these sciences to the useful arts, will be a prominent object. Mining, Metallurgy, Scientific Agriculture, Civil Engineering, Surveying, Navigation, Architecture, and the Mechanical and Chemical professions and trades, will each receive their share of attention. There is this difference, however, between the teaching of the sciences, and that of their applications to the several useful arts. The sciences themselves are for all—old and young, rich and poor, male or female, in every condition of life, as far as their attainment is possible; for a knowledge of the material world about us, concerns every rational individual. This knowledge is in the highest degree desirable for intellectual and moral cultivation, and for the preservation of life and health, and for innumerable practical applications to daily life, which are readily and naturally suggested to every mind. But the extensive and thorough applications of the sciences, in a technical manner, to the different chemical and mechanical trades, are quite different, these are specialities and designed for particular classes of individuals. . . .

The audiences to be attracted, judging from recent experience, will be as follows:—

1. Citizens generally whose leisure may permit them to attend, either regularly or occasionally, for their improvement or amusement.

2. The youth now attending other educational institutions, both private and public. These institutions are mainly literary, and open in the morning. Here they may listen to lectures on science, and study the cabinets in the afternoon and evening.

3. Persons engaged in mechanical pursuits, who may feel the need of learning the nature of those materials which they employ in their daily operations.

4. Students of this Institution—regular matriculants—who may pursue here a course of study with a view of becoming proficients in the sciences, and who may aim at obtaining the collegiate degrees.

The lectures are each about an hour in length, and the ultimate plan of the institution is to have at least four lectures every day: the hours of their delivery are in the afternoon and evening.

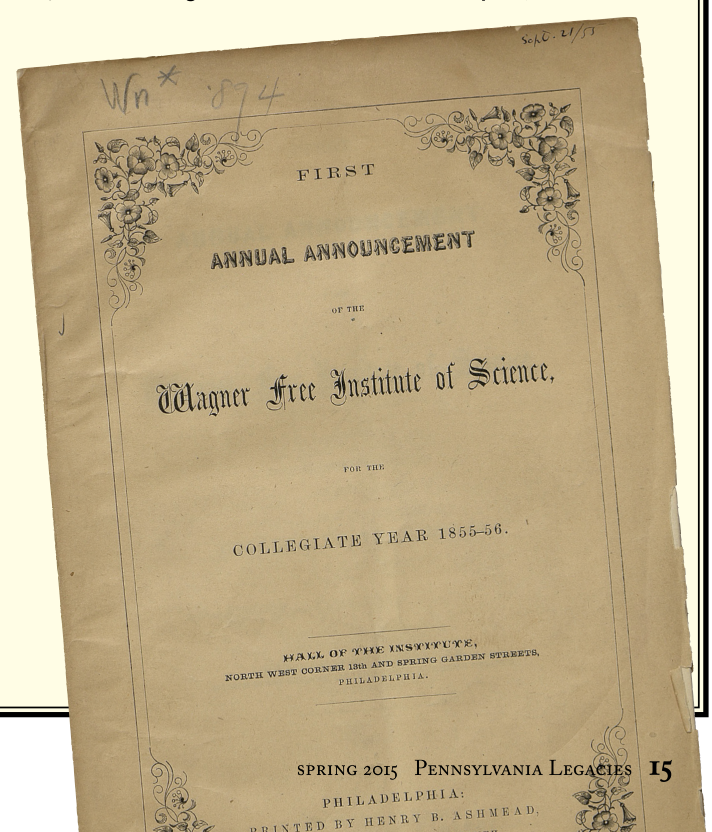
When thus a view is taken of the great number of lectures, the vitally important subjects of which they treat, the ample means for their illustration, and the large audiences of persons from different walks of life who may be accommodated and instructed, it is easy to perceive what a vast benefit this institution is calculated to impart in all future time. . . .

The influences of the sciences are striking as we behold them changing the face of the world. The power of steam applied on the ocean, on rivers, in factories, on railroads; the electro-magnetic telegraph, and the triumphs of civil-engineering in innumerable ways,—these are prominent instances of what has been achieved by an improved knowledge of material things. But this knowledge has been yet more effective in the contrivance and manufacture of thousands of fabrics, that cheaply and conveniently minister to the daily wants of every member of society. And yet there is a sphere in which science has been still more highly effective and beneficial. We allude to its direct effects in elevating the intellectual and moral nature of the human family. The world is no longer regarded as a level plain within narrow bounds. The great globe is revealed to our astonished view as a star rolling among countless millions of stars that glitter through the immensity of space. The most deeply affecting truths have been taught us by Geology concerning the formation and past history of our planet, and Natural Philosophy and Chemistry open to our admiring gaze the mysterious nature of matter. The other sciences, each in their turn, impart their powerful influences to the human mind. We all feel these influences when looking only at the material objects themselves, and how much more do we experience their power when through the sublime creation we extend our thoughts to the great Creator. There is an important sense in which modern science may be regarded as a new revelation—not to contradict nor to supersede the old, but immeasurably to extend and enlarge our views of the power, the wisdom, the goodness, the greatness, and the glory of the Deity.

Whether we regard the sciences in a moral, an intellectual, or a physical point of view, their great value is equally apparent. To provide for imparting them gratuitously, therefore, to every citizen in our midst, whether young or old, poor or rich, and that in the most effective and agreeable manner, we believe to be a great object, and worthy of the contributions of all who are liberally disposed. . . . ■

First Annual Announcement of the Wagner Free Institute of Science for the Collegiate Year 1855–56 (Philadelphia, 1855), excerpt.

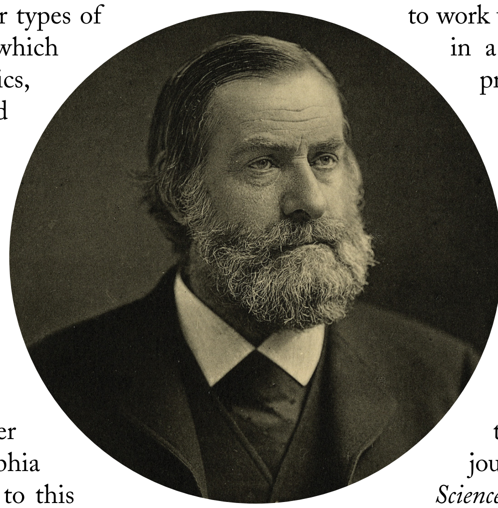
Cover, *First Annual Announcement of the Wagner Free Institute of Science, for the Collegiate Year 1855–56* (Philadelphia, 1855).



flamboyant "cathedral of science," as other, larger natural history museums of the 19th century were often characterized, the Wagner Institute building was described as a "plain, business-like structure" that combined the educational function of a lecture hall—modeled, at Wagner's request, after one designed by James Renwick for the Smithsonian—with storage space for Wagner's growing specimen collection.

This was a period of such immense growth for American museums of all types—especially natural history museums—that some historians have used the phrase "museum mania" to describe it. The growth of natural history museums from Charleston, South Carolina, to Cambridge, Massachusetts, was fueled by the continuous discovery of exotic fossils and new species that were popular with the general public. This excitement was encouraged by the thrilling (and sometimes villainous) exploits of the paleontologists working on the American frontier who braved the elements, Native Americans, and, often, each other, to send ever more fabulous fossils to the East Coast.

This period also saw the growth of other types of educational institutions such as lyceums, which housed public lectures on a range of topics, mechanics' institutes, which promoted invention and industry, and dime museums, which traded on the public's appetite for strange new animals with fake specimens such as the Fiji Mermaid and the Cardiff Giant. Through the twin processes of urbanization and industrialization, the American public was becoming more geographically concentrated and finding itself with more leisure time and money to enjoy a host of new pastimes. The Wagner Free Institute of Science of Philadelphia was one of many institutions that catered to this growing thirst for entertainment and education.



Wagner intended his new institution to combat what he saw as societal evils among the working class. In his view, urbanization, industrialization, and the rise of immigration from eastern and southern Europe also portended increasing criminality, indolence, and drunkenness. Providing free and publicly available scientific education, he explained, "is one great means of rescuing the laboring classes from the debasing influence of intemperance. It will place in their hands the means of self-cultivation, of improvement in the arts and of ennobling the spirit." His institution also provided an appealing and democratic alternative to what he saw as the increasingly inaccessible modes of scientific and technical instruction offered by other Philadelphia institutions, such as the American Philosophical Society and Academy of Natural Sciences. The popularity of his institute's first year of formal lectures in 1855, Wagner explained, was "doubtless in great measure owing to the manner in which the lectures on seven different branches of science were delivered. . . . The vigorous, transparent, and flexible English, we deem far more attractive and efficient in its native purity than when intermingled with strange Greek and Latin words. If eloquence be the aim of the lecturer, good taste will dictate that our own free and copious native tongue affords an ampler field for grace, beauty, and grandeur of demonstration, than any unnecessary mixtures of dead and bygone languages."

For the remainder of his life, Wagner devoted himself to his new institution. The Wagner Free Institute of Science welcomed men and women, and even occasionally children, from all social and economic classes. During his tenure Wagner attempted to found an accredited polytechnic institute, to create a home for a mechanics' institute for the demonstration and announcement of new inventions, and to form a partnership with the University of Pennsylvania for the scientific instruction of its undergraduates. While these ventures varied in success and longevity, each was part of Wagner's ongoing project to bring the study of nature to the largest possible audience.

Though knowledgeable, energetic, and generous with his wealth, Wagner was also an amateur in a field that was growing increasingly professional and exclusive, and increasingly migrating from museums to universities. Wagner himself was often difficult to work with and retained a strong independent spirit in a city and profession where collegiality was prized. Paradoxically, therefore, his death in 1885 breathed new life into the institution. He left the institution a healthy endowment and property. The institute quickly formed a board of trustees, who asked local scientist and prominent paleontologist Joseph Leidy to serve as the first president of the faculty and curator of the museum. Leidy wasted little time making the Wagner a more professional research and educational institution. Under his guidance the institute began publishing a professional journal, *Transactions of the Wagner Free Institute of Science*, and sponsored expeditions to gather original specimens for its collection. The first such expedition was undertaken to western Florida in 1886 by explorer and Wagner faculty member Angelo Heilprin, accompanied by trustee and mineralogist Joseph Willcox. The expedition discovered a cache of mammalian fossils from the Pleistocene, including two that together comprised almost a complete skull of a saber-toothed cat: the first fossils of this distinctive feline found in North America. Described in the second volume of the Wagner's *Transactions*, the two fossils served as type specimens for a new species of saber-toothed cat, *Smilodon floridanus*, and are still on display at the Wagner Free Institute of Science.

Leidy had a more profound impact on the building itself. One of his first acts as president was to embark on a $50,000 effort to enlarge and improve the building, adding to the library and completing exterior work. Even more important, Leidy strove to impose order on what was by then an imposing and poorly organized natural history collection. He transformed the clutter into a systematic display showing the relationship of each organism to its closest relatives, illustrating crudely, but clearly, the basic principles of Charles Darwin's theory of evolution by means of natural selection. When visitors entered the redesigned museum in 1891 they encountered first specimens of

(ABOVE) Joseph Leidy. Historical Society of Pennsylvania Portrait Collection. **(RIGHT) Saber-tooth cat fossils, from Joseph Leidy, "Description of Mammalian Remains from a Rock Crevice in Florida,"** ***Transactions of the Wagner Free Institute of Science of Philadelphia 2*** **(1889): plate 3.** Archives of the Wagner Free Institute of Science.

the simplest organisms, including coral sponges. As they proceeded through the museum, they walked past cases of specimens—insects, birds, reptiles, and mammals—arranged according to evolutionary sequence, finishing with a skeleton of *Homo sapiens*.

During this period the institute also saw growth in the number and types of programs offered to the public. The Wagner Free Institute joined the University of Pennsylvania, Temple University, and other local institutions in November 1890 to form the Society for the Extension of University Teaching, which offered college-level courses and certifications to the working people of Philadelphia. In 1892 the Wagner also opened and housed Branch Number One of the Philadelphia Public Library (merged into the Free Library of Philadelphia in 1894). It proved so popular that an extra wing was added to the institute in 1901 just for the library branch.

Though this period of energetic growth, publication, and education carried the Wagner Free Institute into the early years of the 1900s, several factors contributed to a reduced profile as the century progressed. The Wagner did not adapt—in fact, it missed almost every major museum and natural history innovation of the next 50 years. The exhibition Leidy designed for the Wagner was passé almost before it opened in 1892; naturalistic arrangements of artifacts and habitat dioramas became the fashion in larger and more famous natural history museums. As a discipline, too, natural history was quickly losing ground to university-based biology, genetics, and other scientific specialties. While the Wagner was able to keep the doors open and lectures scheduled, it was too poor to change, upgrade, and grow. Changes in the Wagner's neighborhood also dampened its popularity. When originally constructed, the museum occupied a part of well-to-do Philadelphia that was difficult to reach at times, but largely safe and quiet. This began to change as early as the 1890s, when the city began to encroach on the bucolic surroundings of the Wagner. Gradually the old landmarks began to disappear, replaced by thousands of middle- and working-class row houses serviced by a growing network of cable cars. At first the Wagner thrived in this suburban milieu, charging rent for the row houses on its property and offering free library lending services and classes to the neighborhood. By World War II, however, longtime residents had abandoned the neighborhood, giving way to poorer neighborhoods, boarded-up buildings, and diminishing income from rental properties. During this decline lectures were moved off-site, as attendees were increasingly too afraid of the neighborhood to visit the main building. During this period the Wagner continued to offer free lectures, a lending library, and other scientific programs, but its program of original research and publication shrank to a few endowed publications and special lectures. The Wagner Free Institute entered a period of isolation. In 1962, it closed its branch of the Free Library, signaling, if not the end of the institute's service to the community, then at least its decline.

Lack of funding and geographic isolation may have ensured a certain stasis in the buildings, collections, and programs of the Wagner Free Institute of Science, but its unchanging nature soon made it a historic treasure. The Wagner was named a national historic landmark in 1990, and the institute began to look for ways to interpret its heritage without compromising its scientific integrity. The founders' original goal of providing free scientific education to the public fit neatly into 21st-century museum theory, which stresses community engagement and a profession-wide push to lower admissions. In recent years, the Wagner's visitation has not only increased, but its audience has broadened to include artists, architects, aficionados of 19th-century science, and even museum professionals looking for inspiration from a past when science still had room for amateurs to work alongside professionals to collect, display, research, and teach and science was open to all. ■

Matthew A. White is a museum educator specializing in museums of the history of science and technology. He is currently a PhD candidate at the University of Florida. His dissertation is tentatively titled "Patronage, Public Science, and Free Education: The Wagner Free Institute of Science of Philadelphia, 1855–1929." He would like to thank Lynn Dorwaldt and the Wagner Free Institute of Science for their cooperation and the Consortium for History of Science, Technology and Medicine, who funded this research.

THE TRIALS & TRIBULATIONS OF GEORGE WESTINGHOUSE, SERIAL ENTREPRENEUR

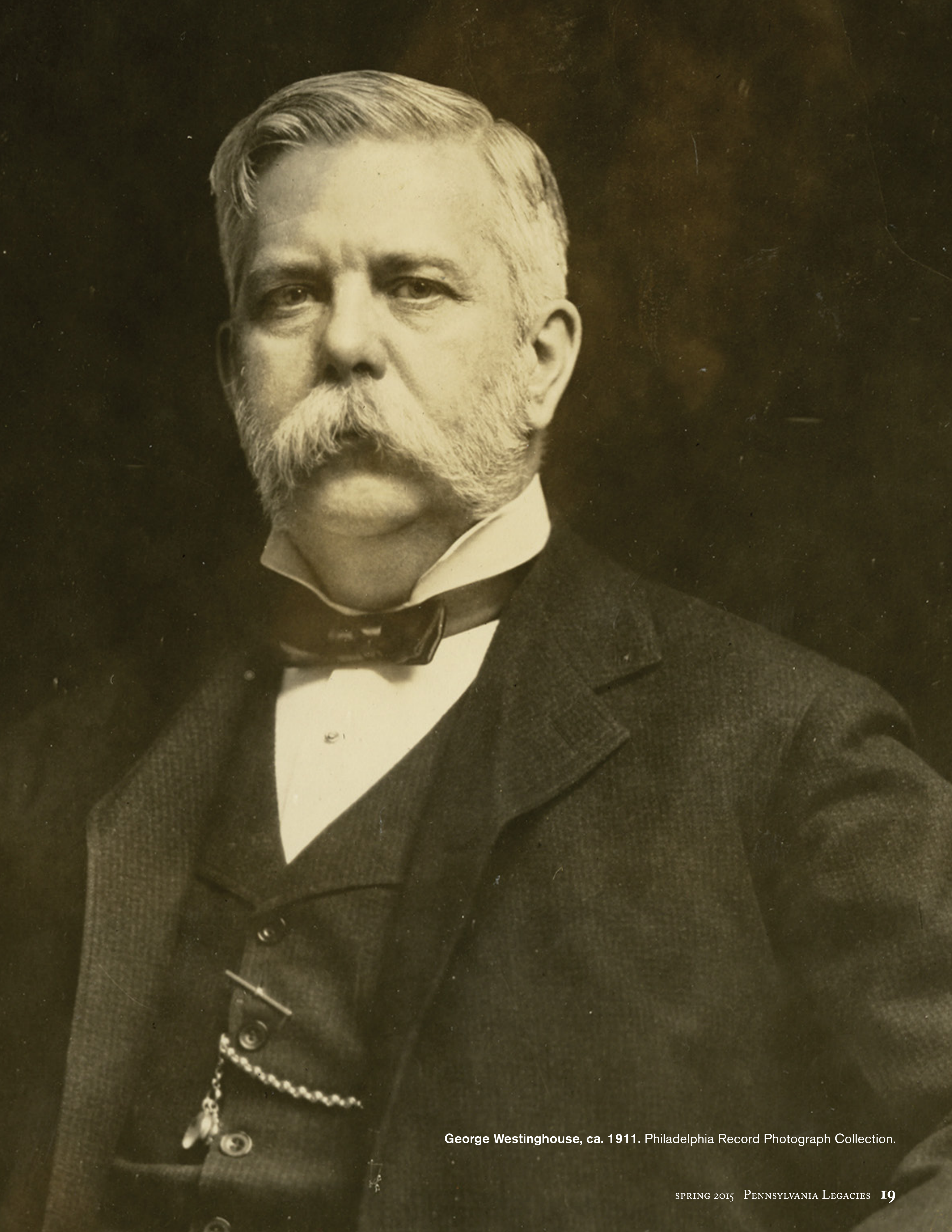
By Steven W. Usselman

In the spring of 1887, George Westinghouse had a major public relations problem on his hands. The famed inventor and industrialist had spent years building an imposing portfolio of valuable patents. From these, he and his able assistants had stitched together a comprehensive technological system, assembled from complex components manufactured in his Pittsburgh foundries and factories. The novel system was of obvious utility to the nation's burgeoning industrial economy, and Westinghouse stood poised to reap spectacular dividends. Now, on the brink of triumph, Westinghouse was about to be undone by a highly organized opposition intent on publicly discrediting his system and undermining his reputation. These adversaries, who held substantial financial stakes in alternative technologies, sponsored public trials aimed at exposing Westinghouse as someone willing to compromise safety in pursuit of profit.

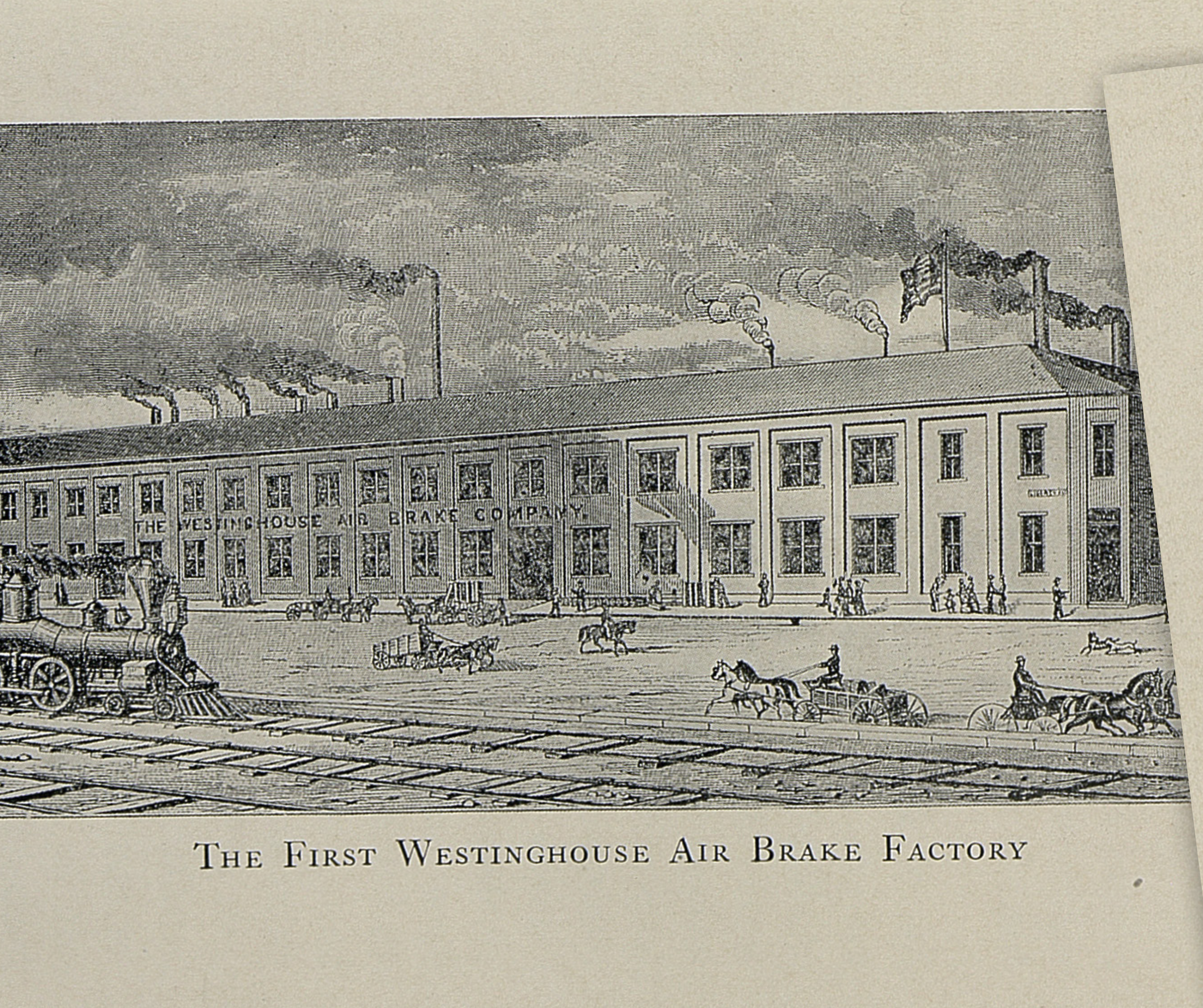
No, this is not the story of the famed "battle of the currents," in which Thomas Edison and other advocates of direct current (DC) electric light and power systems attempted to brand Westinghouse's alternating current (AC) system as so dangerous it deserved to be known as the "executioner's current." This tale involves a technology that meant even more to Westinghouse's fortunes than electric light and power: the air brake. This story takes us to the prairies of eastern Iowa, where, along the mainline of the Chicago, Burlington, and Quincy Railroad, a consortium of technical experts from railroads and their suppliers assembled in May 1887 to conduct trials of automatic brakes on 50-car freight trains.

Westinghouse had an enormous stake in what transpired at those trials. As a young inventor, fresh from service in the Union army and still in his early 20s, he had devised a braking system utilizing compressed air. Prior to his invention, railroad brakes were applied manually by men who jumped from car top to car top in response to an engineer's whistle, turning wheels connected to ratchets that tightened the brake shoes. The procedure was slow, cumbersome, and dangerous, not least for the brakemen.

Westinghouse's air brakes had replaced roof-hopping brakemen with mechanical linkages powered by compressed air stored in



George Westinghouse, ca. 1911. Philadelphia Record Photograph Collection.

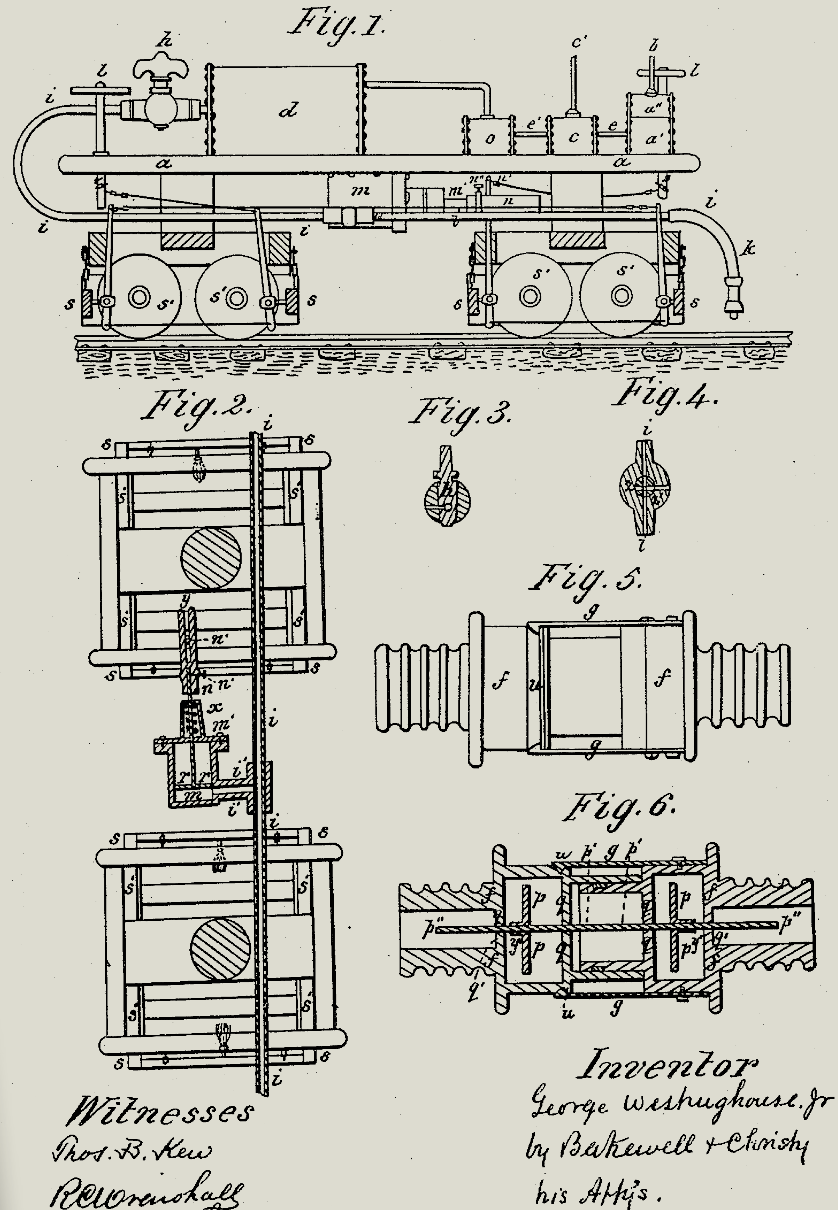


(ABOVE) The First Westinghouse Air Brake Factory and (RIGHT) wartime portrait of George Westinghouse. Francis E. Leupp, *George Westinghouse: His Life and Achievements* (Boston, 1918). (FAR RIGHT) Westinghouse air brake, as depicted in Westinghouse's 1869 patent application. US Patent 88,929, issued Apr. 13, 1869.

cylinders under each car and released when the engineer turned a lever in the cab of the locomotive. A pipe running the length of the train carried the air from a compressor mounted on the locomotive to the individual cylinders. When the engineer activated the brakes, the pressure in this pipe dropped, enabling the stored air on each car to escape from its cylinder and power the brakes. A complex mechanical wonder of Westinghouse's invention, known as the triple valve, governed the flow of air among train pipe, storage cylinder, and brake apparatus on each car. The system was more than twice as responsive as mechanical hand brakes, and it had a fail-safe feature; if the cars separated due to a faulty coupler or derailment, the pipe severed, causing the pressure to drop and the brakes to activate.

During the 1870s, air brakes had rapidly become a universal feature of railroad passenger service. Newly created state railroad commissions advocated them, and the traveling public insisted upon them. In the United States, and in much of Europe, virtually all air brakes were supplied by Westinghouse. By 1876, when the inventor turned 30, he was already a legendary figure and a man of considerable means. His Pittsburgh factory, located on Liberty Avenue across from the shops of the Pennsylvania Railroad, was a fixture within the thriving manufacturing community on the city's north side.

Westinghouse had relocated to the Steel City in 1869 from his home town of Schenectady, New York, at the encouragement of the Pennsylvania Railroad, which acted as what today we might call an angel investor. Its executives personally invested in the start-up firm and funneled large orders its way. In addition to access to capital, the move to Pittsburgh provided ready access to southern and western markets and immersed Westinghouse in a vibrant



industrial district. Anchored by the giant railroads that converged in its tight valleys and by a few large enterprises such as Carnegie's steel mills, the region fostered hundreds of small machine shops and metalworking facilities that were founts of inventive creativity and entrepreneurship. Labor flocked to the area, including the skilled draftsmen, patternmakers, foundry workers, and machinists who could transform rough designs into precision parts such as those required for the air brake. In the late 19th-century world of metal and machinery, Pittsburgh occupied a place not unlike that held by Silicon Valley in our era of microprocessors and software.

As with Steve Jobs and other wunderkind of our time, the brash Westinghouse did not lack for critics. His rapid success brought skepticism and resentment, not least from his customers the railroads. Many rail executives felt bullied into adopting air brakes by a public whose fears had been aroused unduly by the railroad commissions. They complained that Westinghouse, with his strong patent rights, had effectively been handed a monopoly. Several lines launched a concerted effort to develop automatic brakes of alternative design, only to stand by hopelessly as Westinghouse purchased and suppressed the rival patents. Even the Pennsylvania Railroad came to rue the leverage its former protégé now exercised over the market for brakes. In the late 1870s, it joined a national effort to revise the patent laws in ways expressly intended to undermine Westinghouse.

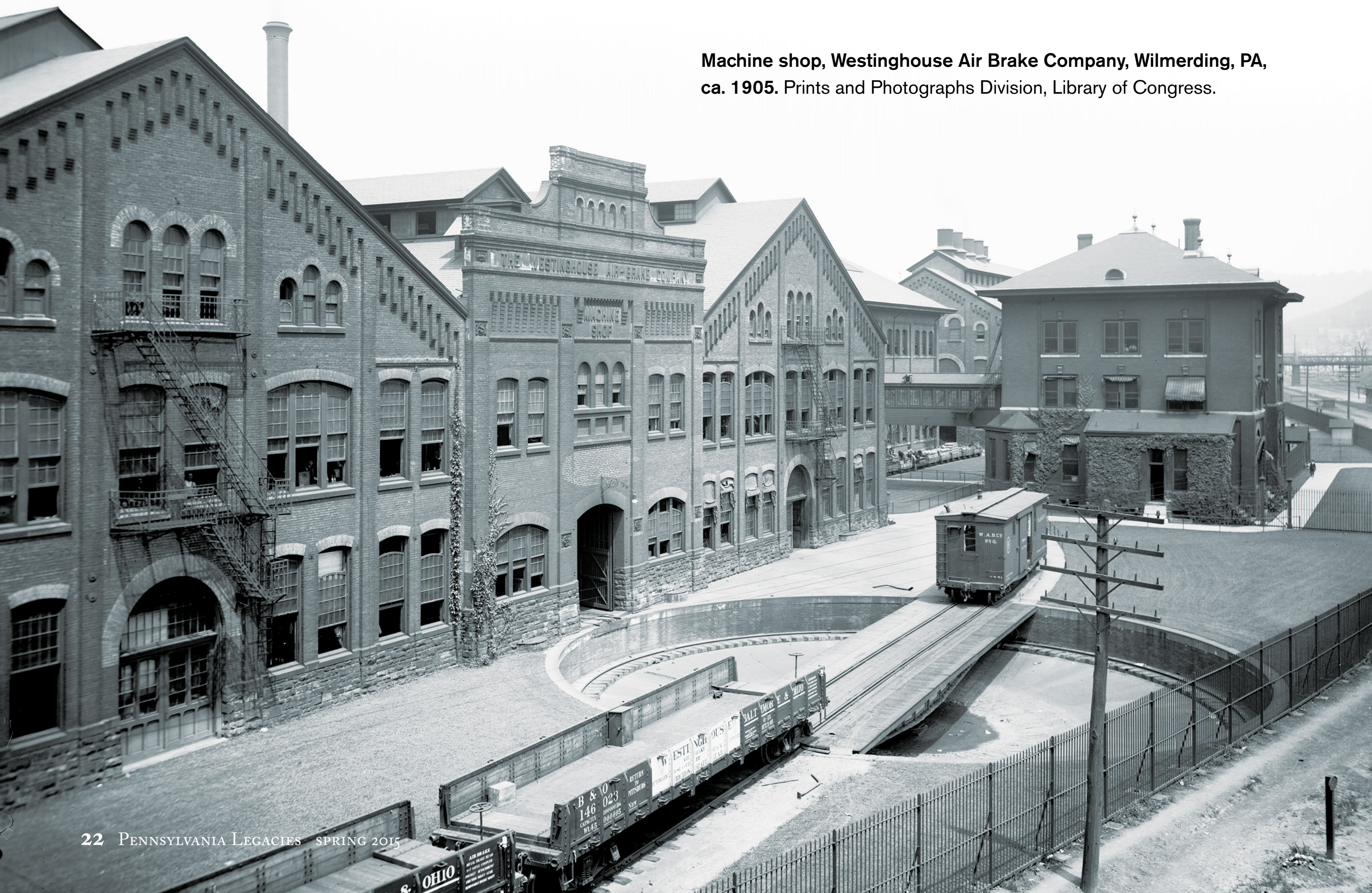
The rift between railroads and Westinghouse frustrated efforts to introduce air brakes into freight service. Except in rare situations demanding high speed and involving expensive cargo, such as shipments of livestock, most railroads chose to stick with conventional

One difference between Westinghouse and many of today's serial entrepreneurs, however, is that he looked to build enduring enterprises, rather than sell out to others.

hand brakes until the Westinghouse patents expired. In the meantime, they laid plans to conduct trials of rival designs for automatic brakes. While blocked from the vast railroad freight market, Westinghouse looked for other opportunities. Not surprisingly, he first gravitated toward automatic switching and signaling, but soon his interests came to encompass initiatives such as the supply of natural gas. This project drew upon technological spillovers from the air brake business, such as pipe fittings and regulating devices used to handle gases under pressure, which Westinghouse patented.

In today's parlance, one might describe Westinghouse as a serial entrepreneur, founding a series of start-up companies built upon previous experiences. Westinghouse drew on the explosion of new opportunities opened by the technologies of metallurgy and metal machining, as epitomized by the foundry and machine shop. These were the late 19th-century equivalents of modern software shops; although the underlying technologies are different, the opportunities they opened for rapid prototyping and accomplishing old tasks in dramatically new ways are similar. One difference between Westinghouse and many of today's serial entrepreneurs, however, is that he looked to build enduring enterprises, rather than sell out to others. At his core, Westinghouse was an inventive manufacturer. His ventures consistently combined the same basic elements. They were grounded upon patented mechanical devices of great complexity built by Westinghouse in his own shops and factories from raw metal to intricate finished product. Those key mechanical components were combined in tightly integrated systems, in which a form of power produced from a central source (such as an air compressor, a natural gas well, or an electric generator) was distributed through conduits such as pipes or wires to achieve action at a distance. Flow through those conduits was governed by intricate regulating devices, such as the air brake triple valve and the electrical transformer, which often provided Westinghouse his strongest patent protection.

Launching and retaining control over these many enterprises called for remarkable energy and managerial abilities. Even as he continued to invent and patent under his own name, Westinghouse mastered other elements of business. He became a shrewd evaluator of technology and of technical talent, purchasing key



Machine shop, Westinghouse Air Brake Company, Wilmerding, PA, ca. 1905. Prints and Photographs Division, Library of Congress.

George Westinghouse and wife, Marguerite Erskine Walker, during the early years of their marriage. Francis E. Leupp, *George Westinghouse: His Life and Achievements* (Boston, 1918).

patent rights such as those covering the AC induction motor and placing its inventor Nikola Tesla and other creative talents under retainer. He mastered the legal intricacies of intellectual property law and corporate finance. He built and managed expansive factories, which eventually spread for miles along the Turtle Creek Valley and its tributaries east of Pittsburgh. These state-of-the-art facilities could produce established designs in volume, using novel techniques that drew attention from manufacturers around the globe. Yet they were also capable of taking a sketch of some new design, dreamed up by Westinghouse or one of his assistants one afternoon, and transforming it into material reality by the following morning. Through it all, no matter what else might be occupying his mind, Westinghouse never lost his flair for the dramatic, or his capacity to rise to meet a challenge with a heady mix of inventive aptitude and savvy public relations.

Never was this more apparent than during that chaotic spring of 1887 when Westinghouse headed to Iowa. An initial trial of freight brakes at Burlington the previous summer had ended in disaster. Organizers had hoped to discover several alternatives capable of governing the movement of long trains descending steep grades and handling other demanding conditions characteristic of freight railroading. Although several designs passed these tests, all of them, including Westinghouse's, failed miserably when attempting emergency stops.

The troubles sprang from an intrinsic design flaw. When engineers activated air brake systems by abruptly opening a release valve on the locomotive, air pressure dropped and brakes snapped on almost immediately at the front of the train. Brakes at the rear of the train remained off, however, since pressure had not yet dropped in that part of train pipe. Because loosely coupled long freights contained a great deal of slack, the unchecked rear cars slammed into the braked front portion of the train. Officials monitoring the tests, tossed from one end of the last car to the other, immediately called off the trials. Interested manufactures should reconvene a year hence, they announced, armed with remedies for the problem.

This dramatic turn of events, which appeared to open a clear path for upstarts to enter the field with brakes of novel design, could hardly have come at a worse time for Westinghouse. Still occupied with his risky venture in natural gas distribution, the restless inventor had begun to assemble the key components of his alternating current electrical system—and already Edison had mobilized to discredit him. Now, Westinghouse had suffered a public embarrassment that threatened his established air brake empire. Reluctantly, he put his other projects on hold and turned his attentions back toward the enterprise that had made his fortune.

Things seemed to turn from bad to worse the following May, when several capable rivals showed up at Burlington with brakes that could handle emergency stops using electrically activated mechanisms. In some cases, the electrical components powered brakes directly. In others, an electric current opened valves that released air along the entire length of the train pipe, so that brakes activated nearly simultaneously on every car. Westinghouse, in fact, had utilized such an arrangement for its own entry. Organizers happily concluded that such electrically activated air brake systems, now available from several manufacturers, would become the new standard in freight service.

Such an outcome was unacceptable for George Westinghouse. Upon arriving in Burlington, he dismissed all braking systems utilizing electrical appliances as incapable of withstanding the rigors of ordinary railroad freight service. In a moment rich with irony, the man then embroiled in defending himself from accusations about the dangers of his alternating current power systems proclaimed that reliance upon electrical devices in freight railroading would imperil workers and the public.

To be fair, the warning had some merit. Although electrical devices would be made sufficiently robust by the turn into the 20th century to become standard issue on subway braking systems, in 1887 one could easily envision how a wire might become dislodged and render the brakes inoperable during an emergency. Yet Westinghouse was not acting out of altruism; he was buying himself time. Over the course of the previous year, he and his staff had been hard at work on an entirely mechanical remedy to the shock problem. A newly designed "quick-action" triple valve would release air almost immediately from the brake pipe on each car of a train and direct it straight into the brake apparatus.

The new valve was not quite ready in time for the trials at Burlington. But after working relentlessly for several weeks thereafter in the railroad shops at Burlington, the Westinghouse team had perfected the system sufficiently to take a 50-car train on a triumphant national tour. Like an engineering rock star, the train appeared in all the major railroading centers, performing emergency stops for admiring audiences. To the chagrin of his rivals and of many railroads, Westinghouse had managed to emerge

The Battle of the Brakes

THE NEW AIR BRAKES.

—

Great Freight Trains Stopped in a Magical Manner.

—

Scientific Tests Given by the Westinghouse Company in the Presence of the Leading Railroad Officials.

—

President Roberts, of the Pennsylvania Railroad, surrounded by a score of prominent railroad men and distinguished persons from all the business walks of life, on Saturday afternoon witnessed a successful series of tests of the Westinghouse Air Brake Company's freight train brake. A special train left the Broad Street Station at 1 o'clock with nearly four hundred gentlemen who had accepted invitations to witness the tests on the main line of the Pennsylvania Railroad near Wynnwood station. It is probable that the tests were the most interesting ever made in this country. The exhibitions were given with a train of fifty large freight cars, each car being thirty-eight feet four inches long, with a capacity of sixty thousand pounds. The appliance, it was explained, was the latest improvement on the triple valve automatic brake, and is especially adapted to long freight trains. The tests, in the opinion of those competent to judge, were more successful than the famous ones given at Burlington, Ia., by the Master Car Builders' Association.

In Less Than Twenty Seconds.

The spectators ranged themselves on either side of the tracks near Wynnwood. The first exhibition was that of an emergency stop with the train running twenty miles an hour. In order to attain sufficient speed the fifty cars were run back as far as Ardmore. In a short time it came into sight at a rate which the indicator showed to be twenty-three miles an hour. Just as the engine reached the marking post the air brakes were applied, and in fourteen and one-half seconds the train was at a standstill. It ran two hundred and sixty-four feet after the brake had been applied. The second test, also an emergency stop, was given with the train running nearly forty miles an hour. It was necessary to run the train back as far as Bryn Mawr to get the rate of speed. The spectators waited with the greatest expectancy, and when the train came thundering along every eye was on the brakes. They were applied and the train stopped in just nineteen and one-half seconds. The engine ran 593½ feet beyond the stopping point. The next exhibition was that of applying the brakes while standing still, to show the quickness of application. The train was placed so that the thirty-fifth car was at the stopping post and the operation of the brakes could be observed at that point. The work was almost instantaneous.

How the Emergency Stop Worked.

The fourth test proved very interesting. It was an emergency stop, with passengers on board, at a speed of forty miles an hour. Two cars in the front of the train, two in the middle and two in the rear had been provided with seats, and when the train started, they were all filled with curious spectators. The train got up a speed of thirty-six miles an hour, and was stopped in a little over a quarter of a minute. There was very little jarring, and the stop was a strong, steady one.

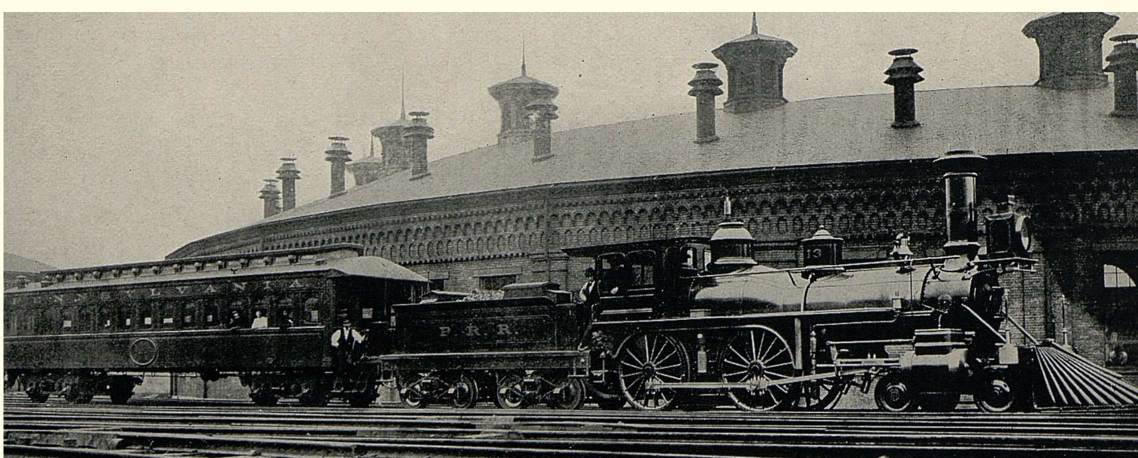
The next test showed the kind of a stop made when a sudden stop was not necessary. This was followed by an exhibition of a hand brake stop. It was given with five brakemen at their posts and the train going at the rate of twenty miles an hour. It took seventy-five seconds to stop the train, which ran 1889 feet after the brakes were applied. The train was then broken in two to show how, with the pipes disattached, the appliance worked automatically.

The Old and the New.

All the stops were made with the braking power so low that it did not slide the wheels of empty cars in regular service. By using greater power, quicker stops could be made, but there would be more or less sliding of wheels and it is not thought that the advantage gained would be enough to make up for the damage done in freight service.

Finally a train of twenty freight cars and a train of twelve ordinary passenger coaches were run alongside of each other on parallel tracks and the brakes applied at the same time. The test showed the relative stopping power of the old and new brakes. The speed was 59 miles an hour. The freight train was stopped in seventeen seconds and the passenger in 23. . . . ■

Philadelphia Inquirer, Nov. 28, 1887.



Locomotive and Passenger Car that constituted a Part of the First Train Used for a Public Exhibition of the Brake

Locomotive and passenger car used in early test of air brake. Francis E. Leupp, *George Westinghouse: His Life and Achievements* (Boston, 1918).

John L. Pelley, president of the Association of American Railroads, laying a wreath at the bust of George Westinghouse, at permanent exhibit of the air brake at the Smithsonian Institution, on the 100th anniversary of Westinghouse's birth, Oct. 6, 1946. Philadelphia Record Photograph Collection.

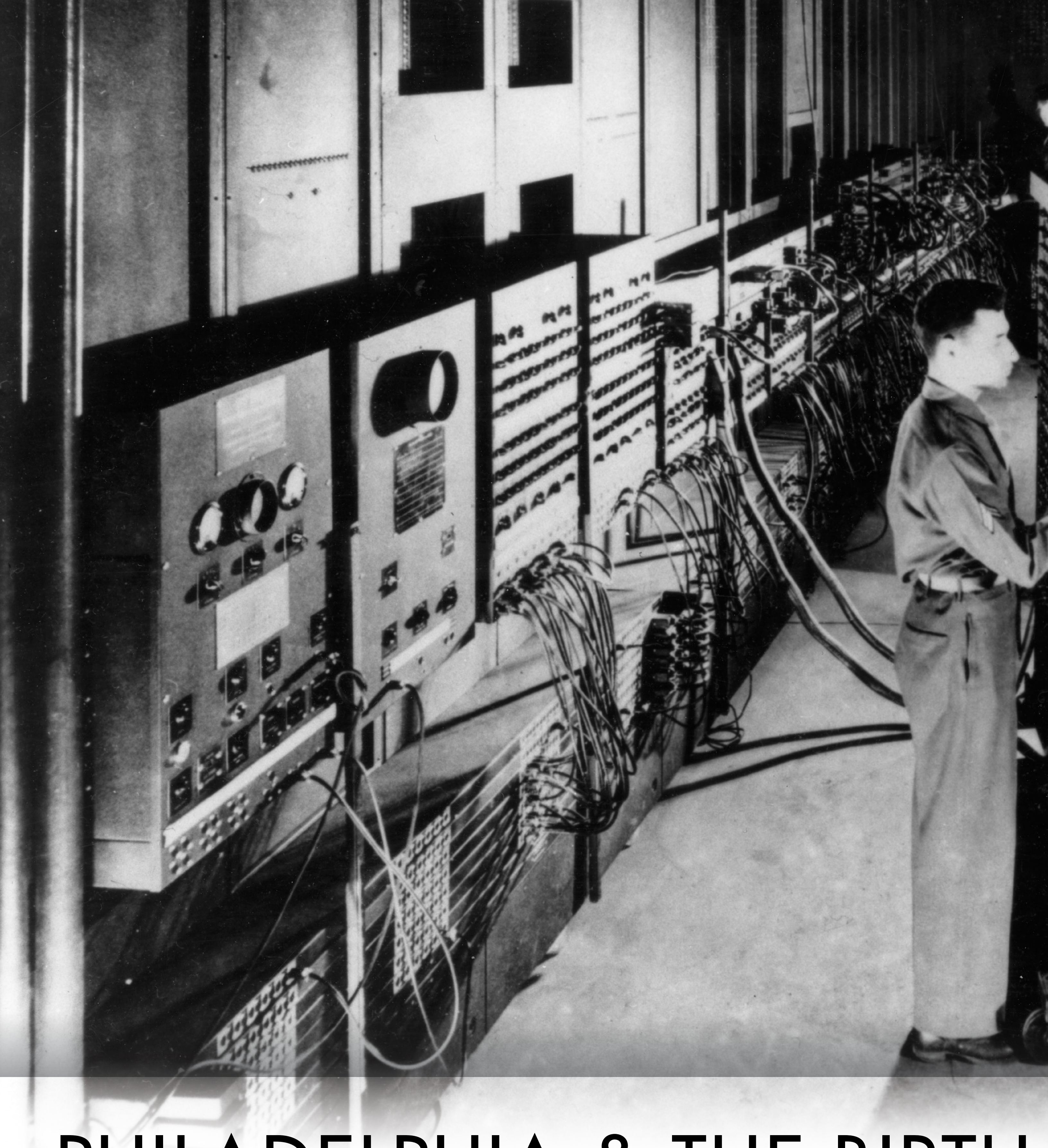
from the ordeal in a stronger position than ever, with a superior design covered by newly issued patents. His competitors were left to devise valves of alternative design, whose patents Westinghouse challenged all the way to the Supreme Court over the course of the next 15 years.

By the time those cases were resolved George Westinghouse had attained considerable renown for his achievements in electric power. To the surprise of no one who had observed his previous endeavors, Westinghouse had established his reputation in large part through a series of spectacular public displays, lighting the World's Columbia Exposition at Chicago in 1893 and tapping the power of Niagara Falls to provide electricity to the World's Fair at Buffalo in 1901. For another fair, held at St. Louis in 1904, Westinghouse commissioned the famed cinematographer Billy Bitzer, whose credits would later include *Birth of a Nation,* to make movies touring the electrical manufacturing facilities located along Turtle Creek and riding an electric train traversing through the New York subway system.

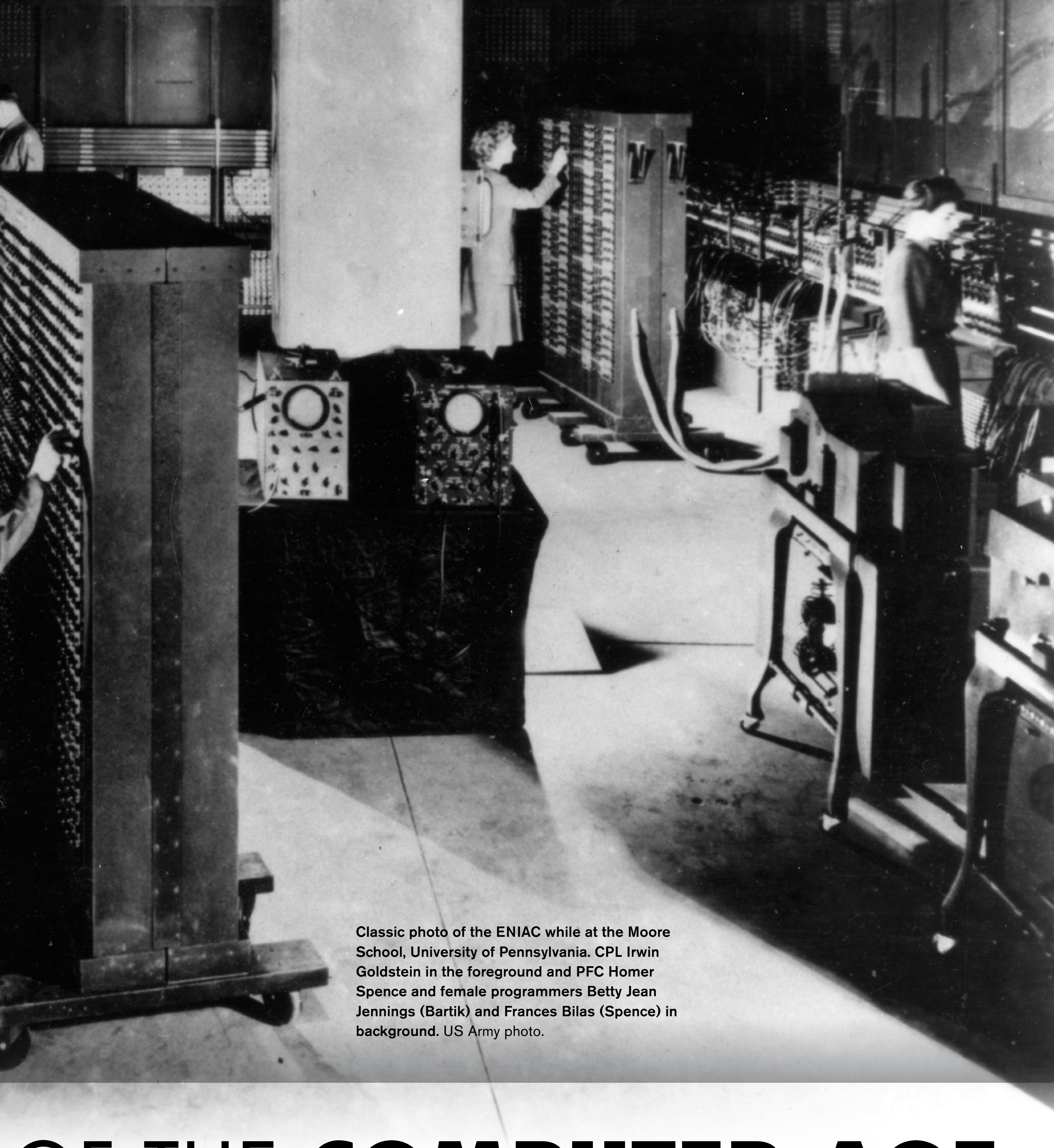
George Westinghouse lived another decade after the fair at St. Louis, during which those electrical systems manufactured in East Pittsburgh grew commonplace in the nation's booming urban metropolises. Following his death, the link between Westinghouse and the electrical industry grew ever stronger in the public mind. Yet in his lifetime, this extraordinary figure had in fact attained his greatest heights in the railroad industry. A reliable 1912 accounting identified the Westinghouse Air Brake Company as the 13th-largest industrial corporation in the United States. With a capitalization of more than $100 million, it was half again as valuable as Westinghouse Electric.

Ironically, by then George Westinghouse no longer owned either of those assets. Ever the serial entrepreneur, he had continued to invest in new ventures—some 60-odd companies all told. His insatiable appetite for enterprise had left Westinghouse financially exposed, and a sharp recession in 1907 threw him into bankruptcy. It was an ignoble finish to a grand career, born in the innovative hotbed of late 19th-century Pittsburgh. ■

Steve Usselman is professor of history and chair of the School of History, Technology, and Society at Georgia Institute of Technology. He is the author of Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920 *(Cambridge University Press, 2002).*



PHILADELPHIA & THE BIRTH



Classic photo of the ENIAC while at the Moore School, University of Pennsylvania. CPL Irwin Goldstein in the foreground and PFC Homer Spence and female programmers Betty Jean Jennings (Bartik) and Frances Bilas (Spence) in background. US Army photo.

OF THE **COMPUTER AGE**

By Paul Ceruzzi

Kay McNulty, Alyse Snyder, and Sis Stump operating the differential analyzer at the Moore School, ca. 1942–45. US Army photo.

"How's for some bright ideas as to how to get the Moore School profitably occupied[?]"

That was the somewhat dismissive reaction by a member of a government committee that met in April 1943 to discuss the development of devices to aim and control artillery and antiaircraft guns. War was raging across the Atlantic and Pacific Oceans, and the problem was urgent. Government funds were available, but the committee had to choose among a variety of novel proposals. The University of Pennsylvania's Moore School of Electrical Engineering was already computing firing tables for the army's Aberdeen Proving Ground, about 60 miles south of Philadelphia on the Chesapeake Bay. But the army was falling behind: it could not produce firing tables fast enough to satisfy the rapidly changing needs of artillery officers in the field. The Moore School proposed an all-electronic machine that would replicate the work done by human computers—"computer" at the time was the job title for one who performed mathematical calculations—and also take the place of the differential analyzer, a mechanical device that used wheels and discs to solve complex equations. By using electronics in place of mechanical gears or magnetic relays, this machine would operate many times faster and break the army's logjam.

Although the army respected the Moore School's work with the differential analyzer, it did not have a longstanding relationship with the school like it did with MIT, RCA, or Bell Telephone Laboratories—firms that were vying for the same contract. A greater cause for skepticism lay in the technical details of the proposal itself: an all-electronic computer with upwards of thousands of vacuum tubes for its active elements. In spite of the risks, the army executed an agreement with the Moore School in May 1943 for the machine, called ENIAC: Electronic Numerical Integrator and Computer. Its completion two-and-a-half years later helped inaugurate the computer age we now live in.

At the time, military radar equipment was being produced that contained hundreds of tubes, and that was pushing the state of the art of electronics. The proposed machine was to represent numbers as pulses carried in the tubes. For example, the number "6" would be represented by having the 6th in an array of 10 tubes conduct current, while the other 9 tubes would not pass current. Thus the array would handle numerical values as discrete digits, not as varying voltages. The failure of even a single tube, however, could render an entire calculation in error. Vacuum tubes tended to be the most unreliable component of an electronic device, mainly because the filament inside would burn out after a period of use. Like the incandescent light bulb from which it descended, a vacuum tube was not permanently soldered into a device but was installed in sockets, so that a burned out tube could be replaced quickly.

J. Presper Eckert, a graduate student at the Moore School and co-author of the ENIAC proposal, was confident that he could overcome this drawback. He proposed running the tubes at voltages and currents lower than the manufacturer's specifications. And he designed the circuits in standardized "modules": circuits that performed basic arithmetic functions and which contained an array of tubes. Spare modules were assembled, tested, and kept in reserve. If a circuit failed, one could plug in a replacement module quickly, without having to test each individual tube. Both of these innovations are now standard in the electronics industry, even as the vacuum tube has given way to the silicon chip.

If Eckert supplied the electrical engineering skills needed to make the machine work, John W. Mauchly was the overall architect of the ENIAC and the person who had the vision of what a computing machine could do. He had taught physics at Ursinus College in suburban Collegeville, where, in his words, he was a "one man physics department." As a physicist, he was no stranger to electronics; he was interested in applying calculating machines to analyze weather data. Existing mechanical calculators

The ENIAC was big. The initial proposal, for a device containing about 5,000 vacuum tubes, grew to a final count of around 18,000 tubes.

John Mauchly (far left) and J. Presper Eckert (far right) with Maj. Gen. Gladeon Barnes, head of research and development for the army ordnance, reviewing the ENIAC maintenance records, ca. 1944. From the Collections of the University of Pennsylvania Archives.

were not up to the task, so he explored the idea of using electronic tubes, which switched current much faster. In 1941, he enrolled in a summer course at the Moore School, which was offering a program of instruction in electronics and other topics deemed vital to waging war, and started developing the skills necessary to construct a machine powerful and fast enough to forecast the weather. There he met Eckert.

Eckert's and Mauchly's skills were complementary: Eckert the detail-oriented engineer, Mauchly the theoretician who envisioned the concept of a large-scale computing machine. Mauchly realized that his idea for a computer that could assist weather forecasting could be reconfigured to address the army's ballistics problem. The idea that a computing machine could be applied to a wide variety of problems, including many not foreseen by its creators, was in itself a profound insight. Such a machine would have the flexibility of the human computers who were solving the pressing ballistics problem facing the army at Aberdeen. The idea had been anticipated a decade earlier by the British mathematician Alan Turing, and there were a few mechanical computers in operation that had that capability by 1945. But it was at the Moore School that the idea first became realized in electronic circuits. The machine was completed by November 1945 and dedicated in a public ceremony on February 16, 1946. By then the Second World War had ended, but the army's continuing need for ballistics tables, and the needs of other government agencies for calculations, ensured that the machine would be in constant use. So urgent was the demand for its services that its move from Philadelphia to Aberdeen was postponed for about a year, after which it remained in constant service until 1955.

The ENIAC was big. The initial proposal, for a device containing about 5,000 vacuum tubes, grew to a final count of around 18,000 tubes. Working at an accelerated pace, by late 1943 Eckert and Mauchly had developed a set of circuits that showed that their design would work. In response, the army requested a machine twice as large as the one originally proposed. Burned-out tubes remained a problem, but the ENIAC could do more work during a few hours of operation than a more reliable mechanical computer could complete in days. The ENIAC was a complex machine—it had to be. But it worked, and the army used it extensively after moving it from Penn to Aberdeen, not just for ballistics calculations but for a wide variety of problems.

If the ENIAC were a one-off military project, it would have been significant, but it would hardy have been remembered alongside other developments such as radar or the atomic bomb. But it *is* remembered, thanks to two things that happened next. The first was that its creators, with the help of the Princeton mathematician John von Neumann, used the ENIAC's design as a springboard to develop a plan for what computers ought to look like in the future. Von Neumann summarized the ideas of the three, with contributions from the rest of the ENIAC's developers, in a report privately circulated in 1945. Out of their discussions came the notion of building a computer with a large internal memory, which would store both the data to be acted on and the program that gave instructions to act on it ("to program" was among the many terms coined by Eckert and Mauchly). Future computers would continue to use vacuum tubes, but they would have a simpler structure and would be able to do more calculations at higher speeds. Computer scientists today call this design the "von Neumann Architecture."

The second seems obvious in retrospect but was incredibly bold at the time. Eckert and Mauchly decided to form a company that would manufacture and sell electronic computers to commercial customers. That went against the advice of almost all the experts—including von Neumann—who found plenty of reasons why the scheme would fail. According to computer historian legend, one expert predicted that four or five computers would be more than sufficient to satisfy the world's needs. The statement has never been traced to an individual, but the notion behind it was commonly held. A more serious objection came from those who reasoned that a machine designed to solve complex mathematical equations would be useless for commercial and business customers.

In late 1946 Eckert and Mauchly formed the Electronic Control Corporation, a company whose goal was to commercialize their invention. This move caused friction with the University of Pennsylvania, which wanted to control the rights to the invention, and with von Neumann, who was ambivalent about commercializing a scientific instrument. Under pressure, the pair resigned from their university positions. In the summer of 1947, they began work on a commercial computer, which they called UNIVAC, an acronym for Universal Automatic Computer. The name was deliberately provocative: it was a "universal" machine, as suited for scientific calculations as it was for business. Installations ranged from the atomic weapons lab at Livermore, California, to the US Census Bureau, several life insurance companies, and a well-publicized installation at General Electric's Appliance Park in Louisville, Kentucky. The UNIVAC's creators assembled a team of diverse and talented engineers, working in a modest plant at 3747 Ridge Avenue in Philadelphia. In December they incorporated the partnership, renamed the Eckert-Mauchly Computer Corporation, in the hopes of raising capital by selling stock. Unfortunately for them, the era of venture capital was decades into the future, and they were unable to remain independent. In 1950, the business equipment firm Remington Rand acquired EMCC, which remained as a division, with its headquarters remaining in Philadelphia. They began delivering UNIVAC computers in 1951. Sales were modest, but the computer was well engineered and every bit as revolutionary as the ENIAC had been five years earlier.

Among the team the Eckert-Mauchly Division hired were several women, some of whom had come to Philadelphia during the war to work as human computers for the army. At a time when it was difficult for women—even those trained in mathematics—to find meaningful work, women such as Jean Jennings Bartik, Betty Snyder Holberton, and Kathleen McNulty Mauchly were among the original programmers of the ENIAC. Several would go on to work on the UNIVAC and other projects. One of Eckert-Mauchly's most important hires was Grace Murray Hopper, a mathematician who had worked on a mechanical computer at Harvard under the direction of Howard Aiken (one of the skeptical experts mentioned above). Hopper recognized that it was not enough to have a powerful machine like the UNIVAC; one also had to program it to do the different sorts of tasks it was capable of. Programming was an opaque art in those days, and Hopper devoted the rest of her long career to making it easier. Hopper's insight was to write codes for the UNIVAC that would calculate basic functions, or take care of the routine tasks of organizing the work, thus allowing the programmer to concentrate on writing code that addressed a specific problem. A master program would select these routines and "compile" them into the user's program. Hopper was not alone in conceiving of this idea, but her tireless advocacy of developing such compilers and high-level programming languages played a large role in making computers accessible to people outside the inner circle of engineers and mathematicians. That legacy survives deep down inside the smartphones and laptops we use today.

The defense and electronics company Sperry acquired Remington Rand in 1955, with the headquarters of its UNIVAC Division located in suburban Blue Bell, Pennsylvania. It continued to produce large computers, although, like so many of the other early computer companies, it struggled after the IBM Corporation aggressively entered the market. Eckert remained as an executive at Sperry, while Mauchly left in 1960. Their role in birthing the computer age has been mired in controversy, especially after a court case ruled in 1973 that Eckert and Mauchly's patent on the ENIAC was invalid. Mauchly especially felt that his contributions had not been recognized, at least as judged by coverage in the popular press. Academic historians are more generous. Hollywood has yet to make a movie about Eckert and Mauchly as it has about Alan Turing or other scientific geniuses who toiled during the 1940s, but their legacy is found everywhere—not just in the Philadelphia region, but all over the industrialized world. ■

Paul Ceruzzi is curator of aerospace electronics and computing at the Smithsonian Institution's National Air and Space Museum. He is the author of several books on Eckert's and Mauchly's contributions to computing, including A History of Modern Computing, *2nd ed. (2003), and* Computing: A Concise History *(2012).*

UNIVAC computer, ca. 1953. From the Collections of the University of Pennsylvania Archives.

Programming the UNIVAC: An Interview with Grace Murray Hopper

. . .The Navy offered the opportunity for the WAVES to transfer to the regular Navy and I tried it but I was turned down because the cutoff age was 38 and I was 40. I stayed on two more years at Harvard while we built MARK II and MARK III and it got to be 1949 and you can't be appointed more than three years without being promoted at Harvard, so I had to find a job. And I looked around and practically everybody in the industry interviewed me and I found two that appealed to me. One was with John Mauchly at Eckert Mauchly Computer Corporation and the other was with Howard Engstrom at ERA because Engstrom had been one of my professors at Yale. But I decided I wanted to stay nearer my family and besides which it looked as if UNIVAC was going to have an operating computer long before ERA did. Of course, they all ended up together in the long run anyway. So I joined Eckert Mauchly. At that time Betty Holberton was the lead programmer, the programmer. She taught me how to use flow charts and every[t]hing under the sun. And I think the first use of a computer [that] could write a program was Betty Holberton's SORT generator. And that was a tremendous piece of work; nothing like it had ever been done before and I don't think Betty has ever received the credit she should have received.

The other thing that was started—she was working on that for UNIVAC—Mauchly had started short order code which is an i[n]terpreter, they were symbolic but you wrote regular mathematical equations and then they stored all the mathematical subroutines in one corner and it jumped to them and executed them. It was a regular interpretive routine and it had a crude language. I don't think that's ever been properly credited. . . . Then later, it was rewritten and put together in better shape and came out in '52 for UNIVAC I. To the best of my knowledge that's the very first of a true interpreter, interpretive routine. . . .

. . . And we built a differentiator. And nobody would believe that thing would work! Nobody believed it, they said you couldn't possibly, computers could only do arithmetic. The whole industry just thought it was the funniest thing that ever happened. . . .

Nobody would believe it. We finally got a man at the Army Map Service and he had a very nasty function. . . . [H]e spent six months writing those out and checking them. And we got them off UNIVAX I in eighteen minutes. And he looked at it, and I think he was totally horrified they were correct. And he turned and looked at me and said, "Oh, you had somebody sitting behind the computer feeding the answers in." Couldn't believe it.

. . .They sent Jean Samath down from Sperry; she was an engineer at Sperry and she spent a year in the group. She's the one you know that wrote the book on programming languages. She spent a year in that group and she picked it up and later went on to do the format, which . . . does differentiation and all those things. She was the first one that really believed it would work.

In the meantime, we'd gotten this language on to it. Peg Harper did that. And Frank, of course, was in on the development. First A0 I wrote by hand, every single line of it myself and I wrote the documentation. When we started [to] grow . . . they gave me Frank to work with me and he started on A1. . . . Then we got Peg Harper and Ridgway joined us and Peg Harper came down from Aviation Supply Office. And she wrote the one that put this language, which is the A2 language, on top of A0, so as to give us a semblance of the language. . . .

. . . So while they were going forward with the differentiator & MATH-A-MATIC and stuff, I sat down—I must have gone over at least 500 data processing programs—and in order to find out what people were doing when they did data processing, I wrote out English descriptions of what they were doing. And as it went on, and as I got some people to help me do it, I began to notice there were certain verbs that were repeating—that seemed to be the actions of data processing. Over and beyond that—subtract, multiply and divide—I was finding things like read, write, insert, compare, so on and so forth. . . . [S]o the concept came, let's use the words; let's write in English. . . . ■

Interview by Philip F. Holmer, July 20, 1979, transcribed by Dora Mae Blake. *Courtesy of Unisys Corporation and the Hagley Museum and Library.*

Grace Murray Hopper and programmers (left to right) Donald Cropper, K. C. Krishman, and Norman Rothenberg around the UNIVAC. Courtesy of Unisys Corporation and the Smithsonian Institution (gift of Grace Murray Hopper).

TEACHERS' PAGE

Women and Science: Plant Classification and Herbaria

BY ALICIA PARKS

Introduction

In the mid-18th century, Swedish naturalist Carl von Linné created a system of taxonomy that revolutionized botanical study and is the basis for our modern system of classification. Linné's work was made possible by communication with networks of learned scholars and collectors, among whom were several women. Botany was generally considered a suitable science for women to learn, and by the 19th century it became an integral part of women's education.

By the 19th century, educated women were expected to understand the systems of botanical taxonomy, and a number of women even published botanical textbooks, often for the use of female pupils. One such woman was Almira Hart Lincoln Phelps, who wrote *Botany for Beginners* and *Familiar Lectures on Botany*, the two primary sources used in this lesson. These texts were intended to have practical applications, including in the domestic sphere—for example, learning the medicinal properties of plants to improve care for members of the household.

As a part of botanical study, women often compiled *herbaria*, books of dried and labeled plant specimens. Women would sometimes write poems or copy sentimental passages from their favorite books as a way of demonstrating their knowledge and beautifying the book. The famous poet Emily Dickinson kept a herbarium as a young girl while attending Amherst Academy in the 1840s. Dickinson would have learned botany using Phelps's *Familiar Lectures on Botany*, which was assigned to pupils during that time. Harvard recently digitized Dickinson's herbarium; it can be found online through Houghton Library, http://library.harvard.edu/hou.

This exercise exposes students to some of the texts girls were taught from at 19th-century academies. Using historical texts to teach science and literacy allows students to compare and contrast what they learn in their own science and English classes with what was taught almost 200 years ago. This method also includes a hands-on approach to looking at history, science, and language arts, as students will collaboratively create a herbarium, replicate a lesson, and read poetry from 19th-century sources. By recognizing the similarities and differences between science education then and now, students will develop a deeper understanding of the subject matter and connect their learning to the broader context of history.

The primary sources explain to students how to create a herbarium, as well as how to identify the different parts of a flower in 19th-century terms. In this lesson, students will create a herbarium and a poem similar to those created by young women in the 19th century. For this lesson, students will need scissors, a piece of paper, and dried plants.

Essential Questions

- Why is time and space important to the study of history?
- How can the story of another American, past or present, influence your life?

Big Ideas

- US History
- Historical Context

Concepts

- Textual evidence, material artifacts, the built environment, and historic sites are central to understanding US history.
- Learning about the past and its different contexts—shaped by social, cultural, and political influences—prepares one for participation as active, critical citizens in a democratic society.

Competencies

Students will be able to:

- Analyze a primary source for accuracy and bias and connect it to a time and place in United States history.
- Analyze the interaction of cultural, economic, geographic, political, and social relations for a specific time.

Objectives

Students will be able to:

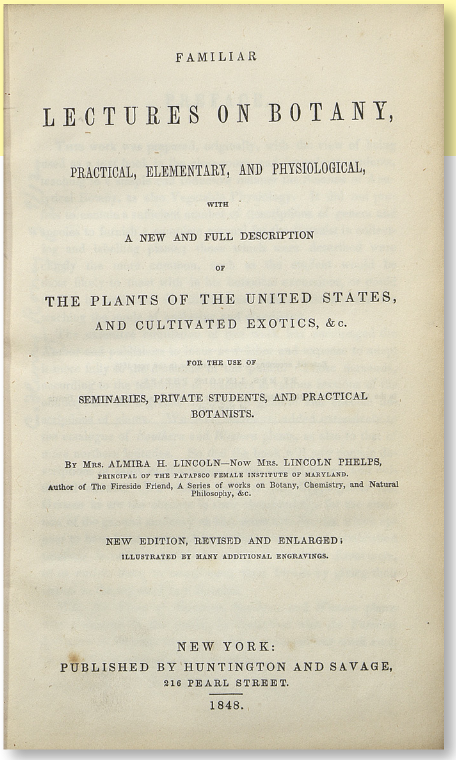
- Understand the context of female education and why it was important to the history of the United States.
- Compare and contrast primary sources to modern studies in plant classification.
- Analyze point of view, symbolism, and rhythmic patterns in 19th-century poetry.

Primary Sources

- Excerpts, Almira Lincoln Phelps, *Familiar Lectures on Botany*, new ed. (New York, 1848)
- Excerpts, Almira Lincoln Phelps, *Botany for Beginners*, 3rd ed. (Hartford, CT, 1835)

Instructional Procedure

- Begin by following the instructions from the "preparing a herbarium" primary source from *Familiar Lectures on Botany*. The plants will need a couple days to dry, so plan accordingly to dry the plants prior to introducing the


FAMILIAR

LECTURES ON BOTANY,

PRACTICAL, ELEMENTARY, AND PHYSIOLOGICAL,

WITH

A NEW AND FULL DESCRIPTION

OF

THE PLANTS OF THE UNITED STATES,

AND CULTIVATED EXOTICS, &c.

FOR THE USE OF

SEMINARIES, PRIVATE STUDENTS, AND PRACTICAL BOTANISTS.

BY MRS. ALMIRA H. LINCOLN—NOW MRS. LINCOLN PHELPS,

PRINCIPAL OF THE PATAPSCO FEMALE INSTITUTE OF MARYLAND.

Author of The Fireside Friend, A Series of works on Botany, Chemistry, and Natural Philosophy, &c.

NEW EDITION, REVISED AND ENLARGED;

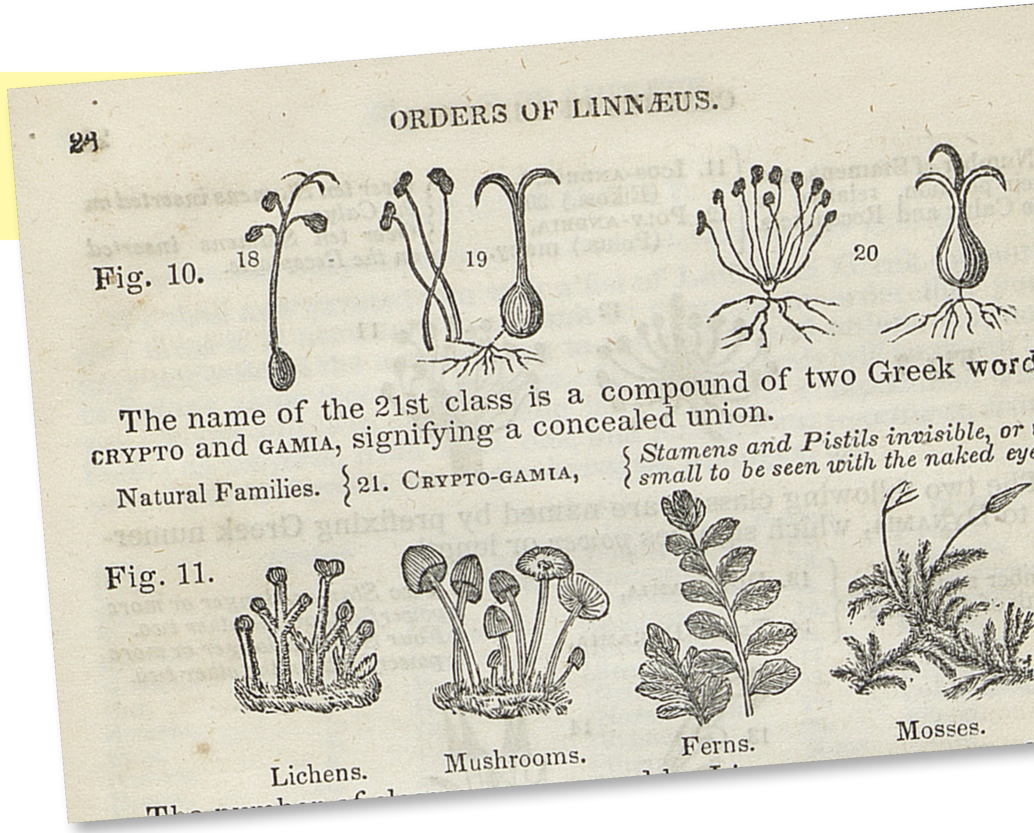
ILLUSTRATED BY MANY ADDITIONAL ENGRAVINGS.

NEW YORK:

PUBLISHED BY HUNTINGTON AND SAVAGE,

216 PEARL STREET.

1848.



Title page and botanical illustrations from Almira Lincoln Phelps, *Familiar Lectures on Botany, Practical, Elementary, and Physiological . . .* (New York, 1848).

rest of the lesson. Use newspaper and textbooks to press the flowers until dry.

- Provide students with a brief background on female education and the Troy Female Seminary, now called the Emma Willard School, which opened its doors in 1821. Information for teachers can be found through *Encyclopedia Britannica* at http://www.britannica.com/EBchecked/topic/606900/Troy-Female-Seminary or by using the book *Learning to Stand and Speak: Women, Education, and Public Life in America's Republic* (2006), by Mary Kelley. This institute was one of the first to provide females with an education comparable to that provided by men's academies. Many of Almira Phelps's famous works were written in response to her students; it is at Troy that she first tested her work.
- Explain to students that women used botany as a useful tool, and knowledge of plants was important for a variety of chores ranging from administering medicine to cooking. Ask the students to think of ways they might use plants or flowers now in their households.
- Next, review the parts of a flower with students by using *Botany for Beginners* by Almira Phelps. Ask students to observe the primary source. What do they notice that is the same and different from modern lessons on plants? Place a flower of your choice on the board. Have each student draw the flower on a piece of paper, then label it using Phelps's classification terms. Provide students with a vocabulary worksheet to reference. Make sure to review words such as root, stamen, style, corolla, petal, filament, filum, anther, pistil, receptacle, calyx, and germ.
- Give each student a sheet of paper on which to place the dried plant and, again, follow the herbarium instructions to properly cut the paper to secure it. Allow each student to be responsible for his or her own page. Students should identify the name of the flower/plant at the top of the page (teachers can help by modeling an example). Once each page is complete, punch holes in the left side and tie the pages together to create a class book.
- Lastly, students should create poetry to add to their pages like many women in the 19th century did. As a supplement to the lesson, show students the poems that went along with Phelps's texts. These can be found as a PDF with the women and science lesson plan at https://www.hsp.org/education/unit-plans/women-and-science. Begin with the poem about water lilies. Ask students to read the poem, then decide the rhythmic pattern of the poem and write down each of the rhyming words. For example the water lilies poem is ABAB.
    - Repeat the following instructions with the other poems. Students may continue with the poetry in groups or individually, based on class ability.
    - If possible, have students identify any figures of speech they can find in the poems. Discuss the descriptive sentences and the language used to compare the flowers. ■

Alicia Parks is the Wells Fargo Education Manager at the Historical Society of Pennsylvania.

PA Standards

Grade Level: Middle Grades
Duration: 60 minutes
Standards: 8.3.6–8.A and 8.3.6–8.B

The material referenced in this lesson and additional resources are available on our website at http://hsp.org/education/unit-plans/women-and-science.

TEACHERS' TURN

Science in the History Classroom

BY EDWARD W. JOHNSON

(Detail) Drawing of Cordylophora, a relative of the jellyfish, by Graceanna Lewis. Delaware County Institute of Science, Media, PA.

Several years ago, a science department colleague and I dreamed of developing a course on the history of technology. It would be a history course with a lab. A classroom lesson on the development of the magnetic telegraph, for example, would be accompanied by a lab in which students would work with a telegraph key. (We even secured two keys used by the Reading Railroad Company to train operators.) Students could use the course toward either a history or a science requirement. Our dream never came to fruition. For us, as for most teachers, the challenge remained to incorporate these topics into a standard history curriculum.

Too often we silo the various disciplines. History is taught during one school period, science in another, math and language arts in yet others. At the same time—and in part as a result of this siloing—we sometime obscure the relationship between history and current events. Yet students need to understand that science has a history, that it is not something apart, and also that our present and our future are shaped by our past. The articles in this issue of *Pennsylvania Legacies* can be used as the basis of a lesson or as supplementary material to address the history of science and technology and provide opportunities to discuss 21st-century issues. Teachers can use each of these articles in an interdisciplinary approach to teaching United States history.

Women and Science

Throughout the 19th century, middle-class women's lives revolved around the home—maintaining the house, preparing meals, and tending to the needs (physical, moral, and educational) of the children. The male world of business, industry, higher education, the professions, and politics was largely closed to them. Jessica C. Linker's article, however, explores the accomplishments of Pennsylvania women who belie this restricted view of women's sphere in early America. Linker argues that in the early 19th century women were able to participate in scientific practice, albeit in gendered ways, to a degree not possible later in the century as science became professionalized. Her article could be assigned to students studying 19th-century society and culture or women's history. Students could then be asked to research other women who made significant contributions in other fields dominated by men.

Discussion questions could include:

- What restrictions confronted women who wished to study or practice science?
- Despite the limits placed on women, what opportunities did they enjoy in scientific education and research?
- Did women face similar opportunities and restrictions in other fields?
- How did most women react to gendered definitions of appropriate activities? Did they accept their places in society and the home? Did they work for change?

Linker's article can be used to prompt a discussion of the role of women in society today. Do they have equal access to occupations in the sciences and technology? To what extent is Silicon Valley dominated by men? Despite the advances made by women, are they still expected to perform the majority of the household tasks?

Public Science

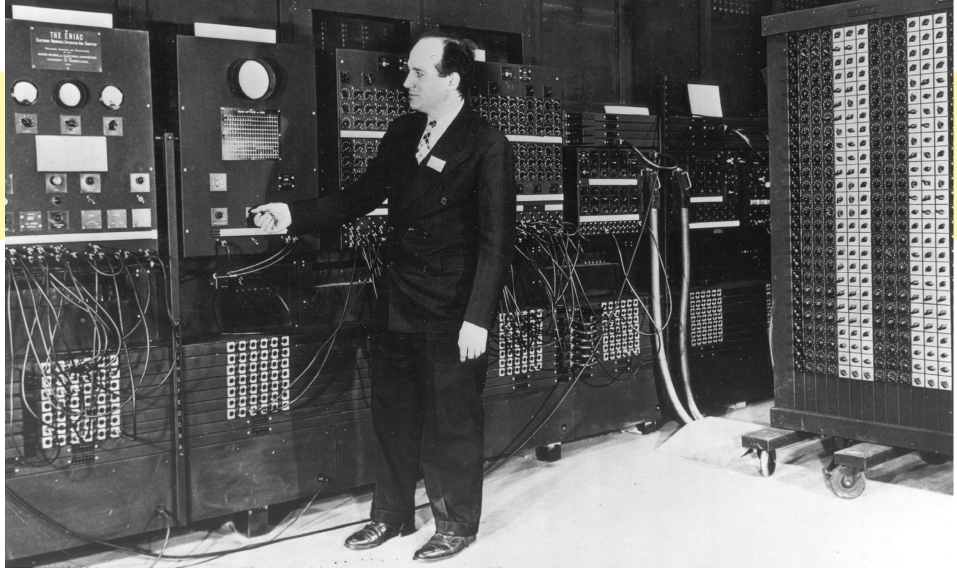
In his article about the Wagner Free Institute of Science of Philadelphia, Matthew A. White examines one individual's attempt to provide the general public with opportunities for self-improvement. William Wagner founded his museum at a time when new species of plants and animals as well as the fossils of dinosaurs were being discovered. It was also a time when higher education was still largely limited to elite white men. All over the country, museums and educational institutions were being established to meet the demand for continuing adult education. Examples include the American Museum of Natural History in New York City, the Smithsonian Institution, and the Chautauqua Institute in western New York. Students could be assigned to read this article for a unit on antebellum society and culture or a unit on the cultural changes that occurred during the great urbanization of the late 19th century.

Discussion questions might include:

- What conditions prompted individuals such as William Wagner to establish institutions for the education of the general public?
- Who was better suited to this work—the increasingly professional men running many institutions, or amateurs like William Wagner?

- Why was Wagner's insistence that admission to his collection and lectures be free of charge and open to all (including women and children) considered to be so revolutionary?

This article could also be a springboard to a discussion of such current issues as the appropriate role of government or corporate funding of America's science museums or the influence of such funding on the content of exhibits and lectures.



J. Presper Eckert at the console of ENIAC, 1946. From the Collections of the University of Pennsylvania Archives.

Science and Industry

Most students are probably familiar with such Westinghouse appliances as ranges and refrigerators. Some might have learned about the "battle of the currents" between the advocates of alternating current and those who favored direct current. Steven W. Usselman's article looks at an earlier period in George Westinghouse's career, examining his development of the air brake for railroads and his technological and legal battle to retain a monopoly in air brake production. This article could be assigned to students studying industrialization after the Civil War. The article is particularly useful for exploring the importance of intellectual property rights for innovation as well as the rise of corporations and corporate power in Gilded Age America. Students should read the copyright clause of the US Constitution (article 1, section 8, clause 8) and the 19th-century patent acts (both at http://ipmall.info/hosted_resources/lipa/lipa_patent_index.asp). They should also read Westinghouse's patent for the air brake (patent no. US88929; http://www.freepatentsonline.com/88929.pdf). Students could also research other technological advances of the late 19th century. An interesting resource is *Modern Wonder Workers: A Popular History of American Invention* (https://archive.org/details/modernwonderwork00kaemrich).

Possible discussion questions include:

- Why was invention of the air brake so important in the development of the railroad and America in the late 19th century?
- How long should the US Patent Office grant exclusive rights to an invention?
- According to Usselman, in what ways was the work of Westinghouse both similar to and different from the work of today's technology entrepreneurs?

This article could also contribute to a discussion about the development of large corporations and the concentration of economic power, which led to such legislation as the Sherman Anti-Trust Act. Students could be asked to debate whether strong intellectual property rights contribute to or hinder innovation and economic development. Teachers also might like to have students view the "actuality films" Westinghouse commissioned in 1904 (see website reviews, p. 39).

The Birth of the Digital Age

All wars bring new advances in technology to military action. Conversely, war has also spurred technological innovation. World War II was no exception. Paul Ceruzzi's article about John Mauchly and J. Presper Eckert's efforts to develop the first general purpose electronic computer clearly explains the military needs for which ENIAC was designed. It also highlights the importance of government funding and university sponsorship of scientific research in the 20th century. This article could be used in a unit on World War II to illustrate the increased role of government as well as the role women played during the war. Students can learn more about these women programmers at http://eniacprogrammers.org/ and http://www.nwmissouri.edu/onlinemuseum/computing/index.htm. Students would also benefit from discussing the article as it relates to the postwar boom in science, technology, and industry that introduced Americans to the Salk vaccine, television, the jet airplane, synthetics, and the space program.

Questions for discussion might include:

- How did World War II change the role of women in American society?
- Should scientific research be funded with public (government) or private (individual or corporate) money?
- What is the proper role of the scientist and of scientific research, the advancement of knowledge (science for science's sake) or the development of useful products (science for the sake of consumer products)?

For students who cannot remember a time when computers were not ubiquitous and apps for every imaginable problem seem to be available, this article can provide some useful perspective on how much digital technology has changed our world. Students might enjoy trying to program the ENIAC, which they can do at http://zuse-z1.zib.de/simulations/eniac/simulation.html.

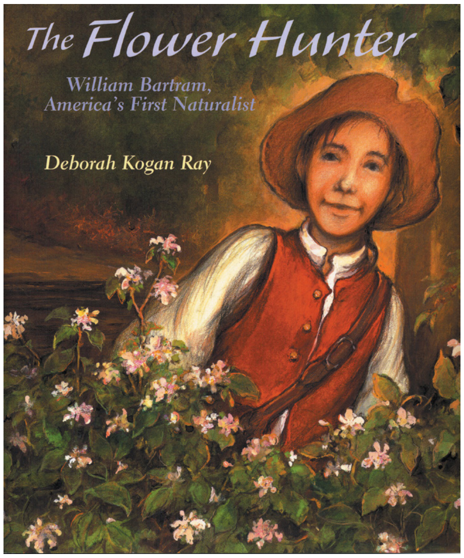
Collectively, these articles demonstrate that science both shapes and is shaped by it historical context. ■

Ed Johnson taught high school American history, among other subjects, for 35 years in the Pennridge School District.

Legacies for Kids

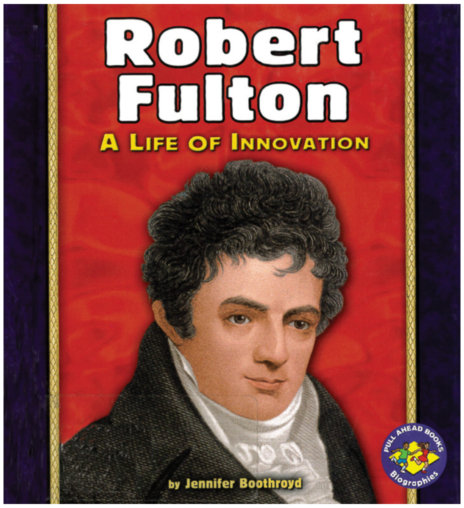
Book Reviews

BY SARAH STIPPICH



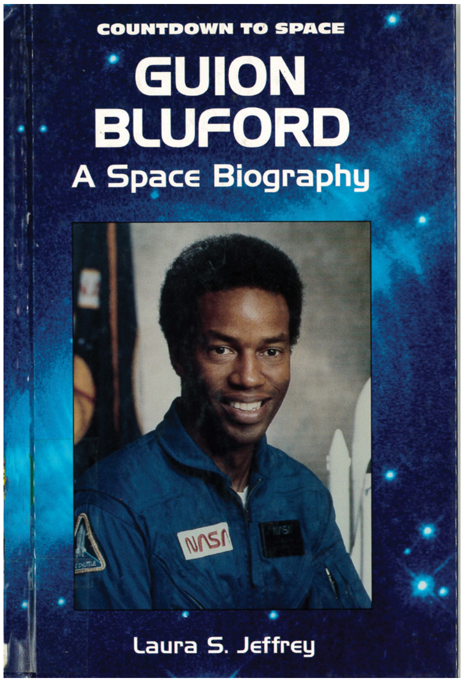
The Flower Hunter: William Bartram, America's First Naturalist
By Deborah Kogan Ray
New York: Farrar, Straus and Giroux, 2004, 32 pp. Ages 5–10.

Designed as a journal with drawings and personal insights, Ray's book chronicles the life of young "Billy" Bartram. Apprenticed by his father, a farmer and experimental botanist, he explores his Philadelphia-area home, learns plant identification, has an electricity lesson with Ben Franklin, and, as a young man, hones his skill painting wildlife and plants while traveling through a new American nation. His journeys take him throughout Florida, through lands of the Choctaw, Cherokee, and Creek Nations, and to the Mississippi River. Illustrations rich with browns, oranges, and greens decorate each page and hint at the majesty and mystery of the natural world William loved. An afterword provides more information, a bibliography, and drawings of some of Bartram's discoveries.



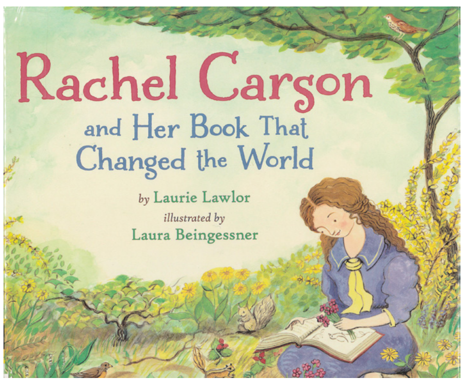
Robert Fulton: A Life of Innovation
By Jennifer Boothroyd
Minneapolis: Lerner Publications Company, 2007, 32 pp. Ages 6–8.

Robert Fulton, born in Little Britain, Pennsylvania (near Lancaster), in 1765, developed new ways to travel. He designed canals, a steamboat, and an early version of a submarine. One of the Pull Ahead series biographies for the youngest readers, *Robert Fulton: A Life of Innovation* features short, easy sentences, lots of pictures, and a glossary for unfamiliar words. Boothroyd's book could be a good introduction to a Pennsylvania-born inventor, or to the idea of innovation itself.



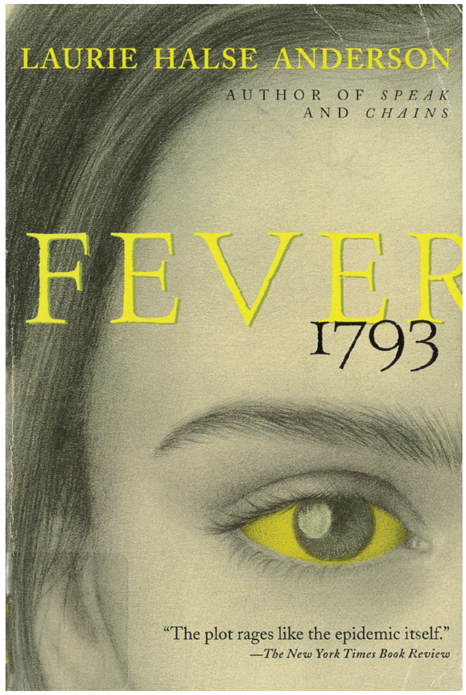
Guion Bluford: A Space Biography
By Laura S. Jeffrey
Springfield, NJ: Enslow Publishers, 1998, 48 pp. Ages 8–12.

This biography chronicles astronaut Guion Bluford's life as the first African American to go on a space mission, beginning with his childhood in Philadelphia. A shy, soft-spoken boy, "Guy" showed an early interest in space exploration during the beginning of the NASA program. He was encouraged by his parents and was a determined, hard-working student who went on to become part of one of the largest and most diverse classes of astronauts during the early 1980s. This book captures his love for the job and his family, and, like Bluford, focuses mostly on his work rather than the fact that he was a "first." Jeffrey's book could use an update, due to information about NASA and photographs that date from the 1980s, but this is a good introduction to an inspiring, important figure.



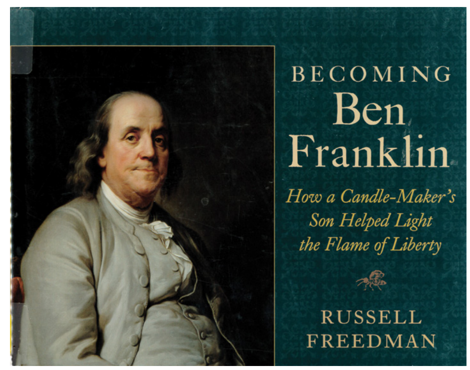
Rachel Carson and Her Book That Changed the World
By Laurie Lawlor
Illustrated by Laura Beingessner
New York: Holiday House, 2012, 32 pp. Ages 5–8.

Discovery, curiosity, and love of nature are common childhood traits, and this picture-book biography about Rachel Carson depicts a life that children can identify with. As a precocious girl growing up on the banks of the Allegheny River, Carson developed an early love of the natural world. Her studies took her to Pittsburgh, but she kept tabs on her hometown of Springdale and the way local industry polluted her beloved countryside. Her later life is also chronicled here—her in-depth study of marine life, her writing about the myriad of life forms under the ocean's waves, and her groundbreaking, brave publication about the effects of chemical pesticides on nature and humankind. Warm illustrations, populated with birds and other wildlife, provide backgrounds to the simple text. An epilogue further explains the repercussions of her book *Silent Spring* for teachers and parents.



Fever 1973
By Laurie Halse Anderson
New York: Simon & Schuster, 2002, 251 pp. Ages 12 and up.

Fourteen-year-old Mattie would rather sleep in than help her mother run their coffee shop, but when yellow fever hits Philadelphia she is forced to grow up quickly. She sees her friends and neighbors (and finally her mother) fall ill and is sent to the farmland outside Philadelphia, only to come down with the illness herself. After her recovery, she returns to the city and joins efforts by the African American citizens to nurse and help the sick. Anderson portrays a realistic teenage girl's thoughts and motivations, including Mattie's blossoming crush on an artist's apprentice. Further notes are appended for more in-depth information.



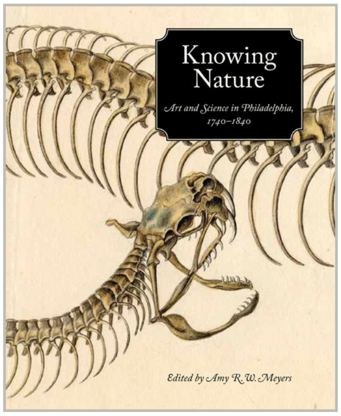
Becoming Ben Franklin: How a Candle-Maker's Son Helped Light the Flame of Liberty
By Russell Freedman
New York: Holiday House, 2013, 86 pp. Ages 10 and up.

Freedman has condensed the story of Benjamin Franklin's life to chapter-length intervals digestible to younger readers in an entertaining, engaging way. Starting with his arrival from Boston as a 17-year-old runaway, *Becoming Ben Franklin* gives insight into an American legend. After establishing his career as a printer, Franklin rose to become a member of Philadelphia's ruling elite, even before his experiments in electricity contributed to his becoming the world's most famous American. Also covered are his representing of Pennsylvania at the British Parliament and his subsequent denouncement, his role in the battle for independence, and his later life in France. Most pages are broken up by photographs and archival images, and a timeline and thorough bibliography are appended.

Sarah Stippich is a children's librarian at the Free Library of Philadelphia.

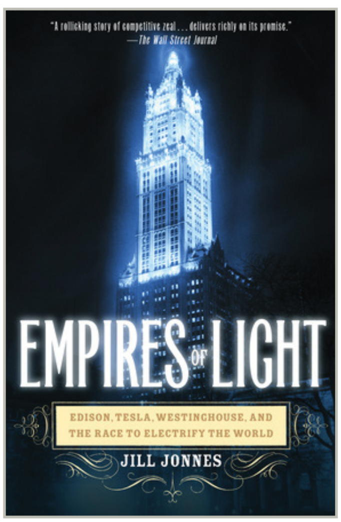
Book Reviews

BY RACHEL MOLOSHOK



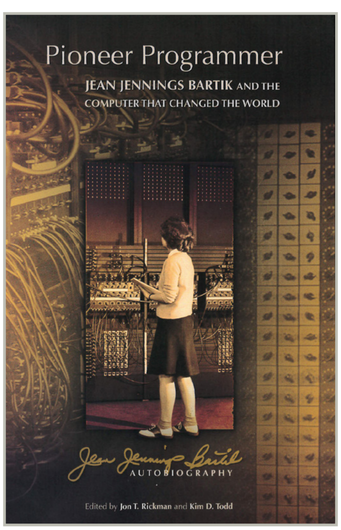
Knowing Nature: Art and Science in Philadelphia, 1740–1840
Edited by Amy R. W. Meyers
New Haven: Yale University Press, 2011

Knowing Nature is a large and gorgeous book, filled throughout with rich, full-color reproductions of early American artwork. Yet this volume contains too many scholarly insights to be considered a mere coffee-table book. The impressive visuals are used to illustrate the arguments made in 14 chapters, by various authors, about the relationship between art and science in colonial and early national Philadelphia, anchored by an editorial introduction that points out that our tendency to imagine a "hierarchy" of knowledge, with scientific insights and observations at the top, filtered down through fine and decorative arts and diffused through popular and material culture, may have it backward: "indeed, the many ways in which the process of coming to know nature was essentially reversed—in which artistic and artisanal culture informed scientific interpretations of the natural world—might be considered a central theme of this book" (4). The book also features notes and an appendix of the plants and animals featured in this work.



Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World
By Jill Jonnes
New York: Random House, 2003

This retelling of one of technology's greatest rivalries brings us into the minds and workshops of Thomas Edison, Nikola Tesla, and George Westinghouse, "three titans of America's Gilded Age" (335). The War of the Electric Currents was "one of the most unusual and vicious battles in American corporate history . . . a modern industrial epic where American business titans battled to dominate and control a world-changing technology, to create whole new Empires of Light" (xiv). These battles, which pitted Tesla and Westinghouse's alternating current (AC) against Edison's direct current (DC), were waged from Wall Street to the World's Fair, from Niagara Falls to the execution chamber. The macabre details of the Edison camp's attempts to convince the American public of the lethality of AC electricity—in which animals and, eventually, humans, were tortured and killed via electric voltage—are not for the faint of heart (or stomach). Although the War of the Currents has permeated the popular imagination, it is primarily framed as a rivalry between the idealistic Tesla and the unscrupulous Edison. Jonnes's book, however, concludes that it was George Westinghouse alone "among the Promethean three [who] completely mastered the new industrial order of gigantic capital, swift and treacherous change, and colossal corporate enterprise. Ever the audacious innovator and empire builder, George Westinghouse continued to make AC electricity so cheap, abundant, and versatile that it could power anything" (335).

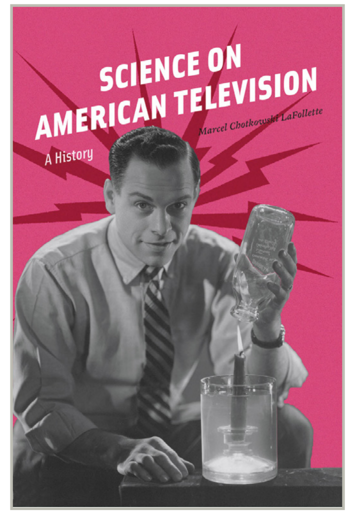


Pioneer Programmer: Jean Jennings Bartik and the Computer That Changed the World
By Jean Jennings Bartik; edited by Jon T. Rickman and Kim D. Todd
Kirksville, MO: Truman State University Press, 2013

When 21-year-old Betty Jean Jennings answered an ad looking for female math majors to work as "computers" of shell trajectories for the Aberdeen Proving Ground during World War II, she entered into a lineage stretching back to Ada Lovelace's 19th-century work on the programming of an "analytical engine." Jennings and five other women would become the first computer programmers in the world as they worked to program the Electronic Numerical Integrator and Computer (ENIAC); like Lovelace, however, they would not receive their due recognition for many years. Jennings Bartik describes how, after four months of work to compute a shell trajectory program for the ENIAC, she and her coworker Betty Snyder were given 12 days to program and debug the ENIAC for a fateful demonstration, on which rode the fulfillment of the University of Pennsylvania's contract with the US Army. After the demonstration, however, the male engineers of ENIAC were celebrated while the female programmers were ignored by the press and their own colleagues. As she recalls, "On probably no other day of my life have I experienced such thrilling highs and depressing lows. . . . It felt as if history had been made that day—and then it had run over us and left us flat in our tracks" (99). She would continue to encounter the frustrations of the "glass ceiling" throughout her illustrious computing career, which included programming work on the BINAC, the first hardware-based, stored-program computer, and the UNIVAC, the first successful commercial computing system. This autobiography, which provides firsthand insight into how early computers worked and the day-to-day life of the people who created them, also brings the too-often overlooked stories of women and science and technology to the forefront.

Science on American Television: A History
By Marcel Chotkowski LaFollette
Chicago: University of Chicago Press, 2013

This cultural history of science on American television from the 1940s through the 1990s explores the possibilities that arose with television broadcasting technology and its eventual disappointments. At the dawn of the "Television Era," the new technology seemed poised to allow scientists to share their knowledge with as wide a public as possible and for the American people to participate in great scientific and technological ventures. And yet, "within a decade, television's science had become mediated, transformed into entertainment at a distance, made into a spectacle presented by surrogates and celebrities" (219). Scientists as well as television producers were responsible for this collective failure. Along the way, however, dedicated science "popularizers" used television's possibilities to their fullest potential, "hosting, writing, and producing creative programs that were outstanding examples of how to bring technical content into the studio and make it sing" (6). One of the first among these popularizers was Roy K. Marshall, director of the Fels Planetarium of Philadelphia's Franklin Institute, who moved from hosting telecasts from the museum to premiering NBC's science series *The Nature of Things* in 1948.



LEG@CIES

INTERESTING PLACES TO EXPLORE ON THE WEB

Museum of the History of Science: Online Exhibits

http://www.mhs.ox.ac.uk/exhibits/

The website of the Museum of the History of Science, based in Oxford (UK), features approximately 50 online exhibits on a wide and interesting spectrum of topics, from a video showing how an astrolabe can be used to tell time to an illustrations-based exhibit on physical science education in the 18th century, to exhibits on wireless technology, Victorian optical toys, drug trades, photography, and even cultural genres such as science fiction and steampunk.

Inside an American Factory: Films of the Westinghouse Works, 1904

http://www.loc.gov/collections/films-of-westinghouse-works-1904/about-this-collection/

The Library of Congress's Westinghouse Works Collection features 21 short, silent films from 1904 that take viewers inside Westinghouse's various Pittsburgh-area companies, showing machines, women, and men hard at work. The collection is supplemented by teaching resources, essays, and a timeline.

IEEE Global History Network

http://ghn.ieee.org/wiki/index.php/Special:Home

The IEEE (Institute of Electrical and Electronics Engineers) global history network is a wiki-based platform (registered users are encouraged to contribute) hosting an ever-growing body of knowledge on scientific and technological history. The site features a global "Innovation Map" with pinpoints charting sites of milestones in electrical and engineering history and an interactive timeline, spanning 1575–present, highlighting significant events in bioengineering; communications; computer science; electromagnetism, radio, and radar; lasers and lighting; machinery; power engineering; and transportation. The site also hosts oral history collections and written "First Hand Histories" from contributors who share their experiences in electrical/computer/engineering sciences; searchable archives; and an education portal featuring lesson plans on the history of technology.

Chemical Heritage Foundation Online Resources

http://www.chemheritage.org/discover/online-resources/index.aspx

The CHF's website boasts useful education materials for those who want to learn more about chemistry and its history. Users will find many biographies of significant scientists past and present, including several series of video biographies and oral histories. Women in chemistry–including many women of color–are well represented. There are also links to lesson plans and chemistry classroom activities, including "Priestley and Soda Pop" and "Build Your Own Molecule." Interactive online exhibits, podcasts, and a "Thanks to Chemistry" portal that explores principles of chemistry through day-to-day objects and activities provide engaging content for learners of all ages and experience levels.

RM

FOOD FOR THOUGHT

On the Cutting Edge of Yesterday

BY AMY E. SLATON

When people sitting next to me on an airplane or standing behind me in a grocery line ask me what I do for a living, I tell them that I teach history. Two more questions almost invariably follow: "What kind of history?" and then, "Really? Science has a history?" Often, a half second later, a look of recognition comes over their faces: "Of course! Galileo! Einstein! Penicillin! That's sounds like a fascinating subject!"

I couldn't agree more! I love these chance encounters and almost inevitably use the opportunity to tell these unwitting strangers a great deal more than they wanted to know about my field. But I share this experience here to point out that for most of us in the United States, the idea that science *has* a past, a deep and complicated path it has traveled to its current role in our lives, makes perfect sense when we stop to think about it—and yet, we almost never stop to think about it. It is a notion that remains remote from our day-to-day engagements, whether getting a flu shot or pouring a glass of pasteurized milk, filling our cars with gas or studying for a biology exam. Even those employed in science and technology occupations are given little opportunity to think about the histories that have formed their disciplines and life's work. In a sense, our culture has systematically denied the shaping of science over time, and I'd like to argue here for a much greater role for this subject in our classrooms and communities.

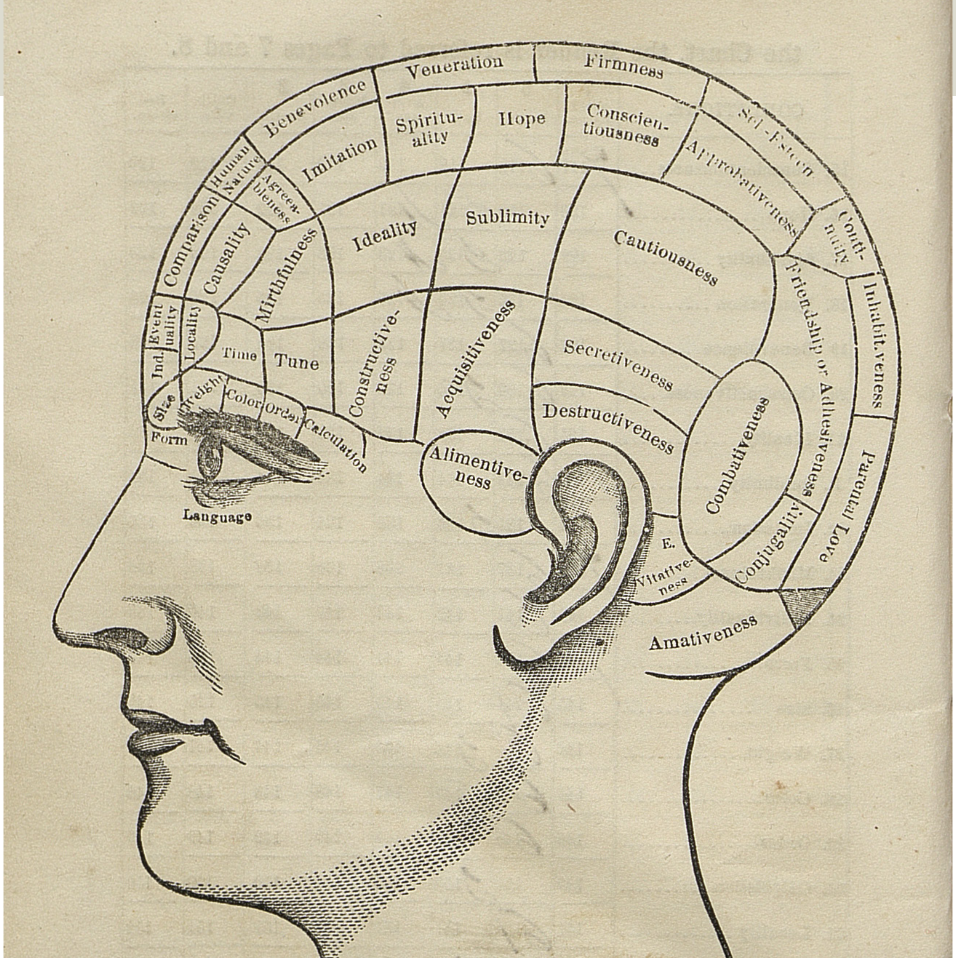
Let's first take a moment to appreciate the cultural paradox at work here. While we are surrounded by the products of science, reflection on those circumstances is almost entirely absent from our lives. When we visit doctors, ride the subway, or drink clean water from our kitchen taps, the long historical development of knowledge about nature that has supported these experiences is not on our minds. We have national holidays in America for presidents' birthdays or armistices that occurred centuries ago; we do not, however, celebrate together the anniversary of Jonas Salk's discovery of a polio vaccine, let alone the first affordable test for clean municipal drinking water or the perfection of the chemistry behind unleaded gas. Our geopolitical interests are similarly firewalled from this kind of curiosity: our military and energy security worry us, but the importance of exploring *how* we came to be dependent on fossil fuels (many produced in other countries) or cyber-networks (now proving vulnerable to terrorist incursions) feels extraneous to our contemporary challenges.

This is not to say that we never think about the history of science. Virtually all science museums include some material on scientific superstars of the past, such as Benjamin Franklin and Charles Darwin. Once in a while I will even come across a statue in a public park celebrating a scientist or engineer. But these celebrations of science almost always focus on accomplished individuals, offering us static portraits rather than dynamic panoramas of scientific change makers living in real times and places. It takes nothing away from our respect and awe for individual scientific thinkers when we seek to place them in historical context. On the contrary—when we do so, we find a much richer set of human activities underway and stand to learn much more than had we stopped at the laudatory or sympathetic impulse.

Right now we simply don't build scientific topics into our history curricula the way we might typically weave in politics, social movements, or arts and letters; nor does discussion of historical events and trends enter into STEM (science, technology, engineering, and mathematics) classrooms. True, there are always a few sentences in science or engineering textbook introductions on the overall value of a discipline, such as, "Biology has been a long-standing pillar of environmental science." But to me, this kind of bland generalization shuts down students' curiosity about their future disciplines. Another recurrent element of these textbooks? Sidebars in each chapter on (once again) great practitioners of past eras: "The first material scientist to use a strain gauge was. . . ." If ever there was instructional content better calculated to make a student's eyes glaze over, I can't think of it.

The scholarly disciplines of the history of science, of technology, and of medicine are thriving, and all have venerable heritages in many parts of the world. In the United States, some universities offer history of science degrees, and a few even offer undergraduate minors (a great option for those headed to STEM careers, incidentally). But this subject matter rarely finds its way onto undergraduate transcripts, let alone into high school programming. And only a tiny number of high school or college STEM instructors that I know of have sought thoroughly to integrate societal factors, past or present, directly into their teaching. Several who have done so have then faced questions from peers about the appropriateness of using student time in this way, as critical historical thought is seen not only to distract from but to dilute the "essential" scientific content of our curricula.

It becomes clear that as a culture we construct many impediments to thinking about the ways in which our food and farms, our cities, our national infrastructures, and our geopolitical stature—even our bodies—have been shaped by the work and patronage of science over time. But it really takes very little exploration to reveal that shaping. For example, if our federal government had not established an unwavering pattern in the mid-19th century of supporting university research on agricultural sciences, we would not have today the sturdy, predictable crops that result in the vast displays of safe, affordable produce and meat filling our grocery shelves. Similar institutional relationships have configured our thriving pharmaceutical and electronics sectors and helped produce our skyscrapers, highways, and digital networks. Once we detect this historical pattern, we might recognize as well the immense consequences of our present-day federal science funding policies. Imagine a young person growing up grasping that voting can have that kind of significance!



Frontispiece of O. S. Fowler and L. N. Fowler, *New Illustrated Self-Instructor in Phrenology and Physiology . . .* (New York, 1859).

And then there are the less uplifting past moments of American science: the development of pesticides that have caused profound harm to farmers, farm workers, and the ecosystem, or of drugs that have harmed consumers; past psychiatric science that has pathologized homosexuality; the planet-punishing impacts of metallurgical and chemical sciences as deployed by industry or defense sectors over the last 150 years. There are also countless examples of discrimination in the histories of US STEM education and employment, centered on racial, gender, or ethnic identity as well as age, LGBTQ identities, and differing types of intellectual and physical ability. These inequities exert tremendous constraints on who and what shall constitute the American scientific establishment, and yet it is a common refrain today that we are a meritocratic nation—and that science is an egalitarian field—offering equal opportunities to all. Surely a healthy democracy would not let such feel-good falsehoods go by unchallenged.

This is not cheerful stuff, I know. It doesn't fit in any obvious way with the current exhortations to get young people "excited about science and innovation" in order to lure them into these disciplines. And sometimes my students will just come right out and say that I am being a "downer," stressing the negative impacts of science or technology on society instead of the positive, indicting a universe of knowledge that has helped people in uncountable numbers. At those moments I go back and clarify that such wholesale condemnation of science is just what I want to avoid. Relying on that positive/negative binary to investigate the history of science is not only dull as dishwater, it is largely pointless. *Of course* "science," "engineering," and "medicine" as classes of human activity have had both helpful and harmful impacts on humanity. But coming up with a final judgment about whether one impact or the other has been greater in the aggregate gets us nowhere; at least, it gets us to no lesson about these human enterprises that we can apply going forward. Instead, we can strive to learn instead that it is context—the time, place, and political vantage point from which it is regarded—that makes any scientific effort seem beneficial or harmful.

When we teach our students, of all ages, that science, engineering, and medicine have mixed societal impacts and face multiple and changing valuations, we open a vista of political reflexivity and responsibility to them. It is not merely the ethics of the sciences behind, say, modern drug development or fracking or GMO foods that they may then explore, but also the central roles of time and place and position in determining all of our ethical judgments. As for time, we can easily demonstrate that what strikes us as a sufficiently understood bit of science one day may seem less so the next. (Phrenology, anyone? Eugenics?) Similarly, when it comes to place, the science that works well for an affluent community (say, the chemistry and engineering that drive the conversion of solid wastes to renewable energy by burning) may be detrimental to others (the poorer neighborhoods abutting that trash-burning plant). The same geographic complexity can be seen on a global scale—for example, the cutting-edge science that deploys rare-earth metals in our electronic devices exacts a huge toll on the labor forces and environmental health of the nations in which those metals are mined and old devices dumped. If scientific discoveries are celebrated in a given time and place (including our own), we need to ask if that is because they support the economic, political, or health interests of the celebrants with conveniently unseen costs to others.

Bluntly acknowledging this lived, messy, historical character of science promises excited classrooms. I have come to embrace the irony that in learning, uncertainty empowers inquiry. Conveying that science has never been a tidy, easily summarized set of events incites my students' curiosity. Some of the very best moments in my history of science courses are the ones where students get "that look" in their eyes: the grinning, sly glance as if they have just been let in on a secret, been shown the man behind the curtain. Those are the moments when I know they're seeing science not as one thing but many, as currents of complex, unpredictable social and cultural forces playing out in and revealing the roiling flow of history. ■

Amy Slaton is a professor of history at Drexel University interested in the social origins and impacts of American science and technology. Her current research focuses on issues of diversity in the nation's high-tech workforce.

Historical Society of Pennsylvania

1300 Locust Street
Philadelphia PA 19107

THE HISTORICAL SOCIETY OF PENNSYLVANIA INSPIRES PEOPLE TO CREATE A BETTER FUTURE THROUGH HISTORICAL UNDERSTANDING

ADDRESS SERVICE REQUESTED

"Arctomys Monax: Maryland, Marmot, Woodchuck, Groundhog," lithograph, published in John James Audubon and Rev. John Bachman, *Viviparous Quadrupeds of North America* (New York, 1846–54).