

## In the Name of Science: Suffering, Sacrifice, and the Formation of American Roentgenology

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ACCOUNTS OF EARLY AMERICAN EXPERIMENTATION WITH X-RAYS TEND TO LINGER over the ghastly wounds of scientific practice: ruptured blisters, cancerous limbs, and pus-ridden grafts.<sup>1</sup> Curiously, these descriptions of decaying flesh are joined by vigorous assertions of practitioners' unflagging devotion to science; scrupulous litanies of dismemberment and death glorify, rather than trouble, the quest for new knowledge. In place of cool-headed assessments of radiation protection or surgical anesthetics, we find instead stress on experimenters' willing—even fervent—embrace of further pain. In 1926, for instance, the *New York Times* reported the seventy-second operation on Johns Hopkins University roentgenologist Frederick H. Baetjer, a physician whose years of research with x-radiation had already cost him eight fingers and one eye. "Despite the suffering he has undergone in the interest of science," the paper announced, Baetjer planned to "continue his work as long as he lives, fingers or no fingers."<sup>2</sup> Journalists were not alone in lauding investigators' eager return to the source of their wounds. Describing a young physician who continued his research with the ray even as chunks of his fingers, hands, and chest were disintegrating from cancer, a fellow x-ray investigator averred that the physician's "enthusiasm for his work never faded up to the moment of his end."<sup>3</sup> Even non-fatal research offered a chance to fortify the ethos of bodily punishment permeating early x-ray practice. The eminent x-ray experimenter and General Electric engineer William D. Coolidge, for example, was lampooned at company dinner by "N. Thusiasm," a figure who labored

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away at new experimental problems “while everyone else slept.”<sup>4</sup> What are we to make of these varied accounts of early twentieth-century scientific research, specifically their common focus on investigators’ ardent suffering? Of what significance is this striking recurrence of “enthusiasm” (*en theos*)—with its connotations of spiritual possession, of “god within”?<sup>5</sup>

To be sure, the valorization of voluntary suffering was hardly unique to early roentgenologists. In the decades immediately preceding the Great War, the moral authority of pain was marshaled equally by poets and pastors, generals and presidents, managers and laborers. Several recent histories have artfully amplified this trend, suggesting that renewed emphasis on stringent bodily disciplines—from fasting to self-flagellation—helped assuage *fin-de-siècle* anxieties about feminization, racial degeneration, and other perceived threats to bourgeois American manhood.<sup>6</sup> Less well understood, however, are the relations between such religious, bodily disciplines and the seemingly secular, cerebral realm of late nineteenth-century natural science. Indeed, exaggerated assessments of the “war” between science and religion in American history have long impaired such understandings.<sup>7</sup> Seen in this light, such a voluble preoccupation with debilitating, painful scientific investigation would seem to merit further consideration—a means by which to query received accounts of late nineteenth-century secularization.

Focusing on the work of early x-ray investigators, I here describe how voluntary self-wounding—which investigators frequently termed “sacrifice”—shaped the boundaries and character of one field of science—roentgenology—in the United States. My discussion does not address tantalizing (yet fundamentally opaque) questions of “personal motivation”—why some investigators embraced ulcerating wounds, spreading tumors, and repeated amputations while others sought available radiation protection. I focus not on the mindset of individuals who chose to suffer and die for science but rather on that “for” which they took on such pain. The essay concerns, in other words, the advent of a particular concept of enthusiastic suffering, one born in and through the allegedly godless world of late nineteenth-century physical research. In what historical conditions could roentgenologists claim to suffer and die in the name of “science”?<sup>8</sup> What effects did such sacrificial claims have on the organization and solidity of the new field of roentgenology? How, in turn, did the increasing cultural authority of science shape the limits and possibilities of voluntary suffering?

The emerging field of roentgenology, I suggest, gained definition through the spectacular deaths and mutilations of its adherents.<sup>9</sup> As a number of scholars of nationalism have noted, willingness to shed blood coalesces the fictive borders of the state, much as ritualized religious violence lends coherence and immediacy to intangible, supernatural deities. Both nations and gods acquire authority through the voluntary sacrifice of their adherents.<sup>10</sup> In a similar manner, American roentgenology incorporated around the visible injury of its subjects. While bringing new cultural authority to a fledgling profession and its enigmatic x-ray, the willing suffering of roentgenologists also served to invigorate a larger vision of the past, present, and future of science. Like “America” itself, the amorphous body of science roused the prospect of continual progress, of a beneficent and boundless unfolding. And, like America after the Civil War, the legitimacy of this imagined body—a sense of definition, autonomy, and purpose—was secured partly through destruction, through the considered squandering of life and limb. At the center of this devotional expenditure were x-ray investigators, producing the cause of roentgenology even while suffering in its name. As the wizened remains of martyrs convey the prospect of eternal life to the faithful, or the wounds of soldiers come to bear national significance, so, too, the disintegrating bodies of individual x-ray investigators were reclaimed as pieces of the ancient and immortal body of Science.

The organization of a roentgenological profession began shortly after Roentgen’s announcement of his discovery of a “new kind of light” in the closing weeks of 1895. In the first months of x-ray experimentation, investigation was unhindered by regulations on the purchase or maintenance of x-ray equipment. Anyone with means might purchase static generators, induction coils, x-ray tubes, and sundry other experimental components. Investigators, who tended to work alone or with small, local groups of other interested persons, flocked to the new technology. They carried with them an eclectic array of interests and backgrounds, including surgery, general medical practice, physics, photography, and electrical engineering. These disparate groups soon organized, taking a major step forward with the formation of the American Roentgen Ray Society in 1900. The infant specialty was pushed further down the path toward professionalization by the publication of the damning 1910 Flexner Report, which stirred

reform throughout American medical communities. World war provided additional stimulus for social and technical expansion, and membership in regional and national roentgenological societies grew accordingly.<sup>11</sup>

Throughout this period, x-ray practice was inescapably manual, as investigators gingerly shifted the glass plates on which radiographs appeared, carefully rearranged broken limbs and other objects for better observation, and passed their own hands beneath active rays when testing and modifying equipment and dosages. Today, medical and dental x-ray technicians often exit the room entirely after each adjustment of patient or apparatus prior to re-activating radiation equipment; in contrast, early twentieth-century investigators often performed each task beneath (or near) a charged x-ray tube. Furthermore, early x-ray equipment was testy and fragile, requiring lengthy, repeated exposures for therapeutic or diagnostic effect.<sup>12</sup> Fingers, hands, arms and faces—the parts of the investigator's body most involved in this meticulous manual labor—were thus particularly vulnerable to radiation damage.<sup>13</sup>

The first American known to die after prolonged exposure to the x-ray, Clarence Madison Dally (b. 1865), succumbed to cancer even as the first x-ray professional societies were being established. A glass-blower employed in Thomas Edison's New Jersey laboratory, Dally had been investigating x-rays since the news of Roentgen's discovery first hit the States in 1896, working primarily on the development of the focus-tube and improved fluorescing chemicals. Shortly after Dally began his research, he began to experience the effects of prolonged radiation exposure. By 1900, Dally lost all the hair on the front of his scalp, on his hands and fingers, and his eyebrows and eyelashes. The skin on his hands grew swollen and painful, and he continuously switched hands in order to continue his work with the ray. In 1902, after six years of constant pain, Dally underwent the first of a series of grafts designed to relieve the ulceration on his left hand. When the skin failed to graft and examinations revealed carcinoma in the remaining tissue, the hand was amputated above the wrist. The cancer continued to spread, and eventually both arms required removal. Despite the amputations, Dally died from cancer in October 1904.<sup>14</sup>

Other, even more conspicuous deaths soon followed. On August 3, 1905, Elizabeth Fleischmann-Ascheim, known at the time as "the most expert woman radiographer in the world," died from x-ray induced

cancer in San Francisco after a series of amputations.<sup>15</sup> Fleischmann-Ascheim, one of the first x-ray experts in California and one of the few women in the world known for her work with the ray, gained national renown for her radiographs of U.S. soldiers wounded in the Philippines during the Spanish-American war. On her death, major newspapers published full-page eulogies on “America’s Joan of Arc.”<sup>16</sup> Fleischmann-Ascheim’s death was followed shortly by others around the country, among them Louis Andrew Weigel of Rochester, New York (1854–1906); William Carl Egelhoff of Chicago (1872–1907); Wolfram Conrad Fuchs of Chicago (1865–1908); and Rome Vernon Wagner of Chicago (1869–1908).

By 1911, more than fifty such cases of x-ray-induced cancer had been reported. Like Dally, these roentgenologists suffered repeated amputations, excruciating pain, and shortened lives. By 1949, at least sixty-five Americans had perished as a result of their work with x-rays.<sup>17</sup> Of course, these statistics are hardly remarkable when compared with other occupational hazards of the early twentieth century (railroads, for instance, killed seventy-two thousand employees between 1890 and 1917 on the tracks alone).<sup>18</sup> Yet both contemporary commentators and later historians endowed the deaths of early x-ray investigators with significance beyond mere numbers. They became, in the period press and in the historical record, “martyrs to science.”

These martyrs were hardly the first investigators of the natural world to be memorialized in overtly religious terms. Sir David Brewster’s 1841 *The Martyrs of Science*, for instance, demonstrates an established tradition of scientific hagiography.<sup>19</sup> In the U.S., however, the ideal of sacrifice for science gained particular resonance and popularity in the last quarter of the nineteenth century, as a reified “science” acquired increasing cultural prominence. Remarkably, even as practices labeled “scientific” became more institutionally diffuse and disunified, *science* came to be represented as ever more singular, coherent, and autonomous—a self-governing agent said to demand sacrifice.

Certainly science had been objectified earlier in the century. In 1838, for example, Joseph Henry wrote of his desire to “advance the cause” of science.<sup>20</sup> A generation before, the American Philosophical Society employed a similar language of devotion to “science” when requesting funding from the legislature of Pennsylvania.<sup>21</sup> Yet such uses of the term appear infrequently before the Civil War. More typically, *science* instead referred to a certain type of mental discipline, a characteristic of

the human mind. This pervasive conception of science lingered late into the century. As the editor of *Popular Science Monthly* proclaimed in 1872, science is not regarded as “applying to this or that class of objects,” but “as being, in fact, a method of the mind, a quality or character of knowledge upon all subjects of which we can think or know.”<sup>22</sup>

This image of science as a “method of the mind” would be dramatically transformed in the last quarter of the nineteenth century. After about 1875, science rarely implied a form of mental discipline, but instead an entity or force conceived as external to practitioners themselves. Physicist T.C. Mendenhall made this perspective clear in an 1890 address:

[W]henver the public is disposed to consider its obligations to Science and her votaries, there are some things which must not be forgotten. . . . [T]hanks to science, the whole world is now aflame. Time and space are practically annihilated; night is turned into day; social life is almost revolutionized; and scores of things which only a few years ago would have been pronounced impossible, are being accomplished daily.<sup>23</sup>

Annihilating space and time, making the impossible possible, (almost) revolutionizing social life, “science” emerges here as an active, autonomous—and gendered—being. Externalized from the mind of man and set out into the world, a feminized science was now said to require protection, to need financial support, and to command sacrifice. Five years later, chemist Edwin Emory Slosson made these sacrificial requirements plain. Declaring that science has always necessitated an “immense expenditure of labor and of life,” Slosson insisted, “the most curious misconception is that . . . the aim of science is the cure of disease, the saving of human life. Quite the contrary, the aim of science is the advancement of human knowledge at any sacrifice of human life.”<sup>24</sup> As a reified “science” gained new imaginative force in the late nineteenth century, American writers consecrated themselves anew to the cause of its advancement.<sup>25</sup>

Specific material transformations supported this semantic change. The passage of the Morrill Land Grant Act in 1862, the adoption of the elective system at Harvard, Yale, and other denominational colleges, and the establishment of new research universities such as Johns Hopkins (1876), Clark (1889), Stanford (1891), and Chicago (1891) provided physical space for “science.” From these transformed colleges and universities emerged a growing number of highly educated,

middle-class Americans dedicated to the promotion of “higher learning.”<sup>26</sup> These middle-class Americans, whose everyday lives were increasingly filled with innovations such as the telephone (patented in 1876) and electricity (established with New York’s Pearl Street station in 1882), were bombarded with claims that “science” enabled these attention-grabbing novelties. The fanfare surrounding the opening of Edison’s Menlo Park research laboratory in New Jersey (1876), the popularity of spectacles such as the Centennial Exposition in Philadelphia, and the prevalence of popular science publications all attest to late nineteenth-century lay interest in scientific research and its “resulting” technical innovation.<sup>27</sup>

Meanwhile, the organization of federal agencies, such as the Bureau of American Ethnology (1879), an independent Department of Agriculture (which achieved cabinet status in 1889), and the National Bureau of Standards (1901), promoted a sense of solidarity among various practitioners scattered around the country. So, too, did the formation of new professional societies such as the American Chemical Society (1876), the American Society of Naturalists (1883), and the American Physical Society (1899). A series of nationally distributed journals such as *Science* (1883) and *The Physical Review* (1893) further unified investigators dispersed by geographical, disciplinary, and institutional location. The availability of large sums of capital upheld many of these transformations, as philanthropists enlarged endowments to libraries, museums, universities, and research agencies. In 1899 alone, donors gave \$55 million to higher education, more than \$5 million to libraries, and nearly \$3 million to museums.<sup>28</sup> In short, the increasing organization and consolidation of allied resources gave new institutional substance and visibility to “science.”

Even as images and practices of science were acquiring new solidity in American culture, images and practices of “sacrifice” were being equally transformed. The valorization of sacrifice had deep roots in American culture, particularly in the diverse traditions of New England Protestantism. Focusing on the image of the suffering Christ on the Cross, for instance, Cotton Mather often exhorted his congregations to master the “Holy Skill of Sacrificing.”<sup>29</sup> Yet these inherited Christian ideals gained new significance in the late Victorian period.

Alongside intensified monopoly capitalism rose concern about the corrosive influences of consumerism, urbanization, and the consolida-

tion of unprecedented personal fortunes. Increasing emphasis on the value of suffering emerged as part of a larger reaction to the excesses of capital, an antidote to the impious influences of the nation's gluttonous economic life. The pampered clamored for pain.<sup>30</sup> Particularly as Americans recovered from the vicious war between the states, mixed ideals of self-abnegation and self-denial became intertwined with a bourgeois fascination with blood sacrifice. By 1880, the massive slaughter of the Civil War had assumed a rosy glow in the white national memory, and violent self-immolation seemed a way to renew the solid values of a bygone era.<sup>31</sup> Against the backdrop of anti-labor violence, hideous lynchings, and open warfare over Indian lands, multiple realms of white middle-class activity were re-described in lavishly sacrificial terms. As the ideal scientist was newly constituted as a courageous martyr, so too the ideal citizen was portrayed as gallantly offering his life for his country, the ideal artist his life for his art, and the ideal Christian his life (or, less frequently, her life) for God.<sup>32</sup>

Increasing stress on the *value* of suffering was matched by new assertions of the *necessity* of suffering; moral ideals seemed to spring from natural law. Appeals to the nobility and valor of sacrifice lent a romantic gloss to the more widespread assumption—pandemic among intellectuals in the wake of Darwin—that *all* progress requires some degree of pain. Anthropologist Lewis Henry Morgan (1818–1881) exemplified this view when noting that “civilization” owes its “present condition . . . to the struggles, the sufferings, the heroic exertions and the patient toil of our barbarous, and more remotely, of our savage ancestors.”<sup>33</sup> This assumption of phylogenic sacrifice would be recapitulated in ontogenic theories; the necessary suppression of ancestral savages became the necessary suppression of the savage within. Freud exemplified this view when proposing that psychic coherence arises from the painful suppression of instinct. As a consequence of the civilizing process, Freud declared in 1912, “renunciation and suffering...cannot be avoided by the human race.”<sup>34</sup> Freud's pupil Theodor Reik reiterated this theme in 1941 when he described masochism, a love of pain, as an eminently sensible response to the “blood and tears” which necessarily attend the individual's psychic development.<sup>35</sup> In Reik's view, learning to love pain accommodates the fact that “every step forward has to be paid with frustrations, losses, and discomfort. . . . We may deplore the fact that cultural progress includes increased



suffering for mankind—but we cannot deny it.”<sup>36</sup> Whether “civilized” individuals or “barbarous” peoples paid the price, turn-of-the-century thinkers commonly presumed that “progress” must rest on suffering.

However widespread the assumption that all progress (moral, institutional, civilized, natural) necessitated suffering, only some “suffering” appeared noble or even noteworthy. Even as figures like Henry Ward Beecher came to declare suffering the “universal measure of value,” such claims typically reserved sacrificial ideals for white, middle- and upper-class men.<sup>37</sup> An exception was found in white women, whom earlier Victorian writers characterized as endowed with a “positive love of self-sacrifice.” They, too, entered the realm of “noble suffering,” but almost exclusively as nobly suffering mothers.<sup>38</sup> The valor of self-sacrifice, in other words, presumed a certain “self” at the outset. While self-destruction might, in the words of William James, “redeem life from flat degeneration,” self-destruction offered moral redemption only to those already residing in positions of privilege.<sup>39</sup>

For these privileged few, however, “science” appears to have offered a comforting realm of transpersonal identification, the allure of direction and purpose in a changing, confusing world. As industrialization and urbanization eroded conventional religion- and kin-based systems of meaning, a newly reified science absorbed yearnings for significance. The pain of science, like the pain of a nation’s wars, provided a way to turn misfortune into destiny, and finitude into immortality. Moreover, as with the reconstruction of “America” after the Civil War, some commentators sought to extend the new symbolic and material power of science through sacrificial affiliations. As the first editorial of the new national journal *Science* trumpeted in 1883, “Higher than all, [science] must be devoted to the truth. It must cheerfully undertake the severest labor to secure it, and must deem no sacrifice too great in order to preserve it.”<sup>40</sup>

In roentgenology, inchoate sacrificial ideals found specific expression. The enigmatic new rays—appropriately named “X” by Roentgen—confounded simple explanations of cause and effect. Like Henry Adams lying prostrate in the Gallery of Machines at the Great Exposition of 1900, early researchers struggled for metaphors adequate to the bewildering new force.<sup>41</sup> Invisible, active at a distance, and powerful beyond any received understanding, the uncanny x-ray invited religious comparison. Adopting common Christian tropes, William H. Greene played on these affinities when writing to x-ray

investigator Elihu Thomson in 1896. Referring to the oozing, suppurating blister Thomson obtained after he had tested the ray's action on his own hand, Greene queried:

Why don't you help some of the good New England Congregationalists get up a new theory of Hell in which the quivering flesh shall be scorched through and through with these rays which blast and wither but do not consume?<sup>42</sup>

Like divine judgment, the ray seemed invested with eternal, infinite power. And, like early Christian ascetics' search for divine truth, the pursuit of x-ray knowledge seemed to demand the mortification of the body, what the chemist Slosson (writing for a religious newsweekly) termed "self-immolation on the altar of science."<sup>43</sup>

Far from a Baconian narrative of man's domination of nature, then, here it is the *scientist* who is bound and submissive, obsequiously fulfilling science's larger plan. Describing in meticulous, grisly detail the loss of his fingers and lips from x-ray exposure, x-ray "pioneer" Émil Grubbé concluded that "Nature assigned this job to me, and I consider it a privilege to have done the part which was allotted to me."<sup>44</sup> While Grubbé suggested that he was "entirely unconscious of any danger" during his early years of x-ray experimentation, his assessment was uncommon; most other investigators eagerly stressed the voluntary nature of their sacrifices.<sup>45</sup> "Like the explorers of unknown countries who suffer privations and the pangs of hunger and thirst," wrote P.J. Hickey in his reflections on the early years of the science, "so our predecessors in American roentgenology frequently and willingly brought upon themselves subsequent sufferings."<sup>46</sup> Hickey and others who highlighted the deliberate nature of roentgenologists' self-injuries understood better than Grubbé the importance of voluntarism in the era's ideals of sacrifice. The courageous willingness to suffer appears paramount: man must choose his distress, lest his actions lose their greater meaning.

Today—in the wake of the bombings of Hiroshima and Nagasaki, the transnational anti-nuclear activism of the 1980s, and the disaster at Chernobyl—this emphasis on voluntary suffering may seem disingenuous. Steeped in popular idioms of radiation risk, twenty-first century readers tend to approach early x-ray fatalities as a tragedy of ignorance, despite evidence to the contrary. "If only they had known," we murmur to ourselves as we learn of ghastly cancers and piecemeal amputations;

“they simply didn’t realize how to protect themselves.” While surely some experimenters abandoned the ray when learning of its potential for harm, it is crucial to recognize that most x-ray investigators were neither so passive nor so unwitting as a narrative would have it.

Alarm over the dangers of prolonged x-ray exposure rose alongside the earliest experimentation with them. The first published reports of hair loss after prolonged exposure appeared within weeks of Roentgen’s first public announcement, and x-ray investigators soon began to notice the drying and inflammation of skin exposed to the ray.<sup>47</sup> Already in August of 1896, prominent journals were carrying reports of more serious effects. An article in the *Electrical Review* titled “Deleterious Effects of X Rays on the Human Body” recounted the experience of Herbert D. Hawks, a student at Columbia who had earned extra money exhibiting the new x-ray machine in a New York department store. Demonstrating this “unusually powerful X-ray outfit” for two to three hours at a time over four consecutive days, Hawks was forced to stop work “owing to the physical effects of the X rays upon his body.” His hands swelled and took on the appearance of having “a very deep sunburn.” Two weeks later, the skin fell off his hands, his fingernails stopped growing, and he lost all of the hair on his face and the sides of his head.<sup>48</sup> The young man’s vision was impaired, his eyelashes fell out, and his eyelids swelled. Physicians consulted on the damage responded to the symptoms as though it were an instance of “parboiling.”<sup>49</sup>

Over the next several months, other electrical investigators, physical scientists, and medical doctors engaged in x-ray research contributed their knowledge of the ray’s deleterious effects to the country’s leading journals. Boston tube manufacturer G.A. Frei reported that the skin on his hands and the hands of a worker, “Mr. K,” turned red, hardened, blistered, and fell off after repeated exposure to the ray. In addition, K.’s eyes burned and ached, and his fingernails felt as “if pounded by a hammer.”<sup>50</sup> In September, an investigator from the University of Minnesota described the “angry sore” which had once been his forehead, and a mouth so cracked, bleeding, and blistered that he could ingest only tiny bits of liquidized food.<sup>51</sup> In October 1896, the prominent journal *Nature* carried a full-page description of the ghastly results of one researcher’s prolonged exposure to the ray.<sup>52</sup> By the end of the year, reports of x-ray burns were front-page news in most prominent electrical, medical, and scientific periodicals.<sup>53</sup>

As medical and electrical experts became aware of the effects of prolonged exposure, lay discussions of the x-ray also included an awareness of danger. Even the first popular books on the x-ray discussed its potential for “destruction,” and by the turn of the century, physicians were compelled to assuage anxious patients before conducting x-ray examinations.<sup>54</sup> X-ray patients had been exhibiting severe lesions since the first year of the ray’s use, and between 1900 and 1902, patients who had been injured by prolonged exposure to the x-ray began to sue for damages.<sup>55</sup> Forced to act by litigious patients, x-ray experts began to respond. By April 1898, popular apprehension about the ray’s latent effects reached such proportions that even the Council of the Röntgen Society—a group unequivocally supportive of the new technology—resolved to appoint a Committee “to collect information on the subject of the alleged injurious effects of Röntgen rays.”<sup>56</sup>

Any remaining doubts that prolonged exposure to x-rays might have grave physiological consequences were dispelled by the first deaths among early x-ray investigators. When Dally died in autumn 1904, Edison was despondent. He attributed his decision to abandon lucrative x-ray research to the suffering experienced by Dally and other x-ray workers.<sup>57</sup> When Edison first began to discuss the x-ray burns in the country’s newspapers, medical publications derided the inventor for “rehashing in the daily press facts that had been learned by physicians through sad experience seven years ago.”<sup>58</sup> By the time of Dally’s death, physicians already assumed that the dangers of x-radiation were commonly understood.

Thus by the end of the first decade of x-ray experimentation, lay and expert opinion concurred that the x-rays could cause severe physiological damage, if not death. Recognition of this fact confounds any simple narratives of ignorance through which we might try to understand early investigators. Aware of radiation risk, at least a few investigators began to conduct their research with the aid of protective clothing and devices. The physicians William Rollins and Francis H. Williams, for example, started to shield themselves even before the first sign of injury. As Williams later recalled, “I thought that rays having such power of penetrating matter, as the x-rays had, must have some effect upon the system, and therefore I protected myself.”<sup>59</sup> Still others, particularly those who began their work in the first decade of x-ray experimentation, might simply have assumed that their cancers were already too far advanced to bother retiring from x-ray work.

Yet as Hickey suggested when likening roentgenologists to intrepid explorers, others simply took on the role of willing sufferer, exposing themselves to the x-ray long after the grave risks involved had been amply demonstrated. In one such instance, the Philadelphia physician Charles Lester Leonard (1861–1913) underwent one amputation after another (first the finger, then the hand and forearm, then the upper arm at the shoulder) before succumbing to cancer in 1913 at the age of fifty-one.<sup>60</sup> His pain, however, seems merely to have intensified his fascination with the ray. Even after publishing warnings on the dangers befalling the x-ray specialist, he continued his radiological investigation of the urinary tract.<sup>61</sup> The ten years of his most productive research coincided with the ten years of his “steadily increasing physical distress.”<sup>62</sup> Another investigator, the surgeon Stephen Clifton Glidden (1870–1917) continued his work with the x-ray following the amputation of several fingers in 1907. After further amputations made surgical practice impossible, Glidden began other investigations with the x-ray. Even the amputation of his arm at the shoulder did not dissuade him from his research, and in 1916 he began additional experiments with radium. Finally forced to cease practice later in the year due to ill health, Glidden died on February 20, 1917.<sup>63</sup> Mihran Krikor Kassabian (1870–1910) continued his work with the x-ray years after publishing a report on its hazards, “X-Ray as an Irritant,” in a prominent journal of roentgenology.<sup>64</sup> In 1903, even as the injuries to his hands grew more severe, Kassabian accepted a position in the Roentgen-Ray Laboratory at the Philadelphia Hospital.<sup>65</sup> The itching, toughening, and blistering of his skin continued, yet Kassabian persisted in his diagnostic and therapeutic practice. By 1908, after a decade of relentless exposure to x-radiation, Kassabian was in serious condition. The fourth finger of the right hand was completely covered with horny tissue, and the left hand had an open sore running across the area between the middle and fourth fingers. In April, the fingers were amputated to stop the spread of x-ray induced cancer. The following year brought the appearance of cancer in Kassabian’s axillary glands, which were also surgically removed. When this wound failed to heal, surgeons cut further tissue from his chest. Throughout the period of these surgical excisions, Kassabian continued his x-ray practice, ceasing only when too weak to work. In 1910, as his important textbook on x-rays was appearing in its second edition, Kassabian died from cancer.<sup>66</sup>

Surely the most spectacular demonstrations of willing suffering, however, are found in Walter J. Dodd, a central figure in the founding of roentgenology in the United States. “The name of Walter Dodd,” writes one historian, “is as infrangibly interlocked with the course of early American radiology as is that of Rontgen [sic] himself an integral part of the scientific annals of Germany.”<sup>67</sup> As early as November 1896 (less than a year after Roentgen’s discovery in his Würzburg laboratory), Dodd was tormented by severe dermatitis. Within five months, the pain was “beyond description,” and his face and hands appeared visibly scalded. Dodd’s employer, the Massachusetts General Hospital, placed his name on a list of those with grave injuries. When the pain in his hands kept him awake at night, Dodd paced the floor of the hospital pharmacy, hands raised over his head.<sup>68</sup> In July 1897, he received the first series of skin grafts performed by his friend, Dr. Charles Allen Porter of Boston (soon to become the nation’s leading expert in the treatment of chronic x-ray injuries). The grafts proved unsuccessful, however, and by 1902, cancer had spread through his fingers. Thus began the effort to salvage Dodd’s “useful hands” for further work:

From that time on surgeon [Porter] and patient together fought stubbornly and courageously to save as much as possible of those useful hands. There were fifty operations under ether, which lasted from an hour and a half to three hours. The capable fingers were taken away bit by bit. Rather than yield a fragment of a joint, Dodd would endure the agony of keeping it for months after it should have been removed. . . . [Often] Dodd went to the operating-table without knowing how much of his hands would be left when he awoke from the ether.<sup>69</sup>

As Dodd and his surgeon evaluated how much to excise from each cancer-ridden hand, they based their judgments on the finger’s relative usefulness. Despite the agonizing pain caused by the exposure of raw nerve endings in a cancerous ulcer, Dodd put off the amputation of his little finger for months, fearing that its loss would leave his thumb nothing to press against—rendering it impossible to grasp the controls of the x-ray.<sup>70</sup>

At first glance, this emphasis on utility would seem to evoke a conception of the white male body often articulated by historians of the early twentieth century: namely, the body as machine, a collection of interchangeable parts subject to dismantling and reconstruction.<sup>71</sup> Yet in crucial aspects, Dodd was far from this instrumental vision of manhood, neither so stoic nor so orderly. Dodd (at least the “Dodd”

recalled by biographers and colleagues) *embraced* his suffering. Unlike an impassive machine, Dodd was said to have “loved difficulty” and to have sought it out for its own sake.<sup>72</sup> Although painkillers would easily have made the performance of his work less excruciating (and perhaps more efficient), Dodd reportedly refused narcotics, even his physician’s ordered injections of morphine.<sup>73</sup> He typically took only aspirin for his wounds, wounds which his surgeon insisted must have caused more constant, intense physical suffering than any others he had seen.<sup>74</sup> Upon awakening from surgical ether after yet another amputation, Dodd always returned immediately to his radiological work.<sup>75</sup> “Everybody warned him when the danger became evident,” recalled one colleague, “but he would not give up his work and was always eager for the next case.”<sup>76</sup> “No man,” noted Dodd’s biographer, “was ever more enthusiastically absorbed in his task.”<sup>77</sup> Even after Dodd’s face had grown parchment-like “from the fibrillary contractions of old scars,” wrote another friend, “[it] was never too inelastic to break into a smile.”<sup>78</sup>

Far from appearing pathological in the eyes of his colleagues (or subsequent historians), Dodd’s embrace of pain and his unswerving love for the agent of his destruction appear to have made him an exemplary roentgenologist.<sup>79</sup> As one x-ray expert recalled, “Dodd won the respect and affection of everyone on the M.G.H. staff by his careful, painstaking work and by his ever-willing self-sacrifice.”<sup>80</sup> Described as a “‘roentgen’ Saint,” Dodd’s enthusiasm for pain was treated reverentially by his fellows.<sup>81</sup> According to some recollections, Dodd’s cheerfulness not only won him respect and affection but also increased his scientific abilities. For example, when Dodd counseled patients reluctant to undergo roentgen treatment or examination, he offered stories from his experience. Patients, “touched and strengthened by the visible evidence of his own suffering,” would acquiesce to the recommended diagnostic test or treatment.<sup>82</sup> His biographer describes one instance when a “sturdy” young man petulantly refused a requested radiological examination. One visit to the scarred and amputated Dodd ended all “boyish grumbling.” The boys who passed through the x-ray room “met a man, and they would have stood on their heads for him.”<sup>83</sup>

Certainly these descriptions of Dodd’s happy suffering must be understood as part of the era’s funereal genre, lush praise given in memory of a beloved colleague. Yet in their concentration, these words illuminate critical underlying assumptions about manliness, science,

and sacrifice present in the early twentieth century. Hardly machine-like or impassive, Dodd was lauded for his anti-utilitarian love of pain. Although in other circumstances such suffering might be indicative of barbarity (e.g. the “ancestral savages” of Lewis Henry Morgan) or of pathology (e.g. the “masochism” of Richard von Krafft-Ebing), here a sanctioned affiliation with “science” circumvents such connotations. Rather than appearing atavistic or perverse, Dodd’s willing suffering highlights his civility, his manliness, his rationality—indeed, his *scientificity*. Like his fellow “martyrs” Leonard, Glidden, and Kassabian, Dodd not only endured repeated amputations and ulcerated nerve endings but also strode toward them “enthusiastically” in the name of science.

This enthusiastic rush toward death and dismemberment proved formative of the eclectic field known as “roentgenology,” as the fledgling community defined itself through its shared “spirit of sacrifice.”<sup>84</sup> Nowhere is definition more evident than in the official narrative crafted by Dr. Percy Brown, one-time president of the American Roentgen Ray Society. Described by a colleague as one of the “great living suffering martyrs from this cause,” Brown carefully defined the field according to the embrace of sacrifice.<sup>85</sup> Within ninety days of Roentgen’s first announcement, Brown insisted, x-ray investigators understood the prospect of danger. Armed with “ample warning” and a full “chance to retire,” many individuals abandoned their work with the ray. Those who did, according to Brown, included: 1) profiteers who hoped to “exploit the x-rays” in popular exhibits; 2) physicists who understood that they’d “paved the way for the practical usefulness of the roentgen-rays” and hence turned to new investigations; and 3) medical practitioners who recognized the need to “relinquish” the ray to further development in “special hands.”<sup>86</sup> In Brown’s account, those who remained in the face of published warnings were the true founders of the science, “avowed and determined special workers, pioneers in the cause of their Work and in many instances ultimate martyrs to it.”<sup>87</sup> Brown thus sets the boundaries of roentgenology according to the will to martyrdom: “special workers” willing to endure pain become scientists; those who leave, by definition, do not.<sup>88</sup>

The rhetoric of martyrdom adopted by Brown and his colleagues served several functions for the emerging professional community. Most obviously, the promotion of voluntary suffering helped alleviate concern that practitioners would depart the field. Retrieved as noble



and heroic, the deaths of the field's founders preserved and increased the image of the profession as a worthwhile calling and promised to attract new members to it. References to martyrdom also protected existing practitioners from popular criticism about unnecessary injury and death. "By making the victims of X-ray induced carcinoma martyrs to science," Daniel Serwer summarizes, "the medical radiological community could hope to justify the loss of life and also thereby off-set . . . negative public reaction."<sup>89</sup> In the context of a larger cultural valuation of voluntary suffering, turning destruction into glorious sacrifice helped to protect a newborn profession.

Yet it would be a gross misreading to say that professionalizing investigators simply deployed martyrdom as tactical rhetoric. The rhetoric of sacrifice acquired its fullest form in the tattered flesh of x-ray investigators. Scarred and limb-less roentgenologists came to embody the abstract cause of "science," much as stigmata render palpable the ineffable presence of divinity. Indeed, embodiment mattered a great deal: by the late 1910s, "roentgenologists" were identified by their mutilated limbs.<sup>90</sup> At one 1920 professional gathering, historian Bettyann Holtzmann Kevles reports, so many attendees were missing at least one hand that when the chicken dinner was served, no one could cut the meat.<sup>91</sup> Participants in this and other macabre scenes forged a community not only through the inflated rhetoric of martyrdom but also through the lived experience of dismemberment and pain. Injury became the basis for a shared scientific identity.<sup>92</sup>

The relationship between roentgenology and injury was materialized not only in the missing fingers and hands of the living but also in monuments to the dead. As states tend to consolidate and define national identity through war memorials, so, too, the young profession solidified its scientific identity in the construction of public monuments. One of the more striking examples is an official tribute to the "martyrs of radiology" erected in the garden of Hamburg's Saint Georg Hospital in the spring of 1936.<sup>93</sup> The monument's single vertical stone might be read as a symbolic recovery of the individual investigator's amputated finger, revived as part of the larger, undying body of science. The names of individual investigators are inscribed on its sides in alphabetical order, de-emphasizing differences in rank and status and enhancing their shared scientificity. As in so many war memorials, the emphasis of the monument is on *collective* contribution to the higher

goal—in this case, collective contribution to the new science of roentgenology.<sup>94</sup>

However, such collective memorials overlook full-time x-ray investigators. None of those equally exposed to x-radiation—wives and other assistants, patients and laboratory animals—garners the high title of “martyr.”<sup>95</sup> With the important exception of two women, Marie Curie and the San Franciscan Elizabeth Fleischmann-Ascheim, the only “Martyrs and pioneers of radiological science” to feature in these descriptions are men employed as full-time x-ray investigators.<sup>96</sup> By dubbing Fleischmann-Ascheim “America’s Joan of Arc,” roentgenologists and the wider popular press preserved the status of the field as a sacrificial scene without troubling its overarching masculinization: roentgenologists remain (male) “soldiers for science,” with the lone exception of this beautiful *Jeanne d’Arc*. (Fleischmann-Ascheim’s Judaism appears not to have hindered those who identified her with the young saint.<sup>97</sup>) References to Marie Curie’s exceptional “sacrifices” appeared regularly in American accounts only after her death in 1934.<sup>98</sup> Most other accounts focused on professional men. Although technicians were occasionally included in the rosters of the dead (particularly the first American “martyr,” Charles Madison Dally), those said to possess a true “sacrificial fidelity” generally were men with advanced degrees in medicine or science.<sup>99</sup>

In a similar fashion, sacrifice was narrowed to the perils of radiation, neglecting all other dangers of x-ray work. Despite equal deadliness, none of the other hazards of roentgenological practice (e.g. the flammability of the film, the fragility of the large chemically-treated glass plates, or the potential for electrocution from high-voltage equipment) produced a “martyr to science” in early twentieth-century accounts.<sup>100</sup> A 1929 fire at *one* x-ray storage area killed at least 124 people, comparable to the numbers of investigators who succumbed to x-radiation *in the entire country*.<sup>101</sup> No monuments were raised for these dead, no glowing hagiographies composed. Countless industrial workers might have been injured by electrocution, by broken glass, by the movement of heavy equipment, by toxic chemicals, or by industrial fires. To preserve the special distinction of the field of roentgenology, however, only those workers succumbing to irradiation counted as willing sufferers.

“Roentgenology” was thus characterized as that pursuit for which certain individuals endured bitter pain and disfigurement. “Roentgen-

ologists,” by implication, were those rare individuals willing to take on the dangers of radiation. Just as the reverence of disciples maintains the power of deities, or the dedication of individual citizens augments the boundaries of nations, so, too, a new science was entwined with a new subject, the self-sacrificing scientist. Far from simply supplanting “religion” with “science,” then, late nineteenth-century physical research coupled enlightenment sensibilities and age-old customs of “disciplining-the-body-for-getting-at-the-truth.”<sup>102</sup> The cause of roentgenology was consecrated with each additional finger removed.

Certainly the valorization of sacrifice present among early x-ray workers was not the only narrative of scientific advancement available at the time. An equally standard narrative of progress may be found in the fortuitous scientific “accident,” such as Antoine-Henri Becquerel’s 1896 discovery of natural radioactivity after leaving some uranium rocks in a drawer containing photographic plates. Furthermore, one can easily envision a professional community which took the idea of willful suffering as a problem to be understood rather than a value to be reproduced: consider, for instance, psychoanalytic studies of masochism which proliferated even as Dodd enthusiastically returned to the source of his pain. Despite other possible formulations, this community of practice entwined pain with the pursuit of new knowledge, building a new field of research on an ethic of voluntary suffering. Rather than positioning this essay as for or against such suffering, I have here tried to describe how this ethic came into being, to mark it as a product of late nineteenth-century American culture rather than an intrinsic, eternal demand of “science.” Such historical understanding certainly won’t free us from the tendency to couple knowledge and pain, but it may enable better determinations of when, and how, we want to take our blows.

### NOTES

For helpful criticism on earlier versions of this essay, the author thanks Deborah Fitzgerald, Evelyn Hammonds, Lucy Maddox, Leo Marx, and the anonymous reviewers of *American Quarterly*. Support for this research was generously provided by Bates College, the Centre for the History of Science, Technology, and Medicine at the University of Manchester, and the Bakken Museum and Library for Electricity in Life.

1. For example, see [n.a.], "Untoward Effects of X-rays," *Boston Medical and Surgical Journal* 152 (Feb. 1905): 173; or S. Burt Wolbach, "Summary of the Effects of Repeated Roentgen-Ray Exposures Upon the Human Skin, Antecedent to the Formation of Carcinoma," *American Journal of Roentgenology and Radiology* 13 (Dec. 1925): 139–43.

2. "Operated on 72 Times: Roentgenologist Has Lost Eight Fingers and an Eye for Science," *New York Times*, 12 Mar. 1926, p. 22, col. 2–4. See also "Undergoes 50th Operation: Dr. Baetjer of Johns Hopkins is a Victim of X-Ray Infections," *New York Times* 2 May 1924, p. 26, col. 4.

3. Percy Brown, *American Martyrs to Science through the Roentgen Rays* (Springfield, Ill.: Charles C. Thomas, 1936), 98.

4. Sande Bishop, *Radiology in New England: The First Hundred Years (1896–1995)* (Boston: The Massachusetts Radiological Society and The New England Roentgen Ray Society, 1995), 74.

5. John V. Pickstone, *Ways of Knowing: A New History of Science, Technology, and Medicine* (Manchester: Manchester Univ. Press, 2000), 48. Historians of radiology have joined early roentgenologists in stressing the "enthusiasm" of early researchers. "The answer" to why so many x-ray investigators cheerfully subjected themselves to manifestly life-threatening work, writes one historian, "seems to be largely enthusiasm." See Stephen B. Dewing, *Modern Radiology in Historical Perspective* (Springfield, Ill.: Charles C. Thomas, 1962), 83.

6. See, e.g., R. Marie Griffith, "Apostles of Abstinence: Fasting and Masculinity during the Progressive Era," *American Quarterly* 52 (Dec. 2000): 599–638; Gail Bederman, *Manliness and Civilization: A Cultural History of Gender and Race in the United States, 1880–1917* (Chicago: Univ. of Chicago Press, 1995); Michael Grossberg, "Institutionalizing Masculinity: The Law as a Masculine Profession" in Mark C. Carnes and Clyde Griffen, eds., *Meanings for Manhood: Constructions of Masculinity in Victorian America* (Chicago: Univ. of Chicago Press, 1990): 133–51; Elizabeth H. Pleck and Joseph H. Pleck, eds. *The American Man* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1980).

7. Review of this exaggerated assessment may be found in Charles E. Rosenberg, *No Other Gods: On Science and American Social Thought* (1976; Baltimore: Johns Hopkins Univ. Press, 1997): 2ff, and John Brooke and Geoffrey Cantor, *Reconstructing Nature: The Engagement of Science and Religion* (Edinburgh: T & T Clark, 1998). For a period statement on this "war," see Andrew Dickson White's classic *A History of the Warfare of Science with Theology in Christendom*, 2 vols. (1896; New York: D. Appleton and Company, 1919).

8. I here employ quotation marks around "science" to highlight the term's inchoate and shifting character. This essay does not address the innumerable people, institutions, practices, and beliefs which have been (or might be) labeled "science." Rather, as I explain further below, it concerns the transformation of these heterogeneous, disputed formations into a singular, idealized abstraction, which was thought to demand sacrifice. I will use the term "science" to evoke that mobile totality, with full awareness of the tremendous disunity and plurality of the *sciences*. While I typically avoid incessant quotation marks in the interest of readability, hopefully the complexity of the term will remain evident throughout.

9. A final note on terminology: like most people engaged in a novel endeavor, early practitioners of roentgenology debated nomenclature. I here use the terms "roentgenology" and "roentgenologist" in favor of the now more familiar term "radiology," since it corresponds to the name selected by the first relevant professional body in the United States, the American Roentgen Ray Society. "Radiology," moreover, might connote

any study of high-energy radiation, while “roentgenology” refers more specifically to the field of x-rays, the subject of this paper. I employ the anglicized spelling “Roentgen” for the German proper name, and the alternate “Röntgen” only when directly citing period sources.

10. Benedict Anderson, *Imagined Communities: Reflections on the Origin and Spread of Nationalism* (London: Verso, 1983), 4. Among the many recent treatments of nationalism, studies which give particular focus to the significance of sacrifice include Michael Rowlands, “Memory, Sacrifice and the Nation,” *New Formations* 30 (winter 1996): 8–17; Adam J. Lerner, “The Nineteenth-Century Monument and the Embodiment of National Time,” and Jean Bethke Elshtain, “Sovereignty, Identity, Sacrifice,” both in Marjorie Ringrose and Adam J. Lerner, eds., *Reimagining the Nation* (Buckingham: Open Univ. Press, 1993).

11. The professionalization of x-ray work has been described at length by others; I here focus only on the centrality of martyrdom in this process. For other useful accounts, see Sande Bishop, *Radiology in New England*; Arthur C. Christie, “Fifty Years of Progress in Radiology” in *The American Roentgen Ray Society, 1900–1950: Commemorating the Golden Anniversary of the Society* (Springfield, Ill.: Charles C. Thomas, 1950), 25–29; Arthur U. Desjardins, “The Status of Radiology in America,” *Journal of the American Medical Association* 92 (Mar. 1929): 1035–39; Joel D. Howell, *Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century* (Baltimore: Johns Hopkins Univ. Press, 1995), esp. 103–32; Nancy Knight, “The New Light: X-Rays and Medical Futurism” in Joseph Corn, ed., *Imagining Tomorrow: History, Technology, and the American Future* (Cambridge, Mass.: MIT Press, 1986); Stanley Joel Reiser, *Medicine and the Reign of Technology* (Cambridge: Cambridge Univ. Press, 1978), 58–60; and Ruth Brecher and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: The Williams and Wilkins Company, 1969). Canonical narratives of Roentgen’s discovery have been scrutinized only rarely. For two such critiques, see Lisa Cartwright, *Screening the Body: Tracing Medicine’s Visual Culture* (Minneapolis, Minn.: Univ. of Minnesota, 1995); and Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (1962; Chicago: Univ. of Chicago Press, 1970), 57–59.

12. Robert G. Arns discusses changes in “finicky” x-ray tubes in “The High-Vacuum X-Ray Tube: Technological Change in Social Context,” *Technology and Culture* 38 (Oct. 1997): 852–890.

13. Equipment salespeople, who repeatedly demonstrated the efficacy of their merchandise for potential customers, were also at risk for x-ray injuries. Boston x-ray salesman Frank Howard Swett, for instance, died in 1929 from complications resulting from x-ray exposure. See Bishop, *Radiology in New England*, 39–42. For a further description of some of the manual labor involved in early x-ray work, see Merrill C. Sosman, “Roentgenology at Harvard,” *Harvard Medical Alumni Bulletin* 21 (Apr. 1947): 65–76.

14. Carl Beck, *Röntgen Ray Diagnosis and Therapy* (New York: D. Appleton and Company, 1904), 368ff; Brown, *American Martyrs to Science*, 33, 40–41; Ruth Brecher and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: The Williams and Wilkins Company, 1969), 163.

15. [n.a.], “Death of a Famous Woman Radiographer,” *San Francisco Chronicle*, Saturday, Aug. 5, 1905, p. 10, col. 7. See also Peter E. Palmquist, *Elizabeth Fleischmann: Pioneer X-ray Photographer* (Berkeley, Calif.: Judah L. Magnes Museum, 1990).

16. [n.a.], “The Woman Who Takes the Best Radiographs in the World,” *San Francisco Chronicle*, Sunday, June 3, 1900, p. 30. The role of roentgenology in the war

is described in detail in W.C. Borden, *The Use of the Röntgen Ray by the Medical Department of the United States Army in the War with Spain 1898* (Washington, D.C.: Government Printing Office, 1900). The 1898 war was not the first to employ roentgenology; x-rays were taken of soldiers returning to Italy from the Ethiopian Campaign of 1896 and were first used in field operations as early as the Tirah Campaign of 1897. See Lawrence Reynolds, "The History of the Use of the Roentgen Ray in Warfare" in André J. Bruwer, ed., *Classic Descriptions in Diagnostic Roentgenology*, vol. 2 (Springfield, Ill.: Charles C. Thomas, 1964), 1307–17.

17. Bettyann Holtzmann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, N.J.: Rutgers Univ. Press, 1997), 48; Emil H. Grubbé, *X-Ray Treatment: Its Origin, Birth and Early History* (Saint Paul, Minn.: The Bruce Publishing Company, 1949), 139–40.

18. Alan Trachtenberg, *The Incorporation of America: Culture and Society in the Gilded Age* (New York: Hill and Wang, 1982), 91.

19. Brewster, *The Martyrs of Science* (New York: Harper & Brothers, 1841).

20. Letter from Joseph Henry to Alexander Dallas Bache, quoted in Robert V. Bruce, *The Launching of Modern American Science: 1846–1876* (Ithaca, N.Y.: Cornell Univ. Press, 1987), 220.

21. The APS noted that members of their organization were "Animated by a love of science." See "To the Senate and House of Representatives of the Commonwealth of Pennsylvania" [Jan. 17, 1800], *Early Proceedings of the American Philosophical Society . . . 1744 to 1838* (Philadelphia: McCalla and Staveland, 1884), 292.

22. [n.a.], "Editor's Table: Purpose and Plan of Our Enterprise," *Popular Science Monthly* 1 (May 1872): 113. See also Rev. Charles Kingsley, "The Study of Physical Science: A Lecture to Young Men," *Popular Science Monthly* 1 (Aug. 1872): 456.

23. T.C. Mendenhall, "The Relations of Men of Science to the General Public," *Science* 16 (Oct. 24, 1890): 233.

24. E.E. Slosson, "The Relative Value of Life and Learning," *The Independent* (Dec. 12, 1895), 7.

25. Further discussions of the history of the concept of "science" may be found in John Heilbron, "Historiographical Issues on the Problem of Representing the Rise of Modern Science," paper presented at the International Summer School in the History of Science, Bologna, Sept. 16, 1997; Stanley M. Guralnick, *Science and the Ante-Bellum American College* (Philadelphia: American Philosophical Society, 1975), 60; Sydney Ross, "Scientist: The Story of a Word," *Annals of Science* 18 (June 1962): 65–85; Roslynn D. Haynes, *From Faust to Strangelove: Representations of the Scientist in Western Literature* (Baltimore: Johns Hopkins Univ. Press, 1994), 6–8; Leonard N. Neufeldt, "The Science of Power: Emerson's Views on Science and Technology in America," *Journal of the History of Ideas* 38 (Apr.–June 1977): 333.

26. Alexandra Oleson and John Voss, eds., *The Organization of Knowledge in Modern America, 1860–1920* (Baltimore: Johns Hopkins, 1979), ix.

27. Here I describe the relationship between science and its resulting applications in accordance with period sources. Historians of technology have revealed numerous flaws in this received model of the science-technology relationship.

28. Oleson and Voss, *The Organization of Knowledge*, xi.

29. See Mather, *The Sacrificer: An Essay Upon the Sacrifices Wherewith a Christian, laying a Claim to an Holy Priesthood, Endeavours to Glorify God* (Boston: T. Fleet, 1714), 44 and *A Brief Essay Upon the Cross* (Boston: John Allen, 1714).

30. T.J. Jackson Lears, *No Place of Grace: Antimodernism and the Transformation of American Culture: 1880–1920* (New York: Pantheon Books, 1981); Trachtenberg, *Incorporation of America*, 140ff. On changes in "sacrificial thinking" in this period,

see Susan L. Mizruchi, *The Science of Sacrifice: American Literature and Modern Social Theory* (Princeton: Princeton Univ. Press, 1998); and Alice Owen Letvin, *Sacrifice in the Surrealist Novel: The Impact of Early Theories of Primitive Religion on the Depiction of Violence in Modern Fiction* (New York: Garland Publishing, 1990).

31. Gerald F. Linderman, *Embattled Courage: The Experience of Combat in the American Civil War* (New York: Free Press, 1987), 291. The advent and dissemination of anesthesia also transformed cultural attitudes toward pain. See S. Weir Mitchell, "The Birth and Death of Pain" [a poem read at the fiftieth anniversary of the demonstration of ether], *Boston Medical and Surgical Journal* 135 (Oct. 15, 1896): 386; and Martin S. Pernick, *A Calculus of Suffering: Pain, Professionalism, and Anesthesia in Nineteenth-Century America* (New York: Columbia Univ., 1985).

32. On the artist, see T.S. Eliot, "Tradition and Individual Talent" in *The Sacred Wood: Essays on Poetry and Criticism* (1920; London: Methuen and Co., 1948), 52–53; on the Christian, see Charles A. Briggs, "The Salvation Army," *North American Review* 159 (Dec. 1894): 697–710.

33. Quoted in Trachtenberg, *The Incorporation of America*, 36.

34. Sigmund Freud, "On the Universal Tendency to Debasement in the Sphere of Love" in *The Standard Edition to the Complete Works of Sigmund Freud*, trans. James Strachey, vol. 11 (1912; London: Hogarth Press, 1957), 190.

35. Theodor Reik, *Masochism in Modern Man*, trans. Margaret H. Beigel and Gertrud M. Kurth (New York: Farrar, Straus, and Company, 1941), 398.

36. Reik, *Masochism in Modern Man*, 382.

37. "Suffering," Beecher declared in 1870, "is universally accepted as the measure of value." Beecher, "Suffering, the Measure of Worth," *The Sermons of Henry Ward Beecher in Plymouth Church, Brooklyn*, "Plymouth Pulpit," *First Series*, 327, quoted in Pernick, *A Calculus of Suffering*, 279–80.

38. See, e.g., Frank Moore, *Women of the War: Their Heroism and Self-Sacrifice* (Hartford, Conn.: S.S. Scranton and Co., 1866). For further discussions of women, gender, and sacrifice in the nineteenth century, see Mary Poovey, "Speaking of the Body: Mid-Victorian Constructions of Female Desire" in Mary Jacobus, Evelyn Fox Keller, and Sally Shuttleworth, eds., *Body/Politics: Women and the Discourses of Science* (New York: Routledge, 1990), esp. 33; Judith Rowbotham, "'Soldiers of Christ?' Images of Female Missionaries in Late Nineteenth-Century Britain: Issues of Heroism and Martyrdom," *Gender & History* 12 (Apr. 2000): 82–106; Drew Gilpin Faust, "Altars of Sacrifice: Confederate Women and the Narratives of War," *Journal of American History* 76 (Mar. 1990): 1200–28; and Pernick, *A Calculus of Suffering*, 47–9.

39. William James, *The Essential Writings*, ed. Bruce W. Wilshire (Albany, N.Y.: State Univ. of New York Press, 1989), 352.

40. [n.a.], "The Future of American Science," *Science* 1 (Feb. 1883): 3.

41. Henry Adams, "The Dynamo and the Virgin" in *The Education of Henry Adams* (Boston: Houghton-Mifflin, 1961), 381.

42. Greene to Thomson, Dec. 20, 1896, in Harold J. Abrahams and Marion B. Savin, eds., *Selections from the Scientific Correspondence of Elihu Thomson* (Cambridge, Mass.: MIT Press, 1971), 247–248.

43. Slosson, "The Relative Value of Life and Learning," 7.

44. Grubbé, *X-Ray Treatment*, 89.

45. *Ibid.* Though Grubbé was rare among early x-ray workers in disavowing knowledge of the ray's dangers, in other ways his narrative offers a comfortably conventional model of scientific progress: through the scientist's noble sacrifice, society passes from ignorance to truth, from suffering to salvation, from risk to safety.

His claim of ignorance—like his disputed claim to have been the first investigator in the world to develop and discuss x-ray sequelae—is difficult to maintain under closer inspection. See Brecher and Brecher, *The Rays*, 91ff; and Paul C. Hodges, *The Life and Times of Emil H. Grubbé* (Chicago: Univ. of Chicago Press, 1964).

46. P.M. Hickey, "The First Decade of American Roentgenology," *American Journal of Roentgenology* 20 (Aug. 1928): 150.

47. Asked to locate a bullet in the head of a wounded child, Professor John Daniel and Dr. William L. Dudley decided to experiment with the feasibility with skull x-rays in Feb. 1896. As Professor Daniel later recalled the chain of events, Dudley, "with his characteristic devotion to the cause of science," agreed to lend himself to the first trial. Daniel proceeded to expose his partner's scalp, one-half inch from the ray, for an hour. Twenty-one days later, all hair had fallen out from the area of Dudley's head closest to the tube's discharge. See John Daniel, "The X-rays," *Science* 3 (Apr. 10, 1896): 562–63.

48. Hawks had been using the x-ray to reveal the bones of his jaw for spectators.

49. [n.a.], "Deleterious Effects of X Rays [sic] on the Human Body," *Electrical Review* 29 (Aug. 12, 1896): 78; Kevles, *Naked to the Bone*, 47.

50. G.A. Frei, "Deleterious Effects of X Rays on the Human Body: Further Evidence that Repeated Exposure to the Rays Produces a Sunburn Effect," *Electrical Review* 29 (Aug. 19, 1896): 95.

51. Fred S. Jones, "Deleterious Effects of X Rays on the Human Body," *Electrical Review* 29 (Sept. 9, 1896): 127.

52. S.J.R., "Some Effects of the X-Rays on the Hands," *Nature* 54 (Oct. 29, 1896): 621.

53. Whether the ray itself were responsible for the so-called "x-ray burns," however, had not yet been decided. The New Yorker Hawks, for instance, dismissed the x-ray as a factor in his injuries. Positing that the damage done to his skin was "purely an electrical effect . . . the ray has nothing to do with it," Hawks reported that his mangled skin became entirely "healthy again" within a matter of days (H.D. Hawks, "The Physiological Effects of the Roentgen Rays," *The Electrical Engineer* 22 [Sept. 16, 1896]: 276.) Hawks was not alone in looking beyond the ray to explain the "burning" effects. Other researchers attributed x-ray injuries to the ozone produced by the apparatus, to a "brush discharge" which occurred when the ray was held too near the skin, to ultra-violet rays, or to "static changes" which interfered with the nutrition of the exposed body part. Some suggested that only peculiarly sensitive patients were susceptible to x-ray burns; others pointed to faulty or weak x-ray tubes. By late 1896, however, the vitriolic debate between noted electrical and medical experts over the causes of the observed skin effects had waned, partly due to the published findings of the eminent investigator Elihu Thomson. As mentioned above, Thomson tested, on his own body, the theory that the ray itself was the source of the problem. In the eyes of Thomson and many of his colleagues, the growing, seeping blister on the exposed hand seemed to confirm the danger of the ray. See Elihu Thomson, "Some Notes on Roentgen Rays," *The Electrical Engineer* 22 (Nov. 18, 1896): 520–521, "Röntgen Rays Act Strongly on the Tissues," *The Electrical World* 28 (Nov. 28, 1896): 666, and "Roentgen Rays Act Strongly on the Tissues," *Electrical Review* 29 (Nov. 25, 1896): 260, "Roentgen Rays Act Strongly on the Tissues," *The Electrical Engineer* 22 (Nov. 25, 1896): 534; and the responses to this report by E.A. Codman, "The Cause of Burns from X-Rays," *Boston Medical and Surgical Journal* 135 (Dec. 10, 1896): 610–11; and R.B. Owens, "Effect of Röntgen Rays on the Tissues," *The Electrical World* 28 (Dec. 19, 1896): 759.



54. Philip Atkinson, *Electricity for Everybody; Its Nature and Uses Explained*, 2nd ed. (New York: The Century Company, 1897), 239 (the second edition was expanded to include a tenth chapter on the new rays); Samuel Howard Monell, *A System of Instruction in X-Ray Methods and Medical Uses of Light, Hot-Air, Vibration, and High Frequency Currents* (New York: E.R. Pelton, 1902), 26.

55. On patients' lesions, see J.C. White, "Dermatitis Caused by X-Rays," *Boston Medical and Surgical Journal* 135 (Dec. 3, 1896): 583. On litigation, see Serwer, "The Rise of Radiation Protection," 39–40; and Tal Golan, "Science on the Witness Stand: Expert Testimony in U.S. Courts, 1870–1923" (Ph.D. diss., Univ. of California, Berkeley, 1997).

56. Hector Alfred Colwell and Sidney Russ, *X-ray and Radium Injuries, Prevention, and Treatment* (London: Oxford, 1934), 8–9.

57. Kevles, *Naked to the Bone*, 47.

58. See [n.a.], "Edison and X-Ray Injuries," *Journal of the American Medical Association* 41 (Aug. 22, 1903): 499.

59. Quoted in Otto Glasser, *Wilhelm Conrad Röntgen and the Early History of Röntgen Rays* (Springfield, Ill.: Charles C. Thomas, 1934), 293–4.

60. Charles Allen Porter, "The Pathology and Surgical Treatment of Chronic X-Ray Dermatitis," *Transactions of the American Roentgen Ray Society* (1908): 128, 169–70; P.M. Hickey, "The First Decade of American Roentgenology," *American Journal of Roentgenology* 20 (Aug. 1928): 155; Brown, *American Martyrs to Science*, 123.

61. C.L. Leonard, "The Protection of the Roentgenologist," *New York Medical Journal* 86 (Nov. 1907): 917–20. See also C.L. Leonard, "The X-Ray 'Burn': Its Productions and Prevention. Has the X-Ray any Therapeutic Properties?" *New York Medical Journal* 68 (July 2, 1898): 18–20.

62. Brown, *American Martyrs to Science*, 123.

63. *Ibid.*, 158–59.

64. Mihran Krikor Kassabian, "X-Ray as Irritant," *American X-Ray Journal* 7 (1900): 784–86.

65. Brown, *American Martyrs to Science*, 93.

66. *Ibid.*, 97–98.

67. [Percy Brown?], "Walter James Dodd, 1869–1916," unpublished, undated typed manuscript, in Francis A. Countway Library of Medicine, Boston, Massachusetts (hereafter CLM), B MS C42.5, 1. John Macy, *Walter James Dodd: A Biographical Sketch* (Boston: Houghton Mifflin Company, 1918), 11. Unfortunately, I have been unable to locate Dodd's papers at the Massachusetts General Hospital, Countway Medical Library, Univ. of Vermont, Radiological Society of North America, Massachusetts Medical Society, or American College of Radiology and must rely on biographies and obituaries here. I would be indebted to the reader who directed me to Dodd's private papers.

68. Porter, "The Pathology and Surgical Treatment of Chronic X-Ray Dermatitis," 141; Macy, *Walter James Dodd*, 21, 23.

69. Porter, "The Pathology and Surgical Treatment of Chronic X-Ray Dermatitis," 141; John P. Tampas, M.D., "Hampton Lecture," Department of Radiology, Medical Center Hospital of Vermont, photocopy, p. 8, 26. I am grateful to Dr. Tampas for providing me with a copy of his lecture.

70. Porter, "The Pathology and Surgical Treatment of Chronic X-Ray Dermatitis," 143, 145.

71. This evaluation of early twentieth-century visions of the white male body can be found in Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (Berkeley, Calif.: Univ. of California Press, 1990); Roxanne Panchasi,

“Reconstructions: Prosthetics and the Rehabilitation of the Male Body in World War I France,” *differences* 7 (spring 1995): 110–40; Bill Brown, “Science Fiction, the World’s Fair, and the Prosthetics of Empire, 1910–1915” in *Cultures of United States Imperialism*, ed. Amy Kaplan and Donald E. Pease (Durham, N.C.: Duke Univ. Press, 1993), 129–63; Lisa Herschbach, “Prosthetic Reconstructions: Making the Industry, Re-making the Body, Modeling the Nation,” *History Workshop Journal* 44 (1997): 23–57, and Siegfried Giedion, *Mechanization Takes Command: A Contribution to Anonymous History* (New York: Oxford Univ. Press, 1948).

72. Macy, *Walter James Dodd*, 58.

73. *Ibid.*, 29. Porter reports administering opiates to Dodd on one occasion (“The Pathology and Surgical Treatment of Chronic X-Ray Dermatitis,” 144).

74. Porter, “The Pathology and Surgical Treatment of Chronic X-Ray Dermatitis,” 159; Macy, *Walter James Dodd*, 29.

75. Macy, *Walter James Dodd*, 26; Sosman, “Roentgenology at Harvard,” 71.

76. Harris P. Mosher, quoted in Sosman, “Roentgenology at Harvard,” 69.

77. Macy, *Walter James Dodd*, 27.

78. Brown, *American Martyrs to Science*, 149–50.

79. Only one commentator appears to have adopted the term “masochism” when describing the so-called “martyrs”: see Cartwright, *Screening the Body*, 110, 128.

80. Sosman, “Roentgenology at Harvard,” 68.

81. [n.a.], “Walter James Dodd, 1869–1916,” 6.

82. Macy, *Walter James Dodd*, 35. One might imagine that patients would *refuse* treatment after hearing stories of the physician’s own anguish; no records exist to ascertain how, exactly, Dodd managed to inspire his patients.

83. Macy, *Walter James Dodd*, 36.

84. Lewis Gregory Cole, “In Memoriam,” *The American Journal of Roentgenology* 4 (1917): 630.

85. George E. Pfahler, “Fifty Years of Trials and Tribulations in Radiology” in *The American Roentgen Ray Society, 1900–1950: Commemorating the Golden Anniversary of the Society* (Springfield, Ill.: Charles C. Thomas, 1950), 17.

86. Brown, *American Martyrs to Science*, 16.

87. *Ibid.*

88. Brown’s emphasis on the special character of “Work” echoes usage found in contemporary artistic and literary circles (such as Alfred Stieglitz’s journal, *Camera Work*) and contributes to the aura of unprofitable devotion permeating both science and aesthetics. Unlike being “in work” or “out of work,” here “Work” is a pure, preposition-less thing in itself, cleansed of specific social relations. On nineteenth- and twentieth-century transformations in the concept of “work,” see Raymond Williams, *Keywords* (New York: Oxford Univ. Press, 1976), 334–37.

89. Serwer, “The Rise of Radiation Protection,” 63.

90. Kevles, *Naked to the Bone*, 47.

91. *Ibid.*, 48.

92. The political theorist Wendy Brown discusses the place of injury in the constitution of political identities in late modernity in her *States of Injury: Power and Freedom in Late Modernity* (Princeton: Princeton Univ. Press, 1995), 52–76.

93. This monument was part of a broader post-WWI remembrance of radiology, which sought not only to carry the x-ray’s wartime prominence forward into the peacetime promotion of radiology but also to reunite (symbolically and practically) an international field divided by the war. Percy Brown’s 1936 book, *American Martyrs to Science through the Roentgen Ray*, also contributed to this effort in a particularly nationalistic vein. For a lucid general discussion of the significance of memorials,

portraits, and other forms of commemoration in cultural understandings of “science,” see Ludmilla Jordanova, “Presidential Address: Remembrance of Science Past,” *British Journal for the History of Science* 33 (Dec. 2000): 387–406.

94. Michael Rowlands, “Memory, Sacrifice, and the Nation,” *New Formations* 30 (winter 1996): 11.

95. Researchers frequently experimented on their wives and other assistants to discover the effects of x-rays. See, e.g., S.H. Sharpsteen, “The History of an X-ray Burn,” *The Electrical Engineer* 24 (July 8, 1897): 10–11. Laboratory animals, too, were expended in the search for new knowledge of the rays. See the discussion of William Herbert Rollin’s experiments with guinea pigs in Kevles, *Naked to the Bone*, 51.

96. Brown, *American Martyrs to Science*, 4; [n.a.], “Death of a Famous Woman Radiographer”; [n.a.], “The Woman Who Takes the Best Radiographs in the World.” X-radiation made its presence felt outside the laboratory as well; other communities adversely impacted by early x-ray exposure are described in Jacalyn Duffin and Charles R.R. Hayter, “Baring the Sole: The Rise and Fall of the Shoe-Fitting Fluoroscope,” *Isis* 91 (June 2000): 260–82; and Rebecca Herzig, “Removing Roots: ‘North American Hiroshima Maiden Syndrome’ and the X-ray,” *Technology and Culture* 40: 4 (Oct. 1999): 723–45.

97. Brown, *American Martyrs to Science*, 49. More recently, Peter Palmquist elaborates on the exceptional achievements of Fleischmann-Ascheim, a young Jewish woman who apparently never completed high school, by comparing her accomplishments (and heroic sacrifices) to that other famously exceptional woman in science, Mme. Curie. Again, Fleischmann-Ascheim’s exceptionality is preserved, maintaining the general masculinization of the field. See Palmquist, *Elizabeth Fleischmann*, 10.

98. On representations of Curie’s sacrifice, and the ways it strengthened popular conceptions of appropriate womanhood, see Susan Lindee, “The Scientific Romance: Purity, Self-Sacrifice, and Passion in Popular Biographies of Marie Curie,” paper presented at the annual meeting of the History of Science Society, Atlanta, Georgia, Nov. 8, 1996; Helena M. Pycior, “Marie Curie’s ‘Anti-Natural Path’: Time Only for Science and Family” in *Uneasy Careers and Intimate Lives: Women in Science, 1789–1979*, ed. Pnina G. Abir-Am and Dorinda Outram (New Brunswick, N.J.: Rutgers Univ. Press, 1987), esp. 213. Adrienne Rich treats the significance of Curie’s wounds in “Power,” in *The Dream of a Common Language, Poems 1974–1977* (New York: Norton and Company, 1978), 3.

99. Brown, *American Martyrs to Science*, 264.

100. On some of these other dangers, see Sosman, “Roentgenology at Harvard,” 66–67.

101. Dewing, *Modern Radiology in Historical Perspective*, 75; Kevles, *Naked to the Bone*, 110.

102. This phrase comes from Talal Asad’s provocative “Notes on Body Pain and Truth in Medieval Christian Ritual,” *Economy and Society* 12 (Aug. 1983): 294.